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Influence of fermentation parameters on physicochemical characteristics of *Elaeis guineensis* Jacq. wine used for spirit production

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Abstract

The spirit (Sodabi) produced with fermented palm wine has very important socio-cultural place in Benin and is used of numerous traditional ceremonies. The production of spirit requires many operations among which fermentation is fundamental. The quality of sodabi depends on success of this stage. This study aims to define optimal time of traditional fermentation of palm wine to be distilled in spirit and to improve its physico-chemical characteristics with *Saccharomyces cerevisiae* external supply. Investigation of spirits producer's has allowed identifying the different durations observed in a real environment. Experiments have been conducted to evaluate the influence of variation of fermentation time and the *Saccharomyces cerevisiae* supply on characteristics of wine. Results showed that the duration of traditional fermentation choice's is random and based entirely on judgment of each other. It varies from three to ten days. In addition, experiments showed that fermentation length exceeding three (03) days involved a decrease of pH and ethanol content, an increase of the relative density and the volatile acidity of wines. Otherwise, contribution of 2 gram per wine liter of yeast significantly increases the alcohol content. The present study shows that, for sodabi production, the optimal length of wine fermentation is three days.

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Introduction

Palm trees (Arecaceae or Palmeae) are an important source of products for everyday life in rural areas of developing countries. Among these products, palm wine has great socio-economic importance (Tapsoba *et al.*, 2011). Whitish alcoholic beverages, effervescent produced by spontaneous fermentation by the action of lactic yeast sweet palm sap transparent (Ezeronye *et al.,* 2000), palm wine is obtained from various species including *Elaeis guineensis*, *Raphia vinifera*, *Raphia hookeri Borassus aethiopum* in most African countries, but also *Hyphaene coriacea* and *Phoenix reclinata* in South Africa (Bisi-Jonhnson *et al.,* 2011). Palm wine is consumed in different regions of the world (Santiago-Urbina and Ruiz-Téran, 2014). Indeed, it is a traditional drink, popular, symbolic and consumed by more than ten million people in West Africa (FAO, 1998; Ukhum *et al.,* 2005).

A fresh, palm wine contains yeast, mainly *Saccharomyces cerevisiae* species, bacteria of the genus Acetobacter, Lactobaccilus (Amoa-Awua *et al.,* 2006) and Zymomonas (Assi, 2003; Nwachukwu *et al.*, 2006). Given this wealth of microorganisms palm wine is known to be difficult to keep drinking. It is then used to produce a strong alcohol (Amoa-Awua *et al.,* 2006; Ameyapoh et Wokpor, 2006) by the use of traditional technology can be divided into two fundamental steps: fermentation and distillation.

In Benin, sodabi, local spirit drink produced by the distillation of wine *Elaeis guineensis* makes a capital role in the traditions and customs like many other traditional African societies (Amoa-Awua *et al.,* 2006). Thus, because of the importance of this activity (the distillation of palm wine) in the lives of the majority of the people of South Benin (Ade *et al.*, 2010), it is important to improve the operations of this critical technology to help the artisan producers to better monetize this activity. This study aims to study the effectiveness of traditional fermentation process and to define the optimal duration.

Material and methods

Plant material used, wine of *Elaeis guineensis* was collected directly in palm grove and stored at 0°C (with ice packs) and conveyed to the laboratory for different experiments.

The biological material is composed of baker's yeast specifically *Saccharomyces cerevisiae* whose effectiveness has been tested.

Survey

The survey was conducted in three municipalities in southern Benin namely Bonou in the department of Oueme, Dogbo in the department of Couffo and Abomey-Calavi in the department of Atlantic. It is realized to better understand traditional fermentation of *Elaeis guineensis* wine in real environment. The choice of the zones has been operated according to the non-probabilistic statistical method, so-called the reasoned choice. This reasoned choice has been based on next criteria: the culture of *Elaeis guineensis* in these and the distillation of palm wine as generating activity of incomes for the autochthonous populations. Data collect is based on the observation of the traditional process and on a list of questions. The wines physicochemical characteristics depending on fermentation duration were noted.

Fermentation in controlled environment

After based on experiences with local producers, three fermentation times are retained for controlled experiments: 3, 5 and 8 days. Also, controlled fermentations were carried out by external addition of *Saccharomyces cerevisiae* at 0.5, 1 and 2 g/l (Table 1). For all samples, one (1) liter was used for fermentation at ambient.

Physicochemical characteristics

During the fermentation process, total sugars, relative density, hydrogen potential, volatile acidity and alcoholic strength of wine samples were determined. Total sugars were determined by colorimetric phenol-sulfuric acid method developed by Dubois (Dubois *et al.*, 1956). Relative density, Potential Hydrogen (pH), Volatile acidity (express to percent of acetic acid) were determined according to standardized methods of OIV (OIV-MA-AS2-01A: R 2009, OIV –MA-BS-13:R 2009, OIV-MA-AS313-02: R2009). At last, alcoholic strength by volume (% v/v) calculated from the results from the determination of ethanol by nitrochromique Cordebard method which is based on the one hand, on the oxidation of ethanol to a cold solution of excess potassium dichromate in an acidic environment and on the other hand, on the feed-back iodometric titration of excessed dichromate ions.

Expression: alcoholic strength by volume (% v/v) = [1150. (Vrwhite – Vrdosage)/$\rho_{ethanol}$].(d_{sample}/$d_{absolute\ alcohol}$).

Statistical analysis

SPSS Statistics version 20 is used to determine eventual differences between the samples by ANOVA and to compare the averages by Student Newman Keuls test. P values below 0.05 were considered statistically significant.

Results and discussion

Survey

In real areas, it appears that producers observe different fermentation times ranging from 3 days to 8 days sometimes 10 days.

Indeed, once palm wine is harvested, it is conditioned for fermentation in carboys of a big capacity, tightly closed.

The length of fermentation varied by region: four, eight and five days respectively in Bonou, Dogbo and Abomey-Calavi.

These fermentations have been made without sugars or yeasts addition. For 66.66% of people, palm wine is truly ready to be distilled in sodabi after five days.

Table 1. Variation of fermentation length and rate of yeasts added to wines.

Yeats (g /l)	Fermentation time (days)		
	3	5	8
0	0/3	0/5	0/8
0.5	0.5/3	0.5/5	0.5/8
1	1/3	1/5	1/8
2	2/3	2/5	2/8

Alcohol content of traditional wines varies between 8.95% and 12.45%. The contents in total sugars varied between 1.16 and 2.89% and the values observed for volatile acidity varied between 0.74 and 1.67 (Table 2). The physicochemical characteristics revealed that Dogbo palm win which underwent eight days of fermentation, presented the best values of density and alcohol content.

However, the differences observed for three wines cannot be assigned to the only variation of the duration of fermentation. Indeed, the initial composition of the palm wines: as the presence of microorganisms responsible for the alcoholic fermentation, composition of sap, species of palm tree, environmental conditions: temperature and velocity of the wind (Santiago-Urbina *et al.*, 2013), could influence these values.

Table 2. Characteristics of traditional palm wine distilled.

	Voluminal mass (g/l)	pH	Volatile acidity (%)	Alcohol content (%v/v)	Sugar (%)
Bonou	997,80±0,40 (b)	4,05±0,01 (c)	0,74±0,01 (a)	10,70±0,22 (b)	1,16±0,02 (a)
Dogbo	991,10±0,40 (a)	3,5±0,05 (b)	1,17±0,01 (b)	12,45±0,22 (c)	2,89±0,03 (c)
Abomey-Calavi	999,90±0,00 (c)	3,3±0,01 (a)	1,67±0,01 (c)	8,95±0,22 (a)	1,73±0,03 (b)

In the same column, the numbers with different letters are significantly different at 5%.

Evolution of physicochemical characteristics depending on fermentation time

Total sugars

The evolution of total sugars over time, for different dosages of yeast (Fig. 1.) showed a decrease of this parameter.

For four types of samples, two main phases can be distinguished. The first is significant reduction in sugar content between 0 and 3 days, reflecting strong activity of yeasts including *Saccharomyces cerevisiae* by transformation of fermentable sugars into ethanol.

This observation is supported by the findings of Amoa-Awua *et al.* (2006) for which, the fermentation time lead to a substantial decrease of the palm wine sugar.

The second phase is slight decrease in the rate of 3and 5 days then 8 days, reflecting the decline of yeast activity and early stabilization of the sugar content.

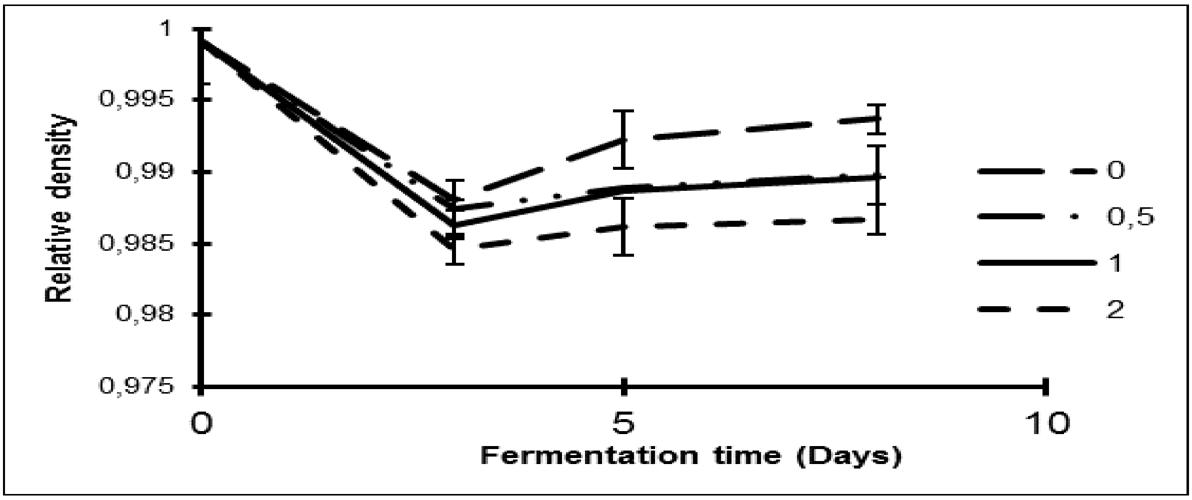

Fig. 1. Evolution of total sugars depending on fermentation time.

This stabilization is the result of the composition of the environment which became inappropriate for yeast activity. For Amoa-Awua *et al.* (2006), yeast concentration of palm wine remains moderately constant four days and begins to fall on the fifth day.

Relative density

The evolution of relative density (Fig. 2.) shows an identical look at the four samples of palm wine. Three phases could be distinguished.

The first is a significant drop between 0 and 3 days, which reflects a strong production of ethanol by conversion of sugars; the second, an increase between 3 and 5 days, which indicates a reduction in ethanol content and the last is a slight growth foreshadowed an early stabilization between 5 and 8 days. The minimum values of relative density have been obtained for a period of three days. It is therefore not necessary to go beyond three days of fermentation.

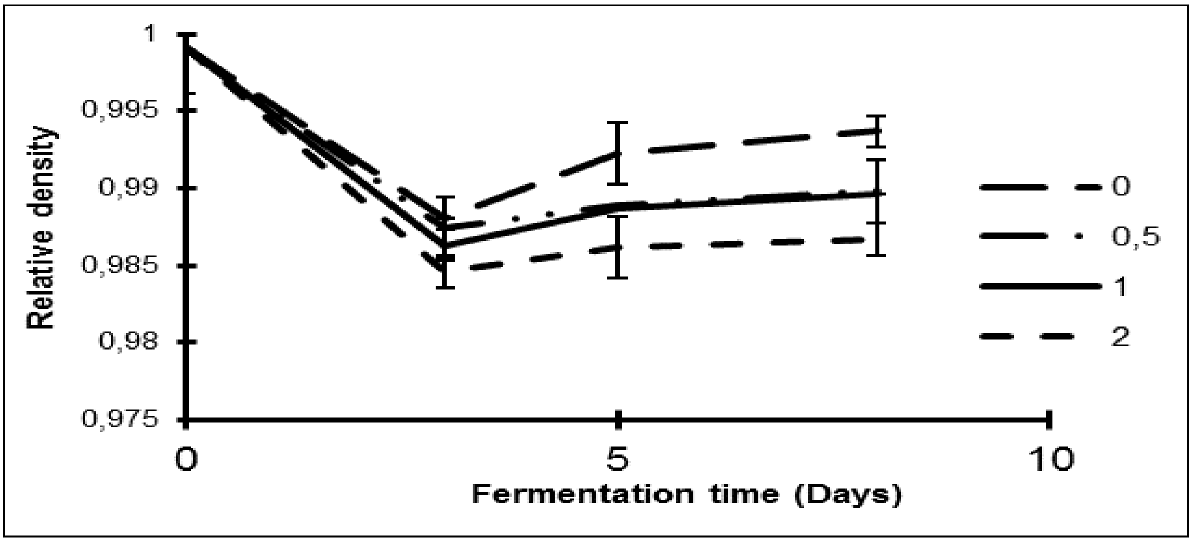

Fig. 2. Evolution of relative density depending on fermentation time.

The samples that received a contribution of yeasts were also those who submitted the lowest density values. And the third day, the densities of samples 0, 0.5, 1 and 2 were respectively 988.16, 987.41, 986.31 and 984, 61 g/l; values lower than values obtained for the samples wine distilled in a real environment (991.40 to 999.90 g/l). Sample 2/3 is the one who presented the minimum density.

Alcohol content

The curves of samples 0, 0.5, 1 and 2 showed the same trend (Fig. 3.). This evolution of was submitted in three phases. First, we observed a significant increase between 0 and 3 days of fermentation, which reflects the activity of yeasts mainly *Saccharomyces cerevisiae*.

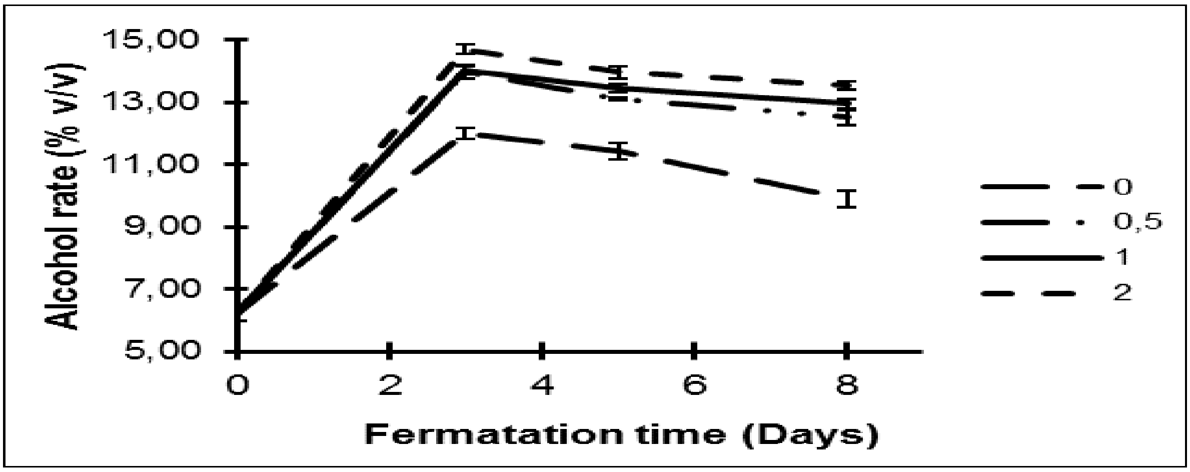

Fig. 3. Evolution of alcohol content depending on fermentation time.

This increase of alcohol rate is in agreement with the reduction of sugars and density rate observed. For (Obire, 2005) during the fermentation sugars are metabolized to alcohol and acid. Then, a decrease between 3 and 5 days indicates that the beginning of activity of acetic acid bacteria. Indeed, the activity of these bacteria that convert ethanol to acetic acid in the wine will start after the first three days (Amoa-Awua *et al.*, 2006). Finally, a relatively small decrease which foreshadowed the beginning of the stabilization between the 5th and 8th day, which can be explained by a decrease in the activity of acidifying bacteria due to the composition of the wines, become not conducive to their development.

The maximum values of the alcoholic content have been obtained for a period of three days for the four samples. These results are confirmed by those of (Amoa-Awua *et al.*, 2006). Indeed, during the fermentation of palm wine, there was a drastic increase in v the alcohol content on the first day; this level remains high until the third day, and then begins to fall on the fourth day. This parameter confirms once again that eight days is long enough to have a significant amount of ethanol.

For the duration of three days of fermentation, the values of alcohol content for samples (0, 0.5, 1 and 2 g/l yeast) were respectively 12.01, 13.08, 14.05 and 14.70% (v / v). Sample 2/3 is the one that presented the maximum alcohol rate.

In general, the alcohol rate of samples free yeast contribution ranged from 9.90 (sample 0/8) and 12.01% (sample 0/3) for an initial value (0/0) equal to 6.19%. These values are similar to those obtained for the samples distilled in a real environment (from 8.95 to 12.45%), but they are higher than the values reported by (Amoa-Awua *et al.*, 2006), which are between 7.47 and 10.58%, and much higher than those of (Tapsoba *et al.*, 2011) which are 4.08% to 7.25% for four days of fermentation in Burkina Faso.

In addition, there is a significant difference at 5% between alcoholic rate of all wines having undergone for the same yeast contribution, different fermentation times. For the same periods, only samples 0/3 and 1/3, do not show any significant differences.

Volatile acidity

The analysis of Fig. 4 shows, an extension of fermentation duration meant increase of volatile acidity. This is conforming to the observations made by (Olasupo and Obayori, 2003; Amoa-Awua *et al.*, 2006; Karamoko *et al.*, 2012).

Indeed, these authors argue that the acidity of the palm wine increases during the fermentation period and this increase coincides with the decline in alcohol content. Thus, the observed increase confirms the increase in density and lower alcoholic rate previously observed during the extension of fermentation.

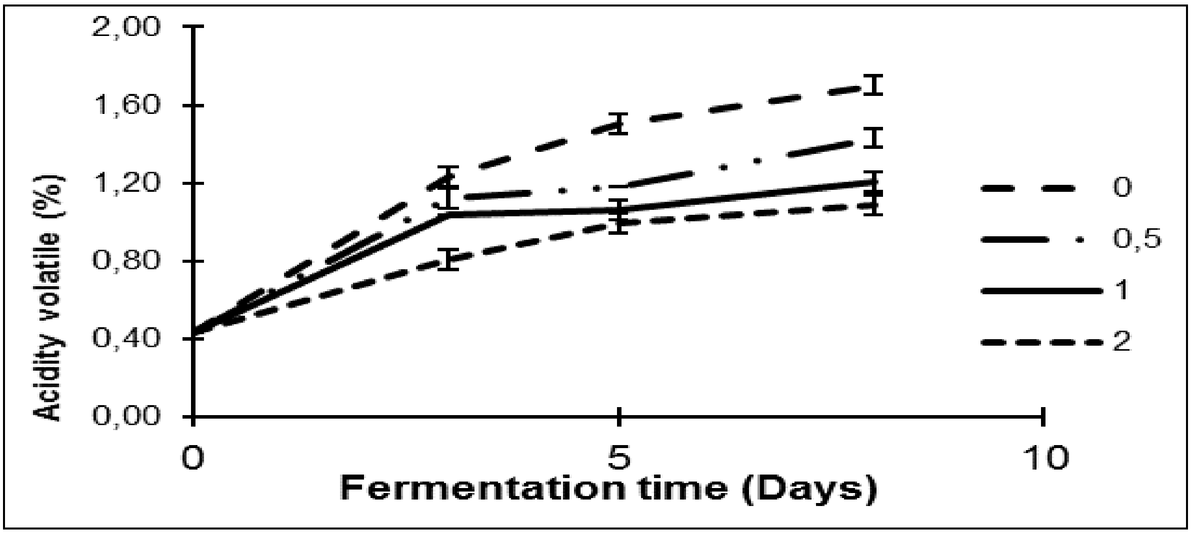

Fig. 4. Evolution of the volatile acidity according to the length of fermentation.

Initial acidity of palm wine was 0.43%, which reflects the activity of lactic acid bacteria (*Lactobacillus plantarum*, *Leuconostoc mesenteroides*). Indeed, Amoa-Awua *et al.* (2006) consider the lactic acid bacteria as being responsible for the rapid fermentation of fresh palm wine as the acetic acid-producing bacteria are absent three first days.

The value of the volatile acidity is much higher than the acetic acid content between 0.11% and 0.13% observed by these authors in Ghana for palm wines collected on the market and to undergo an additional fermentation to be distilled. It is however very close to the value (0.42%) found by (Olasupo and Obayori, 2003) in Nigeria for fresh palm wine.

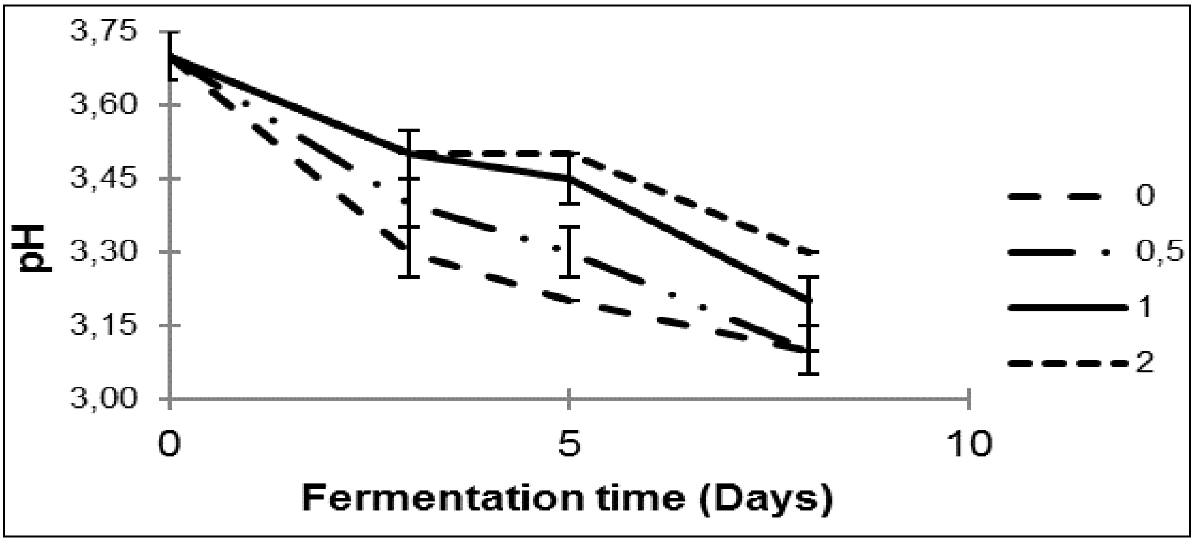

Fig. 5. Change in pH as a function of fermentation time.

Palm wines having undergone the addition of yeast showed lower values than free samples. This could be explained either by the high concentration of ethanol of samples having undergone the addition of yeast (this high concentration of ethanol would inhibit one way or another activity acidifying bacteria) or by inhibition of the activity of these bacteria by high concentration of *Saccharomyces cerevisiae*.

In general, the acetic acid content of fermented wine ranged from 0.80 (sample 2/3) and 1.70% (sample 0/8). The values of acidity obtained on the third day are slightly higher than the 0.6% value found by (Amoa-Awua *et al.*, 2006) in Ghana for palm wine of three days of storage. The values obtained on the eighth day, are lower than 2.03% found by the same authors for wine of six days of storage.

In addition, there is a significant difference at 5% between volatile acidity rate of all samples having undergone for the same yeast contribution, different fermentation times. For the same periods, only samples 0/3 and 2/3, do not show any significant differences.

pH

The analysis of Fig. 5. shows a decrease in pH during the fermentation as pointed by (Olasupo and Obayori, 2003; Ogbulie *et al.*, 2007). For (Akin, 2008), this drop in pH during fermentation is directly related to the assimilation of nitrogen source by the yeast. It also reflects the acidification of the environment by production of acetic acid (Fig. 4.).

The samples that have been eight days of fermentation are those who submitted the lowest pH. The pH value observed for the control wine has not undergone any fermentation time is equal to 3.70. This value is close to that found (3.73 and 3.86) by (Amoa-Awua *et al.*, 2006). In general, after undergoing various combinations of fermentation, the pH of wine samples ranged from 3.1 to 3.5. These values are slightly higher than the values (Ogbulie *et al.*, 2007) who noted a pH between 2.10 and 3.4 for Nigerian wines has undergone three to ten days of fermentation.

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