Functional properties of roselle (*Hibiscus sabdariffa* L.) seed and its application as bakery product

Kar-Lin Nyam · Sod-Ying Leao · Chin-Ping Tan · Kamariah Long

Revised: 17 October 2012 / Accepted: 22 November 2012 / Published online: 8 December 2012
© Association of Food Scientists & Technologists (India) 2012

Abstract Roselle (*Hibiscus sabdariffa* L.) seed is a valuable food resource as it has an excellent source of dietary fibre. Therefore, this study examined the functional properties of roselle seeds. Replacement of cookie flour with roselle seed powder at levels of 0–30 % was investigated for its effect on functional and nutritional properties of cookies. Among the four formulations cookies, the most preferred by panelists was 20 % roselle seed powder cookie (F3), followed by 10 % roselle seed powder cookie (F2) and 30 % roselle seed powder cookie (F4). The least preferred formulation among all was control cookie (F1). Cookie with 20 % roselle seed powder added showed higher content of total dietary fibre (5.6 g/100 g) as compared with control cookie (0.90 g/100 g). Besides that, cookies incorporated with roselle seed powder exhibited improved antioxidant properties. Thus, roselle seed powder can be used as a dietary fibre source and developed as a functional ingredient in food products.

Keywords Roselle seed · Functional properties · Antioxidant activity · Cookies · Dietary fibre

Introduction

Health, convenience and indulgence continue to dominate the eating habits of our society. Despite the general knowledge about the relation between dietary fibre and health, a big gap exists between mean daily intake and the recommended daily intake (Handa et al. 2012). According to the American Dietetic Association, the current recommended fibre intakes for adults range from 25.0 to 30.0 g/day and the insoluble/soluble fibre ratio should 3:1 (Borderias et al. 2005). The food fibres have led to the development of a large potential market for fibre-rich products and ingredients. Fibre fortification of common foods has the advantage of requiring the least dietary changes for our fast food or convenience food consuming population (Lo 1989). Cookie is the famous convenient food worldwide, but it has high sugar content that causes less physiological benefits. The addition of fibre to bakery products will decrease the fat content, by using dietary fibre as substitutive of fat without loss of quality (Martin 1999). Food scientists have been encouraged to find new sources of dietary fibre that can be used as ingredients in the food industry and to develop fibre-rich products. Thus, this study was aimed to develop fibre enriched cookie and improve nutritional quality of cookies.

In many countries, cereal grains, legumes, roots and tubers are important in human diet (Koehler et al. 1987). Even though the nutritional guidelines place grains and grain products at the base of food guide pyramid that are important for optimal health, seeds also have notable nutritional value which are able to compare with grains. Seeds are one of the cheapest food sources. Most of researchers have confirmed the nutritional usefulness of seeds (Barampama and Simard 1993). In food industry, the roselle calyces are processed to produce juices; the seeds are removed and disposed as a by-product. Recently, many researchers found the nutritional

K.-L. Nyam (✉) · S.-Y. Leao
Department of Food Science and Nutrition, Faculty of Applied Sciences, UCSI University, 56000, Kuala Lumpur, Malaysia
e-mail: nyamkl@ucsi.edu.my

C.-P. Tan
Department of Food Technology, Faculty of Food Science and Technology, Universiti Putra Malaysia,
43400, Serdang, Selangor, Malaysia

K. Long
Malaysian Agricultural Research & Development Institute (MARDI), PO Box 12301, 50774, Kuala Lumpur, Malaysia

usefulness of roselle seeds (Amin et al. 2008). Thus, the food industry has been focused on the utilization of roselle seed in order to avoid waste disposal problems.

Roselle (*Hibiscus sabdariffa* L.) seed is a valuable food resource due to it is rich in protein content and micronutrients. It is also an excellent source of fibre (Omabuwajo et al. 2000). Roselle seeds contain 18.3 % of total dietary fibres (Hainida et al. 2008). Roselle seed might be useful as low cost source of dietary fibre substitute in dietary supplement or food ingredient in food industry. Therefore, it will improve the daily intake of dietary fibre and overcome the fibre deficit. According to Tosh and Yada (2010), the edible seeds from pulses are rich food source of dietary fibres that enhance various health benefits. The hull of seed contains substantial amount of insoluble dietary fibre, while the inner part of seeds accounts for soluble dietary fibre. Dietary fibre present in roselle seeds contribute to physiological and health benefits. Roselle seeds can be considered good ratio of soluble to insoluble fibre fraction (Hainida et al. 2008). Therefore, it can lower serum cholesterol, produce short chain fatty acids from fibre fermentation in colon, alter the concentration of insulin and hormones, and reduce risk of colon cancer. Roselle seeds fibre is supposed to have good nutritional and functional properties. The fibres from roselle seeds are suitable for incorporation into food products because it can improve the texture of products.

The aims of this study were to develop fibre enriched cookies by using roselle seed powder and study the effects of fibre derived from roselle seed on cookies in terms of antioxidant activity, physical and chemical characteristics.

Materials and methods

Materials

Dried roselle (*Hibiscus sabdariffa* L.) seed was obtained from Malaysian Agricultural Research and Development Institute (Selangor, Malaysia).

Methods

Pre-treatment

According to Halimatul et al. (2007), heat treatments such as boiling of roselle seeds can lead to inactivation of anti-nutrient or enzyme inhibitors. Besides that, Halimatul et al. (2007) also confirmed that the higher protein quality found in boiled roselle seeds. Pre-treatment of roselle seed was conducted by using modified method from Morton (1987). 300 g of roselle seeds were soaked in 600 mL of distilled water for 12 h at room temperature. The distilled water was then drained and roselle seeds were rinsed three times with

distilled water. The rinsed seeds were then blanched with distilled water in microwave oven (Memmert, Copens Scientific, Germany). Later, the seeds were dried in oven for 24 h at 60 °C. The dried seeds were milled into 1 mm particle size by microfine miller (Sharp, Japan). The milled seeds were vacuum packed and stored in dark and dry place for future use.

Proximate analysis of roselle seeds

Moisture, crude protein (micro-Kjeldahl), crude oil (soxhlet), fibre and ash content were determined using the AOCS (1997) Methods Ba 2a-38, Ba 4a-38, Ba 3-38, Ba 6-84 and Ba 5a-49, respectively, and total carbohydrate was determined by difference. All determinations were done in triplicate.

Functional properties

Water holding capacity (WHC) Water holding capacity was determined according to the method from Rosell et al. (2009) with slightly modification. 1 g of dried sample was mixed with 20 mL of distilled water and allowed to hydrate for 24 h at room temperature. The mixture was filtered and the weighted wet sample was then subjected to oven-dried at 105 °C until constant weight. The dried sample was cooled for 15 min in a dessicator filled with silica gel to room temperature. The mass of sample was weighed and recorded. Water holding capacity was calculated using Eq. 1.

$$\text{Water holding capacity (g/g)} = \frac{\text{Wet weight (g)} - \text{Dry weight (g)}}{\text{Dry weight (g)}} \quad (1)$$

Water retention capacity (WRC) This property was determined according to the method from Garau et al. (2007), with slightly modification. 1 g of dried sample was allowed for hydration in 30 mL of distilled water in centrifuge tube. The mixture was allowed to hydrate for 24 h at room temperature. The mixture was centrifuged at 3,000×g for 20 min. The mixture was filtered, it was then weighed and subjected to oven-dried at 105 °C until constant weight. The dried sample was cooled for 15 min in a dessicator filled with silica gel to room temperature. The mass of sample was weighed and recorded. Water retention capacity was calculated using Eq. 2.

$$\text{Water retention capacity (g/g)} = \frac{\text{Residue fresh weight (g)} - \text{Residue dry weight (g)}}{\text{Residue dry weight (g)}} \quad (2)$$

Swelling capacity This property was determined by using a modified method from Rosell et al. (2009). 1 g of dried sample was immersed in 20 mL of distilled water to hydrate for 24 h at room temperature. The volume of the swollen sample was recorded. The swelling capacity was expressed as mL per gram of sample and calculated using Eq. 3.

Swelling capacity (mL/g)

$$= \frac{\text{Volume Occupied by Sample}}{\text{Original Sample Weight}} \quad (3)$$

Oil holding capacity (OHC) This property was determined by using a modified method from Vazquez-Ovando et al. (2009). 1 g of dried sample was mixed with 20 mL of palm cooking oil (Saji) in centrifuge tube. The mixture was left for 24 h at room temperature. The sample was centrifuged at $2,200 \times g$ for 30 min. The volume of supernatant was measured and recorded. Oil holding capacity was expressed as grams of oil held per gram of sample.

Emulsifying activity (EA) and emulsion stability (ES) These properties were determined according to modified methods by Vazquez-Ovando et al. (2009). 2 g of dried sample was immersed in 100 mL of distilled water in and homogenized at 250 rpm for 2 min. Subsequently, 100 mL of palm cooking oil was added into the mixture and homogenized at 250 rpm for 1 min. 40 mL of the emulsion formed was centrifuged at $1,200 \times g$ for 5 min. Emulsion activity was expressed as volume of emulsion layer per 100 mL of the mixture.

Emulsion stability was determined by heating the prepared emulsion at 80 °C for 30 min and was allowed to cool to 40 °C, subsequently homogenized at 250 rpm for 1 min. 40 mL of emulsion was transferred to a 50 mL centrifuge tube and centrifuged at $1,200 \times g$ for 5 min. Emulsion stability was expressed as volume of the remaining emulsion per 100 mL the original emulsion volume.

Organic molecule absorption capacity (OMAC) This property was determined by using a modified method from Vazquez-Ovando et al. (2009). 3 g of dried sample was mixed with 10 mL of palm cooking oil in centrifuge tube and was stored in the cabinet and left for 24 h at room temperature. The mixture was centrifuged at $2,000 \times g$ for 15 min at 25 °C. The weight of supernatant was measured. Organic molecule absorption capacity was calculated in terms of sample weight gain and expressed as grams of oil per gram of sample.

Antioxidant activity

2,2-diphenyl-1 picrylhydrazyl (DPPH) radical scavenging capacity DPPH was determined according to the method of Liu and Yao (2007). 2 g of sample was mixed with 10 mL of

methanol. The mixture was shaken on the shaker for 1 h at 120 rpm. After that, the mixture was filtered and the solution was collected. The solvent was evaporated off at 35 °C by using rotary evaporator (Buchi, Switzerland). Hence, the sample extract was obtained. 0.5 mL of ethanol was then added in to dissolve the fat. Subsequently, 0.2 mL of sample was mixed with 2.8 mL of ethanol. Then, 2.8 mL of 0.004 % DPPH solution was added and the mixture was shaken vigorously. Control without addition of sample was used. The mixtures were allowed to stand in the dark at room temperature for 30 min. Absorbance was measured at 517 nm against ethanol. The antioxidant activity was expressed as Eq. (4).

$$\text{Percent(\%)inhibition of DPPH activity} = \frac{A-B}{A} \times 100\% \quad (4)$$

A absorbance of the control

B absorbance of the sample

Total phenolic content (TPC) The total phenolics content (TPC) of the sample was determined according to Waterhouse (2002) with slight modification. 2 mL of methanol with water (60:40) was mixed with the 1 mL of sample extract. Subsequently, 1.5 mL of 10-fold diluted Folin-Ciocalteu (FCR) was added and allowed to stand in room temperature for 3 min. 800 μ L of 7.5 % (w/v) sodium carbonate solution was added and mixed well. It was allowed to stand in a dark environment at room temperature for 1 h. The absorbance was measured against the blank reagent at 765 nm. Gallic acid standard curve was calibrated and TPC of the sample was expressed as mg GAE/100 g sample.

Cookie preparation

The cookies were made using cookie flour, baking powder, roselle seed powder, white sugar, brown sugar, unsalted butter, vanilla essence and eggs. The dough was formed after addition all the ingredients and baked in oven at 180 °C for 15 mins. Four different formulations of cookies were made to test the effects of fibre derived from roselle seed on cookie texture, physical and chemical characteristics, four different formulations were used in this study. For formulation 1 (F1), no roselle seed powder was added, which acts as control. 10 % of roselle seed powder was added in formulation 2 (F2), 20 % of roselle seed powder was added in formulation 3 (F3) and 30 % of roselle seed powder was added in formulation 4 (F4). The cookies were stored in air tight container. Cookies were ground into powder and vacuum packed for future chemical analysis.

Physical analysis of cookie

Spread factor The spread factor (SF) was determined by the thickness (T) and diameter (D) of the cookies using the Eq. 5 (Hussain et al. 2006).

$$SF = \frac{D}{T} \times CF \times 10 \quad (5)$$

where CF is a correction factor at constant atmospheric pressure, which was 1.0 in this study.

Water activity Water activity of cookie was determined by using water activity meter (AquaLab, USA).

Texture The textural characteristics of cookies were measured in TA.XT *plus* Texture Analyser using Warner-Bratzler blade (Texture Technologies, New York). Force required to break cookies individually was recorded and the average was calculated (Ajila et al. 2008).

Colour Cookie surface colour was measured using UltraScan Pro HunterLab Colour Measuring System. *L* (brightness), *a* (redness) and *b* (yellowness) values were obtained after calibrating the instrument using a white tile. The *L* value was a measure of lightness and varies from -100 (black) to +100 (white), the *a* value varies from -100 (green) to +100 (red) and the *b* value varies from -100 (blue) to +100 (yellow) (Nyam et al. 2009).

Sensory evaluation of cookie

Sensory evaluation of cookies was done using Hedonic test based on the appearance, aroma, texture, flavour, and

overall acceptability from 15 untrained panelists (Hussain et al. 2006).

Chemical analysis of cookie

The most preferred and control cookies grounded into powder form in order to perform proximate analyses and antioxidant activities. Dietary fibre was determined according to AOAC (2000) Method 985.29.

Statistical analysis

All experiments and/ or measurements were replicated three times. All the results were analyzed by using Minitab software (Minitab version 13) for One-way analysis of variance (ANOVA) with Tukey's test which was used to determine the significant differences between the means at the 5 % level. Differences are considered statistically significant at $p < 0.05$.

Results and discussion

Proximate analysis, functional properties and antioxidant activity of roselle seed powder

Table 1 shows the results of proximate analyses, functional properties and antioxidant activity of dietary fibre derived from roselle seed powder. The moisture content of the roselle seed was 6.6 % indicated that it could be stored for a longer period and prevent microbial activity as it was in the range of 4–8 % (Ellis and Roberts 1991). The ash content

Table 1 Proximate composition, functional properties and antioxidant activity of roselle seed powder

Analysis	Mean ± standard deviation
Moisture (%)	6.6±0.14
Ash (%)	1.1±0.09
Crude protein (%)	13.0±0.28
Crude fat (%)	17.4±0.51
Crude fibre (%)	24.7±0.71
Total carbohydrate (%)	37.3
Water holding capacity (g/g)	2.1±0.16
Water retention capacity (g/g)	2.2±0.04
Oil holding capacity (g/g)	14.1±0.36
Swelling capacity (g/g)	1.0±0.00
Emulsifying activity (mL/100 mL)	2.1±0.48
Emulsion stability (mL/100 mL)	3.0±0.41
Organic molecule absorption capacity (g/g)	0.65±0.02
DPPH radical scavenging capacity (%)	44.7±3.61
Total phenolic content (mg GAE/100 g seed)	18.8±1.86

*Total carbohydrate is obtained by difference. Total carbohydrate = 100 % – (%moisture+ %ash+ %protein+ %fat+ % crude fibre)

from current study was lower than that reported by Nyam et al. (2009) because the roselle seed was subjected to cooking process during pre-treatments. The roselle seed became soft and easily crushing with fingers after it cooked under microwave for 5 min, which caused the leaching of mineral content from roselle seed. Protein content was influenced by the effects of processing like boiling, cooking and thermal treatment. Pre-treatment to roselle seed, such as microwave cooking and oven-drying caused the loss of its protein content. The crude lipid of roselle seed in this study was significantly higher ($p < 0.05$) than that reported by Nyam et al. (2009). This was probably due to variation in organic solvents used in crude fat analysis. Besides, the lipid content can be affected by genetic and environmental factors (Izquierdo et al. 2012). Roselle seed is an excellent source of culinary oil (Nyam et al. 2009). It has substantial amount of lipids or fats that benefits to human health. High amount of crude fibre (24.7 %) implied that the roselle seed could be considered as a good source of dietary fibre. Hainida et al. (2008) indicated that roselle seed contained a balance proportion of soluble and insoluble fraction of dietary fibre. The total dietary fibre of the roselle seeds was within the acceptable range, with soluble and insoluble fibre ratios ranging from 1.2 to 3.3. Thus, roselle seed is effective to exert the physiological effect such as lowering the risk of cardiovascular disease, gastrointestinal disease, colon cancer, glycemic response and obesity (Rosamond 2002). The major component in the roselle seed was carbohydrate (37.3 %), which was similar to that reported previously (35.6 %) by Nyam et al. (2009).

Dietary fibre from roselle seed contributed to 2.2 g/g water retention capacity (WRC) and 1 mL/g swelling capacity (SC). Low WHC (2.1 g/g) found in roselle seed powder could be attributed to the lower number of free hydroxyl groups, subjected to high temperature during drying process and also higher protein and fat content (Yamazaki et al. 2005). In contrast to its WHC, the roselle seed powder had a high oil holding capacity (OHC). Soluble dietary fibre is responsible for absorption or binding of hydrophobic substances (Betancur-Ancoma et al. 2004). Ingredients with high OHC are useful as emulsifiers for high fat food products (Elleuch et al. 2008). Thus, high OHC of roselle seed powder suggests their potential use as fibre-rich ingredient in food-stuffs requiring oil retention and cholesterol absorption. Low OMAC in roselle seed powder probably due to the degradation of insoluble fibre structure during thermal treatment and consequently loss ability to absorb oil in insoluble fibre (Lopez et al. 1997).

The DPPH radical scavenging activity of roselle seed was high (44.7 %). The roselle seed extracts had the strongest radical scavenging activity compared with other parts of roselle (Mohd-Esa et al. 2010). The phytosterols (β -sistosteol) and vitamin E (γ -tocopherol) can reduce and

decolourise DPPH by their hydrogen donating ability (Mohammed et al. 2007). Moreover, phenolic compounds in roselle seed powder extracts are involved in their anti-radical activity. The TPC in methanolic extract of roselle seed was 18.8 mg GAE/100 g seed. Phenols play an important role in plant constituents because it contributes to overall antioxidant activities (Khattak et al. 2008).

Cookie analysis

Physico-chemical analysis of cookie

Four formulations of cookie were prepared. 0.0 % (control, F1), 10.0 % (F2), 20.0 % (F3) and 30.0 % (F4) of roselle seed powder were incorporated into cookie flour, respectively and their physicochemical properties were shown in Table 2. The moisture content of all cookies formulas were in the range of 2.5 to 3.0 %. The formulations of the cookie with the higher amount of roselle seed powder had lower moisture content. The results showed significant difference ($p < 0.05$) between the control cookies (F1) with the other three formulations of cookies that added with roselle seed powder. Water activity of the four formulations of cookies were decreased from F1 (0.31), F2 (0.26), followed by F3 (0.25) and F4 (0.25). Roselle seed powder added in cookie making would affect the water absorption of dough, therefore the end product had lower water activity.

The spreadability of cookies decreased from F1 (59.4), F2 (51.4), F3 (49.3), followed by F4. The 30 % of roselle seed powder cookies (F4) had the lowest spread factor (47.4). Increased the amount of roselle seed powder in cookie making would decrease the spread factor of the cookies. Although there was no significant difference ($p > 0.05$) between the hardness of cookies supplemented with 10 % to 20 % roselle seed powder and the control cookie (100 % cookie flour), the hardness of control cookie was significantly harder as compared with 30 % roselle seed powder cookies. The hardness of cookie was affected by the amount of roselle seed powder added into cookie making. This is because of the water retention capacity of roselle seed powder influences the hardness of cookies. Roselle seed powder that added into cookie caused the cookie dough had low water content. Dough having low water content will not produce an extensive gluten structure and resulted in softer cookies (Ajila et al. 2008). The gluten structure plays an important key in hardness of cookie. There was no significant difference ($p > 0.05$) between the crispness for all formulations of cookies.

As shown in Table 2, the 'L' value was significantly decreased with the incorporation of roselle seed powder in the formulations. Control cookie was the most brightness as compared with the cookies incorporated with roselle seed powder. Increased the amount of roselle seed powder in cookie resulted in darker colour of cookie. The 'a' and 'b'

Table 2 Physicochemical and sensory quality (Hedonic test) properties of different formulations of cookies

Components	Formulations			
	F1	F2	F3	F4
Physicochemical properties				
Moisture content	3.0±0.15 ^a	2.7±0.08 ^b	2.5±0.07 ^c	2.5±0.06 ^c
Water activity	0.31±0.00 ^a	0.26±0.01 ^b	0.25±0.00 ^b	0.25±0.00 ^b
Spread factor	59.4±2.57 ^a	51.4±3.09 ^b	49.3±1.09 ^b	47.4±1.14 ^c
Hardness	8048.4±792.30 ^a	7358.0±687.79 ^a	6570.1±1058.87 ^{ab}	6196.6±341.85 ^b
Crispness	44.0±5.29 ^a	47.7±2.52 ^a	49.3±9.71 ^a	49.3±15.57 ^a
<i>L</i> *	58.70±1.70 ^a	50.3±0.02 ^b	45.5±2.37 ^c	43.5±0.19 ^c
<i>a</i> *	9.9±0.29 ^a	6.3±0.19 ^b	5.1±0.06 ^c	5.1±0.10 ^c
<i>b</i> *	16.8±0.38 ^a	10.7±0.31 ^b	8.1±0.04 ^c	6.9±0.10 ^d
Hedonic rating				
Appearance	5.1±1.58 ^b	6.5±0.99 ^a	6.2±1.05 ^{ab}	5.5±1.60 ^b
Aroma	4.7±1.45 ^b	5.9±1.39 ^a	6.7±0.88 ^a	5.9±1.51 ^a
Texture	4.9±1.55 ^b	6.3±1.58 ^{ab}	7.2±1.05 ^a	5.7±1.35 ^b
Flavour	5.1±1.46 ^b	6.1±1.64 ^a	7.4±1.01 ^a	5.3±1.63 ^a
Overall acceptance	5.0±1.07 ^b	6.3±1.40 ^{ab}	7.0±0.83 ^a	5.7±1.53 ^b

Mean ± standard deviation. Value at the same row with different superscript differ significantly ($p < 0.05$)

*L**, *a** and *b** is the colour coordinate which present of lightness (*L**), redness (*a**, red-green) and yellowness (*b**, yellow-blue)

F1 (control), F2, F3 and F4 correspond to)%, 10 %, 20 % and 30 % roselle seed powder incorporated into cookie flour, respectively

Hedonic rating ($n=15$) based on 9-point scale with descriptors: 1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much, 9=like extremely

values were significantly different between control cookie with the other three formulations of cookies. The increased the levels of roselle seed powder in cookies caused the cookies became less yellowness as well as redness.

Sensory evaluation

A hedonic test was carried out among the four samples to evaluate the acceptability of the consumers in the sensory

attributes of appearance, aroma, texture, flavour and overall acceptance. The results were tabulated in Table 2. The appearance for F2 was the most preferred by panellists, followed by F3 and F4. The appearance of F1 was the least preferred because the colour of F1 was pale as compared to F2. F4 was looked like burnt after baking due to the high level incorporation of roselle seed powder added into cookie making. The aroma for F3 was the most preferred by panellists, followed by F2, F4 and lastly F1. However, F2, F3

Table 3 Proximate composition and antioxidant activities of F1 (control) and F3 (20 % roselle seed powder)

Analysis	F1	F3
Ash (%)	0.80±0.03 ^a	0.88±0.01 ^b
Crude protein (%)	5.9±0.32 ^a	9.4±0.32 ^b
Crude fat (%)	25.6±0.51 ^a	26.6±0.40 ^b
Total dietary fibre (%)	0.9	5.6
Total carbohydrate (%)	63.9	55.0
DPPH radical scavenging capacity (%)	82.2±0.39 ^a	98.0±1.36 ^b
Total phenolic content (mg GAE/100 g seed)	28.4±2.28 ^a	60.2±1.08 ^b

*Mean and standard deviation. Value at the same row with different superscript differ significantly ($p < 0.05$)

*Mean value for total dietary fibre ($n=2$)

*Total carbohydrate is obtained by difference. Total carbohydrate = 100 % - (%moisture+ %ash+ %protein+ %fat+ % crude fibre)

*F1- 0 % roselle seed (control), F3- 20 % roselle seed powder were incorporated into cookie flour

and F4 did not show significant difference because their aroma was similar even though different levels of roselle seed powder incorporated into cookie. In terms of flavour, most of panellists preferred F3, followed by F2, F4 and F1. The flavour of the cookies was improved with the incorporation of roselle seed powder because these cookies had typically pleasant roselle seed flavour. The flavour of roselle seed closely resembled flavour of cranberries, therefore it enhanced the flavour of cookies after it being incorporated in. The control cookie (F1) was significant different ($p < 0.05$) with the other three formulations (F2, F3 and F4). The texture of cookies F3 was the most preferred by panelists, followed by F2 and F4, while the least preferred cookie was F1. F3 was the crunchiest and crispiest cookie among all. On the other hand, F1 was the hardest and the least crispness cookies. Cookie with harder texture and the least crispness was not favoured by the panellists. In overall acceptance, F3 cookie scored the highest among all formula cookies. This indicated that 20 % level of incorporation of roselle seed powder into flour was the optimum.

Proximate analysis and antioxidant activities of cookie

The proximate chemical analysis including ash, crude protein, crude fat, total dietary fibre, total carbohydrate content was carried out on the most preferred cookie (F3) in hedonic test and antioxidant activities were also carried out (Table 3). The results showed that incorporation of roselle seed powder into cookie affected the chemical composition of cookies. The chemical compositions of 20 % of roselle seed powder incorporated cookies (F3) were significant difference ($p < 0.05$) compared to control cookie (F1). All the chemical composition of the cookie incorporated with roselle seed powder was increased except moisture content. Furthermore, cookie with roselle seed powder showed high content of total dietary fibre (5.6 g/100 g) when compared with control cookie (0.90 g/100 g). It might be concluded that roselle seed powder incorporated cookies promote the nutritional composition and prolonging the shelf life of products. Roselle seed could be utilized for the preparation of bakery product and other food products because it provides various beneficial nutritional effects for human health.

The cookies incorporated with roselle seed powder exhibited improved antioxidant properties. The antioxidant activity was significantly increased ($p < 0.05$) by incorporating roselle seed powder into cookie making. Cookies enriched with roselle seed powder showed higher total phenolic content (60.2 mg GAE/100 g cookie) and stronger scavenging activity (98.0 %) than control cookie (28.4 mg GAE/100 g cookie, 82.2 %, respectively). It can be concluded that 20 % of roselle seed powder incorporated cookie had improve its antioxidant activity.

Conclusion

Roselle seed powder is a byproduct from the roselle processing industry. This waste byproduct can be recycled as value added food supplements, which provide advantageous dietary fibre and bioactive compounds. It can be served as non-caloric bulking agents, enhance oil retention, improve emulsion and oxidative stability. It can be utilized for preparation of bakery products and other food products with improved functional and nutritional properties.

Acknowledgments We would like to thank Malaysian Agricultural Research and Development Institute (MARDI) for providing the roselle seeds for this study.

References

- Ajila CM, Leelavathi K, Prasada Rao UJS (2008) Improvement of dietary fibre content and antioxidant properties in soft dough biscuits with the incorporation of mango peel powder. *J Cereal Sci* 48:319–326
- Amin I, Emmy Hainida KI, Halimatul Saadiah MN (2008) Roselle seeds- nutritional composition, protein quality and health benefits. *Food* 2(1):1–16
- AOAC (2000) Methods of analysis of Association of Official Analytical Chemistry, methods 985.29 18th edn. Washington, DC
- AOCS (1997) Official methods and recommended practices of the American Oil Chemists' Society. American Oil Chemists' Society, Champaign
- Barampama Z, Simard RE (1993) Nutrient composition, protein quality and anti-nutritional factors of some varieties of dry beans (*P. vulgaris*) grown in Burundi. *Food Chem* 47:159–167
- Betancur-Ancoma D, Peraza-Mercado G, Mouguet-Ordóñez Y, Fuertes-Blanco S (2004) Physicochemical characterisation of lime bean (*Phaseolus lunatus*) and Jack bean (*Canavalia ensiformis*) fibrous residues. *Food Chem* 84:287–295
- Borderias AJ, Alonso SI, Perez-Mateos M (2005) New applications of fibres in foods: addition to fishery products. *Trends Food Sci Technol* 16(10):458–465
- Elleuch M, Besbes S, Roiseux O, Blecker C, Deroanne C, Nour-Eddine D, Attia H (2008) Date flash: chemical composition and characteristics of dietary fibre. *Food Chem* 111:676–682
- Ellis RH, Roberts EH (1991) Seed moisture content, storage, viability and vigour. *Seed Sci Res* 1:275–279
- Garau MC, Simal S, Rossello C, Femenia A (2007) Effect of air drying temperature on physico-chemical properties of dietary fibre and antioxidant capacity of orange (*Citrus aurantium* v. *Cabobeta*) by-products. *Food Chem* 104:1014–1024
- Hainida E, Amin I, Normah H, Mohd-Esa N, Ainul ZAB (2008) Effects of defatted dried roselle (*Hibiscus sabdariffa* L.) seed powder on lipid profiles of hypercholesterolemia rats. *J Sci Food Agric* 88:1043–1050
- Halimatul SMN, Amin I, Mohd-Esa N, Nawalyah AG, Siti Muskinah M (2007) Protein quality of Roselle (*Hibiscus sabdariffa* L.) seeds. *Asean Food J* 14:131–140
- Handa C, Goomer S, Siddhu A (2012) Physicochemical properties and sensory evaluation of fructoligosaccharide enriched cookies. *J Food Sci Technol* 49(2):192–199

- Hussain S, Anjum FM, Butt MS, Khan MI, Asghar A (2006) Physical and sensoric attributes of flaxseed flour supplemented cookies. *Turk J Biol* 30:87–92
- Izquierdo NG, Nolasco S, Mateo C, Santos D, Aguirrezábal LAN (2012) Relationship between oil tocopherol concentration and oil weight per grain in several crop species. *Crop Pasture Sci* 62:1088–1097
- Khattak KF, Simpson TJ, Ihasnullah (2008) Effect of gamma irradiation on the extraction yield, total phenolic content and free radical-scavenging activity of *Nigella sativa* seed. *Food Chem* 110:967–972
- Koehler HH, Jung-Hsia Chang CH, Scheier G, Burke DW (1987) Nutrition composition, protein quality and sensory properties of thirty-six cultivars of dry beans (*P. vulgaris*). *J Food Sci* 52:1335–1340
- Liu Q, Yao H (2007) Antioxidant activities of barley seed extracts. *Food Chem* 102:732–737
- Lo GS (1989) Nutritional and physical properties of dietary fibre from soybean. *Cereal Foods World* 34:530–533
- Lopez G, Ros G, Rincon F, Periago M, Martinez M, Ortuno J (1997) Propiedades funcionales de la fibra dietetic. Mecanismo de accion en el tracto gastrointestinal. *Arch Latinoam Nutr* 47 (3):203–207
- Martin K (1999) Replacing fat, retaining taste. *Food Eng Int* 24:57–59
- Mohammed R, Fernandez J, Pineda M, Aguilar M (2007) Roselle (*Hibiscus sabdariffa*) seed oil is a rich source of gamma-tocopherol. *J Food Sci* 72:S207–S211
- Mohd-Esa N, Shin Hern F, Ismail A, Lye Yee C (2010) Antioxidant activity in different parts of roselle (*Hibiscus sabdariffa* L.) extracts and potential exploitation of the seeds. *Food Chem* 122:1055–1060
- Morton JF (1987) Roselle. In: *Fruits of warm climates*. Florida Flair Books, Miami, pp 281–286
- Nyam KL, Tan CP, Lai OM, Long K, Che Man YB (2009) Physicochemical properties and bioactive compounds. *LWT J Food Sci Technol* 42:1396–1403
- Omabuwajo TO, Sanni LA, Balami YA (2000) Physical properties of roselle (*Hibiscus sabdariffa*) seeds. *J Food Eng* 45:37–41
- Rosamond WD (2002) Dietary fibre and prevention of cardiovascular disease. *J Am Coll Cardiol* 39:57–59
- Rosell CM, Santos E, Collar C (2009) Physico-chemical properties of commercial fibres from different sources: a comparative approach. *Food Res Int* 42:176–184
- Tosh SM, Yada S (2010) Dietary fibres in pulse seeds and fractions: characterization, functional attributes and applications. *Food Res Int* 43:450–460
- Vazquez-Ovando A, Rosado-Rubio G, Chel-Geurrero L, Betancur-Ancona D (2009) Physicochemical properties of a fibrous fraction from chia (*Salvia hispanica* L.). *J Food Sci Technol* 42:168–173
- Waterhouse AL (2002) Determination of total phenolics. In: *Current protocols in food analytical chemistry*. University of California, Davis, USA, I 1.1.1-1- I 1.1.8
- Yamazaki E, Murakami K, Kurita O (2005) Easy preparation of dietary fibre with the high water-holding capacity from food sources. *Plant Foods Hum Nutr* 1:17–23