

Valorization of Fruits Residues in *Saba senegalensis* (A. DC. Pichon) Juice Processing: Biochemical and Sensory Analysis of the Product

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Abstract

During the small-scale processing of fruit juice from *Saba senegalensis*, the pericarp, seed and seed coat are considered waste and discarded with environmental pollution involvement. Yet, these agricultural by-products or residues often display obvious exploitable nutritional potentials as minerals and antioxidants. This study aims to contribute to the use of fruit residues from *S. senegalensis* into the processing products, to enhance the value of this agricultural resource and improve its profitability. After incorporating 2%, 5% and 10% (w/v) of ground dried residues, the *S. senegalensis* juice was filtered, pasteurized and biochemical and sensory traits assessed compared to the raw juice taken as a control. Results showed that the juice becomes thicker (1.01 to 1.05) and viscous (1.85 to 3.85 mPa.s) and its dry matter and ash contents get increasing (3.92 to 5.43% and 0.08 to 0.22%, respectively) with the incorporation of residues up to 10%. The resulting juices display pH of 2.33 to 2.5, which is friendly against nutrients spoilage by fermentation. The presence of carbohydrates and polyphenols also increases (0.91 to 1.69 g/100 mL and 68.81 to 227.14 mg/100 mL, respectively) with the residue's incorporation into juices. However, the organoleptic traits of the formulations seem more advantageous for raw juice without residue, especially with a greater trend for hedonic acceptance. Incorporating *Saba senegalensis* fruit's residues strengthened the nutritional virtues of processed juices and the use of conventional additives such as table sugar and flavorings could also improve the organoleptic ratings.

Keywords: antioxidants and biochemical traits, fruit's residues, juice processing, organoleptic analysis, *Saba senegalensis*

1. Introduction

Saba senegalensis (Apocynaceae) is a wild non timber plant exploited by numerous tropical African populations according to traditional knowledges through generations (Aziz, 2021). This crop is used in traditional medicine, construction, animal feed and human food from its various parts. The leaves and tendrils are used for treatment of dysentery, diarrhoea, malaria, intestinal nematodes, fever, sinusitis, hip pain, dysmenorrhea, stomach-ache and umbilical hernia. The fruit pulp juice and the unripe fruits are effective against respective stomach bloating and ringworm (Diawara *et al.*, 2022).

The fruits of *Saba senegalensis* are ovoid berries, which are its main food source. Generally available on the market during the local rainy season (May to August), these fruits are consumed by local populations during hunger seasons (Diawara *et al.*, 2022). The fruits are filled with seeds covered by a sweet and sour pulp containing important essential nutrients. Indeed, the fruit's pulp is acidic (pH between 2 and 3) and has a dry matter content of 16% to 24%. The main nutrients delivered are carbohydrates (13 to 16%) and dietary fibre. However, this pulp also contains vitamins (A, B, C and K) and a significant amount of ash (more than 5%)

containing essential minerals such as Fe, Mn, P, Mg and Ca (Nafan *et al.* 2013; Diabagaté *et al.* 2019; Tiendrébéogo *et al.*, 2020; Yao *et al.*, 2024).

Work by Yao *et al.* (2024) also reveals the presence of phenolic antioxidants components in the pulp of *Saba senegalensis* fruits, with more than 100 mg of total polyphenols per 100 g of pulp, most of which consists of tannins (80 mg/100 g). As such, the fruits' pulpy seeds are commonly consumed by local populations, directly as is or processed (Kouyaté *et al.* 2020; Sarr *et al.* 2018). However, the fresh consumption is not recommended due to the presence of antinutritional compounds, particularly phytates and oxalates (Yao *et al.*, 2024). Accordingly, common technologies involve the pulp's processing into juice for drinking, the thermal concentration into syrup, the fermentation into alcoholic beverage, and the use as ingredient in local dishes such as porridge and cereal pastes (Diawara *et al.*, 2022).

The usual processing methods applied to *S. senegalensis* fruits remove their hull and seeds coated and only use the pulp. Apart from the fruit hull, the pulp's residues are discarded after the soaking, boiling and filtration stages during the small- scale juice processing (Soro, 2022). Overall raw by- products usually accumulate in streets and urban areas with a great involvement in environmental pollution (Duque-Acevedo *et al.*, 2020; UNEP, 2024). However, Tiendrébeogo *et al.* (2020) revealed that the fruits' hull contains more nutrients as proteins, lipids, carbohydrates and ash than the fruits' pulp. The fruit pulp's residue is also known to be of significant nutritional and technological interests (Tufail *et al.*, 2024; Kumar *et al.*, 2024), so that it could be processed and incorporated into the pulp-derived products to improve their nutritional potential and quality (Kandemir *et al.*, 2022). This study aims the use of fruit pulp's residues into the *Saba senegalensis* raw juice processing for enhancing the value of this agrosresource and improving its profitability. The work consisted of formulating *Saba senegalensis* juices by incorporating different rates of ground seed coats into the filtered pulp, then analyzing their biochemical and organoleptic traits.

2. Material and Methods

2.1 Plant Product

The plant product used in this study is the fruit of *Saba senegalensis*. Fruits were purchased from traders in communal markets. These fruits were used for juice processing. The biochemical traits of the fruits juice were assessed using laboratory equipment, while the organoleptic characteristics were determined by conscious individual panelists.

2.2 Methods

2.2.1 Sampling

A total amount of 60 kg of ripe *S. senegalensis* fruits displaying clear signs of quite physiological maturity and sanitary quality was purchased from traders in Korhogo, Northern Côte d'Ivoire, in August (local rainy season) by 2023. Thus, 40 kg of *S. senegalensis* fruits were purchased at the Grand Market and 20 kg at the market of *Sinistré* district. These fruits were gathered and then divided into four batches, 15 kg each. One (01) fruits' batch was processed into juice using the standard artisanal method. For the other three batches, juices were processed following formulas incorporating fruits seed coat residues.

2.2.2 Processing of *Saba Senegalensis* Fruits and Residues for Juice Formulations

The juice production from *Saba senegalensis* berries consisted of pre-treatment of the raw material prior to formulation of the juices by incorporating various rates of fruits residues powder.

Fruits of *Saba senegalensis* were first sorted, then washed and sanitized with sodium hypochlorite aqueous bath (bleach) before the seeds' extraction. Each fruit was then opened with a stainless-steel knife and the pulp-covered seeds were removed. The extracted pulpy seeds (Figure 1a) were soaked for 2 h in potable tap water at a ratio of 1:1 (w/w), then kneaded and filtered through a sieve. The seeds gathered in the retentate were soaked again in water (1/1, w/w) for 1 h and the mixture was kneaded and filtered a second time. Both filtrates were then gathered as half-done product of the chart.

Fruits residues were recovered from the fruits' hull (pericarp) and seeds. Thus, after removal of the pulpy seeds, the fruits' hull was recovered and the inner membranous layer extracted as the first residue. During the filtration stage, the pulped seeds were recovered, and their seed coats also extracted as a second residue. Overall residues (Figure 1b) were then dried at 55 °C (Kausar *et al.*, 2025) into a food dehydrator for 36 hours (Figure 1c). The dry residues were cooled, ground using electric blender and sieved (Santos *et al.*, 2022) in fine powder (Figure 1d). The resulted powder was then incorporated into the pulp filtrate, at three different ratios depending on the batch. Batch 1 served as a control and received no residue. Oppositely, batches 2, 3 and 4 (test batches) received

2%, 5% and 10% residue powder, respectively, in the raw juice (Firozi *et al.*, 2022)



Figure 1. Pictures of raw fruit and pulpy seeds (a), fresh fruits residues (b) and dry residues using food dehydrator at 55 °C (c) and powder of dried residues (d) from *Saba senegalensis* fruits

The raw juice obtained from batch 1 (control) was heat-treated to boiling point ($> 80\text{ }^{\circ}\text{C}$) for 10 min, with continuous stirring using a woody spatula. After pasteurization, the juice was bottled for storage. For the test batches, the mixtures were homogenized and boiled for 10 min with continuous stirring. They were then cooled and filtered again to obtain the final juice, which was bottled in plastic food bottles for storage. The entire formulation chart of *Saba senegalensis* juices with incorporation of fruits residues is shown in Figure 2a and samples of the juices obtained are presented in Figure 2b.

2.2.3 Physical Analysis of the Processed Juices

2.2.3.1 Determination of Juice Production Yield

The yield of juice production from *Saba senegalensis* fruits was determined by calculating the pulp yield relative to the whole fruits and then the final juice yield after treatments applied to the pulp. The following calculations were applied according to the relations below:

$$Yield_{P/F}(\%) = \frac{W_P * 100}{W_F} \quad \text{and} \quad Yield_{J/P}(\%) = \frac{W_J * 100}{W_P + W_a} \quad (1)$$

Hence, the final yield of juice production relative to the whole fruits is:

$$Yield_{Final}(\%) = Yield_{P/F} * Yield_{J/P}$$

Where: $Yield_{P/F}$: fruit to pulp relative yield, $Yield_{J/P}$: pulp to final juice relative yield, W_P : pulp weight, W_F : fruit weight, W_a : weight of additives added (residues and water)

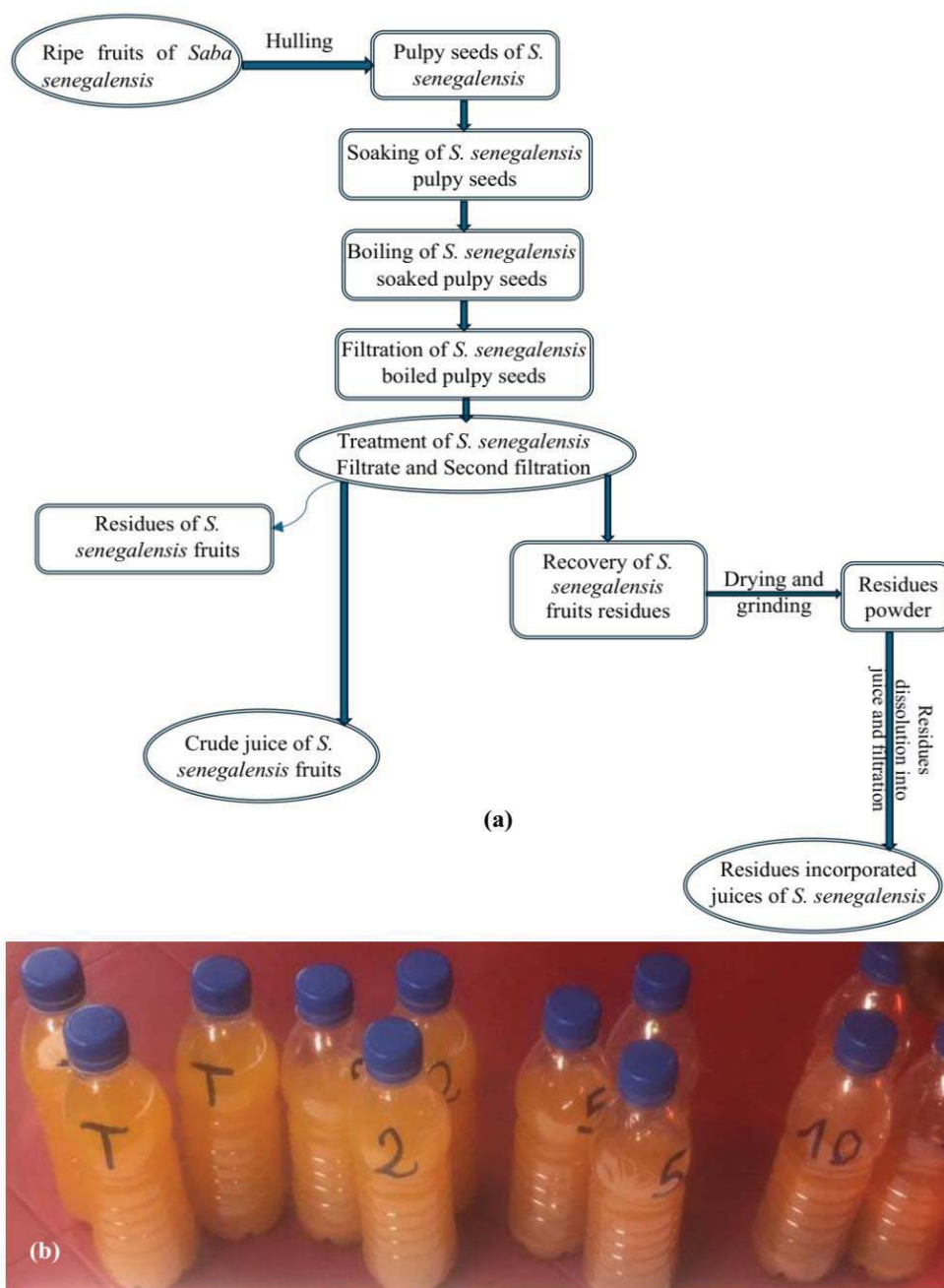


Figure 2. Flow chart of artisanal juice processing from *Saba senegalensis* fruits with or without incorporation de fruits residues (a) and Samples of juice formulations without additive (T) and with incorporation of 2%, 5% and 10% powder of fruits residues (b)

2.2.3.2 Assessment of the Juice Density

The relative density of juices was indirectly assessed by measuring the weight of a precise volume of sample. Thus, on a three digits electronic scale, the weight of a 1 mL sample (V) carefully collected using micropipette was measured (CODEX STAN 234, 2015). The value obtained leads to the calculation of the sample's density according to the following expressions:

$$\text{Den} = \frac{\rho_s}{\rho_w} \quad \text{with} \quad \rho_s = \frac{w_s}{v_s} \quad \text{and} \quad \rho_w = 1 \text{ g} \cdot \text{cm}^{-3} \quad (2)$$

Where w_s : weight of the solution, v_s : volume of the solution

2.2.3.3 Assessment of the Juice Viscosity

The viscosity of the formulated juices was determined using a falling ball Viscometer (HAAKE™ Type C) for Newtonian liquids (ISO 12058-1, 2018; Abboud et Elbir, 2024). The operating principle is based on measuring the flowing time through a fluid contained in the cylindrical tube of the viscometer delimited by a segment [AB]. The viscometer's tube was filled with the juice sample, then its temperature was regulated to 50 °C by thermic transfer using the heating water from a bath in which the tube was plunged. Once the temperature was levelled, the appropriate ball was selected from a set of six balls with different characteristics (material, density, diameter), providing a falling duration of between 25 and 300 seconds (El Kissi *et al.*, 2006). Beyond this selection, the effective falling delay of the ball through section AB was assessed using a chronometer. The dynamic viscosity (η) of each juice sample was estimated using the formula below:

$$\eta \text{ (mPa.s)} = K * (\rho_1 - \rho_2) * t \quad (3)$$

Where K = ball return constant ($\text{mPa.s.cm}^3/\text{g.s}$), ρ_1 = density of the ball (g/cm^3), ρ_2 = density of the tested liquid (g/cm^3), t = ball's falling delay (seconds)

2.2.3.4 Determination of the Total Soluble Solids Content

The total soluble solids content (Brix degree) was determined by pouring two drops of the juice sample upon the prism of the refractometer (OECD, 2018). The Brix degree, expressed as a percentage, was then read through the refractometer's ocular with automatic temperature regulation at 20 °C.

2.2.3.5 Determination of Dry Matter Content

The dry matter content was assessed using gravimetric method (AFNOR, 1991). A 10 g juice sample (m_1) was placed in an empty clean and dry aluminium capsule (m_0). The set was placed into an oven (Mettmert) at 105 °C for water evaporation till a constant weight reached after 8 hours. After drying, the sample was cooled in a desiccator for 1 hour and then weighed. The resulting weight (m_2) was recorded and the dry matter content (DMC) calculated:

$$\text{DMC (\%)} = \frac{(w_2 - w_0) * 100}{w_1} \quad (4)$$

Where: w_0 = weight of the empty dry capsule; w_1 = weight of the test sample; w_2 = weight of the dry set (capsule + dry sample)

2.2.3.6 Determination of Ash Content

Ash is the set of total mineral matter resulting from incineration of samples at higher temperature between 500 and 600 °C (AOAC, 1990). A 10 g (m_1) juice sample was placed in a pre-weighed porcelain crucible (m_0). Thus, the juice sample was first evaporated into an oven at 105 °C for 4 h. Thereafter, the crucible and dehydrated juice were then placed into a muffle furnace at 550 °C for 12 h to incinerate the organic matter. The crucible containing the ash were then removed from the furnace, cooled in a desiccator for 1 h and weighed (m_2) to determine the crude ash content (CAC):

$$\text{CAC (\%)} = \frac{(w_2 - w_0) * 100}{w_1} \quad (5)$$

Where: w_0 : weight of the empty dry crucible, w_1 : weight of the juice sample, w_2 : weight of crucible + ash

2.2.4 Assessment of Chemical Traits of Formulated Raw Juices

2.2.4.1 Determination of Acidity

The AOAC (1990) method was used to determine the acidity (pH and titratable acidity) of the *Saba senegalensis* juice samples. The pH was determined by direct measurement using a pH meter (Consort pH meter P 107) previously calibrated with two buffer solutions of pH 4 and pH 7. The pH of the samples was measured by plunging the unit's electrode into 50 mL of juice collected into a flask. The pH was directly displayed upon the screen and read after stabilizing within approximately 30 seconds.

For titratable acidity, an acid-base titrimetric assay was performed (Kimaryo *et al.*, 2000). Ten (10) mL of juice diluted at 10% (v/v) in distilled water were added to three drops of 1% (w/v) aqueous phenolphthalein solution. The homogenized mixture was titrated with 0.1 N sodium hydroxide (NaOH) solution until a persistent pink colour was obtained. The titratable acidity content (TAC) was calculated using the following formula:

$$\text{TAC (g Eq } H_3O^+ / 100 \text{ g)} = \frac{N_{\text{NaOH}} \cdot V_{\text{NaOH}} \cdot 10^2}{V \cdot w} \quad (6)$$

Where: N_{NaOH} = normality of NaOH = 0.1 N; V_{NaOH} = volume of NaOH used; V = volume of juice solution (10 mL); w = mass of 10 mL of juice

2.2.4.2 Determination of the Total Soluble Carbohydrates Content

Total soluble carbohydrates were measured according to the spectrophotometric method of Dubois *et al.* (1956) using phenol and concentrated sulfuric acid (96%). In a test tube, 0.5 mL of diluted juice (10^{-2}) was taken. Then, 0.5 mL of phenol (5%, w/v) and 2.5 mL of concentrated sulfuric acid were successively added. The homogenized mixture was heated in a boiling water bath for 5 min and then cooled at laboratory room temperature. The absorbance of the final solutions was then measured using a spectrophotometer at 490 nm against a control solution containing distilled water instead of the juice sample in the tube. The absorbances were then converted into total soluble carbohydrates content (TCC) according to a calibration curve achieved from a standard glucose and sucrose solutions with at initial concentration of 1 mg/mL.

2.2.4.3 Determination of the Reducing Carbohydrates Content

Reducing carbohydrates were measured from Bernfeld method (1955) using 3,5-dinitrosalicylic acid (DNS) as main reagent. In a test tube, 1 mL of diluted juice (10^{-1}) was taken, then 1 mL of DNS solution was added. After homogenized, the mixture was heated in a boiling water bath for 5 min, then cooled for 10 min at laboratory room temperature and added with 2 mL of distilled water. The absorbance of the final solutions was then measured at 540 nm from a spectrophotometer, against a control tube containing distilled water instead of the juice sample. The resulting absorbances were converted into reducing carbohydrates content (RCC) using a calibration curve set with standard glucose solutions at initial concentration of 1 mg/mL.

2.2.4.4 Determination of the Total Polyphenols Content

Total polyphenols were quantified according to the method of Singleton *et al.* (1999) using Folin-Ciocalteu reagent. An aliquot of 0.3 mL of the diluted juice (10^{-1}) was taken into a test tube and 1.5 mL diluted aqueous solution of Folin-Ciocalteu reagent was added. The mixture was vortexed and left to stand for 3 min. Next, 1.2 mL of aqueous sodium carbonate solution (Na_2CO_3 20%, w/v) was added, and the reactive mixture was homogenized and stored at room temperature out from light for 30 min. The tubes were then picked, and their absorbance was read at 760 nm using from spectrophotometer against a control tube containing distilled water instead of the juice sample. A calibration achieved under similar experimental conditions with standard gallic acid solutions at initial concentration of 1 mg/mL was used to deduce the total polyphenols content (TPC) of the juices.

2.2.4.5 Determination of the Total Flavonoids Content

Flavonoids were measured using the method described by Meda *et al.* (2005) by successive introduction of 1 mL juice sample, 0.75 mL sodium nitrite (NaNO_2 5% w/v) and 0.75 mL aluminium chloride (AlCl_3 10% w/v) into a test tube. The homogenized mixtures were then left to stand for 20 min out of light and 5 mL of sodium hydroxide (NaOH 1 N) were added. The absorbance of the solutions was read at 415 nm using a spectrophotometer against a blank tube without juice. A calibration curve set under the same experimental conditions and using quercetin as standard flavonoid (0.1 mg/mL) was used to determine the total flavonoids contents (TFC) of juice samples.

2.2.5 Organoleptic Analysis of Formulated *Saba senegalensis* Juices

The formulated juices were subjected to organoleptic analyses through hedonic appreciation and sensory description tests. The organoleptic tests were performed by two panels of volunteer analysts.

2.2.5.1 Hedonic Assessment of the Formulated Juices

Hedonic analyses were carried out with a size of 100 untrained panelists of any gender. Each formulated juice was subjectively assessed in terms of the pleasantness provided for the aroma, flavor, fluidity and distinctive color. The global acceptance of each sample was also assessed (Kodji *et al.*, 2023). For this analysis, 50 mL of each formulated juice was provided to the panelists in clear plastic glasses, previously coded with alphanumeric characters to ensure anonymity. After tasting the sample, the panelists acceptance for each trait was recorded on a rating card provided using a 5-point scale: 1 (reject), 2 (slightly like), 3 (moderately like), 4 (like) and 5 (enjoy), as worked by previous authors (Meilgaard *et al.*, 2006; Ouattara *et al.*, 2016; Konan *et al.*, 2017).

2.2.5.2 Descriptive Sensory Assessment of the Formulated Juices

The descriptive sensory analysis of the formulated juices aims to determine the intensity of the objective perception of certain organoleptic characteristics, namely the appearance (orange- yellowish, dark), aroma, flavor (sour, sweet) and turbidity/clarity.

Twenty (20) conscious people (male and female) were recruited according to their availability and their ability to differentiate between aroma, color, flavor, fluidity and appearance of beverages. These people were taught about the taste areas of the tongue and trained for the sensory description of fruits juices. Following these tests, a final staff of fifteen (15) trained panelists were selected and familiarized with usual commercial juices during tasting training sessions before implementing the sensory description of the formulated juices studied.

The effective descriptive analysis of the formulated juices was carried out by providing each panelist 50 mL of juice samples in plastic glasses of the same appearance and different alphanumeric codes. The different samples were presented monadically to each panelist in a randomized order. After tasting the sample, the panelist then indicated the perceived intensity of the traits assessed (orange-yellowish color, dark color, bitterness, homogeneity, clarity and sour taste). A 5-points rating scale was provided for this purpose: 1 (no perception), 2 (low perception), 3 (average perception), 4 (good perception) and 5 (very good perception) (Meilgaard *et al.*, 2006; Aka *et al.*, 2016; Sidibé *et al.*, 2019).

2.2.6 Statistical Analysis of Data

The biochemical descriptors were assessed in triplicate. Overall data collected was recorded into Excel table and then subjected to statistical analysis using STATISTICA 7.1 software, at 5% significance. The statistical treatment consisted of analysis of variance (ANOVA 1) of the biochemical indicators and descriptive sensory traits, followed by the Student Newman Keuls post-hoc test. However, for hedonic sensory analysis, a Chi-square test was performed to compare the proportions. Results are then reported as average (with standard deviation) and percentage. Multivariate analyses were also performed using principal component analysis (PCA) and ascending hierarchical clustering (AHC) of juice samples.

3. Results

3.1 Biochemical Characteristics of *Saba Senegalensis* Juices

3.1.1 Physical Parameters

The physical indicators assessed from the processed juices are the production yield, viscosity, relative density and dry matter, ash and total soluble solids contents (Table 1).

Using the traditional method, the yield of *S. senegalensis* fruit juice is 41.30%. However, with the addition of residue powder followed by final filtration, the data highlights yield of 41% (J2), 39.6% (J5) and 37.7% (J10).

The relative density of *S. senegalensis* juices formulated is of 1.01 from the control juice (J0) and increases significantly ($P < 0.001$) with the incorporation rate of residue powder, rising to 1.02, 1.03 and 1.05 for respective juices at 2% (J2), 5% (J5) and 10% (J10).

With an average of 2.68 ± 1.58 mPa.s, the dynamic viscosity significantly differentiates ($P < 0.05$) the samples of *Saba senegalensis* pulp juice. The control juice without additives (J0) records the lowest viscosity (1.85 mPa.s). But, the addition of residue powder rises the viscosity to 2.71 mPa.s (J2), 3.05 mPa.s (J5) and 3.85 mPa.s (J10).

The dry matter (DM) content does not show any significant difference ($P = 0.07$) between the juice samples studied. The values obtained ranged from $3.92 \pm 0.5\%$ (J0) to $5.43 \pm 1.12\%$ (J10).

Total soluble solids contents significantly discriminate ($P \leq 0.001$) between the *S. senegalensis* juices formulated. This trait is more from the juice J10 (5.23%) which contains a higher proportion of residues. However, it decreases as the rate of residues incorporation, dropping to 4.43%, 3.85% and 3.53% for respective J5, J2 and J0.

With a general average of 0.15%, the crude ash quantified after incineration of the juice samples differentiates the formulations ($P \leq 0.001$). The ash content is 0.08% in the juice without residue (J0), then increases with the incorporation of residues, and values rise to 0.10% (J2), 0.17% (J5) and 0.22% (J10).

Table 1. Averages of the physical parameters assessed in juices formulated from *Saba senegalensis* fruits

Parameters	Yield (%)	Relative Density	Relative Viscosity (mPa.s)	Total soluble solids content (°Brix or %)	Dry matter content (%)	Crude Ash content (%)
Overall Average	39.9	1.02±0.03	2.68±1.58	4.16±0.88	4.12±1.71	0.15±0.08
J0	41.30	1.01±0.01 ^c	1.85±0.03 ^d	3.53±0.14 ^d	3.92±0.50 ^a	0.08±0.01 ^d
J2	41	1.02±0.01 ^b	2.71±0.03 ^b	3.85±0.21 ^c	4.01±0.57 ^a	0.10±0.01 ^c
J5	39.6	1.03±0.01 ^{ab}	3.05±0.23 ^c	4.43±0.29 ^b	4.78±1.05 ^a	0.17±0.01 ^b
J10	37.7	1.05±0.02 ^a	3.85±0.48 ^a	5.23±0.18 ^a	5.43±1.12 ^a	0.22±0.01 ^a
F-value		31.41	83.52	113	3.38	1436
P-value		<0.001	<0.001	<0.001	0.07	<0.001

Per descriptor, averages± standard deviation with the same lowercase letters are statistically similar at 5% significance. F-value: value of the statistical Fischer test, P-value: value of the probability of the statistical test

3.1.2 Chemical Parameters of Saba Senegalensis Juice Formulations

The juices' acidity differentiates ($P < 0.05$) the overall formulations. Figure 3a shows the lowest pH value (2.33 ± 0.01) from J0 sample, while samples J2 (2.47 ± 0.05), J10 (2.50 ± 0.05) and J5 (2.43 ± 0.03) record statistically more pH values. Oppositely, titratable acidity is lower in sample J0, with an average of 2.82 ± 0.07 g Eq H_3O^+ /100 g, while samples J2, J5 and J10 have comparatively higher values of titratable acidity content (TAC) of respective 3.02 ± 0.06 , 3.57 ± 0.02 , and 4.23 ± 0.04 g Eq H_3O^+ /100 g.

Assessment of carbohydrates contents in the juices shows a clear statistical difference between the samples studied ($P < 0.05$) as displayed by Figure 3b. Total carbohydrates contents (TCC) increase with the rate of residues incorporation into the juice. Values of TCC are of 0.91 ± 0.10 g/100 mL for the control juice (J0), but raise up to 0.95 ± 0.05 , 0.98 ± 0.17 and 1.69 ± 0.05 g/100 mL in respective juices J2, J5 and J10. Regarding reducing carbohydrates, sample J0 also provides a lower content (0.27 ± 0.03 g/100 mL) compared to samples incorporating fruits residues (J2, J5 and J10), which respectively record 0.42 ± 0.01 , 0.47 ± 0.01 and 0.54 ± 0.06 g/100 mL.

The polyphenol compounds assessed through total polyphenols and total flavonoids contents differentiate ($P < 0.001$) the four *Saba senegalensis* juice formulations (Figure 3c). Juice incorporating 10% residues (J10) is provided in most total polyphenols content (227.14 ± 26.37 mg EAG/100 mL), followed by J5 (111.93 ± 9.89 mg EAG/100 mL) and J2 (107.42 ± 15.62 mg EAG/100 mL). The control juice J0 displays the lowest total polyphenols content (68.81 ± 16.65 mg EAG/100 mL). As an important polyphenolic nutrient cluster, total flavonoids contents are also significantly higher in sample J10 (134.42 ± 4.98 mg EQ/100 mL), followed by samples J5 (79.12 ± 5.9 mg EQ/100 mL), J2 (39.65 ± 5.13 mg EQ/100 mL) and J0 (18.18 ± 4.44 mg EQ/100 mL).

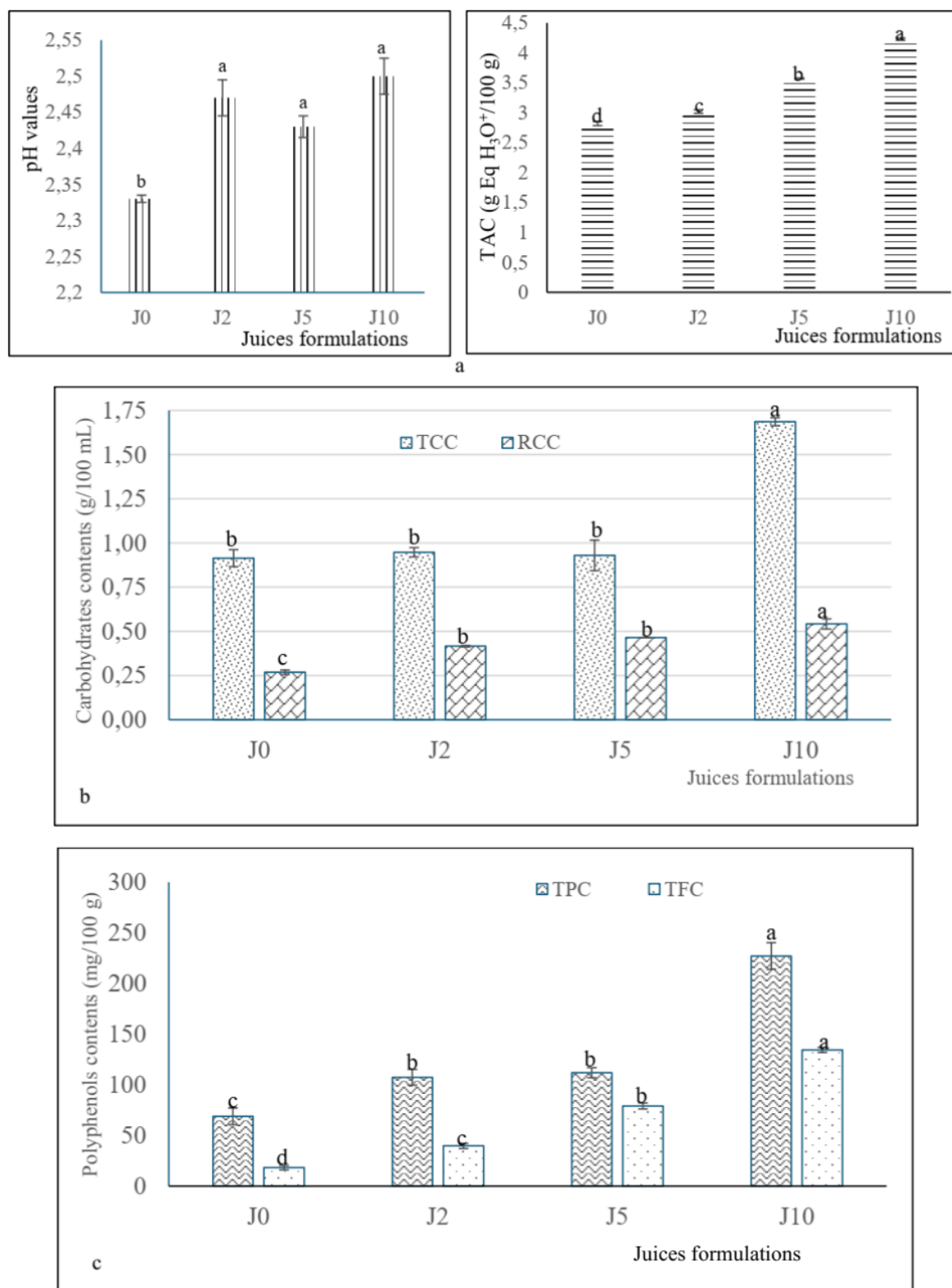


Figure 3. Values of potential of hydrogen and titratable acidity contents (a), total carbohydrates and reducing carbohydrates contents (b) and total polyphenols and total flavonoids contents (c) of juices formulated from *Saba senegalensis* fruits

For each parameter, histograms with different lowercase letters are statistically different at 5% significance. J0: control juice without residues powder, J2, J5, J10: juices with incorporation rate of respective 2%, 5% and 10% fruit residues powder.

3.2 Sensory Characteristics of *Saba senegalensis* Juices

3.2.1 Hedonic Assessment of *Saba senegalensis* Juice Formulations

Without any additives, the control juice (J0) shows comparable percentages ($P > 0.05$) of low appreciation, average appreciation and good appreciation for the respective rating of color (36%, 33% and 31%) and homogeneity (29%, 44% and 27%), according to Table 2. However, this juice received a lower score for good appreciation regarding taste (16%), while it's fairly rated for general appreciation with 53% average appreciation and 30% good appreciation. With the test juices (J2, J5 and J10), the three levels of appreciation for the color, taste, homogeneity and global appreciation are significantly different ($P < 0.01$). In fact, the juice with 2% residue incorporation (J2) is largely poorly rated for color, taste and consistency ($> 50\%$ panelists), with below 15% for good rating of these parameters. For general appreciation, J2 is rated as average or good by 54% panelists against 46% unfavorable ratings. In addition, juice with 5% residue records a very poor rating for the color (73%), taste (59%) and consistency (46%), and less than 15% of positive rating for these parameters. J5 displays average or good global appreciation by 55% of panelists and receives 45% unfavorable feelings. The juice incorporation 10% residue is also poorly rated for the color (67%), taste (60%) and consistency (52%), and records less than 20% of positive rating for these parameters. This formulation is moderately or highly appreciated by 53% of panelists and receives 47% unfavorable opinions.

3.2.2 Sensory Intensity Profile of *Saba senegalensis* Juice Formulations

Table 3 presents the descriptive sensory profile of *Saba senegalensis* juice formulations. A statistical difference is engaged between the feeling of yellowish and dull trends, sour taste, homogeneity and clarity of juices J0, J2, J5 and J10. On the 5-points scale, yellowish color is more perceived in J0 ($3.8 \pm 0.94/5$) and less in J10 ($1.73 \pm 1.22/5$). Oppositely, the dull trend is more evidenced from J10 ($4.33 \pm 1.23/5$) and less in J0 ($3.27 \pm 0.88/5$). The sour taste is more rated from J0 ($3.53 \pm 1.06/5$) and less in J10 ($2.4 \pm 1.18/5$). The control juice J0 is also found more homogeneous ($4.2 \pm 1.15/5$) and clear ($4.13 \pm 0.83/5$), while these parameters are slightly pronounced in respective J5 ($3 \pm 0.85/5$) and J10 ($2.93 \pm 1.28/5$).

Conversely, the four juice formulations show comparable feeling levels of bitterness with scores ranging from 2.2/5 to 2.4/5. Furthermore, the radar charts of Figure 4 illustrate the descriptive sensory profile of each juice studied. J0 is mainly characterized by greater homogeneity and clarity, followed by a strong yellowish color, while J2, J5 and especially J10 are predominantly felt dull. These juices are less clear and homogeneous, but do not have significant rates of bitterness or acidity.

3.3 Variability of Biochemical and Organoleptic Characteristics of *S. senegalensis* Fruits Juice Formulations

The variability of the overall parameters assessed from the fruits juice formulations is structured by principal components analysis (PCA) and ascending hierarchical clustering (AHC).

Figure 5 (A and B) shows the projection of the biochemical and sensory descriptors and *Saba senegalensis* juices in the F1-F2 factorial design accounting for 91.22% of total variance. From the chart, sample J0 is in the negative part of F1 and is correlated with sensory descriptors such as sour taste, yellowish color, clarity and homogeneity. Between samples J2 and J5, which display positive and negative correlation with F2, respectively, only sample J5 evidences a predominant bitterness. Sample J10, located in the positive part of F1, is correlated with biochemical descriptors such as pH, viscosity, relative density and contents in carbohydrates, total soluble solids, dry matter, titratable acidity, polyphenols and dull coloring of the juice. Accordingly, the AHC gathers *Saba senegalensis* fruits juice formulations into three (03) groups at an aggregation distance of 44 (Figure 5C). Group 1 consists of J0, group 2 consists of J2 and J5, and group 3 consists of J10. Thus, AHC strengthens the variability described by PCA and allows the report of sour taste, yellowish color, high clarity and homogeneity from J0; more bitterness from J2 and J5; and higher values of pH, relative viscosity, relative density and total soluble solids, dry matter, carbohydrates, titratable acidity, polyphenols and dull color in J10.

Table 2. Rates of occurrence of hedonic characteristics according to panelists resulting from the sensory analysis of the juice formulated from *Saba senegalensis* fruits

Juices	Appreciation levels	COL	TAS	HOM	OA
J0	Weak Acceptance (%)	36	43	29	17
	Average Acceptance (%)	33	41	44	53
	Good Acceptance (%)	31	16	27	30
	X^2	0.38	13.58	5.18	19.94
	<i>P-value</i>	0.83	0.0011	0.08	<0.001
J2	Weak Acceptance (%)	66	52	50	46
	Average Acceptance (%)	24	37	38	44
	Good Acceptance (%)	10	11	12	10
	X^2	50.97	25.82	22.64	24.56
	<i>P-value</i>	<0.001	<0.001	<0.001	<0.001
J5	Weak Acceptance (%)	73	59	46	45
	Average Acceptance (%)	19	30	42	43
	Good Acceptance (%)	8	11	12	12
	X^2	72.63	35.06	20.72	20.54
	<i>P-value</i>	<0.001	<0.001	<0.001	<0.001
J10	Weak Acceptance (%)	67	60	52	47
	Average Acceptance (%)	23	35	29	37
	Good Acceptance (%)	10	5	19	16
	X^2	53.55	45.50	17.18	15.02
	<i>P-value</i>	<0.001	<0.001	<0.001	<0.001

COL, TAS, HOM, OA: color, taste, homogeneity, overall acceptance of juices; X^2 : value of the statistical Chi-square test; *P-value*: value of the probability of the statistical test; J0, J2, J5, J10: juices with 0% (control), 2%, 5%, and 10% of fruits residues incorporation.

Table 3. Averages of the descriptive parameters assessed for the sensory profile of formulated juices processed from *Saba senegalensis* fruits

Descriptive parameters	Overall Average	J0	J2	J5	J10	F-value	P-value
Yellowish color	2.57±1.20	3.8±0.94 ^a	2.27±0.70 ^b	2.47±0.83 ^b	1.73±1.22 ^b	12.97	<0.001
Dull color	3.67±1.11	3.27±0.88 ^b	3.73±1.03 ^{ab}	3.33±1.05 ^b	4.33±1.23 ^a	3.22	0.03
Sour taste	2.85±1.16	3.53±1.06 ^a	2.93±1.1 ^{ab}	2.53±1.06 ^b	2.4±1.18 ^b	3.2	0.03
Bitter taste	2.32±1.37	2.33±1.29 ^a	2.2±1.32 ^a	2.4±1.55 ^a	2.33±1.45 ^a	0.05	0.98
Homogeneity	3.35±1.18	4.2±1.15 ^a	3±0.93 ^b	3±0.85 ^b	3.2±1.37 ^b	4.15	0.01
Clarity	3.33±1.23	4.13±0.83 ^a	3±1.07 ^b	3.27±1.39 ^b	2.93±1.28 ^b	3.39	0.02

Per descriptor; averages± standard deviation with the same lowercase letters are statistically similar at 5% significance. F-value: value of the statistical Fisher test, P-value: value of the probability of the statistical test.

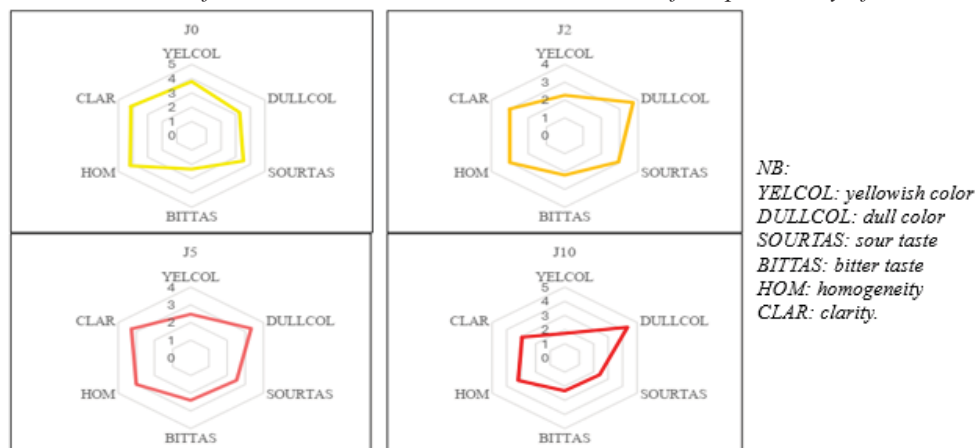


Figure 4. Radar charts of descriptive sensory profiles deriving from *Saba senegalensis* fruit's juice formulations

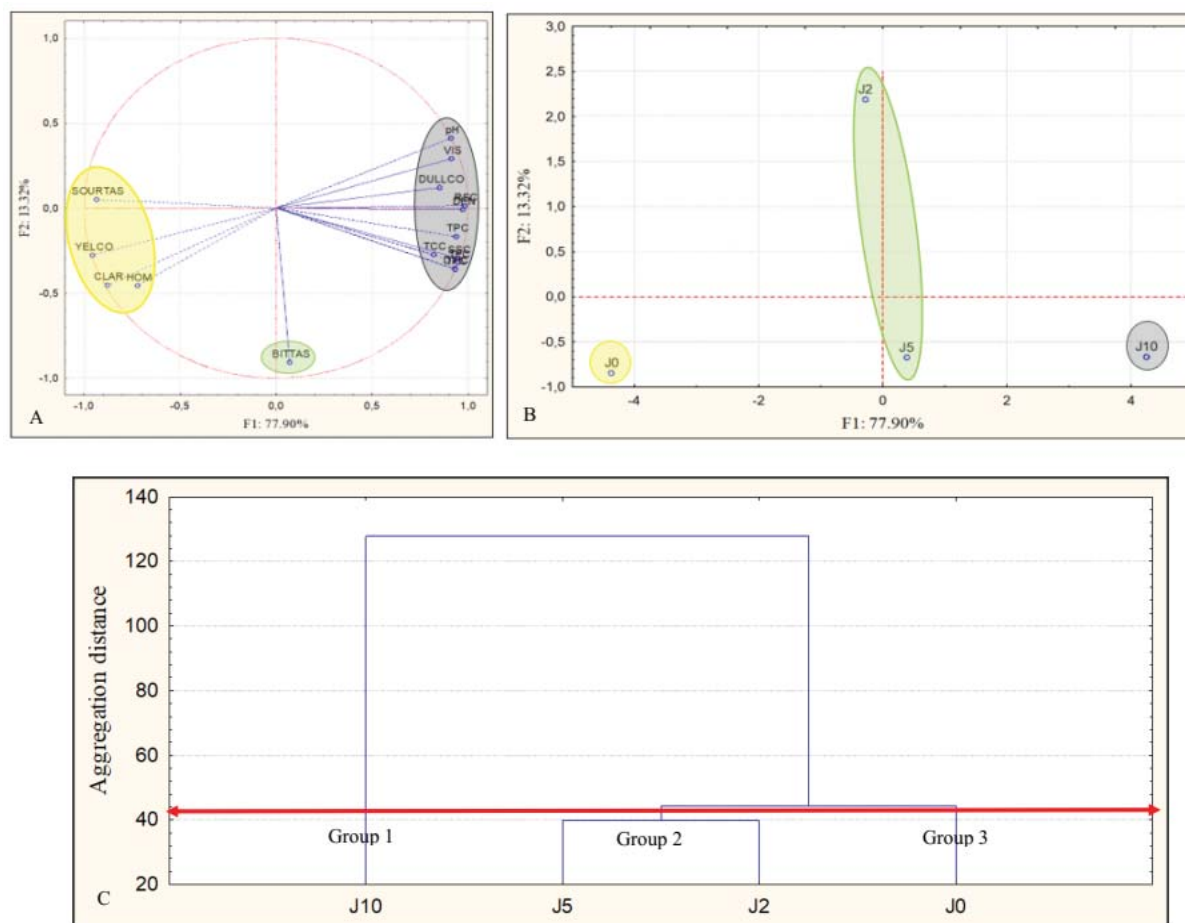


Figure 5. Correlation of biochemical and sensory descriptors (A) and the formulated juice samples (B) in the F1-F2 factorial design of the principal components analysis (PCA) and ascending hierarchical clustering (AHC) of formulated juices using biochemical and sensory descriptors (C) from *Saba senegalensis* fruits

4. Discussion

The current survey aims to valorise *Saba senegalensis* fruits by-products and to increase this crop's profitability. For this purpose, the biochemical and sensory characteristics of processed raw juice with or without incorporation of fruits residues were analysed. The investigation showed increasing pH values with the incorporation of residues but remaining very acidic, from 2.3 (J0) to 2.5 (J10). According to Bates *et al.* (2001), pH values of fruits juice below pH 4 are favorable for quite preservation without precocious change. The pH is a significant parameter of foods preservation; it constitutes one of the main barriers to overcome by microbial flora prior to their proliferation (Sadler and Murphy, 2010). The pH values assessed appear reassuring for the juices' preservation. Titratable acidity (TA) is of the main parameters of the global fruits' quality. It's usually assessed for technological characterization of products resulting from fruits processing (Lozano, 2006). Besides, TA values fill information about the occurrence of organic acids in food samples. The global acidity of the *S. senegalensis* juice recorded in the current works is comparable to the data reported by Tiendrebeogo *et al.* (2020) from Burkina Faso with pH values below 3 and TA of 3,5 to 5%. The juice formulation with 10% residues (J10) could be more provided with in organic acids than the other samples (J0, J2 and J5). According to Vondruskova *et al.* (2010), organic acids reduce pH and the growth of pathogenic bacteria.

The relative density and viscosity of juices increase with the rate of residues addition. Due to its higher density, it is obviously clear that the fruit residue powder tends to sediment at the bottom of the juice container during rest. As key rheological parameter governing the stability of food systems, viscosity values recorded suggest that the J10 sample may exhibit greater resistance to degradation over time (Saheli, 2020; Laaksonen *et al.*, 2020). Nevertheless, from fruit juices, excessive viscosity is generally regarded as a negative attribute by consumers and may reduce acceptability, since thickening agents or overly concentrated suspensions can mask flavour alter

mouthfeel (Pinto *et al.*, 2022).

Total soluble solids (TSS) content is as a quite indicator of the concentration of compounds dissolved in a solution (Zhou *et al.*, 2023). These solids are primarily composed of organic and mineral components. The results revealed considerably higher TSS values in the J10 sample compared to J0, J2, and J5, confirming the greater abundance of these compounds in J10. Regarding dry matter content, the sample J0 displays less value and a higher rate of water. The extraction of *Saba* juice involved the addition of water, followed by filtration after the incorporation or without any adding of fruit residues powder. Consequently, for an equivalent mass of final juice, the test samples naturally contain greater amounts of residues (and therefore less water) compared to the control sample. Overall, a higher dry matter content is generally associated with an increased quantitative presence of nutritional compounds in food products (Fayos-Febrer *et al.*, 2023).

Ash content is an indicator of the amount of minerals in food matrices. The results revealed that sample J10 exhibited significantly higher ash rates than the other samples (J0, J2, and J5). This higher content reflects the presence of minerals within the residues, as ash determination provides a global estimation of the mineral load of fruits, showing a significant correlation with major mineral elements (Aluko *et al.*, 2023; Okoye and Uke, 2024).

Moreover, the juice incorporating 10% of fruit residues also showed higher carbohydrates contents compared to the other samples. This observation indicates that the residues of *S. senegalensis* fruits contain a substantial amount of carbohydrates, consistent with reports for other tropical fruits such as mango, orange, and African pear or *Dacryodes edulis* (Lagou *et al.*, 2018; Ano *et al.*, 2018; Kourou, 2024). In fruit juices, several studies have demonstrated the strong contribution of carbohydrates, especially free carbohydrates, to the overall pleasant flavor of the product (Zhou *et al.*, 2023; Milosavljevic *et al.*, 2023).

In addition, *S. senegalensis* juice contains polyphenolic compounds known to provide significant antioxidant activities. The total polyphenols content (TPC) is a global estimation for the various classes of phenolic compounds in fruits juices (Way *et al.*, 2020; Gabriel *et al.*, 2021). The results showed J10 juice sample exhibiting significantly higher TPC values than J0, J2, and J5. Such observation states that fruits residues are particularly fitted in polyphenolic antioxidants. The incorporation of these residues therefore enhances the overall nutritional quality of the final product. Numerous studies have reported the benefits of fruit- and vegetable-derived polyphenols, including reduction in LDL-cholesterol and triglycerides, decreasing in oxidative stress, and improving glutathione production, without raising blood glucose levels (Khongrum *et al.*, 2022; Micek *et al.*, 2023). Increased dietary intake of polyphenols from sources such as fruit juices has also been associated with improved cardiac metabolic indicators (Li *et al.*, 2023). Furthermore, certain phenolic subclasses, namely flavonols, phenolic acids, and tannins, form non-covalent interactions with anthocyanins, thereby enhancing juice pigmentation (Wang *et al.*, 2024). The total flavonoid content in sample J10 was also higher compared to the other samples, stating that residues are filled in flavonoids as part of their polyphenolic antioxidant profile. Consumption of flavonoid-rich foods has been suggested to play a role in the prevention of cardiovascular diseases (Scalbert *et al.*, 2005).

Other studies have demonstrated the influence of phenolic antioxidants on the bitterness and astringency of fruit juices through physiological mechanisms such as the precipitation of salivary proteins and the activation of taste receptors (Konan *et al.*, 2013; Huang and Xu, 2020). The total polyphenol content of *Saba senegalensis* juice J10 is the most concentrated (227.14 ± 26.37 mg/100 mL), higher than the data reported by Tounsi *et al.* (2011) for citrus juices including bitter orange (78.46 mg/100 mL), lemon (33.3 mg/100 mL), blood orange (25.5 mg/100 mL), and mandarin (10.62 mg/100 mL).

Without fruit's residues, the juice formulation J0 was appreciated moderately to well by 83% consumer panellists compared with formulations incorporating fruit residues (J2, J5, and J10). This result is noteworthy, as the juices were not supplemented with any additives such as sugar or flavorings commonly used by local producers. Descriptive sensory analysis of the formulations J0, J2, J5, and J10 revealed relatively similar perceptions regarding dull coloration, sourness, bitterness, homogeneity, and clarity. This is advantageous, since despite the incorporation of fruit residues, these attributes generally considered depreciative remained weakly expressed in the juices processed. However, the J0 formulation exhibited a more yellowish hue, involving a marked difference between juices prepared from *S. senegalensis* pulp without residues and those containing residues. In the raw juice, the pulp is solely responsible for the coloration, whereas the addition of dull-colored residues results in changes of the juice appearance. Indeed, color is a major visual indicator of quality and palatability, as consumers rely on hue, saturation, and brightness to assess freshness, nutritional value, and overall quality of juices prior to tasting (Kardas *et al.*, 2024). Color perception also influences expectations of sweetness, acidity, and bitterness. Warmer (red, orange, yellow) and lighter tones are generally associated with sweetness and aromatic richness, while

greenish or dull hues may refer to acidity, bitterness, or a perception of lower quality, thereby reducing consumer's acceptance (Motoko *et al.*, 2023). Even purely visual changes in the expected coloration of a juice may reflect a shift in product identity or a degree of denaturation, altering the rates of aroma notes and overall desirability (Fernández-Vázquez *et al.*, 2013; Jeesan *et al.*, 2014). Therefore, optimizing the level of fruit residue incorporation in *Saba senegalensis* juice formulations with care of the color parameters and the possible addition of suitable dietary additives could result in a product with enhanced nutritional quality and improved consumers' acceptability.

5. Conclusion

This study aimed to assess and compare the biochemical potential of *Saba senegalensis* juice incorporating residues from common artisanal production, and to elucidate the sensory parameters of the formulated juices. Juices containing fruit residues exhibited markedly different, generally higher, indicator values compared to the control residue-free juice. Moreover, values are more significant with increasing rates of residue incorporation. However, the juice without residues was generally rated higher in sensory evaluation due to its more yellowish appearance, which fits the traditional consumer preferences for such a product. Optimizing the incorporation of fruit residues into *Saba senegalensis* juice is therefore necessary to enhance the nutritional content of the product while maintaining its sensory appeal.

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Authors contributions

The publication was performed with the effective contribution of overall authors. Dr NYK designed the study, achieved the literature information and the statistical analysis and typed the first draft of the manuscript assisted with Dr BTEZ. Author CAK performed the laboratory analysis and Dr SA contributed to results interpretation. Dr AC assisted in statistical analysis and literature recovery. Dr GHMB revised the first draft of the manuscript and supervised the whole study with Prof ND. All authors read and gave approval of the final manuscript.

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Data sharing statement

No additional data are available.

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References

- Abboud, K., & Elbir, B. (2024). Calculating the viscosity of a fluid using image processing of a falling ball. *Journal of Emerging Investigators*, 7, 1-4. <https://doi.org/10.59720/23-198>
- AFNOR. (1991). Recueil des Normes Françaises d'Agro-Alimentaire. Paris la défense, France. pp. 159.
- Aka, B. A. A., Konan, N. Y., Coulibaly, A., & Biego, G. H. M. (2016). Nutritional and sensory analysis of milk processed from seeds of sweet pea (*Cyperus esculentus* L.) consumed in Côte d'Ivoire. *Journal of Applied Life Sciences International*, 8(2), 1-12. <https://doi.org/10.9734/JALSI/2016/28639>
- Aluko, A., Makule, E., & Kassim, N. (2023). Effect of clarification on physicochemical properties and nutrient retention of pressed and blended cashew apple juice. *Food Sciences & Nutrition*, 11, 1891-1903. <https://doi.org/10.1002/fsn3.3222>
- Ano, A. A. R. R., Koffi, N. E., Adima, A. A., N'da, P. K., & Anin, L. A. (2018). Composition biochimique et phytochimique des tourteaux des fruits du safoutier (*Dacryodes edulis*) de Côte d'Ivoire. *International Journal of Biological and Chemical Sciences*, 12(6), 2535-2546. <https://doi.org/10.4314/ijbcs.v12i6.6>
- AOAC. (1990). Official Methods of Analysis. 15th Edition, Washington D.C., USA. pp. 375-379.
- Arbonnier, M. (2019). *Arbres, arbustes et lianes des zones sèches d'Afrique de l'Ouest*. Versailles, France. Éditions Quæ. pp. 776.
- Aziz, A. (2021). Effect and impact of indigenous knowledge on local biodiversity and social resilience in Pamir region of Tajik and Afghan Badakhshan. *Ethnobotany Research & Applications*, 22(03), 1-26. <https://doi.org/10.32859/era.22.03.1-26>
- Bates, R. P., Morris, J. R., & Crandall, P. G. (2001). *Principles and practices of small- and medium- scale fruit juice processing*. Food and Agriculture Organization of the United Nations, Roma, Italy. pp. 219.
- Bernfeld, P. (1955). *Amylase u and p. Methods in enzymology Colwich and N.O Kaplan* (9th ed.). Academic Press, Lnc., New York, USA. pp. 154.
- CODEX STAN 234 (2015). Recommended methods of analysis and sampling. Adopted in 1999, Amendment in 2015. International Food Standard. *Codex Alimentarius*. pp. 63.
- Diabagaté, H. M. F., Traoré, S., Cissé, M., Soro, D., & Brou, K. (2019). Biochemical characterization and nutritional profile of the pulp of Saba Senegalensis from Côte d'Ivoire Forest. *American Journal of Food and Nutrition*, 7(1), 19-25. <https://doi.org/10.12691/ajfn-7-1-4>
- Diawara, S., Sanou, L., Kabré, B., Savadogo, P., & Ouédraogo, A. (2022). Utilizations, vulnerability and conservation practices of Saba senegalensis (A. DC.) Pichon (Apocynaceae), a high value local species in Burkina Faso. *Ethnobotany Research and Applications*, 24(10), 1-19. <https://doi.org/10.32859/era.24.6.1-19>
- Dubois, M., Gilles, K. A., Hamilthon, J. K., Rebers, P. A., & Smith F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical Chemistry*, 28, 350-356. <https://doi.org/10.32859/era.24.6.1-19><https://doi.org/10.1021/ac60111a017>
- Duque-Acevedo, M., Belmonte-Ureña, L. J., Cortés-García, F. J., Camacho-Ferre, F. (2020). Agricultural waste: Review of the evolution, approaches and perspectives on alternative uses. *Global Ecology and Conservation*, 22, e00902. <https://doi.org/10.1016/j.gecco.2020.e00902>.
- El Kissi, N., Nigen, S., & Pignon, F. (2006). Glissement et rhéométrie. *Rhéologie*, 10, 13-39.
- Fayos-Febrer, J., Juan-Vicedo, J., Rodríguez-Mengod, A., Mazón, J., & Gardón, J. C. (2023). Impact of harvest time on the dry matter content, and nutritional parameters related to forage quality of Maralfalfa (*Cenchrus purpureus* (Schumach.) Morrone, Poaceae) under Mediterranean climate. *Plants*, 12, 4045. <https://doi.org/10.3390/plants12234045>
- Fernández-Vázquez, R., Hewson, L., Fisk, I., Vila, D. H., Mira, F. J. H., Vicario, I. M., & Hort, J. (2013). Colour influences sensory perception and liking of orange juice. *Flavour*, 3, 1-8. <https://doi.org/10.1186/2044-7248-3-1>
- Firozi, M., Amiri, M. E., & Kahneh, E. (2022). Effect of Aqueous Extract of Tea Seed Powder on Quality of *Citrus sinensis* L. Osbeck in Cold Storage Conditions. *Journal of Medicinal Plants and By-products, Special Issue*, 11-15.
- Gabriel, R. M., Alvaro, F. M., Felipe, R. L. D. A., & Ayla, S. A. D. S. (2021). A validated Folin-Ciocalteu method for total phenolics quantification of condensed tannin-rich açai (*Euterpe oleracea* Mart.) seeds extract.

- Journal of Food Science and Technology*, 58, 4693-4702. <https://doi.org/10.1007/s13197-020-04959-5>
- Huang, R., & Xu, C. (2020). An overview of the perception and mitigation of astringency associated with phenolic compounds. *Comprehensive Reviews in Food Science and Food Safety*, 20(1), 1036-1074. <https://doi.org/10.1111/1541-4337.12679>
- ISO 12058-1 (2018). Plastics - Determination of viscosity using a falling-ball viscometer. Part 1: Inclined-tube method. Second Edition, 2018-7. *International Standard Organization*. pp. 5.
- Jeesan, S. A., & Seo, H. S. (2020). Color-induced aroma illusion: color cues can modulate consumer perception, acceptance, and emotional responses toward cooked rice. *Foods*, 9, 1845. <https://doi.org/10.3390/foods9121845>
- Kandemir, K., Piskin, E., Xiao, J., Tomas, M., & Capanoglu, E. (2022). Fruit Juice Industry Wastes as a Source of Bioactives. *Journal of Agricultural and Food Chemistry*, 70, 6805-6832. <https://doi.org/10.1021/acs.jafc.2c00756>
- Kardas, M., Rakula, M., Kolodziejczyk, A., & Staskiewicz, B. W. (2024). Consumer Preferences, Sensory Evaluation, and Color Analysis of Beetroot and Tomato Juices: Implications for Product Development and Marketing in Health-Promoting Beverages. *Foods*, 13, 4059. <https://doi.org/10.3390/foods13244059>
- Kausar, T., Aslam, K., Hussain, A., Arshad, R., Waqas, M. T., Bilal, M., Zia, M., Sidrah, Firdous, N., & Elkhedir, A. E. (2025). Development and evaluation of food bar utilizing the valuable waste in the form of apple and carrot pomace powders. *Discover Food*, 5(304), 1-17. <https://doi.org/10.1007/s44187-025-00620-2>
- Khongrum, J., Yingthongchai, P., Boonyapranai, K., Wongtanarasarin, W., Donrung, N., ... Chonpathompikunlert, P. (2022). Antidyslipidemic, antioxidant, and anti-inflammatory effects of jelly drink containing polyphenol-rich roselle calyces extract and passion fruit juice with pulp in adults with dyslipidemia: a randomized, double-blind, placebo-controlled trial. *Oxidative Medicine and Cellular Longevity*, 1-12. <https://doi.org/10.1155/2022/4631983>
- Kimaryo, V. M., Massawe, G. A., Olasupo, N. A., & Holzapfel, W. H. (2000). The use of a starter culture in the fermentation of cassava for the production of "kivunde", a traditional Tanzanian food product. *International Journal of Food Microbiology*, 56(2-3), 179-190. [https://doi.org/10.1016/S0168-1605\(00\)00159-8](https://doi.org/10.1016/S0168-1605(00)00159-8)
- Konan, N. Y., Konan, K. J.-L., Assa, R. R., & Biego G. H. M. (2017). Variability of sensory acceptance and flavors of the inflorescence sap deriving from four widespread cultivars of coconut (*Cocos nucifera* L.). *Current Journal of Applied Science and Technology*, 22(3), 1-10. <https://doi.org/10.9734/CJAST/2017/33059>
- Konan, Y. N., Konan, J.-L., Assa, R. Rachel, Niamké, S., Kouassi, A., & Biego, H. (2013). Caractérisation physico-chimique de l'eau des noix mûres de nouveaux hybrides améliorés de cocotiers (*Cocos nucifera* L.) grands. *International Journal of Biological and Chemical Sciences*, 7(6), 2385-2395. <https://doi.org/10.4314/ijbcs.v7i6.17>
- Kourou, F. (2024). *Écorces d'agrumes : compositions, bienfaits et valorisations en agroalimentaire*. Mémoire de Master en Agroalimentaire et contrôle de qualité, Université Mouloud Mammeri de Tizi-Ouzou, Algérie. pp. 44.
- Kouyaté, A. M., Diallo, A., Diarra, I., Padonou, E. A., Traoré, S. D., Lykke, A. M., & Van Damme, P. (2020). Local knowledge of *Saba senegalensis* fruits against malnutrition in Mali. *Forests, Trees and Livelihoods*. <https://doi.org/10.1080/14728028.2020.1857310>
- Kumar, M., Prakash, S., Sharma, N., Kumari, N., Waghmare, R., Radha, & Sharma, K. (2024). Potential of fruit seed waste for improving the sustainability of fruit processing industry. In M. Kumar, K. Sharma, & S. P. Bangar (Eds.), *Developments in food quality and safety: Valorization of fruit seed waste from food processing industry* (pp. 1-25). Academic Press. <https://doi.org/10.1016/B978-0-443-15535-2.00008-6>
- Laaksonen, O., Mäkilä, L., Jokinen, M., Metz, T., Kallio, H., & Yang, B. (2020). Impact of storage on sensory quality of blackcurrant juices prepared with or without enzymatic treatment at industrial scale. *European Food Research and Technology*, 246, 2611-2620. <https://doi.org/10.1007/s00217-020-03601-0>
- Lagou, V. C., Konan, N. Y., & Assa, R. R. (2018). Physicochemical and nutritive characteristics of the residues deriving from the oranges (*Citrus sinensis* L.) consumed in Côte d'Ivoire. *Journal of new sciences, Agriculture and Biotechnology*, 58(5), 3777-3785.
- Li, Y., Xu, Y., Ma, X., Le, S. M., Wu, H., Dazzan, P., Nosarti, C., Heiss, C., Gibson, R., & Rodriguez, M. A.

- (2023). (Poly)phenol intake, plant-rich dietary patterns and cardiometabolic health: a cross-sectional study. *Food & Function*, 14, 4078-4091. <https://doi.org/10.1039/D3FO00019B>
- Lozano, J. E. (2006). *Fruit Manufacturing: Scientific Basis, Engineering Properties, and Deteriorative Reactions of Technological Importance*. Springer Science + Business Media, LLC. pp. 230.
- Marzouk, B., Tounsi, M. S., Moulehi, I., Ouerghemmi, I., Mejri, H., Wannes, W. A., Hamdaoui, G., Zemni, H., & Limam, F. (2011). Changes in lipid composition and antioxidant capacity of bitter orange (*Citrus aurantium* L.) and mandarin (*Citrus reticulata* Blanco) oilseeds at different stages of maturity. *Journal of the American Oil Chemists' Society*, 88, 961-966. <https://doi.org/10.1007/s11746-010-1751-2>
- Meda, A., Lamien, C. E., Romito, M., Millogo, J., & Nacoulma O. G. (2005). Determination of the total phenolic, flavonoid and proline contents in Burkina Faso honey, as well as their radical scavenging activity. *Food Chemistry*, 91, 571-577. <https://doi.org/10.1016/j.foodchem.2004.10.006>
- Meilgaard, M. C., Civille, G. V., & Carr, B. T. (2006). *Sensory evaluation techniques* (4th ed.). CRC Press.
- Micek, A., Currenti, W., Mignogna, C., Rosi, A., Barbagallo, I., Alshatwi, A. A., Rio, D. D., Mena, P., & Godos, J. (2023). Are (poly)phenols contained in 100% fruit juices mediating their effects on cardiometabolic risk factors? A meta-regression analysis. *Frontiers in Nutrition*, 10, 1175022. <https://doi.org/10.3389/fnut.2023.1175022>
- Milosavljevic, D., Maksimovic, V., Milivojevic, J., Djekic, I., Wolf, B., Zuber, J., Vogt, C., & Maksimovic, J. D. (2023). Sugars and Organic Acids in 25 Strawberry Cultivars: Qualitative and Quantitative Evaluation. *Plants*, 12, 2238. <https://doi.org/10.3390/plants12122238>
- Motoki, K., Spence, C., & Velasco, C. (2023). When visual cues influence taste/flavour perception: A systematic review. *Food Quality and Preference*, 111, 104996. <https://doi.org/10.1016/j.foodqual.2023.104996>
- Nafan, D., Jesus, F. I., Souleymane, S., Lenifere, S. C., Emmanuel, I. A., & Abdourahmane S. (2013). Genetic variation of *Saba senegalensis* Pichon (Apocynaceae) and few nutritional values. *International Journal of Biotechnology and Allied Fields*, 1(3), 121-135.
- OECD (2018). *Guidelines on objective tests to determine quality of fruit and vegetables, dry and dried produce* (Fruit and Vegetables Scheme). Retrieved from <https://www.oecd.org/content/dam/oecd/en/topics/policy-sub-issues/fruits-and-vegetables/guidelines-on-objective-tests.pdf>
- Okoye, J. I., & Uke P. C. (2024). Evaluation of nutrient composition, physicochemical and sensory properties of mixed fruit juice produced from shaddock (*Citrus maxima*), watermelon (*Citrullus lanatus*) and pawpaw (*Carica papaya*) blends. *Asian Journal of Food Research and Nutrition*, 3(3), 672-688. <https://journalajfrn.com/index.php/AJFRN/article/view/164>
- Ouattara, G. S., Soro, D., Chatigre, K. O., & Koffi E. K. (2016). Caractérisation physico-chimique et sensorielle de diverses formulations de jus à base de pomme de cajou et d'ananas. *International Journal of Biological and Chemical Sciences*, 10(6), 2447-2460. <https://doi.org/10.4314/ijbcs.v10i6.4>
- Pinto, T., Vilela, A., & Cosme, F. (2022). Chemical and sensory characteristics of fruit juice and fruit fermented beverages and their consumer acceptance. *Beverages*, 8(2), 33. <https://doi.org/10.3390/beverages8020033>
- Sadler, G. D., & Murphy, P. A. (2010). pH and titrable acidity. In: Nielsen S S. *Food Analysis*. Springer Science Business Media, pp 219-225. https://doi.org/10.1007/978-1-4419-1478-1_13
- Salehi, F. (2020). Physico-chemical and rheological properties of fruit and vegetable juices as affected by high pressure homogenization: A review. *International Journal of Food Properties*, 23(1), 1136-1149. <https://doi.org/10.1080/10942912.2020.1781167>
- Santos, D., Lopes, da S. J. A., & Pintado, M. (2022). Fruit and vegetable by-products' flours as ingredients: A review on production process, health benefits and technological functionalities. *Food Science and Technology (LWT)*, 154, 112707. <https://doi.org/10.1016/j.lwt.2021.112707>
- Sarr, M. G., Ndiaye, N. D., Ayessou, N. C., Faye, P. G., Cisse, M., Sakho, M., & Diop, C. M. (2018). *Saba senegalensis*: Key features and uses. *Food and Nutrition Sciences*, 9, 1099-1111. <https://doi.org/10.4236/fns.2018.99080>
- Scalbert, A., Johnson, T., & Saltmarsh, M. (2005). Polyphenols: antioxidants and beyond. *American Journal of Clinical Nutrition*, 81, 215S-217S. <https://doi.org/10.1093/ajcn/81.1.215S>

- Sidibe, D., Coulibaly, A., Nyamien, Y. B. J., Konan, N. Y., N'cho, C., & Biego, G. H. M. (2019). Investigation in sensory properties of liquid extract formulations processed from *Capsicum spp* varieties sold in Abidjan. *Journal of Advances in Biology & Biotechnology*, 22(3), 1-11. <https://doi.org/10.9734/jabb/2019/v22i330115>
- Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Methods in Enzymology*, 299, 152-178. [https://doi.org/10.1016/S0076-6879\(99\)99017-1](https://doi.org/10.1016/S0076-6879(99)99017-1)
- Soro, C. D. (2022). Pratiques traditionnelles de collecte de fruits et de production de jus de Saba senegalensis dans la ville de Korhogo [Unpublished bachelor's thesis]. Université Péléforo Gon Coulibaly.
- Tiendrébéogo, S., Ganou, L., Compaoré, C. S., Tapsoba, F. W., & Dicko, M. H. (2020). Biochemical composition of Saba senegalensis fruits from Burkina Faso. *African Journal of Food Science*, 14(10), 322-329. <https://doi.org/10.5897/AJFS2020.1992>
- Tounsi, M. S., Moulehi, I., Ouerghemmi, I., Mejri, H., Wannes, W. A., Hamdaoui, G., Zemni, H., Limam, F., & Marzouk B. (2011). Changes in lipid composition and antioxidant capacity of bitter orange (*Citrus aurantium* L) and mandarin (*Citrus reticulata* Blanco) oilseeds on different stages of maturity. *Journal of the American Oil Chemists' Society*, 88, 961-966. <https://doi.org/10.1007/s11746-010-1751-2>
- Tufail, T., Khan, T., Ul Ain, H. B., Morya, S., & Shah, M. A. (2024). Garden cress seeds: a review on nutritional composition, therapeutic potential, and industrial utilization. *Food Sciences and Nutrition*, 12, 3834-3848. <https://doi.org/10.1002/fsn3.4096>
- UNEP. (2024). Global Waste Management Outlook 2024: Beyond an age of waste- Turning rubbish into a resource. United Nations Environment Programme. pp. 115. <https://doi.org/10.59117/20.500.11822/44939>
- Vondruskova, H., Slamova, R., Trckova, M., Zraly, Z., & Pavlik, I. (2010). Alternatives to antibiotic growth promoters in prevention of diarrhea in weaned piglets: a review. *Veterinari Medicina*, 55(5), 199-224. <https://doi.org/10.17221/2998-VETMED>
- Wang, X., Cheng, J., Zhu, Y., Li, T., Wang, Y., & Gao, X. (2024). Intermolecular copigmentation of anthocyanins with phenolic compounds improves color stability in the model and real blueberry fermented beverage. *Food Research International*, 190, 114632. <https://doi.org/10.1016/j.foodres.2024.114632>
- Way, M. L., Joanna, E. J., David, S. N., Robert, G. D., & Nigel, D. S. (2020). A comparison of laboratory analysis methods for total phenolic content of Cider. *Beverages*, 6(55), 1-11. <https://doi.org/10.3390/beverages6030055>
- Yao, K. K. T., Somda, M. K., Nikiema, M., Mogmenga, I., Dabire, Y., Ouattara, A., Kabore, D., & Dicko, M. H. (2024). Proximate Composition and Nutritional Potential of *Saba Senegalensis* Fruit from Three Climatic Regions in Burkina Faso. *Journal of Food Research*, 13(1), 10-25. <https://doi.org/10.5539/jfr.v13n1p10>
- Zhou, J., Yang, S., Ma, Y., Liu, Z., Tu, H., ... Wang, X. (2023). Soluble sugar and organic acid composition and flavor evaluation of Chinese cherry fruits. *Food Chemistry*, X(20), 100953. <https://doi.org/10.1016/j.fochx.2023.100953>