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Nutritional and amino acid contents of differently treated Roselle (*Hibiscus sabdariffa* L.) seeds

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ABSTRACT

The effects of sun-drying and boiling sun-drying on the nutritional composition of Roselle (*Hibiscus sabdariffa* L.) seeds, grown from Malaysia, were investigated. The treatments were raw freeze-dried Roselle seeds (RRS), sun dried Roselle seeds (DRS) and boiled sun-dried Roselle seeds (BRS). Protein, lipids and dietary fibre were found to be high in all the treatments. The seeds, regarded as by-product of Roselle processing had 57.3% moisture. Raw freeze-dried, sun dried and boiled sun-dried seeds contained 6.81%, 9.9% and 9.8% moisture; 35.4%, 33.5% and 30.6% protein; 27.2%, 22.1% and 29.6% lipids; 2.3%, 13.0% and 4.0% available carbohydrate; 25.5%, 18.3%, and 19.2% total dietary fibre; and 7.4%, 7.5% and 6.6% ash, respectively. The carbohydrate, protein, lipids and moisture of RRS were significantly different ($p < 0.05$) from DRS and BRS. The predominant minerals in Roselle seeds were potassium (99–109 mg/100 g), magnesium (26–28 mg/100 g) and calcium (24–31 mg/100 g). The total dietary fibre of the seeds was within the acceptable range, with soluble and insoluble fibre ratios ranging from 1.2 to 3.3. The study detected 17 essential and non-essential amino acids. The seeds were rich in lysine (14–15 g/100 g), arginine (30–35 g/100 g), leucine (15.4–18.6 g/100 g), phenylalanine (11–12 g/100 g) and glutamic acid (21–24 g/100 g). The study indicated that Roselle seeds may serve as a potential source of functional ingredients.

1. Introduction

Cereal grains, legumes or beans, roots and tubers are an important part of human diet in many countries, particularly in tropical and subtropical regions of the world (Koehler, Iung-Hsia Chang, Scheier, & Burke, 1987). Although nutritional guidelines place grains and grain products at the base of food guide pyramid to emphasize their importance for optimal health, nevertheless, little attention has been paid to grains, beans and seeds consumption as compared with fruits and vegetables. Seeds are however one of the cheapest food sources. Researchers have confirmed the nutritional usefulness of seeds, and many different interpretations and views have been discussed about their nutritional benefits (Barampama & Simard, 1993; Saleh Al-Jassir, 1992). However, limited research has been carried out on exploitation and utilization of seeds as a potential alternative for human food source.

There are more than 300 species of hibiscus around the world. One of them is *Hibiscus sabdariffa*, Linn, which is a member of the Malvaceae family. The origin of *H. sabdariffa* is not fully known, but it is believed to be native of tropical Africa. It is known by different synonyms and vernacular names such as Roselle (Abu-Tarboush, Ahmed, & Al Kahtani, 1997; Chewonarin et al., 1999; Tsai, Mc Intosh, Pearce, Camden, & Jordan, 2002), karkade (Abu-Tarboush et al., 1997) and mesta (Rao, 1996). It was first introduced to West Indies, and cultivated mainly as an ornamental plant. Roselle calyces have repeatedly been shown to have positive health effects (Faraji & Tarkhani, 1999; Tseng et al., 1997). However, most of the studies were focused on the benefits of the calyces rather than the seeds of the plant. There are published reports indicating that the seed are eaten in some parts of Africa, and also have been roasted as a substitute for coffee (Duke, 1983; Morton, 1987). In Malaysia, the seeds of Roselle plant are discarded as by-products. Currently, the production of the flower is about 240 ton annually. During processing, about 50% of the velvety capsules containing the seeds are normally discarded as waste. Value added products may be obtained from the by-product of Roselle processing that will be useful and beneficial to health.

The nutritional usefulness of the Roselle seeds has been rarely studied as compared with the calyces. Information from the literature indicated that Roselle whole seeds powder from other countries contained high amounts of protein, oil, carbohydrate (Abu-Tarboush et al., 1997; El-Adawy & Khalil, 1994; Rao, 1996) and dietary fibre (Rao, 1996). However, no nutritional data have been reported on Roselle seeds grown from Malaysia. Also, nutritional compositions of seeds vary depending on the variety, location and environmental conditions where the seeds were grown.

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Roselle seeds, like other seeds and legume may have anti-nutritional factors that have been associated with the reduction of food digestibility, decrease in nutrient bioavailability and flatulence production. Abu-Tarboush and Ahmed (1996) reported defatted flour and protein isolate of Roselle seeds contained protease inhibitors, phytic acid and gossypol, but they would not pose a problem if the seeds are properly processed. Moreover, Halimatul, Amin, Mohd-Esa, Nawalyah, and Siti Muskinah (2007) indicated that the protein quality of dried Roselle seeds was similar to boiled Roselle seeds, and does not affect the food digestibility and biological values in the rats studied.

The objectives of the study were to study the nutritional composition (proximate composition, amino acids, fibre, minerals, etc.) of Roselle seeds, grown from Malaysia; and to investigate the effects of sun-drying and boiling sun-drying on the nutritional composition of Roselle seeds.

2. Materials and methods

2.1. Materials

Sixty kilograms of Roselle (*H. sabdariffa* L) capsules were obtained from a local farm in Sungkai, Perak, Malaysia. The Roselle capsules were obtained after manually removing the calyces from the flower. All chemicals used for the study were of analytical grade. High performance liquid chromatography (HPLC) was used for amino acids analysis of Roselle seeds. All the reagents used were prepared fresh and used for the study. All chemicals used were of analytical grade from Merck (Darmstadt, Germany) unless stated otherwise. Dietary fibre kit TDF 100 A was obtained from Sigma (St. Louis, MO, USA).

2.2. Preparation of powders

The Roselle capsules were washed with water to remove dirt and foreign materials. The raw seeds were removed manually from the fresh capsules and the seeds were lyophilized using a benchtop freeze dryer (Virtis, Gardiner, NY, USA). To prepare the sun dried seeds, raw or fresh capsules were sun dried until constant weight was obtained. For the boiled sun-dried treatment, fresh capsules were cooked in boiling water at 100 °C for 30 min. The ratio of water to capsules was 1:3. The capsules were then sun dried for 3–4 days until constant weight was obtained. The seeds were removed manually from their capsules, and cleaned to get rid of dust, stones, pebbles and plant debris. Finally, all the seeds were ground, sieved through mesh screen and stored in a refrigerator at 5 °C for equilibration.

2.3. Proximate analysis

Moisture content of seed powders was determined according to an air-oven method. Ash content was determined by incinerating at 550 °C until the constant weight was achieved. Total nitrogen and the protein content were determined based on the Kjeldahl method using the conversion factor of 6.25. Lipids were determined by using Soxhlet method whereas total available carbohydrate was determined using Clegg Anthrone method. All the above determinations were based on the methods of AOAC (1990) except for available carbohydrate which was carried based on a colorimetric assay (Dreywood, 1946).

2.3.1. Gross energy

Gross energy (kJ/g) was estimated by multiplying the percentages of protein, lipid and carbohydrate by the factors 17, 37 and 16, respectively (FAO/WHO/UNU., 1981).

2.4. Minerals analysis

Ashed samples were prepared as described in Section 2.3. (AOAC, 1990). Concentrated hydrochloric acid (5 ml) was added to the ash, mixed and evaporated to dryness over a boiling water bath (100 °C). About 2 ml concentrated hydrochloric acid was added and mixed. The dish was covered with a watch glass and heated until the solution started boiling. Twenty milliliters of distilled water were added, washed down the watch glass and filtered through Whatman filter paper No. 4 into a 100 ml flask. It was allowed to cool and topped to the mark (100 ml) with distilled water. Sodium nitrate, potassium nitrate, calcium nitrate, ferric nitrate, magnesium nitrate, Cu(II) nitrate and zinc nitrate were used as standard solutions. Minerals (sodium, potassium, calcium, iron, magnesium, copper, and zinc) were detected using atomic absorption spectroscopy (GBC 908A, Scientific Equipment, Victoria, Australia). Concentration standards of 0.5–25.0 μg/ml were used to determine the minerals quantitatively.

2.5. Amino acids analysis

The amino acids content of the samples were analysed and quantitatively determined using the HPLC (Waters System Interface module 501, Hewlett Packard, California, USA) as described by Pico-tag method with slight modification (Pico-tag, 1984). About 0.12 ± 0.10 g of seeds powder (containing about 40 mg protein) were weighed into a medium wall pyrex test tube, and 15 ml of 6 M hydrochloric acid was added. The tube was quickly sealed and hydrolyzed under nitrogen environment in an oven at 110 °C for 24 h. After hydrolysis, the mixture was allowed to cool at room temperature, transferred to 50 ml volumetric flask and 10 ml α-aminobutyric acid (AABA) was added as an internal standard. The volume was topped to 50 ml with deionised water. The mixture was filtered through a Whatman filter paper No. 1, and then, through a Whatman filter paper No. 42 before the derivatization process. About 10 μl of filtered sample were transferred into derivatization tube, and evaporated to dryness under vacumm (100–200 mtorr) for 30 min. Subsequently, a redrying reagent (a mixture of methanol–triethylamine and deionised water (2:1:2, w/w/w)) was added and redried for another 30 min. After the final drying, a derivatization reagent (methanol–phenyltiocyanate [PITC] –triethylamine and deionised water [7:1:1:1, v/v/v/v]) was added. To ensure that the coupling reaction with PITC was completed, the derivatization process was set for 20 min. It was then evaporated to dryness for another 20 min. About 100 μl of sample diluent (a mixture of disodium hydrogen phosphate, deionised water, 10% orthophosphoric acid and acetonitrile) were added to the sample. Of the prepared sample, 20 μl of aliquot and 8 μl of blank solution were injected into Pico-tag column (C18, 3.9 × 150 mm, Waters, Medford, MA). All determinations were performed in duplicates. The quantification of each amino acid was determined from a standard calibration. Tryptophan was destroyed by acid hydrolysis (White & Hart, 1992) and thus, was not determined.

2.6. Dietary fibre analysis

Duplicate fat-free samples were analysed for soluble and insoluble dietary fibre according to the method of Prosky, Asp, Schweizer, De Vries, and Furda (1992). After incubation with three enzymes (α-amylase, protease and amyloglucosidase) separately, the mixture was filtered using Fibertec system (Fibertec System E 1023 Filtration Module, Sweden). The insoluble residue was dried in an oven at 130 °C until a constant weight was reached. The filtrate was transferred into a 600 ml beaker and mixed with 4 volumes of 95% ethanol (HmbG Chemicals, Germany). The mixture

was filtered, and the residue (consider as soluble fibre) was dried in an oven at 130 °C until a constant weight was obtained. The total, insoluble and soluble dietary fibre was calculated after correction for ash and protein, using the following formula

$$\text{Insoluble (IDF)/soluble dietary fibre (SDF)}\ \% = \frac{1/2(R1+R2) - \text{sample protein weight} - \text{sample ash weight} - \text{blank}}{1/2(m1+m2)} \times 100 \quad (1)$$

where, blank $= 1/2(bR1 + bR2) -$ blank protein weight $-$ blank ash weight

where $R1$ and $R2$ is the residue weight (mg), $bR1$ and $bR2$ is the blank corrections (mg), $m1$ and $m2$ is the sample weights (mg)

$$\text{Total dietary fibre (TDF)}\ \% = \text{SDF} + \text{IDF} \quad (2)$$

Table 1
Proximate analysis of Roselle seeds powder

	Roselle seed powder[a]		
	RRS	DRS	BRS
Moisture (%)	6.81 ± 0.19a	9.93 ± 0.17b	9.82 ± 0.13b
Ash (%)	7.43 ± 0.17a	7.47 ± 0.12a	6.59 ± 0.06b
Protein (%)	35.35 ± 0.10a	33.45 ± 0.45b	30.60 ± 0.56c
Lipid (%)	27.22 ± 0.17b	22.13 ± 0.39b	29.58 ± 0.13a
Total available carbohydrate (%)	2.27 ± 0.30c	13.04 ± 0.59a	4.03 ± 0.37b
Dietary fibre (%)	25.48 ± 0.11a	18.26 ± 0.37b	19.15 ± 0.49b
Soluble	5.89 ± 0.01c	4.84 ± 0.06b	8.66 ± 0.23a
Insoluble	19.59 ± 0.13a	13.42 ± 0.31b	10.49 ± 0.27c
Gross energy (kJ/g)	394.85 ± 2.21a	381.85 ± 5.78b	403.70 ± 1.27a

RRS, raw freeze-dried Roselle seeds; DRS, sun dried Roselle seeds; BRS, boiled sun-dried Roselle seeds.

[a] Values are expressed as mean ± S.E.M of three measurements, except for dietary fibre. Data were statistically analysed using one-way ANOVA. Values with different letter are significantly different at $p < 0.05$ within the same row.

2.7. Statistical analysis

The experimental data were expressed as mean ± S.E.M, of replicate measurements, and statistically analysed using comprehensive statistical software, SPSS version 12.0 for windows (SPSS Inc, Chicago, Illinois, USA). One-way analysis of variance (ANOVA) and Pearson correlation coefficient, were used with means separated and the least significance set at $p = 0.05$.

3. Results

Proximate composition of raw freeze-dried, sun dried and boiled sun-dried Roselle seeds powder is presented in Table 1. The seeds, regarded as by-product of Roselle processing had 57% moisture content. However, after sun-drying for 3–4 days, the remaining moisture content of BRS and DRS was 9.8% and 9.9%, respectively. Raw freeze-dried seeds contained 7% moisture content. Ash content of BRS decreased significantly ($p < 0.05$) by 11–12% as compared with RRS and DRS. Nevertheless, the ash content did not alter much between RRS and DRS. Protein content of RRS was significantly higher ($p < 0.05$) than DRS and BRS. Statistical results indicated that the protein of Roselle seeds decreased in the order of RRS > DRS > BRS. Protein content of DRS and BRS decreased significantly by 5.4% and 13.4% as compared with RRS. The ANOVA analysis revealed a significant difference ($p < 0.05$) in lipid content of the RRS, DRS and BRS seeds studied. Lipid content was in the order of BRS > RRS > DRS. Total available carbohydrate was found to be higher in DRS than RRS and BRS. The gross energy values of RRS, DRS and BRS were not significantly different from each other.

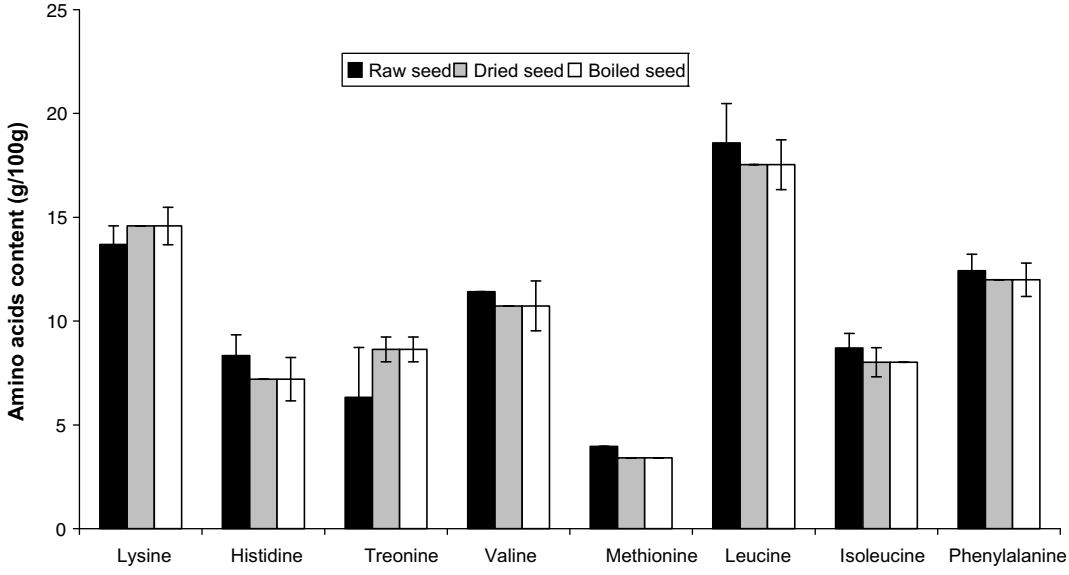

Fig. 1. Essential amino acids composition of acid-hydrolyzed (g/100 g) of Roselle seeds powder. Values are expressed as mean ± S.E.M of triplicate measurements and analysed statistically using one-way ANOVA; all samples were not significantly different ($p > 0.05$), except for lysine and leucine.

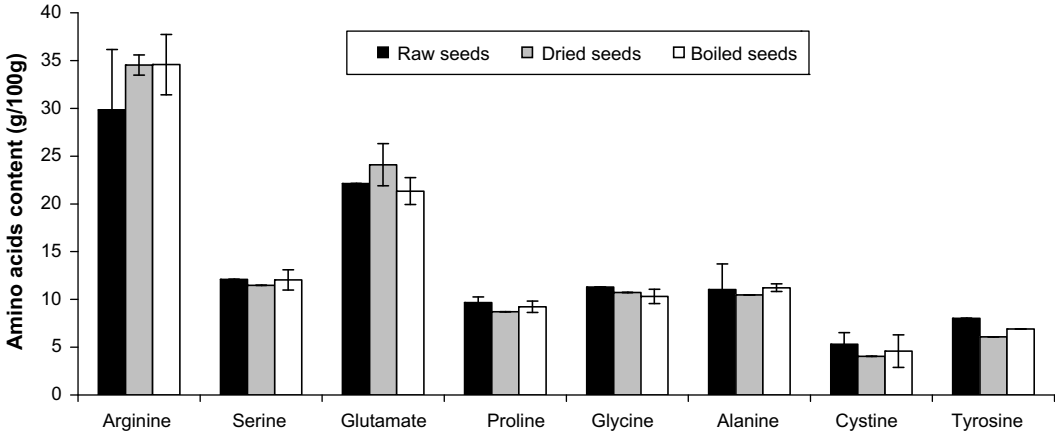

Fig. 2. Non-essential amino acids composition of acid-hydrolyzed (g/100 g) of Roselle seeds powder. Values are expressed as mean ± S.E.M of triplicate measurements and analysed statistically using one-way ANOVA; all samples were not significantly different ($p > 0.05$).

In the present study, proximate composition of the seeds was significantly influenced by heat treatment except for the ash content. Correlations were observed between protein and ash for all the seeds studied ($r = 1.00$), and between protein and total available carbohydrate for BRS ($r = 0.95$). There was however no correlation between protein and lipid content. The amino acid results are presented in Figs. 1 and 2. For all the amino acids studied, no significant difference was observed between RRS, BRS and DRS, except for lysine and leucine. The study indicated that arginine, glutamic acid, leucine and lysine were high in all the seeds. Sulphur containing amino acids, cystine (4.04–5.32 g/100 g protein) and methionine (2.50–3.96 g/100 g protein) were the limiting amino acids in Roselle seeds. However, variations of these amino acids were still considerable (Table 2).

Total, soluble and insoluble fibre values are presented in Table 1. The insoluble dietary fibre was the predominant fraction in all the seeds. One-way ANOVA analysis revealed a significance difference ($p < 0.05$) between DRS, BRS and RRS. Total dietary fibre of RRS was significantly higher ($p < 0.05$) by 25% and 28% as compared with BRS and DRS. The soluble fibre of BRS was significantly higher ($p < 0.05$) by 24% and 32% as compared with DRS and RRS. Statistical results indicated that there was a significance difference ($p < 0.05$) in soluble fibre content of RRS, DRS and BRS. The insoluble fibre was found to be significantly higher ($p < 0.05$) in RRS (32–47%) as compared with BRS and DRS. The soluble to insoluble fibre ratios in RRS, DRS and BRS were 1.0:3.3, 1.0:3.0 and 1.0:1.2, respectively.

The mineral composition of RRS, DRS and BRS seeds is presented in Table 3. Potassium was the predominant element in the seeds, followed by magnesium and calcium. Copper was relatively low in all the seeds studied. There was a significant difference ($p < 0.05$) in sodium, calcium and iron values between RRS, DRS and BRS. There was however no significant difference in trace elements between RRS and DRS. There was a positive correlation between calcium and magnesium for DRS ($r = 0.90$) and BRS ($r = 0.98$), respectively. Such a correlation was also reported by Quenzer, Huffman, and Burns (1978). Negative correlations were also observed between iron and zinc, and zinc and copper, in DRS ($r = -0.96$) and BRS ($r = -0.99$), respectively.

Table 2
Essential amino acids composition of acid-hydrolyzed (g/100 g) of Roselle seeds powder, wheat powder, whole egg protein and FAO/WHO recommended pattern of human requirement

Essential amino acid	RRS[a]	DRS[a]	BRS[a]	Wheat grains[b]	Rice[c]	Human requirement[d] FAO/WHO (1991)			
						Infant [e]	Preschool child [f]	School child [g]	Adult
Histidine	8.35	7.04	7.20	2.4	1.6	2.6	1.9	1.9	1.6
Isoleucine	8.71	7.17	8.02	2.7	2.3	4.6	2.8	1.3	4.2
Leucine	18.58	15.44	17.53	6.9	4.9	9.3	6.6	4.4	1.9
Lysine	13.69	13.77	14.59	2.4	2.5	6.6	5.8	4.4	1.6
Methionine	3.96	2.50	3.41	1.5	1.3	–	–	–	–
Cystine	5.32	4.04	4.59	1.9	1.3	–	–	–	–
Methionine + cystine	9.28	6.55	8.00	3.4	2.6	4.2	2.5	2.2	1.7
Phenylalanine	12.43	11.11	11.99	4.8	3.7	–	–	–	–
Tyrosine	8.02	6.09	6.92	2.6	2.0	–	–	–	–
Phenyalanine + tyrosine	20.44	17.20	18.90	7.4	5.7	6.3	6.3	2.2	1.9
Threonine	6.33	8.50	8.63	3.0	2.3	4.3	3.4	2.8	0.9
Tryptophan	ND	ND	ND	1.4	0.6	1.7	1.1	0.9	0.5
Valine	11.42	9.85	10.73	3.9	4.3	5.5	3.5	2.5	1.3

ND, not detected.
[a] Values are of three determinations.
[b] Values derived from Abdel-Aal and Hucl (2002).
[c] Values derived from Sosulski and Imafidon (1990).
[d] Amino acid requirement/kg divided by safe level of reference protein/kg.
[e] Amino acid composition of human milk.
[f] Individual aged 2–5 years.
[g] Individual aged 10–12 years.

Table 3
Minerals composition of Roselle seeds powder

Minerals (mg/100 g)	Roselle seed powder[a]		
	RRS	DRS	BRS
Sodium	1.10 ± 0.45a	1.16 ± 0.01a	1.42 ± 0.10b
Calcium	23.71 ± 0.21a	23.96 ± 1.70a	31.49 ± 0.14b
Iron	1.10 ± 0.05a	1.16 ± 0.01a	1.42 ± 0.10b
Magnesium	26.36 ± 0.10a	27.61 ± 0.40b	27.08 ± 0.33b
Potassium	99.38 ± 3.95a	109.09 ± 1.18b	102.45 ± 6.21a,b
Copper	0.18 ± 0.00a	0.21 ± 0.00b	0.17 ± 0.01c
Zinc	2.25 ± 0.02a	2.08 ± 0.02b	2.26 ± 0.10a

RRS, raw freeze-dried Roselle seeds; DRS, sun dried Roselle seeds; BRS, boiled sun-dried Roselle seeds.
[a] Values are expressed as mean ± S.E.M of three measurements. Data were statistically analysed using one-way ANOVA. Values with different letter are significantly different at $p < 0.05$ within the same row.

4. Discussion

Moisture, lipids and ash content of DRS seeds were similar to the results reported by El-Adawy and Khalil (1994); Rao (1996) and Samy (1980). Roselle seeds protein results of raw and processed seeds from the present study were similar to the ones reported by Abu-Tarboush et al. (1997) and El-Adawy and Khalil (1994). Nevertheless, Rao (1996) and Samy (1980) reported lower protein content in Roselle seeds. The protein content of raw as well as processed seeds was higher when compared with other common seeds and legume beans such as black seeds (Saleh Al-Jassir, 1992), sunflower seeds , melon seeds, chickpeas, cowpeas, pigeon peas, soybeans, and groundnuts (FAO, 2001). Protein content of the seeds decreased after sun-drying and boiling sun-drying. De-Man (1999) indicated that heating may cause solubilization of protein and lead to loss of protein in the final product. Total available carbohydrate of raw and processed Roselle seeds was lower than other common seeds (FAO, 2001). Although the total available carbohydrate was low, total dietary fibre content of the seeds was considerably high, with the soluble to insoluble ratio within 1.2–3.3 range. This range of SDF to IDF ratio was in agreement with the findings of Rao (1996). The ratio was acceptable comparable with other common sources of dietary fibre, such as wheat bran, oat fibre and rice bran (Claye, Idouraine, & Weber, 1996) (Table 4). The consumption of soluble as well as insoluble fibres was reported to be effective in lowering the risk of cardiovascular disease, gastrointestinal disease, colon cancer, glycemic response and obesity (Nishimune et al., 1991; Rosamond, 2002; Slavin, 2001). Grigelmo, Martín, and Martín (1999) indicated that the ratio of soluble to insoluble fractions in dietary fibres must be within the range of 1.0–2.3 in order to exert the physiological effect associated with both fractions in dietary fibre. The Roselle seeds have been shown to be a good source of dietary fibre that contained a balance proportion of soluble and insoluble fractions. However, further investigation of the Roselle seeds nutritional composition may be needed to confirm its health benefits to humans.

Table 4
Comparison of TDF, SDF and IDF values of raw, dried and boiled Roselle seeds powder with common source of fibre

	Dietary fibres (g/100 g)			
	Soluble (SDF)	Insoluble (IDF)	Ratio SDF:IDF	Total
RRS	5.89	19.59	3.3	25.48
DRS	4.84	13.42	3.0	18.26
BRS	8.66	10.49	1.2	19.15
Roselle seeds[a]	11.2–12.1	28.3–30.5	2.5	39.5–42.6
Wheat bran[b]	4.6	49.6	10.7	54.2
Oat[b]	1.5	73.6	49.1	75.1
Rice bran[b]	4.7	46.7	9.9	51.4
Apple fibre[b]	13.9	48.7	3.5	62.6
Tomato fibre[b]	8.3	57.6	6.9	65.9

RRS, raw freeze-dried Roselle seeds; DRS, sun dried Roselle seeds; BRS, boiled sun-dried Roselle seeds; TDF, total dietary fibre; SDF, soluble dietary fibre; IDF, insoluble dietary fibre.
[a] Rao (1996).
[b] Claye et al. (1996).

The gross energy (kJ/g) was calculated in order to determine the relationship between food composition and available energy (FAO/WHO/UNU, 1981). Gross energy values of raw and processed Roselle seeds were higher than black seeds, chickpeas and wheat powder (FAO, 2001; Saleh Al-Jassir, 1992). The energy values of these seeds were however similar to soybeans (FAO, 2001). All the essential amino acids were detected in the RRS, DRS and BRS. Amino acids results indicated that the seeds were rich in lysine, arginine, leucine phenylalanine and glutamic acid. Methionine and cystine were the main limiting amino acids present. The latter findings were in agreement with Abu-Tarboush et al. (1997) and Rao (1996). El-Adawy and Khalil (1994) indicated that globulin was the major protein fraction of the seeds rather than albumins. According to Murray and Roxburgh (1984), high levels of albumin would elevate sulphur-containing amino acids (cystine and methionine). This may have resulted to lower values of cystine and methionine in the seeds studied. The present study however identified adequate cystine and methionine contents in raw (RRS), as well as DRS and BRS seeds, for human requirement (FAO/WHO, 1991). The amino acids content of the seeds were higher than previous studies (Abu-Tarboush et al., 1997; El-Adawy & Khalil, 1994; Rao, 1996). This may be attributed to higher protein content observed in the current study. In addition, all the essential amino acids were higher than wheat grain and rice (Abdel-Aal & Hucl, 2002; Sosulski & Imafidon, 1990). Lysine content of raw and processed seeds was found to be higher and adequate for human requirement. The high Lysine may be used as a complementary food mixture for poor or low lysine sources.

The major minerals or inorganic constituents of Roselle seeds were potassium, magnesium and calcium. This was in agreement with El-Adawy and Khalil (1994) and Rao (1996). However, the previous values reported in the literature were higher than the current values. Mineral elements were reported to be significantly influenced by variety, location and environmental conditions (Barampama & Simard, 1993; Koehler et al., 1987; Rao, 1996). These factors may be responsible for different variations exhibited from the current and previous values. Sodium, iron, zinc and copper of the seeds were present in low amounts, and another source may be necessary for supplementing some of these elements. According to Seena, Sridhar, and Jung (2004), cooking may drain or leach some of the minerals. The present study however showed that boiled seeds had significantly higher mineral values than RRS. Zinc was however low in RRS, DRS and BRS. Some cereal powders in the baking industry are very deficient in some elements, particularly calcium. Fortification of these powders with Roselle seeds powder may improve their dietary properties.

5. Conclusions

Nutritional values of treated Roselle seeds (DRS and BRS) for human consumption were comparable with raw seeds (RRS). Nutritional benefits of raw (RRS) and treated (DRS and BRS) seeds revealed that these seeds are promising, with good sources of proteins, dietary fibre, essential amino acids and lipids. These potential nutritional features of Roselle seeds powder should be exploited and used as functional ingredients for the development of nutraceuticals or functional food products.

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