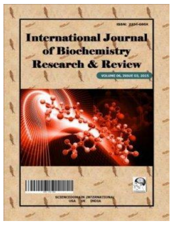

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Sensory Analysis of Dishes Based on Mucilages of *Abelmoschus esculentus, Beilschmiedia mannii, Corchorus olitorius* and *Irvingia gabonensis* from Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration between all authors. Author OYA wrote the protocol, performed the laboratory analysis and wrote the first draft of the manuscript. Authors AC and YNK performed the statistical analysis, checked the first draft of the manuscript and achieved the submitted manuscript. Author DS took part in the interpretation of the results and corrected the first draft of the manuscript. Authors RMM and VDM managed the literature, assisted the experiments implementation and the statistical analysis. Author HMGB designed the study and supervised author OYA in recovering the results. All authors read and approved the submitted manuscript

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ABSTRACT

Aims: The present work evaluates the sensory properties of culinary recipes based on mucilage extracted from mucilaginous food plants derived from the Ivorian flora.

Study Design: MFPs edible parts were dried, mucilage were extracted and sensorial analysis was done on recipes based on mucilage.

Place and Duration of Study: The study was conducted in Laboratory of Biochemistry and Food Sciences, Biosciences Unit, at Felix Houphouet-Boigny University between January and December 2014.

Methodology: The study was carried out on fruits of *A. esculentus* (okra), *B. mannii* (sran), *I. gabonensis* (kplé) and leaves of *C. olitorius* (kplala) collected. The mucilage of different plants has been extracted by optimization methods; dishes were made from the mucilages and subjected to a sensory description (aroma, appearance, flavor and viscosity) and a hedonic appreciation.

Results: These dishes have been tested against commonly used recipes. Meals prepared from *B. mannii* mucilage provided a more appreciable viscosity than other dishes; however this sauce is less preferred than the reference recipe. On the other hand, the bitterness, the astringency and the sour aftertaste were more perceived in the mucilages than in the references recipes. The flavors and appearance of dishes base on mucilage were generally less perceived. As a result, the references were more preferred for *A. esculentus*, *I. gabonensis* and *C. olitorius* respectively between 71.87% and 81.25%, while the recipe based on mucilage of *B. mannii* (sran), the reference preference remains identical to that of the mucilage.

Conclusion: Culinary recipes could also be considered from mucilage extracted from mucilaginous food plants.

Keywords: Sensory analysis; mucilage; culinary recipe; mucilaginous food plants.

1. INTRODUCTION

Mucilaginous food plants (MFPs) are part of a large group of plant species known as non-woody forest plants. These plants contribute significantly to the diet of populations by bringing most essential nutrients. Indeed, MFPs are important sources of carbohydrates, lipids, proteins, vitamins and essential minerals [1,2]. They also contain mucilages that present hunger-cutting properties and blood glucose control, blood pressure, cholesterol and homeostasis [3,4]. MFPs consumption is generally based on a high mucilage content of 56% (*I. gabonensis*) and 25% (*C. olitorius*) [5]. Mucilage is a complex carbohydrate with a highly branched structure containing variable proportions of L-Arabinose, D-Galactose, L-Rhamnose and D-xylose and galacturonic acid [6,7]. The mucilages using possibilities are numerous. They are used in the agro-food, pharmaceutical and cosmetic sectors [8,9].

The consumption of MFPs varies according to the regions. However, okra (*A. esculentus*), kplala (*C. olitorius*), kplé (*I. gabonensis*) and sran (*B. mannii*) are among the species commonly consumed by populations [10].

Okra has very high nutritional value for various nutrients [11,12]. It is consumed in the form of porridge, frying or soup throughout the world, with a yearly production estimated to 120000 tons [13]. The leaves of *C. olitorius* or kplala (Ivorian local name) are consumed in the form of soup characterized by a particularly glutinous texture. These leaves are rich in magnesium, iron and vitamins. They do not present anti-nutritional redhibitory factors [14,15]. With the kernels of *I. gabonensis* and the fruits of *B. mannii*, respectively called kplé and sran in Côte d'Ivoire, interesting nutritive properties are recorded [16,17,18]. Thus, their high nutrient value would promote the nutritional balance of populations.

MFPs being non-woody forest plants (NWFPs); their presence in markets is linked to seasonal availability. Thus, these products often become inaccessible to populations throughout the year [19,20]. To cope with this shortage, the domestication of plants and the transformation of edible parts into finished semi-finished products remains a possibility. Thus, extraction of mucilages, key components of mucilaginous foods, has been considered in order to produce timeless culinary recipes [5]. The question is to know, if recipes based on mucilage only can satisfy organoleptic preferences of the consumers? The present work consists of evaluating the sensory quality of dishes prepared from extracts of these mucilages.

2. MATERIALS AND METHODS

2.1 Plant material

The biological material consisted of the kernels of *Irvingia gabonensis* (kplé) and the fruits of *Beilschmiedia mannii* (sran) collecting in the region of Tonkpi. Then, the leaves of *Corchorus olitorius* (kplala) and the variety koto of *Abelmoschus esculentus* (okra) have been collected in the Gouro market of Abidjan district. The plants have been authenticated by the Centre National de Floristique (CNF) of the University Felix HOUPHOUET-BOIGNY.

2.2 Samples Processing to Obtain Dry Matter

The plant material was collected between January and December 2014 in different regions of Côte d'Ivoire. The fruits of *Irvingia* have been stocked several days then the seeds have been ground to isolate the kernels. As for the fruits of *B. mannii*, they have been cut in small pieces (less than 5 mm of thickness) before drying. In return, the fruits of *A. esculentus* (okra) have been cut in gill, whereas the leaves of *C. olitorius* were sorted, cleaned and drained before being dried. After drying, plants parts collected have been reduced in powder with a grinder of Heavy Duty mark [5].

2.3 Extraction and Mucilage Content

The powder of *I. gabonensis* kernels was delipidated with hexane and then macerated for 24 h in distilled water with a ratio of 1/50 (vegetable/water). The whole is filtered on a muslin cloth. The mucilage is collected, dried and ground and then stored in desiccators.

As for *B. mannii*, *C. olitorius*, *A. esculentus*, the powders are macerated in distilled water for 24 h with a ratio 1/50 (vegetable / water). The mixture is then boiled for 1 hour and filtered on a muslin cloth. The mucilage is collected, dried and ground and then stored in desiccators [5].

2.4 Mucilage Preliminary Tests of Confirmation

Preliminary tests to know, the red ruthenium test, the Molisch test and the iodine test have been done to confirm the mucilaginous nature of substances obtained [21,22,23].

2.4.1 Red ruthenium test

This test is used to confirm the presence of mucilage. A small amount of dried mucilage powder has been mounted on a slide with a solution of ruthenium red and the whole has been observed under a microscope.

2.4.2 Molisch test

This test is used to confirm the presence of carbohydrate in the mucilage. 0.1 g of dried mucilage powder has been placed in a clean test tube. Then, two drops of the freshly prepared Molisch reagent were also introduced. Finally, concentrated sulfuric acid has been added gradually to the side of the tube to form a layer above the aqueous solution. The observations have been done.

2.4.3 Iodine test

This test is used to confirm the presence or absence of starch in the mucilage. 0.1 g of dried mucilage powder has been added to 1 ml of iodine solution at 0.2% dye in a test tube and the mixture has been observed.

2.5 Dishes Preparation

2.5.1 References cooking

The references were prepared from the kernels paste of *I. gabonensis* (kplé), the fruit powder of *B. mannii* (sran) and *A. esculentus* var. Koto (okra), and finally powdered leaves of *C. olitorius* (kplala).

2.5.1.1 I. gabonensis, B. mannii and A. esculentus (koto) cooking

A saucepan containing one liter of water was fired and then a gram of cooking salt was added to the water and the whole was boiled for five minutes. Then 15 g of paste (*I. gabonensis*) or powder (*B. mannii*, *A. esculentus*) are added gradually in small doses in order to avoid the formation of lumps. The mixture was beaten with a spatula for 5 minutes to precipitate the mucilage and allow the homogenization of the preparation. It is left to simmer for 5 minutes and then discharged from the fire. The preparations were cooled to room temperature and served lukewarm.

2.5.1.2 C. olitorius cooking

Fifteen grams of *C. olitorius* powder was gradually dissolved in one liter. Then cooking salt and potash were added to the set. The preparation was then boiled for 15 minutes. It was cooled for 5 minutes at room temperature and then was beaten with a spatula or a ladle to precipitate the mucilage.

The preparation was again boiled for 5 minutes and then discharged from the fire and cooled to room temperature. It was served lukewarm.

2.5.2 Recipes based on mucilages cooking

The recipes based on the mucilages of *I. gabonensis*, *B. mannii*, *A. esculentus* var. Koto and *C. olitorius* have been prepared under the same conditions as their respective references.

These recipes have been formulated without adding ingredients, cooled to room temperature and then subjected to sensory evaluation.

2.6 Sensory Analysis

The sensory analysis consisted in the tasting of the recipes based on the mucilages compared to the dishes of the references. So the hedonic appreciation and descriptive tests have been achieved. The tasting sessions have been made at the laboratory of biochemistry and food sciences of the Felix Houphouët-Boigny University of Abidjan. Every tasting has been made with 15 ml of samples served in disposable rubber plates. The answers have been given by the scores on a scale of 9 points where 1 expressed the lack of sensation and 9 expressed the full sensation.

2.6.1 Hedonic analysis

The analysis has been achieved by a group of 30 people (male and female) of age understood between 20 and 30 years. The panelists have been invited to express their level of acceptance of the appearance, of the flavors acidic, pungent, bitter and astringent, of the aroma and the viscosity. Preference tests were carried out on a 9 point hedonic scale where Level 1 translated "extreme disagreeability" while 9 related to "extreme pleasure" [24].

2.6.2 Descriptive analysis

A panel of 10 volunteers of age between 20 to 30 years has been selected on the basis of their availability, their faculty to recognize and to appreciate the level of perception of the aroma, the appearance, the flavor and the viscosity feature of foodstuffs. Panelists have been trained in the methodology of analysis and appreciation of qualitative characteristics selected according to the requirements of sensory analysis, trained on the taste areas of the tongue and familiarized with mucilaginous dishes [25]. For the evaluation of dishes, panelists were invited to taste samples anonymized with codes (A, B and C) and filled into various orders of presentation, then to fit the rating scale by indicating the value for the intensity perceived. The values varied also from 1, when the sensory parameter is not perceived, to 10 when it is extremely felt [26].

2.7 Statistical Analysis

The statistical processing of the data consisted of an analysis of variance (ANOVA) with a classification criterion using the SPSS software (SPSS 16.0 for Windows, SPSS Inc.). Means were compared by the Newman Keuls test at the 5% significance level. A principal component analysis (PCA) was also carried out using STATISTICA software (STATISTICA version 7.1) in order to structure the variability between dishes and sensory descriptors. Data from the hedonic assays were analyzed using a Chi square (X^2) of proportions comparison.

3. RESULTS

3.1 Mucilage Extraction Results

The mucilage contents differentiate significantly ($p<0.001$) the mucilaginous food plants retained. The different mucilages extracted are shown in Fig. 1. *B. mannii* (63.00 ± 2.69%) and *I. gabonensis* (56.34 ± 5.44%) provide the highest mucilage contents, unlike *A. esculentus* (34.86 ± 5.27%) and *C. olitorius* (25.81 ± 4.13%) (Table 1).

Table 1. Mucilages content

Plants	Mucilage content (%)
I. gabonensis	$56.34±5.44^b$
B. mannii	$63.00±2.69^a$
A. esculentus	$34.86±5.27^c$
C. olitorius	$25.81±4.13^d$
F	**113.70**
P-value	**<0.001**

3.2 Mucilage Confirmation Tests

Preliminary mucilage confirmation tests (Molisch test, ruthenium red test and iodine test) are all positive with the different mucilages (Table 2).

3.3 Sensory Characteristics of Mucilages

The reference recipes (Fig. 2) are predominantly preferred ($p < 0.001$) in the case of *A. esculentus*, *I. gabonensis* and *C. olitorius* with 71.87% to 81.25% favorable opinions. On the other hand, with *B. mannii*, Table 3 shows that there is no significant difference between the reference (43.75% of opinion) and the mucilage (56.25% of opinions) that record the same level of preference ($p = 0.21$).

The viscosities of all references recipes (5.67/9 to 7.17/9) are preferred to those of mucilage dishes (3/9 to 5.33/9). However, Table 4 discloses that the aroma, the appearance and the flavor do not distinguish test samples from controls, with respective averages of 5.00 ± 1.67 to 6.17 ± 1.83; 5.00 ± 1.41 to 6.50 ± 2.43 and 4.50 ± 2.43 to 7.17 ± 1.83 against 5.50 ± 2.26 to 6.83 ± 1.17; 4.33 ± 2.25 to 7.17 ± 1.17 and 5.67 ± 2.94 to 7.50 ± 1.38.

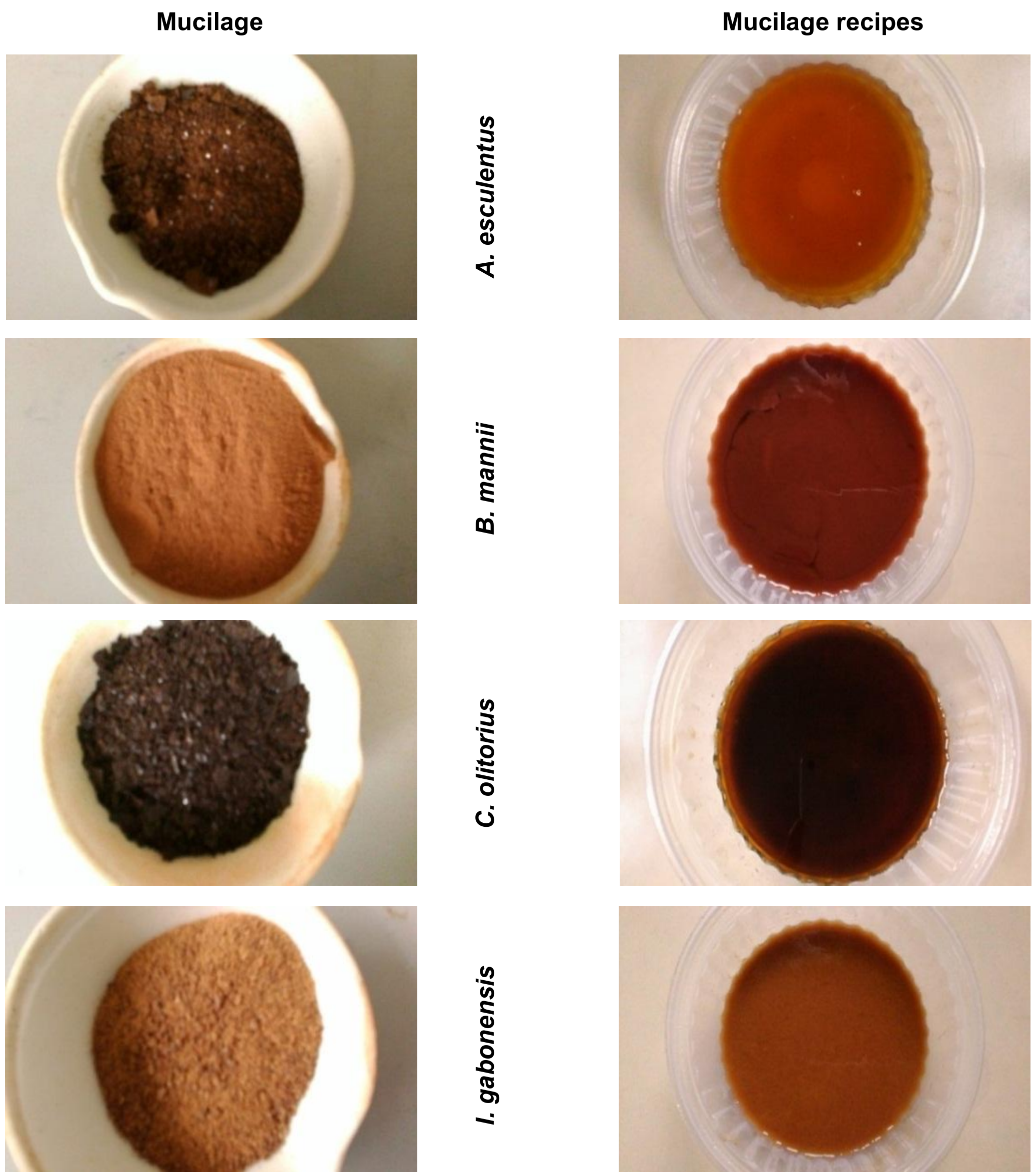


Fig. 1. Formulated recipes based on the mucilage of plants studi

Table 2. Preliminarily tests of confirmation

Plants	Molisch Test	Ruthénium red test	Iodine test
I. gabonensis	+	+	+
B. mannii	+	+	+
A. esculentus	+	+	+
C. olitorius	+	+	+

At the perception level, reference recipes and mucilage-based dishes show significant differences in appearance and viscosity at p<0,001. *C. olitorius*-based dishes are characterized by a very pronounced appearance. *I. gabonensis* and *B. mannii* are distinguished by their viscosity. For the aroma, difference was not observed (p = 0.01) (Fig. 3A). At the flavor level, significant differences were observed for the pungent flavor at p<0,001. Foods based on *C. olitorius* were the most spicy. On the other hand, no significant difference was observed for bitterness (p = 0.1), acidity (p = 0.27) and astringency (p = 0.39) (Fig. 3B)

Fig. 2. References recipes

3.4 Sensory Variability of Studied Dishes

The F1-F2 factorial design of main component analysis, which accounts for 68.34% of the variability, shows a strong correlation between mucilage-based foods and the reference recipes of *C. olitorius* and the astringent and pungent flavors. On the other hand, the reference recipes of *I. gabonensis* and *B. mannii* as well as the mucilage-based foods of *B. mannii* are associated with the strongest perceptions of viscosity, while that mucilage of *I. gabonensis* is significantly more colored, acidic and aromatized (Fig. 4).

4. DISCUSSION

Hydrocolloids are used since decades in the traditional kitchen to thicken and to give the flavor to sauces before being valorized like industrial gums [27]. Mucilages extracted reactions with ruthenium red test, Molisch test and iodine test showed the presence of mucilage respectively, carbohydrate and the absence of starch, thus confirming the mucilaginous nature of extracted substances [28]. The edible parts of plants with high mucilage contents are represented by *B. mannii* (63.00%) and *I. gabonensis* (56.34%) followed by *C. olitorius*. (25.81%) and *A. esculentus* (34.86%), similar results were obtained on *Bombax costatum* (45%) and *Grewia venusta* (20%) [29] and *B. costatum* (46.5%) and *Cissus populnea* (29.8%) [30]. Much work has been done on okra, including [31], which reported a very high yield of 57%, when [32] were able to extract only 9.5% of mucilage. At the same time, our results on *C. olitorius* are close to the 29.18% revealed by [33]. According to [34], this v ariability observed in the levels of mucilage could be explained by the extraction methods, the variety, the stage of maturity of the parts analyzed, as well as the environmental conditions.

Mucilages are characterized by their high water absorbency and swell to form viscous substances due to their high polysaccharide content [7].

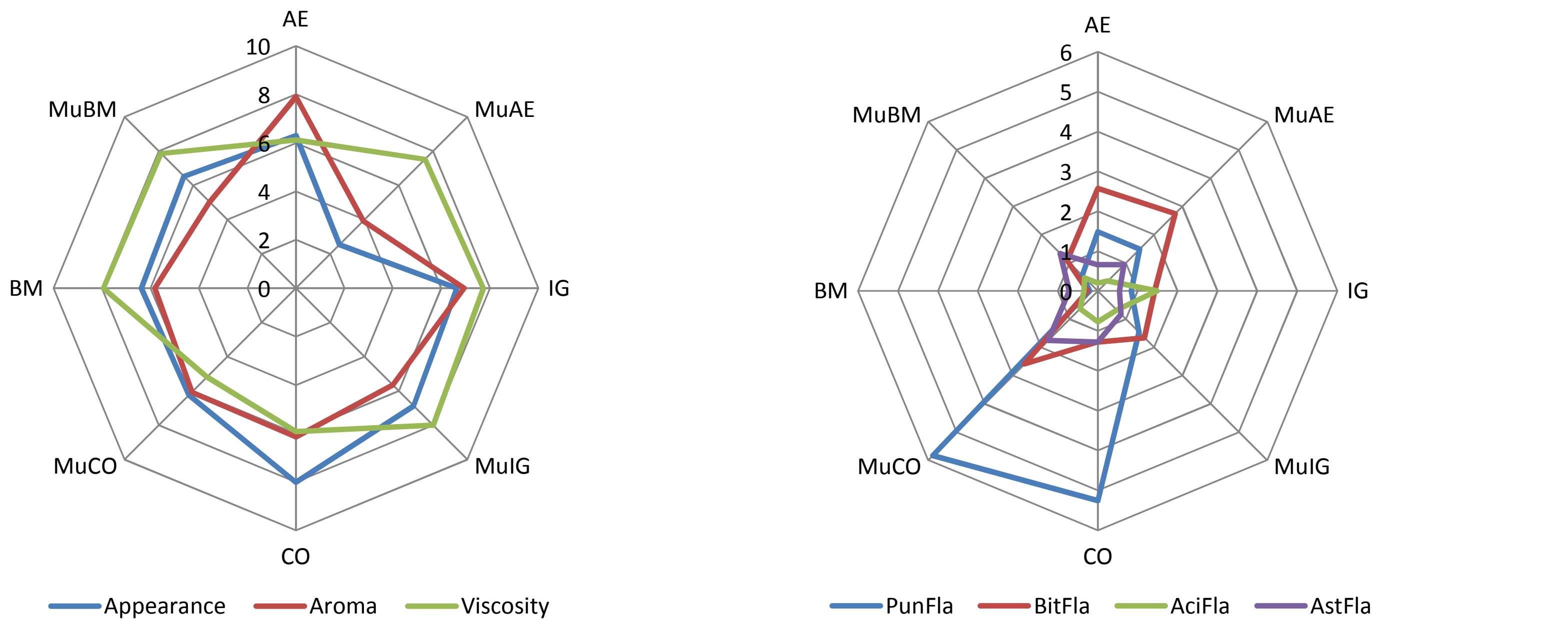
Sensory analyzes revealed that mucilage-based food formulations were less preferred than the reference recipes of *A. esculentus*, *I. gabonensis* and *C. olitorius* which are commonly consumed by populations. In fact the reference recipes contain all the flavors because it is entirety whereas the mucilaginous recipes tested are made up solely of polysaccharides [35,36]. Nevertheless, at the level of *B. mannii*, the mucilage-based dish is as much accepted as the reference recipe, showing the correctness of this technological option. At the perception level, dishes differ in appearance, viscosity and pungent flavor. The viscosity which is the character searched by the majority of MFPs consumers, the analysis revealed that the dishes based on *B. mannii* and *I. gabonensis* would be best suited for possible formulations. Today, several synthetic additives foods are the subject of controversy over their long-term toxicity to populations [37,38], hence an incentive to consume recipes exploiting the properties which exist in certain foods such as MFPs. The mucilage additive food extracted from plants could be suitable for this technological approach [39,40].

Table 3. Tasters proportions translating the preferences of dishes based on MFPs

Types of dishes	Sref	Smuc	X^2	p.value
ddl		**1**		
Theoretical distribution (%)	**50**	**50**		
A. esculentus	81.25^a	18.75^b	39.06	<0.001
I. gabonensis	75^a	25^b	25	<0.001
C. olitorius	71.875^a	28.125^b	19.14	<0.001
B. mannii	43.75^a	56.25^a	1.56	**0.21**

Sref, reference dishes ; Smuc, mucilage dishes ; ddl, degree of liberty ; X^2, value of khi 2 test; P_{-value}, probability value of the statistical test

The different aspects of mucilages studied to know the nourishing, sensory and theology aspect show an interaction between these. Indeed, during the studies of sensory analysis, the choice of the panelists especially carried itself on the recipes references in relation to the recipes based on mucilages those exits of *B. mannii* and *I. gabonensis*. This choice seems to explain itself by two facts: first the recipes references kept the totality of their nourishing components, and then *B. mannii* and *I. gabonensis* are the plants having expressed the strongest viscosities.



f=4.74, p<0.001; f=2.76, p=0.01; f=5.39, p<0.001

f=12.76, p<0.001; f=1.80, p=0.10; f=1.29, p=0.27; f=1.07, p=0.39

A **B**

Fig. 3. Perception profiles of the appearance, the aroma, the viscosity (A) and of the flavors pungent, bitter, acidic and astringent (B) of the references dishes and dishes based on mucilage from the plants studied

IG, I. gabonensis; CO, C. olitorius; BM, B. mannii; AE, A. esculentus; Mu, mucilage; AciFla, acidic flavor; AstFla, astringent flavor; PunFla, pungent flavor; BitFla, bitterness flavor

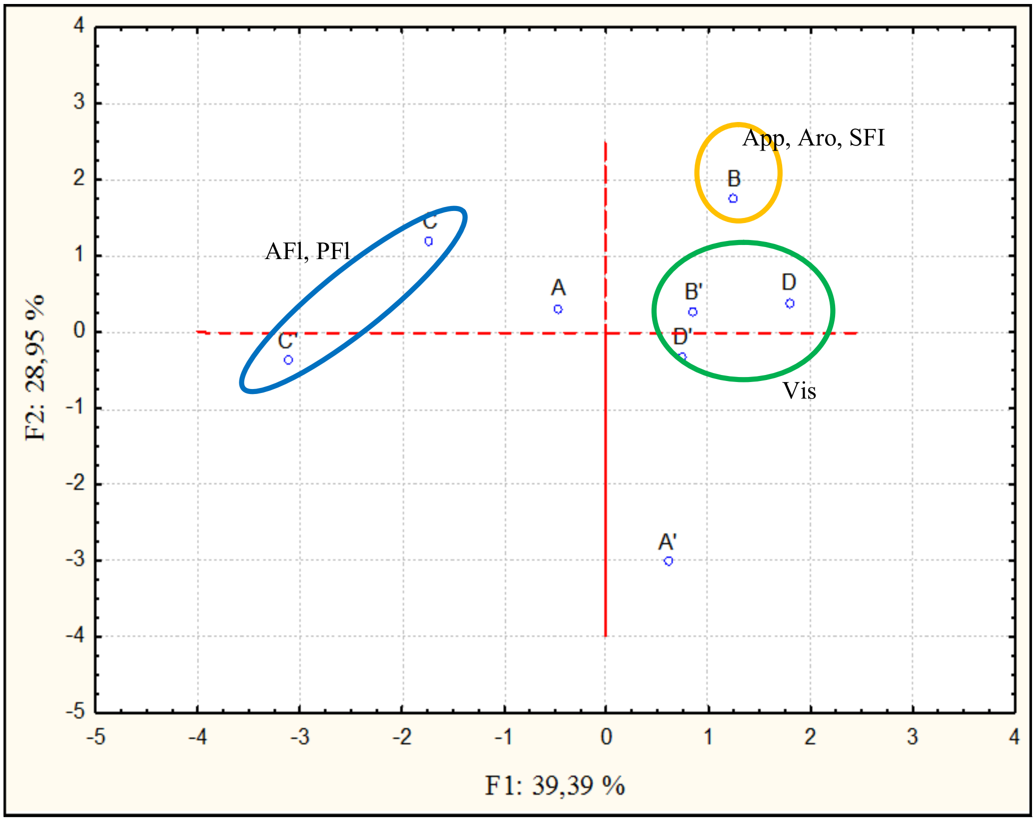


Fig. 4. Distribution of the different MFPs dishes studied and their describers in the plan formed by the factors F1 and F2 of the principal components analysis

A, A. esculentus; A', A. esculentus mucilage; B, I. gabonensis; B', I. gabonensis mucilage; C, C. olitorius; C', C. olitorius mucilage; D, B. mannii; D', B. mannii mucilage; vis, viscosity; aro, aroma; app, appearance; SFL, acidic flavor; AFL, astringent flavor; PFL, pungent flavor

Table 4. Sensory parameters acceptability (on 9) of the dishes based on MFPs according to the preferences

Plants	Options of preference	Average by sensory parameter (on 9)				f	p
		Aroma	Appearance	flavor	Viscosity		
A. esculentus	Sref	6.83 ± 1.17^{aA}	7.17 ± 1.17^{aA}	7.50 ± 1.38^{aA}	5.67 ± 2.94^{aAB}	0.90	0.48
	Smuc	6.17 ± 1.83^{aA}	6.50 ± 2.43^{aA}	7.17 ± 1.83^{aA}	3.00 ± 1.09^{bC}	5.30	**0.003**
I. gabonensis	Sref	4.83 ± 2.64^{aA}	5.83 ± 2.64^{aA}	5.67 ± 2.94^{aAB}	6.17 ± 2.30^{aAB}	0.33	0.85
	Smuc	5.67 ± 1.51^{abA}	5.00 ± 1.41^{abA}	6.17 ± 2.04^{aA}	3.33 ± 1.21^{bC}	2.85	**0.045**
C. olitorius	Sref	5.67 ± 1.37^{abA}	4.33 ± 2.25^{bA}	7.33 ± 2.01^{aA}	5.83 ± 1.60^{abAB}	2.99	**0.038**
	Smuc	5.00 ± 1.67^{aA}	5.83 ± 1.60^{aA}	4.50 ± 2.43^{aAB}	3.17 ± 1.70^{aC}	1.87	0.15
B. mannii	Sref	5.50 ± 2.26^{aA}	4.67 ± 2.50^{aA}	5.83 ± 1.33^{aAB}	7.17 ± 1.83^{aA}	1.24	0.32
	Smuc	5.83 ± 0.98^{aA}	6.50 ± 1.52^{aA}	4.83 ± 1.33^{aB}	5.33 ± 2.34^{aB}	0.83	0.52
F		1.56	2.05	3.50	10.674		
P		0.15	0.053	0.002	0.019		

By line/column, values with the same lowercase/uppercase letter are equivalents. F, Ficher test value; p, probability value of the ANOVA test; Sref, reference dishes; Smuc, mucilage dishes

5. CONCLUSION

The plants *B mannii* and I g*abonensi*s are given the best yields of mucilage. Sensory analyzes of the dishes based on *A. esculentus*, *I. gabonensis*, *B. mannii* and *C. olitorius* showed that the reference recipes are generally more appreciated than the formulas based on mucilages. However, the formulation based on mucilage of *B. mannii* is as much appreciated as the reference recipe. This product is the one richest in mucilage. It could also be suitable for industrial production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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