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# Impact of Brining on the Sensory Properties of Cashew Apple Jams Prepared With or Without the Skin

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**Abstract** Cashew apple processing into various by-products is hampered by the problem of astringency. Previous research to reduce this astringency has mainly focused on the juice. The objective of this work was to determine the combinations of NaCl concentration, brining duration, and peeling applied to cashew apples prior to their processing into jams that would reduce astringency and improve organoleptic properties. A factorial experiment, composed of 26 treatments resulted from a combination of brining duration, NaCl concentration, and peeling, was conducted at the LAPISEN laboratory of the Institute National Polytechnique Felix Houphouet-Boigny in Yamoussoukro (Côte d'Ivoire). The cashew apples pretreatment was followed by a six-week freezing at -4 °C. Jams obtained were both analyzed for tannin contents and subjected to a sensory evaluation. Results revealed a low astringency of the jams after pretreatment, with tannin levels ranging between 0.75 and 2.55 mg/100g of jam, lower than tannin levels in the fresh cashew apples. P-values of the sensory descriptors of the jams were all lower than the alpha-level of 0.05, revealing that panelists could successfully discriminate between the jams. Results of the jam preference test presented to naive subjects revealed that cashew apples with the presence of the skin and soaked in 15 g/L NaCl for one day produced the preferred jam among the set presented to evaluators. This combination of the three factors tested could also be applied to the production of other cashew apple by-products.

**Keywords** Cashew Apples, Sensory Evaluation, Pretreatment, Astringency, Jam

## 1. Introduction

Côte d'Ivoire is the world's leading producer of cashew nuts, with more than one million tons produced in 2022 [1]. The cashew apple, the elongated, round, or pear-shaped fibrous accessory fruit of the cashew tree (*Anacardium occidentale* L.), is a thick receptacle or pseudo fruit, to which the cashew nut is attached [2]. Previous literature reported the cashew apple to represent 9 to 10 times the weight of the nut. Higher estimations report 90 to 95% of the cashew apple production wasted under cashew trees as by-products of every cashew nut ton harvested [3,4]. Côte d'Ivoire presents a low processing level of cashew apples with estimates of 22% leading to over 9 million tons of cashew apples [3] wasted almost entirely at the point of harvest in 2022.

Yet the cashew apple has a high nutritional potential [5]. It is very juicy (85 to 90% water), sweet (10.69 to 18.82 °Brix), slightly fragrant and acidic [6,7]. It is also very rich in vitamin C, polyphenols, and antioxidants [6,8,9]. It contains significant quantities of carotenoids [10]. However, despite its great potential for developing value-added products, due to its functional activity, its

processing into juice remains the main value-added route, similar to many other fruits [11]. Other crucial value-added routes, yet underexploited, such as processing into syrup, jellies, candied fruit, wine, alcohol, vinegar, compote, and jam [5,12,13,14] need to be further explored.

Côte d'Ivoire's jam consumption needs are generally met through importations, which lead to the increase of the cost of this product on the market, with the consequence of its inaccessibility to an important component of the population. Yet, local processing of cashew apples into jam could be a viable solution for increasing national jam production and a reduction of its market prices. One of the major constraints to processing cashew apples into various by-products is the high astringency problem [5]. This astringent taste previously reported as a major problem for poor acceptability of the cashew apple [2] is reported by several studies to be caused by the presence of condensed tannins [15]. The astringency seems to derive essentially from the skin of the cashew apple. For example, Michodjehoun-Mestres [9] reported tannins to be primarily concentrated in this cashew apple's skin, estimated to be approximately 8 times more than that in the inner part of this accessory fruit. Thus, accounting for this astringency remains a major challenge when valorizing cashew apples into its various by-products.

Several operation units, able to preserve the nutritional quality of the raw material, while reducing this astringency, exist [16]. According to Haendler and Duverneui [16], processes for reducing astringency include cold processing (+4 ℃), apple pickling, fruit ripening, washing with very cold water, storage at 0 ℃ for at least 12 to 15 hours before juice extraction, peeled fruit treatment with boiling water, steam treatment of purees. These processes are sometimes used alternatively [2]. Many research activities have been conducted to reduce cashew apple astringency for juice production but not for the other by-products and some of the methods used include fining or clarifying agents such as clays (bentonite, kaolin), proteins (pectin, gelatin, etc.); polysaccharides (agars, cassava starch, "sagou", rice porridge), immobilized tannase enzymes [7,17,18,19]. Other authors used more characteristic separation processes such as membrane techniques [11,20,21]. To our knowledge, no previous research has conducted descriptive and hedonic sensory evaluations for the sensory characterization and the selection of best cashew apple jam, following pretreatments with various levels of brining duration, NaCl concentration, and peeling (presence or absence of the skin). Therefore, the objective of this work was to determine the combination of NaCl concentration, brining duration, and peeling, to be applied to harvested cashew apples, prior to their transformation into jams, to produce less astringent and more organoleptically appreciated jams.

# 2. Materials and Methods

### 2.1. Cashew Apples Pretreatment Methods

Cashew apples (red and yellow) collected during the harvest season which extends from October to February from a farmer's cashew tree (*A. occidentale* L.) orchard near Yamoussoukro (Côte d'Ivoire), were carefully separated from their nuts, and transported to the laboratory in barrels. They were then sorted and rinsed three times with water. Next, they were disinfected using a 100-ppm solution of active chlorine for 30 min and rinsed again with water.

The cashew apples pretreatment consisted of a set of combination of brining for a duration up to three days, NaCl concentrations ranging from 15 to 40g NaCl, and peeling (presence or absence of the fruit skin) which were applied before freezing at -4 ℃ for six weeks. A mixed experimental design was used to better implement these pretreatment operations. The low and high levels of the three influencing factors selected for the cashew apple pretreatments are provided in Table 1.

**Table 1.** Selected factors and their levels for investigating the impact of pretreatment of cashew apples

| **Factors** | | **Levels** | | | |
|---|---|---|---|---|---|
| | | Low (-1) | | | High (+1) |
| Fruit skin | X1 | Absent | --- | --- | Present |
| NaCl concentration (g/L) | X2 | 0 | 15 | 30 | 45 |
| Brining duration (days) | X3 | 0 | 1 | 2 | 3 |

Table 2 provides the various combinations for cashew apple pretreatment trials preceding jam preparations. In practice, when the brining time (X3) is 0 days, no NaCl was added. For this reason, tests 1, 5, 9, and 13 were assumed to be identical, as well as tests 17, 21, 25, and 29 assumed to be identical. Therefore, a total of 26 trials were carried out for cashew apple pretreatment instead of 32.

The response variables of interest for selecting the pretreatment combination that produced the best jams were tannin contents and the sensory evaluations of the jams by descriptive and hedonic tests. Four descriptors selected for the descriptive test were texture, salinity (least salty taste or (-) salinity), sweetness, and the least astringent taste or (-) astringency. The descriptive test was rated on a scale from 1 to 9. The scale for the hedonic test had preference ratings of 1, 2, 3, and 4, respectively corresponding to "strongly dislike", "dislike", "like ", and "strongly like".

**Table 2.** Experimental design for cashew apple pretreatments with the levels of peeling (X1), brining duration (X3), and NaCl concentration (X2)

| Experiment (N°) | Jams' Codes | Factors' codes | | | Factors | | |
|---|---|---|---|---|---|---|---|
| | | X1 | X2 | X3 | Fruit skin | NaCl concentrations (g/L) | Brining duration (days) |
| 1(1) | C608 | -1 | -1 | -1 | Absent | 0 | 0 |
| 2(2) | C951 | -1 | -1 | -0,33 | Absent | 0 | 1 |
| 3(3) | C510 | -1 | -1 | 0,33 | Absent | 0 | 2 |
| 4(4) | C330 | -1 | -1 | 1 | Absent | 0 | 3 |
| 5(1) | C608 | -1 | -0,33 | -1 | Absent | 15 | 0 |
| 6(5) | C179 | -1 | -0,33 | -0,33 | Absent | 15 | 1 |
| 7(6) | C381 | -1 | -0,33 | 0,33 | Absent | 15 | 2 |
| 8(7) | C308 | -1 | -0,33 | 1 | Absent | 15 | 3 |
| 9(1) | C608 | -1 | 0,33 | -1 | Absent | 30 | 0 |
| 10(8) | C753 | -1 | 0,33 | -0,33 | Absent | 30 | 1 |
| 11(9) | C157 | -1 | 0,33 | 0,33 | Absent | 30 | 2 |
| 12(10) | C308 | -1 | 0,33 | 1 | Absent | 30 | 3 |
| 13(1) | C608 | -1 | 1 | -1 | Absent | 45 | 0 |
| 14(11) | C790 | -1 | 1 | -0,33 | Absent | 45 | 1 |
| 15(12) | C378 | -1 | 1 | 0,33 | Absent | 45 | 2 |
| 16(13) | C313 | -1 | 1 | 1 | Absent | 45 | 3 |
| 17(14) | C223 | 1 | -1 | -1 | Present | 0 | 0 |
| 18(15) | C482 | 1 | -1 | -0,33 | Present | 0 | 1 |
| 19(16) | C839 | 1 | -1 | 0,33 | Present | 0 | 2 |
| 20(17) | C450 | 1 | -1 | 1 | Present | 0 | 3 |
| 21(14) | C223 | 1 | -0,33 | -1 | Present | 15 | 0 |
| 22(18) | C105 | 1 | -0,33 | -0,33 | Present | 15 | 1 |
| 23(19) | C504 | 1 | -0,33 | 0,33 | Present | 15 | 2 |
| 24(20) | C785 | 1 | -0,33 | 1 | Present | 15 | 3 |
| 25(14) | C223 | 1 | 0,33 | -1 | Present | 30 | 0 |
| 26(21) | C245 | 1 | 0,33 | -0,33 | Present | 30 | 1 |
| 27(22) | C702 | 1 | 0,33 | 0,33 | Present | 30 | 2 |
| 28(23) | C895 | 1 | 0,33 | 1 | Present | 30 | 3 |
| 29(14) | C223 | 1 | 1 | -1 | Present | 45 | 0 |
| 30(24) | C970 | 1 | 1 | -0,33 | Present | 45 | 1 |
| 31(25) | C650 | 1 | 1 | 0,33 | Present | 45 | 2 |
| 32(26) | C527 | 1 | 1 | 1 | Present | 45 | 3 |

### 2.2. Jam Preparation Methods

Pretreated cashew apples, with or without the skin, depending on the experimental design, were cleaned of all impurities. They were then cut into pieces and pre-cooked for 5 min, using the juice contained in the cashew apples, with no water addition. A follow-up grinding was made using a sieve mill. The jam was cooked for approximately 7 to 10 min using a 50:50 ratio (w:w) of cashew apple and sugar. A refractometer (HANNA, Romania) was used to monitor the cooking. The jam was poured into glass jars at a temperature of over 90 ℃. Before packing, the glass jars and their lids were sterilized in boiling water for 10 min. The resulting jars were immediately sealed and turned upside down, to allow the hot jam to pasteurize the lid.

### 2.3. Tannin Assay Methods

Total tannins were determined using the colorimetric method, with Folin Ciocalteu reagent [22]. One hundred microliters (100 µL) of solution extract, prepared at 2.5 mg/mL, were added to a test tube containing 7.5 mL distilled water and 0.5 mL Folin Ciocalteu reagent. Next, 1 mL of 35% $Na_2CO_3$ was added. The volume was brought to 10 mL by adding 900 µL distilled water. The reaction mixture was stirred, then allowed to react for 30 min at laboratory temperature (25 - 30 ℃). A UV/visible spectrophotometer (JASCO, Japan) was used for absorbance readings at 700 nm using distilled water as a blank. A calibration line, drawn from a range of tannic acid concentrations, was used as a standard for determining the tannin content. The tannin content (mg EAT/g TPC) was determined first on the cashew apples before their pretreatments then on the cashew apple jams obtained.

### 2.4. Sensory Evaluation Methods

#### 2.4.1. Descriptive Test

A sensory evaluation was conducted during a one-week period to characterize the 26 jams produced. A batch of 4 to 5 pre-coded jam samples was served per session. A panel of 15 trained personnel of the LAPISEN laboratory generated 4 descriptors (texture (gelation), sweetness, least salty, and least astringent), tasted the products while filling out a descriptive test sheet.

#### 2.4.2. Hedonic Test

Following the descriptive test, four (4) jams out of the 26 were selected by the expert panel. They were subjected to a questionnaire of hedonic test allowing naive subjects, to give their preferences in order to determine the jam with the best organoleptic properties; meaning the jam that resulted from the best combination of brining duration, NaCl concentration, and peeling. A total of 249 opinions were collected.

### 2.5. Statistical Analysis

Tannin contents, descriptors values, and rating values from naive subjects were subjected to ANOVA using the software program Statistica version 8.0. Treatment means were separated using Duncan's test at an alpha level of 0.05. The chi-square test allowed to find a possible link of dependence between the items of the hedonic test questionnaire and the preferences of the naive subjects. The coefficients of the experimental design factors and statistical tests were estimated using the same software program. A multivariate linear regression was used to estimate the coefficients of the factors of the experimental design.

## 3. Results and Discussion

### 3.1. Tannin Contents in Cashew Jams

Tannin contents of the jams showed considerable variability (Figure 1), with average values of $0.75 \pm 0.20$ and $2.55 \pm 0.27$ mg/100g for jams prepared without (SP) and with (P) the cashew apple skin, respectively. The tannin contents obtained in fresh apples before pretreatment were $296 \pm 15$ mg/100g, representing a reduction rate of 99.75% and 99.14% compared with jams prepared without the skin (SP) and with the skin (P) of the apple respectively. These tannin contents in jams were lower than the values (between 290 and 380 mg/100g) previously reported by Lauti é [7] in fresh cashew apples and the values (240 mg/100g) reported by Soro [11] in raw juice of cashew apple. The pretreatments implemented in the experimental design therefore contributed to this large reduction in tannin contents. Tannins are highly water-soluble and might have migrated to the aqueous brine solution during pretreatment [8]. Additionally, their highly heat-sensitive nature [23] might also have contributed to lowering the tannin content of the jams during cooking. Results showed that peeling had a highly significant impact on jam tannins (Table 3). In fact, jams produced with the presence of the skin of the cashew apples (P) had higher tannin contents compared to those prepared without their skin (SP). This result is consistent with previous results by Haendler [16] which reported cashew apple skin as richer in tannins. The brining duration-by-NaCl concentration-by peeling interaction was significant (Table 3).

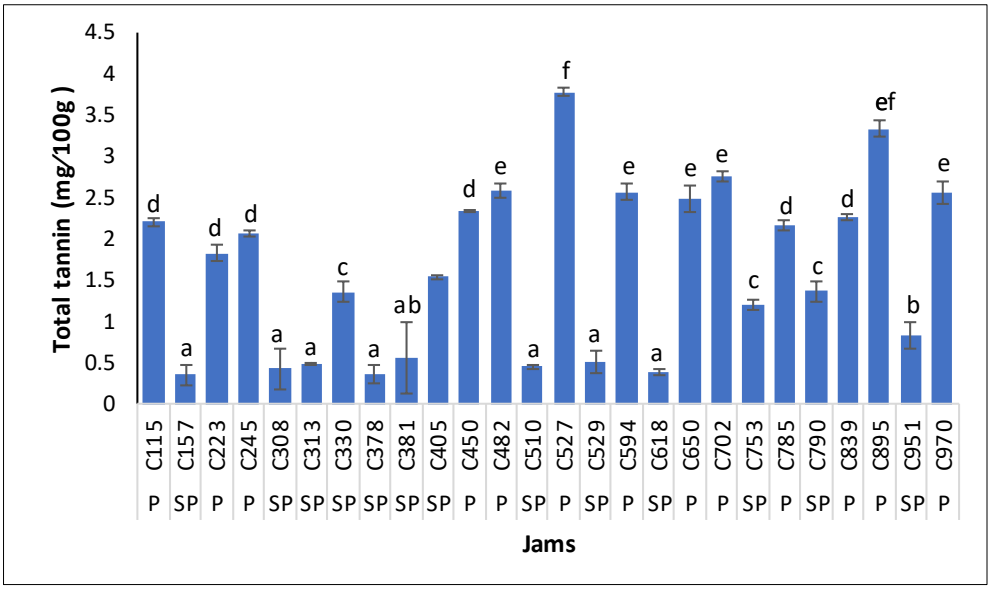



**Figure 1.** Tannin contents in cashew jams from an experiment evaluating the impact of pretreating cashew apples *Identical lower case letters above bars indicate a subset of jams with mean tannin contents that were not significantly different at an alpha-level of 0.05

**Table 3.** Results for tannin coefficients in experimental design models

| | | TANNINS | |
|---|---|---|---|
| | | ***Coef.*** | ***P-value*** |
| **Factor** | Const. | 1623 | <0.001 |
| Fruit Skin (presence (P) or absence (SP) ) | X1 | 0.8 | **<0.001** |
| NaCl Concentration | X2 | 0.136 | 0.19 |
| Brining duration (days) | X3 | 0.213 | 0.098 |
| Interactions | X1X2 | 0.062 | 0.5448 |
| | X1X3 | 0.283 | **0.0328** |
| | X2X3 | -0.068 | 0.6528 |
| | X1X2X3 | 0.51 | **0.003** |

*In bold the significant p-values

### 3.2. Expert Panel Descriptive Test

#### 3.2.1. Analysis of Descriptor Scores

For each of the 26 coded jams from the experimental design, a descriptive test was carried out by an expert panel. Figures 2 and 3 show histograms of the average scores attributed to the descriptors and their discriminating power according to Fisher's test. The average descriptor scores varied widely according to experimental conditions (Figure 2). Factor levels had therefore been correctly chosen.

The p-values of the jam descriptors are all lower than 0.05. All the sensory descriptors can therefore be used to discriminate between jams. Descriptors were ranked in ascending order according to their discriminating power, as sweetness (p=0.039), (-)astringency (p=0.014), gelling aspect ($p=2.49x10^{-4}$), and (-)salinity ($p=4.15x10^{-8}$). With its p-value being the smallest within the set, salinity was the most discriminating descriptor for all jam samples. The significant differences recorded for the descriptors provided a confirmation that the tasters were able to distinguish the jam samples, and that the factorial experiment influenced the preparation of the jams.

#### 3.2.2. Effects of Pretreatment Parameters on Descriptors

The results of the factors' coefficients for each descriptor from the experimental design are shown in Table 4.

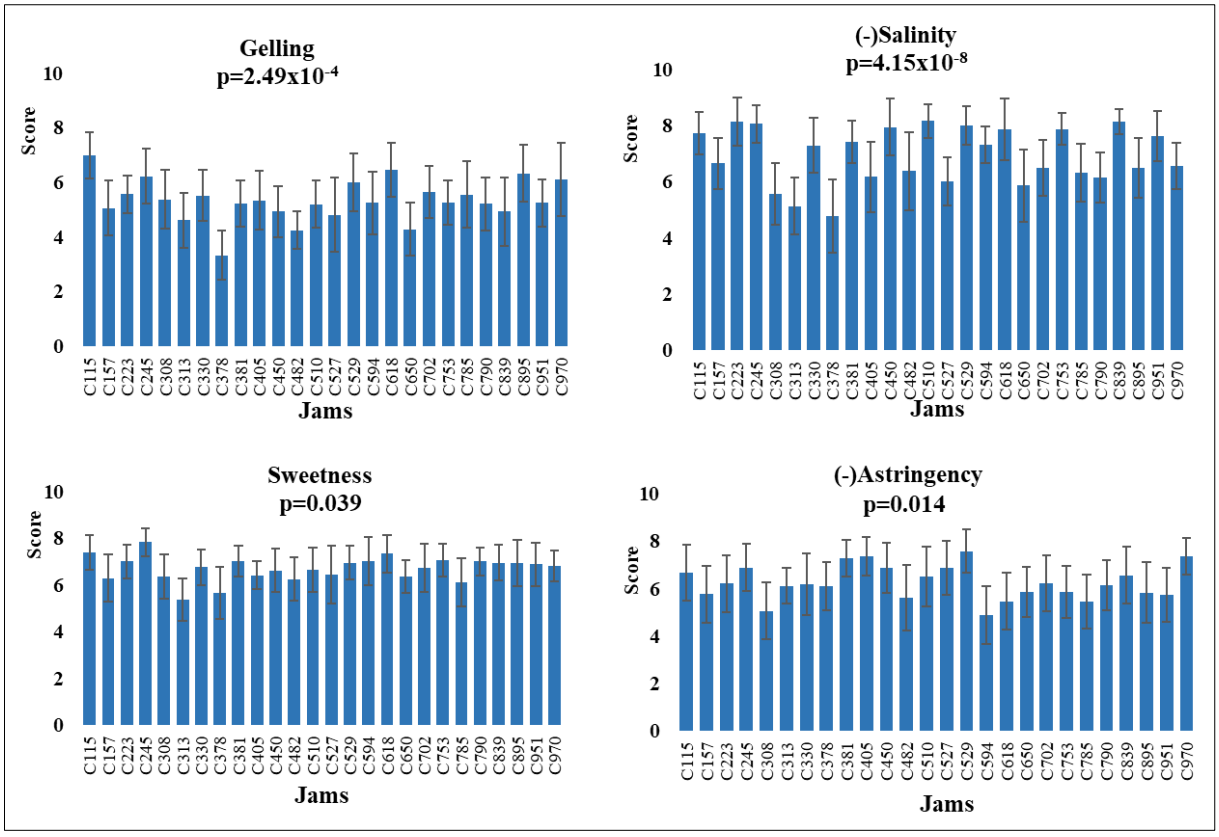
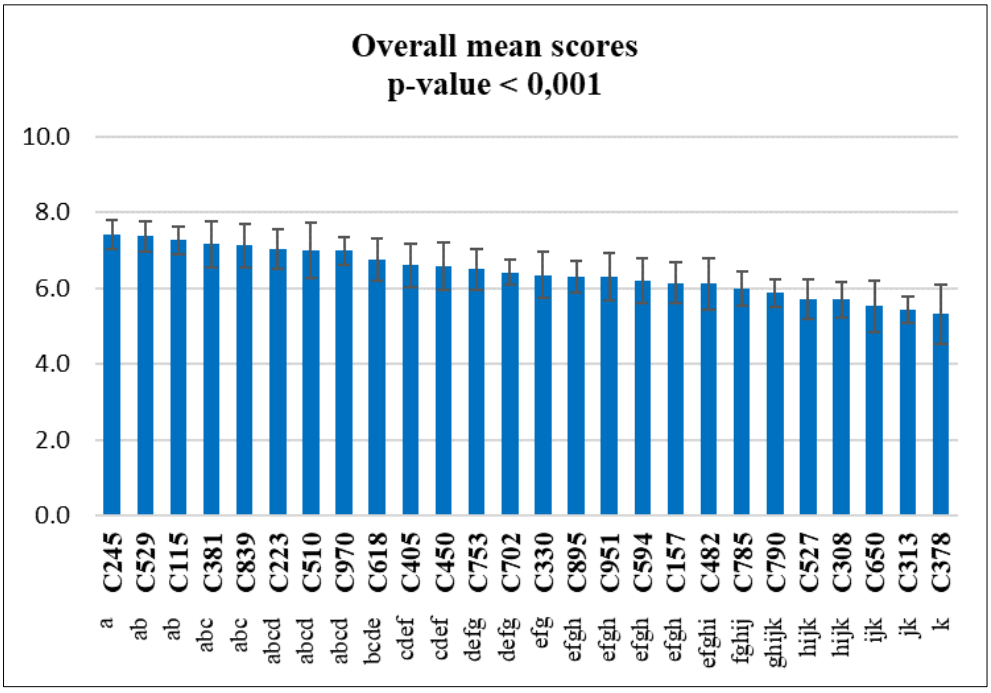



**Figure 2.** Histograms of average descriptor scores and p−value associated with the F−test of the jam effect for each descriptor




(Identical lower case letters indicate subsets of jams with overall mean scores not significantly different from each other (alpha = 0.05))

**Figure 3.** Distribution of overall mean scores in descending order for 26 jams

**Table 4.** Results of factors' coefficients for various descriptors obtained from the experimental design

| | | **Gelling aspect** | | **(-) Salinity** | | **Sweetness** | | **(-) Astringency** | |
|---|---|---|---|---|---|---|---|---|---|
| **Factors** | | *Coef.* | *P-value* | *Coef.* | *P-value* | *Coef.* | *P-value* | *Coef.* | *P-value* |
| | Const. | 5.58 | **< 0.001** | 7.49 | **< 0.001** | 7.07 | **< 0.001** | 6.86 | **< 0.001** |
| Fruit skin (presence or absence) | X1 | 0.36 | **0.009** | 0.13 | 0.28 | 0.05 | 0.531 | -0.15 | 0.344 |
| NaCl concentration | X2 | -0.17 | 0.317 | -0.97 | **< 0.001** | -0.18 | 0.056 | 0.16 | 0.423 |
| Brining duration (days) | X3 | -0.48 | **0.022** | -0.8 | **< 0.001** | -0.34 | **0.004** | 0.19 | 0.441 |
| Interactions | X1X2 | 0.29 | 0.094 | 0.25 | 0.093 | 0.14 | 0.139 | 0.23 | 0.253 |
| | X1X3 | -0.18 | 0.381 | 0.2 | 0.264 | 0.11 | 0.318 | -0.26 | 0.284 |
| | X2X3 | -0.39 | 0.124 | -0.68 | **0.003** | -0.18 | 0.205 | -0.65 | **0.027** |
| | X1X2X3 | -0.32 | 0.202 | 0.19 | 0.376 | -0.03 | 0.831 | 0.08 | 0.789 |

*In bold the significant p-values

When it comes to the descriptor gelling aspect, the cashew apple peeling and brining duration have significant effects (Table 4). However, these factors have opposite effects on gelling as their coefficients have opposite signs.

Indeed, the regression reveals an increase in the gelling aspect of the jams in the presence of apple skins (X1) and a decrease in the gelling aspect with the increase in the brining duration (X3). Pectin, responsible for the gelling of jams, is highly concentrated in the appleskin [24]. For this reason, jams prepared with the apple skin could have a more gelling appearance than jams prepared without the appleskin.

Pectin is also soluble in water, so the content of the apples may decrease, with time, because the pectin could dissolve easily in the brine. Thus, jams prepared with a longer apple's brining duration could induce a reduction in the gelling appearance.

The descriptor least salty taste or (-) salinity descriptor was very highly influenced by NaCl concentration (X2) and brining duration (X3), with p-values less than 0.001. Moreover, the NaCl concentration-by-brining duration interaction was significant for this descriptor. The negative coefficients of the regression for factors X2 and X3 revealed that, less salty taste decreased with increases in NaCl concentration (X2) and brining time (X3). In other words, the salty taste increases with the addition of NaCl and the duration of brining (X3). This result seems logical. In fact, brining means that the products do contain salt and become saltier with the increase in salt concentration. The membrane constituting the skin of cashew apples would therefore be semi-permeable because in addition to the passage of water by osmosis, a fraction of the solute (NaCl) crosses this membrane by diffusion [25,26,27].

For the sweetness descriptor, only brining duration (X3) showed a significant effect (< 0.05). Its regression coefficient was negative, indicating that brining duration had a tendency to reduce sweetness. Indeed, the longer the cashew apples stay in the brine, the more enriched with salt they become; as a result, they experience a decrease in sweetness [28,29].

With regard to the least astringent (-) taste, no main effect was observed. However, there was a significant interaction effect between NaCl concentration (X2) and brining duration (X3) which is consistent with previous research. Astringency is influenced by several brining parameters, including brining duration and NaCl concentration [8,19].

### 3.2.3. Experts Panel Rankings' of Jams

#### 3.2.3.1. Ranking of Jams According to the Overall Average Scores

Overall average scores of the jams, in a descending order, are presented in Figure 3. These overall averages ranged between 5.2 and 7.7. Highly significant differences were detected between these averages (p-value < 0.001).

Mean separations, using Duncan's post hoc test, allowed a selection of jams with relatively high overall averages and which were not significantly different from each other. These jams, with the same lower case separation letter "a" are, in descending order, C245, C529, C115, C381, C839, C223, C510, and C970 (Figure 3).

#### 3.2.3.2. Sensory Profile and Selection of Jams According to the Descriptive Test

The sensory profiles of the eight jams are shown in Figure 4, with jams C381, C839, C223, and C510 showing a relatively lower gelation compared to jams C970, C245, C529, and C115. Of these last four jams, C529 and C115 appeared to have less dispersed descriptor scores; therefore, they seemed to have more stable sensory profiles. The analysis of the table 5 reveals that 75% of these four jams (C115, C245, and C970) were prepared with the presence of the skin, 50% (C529 and C115) were prepared with 15g/L NaCl and 100% were prepared with a brining duration of 1 day. Thus, the pretreatment that produced jam C115 seemed to be the preferred choice. This treatment (trial 18) was carried out with the presence of the fruit skin and a brining duration of 1 day in 15g/L NaCl. However, jams C970, C245, C529, and C115 were selected and subjected to the hedonic test for a better choice.

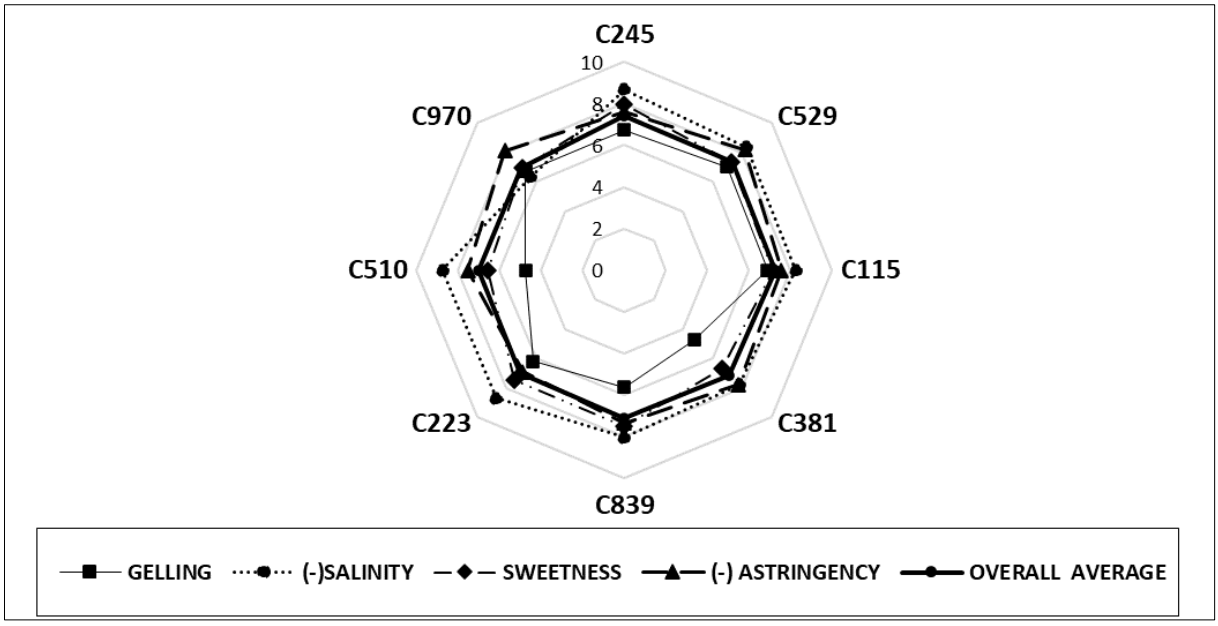



**Figure 4.** Sensory profile from eight jams

**Table 5.** Pretreatments selected on the basis of the overall average

| | | Pretreatments | | | |
|---|---|---|---|---|---|
| Jams | | **C529** | **C115** | **C245** | **C970** |
| Experiment | | (5) | (18) | (21) | (24) |
| Fruit skin | X1 | Absent | Present | Present | Present |
| NaCl concentration (g/L) | X2 | 15 | 15 | 30 | 45 |
| Brining duration (days) | X3 | 1 | 1 | 1 | 1 |

### 3.3. Hedonic Test According to the Naive Panel

#### 3.3.1. Responses to Questionnaire Items from the Hedonic Test Survey in Relation to the Preferences of Naive Subjects

Table 6 presents for each item the percentages of the modalities of the questionnaire submitted to the 245 naïve subjects. We had 60% for the "female" gender compared to 40% for the "male" gender. More than half of the individuals surveyed (57%) have an age range [20-35] years old. The age range "less than 10 years old" obtained the smallest number of individuals surveyed (9%). Concerning the item "Which sensory descriptor guided your preference?", 65% of individuals surveyed based their preference on "sweet". The descriptors "astringency", "gelation" and "salinity" attract less attention from naive subjects with a low cumulative percentage of 7%. Some individuals (26%) based their preference on "more than one descriptor". Concerning the item about "Do you like the sweet taste?" », 86% responded with "Yes".

**Table 6.** Results of the hedonic survey on 249 naive subjects

| **Items of questionnaire** | **Modalities** | **Numbers (%)** |
|---|---|---|
| Gender | Male | 60 |
| | Female | 40 |
| Age range | Less than 10 years old | 9 |
| | [10 - 20] years old | 17 |
| | [20 - 35] years old | 57 |
| | More than 35 years old | 17 |
| Which sensory descriptor guided your preference? | Sweet | 65 |
| | Astringency | 4 |
| | Gelation | 2 |
| | Salinity | 1 |
| | More than one descriptor | 26 |
| | Others | 2 |
| Do you like sweet taste? | Yes | 86 |
| | No | 14 |

Figure 5 graphically shows the relationships between the items of the hedonic test questionnaire and the preferences of naive subjects. The analysis of the different items in the figure shows variability in preferences of the subjects within each modality. At the gender level (figure 5A), preferences ("strongly dislike", "dislike", "like" and "I strongly like") in the male are also observed in the female in the same percentages with non-significant differences. Preferences therefore seem not to depend on gender. The men and women surveyed had the same appreciation of cashew apple jams. These observations are confirmed by chi-square's test ($p>0.05$) which allows us to conclude that there is no significant link between preferences and gender (table 6). At the age range level (figure 5B), the observations are the same as those for the "gender" item: the preferences seem not to depend on the age range. So whatever the age range, the individuals surveyed gave the same preference for cashew apple jams ($p>0.05$). These observations are confirmed with those of Jefferson N. Curammeng *et al.* [30]. These authors working on acceptability of bamboo shoot tart showed that on certain descriptors (appearance; texture and taste) the preferences in terms of gender (male or female) and civil status (married or single) of the respondents could be the same.

Concerning about items "Which sensory descriptor guided your preference?" and "Do you like sweet taste?", the answers given depended on the individuals surveyed. This is observed by the preference percentages ("Strongly dislike", "Dislike", "Like" and "Strongly like") which varied from one modality to another within the same item (figure 5:C,D). According to Table 7, Chi-square tests applied to these two items are very highly significant ($p<0.001$) which confirms that the answer to these questions is linked to the given preference attributed to cashew apple jams.

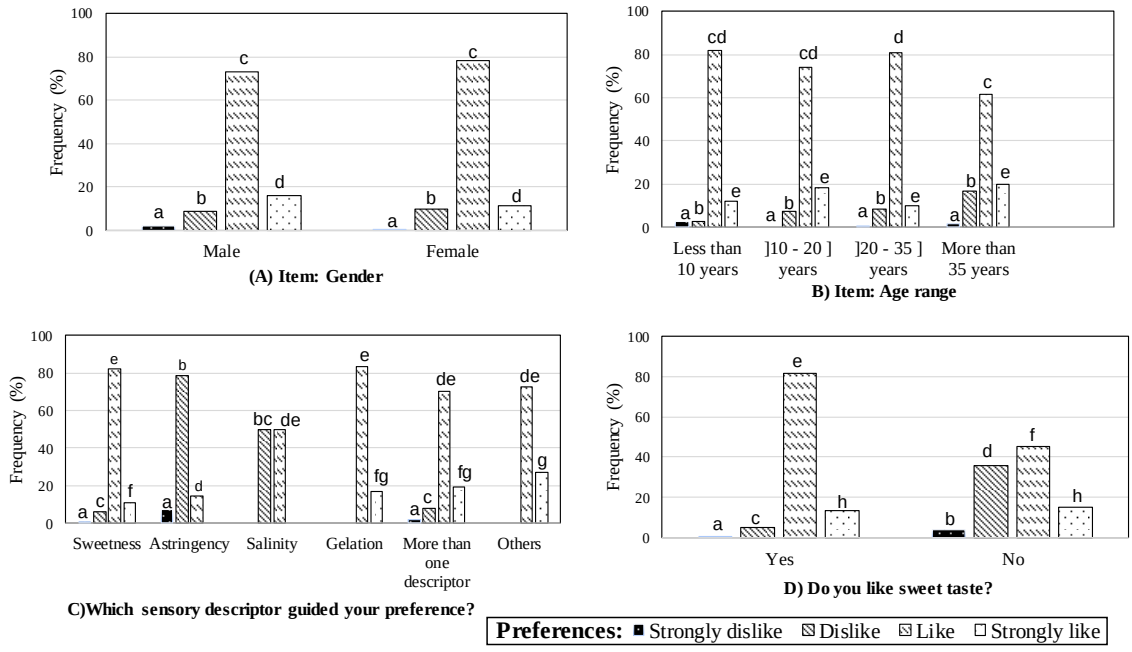
### 3.3.2. Appreciation of Selected Jams by Naive Subjects

The results of the hedonic preference test are shown in Figure 6 for the selected four jams. In ascending order, the mean scores (M) obtained on a 4-point score were 3.25, 3.00, 2.95, and 2.87, respectively, for jams C115, C529, C245, and C970. The cumulative percentages of "like" and "strongly like" were 72%, 44%, 50%, and 19% for the C115, C529, C245, and C970 jams, respectively. Thus, C115 seemed to be the preferred jam.

### 3.3.3. Sensory Profile and Choice of Pretreatments According to the Hedonic Test

The results of the ANOVA test of the ratings in Table 8 give a p-value of 0.0018 highlighting the highly significant difference between the four jams offered to naive subjects. Duncan's test showed two distinct groups of formulations which were group A (C950, C245, and C529) and group B (C115) (Table 8). These results revealed that naive subjects appreciated jam C115 more than the other jams. But they appreciated the jams C950, C245, and C529 the same way (Table 8).

Jam C115 was prepared after the application of the pretreatment that combined the presence of fruit skin, with a brining duration of one (1) day, and a NaCl concentration of 15g/L. Its sensory profile for three replications (Rep) is shown in Figure 7.




(Each letter on a histogram indicates a preference in a subset of the questionnaire item whose proportions do not differ significantly from each other in the item at an alpha-level of 0.05.)

**Figure 5.** Distribution of preferences of naive subjects for each questionnaire items

**Table 7.** P-values of Chi-square test's between questionnaire's items and naive subjects preferences

| Items | Gender | Age range | Descriptor | Sweet taste |
|---|---|---|---|---|
| p-values | 0.287 | 0.073 | <0.001 | <0.001 |

*In bold the significant p-values

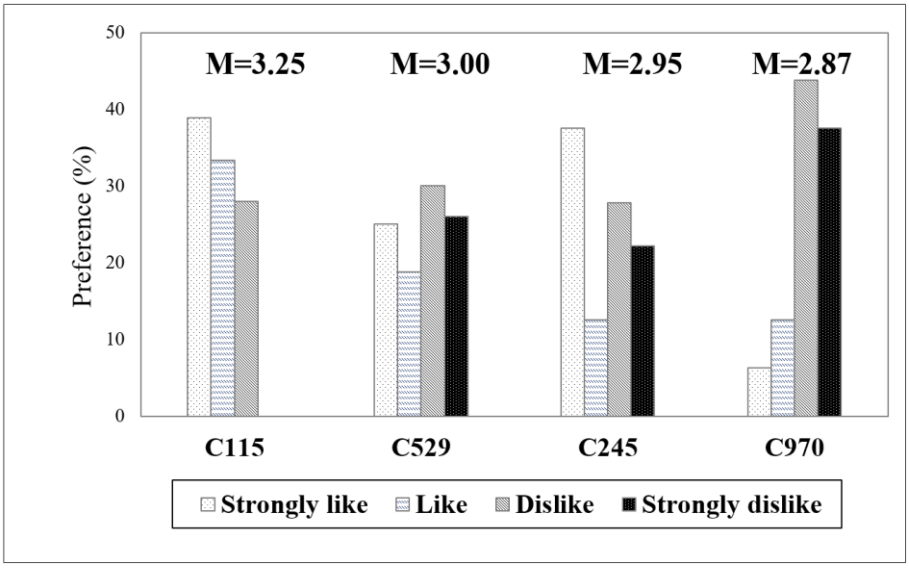



**Figure 6.** Percentage of naive subjects' preferences for jams after the hedonic test

**Table 8.** Jam groups according to Duncan's test at 0.05 threshold with p-value (ANOVA)=0.0018

| Formulation | Groups | |
|---|---|---|
| | A | B |
| C970 | 2,89 | |
| C245 | 2,95 | |
| C529 | 3,00 | |
| C115 | | 3,25 |

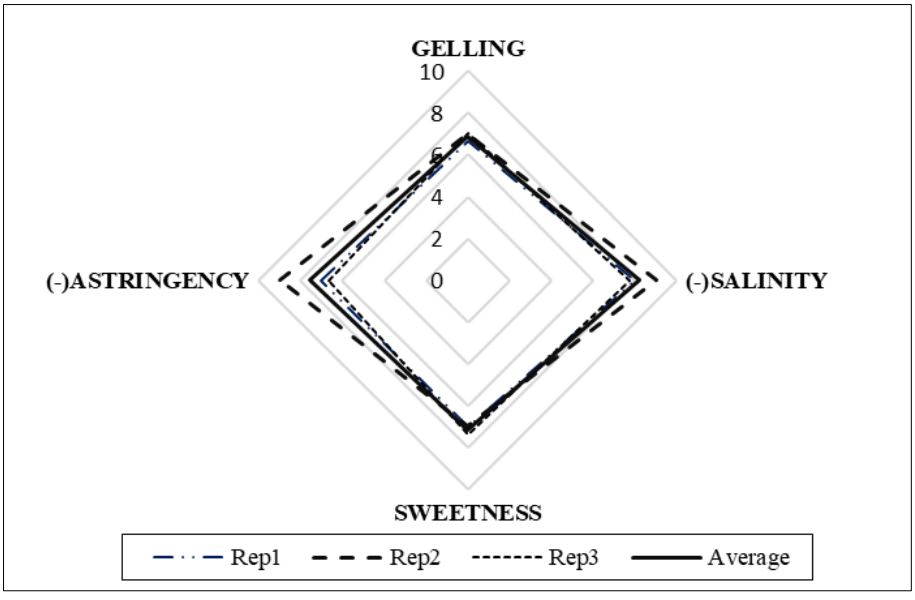



**Figure 7.** Sensory profile of C115 jam

## 4. Conclusions

This study shows that the factors "presence or absence of the fruit skin", "NaCl concentration", and "brining duration" used for the pretreatment of cashew apples, followed by their freezing at -4 ℃, resulted in jams with relatively low tannin content (0.75 to 2.55 mg/100g of jam) and consequently that are less astringent. These values remain lower than those in fresh cashew apples. The results of the sensory evaluations showed that naive subjects preferred jam C115 out of the 26 jams obtained after pretreatments applications to the cashew apples. This pretreatment resulted from a combination of the presence of the fruit skin, a brining duration of 1 day, and a NaCl concentration of 15g/L. These results should allow producers to better use cashew apples for jam production. The method used in this study for astringency reduction is accessible and affordable. These results can also help Côte d'Ivoire to produce more jams from cashew apples at a reduced cost and decrease its jam importations.

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## REFERENCES

[1] Maussion Estelle, "How Côte d'Ivoire Plans to Double cashew processing capacity", The africareport, https://www.theafricareport.com (accessed December 26, 2023).

[2] Das, I. and Arora, A., "Post-harvest processing technology for cashew apple", - A review. Journal of Food Engineering, vol. 194, pp. 87-98, 2017. DOI: 10.1016/j.jfoodeng.2016.09.011

[3] Rocha, M.V.R., Souza, M.C.M., Benedicto, S.C.L., Bezerra, M.S., "Production of biosurfactant by *Pseudomonas aeruginosa* grown on cashew apple juice", Appl. BioChem. BioTechnol, Vol. 137, pp. 185-194, 2007. DOI: 10.1007/s12010-007-9050-6

[4] Gawankar MS, Salvi BR, Pawar CD, Khanvilkar MH, Salvi SP, Dalvi NV, Malshe KV, Kadam DS, Saitwal YS, Haldankar PM, "Technology Development for Cashew Apple Processing in Konkan region - A review" Advanced Agricultural Research & Technology Journal, Vol. II, no. 1, pp. 40-47, 2018. https://www.researchgate.net/publication/328096084_Technology_Development_For_Cashew_Apple_Processing_In_Konkan_Region-A_Review

[5] Barve Ketak, Agte Vaishali Arora Amit, "Anacardium occidentale by-Product: A Review on sustainable application and added-value", Journal of food nutrition and metabolism, Vol. 3, no. 1, pp. 1-6, 2020. DOI: 10.31487/j.JFNM.2020.01.04

[6] Oliveira V, Silva F, Resende E, Pereira P, de Silva F et Egea M.. "Caractérisation physico-chimique des fruits et pseudo-fruits de la noix de cajou 'Cerrado' (*Anacardium othonianum* Rizzini)", Journal of the Science of Food and Agriculture, Vol. 99, no. 14, pp. 6199-6208, 2019. DOI: 10.1002/jsfa.9892

[7] Lautié, E., Dornier, M., de Souza Filho, M. et Reynes, M. "Les produits de l'anacardier: caractéristiques, voies de valorisation et marchés", Fruits, Vol. 56, no. 4, pp. 235-248, 2001. DOI: 10.1051/fruits:2001126

[8] Dao, T. P., Nguyen, D. V., Tran, T. Y. N., Pham, T. N., Nguyen, P. T. N., Bach, L. G., Nguyen, V. H., Do, V. Q., Nguyen, V. M., & Tran, T. T.. "Effects of tannin, ascorbic acid, and total phenolic contents of cashew (*Anacardium occidentale* L.) apples blanched with saline solution", Food Research, Vol. 5, no. 1, pp. 409–416, 2021. DOI: 10.26656/fr.2017.5(1).454

[9] Michodjehoun-Mestres, L., J.-M. Souquet, H. Fulcrand, C. Bouchut, M. Reynes and J.-M. Brillouet, "Monomeric phenols of cashew apple (*Anacardium occidentale* L.)", Food Chemistry, Vol. 112, no. 4, pp. 851-857, 2009. DOI: 10.1016/j.foodchem.2008.06.056

[10] Assunção, R. B. and A. Z. Mercadante "Carotenoids and ascorbic acid composition from commercial products of cashew apple (*Anacardium occidentale L.)."* Journal of Food Composition and Analysis, Vol. 16, no. 6, pp. 647-657, 2003. DOI: 10.1016/S0889-1575(03)00098-X

[11] Soro Doudjo, Cissé Moctar, Kone Youssouf Kisselmina, Assidjo Emmanuel Nogbou, Yao Benjamin Kouassi and Dornier Manuel, "Valorization of cashew apple (*Anacardium occidentale*) and impact of vaccum evaporation at different temperatures in the juice quality" International Journal of Innovation and Applied Studies, Vol. 19, no. 1, pp. 98-107, 2017. https://issr-journals.org/xplore/ijias/0019/001/IJIAS-16-186-03.pdf

[12] Trakul Prommajak, Noppol Leksawasdi and Nithiya Rattanapanone, "Biotechnological valorization of cashew apple": A review, Chiang Mai University Journal of Natural Sciences, Vol. 13, no. 2, pp. 159-182, 2014. DOI: 10.12982/CMUJNS.2014.0029

[13] David, C.T. and Prasad, S.M., "Value added products from cashew apple", 1st International symposium on Cashew Nut -Acta Horticulturae 1080, 2015, pp. 383-389. DOI: 10.17660/ActaHortic.2015.1080.51

[14] Runjala, S. and Kella, D.L., "Cashew apple (*Anacardium occidentale* L.) therapeutic benefits, processing and product Development: An over view". Pharma Innovation, Vol. 6, no. 7, pp. 260-264, 2017. https://www.thepharmajournal.com/archives/2017/vol6issue7/PartD/6-7-53-698.pdf

[15] Emmanuelle, D., Joseph, D., Victor, A., and Mohamed, M. S., "A review of cashew (*Anacardium occidentale* L.) apple: Effects of processing techniques, properties and quality of juice". African Journal of. Biotechnology, Vol. 15, no. 47, pp. 2637-2648, 2016. DOI: 10.5897/AJB2015.14974

[16] Haendler L and Duverneui G., "Note sur les possibilités de transformation des fruits et des Faux fruits de l'anacardier (*Anacardium occidentale* L.", Institut français de Recherches fruitières Outre-Mer Fruits, Vol. 25, no. 5, pp.

379-384, 1970.https://agritrop.cirad.fr/421912/1/document_421912.pdf

[17] Zoecklein B, "Bentonite fining of juice and wine". Department of Horticulture. Virginia Polytechnic Institute & State University. Publication 463-014, pp. 1-8, 1988. https://enology.fst.vt.edu/downloads/bentonite01.pdf

[18] Ukonze, J.A., Ogu, E., Onu, F.M., Dimelu, I., Ifeanyieze, F.O. and Ejiofor, T.E. "Impact of clarification process on the nutritional, mineral and vitamin composition of cashew (*Anacardium occidentale*) apple juice. African Journal of Biotechnology", Vol. 17, no. 10, pp. 337-342, 2018. DOI: 10.5897/AJB2017.16337

[19] Naka, T., Martin, D.K., Soumaila, D., Simplice, G.T., Patrice, K.L. and Abrogoua, N. "Some physico-chemical properties of cashew gum from cashew exudates and its use as clarifying agent of juice from cashew apple". Agriculture and Biology Journal of North America, Vol. 7, no. 2, pp. 107-115, 2016. DOI: 10.5251/abjna.2016.7.2.107.115

[20] Campos, D.C.P., Santos, A.S., Wolkoff, D.B., Matta, V.M., Cabral, L.M.C. and Couri, S., "Cashew Apple Juice Stabilization by Microfiltration", Desalination, Vol. 148, no. 1-3, pp. 61-65, 2002. DOI: 10.1016/S0011-9164(02)00654-9

[21] Mai, H.C., "Application of cross-flow filtration technique in purification and concentration of juice from vietnamese fruits", Beverages, Vol. 3, no. 44, pp. 1-15, 2017. DOI: 10.3390/beverages3030044

[22] Kavitha Chandran CI and Indira G, "Quantitative estimation of total phenolic, flavonoids, tannin and chlorophyll content of leaves of Strobilanthes Kunthiana (Neelakurinji)", Journal of Medicinal Plants Studies, Vol. 4, no. 4, pp. 282-286, 2016. https://www.plantsjournal.com/archives/2016/vol4issue4/PartD/4-4-4-759.pdf

[23] Dheeraj, Ananya Srivastava, Anuradha Mishra., "Mitigation of cashew apple fruits astringency", Environmental Sustainability, Vol. 6, pp. 319-329, 2023. DOI: 10.1007/s42398-023-00276-7

[24] Hiroshi Moriwaki, Naoya Komori, Yoshitake Akiyama, "Interaction between nanoplastics and pectin, a water-soluble polysaccharide, in the presence of Fe (III) ion", Journal of environemental chimical engeering, Vol. 10, no. 3, pp. 1-19, 2022. DOI: 10.2139/ssrn.4085477

[25] Camirand, W.M., Forrey, R.R., Popper, K. Boyle, F.P. and Stanley, W.L., "Dehydration of membrane-coated foods by osmosis". J. Sei. Food Agric, Vol. 19, n0. 8, pp. 472-474, 1968. https://doi.org/10.1002/jsfa.2740190813

[26] Ashok Kumar Yadav, Satya Vir Singh, "Osmotic dehydration of fruits and vegetables: a review", Journal of Food Science and Technology, Vol. 51, no. 9, pp. 1654–1673, 2014. DOI: 10.1007/S13197-012-0659-2

[27] Bolin, H.R., Huxoll; C.C., Jackson, R. and NG, K.C. "Effect of osmos1s agents and concentration on fruit quality", J. Food Sei. Vol. 48, no. 1, pp. 202-205, 1983. DOI: 10.1111/j.1365-2621.1983.tb14823.x

[28] Bourge Mathilde, "Comment rattraper un plat trop salé ? 3 astuces pour sauver la mise", Fine Dining Lovers. https://www.finediningloversfr (accessed December 26, 2023).

[29] World Health Organization (WHO). "Reduce salt consumption", WHO. https://www.who.int/fr/news-room/fact-sheets/detail/salt-reduction (accessed December 20, 2023)

[30] Jefferson N. Curammeng, France Marie Ann R. Tacadena, Jonathan N. Tariga, Mary Joy A. Roldan, "Consumer Acceptability and Commercialization of Bamboo Shoot Tart". Food Science and Technology, Vol. 9, no. 4, pp. 77-86, 2021. DOI: 10.13189/fst.2021.090402