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Influence of Heat Treatment on the Nutrient Profile of Cashew Kernel Milk (*Anacardium occidentale* L.)

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Abstract During cashew processing, many kernels are broken and cracked, which exposes them to rapid deterioration and thus negatively impacts their market value. Consequently, broken kernels represent non-exportable cashew by-products. In this study, milk was produced from broken cashew kernels as a value-added product and the effect of heat treatment time on the biochemical characteristics of this milk was determined in order to add value. The milk was boiled at 98°C for 45 min during which samples were regularly taken every 15 min and subjected to biochemical analysis. The water content of cashew milk decreased significantly ($P<0.05$) during this treatment, from 88.9% to 84.96%. Energy macronutrients were significantly concentrated during the 45 min treatment ($p<0.001$). Thus, carbohydrate, lipid and protein contents increased from 1.79% to 2.22%; 2.94% to 4.82% and 6.24% to 7.75%, respectively; and generate an energy value evolving from 58.58 to 83.26 Kcal. Also, boiling milk increases its mineral density and leads to the highest ash content (0.25%) after 45 min of treatment. This mineral concentration provided mineral salt contents from 171.7 to 285.8 mg Mg/L, 175.1 to 229.5 mg Fe/L, 100.6 to 101.4 mg Ca/L, 29.4 to 74.4 mg K/L, 46.4 to 60.9 mg Zn/L and 27.2 to 20.6 mg Na/L of product. In addition, heat treatment significantly influenced the presence of anti-nutritional factors ($P<0.001$) in cashew milk, leading to a decrease in the contents of tannins (19.52 mg/100 g DM), phytates (37.57 mg/100 g DM) and oxalates (44.52 mg/100 g DM) to values of 15.55, 28, 46 and 40.60 mg/100 g DM after 15 min, respectively, and then to their total absence after 30 min of treatment. Heat treatment increases the nutritional value of cashew kernel milk while removing the anti-nutrients typical of vegetable milks.

Keywords: *cashew almond milk, broken almonds, boiling, nutritional composition, anti-nutrients*

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1. Introduction

The cashew tree of its scientific name *Anacardium occidental* L. is a tree native to South America belonging to the Anacardiaceae family [1,2,3]. It is cultivated on nearly 7091275 hectares (ha) in the world including 1913073 ha in Côte d'Ivoire with cashew nuts as the main product [4]. The production of cashew nuts amounts to about 4 million tons (T), with nearly 800 000 T in Côte d'Ivoire [4].

The cashew kernel, extracted from the cashew nut, is the main product of the cashew tree. This kernel is an excellent source of protein, carbohydrates and lipids and contains high levels of dietary fibre (5.9g/100g) and unsaturated fatty acids (20-60% of fat) [5]. Cashew kernels also contain various micronutrients. Thus, the presence of vitamins such as vitamin E and B (0.9 mg/100g and 25 µg/100g, respectively) and mineral elements such as potassium (660 mg/100g), magnesium (292 mg/100g) and calcium (37mg/100g) have been reported [6]. Also, phytosterol contents of 150 to 158 mg/100g have been reported [7].

Cashew kernel is consumed salted or spiced. It is also used in the food industry for pastries (cakes and ice cream), chocolate and confectionery, and its oil is used to produce cashew butter with considerable nutritional value. Thus, the nutritional potential of cashew kernels is an asset in the face of malnutrition linked to deficiencies in energy, proteins and essential fatty acids. [8].

In addition, various valorisation trials have concluded on the use of cashew kernel in the production of vegetable milk, as an alternative to animal milk. In fact, in view of the cases of lactose intolerance, hypercholesterolemia and to a lesser degree vegetarian diets, which are incompatible with the consumption of cow's milk, the popularization of cholesterol- and lactose-free vegetable milks constitutes an important advantage for the health of many social classes. [9]

However, despite these nutritional benefits, cashew kernels contain anti-nutritional factors, including phytic, oxalic and tannic acid derivatives that inhibit the absorption of certain nutrients [10,11].

Heat treatment is a common practice used in food processing to prevent spoilage and extend the shelf life of products [12]. During heat treatment, physical and chemical changes are observed. These changes include denaturation of proteins, coagulation of lipids, decomposition of starch, leaching of mineral salts, degradation of essential amino acids and vitamins, often with a negative impact on food quality [13]. Heat treatment is therefore an important factor to control in the processing and nutritional enhancement of food products.

During the extraction of cashew nuts, large quantities of kernels are broken and represent by-products.

These broken kernels, which are of inferior marketable quality and generally not exported, are subject to rapid deterioration, especially if they are not stored properly. Their value lies in the transformation into local products that can be appreciated by consumers. The present investigation evaluates different parameters of cashew kernel milk following different heat treatment times, in order to provide a product with appreciable nutritional qualities with a lower presence of anti-nutrients and thus improve the profitability of cashew trees.

2. Material and Methods

2.1. Material

The biological material used in the study consisted of cashew kernel chips. These kernels were collected from the Cashew Innovation and Technology Center (CITA) located in the city of Yamoussoukro (Aries region) in central Côte d'Ivoire at 6°49′13″ North latitude and 5°16′36″ West longitude.

2.2. Methods

2.2.1. Production of Cashew Nut Milk

The broken almonds were soaked in hot water for 6 hours to be blanched. After blanching they were drained through a sieve. The drained almond fragments were then ground in a blender (Binatone brand) at a ratio of 1: 4 (w/v: weight of cashew kernels/volume of water). The grinding of the kernels was carried out for 5 min. The resulting dispersion was homogenized and then filtered three times through muslin cloth to collect the refined milk. This milk was acidified with edible citric acid in sufficient quantity to obtain a product with a pH of about 4. The cashew kernel milk thus obtained was packaged in sterile glass containers and stored at 4°C before the various analytical treatments. [13]

2.2.2. Cooking of Cashew Almond Milk

Cooking of cashew milk was carried out according to the method of Orhevba [14]. A four-litre (4 L) test sample of almond milk was boiled at a temperature of 98°C, measured with a food thermometer (FPT EUROCOLDCHAIN). As soon as boiling was observed, a first sample of the milk was taken (E1). Then, at intervals of 15 min, three other milk samples were also taken, namely E2 at 15 min, E3 at 30 min and E4 at 45 min. All these samples were packed in 350 mL polyethylene storage jars and previously sterilized.

2.2.3. Physicochemical and Biochemical Analysis of Cashew Kernel Milk

Cashew milk samples were analyzed for acidity (pH and titratable acidity), dry matter and macronutrient content (carbohydrates, proteins and lipids) to estimate energy value, as well as for mineral composition and anti-nutritional factors (tannins, phytates and oxalates).

The pH was determined using a pH meter (HI8314 - Hanna Instruments Morocco) [15]. The titratable acidity was estimated by acid-base determination with a soda solution (NaOH) at 0.1 N in the presence of phenolphthalein as a colored indicator, according to the AFNOR method [16], The dry matter (DM) and moisture (HUM) contents were obtained by gravimetric measurement using an oven (UN55 - Memmert) and a scale (Sartorius Practum 224-1S) [17].

The free sugar contents were obtained by spectrophotometric assays. Total sugars were determined using phenol and sulphuric acid [18]; while the use of 3, 5 dinitrosalycillic acid (DNS) was used to quantify reducing sugars [19]. Protein content was assessed using the Kjeldahl total nitrogen method [17]**.** The fat content (TMG) of cashew milk samples was determined by cold extraction using dichloromethane/methanol (2: 1, v/v) solution as a binary mixture of extraction solvents [20]. From the protein, fat and dry matter contents, the total carbohydrate contents (TCC) were calculated by the difference method [21]. The content of caloric macronutrients was used to determine the total energy value (TEV) of cashew milk samples by applying their caloric coefficients [22].

The mineral element composition of cashew milk samples was recorded from their ash produced by incineration [23]. Then, the mineral composition of the ash (Ca, Na, Fe, Mg, Zn and K) was determined by atomic absorption spectrophotometry using strong acids [17].

Cashew milk tannins were quantified using vanillin [24]. The determination of oxalates and phytates was carried out using potassium permanganate [25] and Wade's reagent [26] respectively.

2.2.4. Statistical Analysis

Statistical analysis was carried out by the Statistical Package for Social Sciences (SPSS version 22.0). An analysis of variance was performed at 5% significance with respect to the processing time of cashew milk samples. Then, the means of the biochemical indicators were compared using the Student Newman Keuls test.

3. Results and discussion

3.1. Results

3.1.1. Physicochemical Composition

Figure 1 and Figure 2 show the acidity (pH, titratable acidity) of the milk samples studied, while Figure 3 shows the amount of material dissolved in the milk. At the beginning of boiling at 98 ° C, the pH of cashew milk is acidic and is established at 4.19, with a titratable acidity of 58°D. This acidity remains almost constant (P > 0, 05) in the samples analyzed during the 45 minutes of heat treatment where the cashew milk has a pH of 4.2 for 57 °D. With dry matter, the initial content of 11, 1% at the beginning of boiling (E1) increases significantly (P<0.001) by 15 min delay. The values increase to 12. 02%, 13. 44% and 15.04% after boiling times of 15 min (E2), 30 min (E3) and 45 min (E4) respectively. Conversely, the moisture content of the milk decreases significantly with boiling time from 88.9% (E1) to 87.98% (E2), 86.59% (E3) and 84.96% (E4) after 15, 30 and 45 min of treatment respectively.

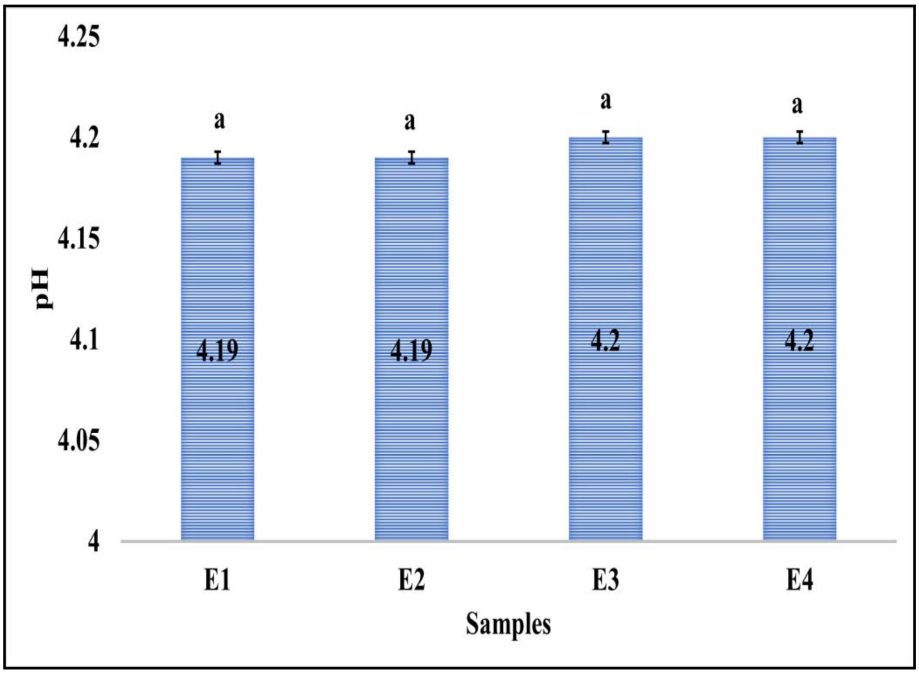

Figure 1. Hydrogen potential (pH) of cashew nut milk samples studied

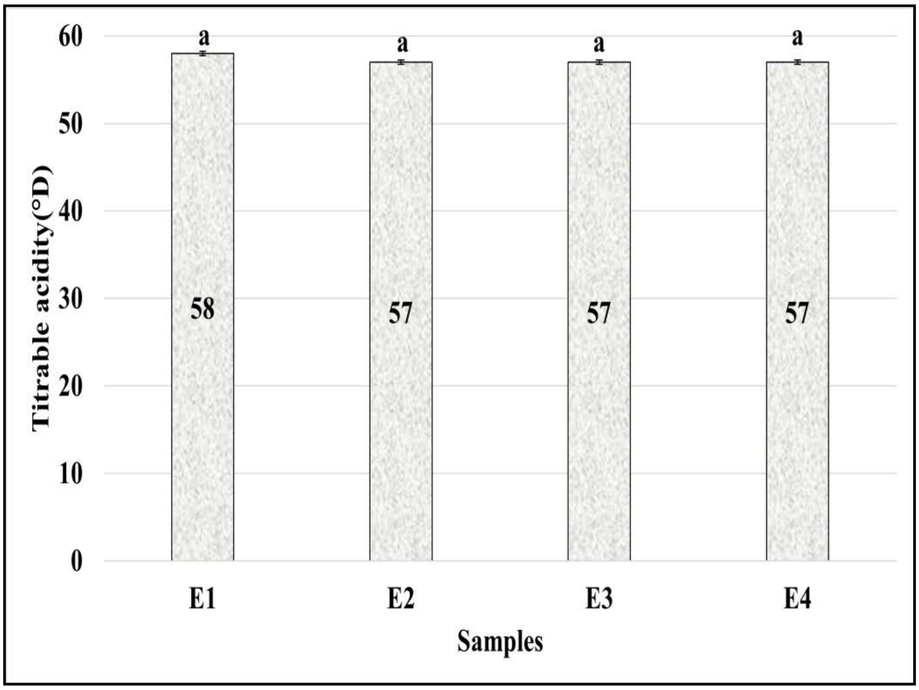

Figure 2. Titratable acidity (in Dornic degree or °D) of cashew kernel milk samples studied

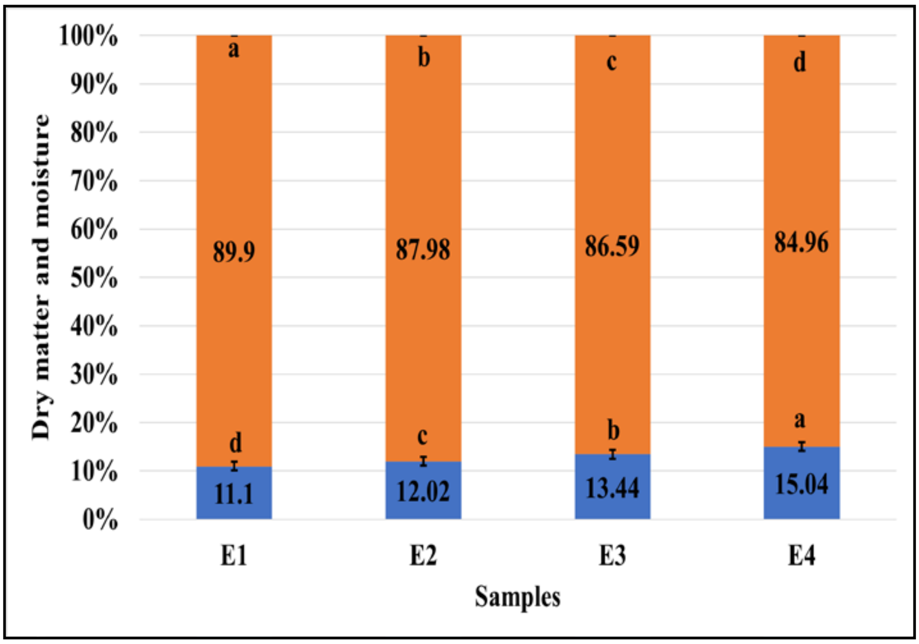

Figure 3. Dry matter content (blue) and moisture content (green) of cashew kernel milk samples

3.1.2. Macronutrient Composition

The increase in energy macronutrient composition of cashew milk is presented in Table 1. Overall, the content of these nutrients increases significantly during the 45 min of boiling milk at 98 ° C. Thus, the protein content is estimated to be 6.24% at the beginning of boiling. It increases steadily during the treatment to reach a value of 7.75% after 45 minutes of boiling. With fat, the content is 2.94% at the onset of boiling; then increases to 3.55, 4.35 and 4.82% after 15 min, 30 min and 45 min of treatment. The percentage of total carbohydrates in cashew milk was significantly affected during the boiling periods. A significant increase ($P<0.05$) was observed with values ranging from 1.79% (E1) and 2.22% (E4). However, the fraction of total free sugars shows generally increasing contents ($P<0.001$) with the duration of heat treatment; the contents going from 25.57 mg/100 mL to 34.01 mg/100 mL. On the other hand, the amounts of reducing sugars remain statistically unchanged during the first 30 minutes of treatment where the values are about 5 mg/100 mL, while it increases significantly after 45 min of treatment (8.02 mg/100 mL). On the basis of caloric nutrients, the overall energy value of the milk samples analyzed varied during the treatment. From a statistically lower value at the beginning of boiling (58.58 Kcal), cashew milk provides 65.07, 74.47 and 83.26 Kcal/100 g, after 15, 30 and 45 min of boiling at 98°C respectively.

3.1.3. Mineral Composition

Table 2 shows the mineral parameters of the cashew milk samples studied. The milk has a lower ash content (0.13%) in the first moments of boiling at 98°C. But during the 45 minutes analyzed after boiling, the ash contents are significantly higher, increasing progressively to 0.19%, 0.23%, and 0.25%. In the heat-treated ash, the contents of desired minerals are significantly different ($p<0.05$). Thus, magnesium (Mg), iron (Fe) and calcium (Ca) are more abundant in cashew milk (more than 100 mg/L), compared to potassium (K), zinc (Zn) and sodium (Na) with less than 50 mg/L. From boiling at 98°C, the contents of Mg (171.7 mg/L) and Fe (175.2 mg/L) increased significantly and steadily to reach values of 285.8 and 229.5 mg/L respectively 45 min later. For K and Zn, the contents are 29.4 and 46.4 mg/L at the beginning of boiling; then significantly during boiling to values of 74.4 and 60.9 mg/L after 45 min. With Ca, the content is relatively higher for a treatment of more than 30 min after boiling (> 101 mg/L), compared to the value of 100 mg/L obtained within 15 min after boiling. As for the Na content, a decrease is observed during boiling, dropping from 27.23 mg/L (E1) to 20.60 mg/L (E4).

Table 1. Macronutrient composition of cashew milk samples studied

Indicators	E1	E2	E3	E4	F-*value*	P-*value*
Proteins (%)	6.24 ± 0.01^{d}	6.47 ± 0.02^{c}	6.86 ± 0.01^{b}	7.75 ± 0.01^{a}	12217.04	<0.001
Lipids (%)	2.94 ± 0.01^{d}	3.55 ± 0.01^{c}	4.35 ± 0.01^{b}	4.82 ± 0.07^{a}	1779.27	<0.001
Carbohydrates (%)	1.79 ± 0.03^{d}	1.81 ± 0.19^{c}	1.97 ± 0.19^{b}	2.22 ± 0.08^{a}	0.75	<0.001
Total sugars (mg/100 mL)	25.57 ± 0.16^{c}	22.9 ± 0.17^{d}	27.03 ± 0.46^{b}	34.01 ± 0.61^{a}	408.721	<0.001
Reducing sugars (mg/100 mL)	5.03 ± 0.25^{b}	3.97 ± 0.55^{b}	5.02 ± 0.67^{b}	8.02 ± 0.66^{a}	29.157	<0.001
Energy value (Kcal/100 g)	58.58 ± 0.15^{d}	65.07 ± 0.89^{c}	74.47 ± 0.67^{b}	83.26 ± 0.47^{a}	932.21	<0.001

E1: Cashew milk taken immediately after boiling at 98 °C; **E2**: Cashew milk taken 15 min after boiling at 98°C; **E3**: Cashew milk taken 30 min after boiling at 98°C; **E4**: Cashew milk taken 45 min after boiling at 98°C; **°D**: dornic degree; **TPR**: protein content; **TMG:** fat content; **TGT**: total carbohydrate content; **TST:** total free sugar content; **TSR:** reducing sugar content; **TEV**: total energy value; **F-value**: value of the Ficher statistic; **P-value**: value of the probability of the statistical test.
Per line, the means ±scales with the same letter are statistically equivalent.

Table 2. Mineral composition of cashew milk samples during boiling at 98°C (mg/L)

Indicateurs	E1	E2	E3	E4	F-*value*	P-*value*
Ash (%)	0.13±0.02[c]	0.19±0.01[bc]	0.23±0.06[b]	0.25±0.02[a]	8.3	.008
Magnésium (Mg)	171.7±0.25[d]	246.4±0.5[c]	250.4±0.25[b]	285.8±0.8[a]	27044.9	<0,.01
Iron (Fe)	175.1±0.23[d]	183.7±0.19[c]	191.3±0.26[b]	229.5±0.01[a]	440.96	<0.001
Calcium (Ca)	100.6±0.01[b]	100.8±0.1[b]	101.3±0.02[a]	101.4±0.02[a]	23.17	<0.001
Potassium (K)	29.4±0.4[d]	52.3±0.4[c]	59.6±0.6[b]	74.4±0.18[a]	8819.9	<0.001
Zinc (Zn)	46.4±0.53[d]	49.1±0.4[c]	51.3±0.2[b]	60.9±0.1[a]	414.72	<0.001
Sodium (Na)	27.2±0.08[a]	24.4±0.10[b]	22.33±0.58[c]	20.6±0.2[d]	62.96	<0.001

Per line, the means ±scales with the same letter are statistically equivalent.

Table 3. Anti-nutrient composition (mg/100gDM) of cashew milk samples studied

Indicators	E1	E2	E3	E4	F-*value*	P-*value*
Tanins	19.52±0.01[a]	15.55±0.01[b]	0.00±0.00[c]	0.00±0.00[c]	9452057.00	<0.001
Phytates	37.57±0.00[a]	28.46±0.02[b]	0.00±0.00[c]	0.00±0.00[c]	19395541.71	<0.001
Oxalates	44.52±0.03[a]	40.60±0.01[b]	0.00±0.00[c]	0.00±0.00[c]	839533.95	<0.001

Per line, the means ±scales with the same letter are statistically equivalent.

3.1.4. Anti-nutrient Composition

Table 3 shows a highly significant difference (P<0.001) in the anti-nutritional compounds of cashew milk during treatment at 98°C. The first 15 min of boiling of cashew milk is marked by substantial contents of tannins, phytates and oxalates, although with decreasing values of 19.52 to 15.55 mg/100 g DM, 37.57 to 28.46 mg/100 g DM and 44.52 to 40.60 mg/100 g DM respectively. However, after 30 min of boiling at 98°C, the milk samples become totally devoid of these three antinutrients.

3.2. Discussion

The observed decrease in cashew milk moisture is a result of water evaporation with increasing heat treatment time. This analysis is comparable with the results reported for soy milk and sesame milk treated under similar conditions [13,27]. Moisture is a limitation to preservation. Products with high moisture have a high water activity; this favours biological activities such as enzymatic reactions and microbial proliferation at the basis of their rapid deterioration. For the cashew milk analysed, samples subjected to 45 min of boiling at 98°C could induce less water activity and would be more conducive to preservation. The invariability of the acidity of milk during the 45 minutes of treatment could be due to a small change in the acid content of this product. Indeed, a higher treatment temperature (98°C) would induce a greater volatilization of acidic residues, carbon dioxide (CO_2) and destabilize the hydrogen bonds, phenomena favorable to the rapid rise in pH and reduction of the acidity of the environment. Moreover, pH clearly acidic are not compatible with the proliferation of a large number of microorganisms, such as yeasts, whose optimal growth is rather observed at pH between 5 and 6.5. The acidification of cashew milk before its heat treatment and the acidity values obtained in our work could be indicators favorable to the proper preservation of the characteristics of this food product.

Unlike moisture, dry matter and macronutrients in cashew milk show increasing concentrations with boiling time. The increase in protein content does not support the results obtained with soy milk boiled for 15, 30 and 45 min [14]. During this concentration of proteins, the contents (6.24 to 7.75%) remain higher than those of soy milk (3.72 to 4.74%), justifying that almond milk is clearly valuable for its protein content. With fat, the results showed an increase, contrary to the trend of decrease reported in vegetable milks [13,14], which could be due to the evaporation of water during boiling. Indeed, the decrease of water at longer exposure times induces a concentration of lipids that would tend to be found on the surface of cashew milk.

The percentage of total carbohydrates in cashew milk was significantly affected during the boiling periods. A significant increase (P<0.05) was observed with values ranging from 1.79% (E1) and 2.22% (E4). This significant increase could be due to the soaking in hot water of cashew kernels before the production of cashew milk as observed during the production of sesame milk [13,28]. Indeed, the bleaching would have promoted the release of total carbohydrates that during boiling would have been amplified by the hydrolysis of certain bonds in which they are engaged.

An increase in energy value is observed with increasing cooking time. This is in line with the increase in caloric macronutrient content of the analysed samples [22,29].

Milk ash also showed significantly increasing levels during the heat treatment of cashew milk. Together with the macronutrients, the accumulation of ash is an indicator of the nutritional improvement of cashew milk by this processing without altering the quality of the product. This is because the mineral chemical elements remain stable at the applied temperature and are not affected by cooking methods that usually involve heating the food for long periods of time. Thus, most of the mineral elements (Mg, Fe, Ca, K, Zn) become concentrated as the amount of water in the medium decreases. This increase in minerals during the heat treatment of milk at its boiling point between 0 and 30 minutes is also combined with the decrease in anti-nutrients, including tannins, oxalates and especially phytates. These observations could be explained by the fact that various chemical elements such as calcium and potassium are released during boiling because they are part of the molecular skeleton of phytic acid and phytin [30]. In fact, cooking time would have pronounced effects on anti-nutrient factors present in foods [31]. The decrease of these anti-nutrients during cooking is an advantage in the food value of cashew milk. Furthermore, the results revealed a decrease in sodium (Na) content with increasing processing time. Such an observation is a considerable advantage for this processing technology since the consumption of large amounts of sodium is inappropriate with cardiovascular health. An excess of sodium salt consumption is likely to cause physiological deviations such as water retention, skin aging, cardiovascular disorders, increased risk of cognitive decline, arterial hypertension, edema formation, heart and kidney failure, *etc*. Therefore, the reduction of its consumption is advocated in nutritional programs for public health [32]. Cashew milk heated to 98°C for 45 min could thus be consumed without danger to human health.

4. Conclusion

In this study, heat treatment at 98°C for 45 min had a significant effect on the physicochemical composition and nutritional value of cashew kernel milk. The results showed that the values obtained after 45 min of boiling at 98°C are more significant than those of lower treatment times.

At this stage of heat treatment, the cashew milk has a protein, lipid and total carbohydrate content of 7.75%, 4.82% and 2.22% respectively, providing an energy value of 83.26 Kcal. The essential mineral elements are more concentrated while the presence of sodium is clearly reduced and the product is free of anti-nutrients. The production of cashew milk following cooking at 98°C for 45 minutes seems appropriate in the food processing of cashew kernels. It would represent a way to enhance the consumption of cashew products in order to improve the profitability of this crop.

Authors' Contributions

CN conducted the work. She exploited the results and wrote the manuscript. DS participated in the acquisition of the raw material and in the realization of the manipulations in the laboratory. MAY contributed to the improvement of the manuscript by correcting it. EKK contributed to the improvement of the manuscript, validated the laboratory protocols and supervised all the work. He was the scientific leader of this study.

Conflict of Interest

The authors declare no potential conflicts of interest.

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