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Sensory Analysis of Porridges Processed from Flours of Palmyra New Shoots Enriched with Powders of *Moringa oleifera* Leaflets and *Vigna unguiculata* Beans

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Authors' contributions

This work was carried out in collaboration between all authors. Author BGHM supervised the whole investigation. Author MMR designed the study, performed the experiment and wrote the manuscript assisted with authors KNY and EP. Authors DMV, KNY and MMR performed the statistical analysis of the results and checked the revised manuscript. Authors SD and CA participated in interpretation of the results. All authors read and approved the final manuscript.

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ABSTRACT

The current study focuses on the sensory properties of fifteen (15) composite porridges processed from flour of new shoots tubers of *Borassus aethiopum* Mart basis. The composite flours were processed from mixture of various ratios of *B. aethiopum* flour (BAM) and powders of beans of *Vigna unguiculata* (VUW) and leaflets of *Moringa oleifera* (MOL). Sensory analyses were performed

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to reveal the descriptive profile regarding four (04) sensory parameters, namely aroma, flavour, appearance, and texture, and then the general acceptance of the porridges. Thus, the sensory profile of the studied composite flour porridges was determined against two control flours (ET1 and ET2). Then, the general acceptance was probed with two of the composite flours highlighting better sensory profiles, and then compared to both control flours. From the sensory description of the studied porridges, the samples EF07 (57% *BAM*, 26% *VUW, and* 17% *MOL*) and EE09 (61% *BAM*, 24% *VUW, and* 15% *MOL*) provided higher sweet flavour (4.27 and 4.07/9), agreeable aroma (6.67 and 6.47/9), and fluid texture (6.27 and 5.53/9), and revealed lower bitter taste (1.73 and 1.80/9). Besides, composite flours porridges EF07 and EE09 were accepted by 86% and 82% persons including 46% and 24% full acceptance, respectively. Oppositely to the composite flours porridges containing no substantial ingredient, the control porridges (ET1 and ET2) recorded 100% acceptation by panelists. The formulations of composite flours with B. aethiopum Mart new shoots basis could be more accepted as food after addition of additives such as sugar, milk and natural aromas. Such processing could result in better promotion of this plant species culture for the biodiversity preservation and generating significant incomes for farmers in rural zones.

Keywords: Sensory analysis; enriched flours; B. aethiopum; M. oleifera; V. unguiculata.

1. INTRODUCTION

Borassus aethiopum is a wide palm originating from Sub-Saharan Africa and belonging to Palmaceae or Arecaceae systematic plant family [1,2]. It grows in most of the West African countries [3]. In Côte d'Ivoire, *B. aethiopum* is found in the central region where it represents a sentry for the savannah. This plant is very stately, since it usually reaches height between 20 m and 30 m at elder stage [4,5]. It also records quite usages for local populations. Indeed, all parts of Palmyra are used in food (fruits, young shoots), handicraft (leaves, stipe), pharmacopeia (roots, flours, and young shoots), fodder (leaves), calorific energy (stipe, leaves), and as soil fertilizer (dried leaves) [6]. The strong stipe resistant to decay and to ants threats, especially to termites attacks, are also used for building of bridges, shower cabins and dugout canoes mainly in rural lands [7]. The trading of the products deriving from the Palmyra is economically advantageous in its belt regions [6]. From the Ivorian central rural region, the Palmyra adult trees often allow the production of palm wine, a fermented drink resulting from the sap [8]. However, the common palm wine extraction methods implemented unfortunately involve in the rapid death of the Palmyra plants [9]. Yet, the palm wine production is successfully worked from some palm trees (*Cocos nucifera*, *Elaeis guineensis*) using other plant organs like the unopened inflorescences and accounting advantages in the plant's survival [10]. This technology is not yet practiced from the Palmyra plants and their devastation is a serious ecological concern for the biodiversity. Moreover, the new shoots deriving with the germinating Palmyra seeds are consumed, fresh or cooked, by populations as foodstuffs or for medicinal purposes [5]. They are commonly considered as libido enhancer for women, and aphrodisiac properties for men, and their trading provides therefore significant incomes to farmers [11,12]. This valorization seems to be a quite alternative in the plant's uses, and could be popularized for adding significant nutritional, economic and therapeutic values to the Palmyra. Palmyra young shoots are often processed into flour for the preparation of porridge or ''*fufu*'' (a local food in Côte d'Ivoire), especially during the lean season [13].

Many previous works described the nutritional composition of this plant material [4,14]. They showed that the young shoots of *B. aethiopum* are as poor in proteins and micronutrients as most of the starchy foods. This nutritional deficiency is favourable to the incurring of public health disorders. Nevertheless, such concerns could be corrected by fortifying the dishes processed from the Palmyra young shoots basis with other local edible vegetables, such as *Cowpea* and *Moringa*, referring to the recommendations of FAO and WHO [15].

Previous studies regarding the cowpea beans reported high quality proteins in significant contents of about 25% [16, 14]. As for *Moringa oleifera*, the main nutritional advantages are found from the leaflets which are good sources of minerals and vitamins [17,18]. Thus, the enrichment of flours deriving from the Palmyra new shoots with *Moringa oleifera* leaflets and *Vigna unguiculata* beans has been considered for resulting in commonly appreciated food recipes such as porridge [19]. However, the dishes processed from these flours should account good organoleptic properties to record successful behavior form consumers.

The present work consists in evaluation of the sensory quality of flour porridges prepared from mixture of *Palmyra* young shoots, *Moringa* leaflets and Cowpea beans.

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material used for the trials consisted of flour mixtures processed from products of *B. aethiopum, Moringa oleifera* and *Vigna unguiculata*. Two usual marketed flours (ET1 and ET2) have been used as control samples.

2.2 Sampling

The raw material samples were collected between August and December 2015 from three localities, especially Toumodi, Dimbokro, and Didiévi, located in the Centre Region, which are the natural lands accommodating with the Palmyra in Côte d'Ivoire and where large quantities of Cowpea and Moringa are also produced. Three retailers of Palmyra shoot tubers and Cowpea beans were considered per town, and then 30 kg tubers and 10 kg beans were perceived from each retailer, giving total amount of 270 kg Palmyra tubers and 90 kg Cowpea beans. In addition, 50 kg Moringa fresh leaves were collected from two sites per town, 25 kg each, leading to 150 kg leaves. Once acquired, the samples have been conveyed to the laboratory and processed for analyses. Thus, a pool was constituted mixing samples by plant species. Finally, 250 kg, 75 kg and 75 kg of respective samples from Palmyra new shoots tubers, Cowpea beans, and Moringa leaflets were deducted, sorted, washed and processed into meals.

2.3 Processing for Palmyra Flour and Powders from Cowpea and Moringa

Palmyra flour and powders of Cowpea beans and Moringa leaflets were processed according to previous reports of Mahan et al. [14]. The Palmyra new shoots tubers were washed, boiled, peeled, carved, rinsed, and then submitted to fermentation into a tank container for 24 h [20]. The resulted fermented tubers pieces were dried at 65°C into a ventilated oven (Minergy Atie Process, France) for 6 h, and ground using a hammer mill (Forplex). The moringa leaflets were disinfected for 5 min with chlorinated water (50 mL of 8% sodium hypochlorite in 30 L of water), rinsed, and fermented into a tank for 24 h. Then, the fermented leaflets were dried at 30°C for 14 days in shade ambient temperature and ground. Regarding Cowpea, beans were washed, soaked, drained, and submitted to sprouting at 30°C during 48 h. The cowpea seeds were then dried at 40°C using the previous oven for 96 h, and the resulted malt was sprout out, heated for 15 min in boiling water and submitted to 24 h fermentation into tank. The fermented Cowpea beans were strained, roasted, dried at 50°C in the oven for 24 h, and ground. Finally, flour and powders were filtered using 250 µm diameter sieves and the resulting products were put in polyethylene hermetic bags and kept into dry place till analyses.

2.4 Formulation of the Composite Flours

From the raw flours obtained, fifteen (15) composite formulations accounting various flour proportions were constituted (Fig.1) according to the method used by Mahan et al. [19]. Indeed, these authors used a statistical central composite design relating to 3 variables, namely the quantities of *B. aethiopum*, cowpea and *Moringa oleifera*. Referring to Feinberg [21], the combination of the 3 variables led to 20 composite formulations of which 8 factorial essays, 6 star essays, and 6 essays from the central experimental domain. The central domain essays were reduced to a formulation because they displayed the same ingredients ratios. So, a total of 15 composite flours were assessed in the study.

2.5 Porridge Preparation

The fifteen (15) composite flours allowed preparation of 15 porridges for sensory analysis, against two common trading flours selected as controls (references). For processing porridge, 50 g flour were introduced into 250 mL water, and then cooked on low fire for 5 minutes.

The porridges with enriched flours basis and the control porridges were prepared in the same conditions without any extra-ingredient added for resulting in better characterization of the studied porridges. Porridges were cooled at laboratory ambient temperature prior to sensory analysis.

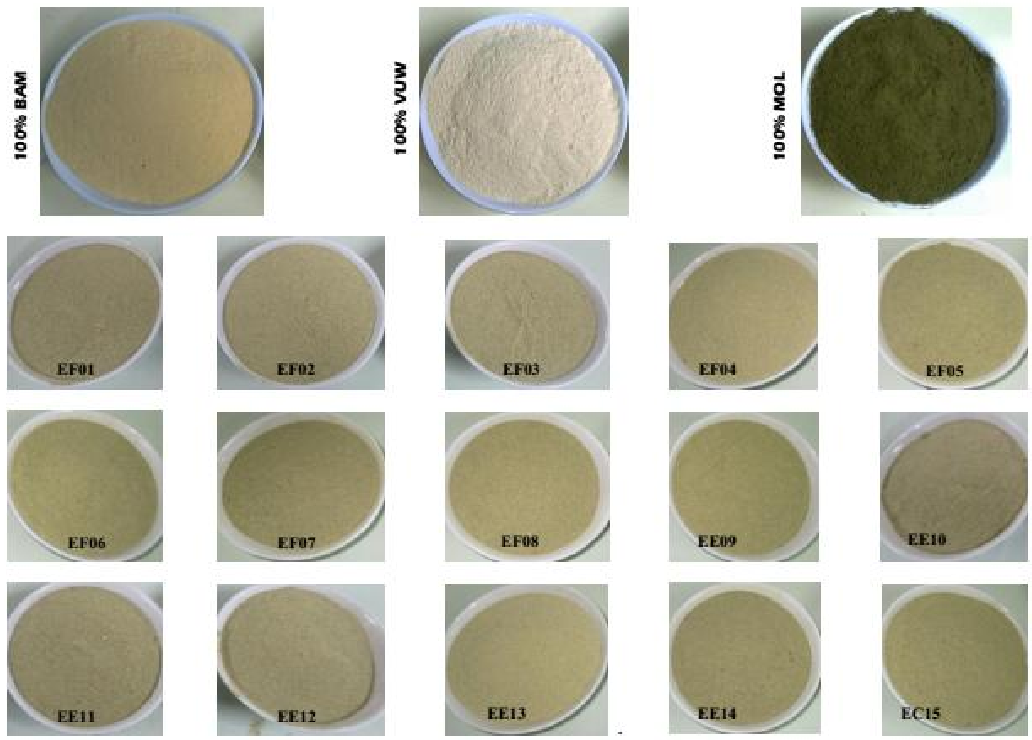


Fig. 1. Various composite flours processed from mixture of Palmyra (*B. aethiopum* M.) flour, and powders of Cowpea (*V. unguiculata* W.) beans and Moringa (*M. oleifera* L.) leaflets

The respective percentages of BAM, VUW, and MOL in the composite flours are: EF01: 72-18-10; EF02: 78-14-8; EF03: 62.5- 28.5-9; EF04: 70- 23-7; EF05: 65-16-19; EF06: 71.6-12.8-15.6; EF07: 57-26-17; EF08: 64.5-21.5-14; EE09: 61-24-15; EE10: 72-17-11; EE11: 75-11-14; EE12: 61.4-27.3-11.3; EE13: 73-21.6-5.4; EE14: 62.8-18.6-18.6; EC15: 67.5-20-12.5; EF: factorial essay ; EE: star essay; EC: centre essay; BAM: Borassus aethiopum Mart.; VUW: Vigna unguiculata Walp.; MOL: Moringa oleifera Lam

2.6 Sensory Analysis

The sensory analysis consisted in tasting overall porridges (essays and controls) for hedonic acceptance and descriptive sensory appreciation. The tasting sessions took place in the laboratory of Biochemistry and Food Sciences at Felix HOUPHOUËT-BOIGNY University of Abidjan by numerous persons (tasters). The trials were carried out with 15 mL per porridge sample filled in disposable plates. Responses were given by scores within a 9 points rating scale where 1 expressed the lack of feeling and 9 revealed the full feeling.

2.6.1 Descriptive analysis

Sensory description consisted in expressing the depth of some properties felt in the porridge. The experiments were performed by a 10 panelists group trained beforehand for the identification of four descriptors, namely aroma, appearance, flavour and texture of the porridge and their feeling degree. Panelists were trained for the methodology of analysis and appreciation of qualitative characteristics selected according to the requirements of sensory analysis. They were also trained about the taste areas of the tongue and familiarized porridge [22]. The panelists were selected according to their availability, health, motivation for participating in the study, and their sensory aptitude, especially for the sight, smell, and taste. For the sensory evaluation of the porridge, 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 [23]. The values varied also from 1, when the sensory parameter is not perceived, to 9 when it is extremely felt.

2.6.2 Hedonic analysis

Hedonic characterization was carried out using two of the 15 enriched flours, namely EF07 and EF09 that have exhibited the most interesting sensory characteristics resulting from the descriptive sensory trials. Both composite porridges were assessed against the control porridges mentioned before. The hedonic analysis was carried out by a group of 30 persons including both male and female genders and recruited for their availability and their awareness of the Palmyra new shoots. The panelists were invited to translate the level of their acceptance of the aroma, appearance, flavour and texture of the porridge samples filled with anonymous codes, by providing values from 1 to 9 [24], for respective extreme disagreeability and extreme pleasure.

2.7 Statistical Analysis

The statistical processing of the data consisted of one-way analysis of variance (ANOVA) using SPSS software (SPSS 22.0 for Windows). Means were compared by the Newman Keuls test at 5% significance level. Furthermore, multivariate analysis consisting in principal component analysis (PCA) was performed using STATISTICA software (STATISTICA version 7.1) for structuring the variability between porridge and sensory descriptors. Data from the hedonic assays were analyzed using a Chi square (X^2) statistical non-parametric test for proportions comparison.

3. RESULTS

3.1 Sensory Profiles

The descriptive sensory analysis of the studied porridges allowed the drawing of various charts shown in Figs. 2, 3, 4, and 5. Except for white appearance, and acid and astringent favours, which are not deeply expressed in the porridges, the other sensory parameters differentiated the samples studied.

The aroma is felt variously agreeable ($p<0.001$) from the porridges. With a score of 3.87/9, the aroma of EF02 records the lowest pleasance. Oppositely, the formulations EF07 and EE09 display significantly higher agreeable aromas (6.67/9 and 6.47/9, respectively) that are similar to the scores resulting from the control porridges ET1 (7.07/9) and ET2 (6.93/9) as shown in Fig 2. Otherwise, the agreeable aroma (3.87/9 to 6.67/9) is more intensive than the fermented aroma (1.13 to 1.87/9) and the Palmyra aroma (1.33 to 3.60/9).

Regarding the appearance, the porridges of the composite flours expressed greener appearance (3.07/9 for EF04 to 6.33/9 for EF05) than the controls (). But, the Fig 3 shows major yellow appearance from the ET1 and ET2 control porridges (5.13/9 and 5.40/9, respectively) compared to the Palmyra basis porridges. Overall porridges highlight minor brown appearance, highest score of which is 2.73/9 (EE13) as displayed in Fig. 3.

The ET1 and ET2 control porridges are also with sweeter flavour (6.13/9 and 5.80/9) than the composite flour porridges. Among those formulations, the EF07 records the sweetest flavour (4.27/10) whereas EF02 provides lowest sweet score of 2.80/10. In addition, the bitterness is expressed with lower scores (< 3.3/9) and the composites flours are more fitted than the controls (Fig 4).

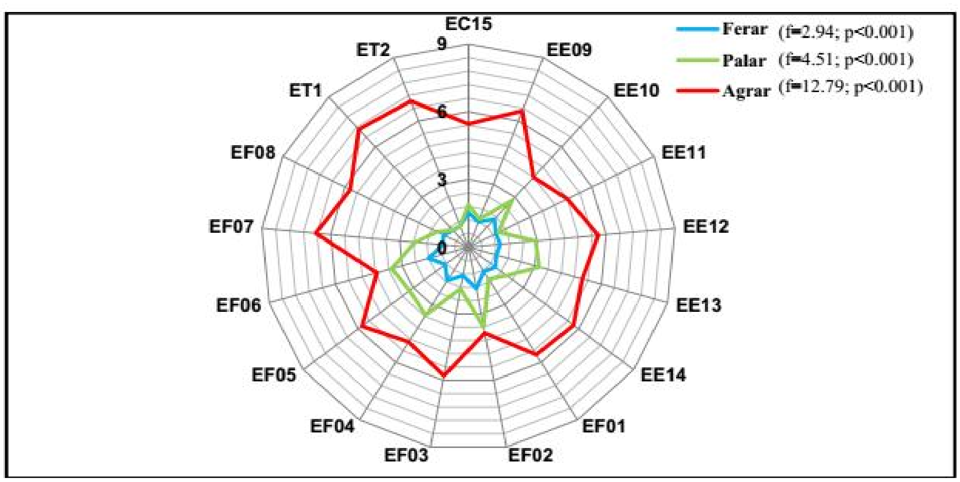


Fig. 2. Sensory profile of the fermented, Palmyra and agreeable aromas (*Ferar, Palar, and Agrar*, respectively) of the studied flours porridges

As for the textures, the panelists felt fluid texture varying from 2.60/9 (ET2) to 6.27/9 (EF07) and sleek texture varying between 3.27/9 (EE14) and 7.20/9 (ET2). The porridge of composite flour EF07 is therefore more fluid than the other studied flours whereas the control ET2 is the sleekest (Fig. 5).

3.2 Sensory Variability of Studied Porridges

The F1 and F2 factors of principal components analysis (PCA) support 80.66% total variability. Thus the correlations between porridges samples and the sensory traits are assessed using the F1-F2 factorial draw (Fig 6). This caption shows a great correlation between the control porridges and the agreeable aroma, the yellow and white appearances, and the sweet flavour. Regarding the composite flour porridges, EF05, EF07, EE09, EE14, EC15 display higher fluid texture. Other formulations, namely EF02, EF04, EF06, EE10, EE11, EE13 record greatest values of bitterness, green and brown appearances, and fermented and Palmyra aromas (Fig. 6).

3.3 Sensory Acceptance

The sensory acceptance of the porridges deriving from the most agreeable composite flours EF07 and EE09 and the controls ET1 and ET2 are presented in the Table 1. The panelists' percentages recorded from each appreciation level (1 to 9) range between 0% and 58%. But, general percentages of 82% to 100% panelists accept both Palmyra porridges basis and the control flours. Specifically, the composite porridges EF07 and EE09 are accepted by 86% and 82% persons, including 46% and 24% full acceptance respectively. However, 12% and 18% tasters show neither aversion nor satisfaction with the respective porridges EF07 and EE09. Compared to these porridges, the controls ET1 and ET2 are accepted by 100% tasters including 86% and 94% full acceptance, respectively.

4. DISCUSSION

The studied porridges were variously appreciated by tasters. The sweet flavour is more perceived than bitter taste, and any astringency or acidic flavour was significantly felt by the panellists. Besides, the control porridges (ET1 and ET2) deriving from the trade flours are sweeter than those of composite flours. In fact, the composite flours aren't added with any other product; whereas the trade foodstuffs are manufactured end-products often containing significant additives such as sugar and milk for consumers' pleasure since the sweet taste is a usually a fundamental appreciation parameter for porridges, especially from children. Some studies also indicate the perception of the foods sweet taste since the birth [25]. The results highlight that the more the cowpea and moringa powders are added, the more the porridges record agreeable aroma, sweet flavour, and fluid

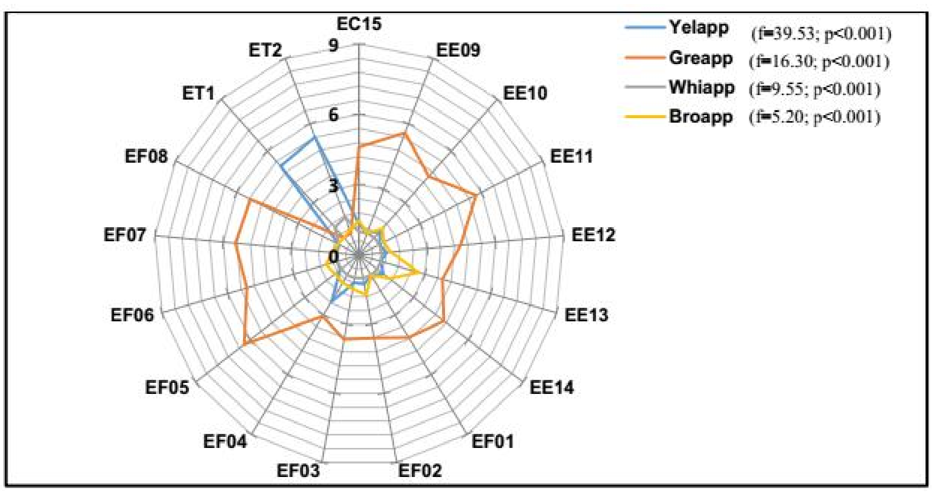


Fig. 3. Sensory profile of the yellow, green, white and brown appearances (*Yelapp, Greapp, Whiapp, and Broapp*, respectively) of the studied flours porridges

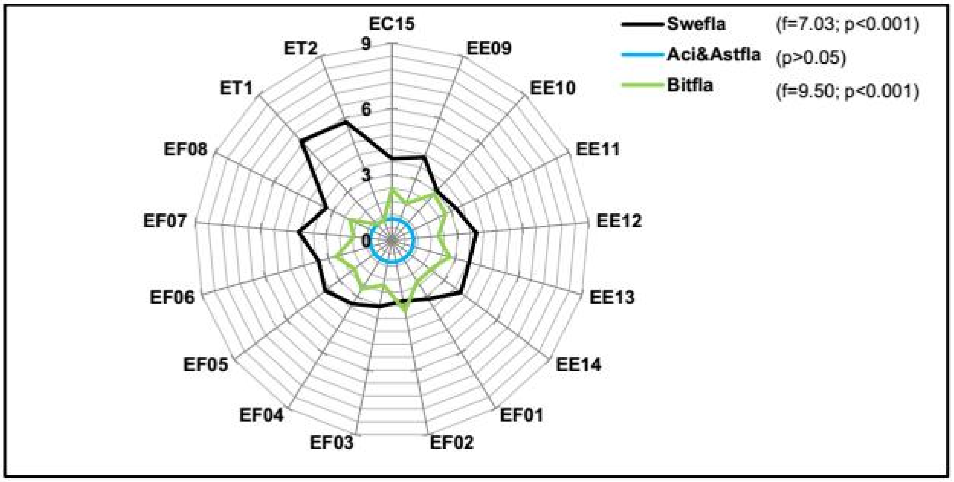


Fig. 4. Sensory profile of the sweet, acid, astringent and bitter flavours (*Swefla, Aci&Astfla, and Bitfla*, respectively) of the studied flours porridges

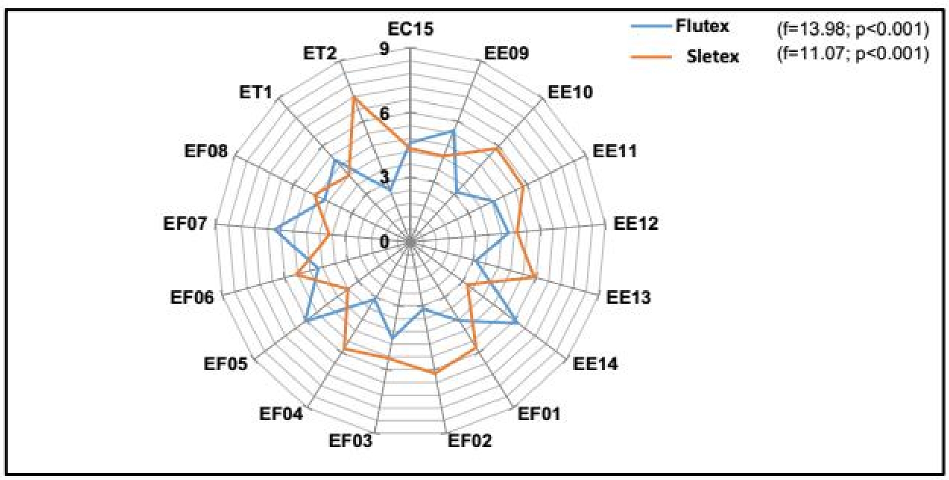


Fig. 5. Sensory profile of the fluid texture (*Flutex*) and the sleek texture (*Sletex*) of the studied flours porridges

texture, and are therefore accepted. It is also known that many consumers appreciate the sweet flavour that often confers a delicious taste to foods [26].

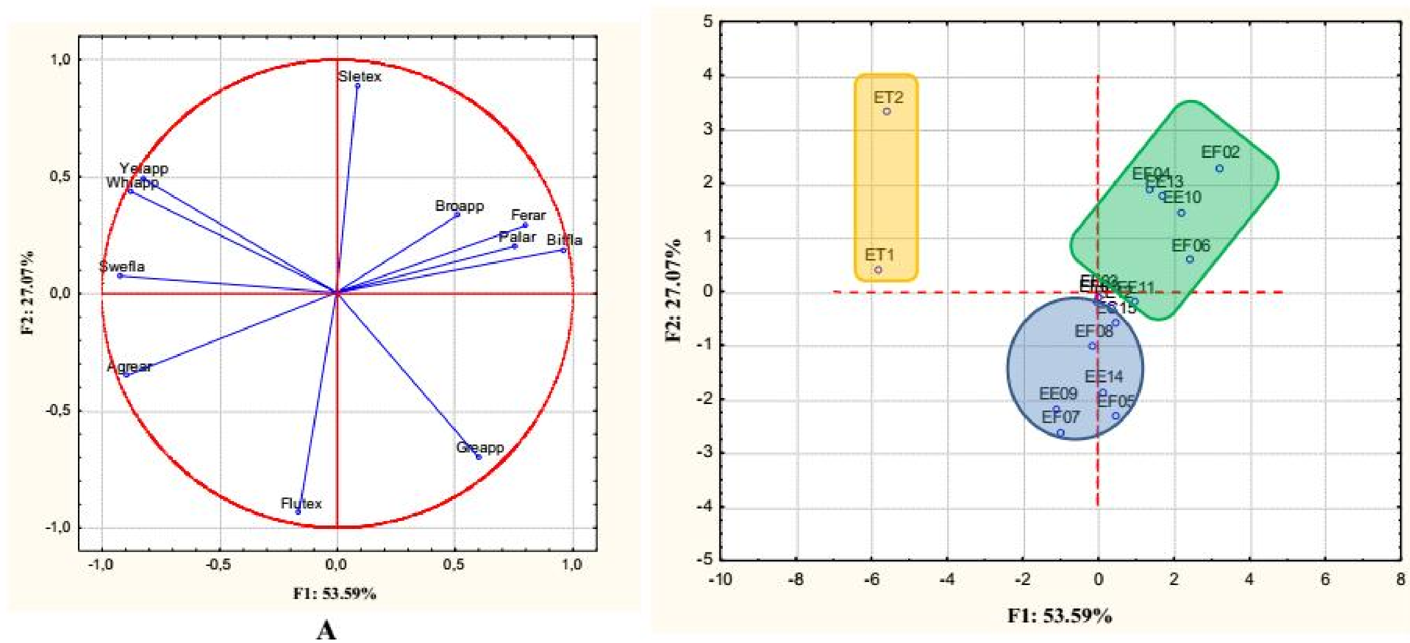
Oppositely, the fermented aroma and bitterness result in negative correlation with the porridges' acceptance. Indeed, the porridges EF07 and EE09 in which bitterness is not really felt are considered pleasant by consumers. So, the acceptance of the Palmyra new shoots basis porridges may also be improved after a period of familiarization since an initially unappreciated food could be better accepted after a familiarization phase [27,28]. Despite the differences in the porridges appearance, the results don't indicate any influence of this sensory character on the porridges acceptability.

Many studies showed increase in the foods acceptance and consumption after addition of chemical or natural aromas, even in fewer ratios [29]. Such processing has positive effect on the olfactory system [30,31]. The composite porridges, especially the formulations EF07 and EE09, could also be supplemented with additives such as sugar, milk and natural flavouring in order to record full acceptance from consumers.

Table 1. Percentages of panelists translating their acceptance preferences of the porridges samples deriving from the studied flours

Appreciation levels		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**X^2**	**P_{-value}**
General trends				**Not accepted**		**Middle**		**Accepted**				
df						**8**						
Theoritical distribution (%)		**11.1**	**11.1**	**11.1**	**11.1**	**11.1**	**11.1**	**11.1**	**11.1**	**11.1**		
Samples (%)	EF07	0.0	0.0	0.0	2.0	12.0	40.0	44.0	2.0	0.0	232.15	<0.001
	EE09	0.0	0.0	0.0	0.0	18.0	58.0	24.0	0.0	0.0	284.04	<0.001
	ET1	0.0	0.0	0.0	0.0	0.0	14.0	44.0	40.0	2.0	236.476	<0.001
	ET2	0.0	0.0	0.0	0.0	0.0	6.0	38.0	50.0	6.0	261.701	<0.001

From appreciation levels: 1, extremely unpleasant; 2, very unpleasant; 3, unpleasant; 4, moderately unpleasant; 5, neither pleasant nor unpleasant; 6, moderately pleasant; 7, pleasant; 8, very pleasant; 9, extremely pleasant; df, statistical degree of freedom; X^2, value of statistical Xhi 2 test; P_{-value}, probability value of the statistical test. $P_{-values}$ <0.05 express statistical significant differences of the percentages.



A

B

Fig. 6. Distribution of the sensory descriptors (A) and the different porridges samples (B) studied in the Fact.1- Fact.2 factorial draw of the principal components analysis (PCA)

Ferar: fermented aroma; Palar: palmyra aroma; Agrear: agreable aroma; Yelapp: yellow appearance; Greapp: green appearance; Whiapp: white appearance; Broapp: brown appearance; Swefla: sweet flavour; Bitfla: bitter flavour; Flutex: fluid texture; Sletex: sleek texture

5. CONCLUSION

The sensory evaluation of porridges showed more appreciation of the trade flours than the Palmyra basis composite flours. However, two composite formulations (EF07 and EE09) are also highly appreciated. Improvement of the organoleptic characteristics of these formulations would be necessary for their quite valorisation in trade flours. Such technologies could promote the Palmyra culture allowing the biodiversity preservation, and have advantages in the food security and providing significant incomes for farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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