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Full Length Research Paper

Sugar and macrominerals composition of sap produced by *Raphia hookeri* palms

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Mature *Raphia hookeri* palms located in the experimental fields of the Nigerian Institute For Oil Palm Research Nigeria were selected, and tapped daily at the base of the inflorescences. The exudates (saps) were collected and the sugars and macromineral composition were determined. Maximum sucrose quantity (9.5%) was obtained about 28 days after initiation of tapping. The sucrose concentration was correlated with the sap volume. Sodium, potassium, calcium, magnesium, phosphorus and nitrogen were present in the varied concentrations throughout the duration of the tapping operation. The concentration of the macrominerals were of the order of K>Mg>N>P>Na. Statistically, significant differences (P<0.05) were observed between the macrominerals detected in the various saps. Heavy metals like mercury, cadmium, selenium and lead were not detectable in the sap.

Key words: Sugar, macrominerals, *Raphia hookeri*, sap exudates.

INTRODUCTION

Raphia is the largest palm in Africa and is one of the most useful economically. The leaves are used for shelter and the stem produces palm sap, which is drank as beverage. The fermented sap could be distilled into alcohol or gin. Succulent, oily larvae of weevils and beetles are obtained from infected palms and serve as delicacy. The trunk could serve as firewood. The mesocarp of the ripe fruit yields edible oil (Otedoh, 1976, 1990)

In human nutrition, sucrose is considered as a macronutrient that yields a quick source of energy. Sucrose is a transportable and mobilizable sugar that is stored in many plant cells as in sugar beets and sugar-cane. Sucrose plays a central role in the carbohydrate metabolism of plants. During the lifetime of a plant, a major portion of the carbon fixed by photo-synthesis will pass through the sucrose molecule. Sucrose as a conversion product of photosynthesis is rivalled only by starch. The concentration of sucrose and starch formed by plants vary with the species and the conditions of growth (Rees, 1980; Dennis, 1987). Plant foods also contain almost all the mineral and organic nutrients established as essential for human nutrition, as well as a number of unique organic phytochemicals that have been linked to the promotion of good health (Grusak and DellaPenna, 1999). Because the concentrations of many of these dietary constituents are often low in edible plant sources, research is under way to understand the physiology, biochemical and molecular mechanisms that contribute to their transport, synthesis and accumulation in plants.

Macrominerals are required in amounts greater than 100 mg/d in human nutrition (Mayes, 1993). Arising from the importance of these macrominerals, the American Food and Nutrition Board of the National Academy of Sciences / National Research Council (2001), developed a Table called the Recommended Dietary Allowances (RDAs) of the above macrominerals for optimum nutrition in infants, children, adults and pregnant women.

Palm wine is the fermented sap of the oil palm (*Elaeis guineensis*) and the *Raphia* palm (*R. hookeri*). Both species are believed to have originated from the swamps of West Africa. *R. hookeri* is restricted to the tropical rain forest, the ideal ecological condition for the *Raphia* palm (Ndon, 2003). *R. hookeri* is hapazanthic i.e. after a period of vegetative growth; it produces flowers and fruits only

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Table 1. Volume and sucrose content of *R. hookeri* sap.

Palm no.	Week	Volume (litre) (Mean per week)	Sucrose concentration (g/100 ml)
1	1	6.00 ± 1.00	2.20 ± 0.40
	2	8.00 ± 0.20	5.00 ± 0.20
	3	4.00 ± 0.10	7.00 ± 0.10
	4	15.00 ± 0.30	8.00 ± 0.20
	5	6.00 ± 0.70	5.60 ± 0.20
2	1	8.00 ± 0.90	4.00 ± 0.50
	2	14.00 ± 0.40	6.50 ± 0.40
	3	18.00 ± 0.80	6.00 ± 0.30
	4	38.00 ± 0.40	8.00 ± 0.20
	5	12.00 ± 0.80	4.00 ± 0.10
3	1	13.00 ± 1.20	8.00 ± 0.50
	2	16.00 ± 0.80	8.70 ± 0.50
	3	20.00 ± 0.60	8.50 ± 0.20
	4	21.00 ± 0.50	9.40 ± 0.30
	5	6.00 ± 1.00	4.50 ± 0.10
4	1	6.00 ± 1.00	4.00 ± 0.90
	2	10.00 ± 0.20	8.00 ± 0.20
	3	8.00 ± 0.10	7.00 ± 0.10
	4	11.00 ± 0.10	9.50 ± 0.10
	5	3.00 ± 1.10	1.50 ± 0.10
5	1	4.00 ± 0.20	5.00 ± 0.50
	2	10.00 ± 0.20	6.50 ± 0.20
	3	14.00 ± 0.10	7.00 ± 0.10
	4	20.00 ± 0.20	9.00 ± 0.10
	5	8.00 ± 0.10	5.00 ± 0.10
6	1	9.00 ± 0.90	5.00 ± 0.50
	2	16.00 ± 0.20	6.00 ± 0.30
	3	17.00 ± 0.60	7.50 ± 0.50
	4	20.00 ± 0.50	8.90 ± 0.10
	5	13.00 ± 1.10	5.00 ± 0.50
7	1	7.00 ± 0.80	4.00 ± 0.20
	2	15.00 ± 0.30	6.50 ± 0.20
	3	17.00 ± 0.40	8.00 ± 0.10
	4	19.50 ± 0.40	9.00 ± 0.10
	5	6.00 ± 1.00	3.00 ± 0.50
8	1	9.00 ± 1.00	3.50 ± 0.50
	2	14.00 ± 0.50	6.00 ± 0.10
	3	15.00 ± 0.70	7.00 ± 0.20
	4	17.00 ± 0.50	8.50 ± 0.20
	5	5.00 ± 0.80	4.00 ± 0.50
9	1	8.00 ± 1.00	4.00 ± 0.50
	2	17.00 ± 0.80	6.00 ± 0.20
	3	18.00 ± 1.00	7.00 ± 0.10
	4	19.00 ± 0.80	8.00 ± 0.10
	5	4.00 ± 0.30	3.00 ± 0.50

Table 1. Contd.

10	1	6.00 ± 1.00	3.00 ± 0.10
	2	15.00 ± 0.80	5.00 ± 0.20
	3	16.00 ± 0.70	7.00 ± 0.10
	4	18.00 ± 1.00	8.00 ± 0.20
	5	3.00 ± 1.00	4.00 ± 0.50

once and dies. The flower is signalled by the simultaneous appearance in the crown of more than one expanded 'spear' leaves. It is usually at this stage that the palm is tapped for wine (sap).

The production of palm wine forms one of the most important occupational engagements of the rural inhabitants in the Nigerian palm belt. But the palm wine tapping activity is done indiscriminately since there is limited information on the quality of sap production. In this study, we monitored these characteristics, which have commercial and economic consequences for the future exploitation of this palm.

MATERIALS AND METHODS

The *R. hookeri* palms used for this study were selected randomly from the gene pool located at the swampy part of river Okhuo, at the Nigerian Institute For Oil Palm Research (NIFOR), Benin City, Nigeria. The maturity of the palms, which were about sixteen years old, was established by the appearance of three inflorescences. The studies were carried out annually in 2003, 2004 and 2005.

The palms were tapped daily in the traditional manner described by Tulley (1964) and precautions were taken to conserve wine quality and palatability. Fire was not applied to the tapping panel (to stimulate the flow of sap), and the panel was covered with polythene sheeting to exclude rain water, insects and maintain overall aseptic conditions (Otedoh, 1990).

Refractometric method was used in determining the sucrose content of the fresh sap (Maley, 1968; Eapen, 1971). Readings were taken with the Abbe hand refractometer as soon as the sap was collected from the palm. The volume of sap exuded was determined every 24 h with the aid of a simple measuring cylinder.

The sugars in the sap were further analysed by paper chromatography. The developing solvent was n-butanol/acetic acid/water (1:1:1, v/v/v) and the chromatograms were sprayed with aniline/ diphenylamine/phosphoric acid to reveal the sugar spots (Plummer, 1971). Appropriate sugars were used as standards.

The mineral elements (sodium, potassium, calcium, magnesium, lead, selenium, mercury and cadmium) were assayed for by a Computerized Atomic Absorption Spectrophotometer, Unican series model 969. Phosphorus content was determined spectrophotometrically by the p-nitrophenol method (Murphy and Rikey, 1962). Nitrogen in the sap was determined by the micro Kjeldahl method (Harris, 1970).

Means ± SD for the parameters measured were compared for statistically significant differences using Student's t-Test. Analysis of variance was conducted with the BBSSTAT package.

RESULTS AND DISCUSSION

In this study, effort was made to use methods validated by the local wine tappers so that the results and recommendations will be easily applicable. However, fire was not applied to the tapping panel, a common procedure to stimulate the flow of sap. Every effort was made to maintain aseptic conditions in tapping and collection of the sap so that fermentation of the sugars in the sap was minimized. Sucrose concentration in the sap samples was determined with the Abbe refractometer rather than the chromatographic methods (Osagie and ap Rees 1990). The hand refractometer is a compact instrument suitable for use at the field level, and does not require extensive training.

The results in Table 1 show the volume of sap obtained from each experimental tree per week, and the concentration of sucrose. These results are clearly presented in the histograms in Figures 1–10. A gradual rise in sucrose concentration and sap volumes were observed in all the palms from week one, and reached a maximum at the 4th week. The sap volumes and sucrose concentrations dropped thereafter. Overall, the results indicated that a maximum of 9.5% sucrose content was obtained in the sap. The paper chromatographic analyses revealed that the sap contained sucrose, fructose, glucose and raffinose. Quantitatively, sucrose contributed over 95% of the sugars. This is the product of photosynthetic activity in the *Raphia* palm and the minor sugars are probably metabolic products of the sucrose. Van Pee and Swings (1971), Eapen (1970/71) and Faparusi (1969) had earlier shown that the sucrose in oil palm sap was quantitatively fermented to monosaccharides and organic acids by yeast and various bacteria. At the end of 48 h, they observed that the sugars in the palm sap were fermented to yield alcohol, carbon dioxide and acetic acid.

The results for the macronutrients, determined in the sap of *R. hookeri* palms are presented in Table 2. The concentrations of the individual elements from the ten palms analysed in year 2005 were compared as presented in Figures 1 – 6. Statistical analysis revealed that there were significant differences ($P<0.05$) between the individual elements detected in the sap of the *R. hookeri* palms, which may be attributed to the difference in need and bioavailability of the elements. Because the concentrations of many of these dietary constituents are often low in edible plant sources, research is under way to understand the physiological, biochemical and molecular mechanisms that contribute to their transport, synthesis and accumulation in plants (Grusak and DellaPenna, 1999). Mercury, cadmium, selenium and lead were not

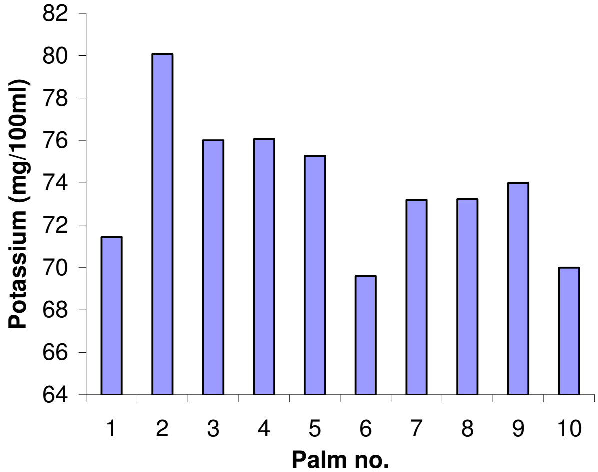

Figure 1. Mean values of potassium in the sap of *R. hookeri* palms.

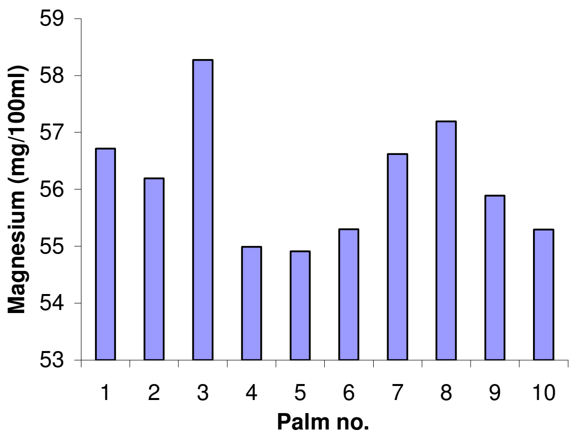

Figure 2. Mean values of magnesium in the sap of *R. hookeri* palms.

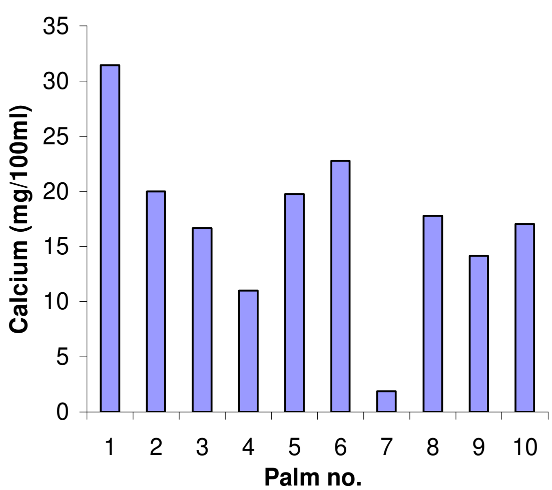

Figure 3. Mean values of calcium in the sap of *R. hookeri* palms.

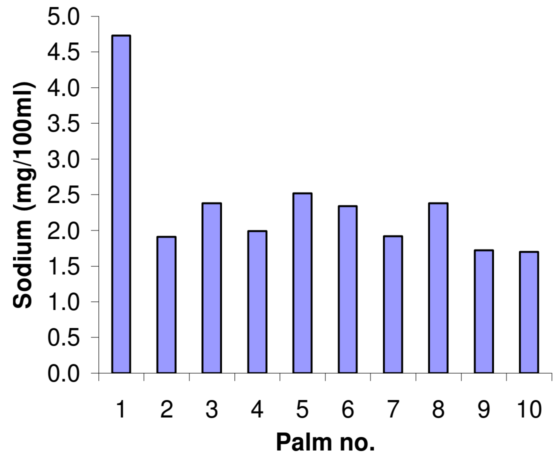

Figure 4. Mean values of sodium in the sap of *R. hookeri* palms.

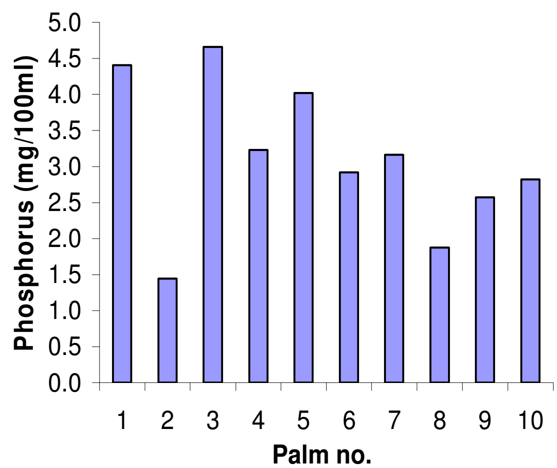

Figure 5. Mean values of phosphorus in the sap of *R. hookeri* palm.

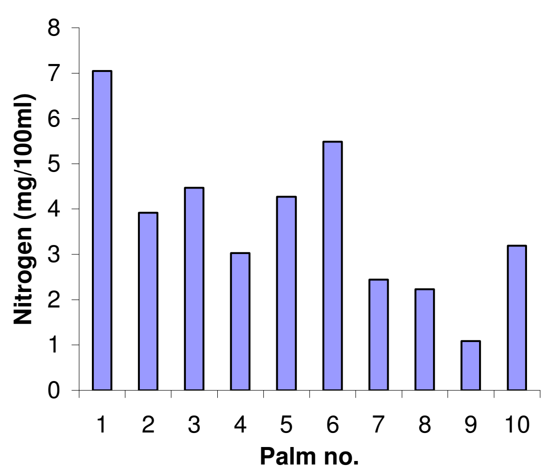

Figure 6. Mean values of nitrogen in the sap of *R. hookeri* palms.

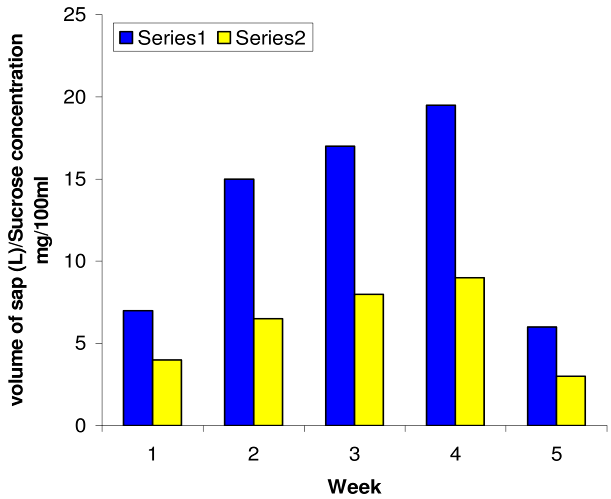

Figure 7. Volume of *Raphia hookeri* sap and sucrose content (Palm no. 7). Series 1 = Volume of sap. Series 2 = Sucrose concentration.

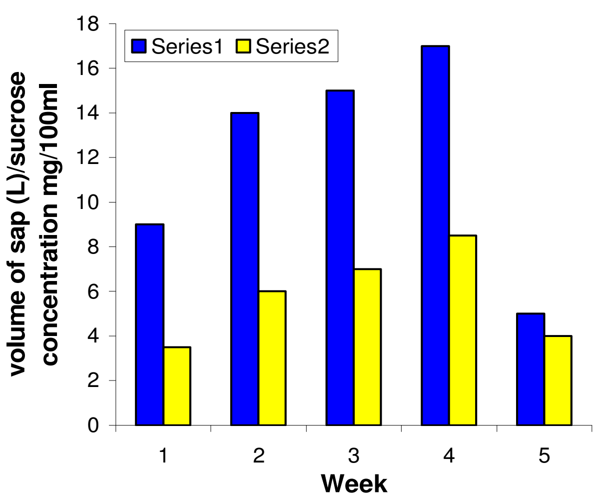

Figure 8. Volume of *Raphia hookeri* sap and sucrose content (Palm no. 8). Series 1 = Volume of sap. Series 2 = Sucrose concentration.

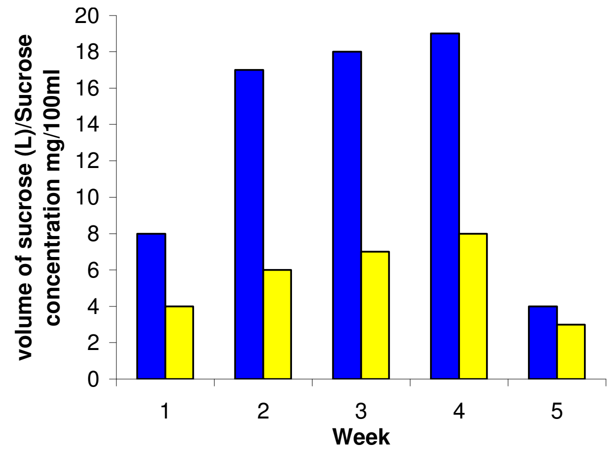

Figure 9. Volume of *Raphia hookeri* sap and sucrose content (Palm no. 9). Series 1 = Volume of sap. Series 2 = Sucrose concentration.

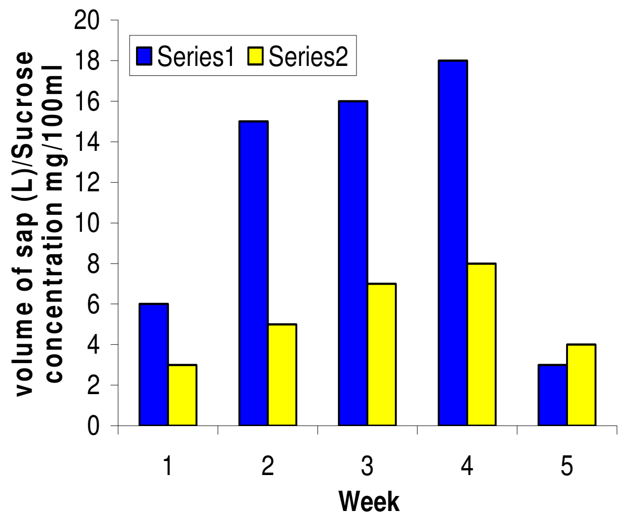

Figure 10. Volume of *Raphia hookeri* sap and sucrose content (Palm no. 10). Series 1 = Volume of sap. Series 2 = Sucrose concentration.

detected in the sap samples.

The drinking of palm wine signals the start and end of all social activities undertaken by 50 million people of Southern Nigeria. *R. hookeri* palms contribute about 20% of the palm wine drunk in its unfermented as well as fermented states, depending on the choice of the consumer. The fermented sap is called *Raphia* palm wine in Nigeria, a source of natural unadulterated drink, rich in minerals and vitamins while the unfermented sap is called *Raphia* palm sap. The sweet taste of the *Raphia* palm sap is a characteristic of the amount of sucrose present. Efforts to improve the productivity of the *R. hookeri* palm has led to improved varieties, which have not been monitored either for sap production volume or sucrose synthesis. Results from this study have provided information on the maximum amount of sucrose produced by the *Raphia* palm and the time scale for the elaboration of this sugar. This information is important because the collection and marketing of palm sap has become a lucrative business in Nigeria. Palm wine tappers and other processors could be guided in their daily activities. The sucrose could be extracted and used as an alternative source of sweeteners in food preparations and fortification. The palm sap already serves as a nutritious drink, completely free of toxic minerals. Additionally, since living organisms cannot synthesize mineral elements like other nutrients, the detected macro-minerals in the saps would obviously play significant physiological roles as structural components of body organs, constituents of body fluids and electrolytes

Table 2. Mean values (mg/100 ml) of macronutrients in the sap of *R. hookeri* palm.

Palm	Week	K	Mg	Ca	Na	P	N	Pb	Hg	Cd	Se
1	1	69.32±0.20	54.02±1.00	27.03±1.10	4.00±0.10	4.31±0.02	3.11±0.01	-	-	-	-
	2	72.20±0.20	58.35±0.60	14.27±1.20	1.61±0.10	4.40±0.05	7.69±0.08	-	-	-	-
	3	67.40±0.30	55.96±1.00	16.84±0.80	2.73±0.20	4.99±0.01	11.09±0.08	-	-	-	-
	4	76.12±0.10	58.70±0.40	26.86±0.60	1.93±0.10	3.42±0.02	6.55±0.04	-	-	-	-
	5	72.15±0.10	56.56±0.70	72.15±0.90	13.39±0.50	4.90±0.09	6.78±0.08	-	-	-	-
2	1	73.01±1.00	56.41±0.30	26.97±0.90	3.23±0.20	0.97±0.03	4.69±0.08	-	-	-	-
	2	88.12±0.50	55.32±1.10	23.37±0.40	1.27±0.20	1.18±0.02	4.64±0.04	-	-	-	-
	3	74.67±0.40	54.97±0.70	23.42±0.20	1.32±0.30	1.13±0.01	2.59±0.08	-	-	-	-
	4	79.75±0.70	57.76±0.20	9.82±0.60	1.87±0.20	2.97±0.02	4.85±0.05	-	-	-	-
	5	84.85±0.20	56.51±0.10	16.38±1.10	1.86±0.40	0.97±0.02	2.81±0.01	-	-	-	-
3	1	83.82±0.60	58.86±0.20	30.46±0.30	4.15±0.10	4.56±0.01	3.83±0.03	-	-	-	-
	2	73.71±0.70	57.86±0.30	12.23±0.20	2.29±0.40	5.61±0.03	2.65±0.01	-	-	-	-
	3	79.42±0.20	59.39±0.10	13.64±0.40	1.68±0.30	5.55±0.02	3.23±0.01	-	-	-	-
	4	73.19±1.10	57.68±0.30	14.48±0.40	2.39±0.20	3.44±0.03	10.00±0.01	-	-	-	-
	5	69.90±0.80	57.57±0.20	12.54±0.30	1.38±0.30	4.12±0.01	2.63±0.03	-	-	-	-
4	1	77.10±1.10	54.84±0.50	14.23±1.00	1.61±0.40	4.74±0.04	1.09±0.01	-	-	-	-
	2	66.50±0.40	54.93±0.70	8.00±0.90	0.89±0.10	1.39±0.08	3.14±0.01	-	-	-	-
	3	78.0±1.00	54.27±0.50	9.85±0.80	1.13±0.20	4.98±0.01	3.15±0.02	-	-	-	-
	4	72.39±1.10	52.47±2.50	12.63±0.40	2.87±0.50	1.62±0.02	3.65±0.01	-	-	-	-
	5	86.32±0.80	56.44±0.10	10.19±0.90	3.46±0.40	3.40±0.01	4.13±0.01	-	-	-	-
5	1	74.10±0.10	55.10±0.20	27.00±0.10	3.10±0.10	4.41±0.20	3.14±0.10	-	-	-	-
	2	76.00±0.20	57.25±0.10	24.25±0.20	1.00±0.20	4.25±0.10	4.00±0.20	-	-	-	-
	3	66.00±0.10	52.00±0.20	16.00±0.10	2.25±0.20	3.10±0.10	6.15±0.10	-	-	-	-
	4	17.10±0.10	54.10±0.10	17.10±0.10	4.00±0.20	5.25±0.20	4.80±0.10	-	-	-	-
	5	14.23±0.20	56.10±0.10	14.23±0.20	2.25±0.20	3.10±0.10	3.75±0.10	-	-	-	-
6	1	68.00±0.10	50.00±0.10	68.00±0.10	2.00±0.10	4.00±0.10	3.10±0.00	-	-	-	-
	2	70.00±0.20	58.25±0.20	70.00±0.20	2.80±0.10	3.50±0.00	7.25±0.20	-	-	-	-
	3	66.00±0.10	56.00±0.10	66.00±0.10	2.00±0.20	2.00±0.00	5.10±0.10	-	-	-	-
	4	76.00±0.10	58.25±0.20	76.00±0.10	1.90±0.20	1.00±0.00	6.25±0.20	-	-	-	-
	5	68.00±0.20	54.00±0.10	68.00±0.20	3.00±0.10	4.10±0.01	5.75±0.20	-	-	-	-
7	1	76.00±1.00	58.10±0.10	24.40±0.20	3.00±0.10	3.10±0.10	3.75±0.30	-	-	-	-
	2	80.00±0.50	54.25±0.20	27.00±0.10	2.00±0.10	4.25±0.02	4.00±0.10	-	-	-	-
	3	75.00±0.50	56.75±0.50	22.14±0.10	1.10±0.10	4.00±0.01	2.75±0.20	-	-	-	-
	4	70.00±1.00	58.00±0.10	25.45±0.20	1.60±0.20	3.50±0.01	2.00±0.00	-	-	-	-
	5	65.00±0.50	56.00±0.10	10.35±0.30	1.90±0.30	0.96±0.01	2.70±0.20	-	-	-	-
8	1	86.10±0.10	57.70±0.20	28.25±0.20	3.00±0.10	2.00±0.00	3.50±0.20	-	-	-	-
	2	70.00±0.50	56.25±0.20	16.10±0.10	2.60±0.10	1.15±0.10	2.00±0.00	-	-	-	-
	3	75.00±0.50	58.00±0.00	14.25±0.10	2.10±0.10	1.12±0.02	2.25±0.10	-	-	-	-
	4	70.00±0.30	57.75±0.20	16.35±0.30	3.00±0.20	2.00±0.10	1.90±0.10	-	-	-	-
	5	65.00±0.50	56.25±0.20	14.00±0.50	1.20±0.10	3.10±0.10	1.50±0.10	-	-	-	-
9	1	75.00±1.00	56.65±0.50	56.65±0.50	1.20±0.10	2.15±0.10	1.25±0.01	-	-	-	-
	2	69.00±0.50	56.25±0.20	56.25±0.20	0.90±0.20	3.12±0.10	0.28±0.00	-	-	-	-
	3	76.00±1.00	56.10±0.10	56.10±0.10	1.00±0.10	2.00±0.00	0.30±0.10	-	-	-	-
	4	70.00±0.50	54.25±0.10	54.25±0.10	2.50±0.20	3.35±0.10	2.10±0.10	-	-	-	-
	5	80.00±0.40	56.20±0.20	56.20±0.20	3.00±0.10	2.25±0.10	1.50±0.10	-	-	-	-
10	1	68.00±1.00	54.25±0.20	20.25±0.20	1.20±0.10	2.10±0.10	3.00±0.01	-	-	-	-
	2	76.00±0.50	56.75±0.70	16.30±0.20	0.80±0.10	2.25±0.00	3.15±0.10	-	-	-	-
	3	65.00±0.20	56.00±0.00	14.35±0.30	1.00±0.10	4.00±0.10	2.70±0.10	-	-	-	-
	4	76.00±0.50	55.20±0.10	18.10±0.20	2.50±0.20	3.50±0.10	3.10±0.10	-	-	-	-
	5	65.00±0.50	54.25±0.20	16.25±0.20	3.00±0.10	2.25±0.02	4.00±0.00	-	-	-	-

lytes and major roles in other vital life processes like the clotting of blood (McDowell, 1992).

Soon after the 4th week of bleeding the plant, sap production and sucrose synthesis decline and the plant finally dies. It should be emphasized that the daily tapping procedure imposes some stress on the plant probably at the nutritional level since a lot of nutrients are removed from the trunk. In an effort to manipulate the life span of the mature palm, we are currently investigating the detailed mechanism of senescence in the *Raphia* palm. It may be possible to determine an upper safe limit for the wine tapping activity to guarantee continued existence of the plant. Improvement strategies may differ between various nutrients, but generalizations could still be made for sugars and mineral elements.

REFERENCES

AP Rees T (1980). Integration of pathways of synthesis and degradation of hexose phosphate in the Biochemistry of Plants, Volume III, Carbohydrate: Structure and Function, ed. J. Preiss, London and New York: Acad. Press. pp. 1–42.

Dennis DT (1987).The Biochemistry of Energy Utilization in Plants. Blackie USA: Chapman and Hal, New York pp. 122-125.

Eapen PI (1970/71). Palm Wine Studies. 17th Annual Report of the Nigerian Institute for Oil Palm Research, pp. 78 – 79.

Faparusi SI (1969). Effects of pH on the Preservation of Palm Wine by Sulfite. Appl. Microbiol. pp. 122 – 123.

Grusak MA, DellaPenna Dean (1999).Annu.Rev. Plant Physiol. Plant Mol. Biol. pp. 133 – 61.

Harris LE (1970). Nutritional Research Techniques for Domestic and Wild Animals. 1:2501.

Maley LE (1968).Refractometers. J. Chem. Educ. 45: 467.

Mayes PA, Granner DK, Murray RK, Rodwell VW (1993). Harpers Biochemistry, 23rd Ed. pp. 604 – 607. Prentice Hall, Englewood Cliffs.

Mcdowell LR (1992). Minerals in Animal and Human Nutrition. Acad. Press, Inc. New York. pp. 26-292.

Murphy J, Rikey JP (1962). A modified single solution method for the determination of phosphorous in natural water. Anal. Chem. 27:31-35.

National Academy of Sciences/National Research Council (2001). Dietary References Intakes for Vitamins and Mineral Elements, Natl. Acad. Press, Washington, D.C. p. 773.

Ndon BA (2003). The Raphia Palm. 1st Ed. p.16. Concept Publications Ltd, Lagos, Nigeria.

Osagie AU, ap Rees (1990).Sugar metabolism by Dioscorea tubers during sprouting. J. Sci. Food Agric. 52: 171-177

Otedoh MO (1976). Ph.D. Thesis. The systematic studies of *Raphia hookeri* palms. Univ. Reading, Lond. p. 157.

Otedoh MO (1990). Sweet Raphia Palm Wine. The Nigerian Field. 55: 59 – 64

Plummer DT (1971). An introduction to practical biochemistry 1st ed. McGraw-Hill, England. pp. 57-58.

.Tulley P (1964). How to tap *Raphia* Palm. The Nigerian Field. 3(2):120–132.

Van Pee W, Swings JG (1971). Chemical and microbiological studies on Congolese palm wines (*Elaeis guineensis*). East Afri. Agric. For. J. 36: 331 – 314.