Original Research Article

Changes in physicochemical parameters during storage of the inflorescence sap derived from four coconut (*Cocos nucifera* L.) varieties in Côte d'Ivoire.

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ABSTRACT

Aim: The study investigated the changes in the main physicochemical parameters of the coconut inflorescence sap derived from MYD, WAT, PB 121^{+} and PB 113^{+} varieties during storage.

Place and duration: Marc Delorme Research Station for coconut, National Agronomic Research Center, Abidjan, Côte d'Ivoire, between March and May, 2013.

Methodology: The coconut sap was collected from six coconut trees per variety, and then a sample for each variety was constituted by mixing the collected saps. Three samples of the coconut sap from each variety, each collected on a different day (three days of collection), were stored at 35±2 °C. Then 10 parameters were assessed during 120 h (5 days) of storage.

Results: The results showed a significant effect of the storage duration upon the whole parameters. Specifically, important decrease was observed for the total sugars contents (from 16.08 to 0.93 g/100 mL), pH (7.32 to 4.17) and the relative density (1.055 to 1) of the coconut sap samples, without any differentiation between varieties. Also, the total soluble solids and the dry matter contents dropped respectively from 16.31 to 3.82% and 16.47 to 3.09 g/100 g. On the other hand, significant increases were recorded with the total titrable acidity (from 0.26 to 1.85 g/100 g) and the tannins contents (from 5.65 à 13.2 mg/L). Concerning reducing sugars and proteins, partial increasing in their contents were recorded respectively, 6.60 to 8.29 g/100 mL and 2.34 to 2.84 g/100 mL after

24 hours of storage. The total polyphenols contents reached peaks of 606.84 mg/L to 1316.24 mg/L after 36 h, before decreasing. The WAT differed from the three other varieties with the highest content of total polyphenols and tannins during the 120 hours of storage.

Conclusion: The study evidenced similar changes in the physicochemical traits during 5 days of natural fermentation of the sap of different coconut varieties. The sap remained stable during the first 12 hours of storage, but up to 5 days the main nutrients were spoiled.

Keywords: Coconut sap - varieties - storage - fermentation - sugars.

INTRODUCTION

The coconut (*Cocos nucifera* L.) is a tropical crop mainly cultivated for the production of nuts. When they are immature, the nuts contain a delicious and refreshing drink [1] and the mature nuts are raw material to oil production for food, cosmetic and pharmaceutical industries. However, ants' attacks and environmental constraints lead to decreases of the yield in nuts production. In addition, the severe crash in the price of the coconut oil, resulting from competition with other oil crops such as oil palm and soya, limits continuously the plant's profitability. For the revival of this sector and to get numerous coconut farmers out of poverty, other diversified products, like coconut sap, seem to be promising perspectives [2]. The coconut sap (*Neera*) remains the most important value added product that has sought the attention of all the stakeholders in coconut [3]. Indeed, the coconut sap records great valorizations in the countries of South-eastern Asia (Philippines, India, Indonesia, etc.) which have the largest coconut farms in the world. The sap contains several nutrients that are mostly carbohydrates (sucrose, glucose and fructose). There are also amino acids such as glutamine, vitamins (C, B) and minerals including potassium, phosphorus and iron [2; 4; 5]. Following the example of the sap derived from other palm species, the coconut sap is often directly consumed by the local populations and is very appreciated thanks to its nutritious values. However, the most important valorizations of the coconut sap are with the processing into syrup, sugar and distilled alcohol [6]. The coco syrup and sugar are among the foods with low glycemic index, lower than 50 [7]. Thus, these by-products record so high value-addition that the production, processing and trading of the coconut sap seem more profitable than the empirical sale of the nuts [8]. Nevertheless, the shelf life remains a limiting factor for the valorization of the coconut sap. Indeed, the rich nutritious composition of the sap leads it logically to a fast spoilage. The deterioration is caused by the microorganisms associated with both environmental and hygienic conditions of the sap production [9]. After the

harvest of the sap, the glucides undergo spontaneous degradation leading to several chemicals as alcohols, acids, aldehyds, ketones and esters [10] characterizing loss of the stability of the product.

In Côte d'Ivoire, there isn't any report on the changes of the physicochemical parameters of the coconut sap after harvesting. Yet, the country owns numerous coconut varieties which differ with the physicochemical traits of their sap [4]. Considering the role of the palms saps in the diet of the populations, it is important to know more about the changes may occur during storage. This study investigates the changes in the physicochemical parameters of the sap provided by four widespread coconut varieties.

MATERIAL AND METHODS

1. Plant material

The plant material was the sap derived from unopened inflorescences (spathes) of four coconut varieties, namely Malayan Yellow Dwarf (MYD), West African Tall (WAT) and the improved hybrids PB 121^{+} (MYD x improved WAT) and PB 113^{+} (Cameroon Red Dwarf x improved Rennell Island Tall).

2. Methods

2.1. Sampling

From each variety, six adult and healthy coconut palm trees were randomly chosen on experimental coconut plots at the Marc Delorme Research Station of the National Agronomic Research Center in Côte d'Ivoire. Then, from each coconut tree, the spathe of rank 8 which should be opened within two months, allowed the sap harvesting. The spathe was severed and its surface was introduced into an empty plastic can through a circular opening allowing the sap gathering. The cans were previously sterilized with boiling water at 100 °C. The can and the spathe were covered with a sterile muslin cloth in order to preserve the hygienic quality of the sap. At each harvesting, the sap was immediately spilled into plastic sterile bottles, placed in an isotherm cool bag with ice sheets, sent to laboratory and kept at -20 ºC until analysis [5]. After each harvest, the continuous oozing of the sap was ensured by removal of 3 to 5 mm thickness from the surface of the spathe. The sap was harvested twice a day, at 7 AM and 5 PM [12]. Later, the saps provided by the trees of each coconut variety were mixed and a sample of 1.5 L was used for analyses. Then the sap samples were stored at 35±2 °C [12] in an oven, and the physicochemical parameters were assessed after 0, 4, 8, 12, 24, 36, 48, 72, 96 and 120 h of storage. The investigations were repeated for three different days of harvest and the whole study was conducted with 12 samples of coconut sap (1 sample of 1.5 L x 4 varieties x 3 repetitions).

2.2. Determination of physical parameters

The dry matter content was determined by drying 10 g of sap sample in an oven (Memmert, Berlin, Germany) at 105 °C [13] for 8 hours. The relative density was determined by measuring the mass of 1 mL of sap. Both determinations used an electronic two digits scale (Mettler BD 202, USA). The total soluble solids content was recorded with a refractometer (DIGIT 032, Brussels, Belgium).

2.3. Determination of the chemical and nutritive parameters

The potential of hydrogen was determined with a pH-meter (HANNA Instruments).

The total titrable acidity was measured by the titration [14] of the sap samples with solution of sodium hydroxide. The total polyphenols content was determined using the folin ciocalteus method [15] improved by Boizot and Charpentier [16]. Then the tannins content was deducted from the total polyphenols with the use of vanillin in acid solution [17]. The proteins contents were determined according to the method described by Lowry *et al*. [18], using also folin ciocalteus reagent. The total carbohydrates contents were assessed with phenol and sulfuric acid method [19], and the reducing sugars contents were determined by using the 3, 5 - dinitrosallicylic acid [20]. All the analyses were achieved in triplicates.

3. Statistical analysis

The sap samples harvested through the three days of investigation were replications for each variety. The statistical analysis was achieved with SPSS software (SPSS 16.0 for windows, SPSS Inc.). It consisted in two factors analysis of variance (ANOVA). The factors were the variety and the duration of the storage. Means were classified by the Newmann Keuls test at 5% significance level. Then, correlations between parameters were assessed according to the Pearson index.

RESULTS

The statistical analysis of the data showed significant effects of the storage duration (P<.001) on the 10 characters assessed from the sap provided by the four coconut varieties (table 1).

1. Physical parameters

1.1 Dry Matter

Considering the four varieties, the dry matter content decreased significantly (P<.001) from a range of 14.64-16.47 g/100 g to 3.09-5.55 g/100 g during 120 h of storage of the coconut saps. The initial 12 h of storage revealed steady dry matter of the sap provided by the MYD (16.47 to 13.86 g/100 g), WAT (14.86 to 12.82 g/100 g), PB 121^+ (14.75 to 14.70 g/100 g) and the PB 113^+ (14.64 to 14.06 g/100 g). However, the means recorded from the WAT were significantly lower than those of MYD, PB 121^+ and PB 113^+. From 24 h until 120 h of storage, the decrease in the dry matter was significant for each variety. It led to 5.53, 3.09, 5.24 and 4.55

g/100 g respectively for the MYD, WAT, PB 121^{+} and PB 113^{+}. Between the 24th hour and the 48th hour of storage, the differences in dry matter of the varieties were not significant. But after 48 h of storage, the PB 121^{+} and MYD varieties provided significantly higher dry matter contents than WAT and PB 113^{+} (figure 1).

1.2 Relative density

The relative density of the coconut saps lowered during storage, with means varying significantly from 1.055 to 1 (P<.001). At the beginning (0-8 h) and the end (96-120 h) of storage, the relative density were stable for each variety, with values of 1.046 to 1.055 and 1 to 1,013, respectively. Moreover, apart from the values of 0 h and 120 h steps, similar means (P=0.69) were provided with the four varieties all along the storage (figure 2).

1.3 Total soluble solids

The total soluble solids contents (TSS) dropped significantly during the 120 hours of storage, with means varying from 16.31-14.31% to 3.82-7.8%. Within the first 12 h of storage, the TSS remained statistically invariable with means between 16.31% and 12.82%. From the 24th hour of storage, the decreasing was significantly faster until 96 h where TSS reached means of 4.95%, 7%, 8.27%, and 8.30% (respectively for WAT, PB 113^{+}, MYD and PB 121^{+}). The last 24 h of storage (96 h-120 h) gave steady means of total soluble solids contents per variety. At the beginning of the storage (0 h to 12 h), the WAT recorded significantly lower TSS (14.69-12.85%) than PB 113^{+} (14.65-13.77%), PB 121^{+} (14.82-14.63%) and MYD (16.31-13.87%). Between 24 h and 120 h of storage, MYD and PB 121^{+} provided more soluble solids than WAT and PB 113^{+} (figure 3).

2. Chemical and nutritive parameters

2.1 Sugars contents

Total carbohydrates

The 120 h of storage of the coconut sap revealed a significant decrease in the total carbohydrates contents (P<.001). The decrease was not significant during the earlier storage (12 hours), with total carbohydrates contents (TCC) ranging between 16.08 g/100 mL and 12.85 g/100 mL. From 24 h (12.11 to 12.58 g/100 mL), the TCC declined significantly until the 96th hour of storage where means were between 1.26 g/100 mL to 1.82 and g/100 mL. Between 96 h and 120 h of storage, the means didn't change significantly from each variety. Moreover, during the storage, the carbohydrates contents didn't differ significantly for the saps provided by the four coconut varieties (figure 4).

Reducing sugars

The reducing sugars contents (RSC) showed significant differences (P<.001) between start and end of this storage. The means were between 2.41 and 3.73 g/100 mL at the harvest of the sap. But 4 h later, they lowered to 0.56, 1.81 and 1.87g/100 mL (respectively for WAT, PB 113^{+} and MYD) or stayed relatively constant at 2.45 g/100 mL (for PB 121^{+}). Then they increased until 24 h of storage and reached maximal means of 6.6, 6.94, 7.85 and 8.29 g/100 mL with MYD, WAT, PB 113^{+} and PB 121^{+}, respectively. Beyond 24 h, the RSC dropped regularly and significantly till recording lower means of 0.06 to 0.12 g/100 mL at 120 h (figure 5).

2.2 Proteins contents

During the 120 hours of storage, the proteins contents fluctuated significantly (P<.001) between 0.14 and 2.84 g/100 mL without any significant difference between the varieties. The proteins contents were statistically stable until the 8th hour of storage, with means of 0.63 to 0.83 g/100 mL (MYD), 0.48 to 0.59 g/100 mL (WAT), 0.49 to 0.58 g/100 mL (PB 121^{+}) and 0.40 to 0.55 g/100 mL (PB 113^{+}). From 8 h, they increased significantly until 24 h and reached peak values ranging from 2.34 to 2.84 g/100 mL for the four varieties. Beyond 24 h of storage, the figure 6 shows continuous dropping of the proteins contents until 120 h where means stated to 0.29 g/100 mL (MYD), 0.14 g/100 mL (WAT), 0.30 g/100 mL (PB 121^{+}) and 0.22 g/100 mL (PB 113^{+}).

2.3 Total titrable acidity

Considering the four varieties, the total titrable acidity increased statistically from 0.26 to 1.85 g/100 g during the 120 h of storage, with relative stability stages. Statistically, significant differences were observed between the acidity of the four coconut varieties (P<.001).

With MYD, the significant increasing of the total titrable acidity was observed between 4 h and 8 h (0.50 to 0.72 g/100 g), 12 h and 24 h (0.84 to 1.17 g/100 mL) and after 72 h (1.53 to 1.85 g/100 g).

Regarding WAT, the acidity increased significantly from the beginning of the storage till 36 h (0.32 to 1.19 g/100 g), then within 48-72 h (1.27 to 1.40 g/100 g).

For PB 121^{+}, the total acidity increased significantly within the early four hours of the storage (0.31 to 0.61 g/100 g) and between 12 h and 120 h (0.77 to 1.65 g/100 g). On the other hand, between 4 h and 12 h, the acidity didn't show any obvious change.

The acidity recorded from PB 113^{+} varied significantly from 0 h to 24 h (0.31 to 1.04 g/100 g) then between 48 h and 72 h (1.20 to 1.31 g/100 g). But within 24 h and 48 h (1.04-1.20 g/100 g) then from 72 h to 120 h (1.31-1.45 g/100 g) the variations were not statistically significant (figure 7).

2.4 Potential of hydrogen

The four varieties of coconut sap provided the same values of potential of hydrogen (pH) at each point in time during storage (P=0.12). However, the pH of each coconut sap sample decreased statistically from 7.32 to 4.17 during the 120 h of storage (P<.001). From the first 8 h, the pH remained statistically steady, fluctuating between 6.97 and 6.83 (PB 113^+), 7.10 and 6.67 (PB 121^+), 7.18 and 6.93 (WAT) and between 7.32 and 6.6 (MYD). Thereafter, it decreased significantly until 96 h of storage where the means became 4.37 to 4.47. Beyond 96 h, the pH didn't change anymore, providing values of 4.17 to 4.2 at 120 h of storage (figure 8).

2.5 Polyphenols compounds

Total polyphenols

During storage, the total polyphenols contents (TPC) of the coconut sap samples were significantly different (P<.001). Specifically, from 0 h to 24 h of storage, the TPC remained statistically constant from MYD (254.2 to 331.9 mg/L), WAT (565.8 to 696.6 mg/L), PB 121^+ (402.8 to 551.3 mg/L) and PB 113^+ (464.4 to 517.1 mg/L). Between 24 h and 36 h, the means increased significantly to a maximum of 606.84 mg/L (MYD), 1021.37 mg/L (PB 121^+), 1045.58 mg/L (PB 113^+) and 1316.24 mg/L (WAT). Then they stayed highest until 48 h, before dropping to values varying between 292.02 mg/L and 601.14 mg/L at 96 h of storage. Between 96 h and 120 h, the TPC didn’t show any obvious change from each type of coconut sap. However, all along the storage, the sap derived from WAT provided more total polyphenols while that of MYD recorded the lowest (figure 9).

Tannins

The tannins contents increased during the storage with significant differences between the four varieties (P<.001). With the MYD, the tannins contents increased significantly (P<.001) from 0 h to 8 h (5.65 to 6.62 mg/L) before stabilizing at 24 h (6.71 mg/L); and later, rose continuously and reached 9.95 mg/L at 120 h.

Regarding the hybrids, the significant increase in the tannins contents appeared within the early 8 hours of storage, where the averages varied between 5.99 and 7.25 mg/L (PB 121^+) and 6.19 and 7.57 mg/L (PB 113^+). However from 8 h, both hybrids provided steady and similar values fluctuating between 7.25 and 8.38 mg/L.

The WAT recorded significant increase in the tannins contents between 0 h and 4 h (6.45 to 7.03 mg/L), 8 h and 12 h (7.34 to 8.42 mg/L) and from 24 h to 96 h (9.41 to 12.88 mg/L). Besides, the tall variety provided higher tannins contents than the other varieties during the 120 h of storage of the coconut sap (figure 10).

3. Correlations between parameters

The values of Pearson indexes (*r*) indicate positive and negative significant correlations between the 10 characters assessed. Thus, pH, relative density and contents of total soluble solids, total carbohydrates and dry matter were closely correlated during the 120 h storage of the sap (*r* varying from 0.84 to 0.98). Also, the

reducing sugars and the proteins contents changed similarly (r=0.81). The tannins contents were directly correlated with the total titrable acidity (r=0.65).

On the other hand, the tannins contents and the total titrable acidity were reversely correlated with the relative density, pH and the contents of total carbohydrates, dry matter and total soluble solids of the coconut saps, with r fluctuating between -0.90 and -0.66 (table 2).

DISCUSSION

The continuous changes of the physicochemical parameters of the coconut sap could probably be attributed to the fermentation. Till dates, numerous of authors have reported the chemical processes explaining the fermentation of the palm saps and the main by-products of these processes [10; 21]. Specifically, the carbohydrates of the unfermented coconut sap had a greater proportion of sucrose [4]. During storage, the sucrose is converted into glucose and fructose by hydrolases, which are used later by the microorganisms for their growth. However, this hydrolysis activity was slower at the beginning of the sap's storage because of the low presence of ferments. But, the acceleration in sugars consumption could have been enhanced by the exponential growth of the microbes. Our results corroborate the works of Eze and Ogan [12] who reported a decrease of the total sugars contents from 11.61% to 0.23% after 33 h of fermentation of saps produced by oil palm at 36-37 °C. Otherwise, after four days, the stable total carbohydrates contents could explain the inhibition of the microorganisms' growth, after the sugars become scarce and the environment hostile by the lower pH. Besides, Xia *et al*. [22] and Stringini *et al*. [23] specified three stages during natural fermentation of the palm saps. They consist of an initial lactic, an intermediate alcoholic and a final acetic fermentation. Thus, effects of the micro-organisms from the first stages improve those of the following ones [24].

The total carbohydrates contents were correlated to the density, dry matter and total soluble solids contents of the coconut saps. Indeed, sugars are the major macromolecules in the sap of the palms trees [4; 25]. According to Miallet-Serra *et al*. [26], the dry matter of the juices, like the coconut sap, is mainly constituted of glucides. The consumption of the sap sugars resulted in a continuous decrease in the relative density of each of the four varieties. After five days of storage, most of the sugars had been consumed so that the relative density of the sap became close to that of water which is 1. The total soluble solids contents remain steady during the first 12 h of storage because the macromolecules of the sap, specifically glucides, would not be significantly metabolized within this time. Besides, WAT provided lower values of total soluble solids during the early storage. The investigations of Konan *et al*. [4] showed that among the four varieties, the WAT produced a sap with lower content of sucrose, the main glucide. Thus the total soluble solids could have depended on the sucrose at the

beginning of the storage. But during the increase in reducing sugars and proteins contents, these molecules would significantly account for the total soluble solids contents.

The initial decrease of the reducing sugars contents could result from the direct use of the residual glucose [4] in the sap at the time it was harvested. Thereafter, the increase of reducing sugar contents until 24 h of storage was combined with drop of the total sugars contents. According to Olive [27], after hydrolysis of sucrose, the microbes, specifically yeasts, would prefer the glucose. As the sucrose is converted into glucose and fructose, the increase of the reducing sugars content could be due the presence of fructose which is not directly metabolized by microorganisms. The results show the maximal reducing sugars contents after 24 h of storage, while a study by Xia *et al*. [22] indicated the highest reducing sugars content (0.8%) after two to three days of natural fermentation of the sap produced by the same type of palm plant. These authors worked with a temperature of 25 °C which could have delayed the hydrolysis ability of the ferments microbes whose optimal activity is between 30-37 °C. Afterwards, the dropping of the reducing sugars contents evidences the consumption of all sugars by the microorganisms.

A natural occurrence of microbes in the sap would produce proteins (enzymes) which enhance spontaneously the fermentation [28]. However, the increase of the proteins contents reveals a continual and significant synthesis of enzymes during the first 24 h of storage. After 36 h, the substrates became scarcer and that would lead to a repression of the enzyme synthesis from the surviving microorganisms [27]. Consequently, the proteins contents decreased during the rest of the fermentation process. This accounted for the positive correlation with the changes in reducing sugars contents.

The results showed a significant increase of the titrable acidity at the beginning of the storage. This earlier acidification could result from lactic acid bacteria (LAB) as reported by Xia *et al*. [22]. Moreover, the LAB whose activity produces lactic acid could lower the pH to values of 5-6 leading to promotion of yeasts and moulds. As the yeasts are responsible of the alcohol fermentation, the partial stabilization of the acidity could characterize stages of alcoholic production in the coconut sap. Later, a third stage of the acidity could be induced by the acetic acid bacteria (AAB) [29] occurring in the sap with production of acetic acid which turn it to sour and vinegar. From these results, the total titrable acidity of the coconut sap was constantly higher than the means reported by Eze and Ogan [12] from the oil palm sap. The intense acidification could have contributed to astringent and bitter tastes of the fermented coconut sap [9].

The raising of the total polyphenols contents results from the hydrolysis of the bonds between the polyphenols and other molecules. According to Xia *et al*. [22], the polyphenols would be naturally bound with sugars,

proteins, cellulose and starch in the sap. Thus, the continuous acid hydrolysis of those bonds during fermentation [30] increased the total polyphenols contents which reached peak means at 36 h. However, after 48 h, the decrease in total polyphenols content could have resulted with enzymatic oxidization by polyphenol oxidase and phenolase according to the hypothesis of Konan *et al*. [31]. The works of Xia *et al*. [22] didn't show any obvious change of the coconut sap's polyphenols content after reaching peaks values from 56 h of fermentation at 25 °C. In fact, our investigations were carried out under 35±2 °C, which could have activated the enzyme mentioned above. The tannins are part of polyphenols compounds. The perpetual increasing of their content reveals the continuous degradation of the polyphenols bindings.

CONCLUSION

The assessment of the physicochemical parameters during the storage of the coconut sap showed a continuous degradation of the total carbohydrates which were the major macromolecules. During the first 12 hours of storage, the sap remained stable. But, the carbohydrates were progressively hydrolyzed into reducing sugars, whose content increased partially, and then were fermented by the microorganisms. Consequently, the acidity increased continuously, evidencing the spoilage of the coconut sap during storage. Beyond four days, the sap contained very little nutrients and its higher acidity could even render it unpleasant for drinking.

Authors contributions:

This work was achieved with collaboration between all authors. Author KNY designed the study, wrote the protocol, performed the laboratory and statistical analyses and wrote the first draft and the revised form of the manuscript. Author KKJL gave the plant material. Authors KKJL, ARR, KBR and BGH supervised the laboratory analyses, took part in the interpretation of the results, and checked the first draft and the revision of the manuscript. Author IAE participated in the statistical analysis. Author OMJ took part in the performing of laboratory analyses. All authors read and approved the submitted and the revised form of the manuscript.

Competing interests:

Authors declare that the whole study results from an original work achieved by them and any other interest does not exist.

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Table 1: Statistical data of physicochemical parameters of the inflorescence saps derived from four coconut varieties namely Malayan Yellow Dwarf, West African Tall and improved hybrids PB121^{+} and PB113^{+}, during the storage at 35±2 °C

Sources of variation	df		PARAMETERS									
			TCC	**RSC**	**PRC**	**TSS**	**TTA**	**pH**	**DEN**	**DMC**	**TPC**	**TAC**
Varieties	3	*SS*	2,18	16,62	0,66	77,31	0,43	0,48	0,00	38,21	2692788	89,75
		F-value	0,47	1,42	1,05	26,60	8,98	1,43	0,76	10,12	68,92	299,25
		P-value	0,70	0,24	0,37	**<0,001**	**<0,001**	0,24	0,52	**<0,001**	**<0,001**	**<0,001**
Durations	9	*SS*	3242,88	710,22	65,41	1048,98	21,93	127,84	0,03	1591,48	5581122	180,57
		F-value	234,61	20,25	34,78	120,31	153,20	127,78	39,87	140,52	47,61	200,68
		P-value	**<0,001**	**<0,001**	**<0,001**	**<0,001**	**<0,001**	**<0,001**	**<0,001**	**<0,001**	**<0,001**	**<0,001**
Varieties		*SS*	37,01	54,32	4,97	27,93	0,34	1,39	0,00	19,20	358718	63,17
X	27	*F-value*	0,89	0,52	0,88	1,07	0,80	0,46	0,21	0,56	1,02	23,40
Durations		*P-value*	0,62	0,97	0,64	0,40	0,74	0,99	1,00	0,95	0,45	**<0,001**
Error	80	*SS*	122,87	311,74	16,72	77,50	1,27	8,89	0,01	100,67	1041940	8,00
Total	120	*SS*	14070,83	2617,15	203,60	17255,04	152,43	4061,49	127,72	16011,77	54522893	8140,03

SS, sum of squares; F-value, value of the statistical test; P-value, probability value of the statistical test; df, degree of freedom.

TCC, total carbohydrates contents; RSC, reducing sugars contents; PRC, proteins contents; TSS, total soluble solids contents; TTA, total titrable acidity; pH, potential of hydrogen; DEN, relative density; DMC, dry matter contents; TPC, total polyphenols contents; TAC, tannins content.

Table 2: Matrix of correlations between physicochemical parameters during storage of the saps derived from four coconut varieties namely Malayan Yellow Dwarf, West African Tall and improved hybrids PB 121^{+} and PB 113^{+}, during 120 h of storage at 35±2 °C.

	TCC	RSC	PRC	TSS	TTA	pH	DEN	DMC	TPC	TAC
TCC	1,00									
RSC	0,39	1,00								
PRC	0,26	**0,81**	1,00							
TSS	**0,91**	0,41	0,23	1,00						
TTA	**-0,86**	-0,08	0,07	**-0,81**	1,00					
pH	**0,91**	0,14	0,05	**0,84**	**-0,90**	1,00				
DEN	**0,88**	0,24	0,06	**0,87**	**-0,87**	**0,84**	1,00			
DMC	**0,95**	0,41	0,23	**0,98**	**-0,85**	**0,88**	**0,89**	1,00		
TPC	-0,08	0,34	0,39	-0,17	0,19	-0,24	-0,15	-0,14	1,00	
TAC	**-0,65**	-0,12	-0,02	**-0,81**	**0,65**	**-0,67**	**-0,66**	**-0,73**	0,33	1,00

The bold values are significant at P=.05.

TCC, total carbohydrates contents; RSC, reducing sugars contents; PRC, proteins contents; TSS, total soluble solids contents; TTA, total titrable acidity; pH, potential of hydrogen; DEN, relative density; DMC, dry matter contents; TPC, total polyphenols contents; TAC, tannins content.

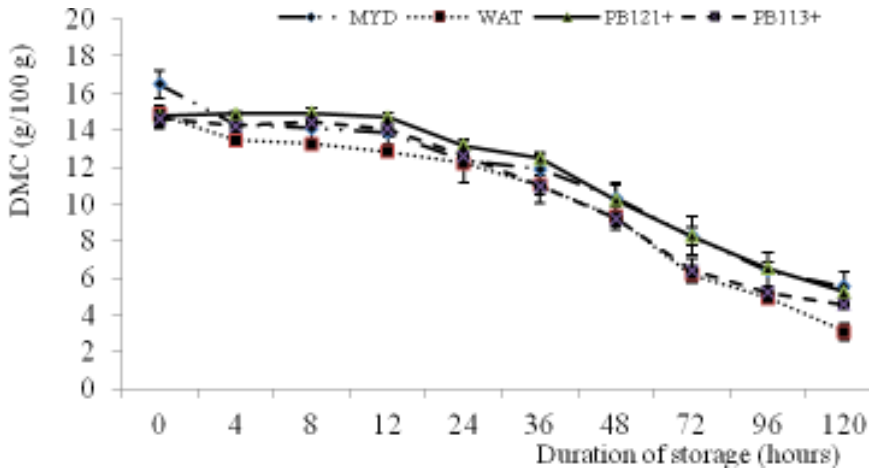

Figure 1: Changes in the dry matter contents (DMC) of the inflorescence sap derived from MYD, WAT, PB 121^{+} and PB 131^{+} coconut varieties stored at 35±2 °C.

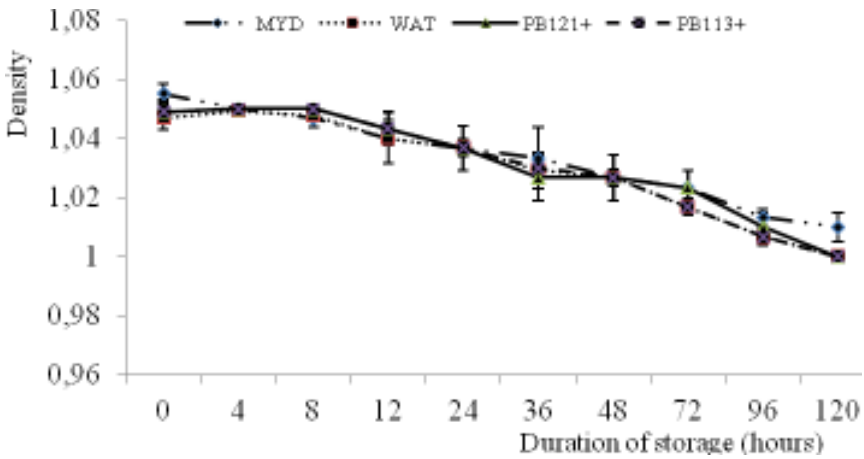

Figure 2: Changes in the relative density during storage at 35±2 °C of the inflorescence sap derived from MYD, WAT, PB 121^{+} and PB 131^{+} coconut varieties.

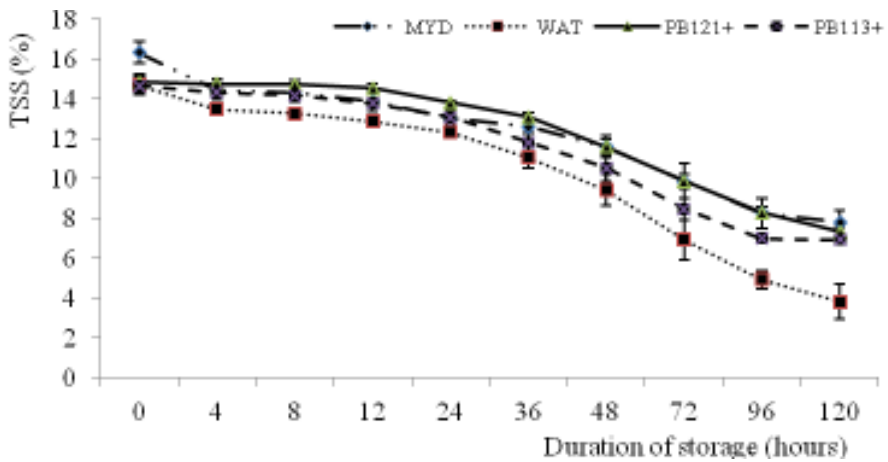

Figure 3: Changes in the total soluble solids contents (TSS) during storage at 35±2 °C of the sap produced by MYD, WAT, PB 121^{+} and PB 131^{+} coconut varieties.

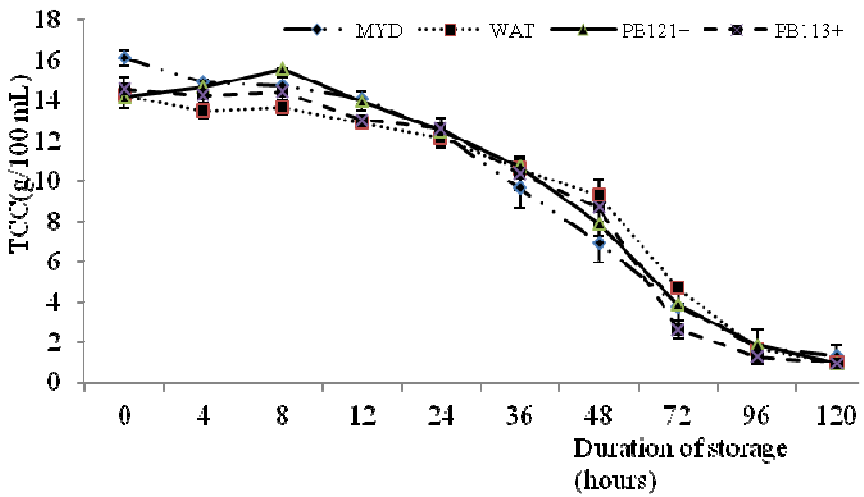

Figure 4: Changes of the total carbohydrates contents (TCC) during storage at 35±2 °C of the sap produced by MYD, WAT, PB 121^{+} and PB 113^{+} coconut varieties.

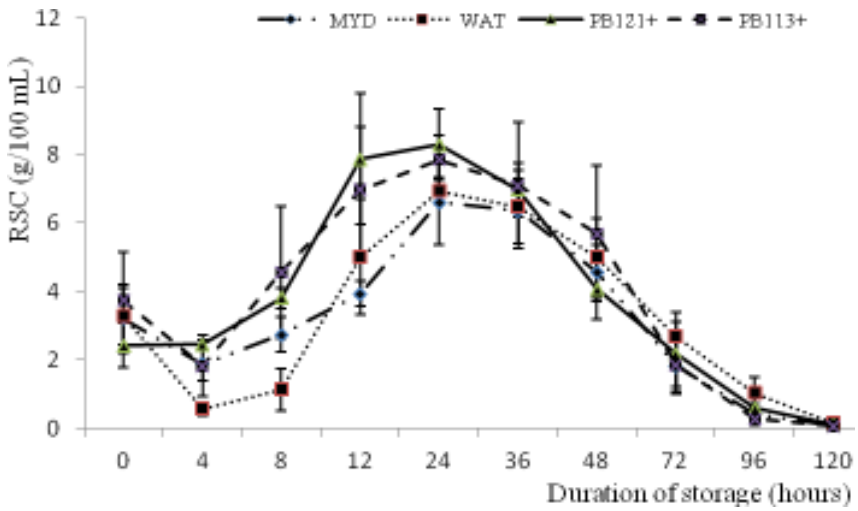

Figure 5: Evolution of the reducing sugars contents (RSC) of the sap of MYD, WAT, PB 121^{+} and PB 113^{+} coconut varieties during the storage at 35±2 °C.

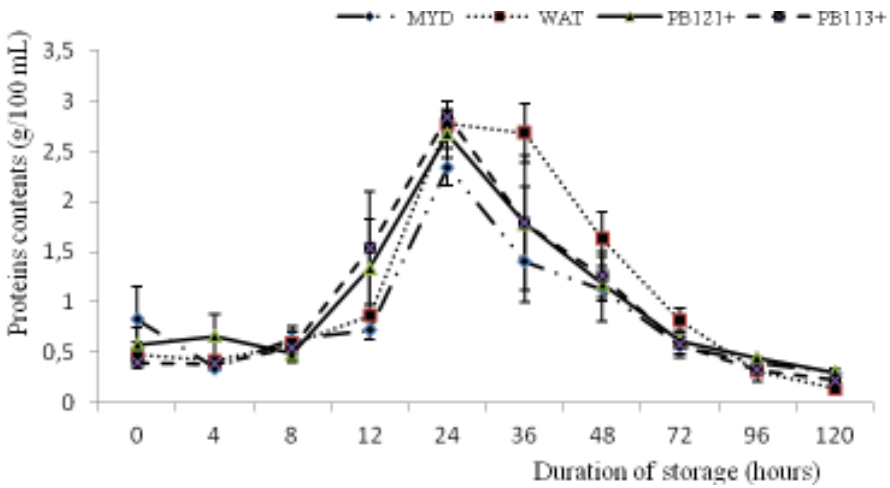

Figure 6: Changes of the proteins contents of the sap of MYD, WAT, PB 121^{+} and PB 113^{+} coconut varieties according to the duration of storage at 35±2 °C.

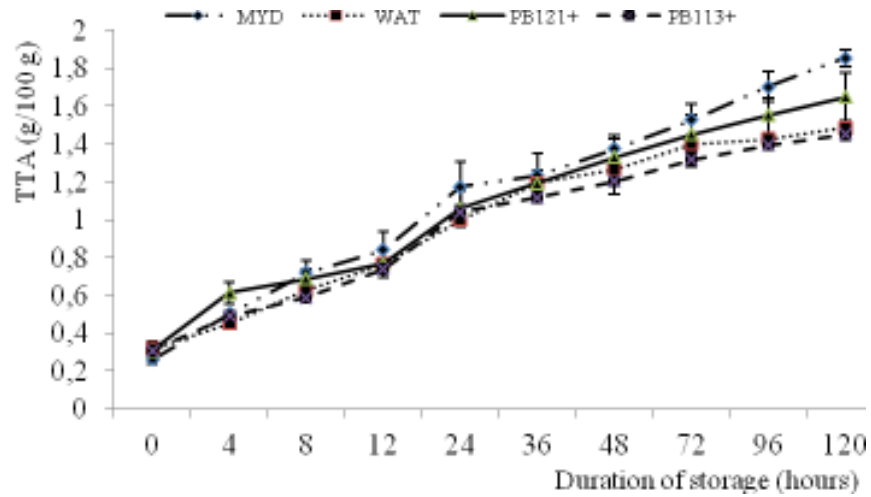

Figure 7: Total titrable acidity of the sap of MYD, WAT, PB 121^{+} and PB 113^{+} coconut varieties according to the duration of storage at 35±2 °C.

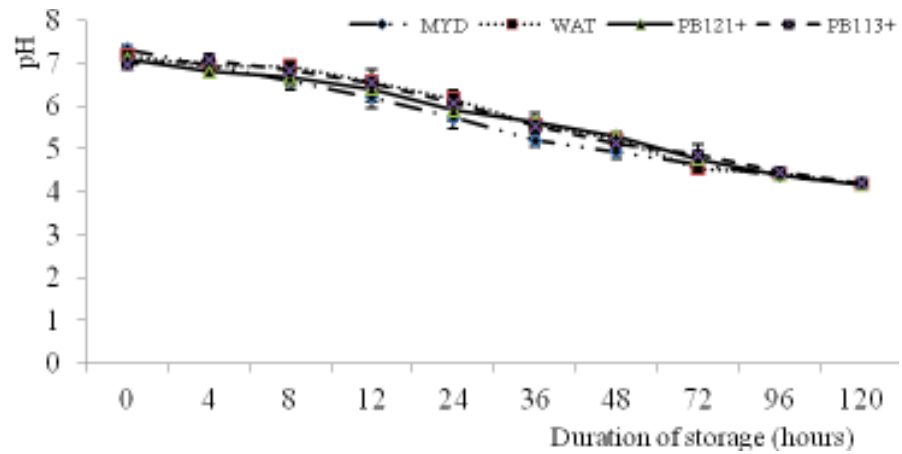

Figure 8: Potential of hydrogen (pH) of the sap deriving from MYD, WAT, PB 121^{+} and PB 113^{+} coconut varieties during the storage at 35±2 °C.

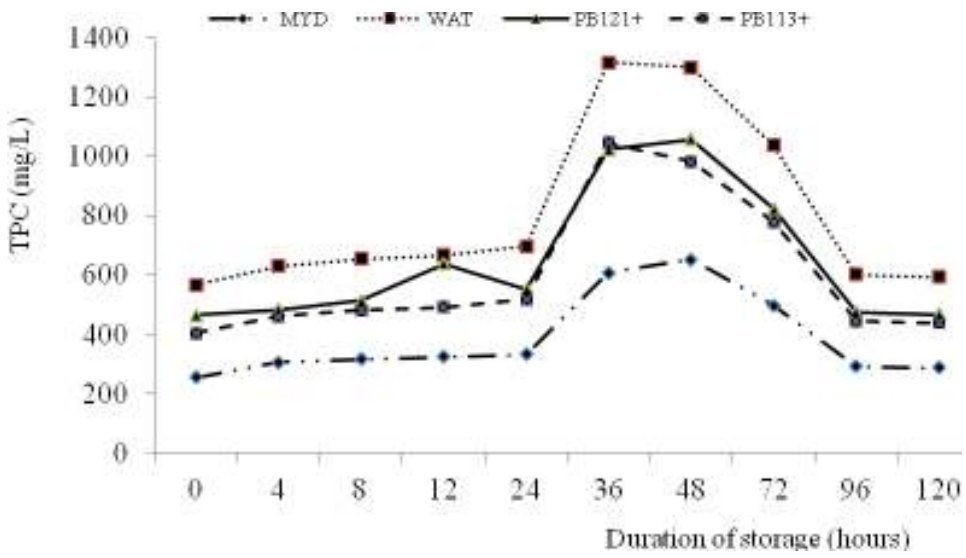

Figure 9: Variation of the total polyphenols contents (TPC) during the storage at 35±2 °C of the inflorescence sap of MYD, WAT, PB 121^{+} and PB 113^{+} coconut varieties.

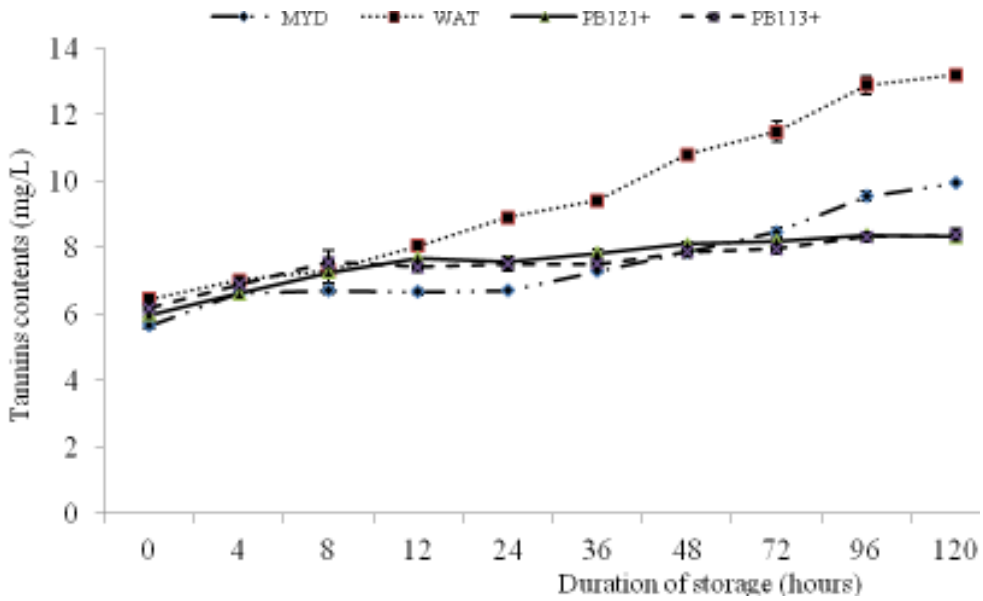

Figure 10: Evolution of the tannins contents of the inflorescence sap of MYD, WAT, PB 121^{+} and PB 113^{+} coconut varieties according to the duration of storage at 35±2 °C.