Bioactive Compounds in Cashew Nut (Anacardium occidentale L.) Kernels: Effect of Different Shelling Methods

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In the present study, the effects of various conventional shelling methods (oil-bath roasting, direct steam roasting, drying, and open pan roasting) as well as a novel “Flores” hand-cracking method on the levels of bioactive compounds of cashew nut kernels were investigated. The raw cashew nut kernels were found to possess appreciable levels of certain bioactive compounds such as β-carotene (9.57 μg/g of DM), lutein (30.29 μg/g of DM), zeaxanthin (0.56 μg/g of DM), α-tocopherol (0.29 mg/100 g of DM), γ-tocopherol (1.10 mg/100 g of DM), thiamin (1.08 mg/100 g of DM), stearic acid (4.96 g/100 g of DM), oleic acid (21.87 g/100 g of DM), and linoleic acid (5.55 g/100 g of DM). All of the conventional shelling methods including oil-bath roasting, steam roasting, drying, and open pan roasting revealed a significant reduction, whereas the Flores hand-cracking method exhibited similar levels of carotenoids, thiamin, and unsaturated fatty acids in cashew nuts when compared to raw unprocessed samples.

KEYWORDS: Anacardium occidentale L.; cashew nut; bioactive compounds; carotenoids; tocopherols; thiamin; unsaturated fatty acids; shelling methods; “Flores” hand-cracking

INTRODUCTION

Nuts are recommended as an important constituent of a healthy diet, although their real intake varies remarkably in human populations in different regions of the world. Nuts constitute a good source of certain vital bioactive compounds that could elicit many health benefits in human beings. Results of several epidemiological studies suggested that there may be a connection between frequent nut consumption and reduced incidence of several chronic diseases (1). Long-term consumption of nuts has been associated with a lower risk of body weight gain and obesity (2). The consumption of nuts as a part of the healthy diet has a positive influence on the fatty acid profile of persons with type 2 diabetes (2). Analysis of the effects of the inclusion of cashew nut in the diet on the antioxidant status of human subjects with metabolic syndrome resulted in an increased antioxidant capacity (3). Furthermore, studies by Chisholm et al. (4) revealed that nut consumption has a cholesterol-lowering effect and also reduced the risk of lipoprotein-mediated cardiovascular disease, and recent emerging scientific findings have demonstrated that the bioactive constituents of whole nuts have cardioprotective, antiobesity, anticancer, and antioxidant effects by a number of different mechanisms (5).

Among the various types of commonly consumed nuts such as almond, Brazil nut, hazelnut, macadamia, peanut, pecan, pine, pistachio, kola nut, and walnut, the cashew nut (Anacardium occidentale L.) occupies a central position in the diets of the human population throughout the world. Cashew nut, native to Brazil, was introduced about two centuries ago into the Goa region of India, which became one of the major producers of cashew nuts, accounting for almost 50% of the total world export (7). The cashew nut is an extremely important agricultural trade product of Brazil, where cashew cultivation occupies an estimated 700,000 ha with a cashew nut production of 280,000 tons/year (8). Thus, cashew nut production has great social and economic importance in many developing countries, including Brazil, India, Indonesia, and some African countries.

The cashew nut kernels, the edible portion of the nut, which contain proteins, fats, and vitamins with high caloric value (7.32–7.76 kcal/g of DM) (9), are accepted worldwide as a nutritious food product. The cashew nut consists of an outer shell (epicarp), a tightly fitted inner shell (endocarp), and a strongly vesicant cashew nut shell liquid (CNSL). The CNSL is located between the inner and outer shells within a honeycomb matrix (10). It protects the nut from being destroyed by foragers that feed on the cashew apple. The kernel is slightly curved back on itself and forms two cotyledons, representing about 20–25% of the whole nut weight. It is wrapped within a thin, reddish-brown membrane called a testa, which is very difficult to remove (11).

The cashew nut represents one of the cheapest major sources of nonisoprenoid phenolic lipids, which have a variety of biological properties and medicinal applications and have also demonstrated a potential antioxidant activity. Previous research works indicated the presence of phenolic components such as anacardic acid, cardol, 2-methylecardol, and cardanol in CNSL (12). Quantitative determination of the major phenolic lipids in cashew apple,
kernels, and shells of cashew nut at various stages of development suggested the possibility of fatty acid type biogenesis of these pheno-
lolic acids (10). The presence of unsaturated fatty acids, tocophe-
rols, squalenes, and phytosterols is also reported in cashew
nuts by Ryan et al. (13). Recently the antioxidant activities of
various bioactive compounds such as phenolics, flavonoids,
phospholipids, sphingolipids, steroids, and tocopherols were repor-
ted in cashew nut samples (14, 15). Furthermore, the ethanolic
extract of cashew nut testa has exhibited significant antioxidant
activity (11), and the polyphenolic compounds present in the testa
appear to contribute to the antioxidant activity (16).

On the world market, large, white, and whole cashew nut kernels
of high quality achieve the best prices. However, the processing of
cashew samples is very expensive due to the specific character-
istics of the shell. The irregular shape in conjunction with the
wood-expressed, rugged enclosure makes manual or mechanical
shelling very difficult. To win a high percentage of whole kernels,
it is necessary to break the shell and remove the testa by means of
high-temperature treatments (17). The highly nutritious kernel of
the cashew nut is removed from the shell by a process known as
shelling, which can be achieved by various methods such as dry-
ing, steam roasting, oil-bath roasting, or cooking under high-
pressure steam (18). During these conventional shelling processes,
the cashew nut samples are exposed to extremely high levels of
temperature (ranging from 75 to 200 °C), which may affect the
heat-sensitive bioactive compounds. Furthermore, the liberated
CNSL during the shelling process also seriously complicates the
processing of cashew nut and extraction of its kernel for food use.

To overcome these constraints, a novel shelling method
(“Flores” hand-cracking method) was introduced by PT. Profil
Mitra Abadi (PT. PMA), Tangerang, Jakarta, Indonesia, by
using a simple hand-cracking machine. In this process, cashew
nut kernels were freed from the shell individually with the help of
a new, specially designed hand-cracking machine. Furthermore,
the shelling process occurs without any contact with a heat source
at any point throughout the cracking process. Subsequently, the
cashews are dried for 3 h at a mild temperature of 45 °C.

Even though few reports are available on the presence of cer-
tain bioactive compounds in cashew nut kernels, to our knowl-
edge there is no information on the effect of various conventional
shelling methods as well as the newly developed Flores hand-
cracking method on the levels of bioactive compounds in cashew
nut kernels. Hence, the present study was carried out to ana-
lyze the levels of β-carotene, lutein, zeaxanthin, α-tocopherol,
y-tocopherol, thiamin, stearic acid, oleic acid, and linoleic acid in
raw and differentially processed cashew nut kernels with a view to
identify the more suitable and effective shelling process, which
minimizes the loss of health beneficial bioactive compounds.

MATERIALS AND METHODS

Sample. The cashew nut samples were collected from the agricultural
farms located at four different villages, Rowo, Ile Padung, Ilenmedo, and
Kringa, in central and eastern Flores Island, Indonesia. To ensure com-
parability of different processing methods with each other, all of the cashew
nut samples were obtained from the same harvesting time and the same
drying and storage conditions were used. The collected samples were ran-
commonly categorized and divided into six batches, and different shelling
processes were carried out as described below. Autodisintegration and iso-
merization of the vitamins were prevented by working under yellow light.

Chemicals. Chemicals such as oleic acid, α-tocopherol, and boron tri-
fluoride in methanol were purchased from Fluka, Taufkirchen, Germany;
linoleic acid, stearic acid, and thiamine were obtained from Sigma-Aldrich,
Steinheim, Germany; lutein, γ-tocopherol, zeaxanthin, and β-carotene
were procured from Roche, Basel, Switzerland; isolate-HM-N was pur-
chased from Separtis, Grenzach-Wyhlen, Germany; and all other chemi-
cals were purchased from Merck, Darmstadt, Germany.

Raw Cashew Nuts. To determine the initial content of bioactive ingre-
dients of cashew nuts, this group was left untreated, cracked manually by
using a wooden hammer, but not dried. Throughout the experiment, these
samples were not exposed to heat at any point.

Oil-Bath Roasting. The oil-bath roasting process was carried out on
the basis of the methodology described by Mandal (18). In the first step,
the water content of the cashew nut samples was increased from 6 to 16% by
conditioning. The cashew nuts were individually weighed, added in
accordance with the required amount of water, and shaken in Falcon tubes
(Sarstedt, Nürnberg, Germany) for 4 days at 9 °C. Then the cashew nut
samples were roasted in an oil bath at 200 °C for 90 s and then cooled to
room temperature. For roasting, locally available vegetable oil (100%
sunflower oil, Biskin) was used. Subsequently, the cashew nuts were crac-
ded and dried at 75 °C in a dry heating block for 3 h. In the dry heating
block, a plastic bowl was lined with aluminum foil, so that the cashew nuts
did not come in contact with the walls of the heating block.

Steam Roasting. The steam roasting of cashew nut samples was per-
formed as described by Jain et al. (17). The apparatus for steam generation
was developed by Giovanni Migliore (Dairy Research and Training,
University of Hohenheim). In this method, the vessel containing the
cashew nut samples was hermetically sealed, so that the steam did not
escape and the pressure could build up completely. The cashew nuts were
processed for 15 min at 120 °C and 15 psi of pressure. Subsequently, the
steam-roasted cashew nuts were cooled to room temperature, cracked, and
dried at 75 °C in a dry heating block for 3 h.

Drying. To analyze whether the two previous methods (oil-bath and
steam roasting) or the subsequent drying is responsible for nutrient loss,
the cashew nut samples were directly dried after cracking at a temperature
of 75 °C for 3 h in a dry heating block and then cooled to room tempe-
rate.

Open Pan Roasting. The cashew nut samples were processed by using
an open pan roasting treatment as described by Mandal (18). Before
the roasting process was began, the container was sparked by fire and logs
created in the wake flame. Then the cashew samples were placed in a
perforated pan, which was placed on the fire for 2 min. The heat caused the
withdrawal of CNSL, which led to ignition of cashew samples. After 2 min,
the cashew nuts were removed from the fire, slowly cooled to room tempe-
rate, cracked with wooden hammers, and stored in the dark.

Flores Hand-Cracking. The hand-cracking of cashew nuts was con-
ducted on the basis of a detailed description of production given by Rudolf
Heering (President Director, PT. PMA, Tangerang, Jakarta, Indonesia).
First, by visual inspection, cashew samples of too small size were removed
from the cracking process and only acceptable cashew samples were passed
through the breakers. It is inevitable that only a minimum amount of CNSL
emerges from the mesocarp of the shell as a result of the cracking process.
Thus, the cashew nut kernels were protected themselves from exiting
CNSL. The outer surface of the cashew nut kernel was not damaged dur-
ing the cracking process, so that the cashew nuts in the pan could be remo-
ved precisely without violating the testa. Furthermore, the cashew nut
kernel, which is protected by testa, was not in contact with CNSL. The
samples were cracked and dried for 3 h at a temperature of 45 °C in a
heating block.

Preparation of the Samples. Processed sample (50 g) per category
was obtained at the end of each shelling process. All of the processed
as well as raw samples were frozen at − 80 °C and freeze-dried for 48 h, and
then the testa was removed manually. The cashew nut kernels without
testa were homogenized by using a mortar and pestle, freeze-dried for 24 h,
and stored at 9 °C until further use.

Carotenoids and Tocopherols. The β-carotene, lutein, zeaxanthin,
and α- and γ-tocopherol contents in cashew nut kernels were analyzed by
RP-HPLC after saponification and extraction as follows: 2 mL of ethanol
containing pyrogallol (2.5%) and β-apo-8’-carotenal-methyleximone and
1 mL of 50% KOH solution were added to 100 mg of the sample in a screw-
capped glass tube. The internal standard β-apo-8’-carotenal-methyleximone
was synthesized as described by Sommerburg et al. (19). For saponifica-
tion, the contents were covered by argon gas, the tubes were closed
with screw caps, and then the mixture was stirred for 4 h in a water bath at
38 °C. After the addition of 2 mL of saline solution (15%), the fat-soluble
substances were extracted twice with 1 mL of hexane. The combined
hexane phases were washed (15% saline solution), evaporated by nitrogen
gas, and finally redissolved in 200 μL of ethanol eluent (1:3, v/v) in order to
be analyzed on a Varian HPLC (Prostar-210) equipped with UV–vis and fluorescence detector (Waters-2487, Waters-474) with following chromatography and mass spectrometry conditions. ODS-2 analytical column (3 μm, 250 × 4.6 mm, Thermo Scientific, Germany) at 40 °C and a mobile phase consisting of acetonitrile (82%), dioxane (15%), and methanol (3%, containing 100 mM ammonium acetate and 0.1% triethylamine) in a recirculation mode with a flow rate of 1.6 mL/min. The carotenoids were detected at 450 nm, whereas α- and γ-tocopherols were measured by fluorescence with an excitation/emission set at 298/328 nm, respectively.

Thiamin. The determination of the thiamin content of cashew nut samples was performed by precolumn derivatization and reverse-phase liquid chromatography and fluorescence detection as described by Gertits et al. (20) with modifications. In brief, 100 mg of the sample was mixed with 7.5 mL of 0.1 M HCl solution and stirred for 1 h at 30 °C in dark.

Subsequently, an aliquot of 1.5 mL of this mixture was centrifuged at 5000g, and the clear supernatant was derivatized as follows: 500 μL of the clear solution was mixed with 100 μL of freshly prepared oxidation reagent (12.1 mM K3Fe(CN)6 in 3.35 M NaOH solution). The “thiochrome reaction” was stopped by the addition of 20 μL of 6 M orthophosphoric acid, and 20 μL of the aliquot was analyzed on a Merck-Hitachi HPLC (LaChrom) equipped with column oven (set at 40 °C), fluorescence detector (L-7480), and Chiral chromatographic station (DA-C50, DataApex Ltd., Prague). Separation was achieved by using a 5 μm analytical column (Grom-Sil 120 ODS-4 HE, 125 × 4 mm, Grom, Rottenburg-Hailfingen, Germany) and a mobile phase consisting of methanol (27.5%, v/v) and phosphate buffer (pH 7.0) at a flow rate of 0.8 mL/min. Thiamin was detected by excitation/emission set at 367/435 nm.

Fatty Acids. The quantification of fatty acids (stearic acid, oleic acid, and linoleic acid) of raw and processed cashew nut samples was carried out by following the method of Thurnhofer et al. (21). Five hundred milligrams of the sample was extracted by using an ASE 200 system (Dionex, Idstein, Germany). For this purpose, 22 mL extraction cells were used, which were filled with Isolute-HM-N, where each cell was extracted twice.

The azeotropic mixture of cyclohexane and ethyl acetate (46:54, v/v) was pipetted into the mixture and extracted with 500 μL of 0.5 M methanolic KOH solution at 80 °C and then saponified. After a reaction time of 5 min, the mixture was cooled in an ice bath. The subsequent methylation was started by adding 1 mL of boron trifluoride in methanol and kept for 5 min at 80 °C. After cooling, 2 mL of hexane and 2 mL of a saturated NaCl were added and shaken. The contents were centrifuged at 8000g, and 180 μL of organic phase was mixed with 20 μL of the second internal standard, oleic acid ethyl ester, which was prepared according to the method of Thurnhofer et al. (21). The solution was diluted in 1:4 ratio and analyzed by gas chromatography in combination with electron ionization mass spectrometry (GC-EI/MS), which consists of 5890 series II gas chromatograph and a 5971 mass selective detector, MS Data analysis version C.05.01. HP 1989–1990 from Agilent Technologies, Palo Alto, California. For GC analysis, helium gas (99.999% purity) was used as carrier with a flow rate of 1.0 mL/min. A fused silica capillary column (100% cyanopropylpolysiloxane, 50 μm × 0.25 mm i.d. × 0.2 μm film thickness, CP-Sil 88 from Chrompack, Middelburg, The Netherlands) was installed in the GC oven. Injection of a 1 μL volume of aliquot was used at a temperature of 250 °C and analyzed for 38.81 min. Under selected ion monitoring (SIM) mode, nine fragment ions were detected, and seven of them were identified during the whole run at (m/z) 74 and (m/z) 87 for methyl esters of saturated and monounsaturated fatty acids, (3) (m/z) 81 and (4) (m/z) 79 for methyl esters of polyunsaturated fatty acids, (5) (m/z) 88 and (6) (m/z) 101 for ethyl esters of saturated and monounsaturated fatty acids, and (7) (m/z) 55. Statistical Analysis. The statistical analysis was carried out by using SPSS for Windows (SPSS Inc., Chicago, IL, version 11.0). Values of analyzed compounds were found to be normally distributed by using the Kolmogorov–Smirnov test and were described by their mean. Means of the groups regarding different shelling methods were compared by one-way ANOVA and Dunnett post hoc test using the raw processed cashew nuts as a control. Two-tailed p values of < 0.05 were considered to be statistically significant.

RESULTS AND DISCUSSION

Bioactive Compounds. In general, the raw cashew nut kernels were found to possess appreciable levels of carotenoids such as β-carotene (9.57 μg/100 g of DM), lutein (30.29 μg/100 g of DM), and zeaxanthin (0.56 μg/100 g of DM) (Table 1). The β-carotene content of cashew nut was found to be higher than that of peanut (2 μg/100 g) but lower when compared to chestnut (24 μg/100 g), hazelnut (29 μg/100 g), almond (120 μg/100 g), pecan (80 μg/100 g), pistachios (150 μg/100 g), walnut (48 μg/100 g), and previously reported values in cashew nut (60 μg/100 g) (23). The lutein content of cashew nut (30.29 μg/100 g) was higher than that of an earlier report on red apple (15 μg/100 g), red grape (24 μg/100 g), mango (6 μg/100 g), peach (11 μg/100 g), and water melon (4 μg/100 g) and comparable with that of orange juice (33 μg/100 g) and tomato (32 μg/100 g) (24). Nonetheless, the zeaxanthin content of cashew nuts (0.56 μg/100 g) was lower than that of endive (3 μg/100 g), red grape (4 μg/100 g), and peach (3 μg/100 g) (24).

In addition to the importance as provitamin A, β-carotene has a photobiological effect, that is, a protective function against UV light. β-Carotene protects against oxidative stress through deactivation of singlet oxygen and by inhibition of lipid peroxidation (25).

Functions of carotenoids are discussed as a precursor of vitamin A, which is required for adaptive immunity and plays a significant role in the development of both T-helper cells and B cells (26). Furthermore, carotenoids are known to play a role in the prevention of diseases such as cancer and atherosclerosis (27, 28).

The levels of α- and γ-tocopherols in raw cashew nut samples were found to be 0.29 and 1.10 mg/100 g of DM, respectively (Table 1). The α-tocopherol content of the present study was comparable with that of an earlier paper (0.26 mg/100 g of DM), but the γ-tocopherol level was found to be lower when compared to a previous paper on cashew nut (5.2 mg/100 g of DM) (23).

Furthermore, the level of tocopherols in cashew nut samples of the present study was lower in comparison with the value given for other kinds of nuts (29), which may be due to the oxidation sensitivity of the tocopherols. It is well-known that tocopherols exhibit a protective role on lipid peroxidation of membrane lipids, lipoproteins, and depot fats (25) and, therefore, protect against atherosclerosis. The ability of vitamin E to induce apoptosis in tumor cells and modulate oncogenes is probably the reason for the low occurrence of cancer as a result of a vitamin E-rich diet, which was demonstrated in a variety of epidemiological studies (30). However, tocopherols are sensitive to light and oxygen, and the most important degradation reaction is the oxidation of tocopherols into tocopherolcholin.

The raw cashew nut kernels were found to contain a considerable amount of thiamin (1.08 mg/100 g of DM) (Table 1). This value was found to be higher when compared to an earlier report on the thiamin content of cashew nut (0.63 mg/100 g of DM), chestnut (200 μg/100 g), peanut (900 μg/100 g), hazelnut (390 μg/100 g), coconut (61 μg/100 g), kola nut (60 μg/100 g), macadamia (280 μg/100 g), almond (220 μg/100 g), Brazil nut (1 mg/100 g), pecan (860 μg/100 g), pistachio (690 μg/100 g), and walnut (340 μg/100 g) (23). Various enzymes of intermediary metabolism, including pyruvate dehydrogenase, α-ketoglutarate dehydrogenase, and transketolase, require thiamin pyrophosphate as an essential cofactor. Thiamin is thermolabile in a neutral or alkaline solution and sensitive to oxidation and ionizing radiation.

The results of quantification of the fatty acids such as stearic acid (4.96 g/100 g of DM), oleic acid (21.87 g/100 g of DM), and...
Table 1. Levels of Various Bioactive Compounds in Raw and Differentially Processed Cashew Nut Kernels

<table>
<thead>
<tr>
<th>Bioactive Compound</th>
<th>Raw Cashew Nut Kernels</th>
<th>Oil-Bath Roasting</th>
<th>Open Pain Roasting</th>
<th>Direct Steam Roasting</th>
<th>Dry Roasting</th>
</tr>
</thead>
<tbody>
<tr>
<td>β-carotene (mg/100 g of DM)</td>
<td>4.92 ± 4.09 (98%)</td>
<td>4.92 ± 0.49 (98%)</td>
<td>4.92 ± 0.49 (98%)</td>
<td>4.92 ± 0.49 (98%)</td>
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<tr>
<td>lutein (mg/100 g of DM)</td>
<td>0.55 ± 0.15 (98%)</td>
<td>0.55 ± 0.15 (98%)</td>
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<tr>
<td>α-tocopherol (mg/100 g of DM)</td>
<td>0.55 ± 0.15 (98%)</td>
<td>0.55 ± 0.15 (98%)</td>
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<tr>
<td>γ-tocopherol (mg/100 g of DM)</td>
<td>0.55 ± 0.15 (98%)</td>
<td>0.55 ± 0.15 (98%)</td>
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<tr>
<td>Thiamin (mg/100 g of DM)</td>
<td>0.55 ± 0.15 (98%)</td>
<td>0.55 ± 0.15 (98%)</td>
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<td>0.55 ± 0.15 (98%)</td>
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<tr>
<td>Oleic Acid (g/100 g of DM)</td>
<td>4.92 ± 0.49 (98%)</td>
<td>4.92 ± 0.49 (98%)</td>
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<td>4.92 ± 0.49 (98%)</td>
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<tr>
<td>Linoleic Acid (g/100 g of DM)</td>
<td>4.92 ± 0.49 (98%)</td>
<td>4.92 ± 0.49 (98%)</td>
<td>4.92 ± 0.49 (98%)</td>
<td>4.92 ± 0.49 (98%)</td>
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<tr>
<td>Total Lipids (g/100 g of DM)</td>
<td>4.92 ± 0.49 (98%)</td>
<td>4.92 ± 0.49 (98%)</td>
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<td>4.92 ± 0.49 (98%)</td>
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Values are mean and SD of nine separate determinations. *p < 0.05:** p < 0.001, significantly different from mean level of the control (raw, unprocessed cashew).
samples (Table 1). Only the content of zeaxanthin was unaffected.

Here the duration of heat is a critical factor for the loss of nutrients in addition to the higher level of temperature. Furthermore, the effect of direct steam roasting caused lower loss of carotenoids (12−17%) and tocopherols (10−11%), because in this treatment the temperature of 120 °C was reached with the pressure of 15 psi in the presence of moisture. However, a drastic loss of thiamin was noted (52%) during this treatment.

The analysis of fatty acids, which has been carried out in the direct steam roasted cashew nut kernels, showed that the content of individual fatty acids was significantly reduced in relation to that of unprocessed cashew nuts as a result of the influence of temperature and pressure. In comparison to the oil-bath roasted samples, a significantly lower concentration of fatty acids was noted in steam roasted cashew nuts, which might be due to a prolonged effect of temperature, and also lipid peroxidation may have been taken place as a result of increased pressure.

Drying. To investigate which stage of the oil-bath and steam roasting methods has the highest impact on the nutrient loss in cashew nut kernels, the samples were subjected to drying alone for 3 h at 75 °C, and the levels of bioactive compounds are shown in Table 1. The most similar β-carotene, lutein, and α-tocopherol contents of the dried batch sample when compared to the oil-bath and direct steam roasted batches suggested that the loss of these nutrients took place mainly during the 3 h drying at a relatively high temperature of 75 °C. This is confirmed by the fact that the concentrations of β-carotene, lutein, and α-tocopherol of the dried batch were significantly reduced by 19, 20, and 14%, respectively, when compared to raw cashew nut samples. However, the reason for the presence of a higher level of β-carotene content in the oil-bath roasted sample than in the dried sample remains unclear. Dried cashew sample was found to contain a significantly lower level of γ-tocopherol content (0.85 mg/100 g of DM) with respect to oil-bath roasted and direct steam roasted batches. Such a drastic level of reduction of γ-tocopherol (23%) in dried samples might be due to a nonuniform processing and storage of dried samples. This assumption is supported by the fact that, in general, the β-carotene, lutein, zeaxanthin, and α- and γ-tocopherol levels in the oil-bath and direct steam roasted batches were located just above the values of dried samples, which could be due to the heating of the samples in the presence of moisture in those treatments.

Similarly, a significantly lower level of thiamin concentration of oil-bath and direct steam roasted batches when compared to dried samples indicates that the loss of thiamin occurs mostly due to high roasting temperature and not due to the drying step. This is confirmed by the fact that the thiamin concentration of the dried samples was similar when compared to that of the raw cashew sample. It is very interesting to note that the content of individual fatty acids of the dried batch was higher than in the raw cashew nut. However, the ratio of the individual fatty acids was very similar and was not affected during processing of the samples by 3 h of drying at 75 °C. The highly significant loss of stearic acid during oil-bath roasting and maximum level of loss of all three unsaturated fatty acids during direct steam roasting when compared to dried cashew nuts were most likely due to the high processing temperatures of 200 or 120 °C.

Open Pan Roasting. The open pan roasting method exhibited by far the strongest reduction of bioactive compounds in cashew nut samples (Table 1). The open pan roasted cashew nut kernels exhibited a significantly lower concentrations of all the bioactive compounds when compared to raw as well as other processed batches. The highly significant decrease in all of the investigated compounds including β-carotene (55%), lutein (58%), zeaxanthin (65%), α-tocopherol (29%), γ-tocopherol (15%), thiamin (53%), stearic acid (43%), oleic acid (44%), and linoleic acid (40%) might be due to the direct action of fire, which also caused the scorching of a high proportion of cashew nuts. It is especially impressive to recognize that the γ-tocopherol concentration was reduced by at least 15%, whereas α-tocopherol was decreased by 29% in relation to raw cashew sample. Furthermore, open pan roasting is the only procedure that caused a significant loss of zeaxanthin.

Flores Hand-Cracking. Among the various shelling methods implemented in the present study, the Flores hand-cracking method recorded by far the least loss of bioactive compounds in relation to conventional methods (Table 1). Because the contents of lutein (0.71 μg/100 g of DM), zeaxanthin (0.5 μg/100 g of DM), stearic acid (5.05 g/100 g of DM), oleic acid (20.05 g/100 g of DM), and linoleic acid (5.70 g/100 g of DM) but above all the highly thermolabile thiamin content (1.07 mg/100 g of DM) of the cashew nut kernels obtained by Flores hand-cracking process were found to be comparable to that of raw samples without any significant difference, it can be considered as an extremely gentle method.

It is noticeable that the levels of zeaxanthin (20%), stearic acid (2%), and linoleic acid (3%) were slightly higher in the Flores hand-cracked cashew nuts in comparison to raw samples. In the Flores hand-cracking method, the 3 h drying at 45 °C has a very low impact on the contents of all the analyzed bioactive compounds. This is confirmed by the fact that an only meager level of reduction of β-carotene (6%) and γ-tocopherol (8%) in the hand-cracked cashew nut kernels appeared in comparison to a highly significant loss of these compounds during conventional processing methods. The cashew nut samples processed by the careful hand-cracking method were found to contain relatively high levels of antioxidants and resulted in a good protection of unsaturated fatty acids against autooxidation. Furthermore, the content of quantified fatty acids in the Flores hand-cracked cashew nut kernels was more or less comparable to that of raw sample, because 45 °C is the usual temperature applied to evaporate the solvents in fatty acid analysis. Therefore, it was expected that such a mild temperature causes no degradation of fatty acids present in the sample. However, the significant reduction of α- and γ-tocopherol was found to be similar to that of the other processing methods. In general, under the Flores hand-cracking method the cashew samples were processed in a very gentle manner, so that only a very low level of loss of bioactive compounds was noted when compared to other conventional processing methods.

The results of the present study indicate that the cashew nut kernels constitute a viable source of certain health-beneficial bioactive compounds. Among the various conventional shelling methods employed in the present study, the open pan roasting exhibited a drastic level of reduction of bioactive compounds in cashew nut samples due to the direct action of fire and therefore represents the most aggressive practice. Oil-bath roasting, which was followed by direct steam roasting, also caused significant losses of bioactive compounds in cashew nut samples. Furthermore, we could show that the reduction of thiamin and fatty acids of the cashew samples took place mainly during the oil-bath, steam, and open pan roasting processes and the significant decreases of tocopherols and carotenoids were found only during the subsequent 3 h drying at 75 °C. Alternatively, the recently developed Flores hand-cracking method exhibited only very low level of reduction of bioactive compounds in cashew nut kernels and is considered to be an extremely gentle and suitable shelling process. Hence, such a potential shelling process could be adapted at the industrial level for the retention of higher...
levels of health-promoting/disease-preventing bioactive compounds in cashew nut kernels. The economic and sensory evaluation of differentially processed cashew nut samples deserves future research.

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