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Evaluation of the Nutritional, Minerals, and Antioxidant Potential of Roselle (*Hibiscus sabdariffa* Linn.) Seeds from Roi Et Province in the Northeastern Region of Thailand

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Abstract

In Thailand, the roselle seeds have a few utilizations other than seeds for planting propagation. Consequently, this study aimed to evaluate the nutritional and mineral profile of roselle seeds in the Northeast region of Thailand. The obtained results proved that roselle seeds were found to be a good source of carbohydrates (41.48 ± 0.31 %), protein (30.40 ± 0.09 %), and fat (19.70 ± 0.04 %). Additionally, the results indicated that roselle seeds were a rich source of fiber (40.61 ± 0.26 %) and had a high energy content (1945.03 ± 12.31 KJ/100 g of sample). The macronutrients and micronutrients of the roselle seeds, such as K, P, Mg, Zn, Fe, Mn, and Cu, were found to be 2092.50 ± 1.89, 891.22 ± 3.71, 366.00 ± 1.34, 7.17 ± 0.13, 6.81 ± 0.20, 5.88 ± 0.14 and 4.22 ± 0.11 mg/g of sample, respectively. Furthermore, the total phenolic compounds as bioactive components and DPPH radical scavenging capacity were equal to 21.22 ± 0.24 mg GAE/100 g of sample and 46.28 ± 1.35 %, respectively. Thus, the roselle seeds were considered a cheap nutrient source and could be a good source of potential food ingredients.

Keywords: Roselle seeds, *Hibiscus sabdariffa* Linn., Nutritional potential, Minerals profile

Introduction

Thailand is one of the most biodiversity-rich countries in Southeast Asia due to its location in the tropical zone, slightly above the equator and next to the sea. Therefore, the climate is suitable for the growth and reproduction of many plant and animal species throughout the year. Moreover, Thailand is generally an agricultural country with a wide variety of cultivated crops. Furthermore, Thailand is an agrarian country with a wide variety of crops being grown, such as food crops, medicinal herbs, and ornamental plants [1,2]. Roselle (*Hibiscus sabdariffa* Linn.), as displayed in **Figure 1(a)**, is one of the plants widely cultivated in Thailand, and they are both a food plant and a medicinal herb. Roselle is a tropical plant which a valuable food resource, and it is a widely consumed vegetable [3-5]. The report of Salami and Afolayan [5], found that different parts of the roselle, namely calyces, pre-flowering green, and flowering red, exhibited excellent bacteria inhibition. Furthermore, they reported that the roselle calyces had better antimicrobial activities and higher toxicological effects than the leaves.

Several studies have reported on roselle extraction, characterization, nutritional, and functional properties. Chumsri *et al.* [6], presented the total anthocyanin, total phenolic contents, and EC_{50} of DPPH radical scavenging assay of fresh roselle calyxes from Amphur Namom, Songkhla Province were 37.67 ±

0.02 mg/100 g, 31.26 ± 0.75 mg gallic acid/g and 39.37 ± 0.61 mg/mL, respectively. Salami and Afolayan [7], reported the evaluation of nutritional and elemental compositions of green and red cultivars of roselle leaves. They found that all the samples showed the carbohydrate in a range of 26.93 - 54.13 %, crude protein 5.70 - 27.06 %, crude fat 1.16 - 13.09 %, crude fiber 15.75 - 36.10 %, energy 631.36 - 1,065.00 kJ, ash 6.08 - 13.74 %, and moisture content 6.00 - 9.70 %, respectively. While the minerals profile namely, calcium (Ca), magnesium (Mg), and iron (Fe) contents in all the samples, were higher than the recommended daily allowance of 1,250, 350 and 15 mg for adults. El-Sayed *et al.* [8], reported that the total phenolic compounds in part of roselle seed, cake, and leaves ranged between 155.04 - 3,288.33 ppm as gallic acid. Additionally, the result indicated that the total phenolic compounds in roselle leaves have the highest of 3,288.33 ppm, followed by part of the stem at 2,086.78 ppm. In addition, they also studied biscuits produced by replacing different ratios of wheat flour with roselle seeds cake and roselle leaves. The results found that using roselle cake or leaves powder in the biscuit formula improved the nutritional profile and physical characteristics of biscuits according to the method described by ISO: 8589 for the sensory evaluation of produced biscuits.

Furthermore, the report from Mohamed *et al.* [9], also showed that the total tocopherols content in different organs of roselle, including seeds, stems, leaves, and sepals, were 229 ± 20, 208 ± 46, 39 ± 4 and 36 ± 1 nmol/g, respectively. While Rimamcwe and Chavan [10], studied the inorganic minerals of India the roselle seeds and they discovered that the mineral content of calcium (Ca), magnesium (Mg), phosphorus (P), potassium (K), iron (Fe), zinc (Zn), and manganese (Mn) were 320.45, 464.36, 590.14, 1,925.67, 11.45, 17.43 and 7.57 mg/100 g dry weight, respectively. Although there are several studies on roselle based on the examples, data on roselle in the Northeastern region of Thailand is also limited due to scanty information currently available, especially on extraction, chemical characterization, nutritional, minerals, and antioxidant potential. Therefore, this study aims to evaluate the nutritional content and mineral profile of roselle seeds derived from Roi Et Province in the Northeast region of Thailand. The main goal of this research is to assess the possible utilization of roselle seeds by comparing the data with other reports.

Figure 1 (a) roselle stems and fruits, (b) fruits-dried roselle, (c) roselle seeds, and (d) size of roselle seeds.

Materials and methods

Materials

The roselle (*Hibiscus sabdariffa* Linn.) seeds, as shown in **Figure 1(c)**, were harvested from Selaphum District, Roi Et Province in Northeastern Thailand, in March 2022. All chemicals used in this work were of analytical grade (AR) purchased from Fluka, Sigma-Aldrich, Carlo Erba, QRëC, Merck, Labscan, and Acros Chemical Co. Ltd.

Preparation of dried roselle seeds

The roselle seeds were cleaned by washing several times to separate poor-quality seeds. The cleaned roselle seeds were dried using a hot air oven at 50 °C for 12 h. After drying, the obtained roselle seeds were ground with a blender to get the powder. Then, the dried roselle seed powder was immediately packed in an amber glass bottle, sealed tightly, and kept in a laboratory refrigerator until used. The overall process diagram of this study was depicted in **Figure 2**.

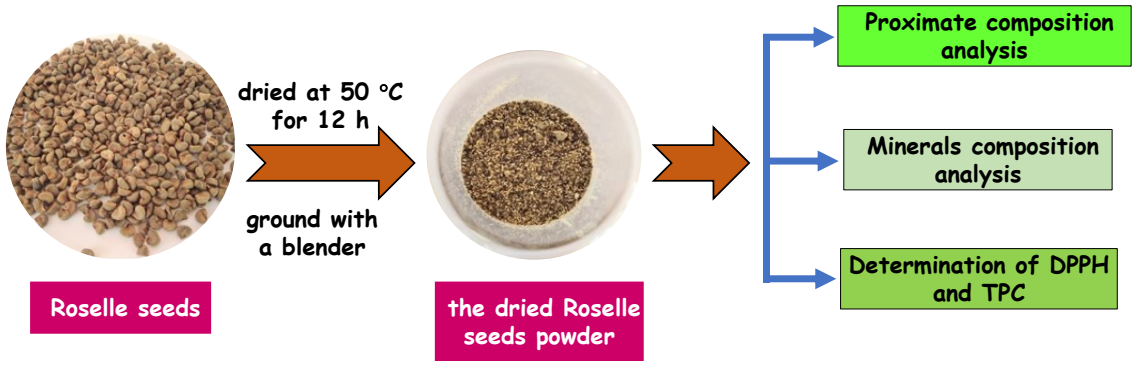

Figure 2 The infographic overall process diagram of this study.

Proximate composition analysis of roselle seeds

The percentage of moisture content, crude protein, crude fat, crude ash, and crude fiber were determined according to AOAC. standard method [11], and the research reports of Salami and Afolayan [7], El-Sayed *et al.* [8], Tounkara *et al.* [12]. While carbohydrate content was calculated by differences in total nutrition (100 %) against the total sum of the percentage of moisture content, crude protein, crude fat, crude ash, and crude fiber. Furthermore, the total carbohydrate content was calculated by aggregating the percentage of crude fiber and carbohydrate content.

Proximate analysis

Determination of moisture content

The determination of moisture content was analyzed with the gravimetric method by drying the sample in a hot air oven at 105 °C until a constant weight was obtained. The percentage of moisture content was calculated by using the following equation:

$$\text{Percentage of moisture content} = \frac{W_1 - W_2}{W_1} \times 100$$

whereas W_1 was the weight of the sample before drying and W_2 was the weight of the sample after drying.

Determination of crude protein

As AOAC. standard method [11], described, the Kjeldahl method was used to determine the crude protein content. The dried roselle seed powder was weighed 0.5 g into a Kjeldahl flask, followed by adding selenium as a catalyst of 10 g and 25 mL of concentrated H_2SO_4. The sample mixture was then digested inside a fume chamber until the sample was clear. After that, it was cooled, diluted with 100 mL of 40 % NaOH, and transferred into a Kjeldahl distillation apparatus. The sample was distilled and collected into a 4 % H_3BO_3 solution containing 3 drops of methyl red indicator until the sample volume was derived at around 50 mL. A 50 mL distilled sample was titrated with 0.1 M hydrochloric acid standard solution. The percentage of crude protein content was calculated using the following equation:

$$\text{Percentage of N content} = \frac{[50 \times (S - B)] \times 0.019057 \times 0.0140 \times 100}{10 \times \text{weight of the dried sample}}$$

$$\text{Percentage of crude protein content} = \text{percentage of N content} \times 6.25$$

S and B were the samples and blank titration values, while 0.019057, 0.0140 and 6.25 were constant.

Determination of crude fat

The Soxhlet method was used to determine the sample crude fat content and petroleum ether was used as a solvent. A pre-dried porous thimble containing 1 g of the dried sample was then placed inside the Soxhlet apparatus with 100 mL of petroleum ether. The solvent in the boiling flask was heated for 6 h to extract crude fat. After the allotted time had passed, the extracted mixture was filtered, and the solvent was removed using a rotary evaporator. The crude fat content value was calculated using the weight of the obtained crude fat divided by the weight of the dried sample used following the formula:

$$\text{Percentage of crude fat content} = \frac{\text{the weight of the obtained crude fat} \times 100}{\text{the weight of the dried sample used}}$$

Determination of crude ash

Determination of total ash content started with weighing 2 g of the sample and put in a crucible. Afterward, the sample was ashed at 250 °C for 1 h and then incinerated at 600 °C for 5 h in a muffle furnace. The sample was later cooled to 150 °C before removal and brought to a desiccator. The percentage of ash content was calculated as follows:

$$\text{Percentage of ash content} = \frac{\text{the weight of the sample after the ashing} \times 100}{\text{the weight of the dried sample used}}$$

Determination of crude fiber

The crude fiber content was determined by weighing 2 g of the dried sample into a glass crucible container. Then, 1.25 %v/v of a H_2SO_4 solution with a volume of 200 mL was added, and n-octanol was dropped 3 - 5 drops for use as an antifoam agent. The sample was digested for 30 min, after that the acid was drained out, and the sample was washed with 30 mL of hot deionized water 3 times. Afterward, 1.25 %w/v KOH was added amount of 150 mL into the residue. Finally, the crucible was boiled again for 30 min, removed from the extraction unit, dried at 110 °C overnight in a hot air oven, allowed to cool in a desiccator, and weighed (W_1). Then the sample was ashed with a muffle furnace at 550 °C for 5 h, cooled in a desiccator, and reweighed (W_2). The percentage of crude fiber was calculated using the following formula:

$$\text{Percentage of crude fiber} = \frac{[\text{digested sample } (W_1) - \text{ashed sample } (W_2)] \times 100}{\text{the weight of the dried sample used}}$$

Determination of carbohydrate (nitrogen-free extract)

The carbohydrate content can be evaluated by subtraction of the percentage of moisture content, crude protein, crude fat, crude ash, and crude fiber from the total dry matter (100 %) as follow:

$$\text{Percentage of carbohydrate content} = 100 - \Sigma\ (\%\text{moisture} + \%\text{protein} + \%\text{fat} + \%\text{ash} + \%\text{fiber})$$

In addition, the total carbohydrate content was determined by the total sum of the percentage of crude fiber and carbohydrate content.

Determination of energy content

The energy value (in Kilojoules per 100 g of sample), which was about the reports of Salami and Afolayan [7], was calculated by aggregation of the multiplied factor value of 16.736 kJ for total carbohydrates, 16.736 kJ for crude protein, and 37.656 kJ for crude fat, respectively as follow:

$$\text{Energy value (KJ/100 g)} = [(16.736\ \text{kJ} \times \text{total carbohydrates}) + (16.736\ \text{kJ} \times \text{crude protein})\ (37.656\ \text{kJ} \times \text{crude fat})]$$

Minerals composition analysis

The mineral compositions of the sample were analyzed by 1 g of dried sample digested in a 100 mL micro-Kjeldahl flask with $HNO_3/HClO_4$ until the solution became colorless. Then, the obtained sample was cooled and diluted to 50 mL in a volumetric flask with 0.1 M HCl. The elemental composition namely calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) were evaluated by using graphite furnace atomic absorption spectrophotometer; AAs (GTA 120 Graphite Tube Atomizer-Agilent Technologies, USA). White phosphorus (P) content was determined by a colorimetric method following the AOAC. standard method [11]. Furthermore, the analysis of the mineral compositions of the sample in this work has applied the technique according to the method described by Bvenura and Afolayan [13], Rimamcwe and Chavan [10], and Salami and Afolayan [7].

Determination of vitamin content in crude fat

The High-Performance Liquid Chromatography (HPLC) method was adopted from the AOAC. standard method [15], for the determination of crude fat-soluble vitamins extracted from roselle seeds containing vitamins A (Retinol), D (D_1, D_2, and D_3), and E (α-Tocopherol) and referred to the report method from Staffas and Nyman [14], and Salami and Afolayan [7]. Reporting results were expressed in μg/100 g of samples for vitamins A and D, while vitamin E would be reported in terms of mg/100 g of samples.

Determination of DPPH radical scavenging activity

The radical scavenging capacity of DPPH (2,2-diphenyl-1-picrylhydrazyl (DPPH) was determined according to the method from the report of Nyam *et al.* [16], and Rimamcwe and Chavan [10]. The assay mixture contained 2 mL of 1.0 mmol/L DPPH radical solution, prepared in methanol. In contrast, 2 g of dried sample was extracted with 10 mL of methanol as a solvent and evaporated off using a rotary evaporator to obtain the extracted sample. Ethanol of 0.5 mL was then added to dissolve the fat. After that, the extracted solution of 0.2 mL was mixed with 2.8 mL of ethanol, while the control was prepared without adding a sample. The standard or extracted solution was rapidly mixed with DPPH radical solution and incubated in the dark at 37 °C for 30 min. Absorbance was measured at 517 nm, and the antioxidant activity was expressed as follows:

$$\text{Percentage inhibition of DPPH activity} = \frac{A - B}{A} \times 100$$

whereas A and B were absorbances of the control and absorbance of the sample.

Determination of the total phenolics content (TPC)

The total phenolics content (TPC) of the sample was determined by the Folin-Ciocalteu colorimetric method as described by Nyam *et al.* [16], Zheng *et al.* [17], and Wongklom *et al.* [18]. The sample extract of 1 mL was mixed with 2 mL of mixing solvent between methanol and water (60:40). 1.5 mL Folin-Ciocalteu was diluted 10-fold, added, shaken for 30 s with a vortex mixer, and set aside at room temperature for 3 min. Then, the sodium carbonate solution with 7.5 %w/v amount of 800 µL was added to the sample mixture and mixed well. Finally, the final solution sample was allowed in a dark environment to be set aside for 60 min at room temperature. The absorbance of the extract and standard solutions were measured spectrophotometrically at a wavelength of 765 nm against the blank. The gallic acid was applied to calibrate a standard curve. The TPC of the sample was expressed as milligrams of gallic acid equivalents (GAE) per 100 g of sample (mg GAE/100 g of the sample).

Results and discussion

Proximate chemical composition analysis

Preliminary studies found that the size of roselle seeds was about 0.2 - 0.4 cm^2, and the flesh in the sources looked opaque white, as demonstrated in **Figure 1(d)**. The major nutrient composition of the roselle seeds sample from Roi Et Province in the Northeast region of Thailand was analyzed, and the results were shown in **Figure 3** and **Table 1**. Furthermore, the comparison values of the proximate nutrient composition of roselle seeds in this current study versus previous studies were also displayed in **Table 3**.

The moisture content of the roselle seed was approximately 3.94 % which is considered to have relatively low humidity. The research report of Ellis and Roberts [19], and Nyam *et al.* [16], described that the moisture content of seeds should be in the range of 4 - 8 % because it could be stored for a more extended period and prevent microbial activity. Crude protein content was recorded as being approximately 30.40 % which was higher than that of the reports of El-Sayed *et al.* [8], Tounkara *et al.* [12], Nyam *et al.* [16], and El-Deab and Ghamry [20]. However, the crude fat content of roselle seeds in this current study was 19.70 %, similar to the report of El-Deab and Ghamry [20]. Still, it was lower than both the report of El-Sayed *et al.* [8], and Tounkara *et al.* [12], with an approximate value of 20.83 and 27.83 %, respectively. As for ash content, the result found that it has similar values to previous research papers of El-Sayed *et al.* [8], and Tounkara *et al.* [12], with an equal to 4.50 %.

Moreover, crude fiber content showed a high value of about 40.61 %, which was higher than that of the previous study report of both El-Sayed *et al.* [8], and Nyam *et al.* [16], approximately 2 times. In addition, the total carbohydrate content in the present study was calculated by aggregating the percentage of crude fiber and carbohydrate content showing a value of about 41.47 %. This data on the total carbohydrate content was close to the previous studies by El-Sayed *et al.* [8], Tounkara *et al.* [12], Nyam *et al.* [16], and El-Deab and Ghamry [20]. Finally, the energy value of the roselle seed was 1,945.03 KJ/100 g of the sample, which was higher than that reported previously by Salami and Afolayan [7].

Table 1 Proximate chemical composition, functional properties, and antioxidant activity of roselle (*Hibiscus sabdariffa* Linn.) seeds from Roi Et Province in the Northeast region of Thailand.

Analysis	Mean ± standard deviation[a]
Proximate chemical composition	
Moisture (%)	3.94 ± 0.06
Crude protein (%)	30.40 ± 0.09
Crude fat (%)	19.70 ± 0.04
Ash (%)	4.50 ± 0.11
Crude fiber (%)	40.61 ± 0.26
Carbohydrate content (%)	0.85 ± 0.01
Total carbohydrate content (%)[b]	41.48 ± 0.31
Energy content (KJ/100 g of the sample)	1,945.03 ± 12.31
DPPH radical scavenging activity and the total phenolics content	
DPPH radical scavenging capacity (%)	46.28 ± 1.35
Total phenolics content (mg GAE/100 g of the sample)	21.22 ± 0.24
Vitamin content in crude fat	
Vitamin A (Retinol) (µg/100 g of the sample)[c]	ND[e]
Vitamin D[c]	
Vitamin D_1 (µg/100 g of the sample)	ND[e]
Vitamin D_2 (µg/100 g of the sample)	ND[e]
Vitamin D_3 (µg/100 g of the sample)	ND[e]
Vitamin E (α-Tocopherol) (mg/100 g of the sample)[d]	< 2.00

[a]This data was averaged from 5 measurements where the deviation was within 3 %.
[b]Total carbohydrate content was calculated by aggregating the percentage of crude fiber and carbohydrate content.
[c]LOD = 10.00 µg/100 g of the sample; LOQ = 20.00 µg/100 g of the sample
[d]LOD = 0.60 mg/100 g of the sample; LOQ = 2.00 mg/100 g of the sample
[e]ND = Not detected

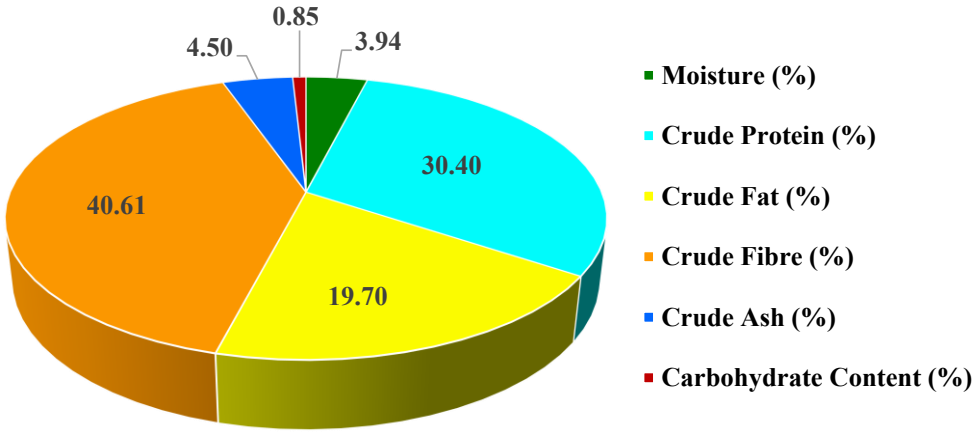

Figure 3 The percentage proximate composition of roselle (*Hibiscus sabdariffa* Linn.) seeds from Roi Et Province in the Northeast region of Thailand.

Hence, all the proximate chemical composition analysis results of the roselle seed from Roi Et Province in the Northeast region of Thailand point out that they were an excellent source of fat, protein, and carbohydrate groups (especially fiber). For that reason, the results presented in this study suggested that roselle seeds could be used as an economical and valuable source in food fortification and other products with improved functional and nutritional properties. However, the quality control of roselle seed in each area depends on many factors. The significant variations in the percentages value of the proximate nutrient composition of roselle seeds in this current study compared with previous studies could describe by different possible factors such as the environment used for plant cultivation such as soil quality, water source, and weather (e.g., humidity, temperature, and sunlight intensity) agreement with that the reports of Salami and Afolayan [7], El-Sayed *et al.* [8], Tounkara *et al.* [12], Nyam *et al.* [16], and El-Deab and Ghamry [20].

DPPH radical scavenging activity and the total phenolics content analysis

The free radical scavenging activity of the extracted roselle seeds was measured in terms of hydrogen donating or radical scavenging ability using the stable radical DPPH. The DPPH free radical has a deep violet color, but this color would be changed to a yellow tone when the antioxidant compound in the extracted roselle seeds caught up with DPPH free radical. While antioxidant compounds generally contain a phenolic group, it was typically analyzed with the Folin-Ciocalteu reagent and used gallic acid as a reference standard. This method uses the UV-vis technique to analyze the simple, convenient, economical, highly accurate, and transparent results of the experiment [21-24].

As illustrated in **Table 1**, the results found that the total phenolic compounds and DPPH radical scavenging activity analysis of roselle seeds were high at 21.22 ± 0.24 mg GAE/100 g of sample and 46.28 %, respectively. As shown in **Table 3**, previous studies by Nyam *et al.* [16], El-Sayed *et al.* [8], and El-Deab and Ghamry [20], showed the results of the total phenolic content of roselle seeds as equal to 18.80, 20.12 and 23.65 mg GAE/100 g of the sample, respectively. The data was similar in value to this research. While the reports of Nyam *et al.* [16], displayed a DPPH radical scavenging capacity of 44.70 % which was less than that in this study. In addition, the report by El-Dean and Ghamry [20], showed the highest value of DPPH radical scavenging capacity of roselle seeds crude extract at about 56.94 %. This phenomenon can explain that various factors might strongly influence the antioxidant activities of roselle seeds crude extract, such as antioxidant compound concentration in the example, temperature, pH value, and plant growth process in different areas. All these possible reasons directly affected on synthesis process of important plant substrates, especially bioactive compounds [5,20,22,25]. For this reason, roselle seeds were another whole cereal source rich in beneficial nutrients and high in bioactive compounds, especially antioxidants that were important for consumers.

Determination of vitamin content in crude fat derived from roselle seeds

Generally known that roselle is one of the essential vegetables to consume by humans due to their being very rich in nutritional, medicinal, and bioactive compounds. Vitamins are one of the critical substances that are beneficial to the human body because it needed for normal cell function, growth, and development [5,7,26,27]. In consequence, the determination of vitamin content, especially in crude fat derived from roselle seeds, namely vitamin A (Retinol), vitamin D (D_1, D_2, and D_3), and vitamin E (α-Tocopherol), was necessary to lead to further development into various products.

The results presented that the vitamin content in the crude fat of roselle seeds was scanty. Vitamin A (Retinol) and vitamin D (D_1, D_2, and D_3) were not detected (ND) by the analysis conditions of a limit of detection (LOD) as 10.00 µg/100 g of the sample and a limit of qualitative (LOQ) as 20.00 µg/100 g of the sample, respectively. On the other hand, there was vitamin E (α-Tocopherol) less than 2.00 mg/100 g of the sample (at LOD = 0.60 mg/100 g of the sample and LOQ = 2.00 mg/100 g of the sample). This result indicated that the roselle seeds might not be a good source of abundant fat-soluble vitamins. In the research report of Salami and Afolayan [7], they found that vitamins A, C, and D were the contents of green and red roselle samples, especially in the part of flower and fruit. Therefore, roselle seeds have fewer vitamins because most components are fat, protein, and carbohydrates [28-31].

Inorganic mineral composition of roselle seeds

Mineral nutrients are essential for health which the body needs in small amounts to work correctly, such as calcium, phosphorus, potassium, sodium, magnesium, iron, zinc, chromium, copper, manganese, and selenium [7,32,33]. Minerals elements content measured in the roselle seeds, both macronutrients, and micronutrients, were presented in **Table 2**. The results could note that potassium (K) was to be the highest concentration for macronutrients, and the next in order was phosphorus (P), magnesium (Mg), calcium

(Ca), and sodium (Na), respectively. While micronutrient content in roselle seeds showed zinc (Zn) that the highest value and iron (Fe), manganese (Mn), and copper (Cu) were to quantity decrease respectively. These finding results agreed with that the report of Salami and Afolayan [7], El-Sayed *et al.* [8], and Rimamcwe and Chavan [10]. The differences in minerals found in the roselle seeds sample might depend on the cultivation areas with different mineral abundances. The minerals contained in the roselle seed samples were all essential to the body, such as helping to strengthen bones and teeth, vital for the nervous system functioning, maintenance of body fluid, the transmission of nerve impulses and muscle contraction, necessary for the proper growth, connective tissue, and brain and heart [7,34,35]. Therefore, roselle seeds were one of the cereals rich in various minerals and important for humans.

Table 2 Inorganic mineral composition of roselle (*Hibiscus sabdariffa* Linn.) seeds from Roi Et Province in the Northeast region of Thailand.

Inorganic mineral	Current Study[a] (mg/100 g of sample)	Previous studies (mg/100 g of sample)	
		Rimamcwe and Chavan [10]	Salami and Afolayan [7]
Macronutrients			
Calcium (Ca)	350.12 ± 2.47	320.45 ± 1.58	245 ± 70.7
Magnesium (Mg)	366.00 ± 1.34	464.36 ± 1.34	395 ± 7.07
Potassium (K)	2,092.50 ± 1.89	1,925.67 ± 1.71	1,415 ± 7.07
Sodium (Na)	23.43 ± 0.47	590.14 ± 1.20	10.0 ± 0.00
Phosphorus (P)	891.22 ± 3.71	590.14 ± 1.20	125 ± 7.07
Micronutrients			
Iron (Fe)	6.81 ± 0.20	11.45 ± 1.89	46.2 ± 7.64
Zinc (Zn)	7.17 ± 0.13	17.43 ± 1.69	5.55 ± 0.07
Manganese (Mn)	5.88 ± 0.14	7.57 ± 1.91	4.35 ± 0.07
Copper (Cu)	4.22 ± 0.11	-	1.1 ± 0.00

[a]This data was averaged from 5 measurements where the deviation was within 3 %.

Table 3 Comparison values of the proximate nutrient composition roselle (*Hibiscus sabdariffa* Linn.) seeds in this current study versus previous studies.

Type of analysis	Current study	Previous studies			
		Nyam *et al.* [16]	El-Sayed *et al.* [8]	Tounkara *et al.* [12]	El-Deab and Ghamry [20]
Proximate chemical composition					
Moisture (%)	3.94 ± 0.06	6.6	7.72	8.14	6.13
Crude protein (%)	30.40 ± 0.09	13.0	26.24	27.32	23.25
Crude fat (%)	19.70 ± 0.04	17.4	27.83	20.83	19.36
Crude ash (%)	4.5 ± 0.11	1.1	5.53	4.47	5.73
Crude fiber (%)	40.61 ± 0.26	24.7	18.10	-	16.25
Total carbohydrate content[a] (%)	41.48 ± 0.31	37.3	40.40	39.24	37.95
Energy content (KJ/100 g of the sample)	1945.03 ± 12.31	-	-	-	-
DPPH radical scavenging activity and the total phenolics content					
DPPH radical scavenging capacity (%)	46.28±1.35	44.70	-	-	56.94
Total phenolics content (mg GAE/100 g of sample)	21.22±0.24	18.80	20.12[b]	-	23.65

[a]Total Carbohydrate Content was calculated by aggregating the percentage of crude fiber and carbohydrate content.
[b]Reference the reports found that polyphenols = 201.19 ppm gallic acid.

Conclusions

The study found that the roselle seeds were a good source of carbohydrates, protein, fat, and fiber and had a high energy content. In addition, the macronutrients and micronutrients of the roselle seeds, such as K, P, Mg, Zn, Fe, Mn, and Cu, were found to be relatively high value and similar to the previous research reports. Furthermore, the result also found that the roselle seeds have a high both of the total phenolic compounds as bioactive components and DPPH radical scavenging capacity. From the results of this study, the roselle seeds derived from Roi Et Province in the Northeast region of Thailand provided advantageously dietary fiber, protein, fat, antioxidant compounds, macronutrients, and micronutrients. Therefore, all the obtained results indicated that the roselle seeds were a good source of potential food ingredients and could be used to prepare other food products, adding some economic value.

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