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Relationships between anthocyanins and other compounds and sensory acceptability of Hibiscus drinks

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ABSTRACT

Chemical composition of Hibiscus drinks (Koor and Vimto varieties, commercial and traditional, infusions and syrups) ($n = 8$) was related to sensory evaluation and acceptance. Significant correlations between chemical composition and sensory perception of drinks were found (*i.e.* anthocyanin content and Hibiscus taste) ($p < 0.05$). Consumers ($n = 160$) evaluated drink acceptability on a 9-point verbal hedonic scale. Three classes of behaviour were identified: (a) those who preferred syrup (43% of consumers); (b) those who preferred infusion (36%); and (c) those who preferred all of the samples (21%). Acceptability of 'syrup likers' was positively correlated to sweet taste, reducing sugar content and inversely correlated to acidic taste and titratable acidity ($p < 0.10$). Acceptability of 'infusion likers' was positively correlated to the taste of Hibiscus drink and anthocyanin content. The study showed that the distinctions between the acceptability groups are very clear with respect to the chemical composition and rating of sensory attributes.
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1. Introduction

Hibiscus sabdariffa L. is an herbaceous plant that belongs to the family of Malvaceae (Cissé, 2011). It is an annual herb cultivated for its leaves, stem, seed and calices (Fasoyiro, Babalola, & Owosibo, 2005). *H. sabdariffa* has high antioxidant content related to the presence of anthocyanins with potent antioxidant activity (El Sherif, Khattab, Ghoname, Salem, & Radwan, 2011). The calyx of *H. sabdariffa* is of greatest interest because it is used for making a variety of products including infusions, food colourants and jam (Gonzalez-Palomares, Estarrón-Espinosa, Gómez-Leyva, & Andrade-González, 2009; El Sherif et al., 2011). The consumption of the drink is widespread in Africa and Asia. In Mali, Côte d'Ivoire and Burkina Faso, the drink is called 'dabileni'. In Egypt, it is known as the "drink of the Pharaohs." In Sudan the name is 'tea Karkade'. In Senegal, in particular, the drink, called Bissap, is very popular (Cissé, 2011). The most commonly consumed varieties of Hibiscus in Senegal are made from the local variety (also called Ordinary or Koor) and one of Sudanese origin (also called Vimto). The drink (called 'juice' in Senegal) is made from an extract or infusion obtained by aqueous extraction. The extraction is typically carried out between 25 °C (ambient temperature) and 100 °C (boiling temperature). After filtration, sugar and other ingredients, such as other artificial flavourings (*e.g.* banana, mint) may be added (Cissé, Vaillant, Kane, Ndiayea, & Dornier, 2011). The process for making syrup is similar; the difference being the amount of water and sugar added.

Consumer acceptance is important for product development or improvement, marketing and promotion strategies. Along with product development or improvement and economic viability, this will give food companies confidence to expand the adoption in Africa and adopt these products in other parts of the world. A number of authors have published on the hedonic acceptability of *H. sabdariffa* infusion in relation with the physico-chemical characteristics of the product (Bamishaiye, Olayemi, & Bamishaiye, 2011; Bolade, Oluwalana, & Ojo, 2009; D'Heureux–Calix & Badrie 2004; Fasoyiro et al., 2005; Gonzalez-Palomares et al., 2009; Mounigan & Badrie 2006; Mounigan & Badrie, 2007; Nwafor & Ikenebomeh 2009; Olayemi, Adedayo, Rukayyah, & Bamishaiye, 2011; Suliman, Ali, Eldeen, Idriss, & Abdualrahman, 2011). However, although

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consumer acceptance was measured using a 9-point hedonic scale for appearance taste and overall acceptance, these studies included a too few people (between 10 and 20 on average; and 50 for the study by D'Heureux–Calix & Badrie, 2004 and Mounigan & Badrie, 2006) that are not statistically valid. Hence there is a need for acceptance studies based on interviews of sufficient consumers (ISO 8587, 2006). At the exception of the study by Mounigan & Badrie, 2006 that related to Hibiscus wine, these research studies have not investigated the relationships between physico-chemical parameters, sensory evaluation and hedonic acceptance.

This study firstly explored the chemical composition of *H. sabdariffa* drinks and then examines the relationships to the sensory profile and acceptance. This will give a better understanding of the relationships and provide valuable information for developing new products that better meet consumer demand.

2. Materials and methods

2.1. Infusion and syrup samples tested

Hibiscus calices from two different varieties of calices (Sudanese and Ordinary) were harvested during the months of January–March 2011. The calices were purchased in Latmingue from Kaolack Region (central Senegal).

Eight different Hibiscus drinks (six infusions and two syrups representative of the consumption of Senegal) were initially tested by the panellists:

1. Commercial Sudanese infusion (CSi).
2. Commercial Sudanese syrup (CSs).
3. Commercial Ordinary infusion (COi).
4. Commercial Ordinary syrup (COs).
5. Commercial Mixed (Sudanese/Ordinary (50:50)) infusion (CMi).
6. Traditional boiled Ordinary infusion (TBOi).
7. Traditional ambient temperature Ordinary infusion (TAOi).
8. Traditional ambient temperature Sudanese infusion (TASi).

Commercial samples of infusions and syrups were manufactured by a local Senegalese fruit juice and syrup company that sells in supermarkets and restaurants in Senegal. Good hygiene and manufacturing practice were applied. Commercially made syrups and infusions were processed from the same batch of calices on a single day (9 am–1 pm) so that they were similar. Ratios of calyx/water (solid-to-solvent (kg kg^{-1})) were 1/20 and 1/4 for infusions and syrups respectively. In practice infusions were prepared with 80 kg of water added to 4 kg of calices and syrups with 40 kg of water added to 10 kg of calices. The process of preparation of commercial infusions and syrups differed mainly in terms of sugar concentration. In both cases calices were soaked in water at ambient temperature (25 °C) for 2 h. This aqueous extraction resulted in a bright red colour extract that was filtered. The liquid was then pasteurised using a cooking pot heated by a gas combustion skimmer. After pasteurisation the drink was cooled down under regular manual agitation.

In the preparation of infusions, sucrose (130 g L^{-1}) was added in the commercial infusions before pasteurization at 85 °C for 20 min. In the preparation of Commercial syrups, the liquid was pasteurised up to a maximum temperature of 105 °C and cooled down immediately. Sucrose (1300 g L^{-1}) was added after pasteurisation. Syrups and infusions were bottled in clear glass bottles as the product reached a temperature of 70 °C. Upon cooling to ambient temperature, infusions were stored in the fridge (between 4 and 8 °C) whilst syrups were stored at room temperature (25 °C).

Traditional samples were prepared by a local processor using traditional practices and applied good hygiene and manufacturing practice. In the traditional method, calices of Sudanese or Ordinary variety were either extracted with bottled water at ambient temperature during 2 h to produce either Traditional ambient temperature Sudanese infusion (TAOi) or Traditional ambient temperature Sudanese infusion (TASi), or boiled during 20 min to make Traditional boiled Ordinary infusion (TBOi). Sucrose (130 g L^{-1}) sugar was added and the filtrated infusion. There was no pasteurisation stage and consequently the drinks were made the day before sensory tests and stored at 4 °C.

The shelf life of the Commercial syrups and infusions is 1 year and 4 months, respectively. The shelf life of the Traditional infusions is 7 days (4 °C).

2.2. Physical and chemical analyses

All reagents used were of analytical grade and were purchased from Sigma (L'Isle d'Abeau, France). Titratable acidity, pH and dry matter were measured using standard methods (AOAC, 1990). In brief, total titratable acidity was determined with a TitroLine easy tritator (SCHOTT Instruments, Mainz, Germany), using 0.1 N NaOH solution. The pH value was determined using a calibrated pHmeter and dry matter was determined by drying a 5 g sample at 105 °C up to constant weight (24 h minimum). Total soluble solids (TSS) content was measured with an Abbe refractometer (Atago, Tokyo, Japan). Total anthocyanin content was assessed by the pH differential method at pH 1 and pH 4.5 (Lee, Durst, & Wrolstad, 2005). All absorbance readings were done against distilled water, which acted as the control. Spectrophotometric measurements were carried out using Specord 200 plus spectrophotometer (Analyik Jena AG, Germany). Concentrations were expressed as delphinidin-3-xylosylglucoside equivalents for Hibiscus (molecular weight = 577 g mol^{-1}). The molar extinction coefficient at pH 1 and 510 nm used for calculation was 26,000 L mol^{-1} cm^{-1}. The total phenolic content was determined with Folin–Ciocalteu reagent, according to the method optimised by George, Brat, Alter, and Amiot (2005) that used aqueous solution of sodium carbonate Na_2CO_3 (75 g L^{-1}), HPLC grade methanol, analytical grade acetone, gallic acid anhydrous solution at 5 mg/mL prepared the same day. Colour measurement was done on samples (30 ml) in glass Petri dishes, using a colorimeter HunterLab Konica Minolta Cr. 410 to measure the L*a*b* scale. The instrument was calibrated with a white tile. Total and reducing sugars were determined using the Luff–Schoorl method (European Economic Community, 1979). Solvents for total and reducing sugars were: cupro-alcaline solution, hydrochloric acid HCl (d = 1.18); sodium hydroxide (NaOH) solution at 33%; potassium iodine (KI), sulfuric acid solution (H_2SO_4) at 25% (d = 1.83–1.84); starch at 5 g L^{-1} in water; sodium thiosulfate 0.1 N and iodine solutions at 0.1 N. Samples were stored at −24 °C during 1 week prior to chemical and physical analyses. Samples were analysed in minimum triplicate for each type of analysis.

2.3. Ethics

This study has been assessed and approved by the University of Greenwich Research Ethics Committee. Consent was sought from sensory panellists and from adult consumers participating in this study. Samples were prepared according to good hygiene and manufacturing practices. Participants were informed about the study and explained that their participation was entirely voluntary, that they could stop the interview at any point and that the responses would be anonymous. A consent form was signed.

2.4. Sensory evaluation

Hibiscus drinks (infusions and syrups) were scored by a semi-trained sensory panel using a modified version of quantitative descriptive analysis (QDA) since standards were not provided

(Meilgaard, Civile, & Carr, 2007; Tomlins, Owori, Bechoff, Menya, & Westby, 2012). Infusions were tested directly whilst syrups were diluted 1:4 with bottled water before consumption. The panel was composed of university technicians, students or private company employees (17 people in total). Sessions were conducted at Cheikh Anta Diop University of Dakar (Senegal) in air conditioned room with controlled lighting and ambient temperature (22–25 °C). The language used for the sensory testing was French. The panellists had been screened for familiarity with the product. Sensory attributes were generated during a preliminary focus group session guided by the panel leader. A total of 11 sensory attributes were developed in consensus with panellists. Sensory attributes generated were as follows (English translation):

- Red colour – colour characteristic of red Hibiscus.
- Clarity – drink you can see through.
- Concentration aspect – like a syrup that can be diluted or concentrated.
- Hibiscus odour – odour characteristic of Hibiscus.
- Fermented odour – alcoholic odour indicating a fermentation and that the product quality is deteriorating.
- Acidic taste – taste characteristic of lemons.
- Sweet taste – taste like sugar.
- Hibiscus taste – taste characteristic of Hibiscus.
- Bitter taste –taste characteristic of coffee.
- Irritant – that has a foreign and piquant taste on the tongue.
- Fermented taste – alcoholic taste indicating a fermentation and that the product quality is deteriorating.

After a period of training using these attributes, the eight Hibiscus drinks (infusions and syrups) were tested blind in triplicate by the panel and the order in which they were presented was random. At each session, four Hibiscus sample drinks (50 ml coded with 3-figure random numbers) were served in transparent plastic cups in random order to each panellist. The panellists were asked to score the intensity for the sensory attributes on a 100 mm unstructured scale, anchored with the terms ‘not very’ at the low end and ‘very’ at the high end.

2.5. Consumer acceptability

Consumers ($n = 160$) were interviewed at five different locations in Dakar using the central location method (Meilgaard et al., 2007). These were the following: Veterinary faculty ($n = 33$); French cultural centre ($n = 72$); Terou Bi (Beach) ($n = 36$), Guediawaye ($n = 9$), and Pikine ($n = 10$) areas. Consumers were from African (mainly resident Senegalese) or from European origin (tourists or residents).

Consumer testing was carried out on four commercial Hibiscus drinks that had been selected among the samples used for sensory tasting based on their contrasted sensory characteristics using cluster analysis:

- Commercial Sudanese syrup.
- Commercial Ordinary infusion.
- Commercial Ordinary syrup.
- Commercial Mixed (Sudanese/Ordinary (50:50)) infusion.

Syrups were diluted with potable water (1:4). All sample drinks were transported in cool boxes with ice. During acceptability testing, each consumer was invited to taste each Hibiscus drink (50 ml presented in random order and coded with three figure random numbers). Consumers were asked to score the acceptability with respect to appearance, taste and overall liking using a nine-point verbal hedonic box scale which varied from dislike extremely to like extremely (Meilgaard et al., 2007).

Along with obtaining information about the acceptability of the Hibiscus drinks, information was elicited from each consumer regarding demographics, education, Hibiscus consumption and buying. All spoken interviews were conducted in French or in the local language (Wolof) and the score sheets and questionnaires were written in French. Trained enumerators assisted the consumers when required. The interview procedure lasted no more than 30 min.

2.6. Statistical analysis

Analysis of variance (mixed effect model), correlation analysis (Pearson), Chi-squared analysis and principal component analysis (correlation matrix) were carried out using SPSS (V 20.0) or XLSTAT (V 5.2, Addinsoft). Hierarchical cluster analysis (Wards method) was used to segment the consumers interviewed at the different locations into three different groups. Segmentation gives a more complex variation in acceptability among the consumers and is helpful to understand differences in consumer behaviour. Multiple pairwise comparisons were undertaken using the Tukey test with a confidence interval of 95%.

3. Results and discussion

3.1. Chemical composition and sensory profile of Hibiscus drinks

3.1.1. General description

The sensory attributes of the Hibiscus drinks tested were significantly different (Table 1) with respect to sample (linear mixed model; ANOVA; $p < 0.05$) for all the sensory attributes (red colour; clarity; concentration; Hibiscus odour and taste; acidic, sweet, bitter, irritant and fermented taste) but for fermented odour. Fermented odour was more difficult to differentiate among the panellists possibly because discriminating between odours that are not very intense can be proved challenging.

3.1.2. Hibiscus taste, anthocyanins and polyphenols

In terms of Hibiscus taste, the infusions were scored significantly higher than the syrups. The Sudanese and Mixed infusions (CSi and CMi) were scored having significantly greater Hibiscus taste than the Ordinary one (COi).

Chemical analyses of the eight Hibiscus drinks are reported in Table 2. In all infusions apart from the traditional boiled infusion (TBOi), titratable acidity, concentration in anthocyanins and in polyphenols was higher than in syrups.

An explanation could be that syrups were more diluted (with water) than infusions and therefore the anthocyanin level was diluted in syrups. Moreover, harsher pasteurisation for syrups could have resulted in greater degradation of organic acids and polyphenols including anthocyanins in syrups and lesser Hibiscus taste.

The lower anthocyanin and polyphenol contents in TBOi may have resulted from over-boiling of the sample. According to Cissé, Vaillant, Acosta, Dhuique-Mayer, and Dornier (2009), anthocyanins are affected by temperature and describe a first order kinetic degradation (Arrhenius model). Ramirez-Rodrigues, Plaza, Azeredo, Balaban, and Marshall (2012) showed that type of process and storage had a significant effect on anthocyanin degradation.

Other reported levels of anthocyanin varied. For example, anthocyanin content in Hibiscus drinks was lower in the study by Wong, Yusof, Ghazali, and Che Man (2003) but higher in the studies by Cissé et al. (2009) and Cissé (2011). Differences in anthocyanin content and titratable acidity in these different studies might result of cultivar differences and seasonal variations. Cissé et al. (2009) reported that there were great differences among cultivars in anthocyanin content and titratable acidity. As

Table 1
Means and probabilities for sensory testing with respect to *Hibiscus sabdariffa* drink and sensory panellist.

Descriptor/sample	Appearance			Odour		Taste					
	Red colour	Clarity	Concentration	Hibiscus	Fermented	Acidic	Sweet	Hibiscus	Bitter	Irritant	Fermented
CSi	61.2 ± 17.0d	61.9 ± 23.7cd	58.4 ± 19.3d	51.5 ± 18.3de	22.5 ± 21.7ab	55.5 ± 23.5cd	22.0 ± 15.4a	65.9 ± 16.5d	46.6 ± 28.0b	37.4 ± 27.1b	29.2 ± 23.9cd
CSs	39.3 ± 18.7b	68.8 ± 22.6de	35.2 ± 18.1b	27.9 ± 19.9a	19.4 ± 20.1ab	16.6 ± 16.1a	69.5 ± 17.1d	23.5 ± 17.7a	16.0 ± 17.4a	14.3 ± 16.3a	27.3 ± 27.0bcd
COi	35.6 ± 15.8b	65.0 ± 24.7cd	35.6 ± 16.5b	45.1 ± 18.5cd	19.4 ± 17.8ab	58.6 ± 23.6d	25.0 ± 16.5ab	49.2 ± 20.6bc	45.7 ± 27.4b	39.8 ± 25.3bc	28.6 ± 25.5cd
COs	16.2 ± 15.3a	78.7 ± 17.8e	18.2 ± 16.0a	24.5 ± 19.6a	15.3 ± 17.0a	12.8 ± 13.1a	63.5 ± 20.5cd	26.7 ± 20.7a	13.7 ± 14.0a	14.5 ± 17.7a	15.2 ± 18.2a
CMi	65.1 ± 16.4d	64.1 ± 22.5cd	60.4 ± 19.9de	54.3 ± 19.5de	20.1 ± 19.5ab	45.7 ± 23.9c	31.5 ± 18.0ab	60.3 ± 17.3cd	40.3 ± 24.3b	28.8 ± 21.3bc	24.9 ± 20.4abc
TBOi	47.9 ± 15.8c	37.4 ± 29.4a	48.3 ± 16.8c	40.1 ± 22.1bc	21.2 ± 19.1ab	52.0 ± 30.9cd	31.7 ± 29.7ab	46.3 ± 25.1b	46.0 ± 29.0b	39.1 ± 29.2c	22.9 ± 22.9abc
TAOi	33.8 ± 16.3b	55.5 ± 26.0ab	31.8 ± 16.5b	30.9 ± 19.5ab	25.6 ± 21.3b	48.9 ± 24.5cd	35.9 ± 17.8b	46.3 ± 20.9b	43.3 ± 25.8b	38.2 ± 28.4bc	36.7 ± 25.7d
TASi	77.7 ± 14.4e	49.2 ± 26.8ab	67.1 ± 22.2e	57.9 ± 23.3e	21.9 ± 23.2ab	30.8 ± 24.1b	52.2 ± 26.3c	55.8 ± 23.3bcd	26.5 ± 23.9a	27.7 ± 23.6b	17.8 ± 16.4ab
Sample	<0.001[a]	<0.001[a]	<0.001[a]	<0.001[a]	0.437	<0.001[a]	<0.001[a]	<0.001[a]	<0.001[a]	<0.001[a]	<0.001[a]
Panellist	<0.001[a]	<0.001[a]	<0.001[a]	<0.001[a]	<0.001[a]	<0.001[a]	<0.001[a]	0.241	<0.001[a]	<0.001[a]	<0.001[a]
Sample × panellist	0.191	<0.001[a]	<0.001[a]	0.003	<0.001[a]	0.015	0.149	0.024	0.079	0.06	<0.001[a]

Where Commercial Sudanese infusion (CSi); Commercial Sudanese syrup (CSs); Commercial Ordinary infusion (COi); Commercial Ordinary syrup; (COs); Commercial Mixed (Sudanese/Ordinary (50:50)) infusion (CMi); Traditional boiled Ordinary infusion (TBOi); Traditional ambient temperature Ordinary infusion (TAOi); Traditional ambient temperature Sudanese infusion (TASi).

[a] Indicate significant differences. Intensity of sensory attributes was scored a 100 mm scale. Average ± standard deviation. Differences between the samples (a, b, c, d or e in columns) were determined by the Tukey method.

Table 2
Chemical analyses of *Hibiscus sabdariffa* drink.

	pH	TSS (g.100 g^{-1})	Dry matter (g.100 g^{-1})	Titratable acidity (mEq L^{-1})	Total sugars (g.100 g^{-1})	Reducing sugars (g.100 g^{-1})	Anthocyanins expressed as delphinidin-3-xylosylglucoside mg L^{-1}	Polyphenols (mg L^{-1})	Colour		
									L*	a*	b*
CSi	2.66^{b} ± 0.39	16.04^{a} ± 0.78	16.58^{a} ± 0.52	146.05^{f} ± 1.57	14.03^{b} ± 0.33	8.24^{c} ± 0.06	241^{g} ± 8.02	597^{e} ± 32.92	24.87^{a} ± 0.07	18.35^{d} ± 0.04	4.07^{c} ± 0.03
CSs	2.57^{b} ± 0.26	18.44^{c} ± 1.04	19.2^{c} ± 0.34	28.06^{a} ± 1.75	17.87^{c} ± 0.33	16.81^{g} ± 0.61	80^{c} ± 2.35	296^{c} ± 14.82	29.14^{c} ± 0.03	26.70^{g} ± 0.03	11.96^{f} ± 0.02
COi	2.49^{a} ± 0.07	15.71^{a} ± 0.88	16.01^{a} ± 0.04	148.60^{f} ± 1.02	13.13^{b} ± 0.53	11.28^{d} ± 0.07	107^{d} ± 2.28	639^{e} ± 36.92	25.13^{a} ± 0.09	0.04^{a} ± 0.02	3.84^{b} ± 0.18
COs	2.62^{b} ± 0.29	16.93^{b} ± 2.49	16.87^{a} ± 0.08	49.78^{b} ± 0.44	17.39^{c} ± 0.08	14.91^{f} ± 0.54	60^{a} ± 1.88	218^{b} ± 13.28	33.52^{d} ± 0.07	27.43^{h} ± 0.07	15.05^{g} ± 0.07
CMi	2.48^{a} ± 0.07	15.49^{a} ± 0.86	16.01^{a} ± 0.05	136.07^{e} ± 2.60	12.18^{a} ± 0.02	13.08^{e} ± 0.33	141^{e} ± 8.83	695^{e} ± 34.75	23.72^{a} ± 0.37	11.88^{c} ± 0.13	1.76^{a} ± 0.02
TBOi	2.49^{a} ± 0.08	14.69^{a} ± 0.95	15.02^{b} ± 0.08	68.92^{d} ± 0.30	13.21^{b} ± 0.27	2.28^{b} ± 0.08	73^{b} ± 1.29	393^{d} ± 15.56	25.63^{a} ± 0.94	19.03^{e} ± 0.05	5.52^{d} ± 0.02
TAOi	2.50^{a} ± 0.08	14.51^{a} ± 0.72	14.89^{b} ± 0.21	60.23^{c} ± 0.71	13.24^{b} ± 0.12	1.63^{a} ± 0.08	167^{f} ± 4.5	296^{c} ± 11.72	27.59^{b} ± 0.02	24.29^{f} ± 0.03	8.62^{e} ± 0.01
TASi	2.76^{c} ± 0.13	14.69^{a}±.04	14.52^{b} ± 0.17	30.23^{a} ± 0.33	14.37^{b} ± 0.27	1.56^{a} ± 0.03	174^{h} ± 3.78	175^{a} ± 9.20	29.87^{c} ± 0.02	24.65^{f} ± 0.26	11.36^{f} ± 0.01
n	9	9	9	6	3	6	9	9	3	3	3

Average ± standard deviation. Where total soluble solid (TSS); number of replicates (*n*); Commercial Sudanese infusion (CSi); Commercial Sudanese syrup (CSs); Commercial Ordinary infusion (COi); Commercial Ordinary syrup; (COs); Commercial Mixed (Sudanese/Ordinary (50:50)) infusion (CMi); Commercial Mixed (Sudanese/Ordinary (50:50)) syrup (CMs);Traditional boiled Ordinary infusion (TBOi); Traditional ambient temperature Ordinary infusion (TAOi); Traditional ambient temperature Sudanese infusion (TASi). Analysis of variance was performed using XLSTAT Release 10 (Addinsoft, Paris, France). Tukey's multiple range test was applied to obtain comparisons among sample means. Different letters (a–h) in the same column indicate significant differences at $p < 0.05$ (from smaller to larger).

an example, varieties of Koor, Vimto and Thai presented levels of anthocyanins of 250, 718 and 360 mg L^{-1} respectively (Cissé et al., 2009). Working with a Mexican variety of *H. sabdariffa* L., Ramirez-Rodrigues et al. (2012) reported levels of anthocyanin much lower of around 50 mg L^{-1}.

3.1.3. Perceived colour and L*a*b*

According to the panellists, the sample that were the most red in colour were CMi and CSi ($p < 0.05$). The Ordinary infusion (COi) and syrup (COs) were scored less in terms of colour. The darker Sudanese Hibiscus was redder in colour and this result was in according with local knowledge of this variety. Wong et al. (2003) evaluated the sensory attributes of *H. sabdariffa* calices submitted to different processes (cold or hot; with or without a press) to prepare the infusion. The infusion was evaluated by a sensory panel who scored colour (redness), odour (grassiness) and taste (grassiness, sourness, sharpness) using a scale of 100 mm. The redness attribute varied according to the method of pressing (screw press) and extraction (hot water extraction). In this work, the redness of the Hibiscus infusion also varied according to the method of processing (infusion or syrup) or extraction (cold or hot).

L* (brightness) a* (positive red) and b* (positive yellow) values tended to be greater for syrup drink as compared with infusion. Therefore syrups tended to have brighter colours than infusions. Infusions were of darker colour and more blue-purple. L*a*b* values of Hibiscus drink were similar to those reported by Wong et al. (2003). Wong et al. (2003) however reported lower values of anthocyanin content. These discrepancies may be explained by the different method used to measure colour that might have resulted in similar reading of colour but in lower concentrations in anthocyanin than in our research.

3.1.4. Acidity and pH value

The acidic taste perceived by the panellists was greater for the Traditional Ordinary infusion (TAOi) compared to Traditional Sudanese infusion (TASi). According to the Senegalese customs, the Ordinary variety is supposed to be more acidic and flavoured than the Sudanese one. It is a habit for some people to mix both types in order to obtain both aroma and redder colour. Cissé et al. (2009) have shown that the Ordinary calices have higher acidity levels than that the Sudanese calices that has a higher anthocyanin content and this is in accordance with our study although the difference in acidic taste among the Commercial sample infusions (CSi and COi) was not perceived by the panellists.

The pH value was in accordance with previous studies on Hibiscus (Bamishaiye et al., 2011; Gonzalez-Palomares et al., 2009; Olayemi et al., 2011; Ramirez-Rodrigues et al., 2012). The pH value was very similar for all the samples ranging from 2.48 in CMi to 2.76 in TASi. Organic acids such as ascorbic acid are known to be more labile than anthocyanins (Torres et al., 2011). Whilst commercial infusions had similar anthocyanin levels to the traditional infusions, their titratable acidity was greater (TAOi and TASi). It is speculated that either organic acids might have been either lost during preparation or storage of traditional infusions or the batch used for traditional processing was naturally less rich in organic acids.

3.1.5. Sweetness and sugar level

Total sugar and reducing sugar contents were greater in syrups compared to infusions: this was a result of greater sugar concentration in the syrups. From a sensory aspect, syrups were perceived significantly sweeter than infusions ($p < 0.05$) and this is in accordance with the way these products are prepared.

Traditional infusions (TBOi, TAOi and TASi) had low reducing sugars compared to the other samples. During heating some disaccharides such as sucrose can be hydrolysed into monosaccharides or reducing sugars such as glucose and fructose (Lamberts, Rombouts, & Delcour, 2008). Therefore these low levels of reducing sugars could be attributed to the lack of thermal treatment rather than an evaporative process that concentrates solids in the syrups and infusions. Total soluble solids (TSS) contents reported by Wong et al. (2003) were excessively lower (0.6 g/kg compared to the values reported in our study. Yet the TSS reported by Cissé et al. (2009) and Cissé (2011) were much greater than TSS values obtained in the present study. The differences in TSS in different research works on Hibiscus might be explained by the different amount of sugar added to the drinks.

Chemical analysis and sensory analysis showed that there are significant differences in the values reported for Hibiscus drinks. These variations are probably the result of processing conditions (syrup or infusion) that might have affected anthocyanins and organic acids and the addition of sugar (*i.e.* sugar level and TSS) but also the result of varietal differences between the calices (Ordinary or Sudanese) (*i.e.* anthocyanins, organic acids).

3.2. Correlations between sensory attributes and chemical analyses of Hibiscus drinks

The sensory perception of the Hibiscus drinks was clearly related to chemical composition (Table 3).

Hibiscus taste, which is an important characteristic of the Hibiscus drink, was significantly correlated with anthocyanin content. This confirmed that the presence of anthocyanins is perceptible by the panellists and linked to the characteristic taste of Hibiscus. In addition, the concentration in polyphenols was significantly correlated to Bitter taste and this was in accordance with Jaeger, Axten, Wohlers, and Sun-Waterhouse (2009) and Lawless, Threlfall, Howard, and Meullenet (2012). Jaeger et al. (2009) reported bitter taste as being characteristic of polyphenol-rich beverages. also reported that bitter taste was associated with total phenolic content in berry juices The bitter taste was significantly more pronounced in infusions compared to syrups ($p < 0.05$) (Table 1). Interestingly, Hibiscus and bitter taste were negatively associated with total sugars, which suggest that addition of sugar would be masking the Hibiscus and bitter tastes.

Surprisingly there were no correlations between red colour as perceived by the panel and L*a*b* values. Hence the perception of colour might be linked to other attributes for panellists.

Acidic taste was positively correlated with titratable acidity and negatively with total sugars and a* value (measuring the red colour). This can be explained by infusions being more acidic, less sweet and less red in colour compared to syrups. Negative correlation of sweet taste to titratable acidity and positive correlation to total sugars also means that addition of sugar would mask the acidity of the drinks perceived by the panellists. Similarly Lawless et al. (2012) working on mixed drinks of blueberry and blackberry infusions and grape concentrates reported that sweetness was inversely correlated to titratable acidity.

The clearer the drink the greater the total soluble solids (TSS), dry matter and reducing sugar content ($p < 0.1$ and 0.05): this might be explained by syrups having higher score for clarity, TSS, dry matter and reducing sugar compared to juices.

3.3. Consumer testing

3.3.1. Consumer acceptance of Hibiscus drinks

Overall, the acceptance of the Hibiscus drinks significantly differed between the four samples at $p < 0.01$ (One-way ANOVA). All of the drinks were on average acceptable since the mean scores were greater than a score of 5 (neither like nor dislike). The most liked was the Commercial Mixed infusion (CMi = 6.2 ± 0.1) (average ± standard deviation) followed by the Commercial Sudanese

Table 3
Correlations between chemical analyses and sensory scoring of *Hibiscus sabdariffa* drink.

Variables	Red colour	Clarity	Concentration	Hibiscus odour	Acidic taste	Sweet taste	Hibiscus taste	Bitter taste	Irritant taste	Fermented taste
pH	0.403	0.048	0.341	0.280	−0.425	0.380	0.098	−0.453	−0.342	−0.502
TSS	−0.398	**0.726****	−0.430	−0.504	**−0.641***	0.623	−0.658	**−0.671***	**−0.758****	−0.142
Dry matter	−0.360	**0.672***	−0.383	−0.479	−0.525	0.518	−0.592	−0.548	**−0.663***	0.009
Titratable acidity (mEq L^{-1})	0.169	0.119	0.257	0.488	**0.746****	**−0.831****	0.657	**0.710****	0.580	0.340
Total sugars (g.100 g^{-1})	−0.468	0.557	−0.530	**−0.653***	**−0.882****	**0.881****	**−0.821****	**−0.895****	**−0.859****	−0.385
Reducing sugars (g.100 g^{-1})	−0.416	**0.849****	−0.419	−0.359	−0.448	0.374	−0.479	−0.482	−0.635	−0.149
Anthocyanins (mg L^{-1})	0.621	−0.173	0.618	0.621	0.474	−0.513	**0.795****	0.471	0.459	0.398
Polyphenols (g L^{-1})	0.221	0.083	0.305	0.473	**0.699***	**−0.762****	0.585	**0.673***	0.499	0.373
L^* value	−0.453	0.384	−0.529	−0.574	**−0.865****	**0.850****	**−0.710****	**−0.866****	**−0.735****	−0.554
a^* Value	−0.106	0.019	−0.171	−0.457	**−0.708****	**0.710****	−0.467	−0.641	−0.585	−0.260
b^* Value	−0.421	0.313	−0.507	−0.611	**−0.878****	**0.897****	**−0.754****	**−0.874****	**−0.740****	−0.456

* and ** values in bold indicate significance at $p < 0.10$ and $p < 0.05$ respectively (Correlation Coefficient (R) (Pearson test)). Correlations graphically represented were linear. Fermented odour was not included since it was not significant differentiated among panellists.

syrup (CSs = 5.9 ± 0.1), the Commercial Ordinary Syrup (COs = 5.6 ± 0.2) and the Commercial Ordinary infusion (COi = 5.2 ± 0.2). The average liking was 5.7 over the four samples. Jaeger et al. (2009) reported that the acceptance of consumers for polyphenol-rich beverages made out of berries and chocolate mixed or single varied between 2.3 and 5.1. Lawless et al. (2012) indicated that the consumer overall liking of blackberry and blueberry juices was between 2.9 and 5.5, respectively. Hence Hibiscus drink as a polyphenol-rich beverage with an hedonic score between 5.2 and 6.2 would be rated higher than the black and blueberry juices described by Jaeger et al. (2009) and Lawless et al. (2012). Comparing acceptability of studies on different polyphenol rich products might however be delicate since it may be influenced by acquaintance with product and the type of consumer.

3.3.2. Segmentation of consumers into groups of similar acceptance patterns regarding the Hibiscus drinks

Hierarchical cluster analysis (Wards Method) indicated three different groups of consumer profile with respect to the Hibiscus drinks (Fig. 1). The mean liking for each of the three groups is illustrated in Fig. 2. We used a score of five 'neither like nor dislike' as an indicator of "neutral attitude". The products rated below five were considered as "disliked" and above five as "liked". For the purposes of cluster division, the groups were grouped as 'syrup likers' (43%), 'infusion likers' (36%) and 'indifferent likers' (21%).

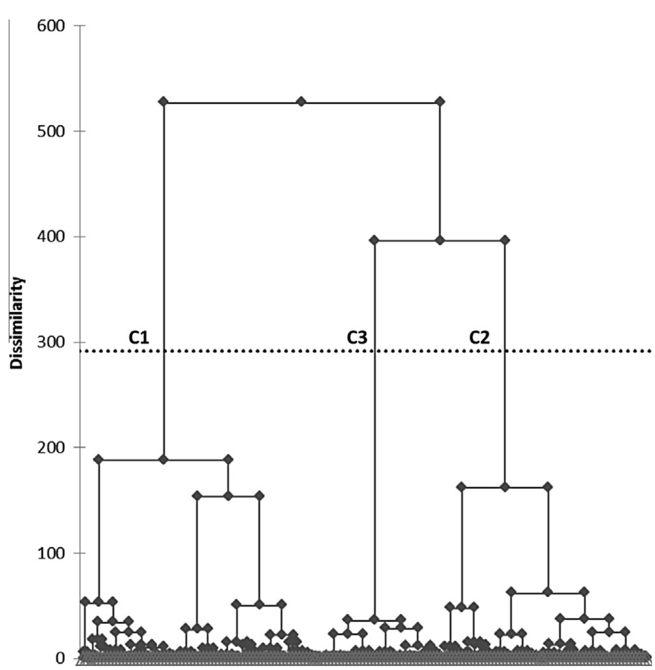

Fig. 1. Agglomerative hierarchical cluster analysis dendrogram for segmenting consumers into groups of similar perceptions of Hibiscus drinks ($n = 160$). Where: Dotted line donates level of dissimilarity along which the four segments (groups) were selected.

Demographic differences and consumer attitudes to Hibiscus with respect to cluster division were calculated at $p < 0.05$.

The three clusters did not significantly differ in terms of sociological criteria such as age, gender, residency, education level, marital status etc. There were no differences in the form consumers from the different clusters purchase Hibiscus: the most common form of buying was as calices followed by infusion (in sachets), infusion in recycled bottles, industrial infusion and syrup. Percentage consumption of Hibiscus natural or with added artificial flavour (*e.g.* banana, strawberry, pineapple and mint) was also the same for the three clusters. Most consumers preferred the natural product (66%) compared, to the one with added flavour (34%).

In each of the three clusters frequency of consumption of Hibiscus drink was quite high (above 60% of people interviewed consume it at least once a week) and shows that Hibiscus drink is popular in Senegal. There were however differences between the clusters in the frequency of consumption: 'syrup likers' tended to consume Hibiscus drinks less frequently than the 'infusion likers' and 'indifferent likers' (62%, 79% and 80%, respectively) ($p = 0.028$). Specific taste for Hibiscus might explain more frequent consumption in the two latter clusters.

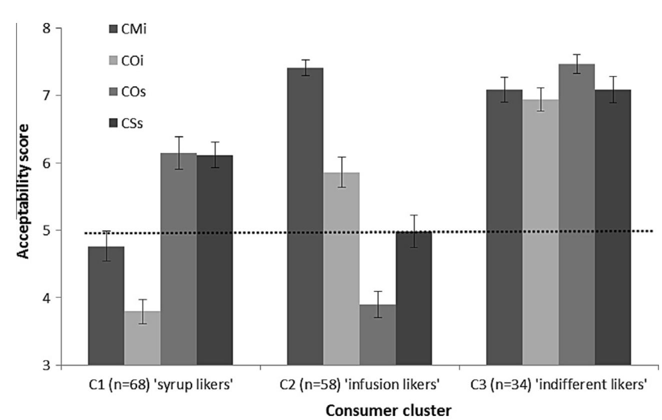

Fig. 2. Mean consumer acceptance of Hibiscus by cluster type ('syrup likers', 'infusion likers', 'indifferent likers'). Error bars represent the standard error of the mean. Commercial Mixed (Sudanese/Ordinary (50:50)) infusion (CMi); Traditional boiled Ordinary infusion (TBOi); Commercial Ordinary infusion (COi); Commercial Ordinary syrup; (COs); Commercial Sudanese syrup (CSs).

Table 4
Correlations between sensory attributes, chemical analyses and acceptability of Hibiscus drinks.

	Variables	All	C1 ($n = 68$) 'syrup likers'	C2 ($n = 58$) 'infusion likers'	C3 ($n = 34$) 'indifferent likers'
Sensory attributes	Red colour	0.667	−0.405	**0.949**[*]	−0.601
	Clarity	−0.174	0.734	−0.883	**0.938**[*]
	Concentration	0.626	−0.466	**0.972**[**]	−0.599
	Hibiscus odour	0.222	−0.808	**0.962**[**]	−0.644
	Fermented odour	0.302	−0.560	0.827	**−0.918**[*]
	Acidic taste	−0.266	**−0.991**[**]	0.748	−0.765
	Sweet taste	0.207	**0.966**[**]	−0.760	0.623
	Hibiscus taste	0.162	−0.815	**0.910**[*]	−0.532
	Bitter taste	−0.173	**−0.975**[**]	0.805	−0.743
	Irritant taste	−0.410	**−1.000**[**]	0.637	−0.720
	Fermented taste	−0.039	−0.588	0.586	**−0.981**[**]
Chemical analyses	pH	−0.054	0.888	**−0.917**[*]	0.840
	TSS	0.122	0.805	−0.651	0.268
	Dry matter (%)	0.229	0.721	−0.474	0.088
	Titratable acidity (mEq L^{-1})	−0.185	**−0.952**[**]	0.762	−0.586
	Total sugars (g.100 g^{-1})	−0.046	0.880	−0.881	0.585
	Reducing sugars (g.100 g^{-1})	0.445	**0.942**[*]	−0.534	0.460
	Anthocyanins mg L^{-1}	0.393	−0.695	**0.996**[**]	−0.647
	Polyphenols(g L^{-1})	0.066	−0.894	**0.923**[*]	−0.732
	L*value	−0.184	0.807	**−0.949**[*]	0.855
	a* Value	0.405	**1.000**[**]	−0.643	0.740
	b* Value	−0.123	0.866	**−0.945**[*]	0.756

[*] and [**] values in bold indicate significance at $p < 0.10$ and $p < 0.05$ respectively (Correlation Coefficient (R) (Pearson test)).

3.4. Correlations between sensory attributes, chemical analyses and consumer acceptance

For the consumer group as a whole, their mean acceptance scores were not significantly correlated to any of the sensory attributes or concentrations of chemical compounds (Table 4).

There were significant relationships regarding the different consumer groups. Significant positive correlations ($p < 0.10$) were identified between acceptability of the 'infusion likers' and red colour, concentration, Hibiscus odour, taste, anthocyanin ($p < 0.05$) and polyphenol levels ($p < 0.10$). Correlations was found between acceptability of 'infusion likers' and b* value (negative b* value is blue colour characteristic of anthocyanins).

Significant positive correlations ($p < 0.10$) were identified between acceptability of 'syrup likers' and sweet taste, reducing sugars and a* value. Negative correlations were found between acceptability of 'syrup likers', acidic taste and titratable acidity, bitter taste and irritant taste.

There were no significant correlations ($p < 0.10$) between the 'indifferent likers' and chemical analyses. However there were significant correlations between the acceptability of 'indifferent likers' and sensory attributes such as clarity. 'Indifferent likers' acceptability was also negatively correlated to Fermented odour and taste. The absence of correlations between the 'indifferent likers' and chemical constituents was expected because 'indifferent likers' did not have any marked preference.

In summary, these correlations accord with the sensory perception of the drinks and highlight that sweetness and sugar addition is an important criterion of acceptability for 'syrup likers' and Hibiscus taste or anthocyanin content would be an important criterion of acceptability for 'infusion likers'.

Cluster analysis is useful to help find the "niche" consumers who have specific tastes that could drive the market for specific products. This present research is new because we reported on relationships between acceptance and chemical constituents.

3.5. Implications for adapting chemical composition of Hibiscus drinks

Cluster analysis approach has been commonly used in consumer acceptance in order to determine which groups of people who would prefer which type of product. This approach is very useful in the marketing approach because it helps target specific consumers with the type of product they like. The liking can be depended upon many factors (socio-economic background; food customs) and knowing the consumers would help predict the product that they are more likely to adopt when launching a new product on the market for instance. In the case of this study involving *H. sabdariffa* drinks, acceptability study will help re-engineering of the product that shall suit the consumer taste.

The sensory and chemical characteristics important to each group of consumers differed. For the indifferent likers who represented 21% of consumers, they were the least discerning consumers but liked all of the products. Their acceptance did not correlated with any specific chemical constituent measured in this research but did relate to specific sensory attributes (clarity, fermented odour and taste). The syrup likers (43% of consumers) were more discerning and their acceptance was related to the chemical constituents such as titratable acidity and colour (a* value). Their acceptance was specifically related to sensory attributes such as sweetness, red colour and non-irritant characteristics (low bitter or acidic taste). The infusion likers (36% of consumers) were also the most discerning consumers and their acceptance was related to different chemical constituents such as anthocyanins and polyphenols and also to different specific sensory attributes being Concentration, Hibiscus odour and Hibiscus taste.

4. Conclusions

The results of this research help to provide a basis of understanding how the chemical constituents of *H. sabdariffa* drinks relate to their sensory profile and acceptance. A significant correlation between clusters of consumers and sensory attributes (*i.e.* syrup likers and sweetness, infusion likers and anthocyanins) support the finding that the acceptance was related to sensory attributes and consumers had selective tastes according the products they like most. This research suggests that a range of chemical constituents correlated with the sensory attributes (appearance, odour and taste) and can help with product development and improvement since the chemical constituents also will relate to the different acceptance profile of the consumer.

This knowledge could help improvement of products meeting specific consumer demand and will have implications for marketing strategies for example.

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