

Technological Impact on the Quality of Palm Oil from Burundi: *Elaeis guineensis*, Variety of Dura and Tenera

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Abstract

The objective of this study is to determine the factors responsible for the acidification of Burundi palm oils. The investigation of the duration of fermentation of palm fruits performed among artisanal producers found that more than 89% of producers from commune of Rumonge ferment for more than 5 days while more than 61% of those from commune of Mutimbuzi ferment for 4 days. The determination of acid value using the method of ISO 660:2009 showed that Dura and Tenera varieties fermented for 4 days had respectively 5.9 ± 2.3 and 5.8 ± 1.8 mg of KOH/g of oil for clustered fruits, 7.03 ± 3.4 and 7.02 ± 3.2 mg of KOH/g for destemmed fruits. After 8 days, the acid values of Dura and Tenera varieties obtained were respectively 10.9 ± 4.7 and 12.5 ± 5.4 mg KOH/g for clustered fruits, 12.5 ± 5.4 and 12.5 ± 4.1 mg KOH/g for destemmed fruits. No significant difference was recorded between varieties. On the other hand, a highly significant difference at $p < 0.05$ was obtained between fruits fermented in the open air (e.g. around the foot of the oil palm, FFOA), in a shed when the fruits were not covered (SFNC) and in a shed when the fruits were covered by branches or straw (SFC). At 8 days of fermentation, the acid values of FFOA, SFNC and SFC were $9.1 \pm 0.7 < 12.6 \pm 0.8 < 17.7 \pm 1.4$ for destemmed fruit and $9.1 \pm 0.7 < 13.2 \pm 1.3 < 13.2 \pm 3.2$ for clustered fruit, respectively. In light of these results, the acidity of Rumonge palm oil is probably due to the long fermentation time and the technique of covering the fruits

during fermentation. These results will allow producers to extract good quality oil and consequently improve the health of consumers.

Keywords

Burundi, Dura, Tenera, Acid Value, Oil Palm

1. Introduction

The oil palm (*Elaeis guineensis* Jacq.) is a perennial plant of the *Arecaceae* family [1]. This plant is the most important source of vegetable oil in the world. Since 2009, oil extracted from oil palm represents more than one-third of the total production of vegetable fats [2]. In Burundi, oil palm constitutes a source of income for many households through the oil itself and its by-products. It is the main cultivated oil plant and contributes to more than 90% of the national oil consumption. However, there is a possibility to vary the vegetable oils. It has been reported that natural forest ecosystems contain indigenous plants that can provide vegetable oils [3] of very high nutritional value [4]. The palm oil varieties cultivated are Dura and Tenera. In most of the palm oil-producing regions, Dura is being replaced by the Tenera variety. The latter is intensively cultivated in the natural region of Southern Imbo, especially in the commune of Rumonge in Rumonge province. It has also been extended to Bubanza, Bujumbura, Cankuzo, Cibitoke, Kirundo, Makamba, Muyinga, Ruyigi and Rutana provinces. The province of Rumonge alone accounts for more than 63% of the palm grove area. It is followed by the provinces of Ruyigi (8%), Bubanza (7%), and Bujumbura (6%) [5]. The Dura variety still exists in the natural regions of Mumirwa and Imbo, which span the provinces of Makamba, Bururi, Rumonge, Bujumbura, Bubanza and Cibitoke. The palm trees of Dura are under scattered feet and left voluntarily in the fields. Their annual production (20,000 tons) of both varieties is far below the population's oil needs, which were estimated at 100,000 tons in 2008 [6]. With the current population of 12 million, the oil needs would be estimated at 300,000 tons of oil because each person must consume 25 kg of oil per year [7]. In the entire palm oil production area, the artisanal extraction technique is the most dominant, which affects quality. There is only one industry (SAVONOR) that extracts palm oil in a modern way. Previous studies have shown that palm oils obtained by artisanal extraction processes often contain more than 10% free fatty acids [8] [9] while those produced industrially contain an average of 4% [9] [10]. Several exogenous and endogenous factors are at the origin of this degradation of triglycerides. Regarding the external factors, it is mainly the lack of good processing and preservation practices before and after extraction that are responsible for acidification. It has been reported that lipases from microorganisms can cause acidification of palm oil [11] [12]. This is observed in the case of fermentation of long period. As for the endogenous factors, they are lipase found in the

palm fruit itself [13] [14]. The release of these lipases from their storage vacuoles is caused by ruptures observed during abscission or injury of the ripe fruit [15] [16]. Free fatty acids first deteriorate the quality of the oil containing them. Free fatty acids can act as pro-oxidants in oils by accelerating the rate of decomposition of hydroperoxides. Thus, a high free fatty acid content in oil can cause further oxidation and lead to the development of an unpleasant taste and flavor in the oil [17]. Both the primary products of oil deterioration (free fatty acids) and the secondary products (caused by free fatty acids) affect human health. It has been reported that hydroperoxide is very toxic [18] and is at the origin of the atherosclerosis hyperlipidemia, Alzheimer's disease brain, and sunburned skin [19]. Free fatty acids are also direct causes of dyslipidemia and the adverse health consequences of obesity [20]. While almost all Burundians consume the palm oil they produce, no studies have been conducted on the acidification factors of oils. It is with the overall objective of contributing to the preservation of the health of consumers that a study of the acidification factors of oil palm was performed. The specific objectives were to determine: 1) the acid value of Burundi palm oils and 2) the factors responsible for acidification of these oils. The results of this study will improve the health of the population by contributing to the reduction of metabolic diseases.

2. Materials and Methods

2.1. Determination of the Fermentation Period of Oil Palm Fruits

More than 80% of palm oil is produced in Imbo Sud (Rumonge and Makamba), and the rest is produced in Imbo Centre (Bujumbura and Bubanza) at 775 to 1000 m of altitude. The determination of the fermentation period was done in the form of a survey. The survey was conducted in the Commune of Rumonge (Imbo Sud) and Mutimbuzi (Imbo Centre). The sample size was chosen based on the formula of François Daniel [21]:

$$n = \frac{t^2 \cdot N}{t^2 + (2e)^2 (N - 1)}$$

2.2. Determination of the Acid Value of Artisanally Extracted Oils in the Two Communes of Rumonge and Mutimbuzi

Oil samples were collected, directly after extraction, in four zones (Kigwena, Rumonge, Kizuka, Minago) of the commune of Rumonge and four zones (Kigwena, Rumonge, Kizuka, Minago) of the commune of Mutimbuzi (Rubirizi, Rukaramu, Gatumba and Maramvya zones). In each zone, three hills were randomly selected. In each hill, three artisanal mining units were sampled. Each zone had nine samples and each commune had 32 samples. The acidity was determined according to the method of ISO 660:2009 [22] norms and expressed in mg KOH/g oil.

2.3. Determination of Fermentation Day of Oil Palm FRUITS

An experiment was conducted to study the parameters that may be responsible for the acidity of palm oils in Burundi. For this purpose, bunches of two varieties (Dura and Tenera) of *Elaeis guineensis* were purchased from producers. To identify the factors responsible for the variation in oil acidity, the experiment was performed by analyzing the influence of the following four parameters on oil acidity:

- 1) Variety;
- 2) The number of days of fermentation of oil palm fruits;
- 3) Destemmed and clustered fruits for fermentation; and
- 4) The impact of leaving oil palm fruits in the open air under a tree, putting them in a shed without covering them with straw or tarpaulin, and putting them in a shed and covering them with tarpaulin has been tested.

2.4. Palm Oil Extraction for Experimentation

After fermentation, according to the four parameters (Section 2.3), artisanal extractions were performed as shown in **Figure 1**. The oils obtained underwent acid value analyses like those collected from the producers.

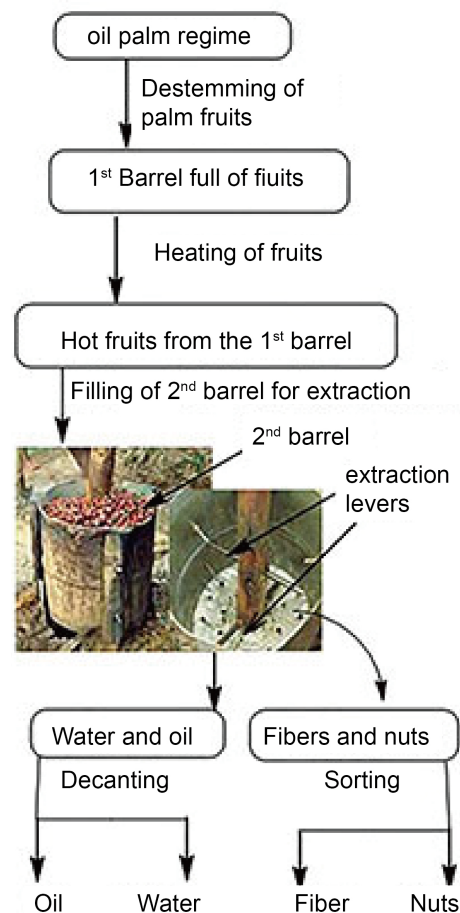


Figure 1. Artisanal extraction of palm oil.

2.5. Statistical Analysis

Data analysis was performed using IBM SPSS statistic 20. Results were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's multiple comparison test. Correlation between various parameters was also investigated. Significance was determined at $p < 0.05$ level and the results were expressed as mean values \pm standard error (SE). All tests were performed in triplicate.

3. Resultants and Discussion

3.1. Peregod of Fermentation of Oil Palm Fruits from Ruzibazi, Rukaramu and Gatumba Zones

A study was conducted in four zones (Rubirizi, Rukaramu, Gatumba and Maramvya) of Mutimbuzi Commune and four others (Kigwena, Rumonge, Kizuka and Minago) of Rumonge Commune. Through this study, it was found that palm oil producers in Rumonge ferment palm fruit for several days more than those in Mutimbuzi (**Table 1**). 61.7% of Mutimbuzi producers ferment for 4 days, while in Rumonge commune, only 10.3% of producers ferment during this period. 51% of Rumonge producers ferment palm fruits for more than a week while more than 85% of Mutimbuzi producers do not exceed 5 days.

Table 1. Number of days of fermentation of oil palm fruits by producers in the commune of Mutimbuzi (PROMU) and Rumonge (PRORU) expressed in percentage.

Day	PROMU (%)	PRORU (%)
Four	61.7	10.3
Five	23.4	20.7
Six	4.3	17.2
Seven	2.1	17.2
Eight	2.1	8.6
Nine	2.1	6.9
Ten	2.1	6.9
Eleven	2.1	6.9
Twelve	0	3.4
Thirteen	0	1.7

It was even revealed that in the commune of Rumonge 5% of producers ferment for more than 12 days.

The longer the fruits are stored, the more the endogenous lipases find the opportunity to be in contact with the triglycerides [16] and thus to degrade them, which leads to the acidification of the palm oil [13] [14]. It has been shown that when fruits are stored, fungi secrete exogenous lipases [11], which are also responsible for the acidification of palm oil. This proves that the oil palm fruits of Rumonge producers are more exposed to acidification factors compared to those of Mutimbuzi.

3.2. Acid Value of Oils Produced in Rumonge and Mutimbuzi

The analysis was conducted on oils sampled directly from artisanal extraction units in the commune of Rumonge (Kigwena, Rumonge, Kizuka and Minago zones) and the commune of Mutimbuzi (Rubirizi, Rukaramu, Gatumba and Maramvya zones). The oil extracted by Rumonge producers is characterized by a significantly ($p < 0.05$) higher acidity than that produced in Mutimbuzi, the order being: $14.1 \pm 0.8 > 9.7 \pm 0.3$ mg KOH/g oil.

The acid value of the oils produced at Mutimbuzi varies from 9 to 10 mg KOH/g oil, while that of Rumonge varies from 13 to 15 mg KOH/g oil. The comparison of the results in **Table 1** and **Table 2** show that the longer the fermentation, the higher the acid value, which greatly affects the quality of the oils.

Table 2. Acidity according to the place of production of the oil (expressed in mg of KOH/g of oil).

Commune	Zone	Acid Value	Average
Mutimbuzi	Rubirizi	9.2 ± 1.7^d	9.7 ± 0.3^a
	Rukaramu	9.6 ± 1.6^{cd}	
	Gatumba	9.7 ± 2.3^{cd}	
	Maramvya	10.3 ± 2.05^{cd}	
Rumonge	Kigwena	13.1 ± 2.7^{ad}	14.1 ± 0.8^b
	Rumonge	13.5 ± 2.6^{ad}	
	Kizuka	14.6 ± 4.1^{ab}	
	Minago	15.5 ± 3.7^a	

Note: The values that include these letters a, b, c and d are significantly different in descending order: $a > b > c > d$.

In the commune of Rumonge, the duration of fermentation was found to be very long: more than 90% exceeds 5 days (**Table 1**). Previous studies have reported that oil extraction from fruits with little or no fermented yields high quality crude oil of about 0.9 mg KOH/g oil and that the acidity of fruits stored for 6 to 26 days ranged from 12.04 to 64 mg KOH/g oil [23]. It has been reported that industrially produced oil has an acidity of about 9.42 ± 0.12 mg KOH/g oil [24]. Although industrially produced, international standards show that these oils are of very poor quality. Refined oils are ≤ 0.6 mg KOH/g oil, cold pressed and virgin oils ≤ 4.0 mg KOH/g oil, and virgin palm oils ≤ 10.0 mg KOH/g oil according to the CODEX STAN 210-1999 norms [25]. As the extraction of the oils of these two communes is artisanal and it is the simple pressing after a light heating, it is considered as virgin. Their acid value should be less than 10.0 mg KOH/g, threshold set by CODEX STAN 219-1999 for virgin palm oils [25]. However, in this study, it was found that the acid values (13 - 15 mg KOH/g) of Rumonge oils are higher than the value fixed (10.0 mg KOH/g) by CODEX STAN 219-1999 for virgin oils. Therefore, it is unfit for human consumption. The producers will have to review their preparation methods from fermentation to sale.

The oils produced from Mutimbuzi commune comply with the standards of CODEX STAN 219-1999 (9 - 10 mg KOH/g). Although they comply with the standards, strict measures during their preparation must be observed to maintain these values below the threshold recommended by CODEX STAN 219-1999.

3.3. Influence of the Variety and the State of the Bunch (Clustered and Destemmed) on Acidity

During fermentation, there are producers who collect the palm fruits without destemming them and the others ferment the destemmed fruits. In this study, experimentation was conducted on the varieties and condition of the bunches. Thus, the acid values as a function of varieties and the state of the fruit regime (clustered or not) are depicted in **Table 3**.

It was found that the oil acid values of Dura variety and Tenera variety had no significant differences at $p > 0.005$. After 4 days of fermentation, for clustered fruits, the acid value of Dura variety oil was 5.9 ± 2.3 mg KOH/g oil while that of Tenera oil was 5.8 ± 1.8 mg KOH/g oil. After eight days of fermentation, the acid value of Dura oil was 10.9 ± 4.7 mg KOH/g oil while that of Tenera oil was 12.5 ± 5.4 mg KOH/g oil.

The same trend was also observed between the acid value for Dura and Tenera destemmed fruit oils respectively at the same days of fermentation: for example for 4, 5 and 8 days, the acid value of Dura destemmed were 7.03 ± 3.4 , 10.8 ± 3.4 and 12.5 ± 5.4 mg KOH/g oil respectively and those of Tenera were 7.02 ± 3.2 , 9.8 ± 3.4 and 12.5 ± 4.1 mg KOH/g oil respectively. This shows that both species have the same physiological properties.

Previous studies have reported that oil palm fruits naturally contain lipases [26]. In the light of these results, it can be deduced that both varieties contain the same amount of endogenous lipases. The acidity can also be caused by the hydrolysis of fatty acids by enzymes secreted by microorganisms [27] through the wounds of the fruits.

Table 3. Acidity of the oils according to the varieties (Dura and Tenera) and the state of the fruit regime (in bunches and destemmed) (expressed in mg KOH/g oil).

	Fermentation Days	Clustered Fruit	Destemmed Fruits
Dura	Four	5.9 ± 2.3^d	7.03 ± 3.4^{abcd}
	Five	9.1 ± 2.9^{abcd}	9.2 ± 3.4^{abcd}
	Six	10.5 ± 3.2^{abc}	10.8 ± 3.4^{ab}
	Seven	10.1 ± 2.4^{abc}	10.7 ± 2.9^{abc}
	Eight	10.9 ± 4.7^{ab}	12.5 ± 5.4^a
Tenera	Four	5.8 ± 1.8^d	7.02 ± 3.2^{cd}
	Five	8.3 ± 2.3^{bcd}	8.9 ± 2.9^{abcd}
	Six	9.4 ± 2.9^{abcd}	9.8 ± 3.4^{abc}
	Seven	9.8 ± 3.1^{abc}	10.3 ± 3.5^{abc}
	Eight	12.5 ± 5.4^a	12.5 ± 4.1^a

Note: The values that include these letters a, b, c and d are significantly different in descending order: $a > b > c > d$.

3.4. Influence of the Fermentation Technique on the Acidification of Palm Oils

Since there were no significant differences at $p > 0.05$ between the acid value of Dura and Tenera oils and the latter being extended to other provinces, the study continued with Tenera. The fermentation techniques are almost the same in both communes. Some people pile them in a shade around the feet of palm trees or other trees; others put them in the sheds without covering them and others in the sheds and cover them with straw or tarpaulins.

Testing of these techniques through this study revealed significant differences ($p < 0.005$) of acid values (**Table 4**) between them. Destemmed and clustered fruit were experimented separately. For destemmed fruit, during four days of fermentation, the acid values of oil fruits stacked in the open air (FFOA), in a shed when fruits uncovered by a tarpaulin (SFNC), and in a shed when a tarpaulin (SFC) covered the fruit were $3.7 \pm 0.9 < 6.5 \pm 0.3 < 10.8 \pm 1.6$ mg KOH/g oil, respectively. All these oils are within the limits (10 mg/100g) fixed by CODEX STAN 210-1999 standards [25]. Just after 5 days of fermentation, the FFOA and SFNC oils were still within the limits fixed by CODEX STAN while the SFC oils exceeded it by a large margin. The order respective is as $5.6 \pm 0.6 < 10.3 \pm 0.3 < 12 \pm 2.9$ mg KOH/g with significant differences at $p < 0.05$. After eight days of fermentation only the FFOA, oils were found to be within, the international standards while those of the SFNC and SFC were higher. They are significant at $p < 0.05$ differences; order being FFOA < SFNC < SFC: their respective values were $9.1 \pm 7 < 6 \pm 0.8 < 17.7 \pm 1.4$ mg KOH/g. Based on these data, this study supposes that these differences are due to the humidity conditions created by covering the fruits. These conditions are favorable to the development of microorganisms. Previous investigations have reported that microorganisms (molds and bacteria) produce lipases [11] [12] [28].

Table 4. Influence of the fermentation technique of Tenera fruits on the acid value expressed in mg of KOH/g of oil (FFOA, fruit in open area, e.g. around the foot of the oil palm; SFNC, in a shed uncovered fruit; SFC, in a shed and fruit covered by branches or straw or tent).

	Fermentation Days	FFOA	SFNC	SFC
Destemmed Fruits	Four	3.7 ± 0.9^g	6.5 ± 0.3^{defg}	10.8 ± 1.6^{bcde}
	Five	5.6 ± 0.6^{fg}	10.3 ± 0.3^{bcd}	12 ± 2.9^{bc}
	Six	6.2 ± 0.2^{efg}	10.6 ± 1.8^{bcde}	13 ± 1.3^b
	Seven	7.4 ± 0.8^{cdefg}	11.9 ± 0.3^{bcde}	13.8 ± 1.8^{ab}
	Eight	9.1 ± 0.7^{bcdef}	12.6 ± 0.8^b	17.7 ± 1.4^a
Clustered Fruit	Four	3.7 ± 2.6^g	6.5 ± 0.5^{defg}	7.5 ± 1.4^{cdefg}
	Five	5.7 ± 0.9^{fg}	9.9 ± 2.4^{bcdef}	10.6 ± 1.8^{bcde}
	Six	6.2 ± 0.1^{efg}	10.5 ± 3.2^{bcde}	12.6 ± 0.7^b
	Seven	7.3 ± 0.1^{cdefg}	10.8 ± 0.3^{bcde}	12.3 ± 1.8^b
	Eight	9.1 ± 0.7^{bcdef}	13 ± 1.3^b	13.2 ± 3.2^b

Note: The values that include these letters a, b, c, d, e, f and g are significantly different in descending order: $a > b > c > d > e > f > g$.

For the clustered fruits, the acidity trends of the oils were the same as those observed in oils from destemmed fruits. They are also significantly ($p < 0.05$) different in the following order: FFOA < SFNC < SFC. Furthermore, there were no significant differences ($p > 0.05$) between the acid values of the oils extracted from the fermented fruits with clusters and those from the destemmed fruits. For FFOA, on the third day of fermentation, the acid value recorded was 3.7 ± 0.9 and 3.7 ± 2.6 mg KOH/g, respectively, for destemmed and clustered fruits. After 8 days of fermentation, the acid value of destemmed and clustered fruits was 9.1 ± 0.7 and 9.1 ± 0.7 mg KOH/g, respectively. The trend was the same for the acid value of SFNC and SFC oils. All this had shown that there was no significant difference ($p > 0.05$) between the acid value of oils extracted from destemmed fruits and those extracted from clustered fruits.

4. Conclusion

The results of this study highlighted that consumers of palm oil in Burundi are exposed to the consequences of the acidity of palm oil. The analysis of oils collected in the commune of Rumonge, the main producer, showed that acid value (14 mg KOH/g) was higher than international standards, while those of Mutimbuzi were within the recommended limits (9 mg KOH/g). The main factors of this acidification were the long fermentation period and the creation of favorable conditions for the proliferation of microorganisms by increasing the humidity. In the commune of Rumonge, fermentation lasts more than 5 days for 89% of producers while it lasts 4 days for 61% of producers in the case of the commune of Mutimbuzi. Taking into consideration, the results of this study will allow producers to extract good quality oil, which will contribute to the improvement of the health of the population.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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