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Nutritional characterization of canistel (*Pouteria campechiana*) and sweet potato (*Ipomoea batatas*) chips

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ABSTRACT
The objective of this study was to formulate and evaluate the nutritional potential of canistel and sweet potato chips. To achieve this, a design using the Solver add-in of Microsoft office Excel 2016 was carried out and three formulations were selected. Proximate analysis was performed by standard methods while minerals were analyzed using atomic absorption spectrophotometry. Total carotenoids were determined by spectrophotometry; vitamin C by titrimetriy and antinutrients by standard methods. A 9-step hedonic test was used for sensory analysis. Chips with 47.36% canistel (C1) were richer in macronutrients and those with 87.34% canistel (C3) had more antioxidants. The fibre content varied from 2.19 to 3.03%; vitamin C from 76.99 to 138.03 mg/100g DM; iron from 5.43 to 17.18 mg/100g DM and total carotenoids from 3.42 to 32.20 mg/100g DM. The sensory analysis showed that all formulations were moderately accepted.
These results show that canistel chips could contribute to the fight against avitaminosis A.
KEY WORDS: *formulation, canistel, sweet potato, potato chip, avitaminosis A.*

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I. INTRODUCTION

Vitamin A deficiency is considered as one of the most common micronutrient deficiencies worldwide (WHO, 2009). It affects about 30% of children under 5 years of age and 19 million pregnant women (Stevens *et al.*, 2015; WHO, 2009). To address this problem, several solutions have been developed such as vitamin A supplementation programmes program's, the use of fortified foods and the promotion of carotenoid-rich foods (carrot, sweet potato) (Allen *et al.*, 2011). However, the accessibility of these products to the most vulnerable groups is not yet assured. Therefore, the third solution that can reach a wider population should be popularized. Sweet potato *(Ipomoea batatas L.), a* member of the Convolvulaceae family, is one of the important crops for food security, especially in rural areas (Xu *et al.*, 2015). Sweet potato tubers have a rather diverse composition. They are rich in vitamins A and C, iron, calcium and amino acids (Sanoussi *et al.*, 2016). Canistel *(Pouteria campechiana),* from the Sapotaceae family, is another food with a high carotenoid content but neglected by the population because little is known about it (Ranaivoson, 2015). Canistel fruit has good antioxidant potential and an excellent source of carotenoids although hardly consumed by humans because of its latex, smell and after taste which can be improved using processing techniques (Costa *et al.*, 2010; Atapattu and Mendis, 2013; Ranaivoson, 2015). There are other forms of processing that have not been studied, such as the formulation of potato chips. Chips are thin vegetable slices in which the dehydration is pushed to the point of almost complete elimination of the initial water (Rojas, 2009). They can be produced by: deep frying, vacuum frying, and extrusion (Ertekin *et al.*, 2019). The objective of this study was to formulate sweet potato and canistel chips; evaluate their acceptability and determine their nutritional potential.

II. MATERIALS AND METHODS

The ripe fruits of *Pouteria campechiana were* purchased in the town of Foumban (in the western region of Cameroon); the tubers of *Ibomoea batatas,* yellow variety, were purchased at the Mfoundi market in Yaoundé. The canistel was sorted, washed, peeled, pitted, pounded, dried at 50°C for 10 hours and pounded again to obtain a homogeneous paste. The sweet potato was washed, peeled, cut (7.3 mm thick), steamed for 5 minutes, dried at 50°C for 5 hours and then mashed to obtain a homogeneous paste. The two pastes were mixed according to the proportions required during formulation with the Solver complement of the Microsoft Excel 2016 software. The formulations (47.36: 52.64; 68.62: 31.36 and 87.64: 12.34 canistel: sweet potato) were developed to contribute significantly to the recommended nutritional references for vitamin C, iron, β-carotene and crude fibre for pregnant and lactating women. 1% salt was used in each formulation. The proportions of pastes according to the formulations and the salt were mixed, extruded using an HV8 machine and then dried at 125°C for 20 min in a MEMMERT oven.

Analysis of physical characteristics

Twenty (20) randomly selected segments of each sample were measured with a caliper and the average value was used to determine the expansion rate in this study (Jyothi *et al.*, 2009).

Bulk density was determined by the method of Seker (2005). Fifteen grams (15 g) of 25 mm strands of potato chips were weighed and placed in a 100 ml test tube. Yellow millet grains were added to fill the cylinder and chips were removed in order to measure the volume of yellow millet.

The rate of rehydration was measured at 30° C by cutting the chips into 35 mm long strands, weighing approximately 20 g and putting in 500 ml of water at 30°C for 15 minutes. The water was drained and the rehydrated samples were weighed.

Proximal analysis

The water content of the chips was determined by steaming at 105°C; ash by incineration in a muffle furnace set at 550°C. The lipid contents were determined by their solubility in organic solvents; proteins by the Kjedahl method, the value obtained was multiplied by 6.25 and the total carbohydrates were obtained by difference. Crude fibre was determined after boiling the chips with sulphuric acid and then with soda. The residue obtained was dried, calcined and weighed. The energy value was calculated using the formula of Livesey, 1995.

Analysis of vitamin C, total carotenoids, total phenolic compounds and flavonoids

Vitamin C content was determined using DCPIP (2,6-dichloro-phenol-indophenol) described by Idah *et al.* The sample (0.5 g) was triturated and shaken for 15 min in the presence of 10 ml of 90% acetic acid. Subsequently, the mixture was filtered into a 20 ml flask and the volume adjusted with 90% acetic acid. Five milliliters (5 ml) of the extract was placed in a test tube and 1 ml of glacial acetic acid added and titrated with DCPIP solution until a pale pink colour was obtained. This titration was repeated with 5 ml of water for the blank and 5 ml of ascorbic acid solution for the standard.

Total carotenoids were determined according to described methods (Kimura and Amaya, 2004). 0.5 g of chips were homogenized in 3 mL of cold acetone for 1 min and filtered, the operation was repeated until the acetone was no longer coloured. Ten (10) mL of petroleum ether was introduced into the separating funnel with a Teflon tap and the acetone extracts were added. Then 75 mL of distilled water was added slowly down the sides of the funnel. The two phases were separated and the lower aqueous phase was discarded. The supernatant was washed 3 times with distilled water (50 mL each time) to remove the acetone. The petroleum ether phase (supernatant) was collected in a 25 mL volumetric flask by passing the solution through a funnel containing 3g of anhydrous sodium sulphate to remove residual water. The volume was adjusted with petroleum ether. The absorbance was read at 450 nm

Total phenolic compounds and total flavonoids were determined by the method of Dhar et *al.* (2012). The extraction was done using 20 mL water/methanol (v/v) solvent for 1 g of sample. After 30 min of stirring, the mixture was filtered through Whatman paper No. 1. From the extract obtained the determination of phenolic compounds was done using gallic acid as standard and the D.O. was read against the blank at 765 nm. The flavonoid standard was quercetin and the D.O. was read at 430nm against the blank. The assays were done in triplicate.

Mineral analysis

Some minerals (Fe, Zn, Cu and Mn) were determined by the modified atomic absorption spectrophotometry method described by Benton and Vernon (1990).

Analysis of anti-nutritional factors

The antinutrients (tannins, phytates, oxalates, saponins) of the chips were determined: total tannins were determined by the method of Ndhlala *et al.* (2007). In a 50 mL Erlenmeyer flask, 0.125 g of chips and 2.5 mL of 96% ethanol were added. The mixture was centrifuged and the supernatant was used to determined tannin. The absorbance was read at 550nm.

Phytates were determined according to Olayeye *et al*. (2013). 1g of chips was introduced into a 100mL flask to which 2% HCl was added. The resulting mixture was filtered. Titration was done with standard iron III chloride solution (0.00195g iron per mL) until a persistent brownish yellow colour was observed for 5min.

Oxalates were determined according to Aina *et al.* (2012). 1g of sample was introduced into an Erlenmeyer flask and 75 mL of H_2SO_4 (3 mol/L) was added. The hot sample was titrated with $KMnO_4$ (0.05mol /L) until a persistent pale pink colour was obtained. The oxalate content was calculated by taking 1ml of $KMnO_4$ as equivalent to 2.2mg of oxalate.

Saponins were determined according to the method of Koziol (1990). 0.5 g of chips was introduced into a test tube and 5 mL of distilled water was added. The tube was shaken vigorously for 30 seconds (s). Immediately after 5-10 s, the height of the foam formed was measured with a ruler graduated to the nearest 0.1 cm.

Sensory analysis

The sensory properties (taste, colour, texture, odour and general acceptability) of the chips were determined by a hedonic evaluation on a 9-point scale (where 1 = extremely unpleasant and 9 = extremely pleasant) (Jones *et al.*, 1955) using 64 panellists (AFNOR, 2010).

Statistical analysis

Statistical analyses were carried out using the Statistical Package for Social Science (SPSS) version 20.0 for Windows using Analysis of Variance (ANOVA) coupled with a Post Hoc test (Turkey) and a significance level set at 5%. The results were represented as mean ± standard deviation. Microsoft Excel 2016 for Windows was used for graphical representations and formulation.

III. RESULTS AND DISCUSSION

Analysis of physical characteristics

The physical characteristics (expansion rate (ER), bulk density (BD), rehydration rate (RR)) of the chips are presented in Table 1.

The expansion rate gives an idea on the degree of swelling of the extruded products at the die exit. It ranged from 0.72 to 0.83 with no significant difference between C1 and C3. These results are lower than values obtained (1.2 to 4.7) by Jáquez *et al.*, 2012 in extruded cottonseed meal snacks. The bulk density (BD) and rehydration rate (RR) provides information on the microstructure of the extruded products. They varied from 0.44 - 0.59 g/ml (BD) and 36 - 88.67% (RR) respectively. The results obtained from BD were similar to those (0.42 to 0.86 g/ml) obtained by other researchers in products extruded from blends of soy protein isolate and maize meal (Yu *et al.*, 2013). Those of RR were lower than those (49% to 205%) obtained from the same product (Yu *et al.*, 2013). These results demonstrate a low relative water absorption by our chips.

Table 1. Physical characteristics of potato chips.

F	Canistel (%)	Sweetpotato (%)	ER	BD (g/ml)	RR (%)
C1	47,36	52,64	$0,83±0,15^b$	$0,44±0,01^a$	$88,67±3,06^b$
C2	68,62	31,38	$0,72±0,03^a$	$0,59±0,03^c$	$84,67±6,22^b$
C3	87,64	12,36	$0,83±0,18^b$	$0,53±0,02^b$	$36±1,14^a$

Values are expressed as mean ± standard deviation (n=3). Values with different letters on the same line are significantly different. F= formulations

Proximal analysis

The results showed that, the water and fat contents increased with the addition of canistel in the preparation of the chips (Table 2). The water contents of the chips (10.38 - 12.34%) was slightly higher than the standard (1 and 10%) required in dry foods (Krokida *et al.*, 2000). This indicates that the chips should be well dried or should not be stored for a long time. The lipid contents varied from 16.21 to 21.67%. This may be due to the pulp of canistel which is rich in lipids. Also, the energy values ranged from 409.22 to 437.87 Kcal/100 g DM. The high energy present in Potato chips would help pregnant and lactating women to cover the additional energy required by the growing foetus (70, 260 and 500 kcal/d on average in the 1st, 2nd and 3rd trimester, respectively) and during milk production (500 kcal/d) (EFSA, 2017).

Protein, crude fibre, ash and total carbohydrate contents increase significantly with the addition of the potato (Table 2). The protein contents of the chips varied from 0.27-2.23%. This value was lower than those obtained (13 to 14.14%) by other researchers in corn and cooked bean tortilla chips (Martínez *et al.*, 2016). This protein could cover the extra protein needed by pregnant and breastfeeding mothers (Anses, 2016). The high crude fibre contents obtained (2.19 - 3.03%) when compared with values of 1-1.7%, observed by Jáquez *et al.* (2012) in extruded cottonseed meal snacks could control constipation which often increases during pregnancy (Champ and Hoebler, 2009). The ash content ranges from 3.09 to 4.15% and the total carbohydrate content from 60.44 to 63.6%. The ash contents are close to those (2.3-7%) found by Iwe *et al.* (2004) in sweet potato and soybean chips. They are an indicator of the mineral contents of the food.

Table 2. Proportions of ingredients and proximal composition

F	Proportions (%)		Proximal Composition per 100 g Dry Matter (MD)						
	Canistel	Sweet-potato	Water (g)	Lipids (g)	Proteins (g)	Fibers (g)	Carbohydrates (g)	Ash (g)	Energy (Kcal)
C1	47,36	52,64	10,38±0,29[a]	16,21±0,29[a]	2,23±0,13[c]	3,03±0,16[b]	63,6±0,1[c]	4,15±0,34[b]	409,22±0,13[a]
C2	68,62	31,38	11,29±0,16[b]	18,94±0,1[b]	0,98±0,05[b]	2,76±0,15[b]	62,85±0,05[b]	3,21±0,04[a]	425,23±0,02[b]
C3	87,64	12,36	12,34±0,41[c]	21,67±0,21[c]	0,27±0,00[a]	2,19±0,13[a]	60,44±0,07[a]	3,09±0,17[a]	437,87±0,08[c]

Values are expressed as mean ± standard deviation (n=3). Values with different letters on the same line are significantly different. F= formulations.

Analysis of vitamin C, total carotenoids, total phenolic compounds and flavonoids

The contents of total carotenoids, vitamin C, total phenolic compounds and flavonoids increased significantly with the addition of the canistel used (Table 3). The total carotenoid contents varied from 3.42 to 32.20 mg/100g DM. Carotenoids prevent oxidative damage caused by free radicals on membrane cells, and some are precursors of vitamin A (Bandalac, 2020). Chips are thought to help prevent cardiovascular disease, inhibit cancer, and reduce the risk of cataracts. The vitamin C contents varied from 76.99 to 138.03 mg/100g DM. Vitamin C helps to fight against oxidative stress, improves the bioavailability of non-haem iron and promotes intrauterine growth. It protects carotenoids against oxidation during their absorption, storage and bioconversion (Schlienger, 2011). The consumption of 100 g of potato chips would cover between 65.71 and 115.23% (Figure 1) of the needs of pregnant women and between 44.52 and 78.06% of the needs of lactating women. The total phenolic compounds content ranged from 4.3±0,43 to 192.74±3,64 mg EAG/100g DM. Flavonoid contents varied from 3.04 to 8.68 mg quercetin/100g DM. Flavonoids are natural components of plants that have potential biological activities, including antioxidant properties (Nadechanok *et al.*, 2017). Chips are thought to help pregnant women combat increased oxidative stress, anaemia, vitamin A deficiency, and in the prevention of chronic diseases.

Table 3. Vitamin C, total carotenoids, total phenolic compounds and flavonoids content of chips.

F	Proportions (%)		Composition per 100 g Dry Matter (MD)			
	Canistel	Sweet-potato	Vitamin C (mg)	Total Carotenoids (mg)	TPC (mg EAG)	Flavonoids (mg Eq quercetin)
C1	47,36	52,64	76,99±5,43[a]	3,42±0,01[a]	4,3±0,43[a]	3,04±0,07[a]
C2	68,62	31,38	111,55±10,06[b]	21,715±0,10[b]	120±7,47[b]	7,47±0,45[b]
C3	87,64	12,36	138,03±7,5[c]	32,20±0,15[c]	192,74±3,64[c]	8,68±0,72[b]

Values are expressed as mean ± standard deviation (n=3). Values with different letters on the same line are significantly different. F= formulations. TPC= total phenolic compounds.

Mineral analysis

Iron and manganese contents increase significantly with the proportion of sweet potato used (Table 4). Iron levels ranged from 5.43 to 17.18 mg/100g DM. According to EFSA (2017), the dietary reference of iron for pregnant and lactating women is 16 mg/d. A 100 g portion (Figure 1) of potato chips would cover 29.19 to 96.23% of the iron required by pregnant and lactating women hence combating anaemia during pregnancy. More so, the manganese content varied from 0.31 to 0.97 mg/100g DM, implying that, the consumption of 100 g of the formulations would cover 10.72 to 34.68% of the needs of pregnant women.

On the other hand, Zinc levels increased with the amount of canistel used and ranged from 0.50 to 0.68 mg/100g DM. These levels are insufficient to meet the needs of pregnant and breastfeeding women hence should be consumed together with other zinc-rich foods. Copper levels ranged from 0.18 - 0.37 mg/100g DM, meaning that 100g of potato chips would cover between 12.27 and 24.87% of copper requirements.

Table 4. Iron, zinc, manganese and copper contents of chips

F	Proportions (%)		Nutritional Composition (in mg/100g DM)			
	Canistel	Sweet-potato	Iron	Zinc	Manganese	Copper
C1	47,36	52,64	17,18±0,001[c]	0,50±0,001[a]	0,97±0,001[c]	0,18±0,001[a]
C2	68,62	31,38	9,67±0,001[b]	0, 56±0,001[b]	0,47±0,001[b]	0,37±0,001[c]

C3	87,64	12,36	5,43±0,001[a]	0, 68±0,001[c]	0, 31±0,001[a]	0,19±0,001[b]

Values are expressed as mean ± standard deviation (n=3). Values with different letters on the same line are significantly different. F= formulations.

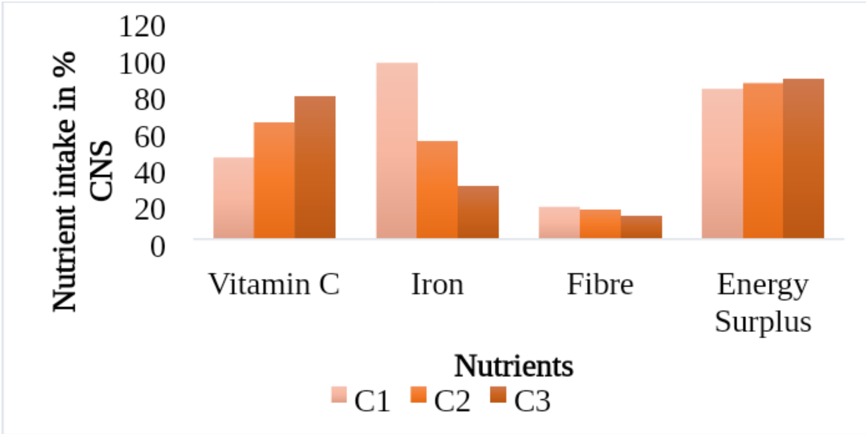

Figure 1. Nutrient intake as a percentage of CNS obtained from the consumption of 100g of chips

Analysis of anti-nutritional factors

Antinutrients were low, increasing significantly with the amount of canistel used (Table 5). The oxalate, phytate, saponin and tannin contents varied from 0.33 - 1.26 mg/100g DM, 0.103 - 0.106 mg/100g DM, 12.26 - 33.18 mg/100g DM and 0.34 - 1.17 mg leucocyanidin equivalent/100g DM respectively. These levels of antinutrients are below the daily consumption limits (between 200 and 500 mg for oxalates, 2% for saponins), indicating that potato chips can be consumed without an effect on the consumer's health (Mohammad and Shadizadeh, 2018). In addition to that, the consumption of antinutrients above the recommended dose like the case of phytate (4-9 mg) reduces the absorption of iron by 4-5 times (Hurrell *et al*., 2003).

Table 5. Anti-nutrient contents of potato chips

F	Proportions (%)		Nutritional Composition (in mg/100g DM)			
	Canistel	Sweetpotato	Oxalates	Phytates	Saponines	Tannins
C1	47,36	52,64	0,33±0,01[a]	0,103±0,00[a]	12,26±0,05[a]	0,34±0,02[a]
C2	68,62	31,38	0,87±0,07[b]	0,104±0,00[b]	13,06±0,04[b]	0,40±0,01[a]
C3	87,64	12,36	1,26±0,07[c]	0,106±0,00[c]	33,18±0,19[c]	1,17±0,07[b]

Values are expressed as mean ± standard deviation (n=3). Values with different letters on the same line are significantly different.
F= formulations.

Sensory evaluation

The scores for the sensory descriptors are above the average score of 5 indicating that taste, colour, texture, smell and overall acceptability were moderately appreciated by the panelists. There were no significant differences for all descriptors between formulations. Sensory characteristics are key determinants of consumer acceptability of food. The lack of significant differences for colour may be due to the presence of reducing sugars in sweet potato and phenolic compounds in canistel as substrates for Maillard reactions at high temperatures and enzymes involved in enzymatic browning reactions respectively (Ndangui, 2015; Kong *et al.*, 2013). That of taste may be due to the fact that canistel tastes is similar to cooked sweet potato (Ranaivoson, 2015). Those of general acceptability of the chips close to 6 may be due to the fact that the canistel used, in addition to its latex content and bitter aftertaste, was not processed before formulation of the chips.

Table 6: Sensory descriptor scores for canistel and sweet potato chips formulations

F	Proportions (%)		Descriptor scores					
	Canistel	Sweet-potato	Colour	Taste	Smell	Texture	General Acceptability	Rank
C1	47,36	52,64	6,73±1,31[a]	5,7±1,57[a]	5,83±1,36[a]	5,45±1,63[a]	6,09±1,55[a]	1,98±0,79[a]
C2	68,62	31,38	6,39±1,20[a]	5,72±1,73[a]	5,64±1,55[a]	5,17±1,66[a]	5,91±1,69[a]	2,03±0,87[a]
C3	87,64	12,326	6,31±1,44[a]	5,77±1,75[a]	5,77±1,42[a]	5,36±2,01[a]	6 ±1,74[a]	1,98±0,81[a]

IV. CONCLUSION

The constraints set resulted in three formulations acceptable to the panel. Formulations made with high levels of canistel gave high levels of carotenoids and vitamin C while those made with high levels of sweet potato had the highest iron content. This study would go a long way to orientate the choices of consumers thereby meeting their nutritional requirements especially pregnant and lactating mothers.

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