

# Evaluation of Physicochemical Characteristics of Marketed Fruit Juices in Côte d'Ivoire

Sawa André Kpaïbé<sup>1,2\*</sup>, Nina Carine Ablé<sup>1</sup>, Adjoua Marcelle Yao<sup>1</sup>, Jean Simon Yao<sup>1</sup>, Linda He<sup>1</sup>, Julien Kouamé<sup>1</sup>, N'cho Christophe Amin<sup>1,2</sup>

<sup>1</sup>Département des Sciences Analytiques et Santé Publique, UFR des Sciences Pharmaceutiques, Université Félix Houphouët-Boigny, Abidjan, Côte d'Ivoire

<sup>2</sup>Laboratoire d'Hygiène, Institut Nationale d'Hygiène Publique, Abidjan, Côte d'Ivoire

Email: \*andresawa@yahoo.fr

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## Abstract

Fruit juices are commonly consumed in Côte d'Ivoire for their nutritional benefits and pleasant flavor profile, serving as significant sources of vitamins and essential micronutrients. However, the extent of their health benefits largely depends on their physicochemical integrity. This study aimed to evaluate the physicochemical parameters of fruit juices produced by a single commercial brand available on the Ivorian market. A total of 21 distinct flavors were analyzed for characteristics, including density, electrical conductivity, pH, titratable acidity, formalin index, dry matter content, Brix value, and protein concentration. The obtained results were compared against established international standards to determine regulatory compliance. Notably, 17 out of the 21 samples failed to meet at least one of the referenced quality benchmarks, with titratable acidity and formalin index being the most frequent points of non-conformity. Among the non-compliant products were blended and nectar varieties such as Apple-Grape Mix, Pineapple-Ginger Mix, Coconut-Pineapple Mix, and 100% Grape Juice. These findings highlight a concerning gap in quality assurance and suggest that several of the analyzed juices should either be reclassified or removed from the market due to failure to meet legal labeling requirements.

## Keywords

Fruit Juice, Physicochemical Analysis, Quality Control

## 1. Introduction

Fruit juices are non-alcoholic, yet fermentable liquids extracted from the edible parts of sound fruits [1]-[3]. They are valued for their nutritional richness, particularly

in essential minerals and vitamins and retain the key physical, chemical, organoleptic, and nutritional characteristics of the source fruit [2] [3]. Owing to their associated health benefits, fruit juices have gained prominence in contemporary diets worldwide [4]-[8]. In Côte d'Ivoire, the rising popularity of fruit juices has fostered a dynamic and diversified market, with numerous brands offering a broad spectrum of flavors. Upholding the quality of these products in accordance with Codex Alimentarius standards is imperative, as non-compliant juices may pose risks to public health. Despite this, there remains a notable gap in the literature concerning the physicochemical evaluation of commercially available fruit juices in the region [9]. This study assessed the physicochemical quality of juice brands available in Côte d'Ivoire, in order to rapidly evaluate their compliance with Codex Alimentarius standards.

## 2. Material and Methods

### 2.1. Equipment

The equipment used for the analyses included a probe pH meter (Hanna<sup>®</sup>, United Kingdom), a probe conductimeter (Wagtech<sup>®</sup>, United Kingdom), a water bath (Mettler<sup>®</sup>, France), a densimeter (Alla France<sup>®</sup>, France), a mercury thermometer (SP Bel-art<sup>®</sup>, United Kingdom), an automated analyzer (Brücker<sup>®</sup>, Germany), a moisture analyzer (Ohaus<sup>®</sup>, Switzerland), a magnetic stirrer (Selecta<sup>®</sup> Barcelona), an analytical balance (Ohaus<sup>®</sup>, Switzerland), and a portable digital refractometer (Infitek<sup>®</sup>, China). The glassware used was of analytical grade quality.

### 2.2. Reagents

The reagents used included phenolphthalein, sodium hydroxide solution (0.1 N), sodium hydroxide solution (0.25 N), distilled water, Tashiro's reagent, copper sulfate, potassium sulfate, boric acid, sulfuric acid (0.1 N), and 35% formaldehyde adjusted to pH 8.1.

### 2.3. Samples

The analyzed sample included 21 different flavors from a batch of commercially available fruit juices. For each flavor, two beverages were selected. The analyses were repeated a second time to ensure the reliability of the results. The quantities, batch numbers, and volumes of the various fruit juices are detailed in **Table 1**.

**Table 1.** Analyzed fruit juice sample. Twenty-one flavors were included. The samples consist of one batch for each analyzed flavor.

<i>Arôme</i>	<i>Volume (ml)</i>	<i>Colisage</i>	<i>Arôme</i>	<i>Volume (ml)</i>	<i>Colisage</i>
<i>100% raisin</i>	<i>1000</i>	<i>12</i>	<i>mini cocktail</i>	<i>200</i>	<i>24</i>
<i>100% ananas</i>	1000	12	mix nectar ananas	1000	12
<i>100% orange</i>	1000	12	mix nectar goyave	1000	12
<i>100% pomme</i>	1000	12	mix nectar mangue	1000	12

## Continued

<i>mix pomme-raïsin</i>	1000	12	tetra square mix nectar orange	1000	12
<i>mix Ananas-gingembre</i>	1000	12	mix nectar pomme	1000	12
<i>mix coco-Ananas</i>		12	Mini orange	200	24
<i>fresh mangue-coco</i>	1000	12	Mini ananas	200	24
<i>100% multifruit</i>	1000	12	Mini pomme	200	24
<i>mix nectar cocktail</i>	1000	12	orange pet	1000	12
<i>pet tropical flacon</i>	1000	12			

## 2.4. Methods

The following physicochemical parameters were analyzed: density, pH, conductivity, dry matter, titratable acidity, formaldehyde index, sugar content, and protein content. The pH meter, refractometer, and densimeter were calibrated using certified standard solutions, in accordance with the manufacturers' recommended protocols. For each parameter, the analysis was performed four times to ensure the reliability of the results. Accordingly, the mean values of each parameter were presented in **Table 2** [1] [10] [11].

**Table 2.** Operating procedures for physicochemical parameters.

Parameter	Operating Procedure
<b>Density</b>	Measurement of density using a densimeter in a 200 ml sample of juice.
<b>pH</b>	pH measurement using an electronic pH meter. The reading was directly displayed on the pH meter screen.
<b>Conductivity</b>	Conductivity measurement using a calibrated conductometer. The conductivity result is expressed in $\mu\text{S}/\text{cm}$ .
<b>Dry Matter</b>	5 ml of fruit juice was introduced into the reader, which, once activated, provided the dry matter content as a percentage.
<b>Titratable Acidity</b>	10 ml of fruit juice and 3 drops of phenolphthalein were added to a beaker. Titration was then carried out with a 0.1 N NaOH solution. The acidity is expressed in grams of citric acid per liter of juice.
<b>Formaldehyde Index (Amino Acid)</b>	25 ml of fruit juice was sampled and placed into a beaker with 2 - 3 drops of phenolphthalein. The sample was then neutralized with a 0.25 N NaOH solution. Afterward, 10 ml of formaldehyde solution was added. After 1 minute, titration was performed with a 0.1 N NaOH solution.
<b>Sugar Content</b>	A drop of the sample was placed on the surface of the refractometer, which was then directed towards a light source with two zones. The equilibrium between the two zones allowed for the reading of the sugar content.
<b>Protein Content</b>	5 ml of juice was placed in a capsule and introduced into the analyzer. The total organic matter value was obtained. The protein content was calculated as follows: Proteins = Total organic matter - (carbohydrates + lipids).

### 3. Results

The physicochemical analysis of various fruit juices and nectars revealed several deviations from the standards established by Codex stan 450 [1] [12].

The pure grape and orange juices showed titratable acidity values lower than the standard established by Codex Alimentarius. The formol index of the pure orange juice, however, was higher than the standard (Table 1). All five analyzed fruit juices exhibited titratable acidity and formol index values lower than those specified by Codex Alimentarius (Table 2) [13].

**Table 3.** Physical and chemical values of 100% fruit juices.

Parameters	100% Grape	100% Pineapple	100% Orange	100% Apple	Standards
Density	1.06	1.05	1.04	1.05	≥1.04
Conductivity (µS/cm)	1689	3265	2918.5	2352.5	-
pH	3.47	3.95	3.45	3.54	3 - 4.5
Temperature (°C)	23	22.9	22.8	22.8	-
Titratable Acidity (mg/l)	3.2	8.4	5.6	7.6	6.3 - 17
Dry Matter (%)	19.25	15.23	12.49	15.03	-
Formaldehyde Index	16.0	14.0	20.8	11.2	8 - 20
Brix Degree (%)	15.7	12.5	11.05	11.5	-
Protein (mg/100 ml)	0.46	1.07	0.54	0.82	0.4 - 1.5

**Table 4.** Physicochemical values of juices based on two fruits.

Parameters	Mix Apple-Grape	Mix Pineapple-Ginger	Mix Coconut-Pineapple	Fresh Mango-Coconut Pet	Standards
Density	1.04	1.05	1.04	1.04	≥1.04
Conductivity (µS/cm)	731	737	731	739	-
pH	3.1	3.0	3.1	3.41	3 - 4.5
Temperature (°C)	22.9	23	22.9	22.7	-
Titratable Acidity (mg/l)	3.2	4.8	3.2	4.0	6.3 - 17
Dry Matter (%)	16.72	15.41	16.72	12.49	-
Formaldehyde Index	6.8	6.8	6.8	4.8	8 - 20
Brix Degree (%)	12.8	12.7	12.8	9.97	-
Protein (mg/100 ml)	0.65	0.45	0.65	0.54	0.4 - 1.5

The tropical fruit juice presented a pH value lower than the limit set by the standard. Both the pasteurized and non-pasteurized cocktails had formol index values below the Codex Alimentarius threshold. Additionally, the titratable acidity values of the Tropical juice and the non-pasteurized cocktail were also below the standard (Table 3). The nectars of guava, apple, pineapple, and mango showed titratable acidity values below the limit defined by Codex Alimentarius. The nectars of guava, mango, and apple had formol index values below the standard as well (Table 4). The orange and pineapple nectars exhibited pH values lower than the Codex Al-

imentarius limit. Overall, the titratable acidity, protein content, and formol index of all nectars were below the limits established by Codex Alimentarius [12] [13] (Tables 5-7).

**Table 5.** Physicochemical values for cocktails and mixed fruit blends.

Parameters	100% Multi-Fruit	Nectar Cocktail Pet	Tropical Flacon	Mini Cocktail	Standards
Density	1.05	1.05	1.05	1.04	≥1.04
Conductivity (µS/cm)	2710	1241.5	805	679.5	-
pH	3.66	3.31	2.98	3.04	3 - 4.5
Temperature (°C)	23	23	22.5	24	-
Titratable Acidity (mg/l)	8.0	6.0	5.2	3.6	6.3 - 17
Dry Matter (%)	15.12	16.50	18.03	12.70	-
Formaldehyde Index	15.2	6.4	8.8	6.0	8 - 20
Brix Degree (%)	11.6	12.5	13.1	10.1	-
Protein (mg/100 ml)	0.84	0.81	0.51	0.51	0.4 - 1.5

**Table 6.** Physicochemical and nutritional values of pasteurized nectars.

Parameters	Mix Nectar Pineapple	Mix Nectar Guava	Mix Nectar Mango	Mix Nectar Orange	Mix Nectar Apple	Standards
Density	1.04	1.05	1.06	1.05	1.05	≥1.04
Conductivity (µS/cm)	1471.5	1396	1102	2411.5	987	-
pH	3.3	3.59	4.13	3.72	3.06	3 - 4.5
Temperature (°C)	23.5	24	23	23	23	-
Titratable Acidity (mg/l)	4.4	4	1.6	9.2	5.6	6.3 - 17
Dry Matter (%)	11.7	3.12	3.37	15.27	17.45	-
Formaldehyde Index	8.4	6	6.8	19.6	5.6	8 - 20
Brix Degree (%)	12.15	12.5	14.7	12.8	14.6	-
Protein (mg/100 ml)	0.71	0.56	0.58	0.88	0.59	0.4 - 1.5

**Table 7.** Values for non-pasteurized nectars.

Parameters	Mini Orange	Mini Pineapple	Mini Apple	Orange Pet 11	Standards
Density	1.04	1.04	1.04	1.05	≥1.04
Conductivity (µS/cm)	647	647	620	873	-
pH	2.89	2.89	3.11	3.01	3 - 4.5
Temperature (°C)	24	24	23.5	22.7	-
Titratable Acidity (mg/l)	3.6	3.6	4	5.2	6.3 - 17
Dry Matter (%)	13.00	13.00	12.69	16.33	-
Formaldehyde Index	7.2	7.2	4	7.2	8 - 20
Brix Degree (%)	10.25	10.25	10	12.7	-
Protein (mg/100 ml)	0.54	0.54	0.59	0.54	0.4 - 1.5

## 4. Discussion

The physicochemical assessment of a selection of commercially available fruit juices revealed substantial variability in key quality parameters, with several samples failing to meet the Codex Alimentarius standards [1] [12]-[14]. While all juices exhibited densities approximating that of water (1.00 g/cm<sup>3</sup> at 25 °C), indicating appropriate dilution levels, notable deviations were detected in pH, titratable acidity, and formalin index values.

Specifically, products such as Mini Orange, Mini Pineapple, and PET Tropical displayed pH levels below 3, reflecting excessive acidity. This heightened acidity may adversely affect sensory attributes and compromise microbiological stability. Variations in pH could result from fruit maturity at harvest, agro-climatic conditions, or acidification during manufacturing.

Titratable acidity and formalin index were the most frequent non-compliant indicators. Elevated formalin index values in juices like 100% Orange and Grape Juice suggest a high concentration of naturally occurring amino acids. Conversely, low formalin index values observed in blended and pasteurized nectars may indicate amino acid degradation or dilution, likely due to water addition or thermal over-processing.

Electrical conductivity measurements revealed greater ionic concentrations in pure juices and orange nectar, suggesting higher mineral content. However, conductivity alone is insufficient to determine overall juice quality without supporting parameters.

Dry matter content, which impacts both texture and nutritional value, varied considerably, with the highest in Grape Juice and Apple Nectar, and lowest in non-pasteurized Guava and Mango Nectars. These low values raise concerns about actual fruit concentration and potential adulteration.

Protein content across all samples remained minimal, consistent with reports that most fruit juice proteins are either insoluble or denatured during processing. While not directly harmful, the low protein levels underscore the limited nutritional contribution of fruit juices in terms of amino acids.

Importantly, all juices complied with international Brix standards, affirming the absence of added sugars, an essential consideration for consumer health and regulatory adherence. Nevertheless, the identification of at least one non-compliant physicochemical parameter in every sample underscores deficiencies in production control. These findings advocate for stricter monitoring of manufacturing practices, enhanced transparency in ingredient sourcing, and improved preservation techniques to ensure both compliance and nutritional integrity.

## 5. Conclusion

This study evaluated the physicochemical characteristics of twenty-one fruit juice varieties produced by a single brand and marketed in Côte d'Ivoire. The analytical findings revealed that seventeen of these samples did not conform to international standards defined by the Codex Alimentarius, notably regarding titratable acidity

and the formal index. These non-compliances suggest potential deficiencies, which could compromise both the nutritional quality and safety of the products. Given these findings, the immediate withdrawal of the non-compliant juices from circulation is advised. Moreover, to better protect consumer health and uphold food safety standards, it is important to broaden the analysis to include microbiological parameters and to establish routine, comprehensive quality control across all fruit juice products on the Ivorian market.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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