Preparation of Doum fruit (*Hyphaene thebaica*) dietary fiber supplemented biscuits: influence on dough characteristics, biscuits quality, nutritional profile and antioxidant properties

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Abstract The increasing demand for functional foods has boosted up the food industry to produce fiber-enriched products. In this study, dietary fiber (DF) was isolated from Doum fruit by exploiting the combination of microwave reactor technique and superfine grinding technology. The isolated Doum dietary fiber (DDF) possessed a high content of total dietary fiber, essential minerals and total polyphenols with good antioxidant activity. Biscuits were prepared by substituting wheat flour with DDF at different levels (0, 2.5, 5, 7.5 and 10%) and assessed for dough mixing properties and biscuit quality. The results showed that an increase of DDF in the flour affected physical parameters of biscuits by increasing the biscuits hardness and reducing the diameter, thickness and spread ratio. Supplementation of biscuits with DDF improved the nutritional value in terms of DF contents and essential minerals. Improvement in total phenolic contents (TPC) and antioxidant activities of the biscuits were also noted as a result of DDF supplementation. Biscuits supplemented with 7.5% DDF showed overall better sensorial characteristics. Conclusively, this study has shown that supplementation of wheat flour with DDF improved nutritional

profile, antioxidant properties and overall consumer acceptability of biscuits. The present findings will be helpful regarding the development of functional foods enriched with DDF.

Keywords *Hyphaene thebaica* · Doum dietary fiber · Supplementation · Biscuits · Nutritional profile · Antioxidant activity

Introduction

In recent years, fruits and vegetables have gained more popularity and attention as sources of dietary fiber (DF) and biologically active compounds with medicinal benefits such as anticarcinogenic, antimutagenic and antioxidant effects (Aboshora et al. 2014b; Singh et al. 2016a). Fruit based dietary fiber (DF) concentrates have a better nutritional profile than cereals DF; this is because of the fact that DFs originated from the fruit have elevated amounts of bioactive compounds, such as polyphenols, flavonoids and carotenoids (Singh et al. 2016a, c). According to the prior reports (Ajila et al. 2008; Jia et al. 2011; Takeungwongtrakul and Benjakul 2017), the consumption of DF and phytochemicals through the intake of DF rich products gave high protection against a number of diseases. Moreover, the products from DF enriched flour had improved the sensory properties of these products (Anil 2007; Izidorczyk et al. 2008; Sangnark and Noomhorm 2004; Sudha et al. 2007a). It is widely acknowledged that increased consumption of dietary fiber and antioxidants, led to open wide doors for marketing of the food products rich with these compounds.

Doum palm is known as Doum or gingerbread palm because its taste and consistency are similar to that of

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gingerbread (Aboshora et al. 2014a; Hsu et al. 2006). Previously, we have reported that Doum fruit possesses a high level of valuable component such as DF, carbohydrate, minerals, vitamins, flavonoids and polyphenol compounds (Aboshora et al. 2014a, b). Moreover, the fruit has been used in bread production to improve its nutritional properties (Aboshora et al. 2016).

Recently, multistage water extraction using microwave has been applied in the isolation of insoluble date fiber from date flesh and the technique has been found with several advantages such as improved efficiency, yield, water and oil holding capacity (Ahmed et al. 2013).

The superfine grinding approach has been reported to improve chemical reactivity, adsorption, dispersion, high solubility and fluidity of reagents during the processing of powders (Wu et al. 2012); as well as enhance the antioxidant properties of DF (Zhu et al. 2010).

Biscuits are among the popular cereal based baked food that is consumed at breakfast and as snacks. Low moisture content, high energy density, easy handling and long shelf life are some key distinctions of biscuits over the other baked products (bread, cakes and muffins) which are suitable for the development of functional foods (Ajila et al. 2008; Gandhi et al. 2001). The aim of the present study was to improve the physical characteristics, nutritional profile and antioxidant properties of biscuits by the supplementation of wheat flour with different levels of dietary fiber which was isolated from Doum fruit.

Materials and methods

Preparation of Doum Dietary fiber (DDF)

Doum fruit was ground to pass through a 20-mesh screen using a laboratory scale hammer mill (Debarker Co Ltd, Beijing, China). To isolate the DF, a microwave reactor apparatus (XH-200A; Beijing Xianghu Science and Technology Development Co., LTD, China) was employed. Briefly, Doum fruit powder was mixed with distilled water in a powder: water volume ratio of 1:10 (w/v); and then the mixture was poured into a 250 ml round-bottomed flask under magnetic stirring. The mixture was kept at 60 °C for 60 min by microwave heating. The mixture was filtered with a thin cloth of 0.318 mm pore size. The process of filtration and extraction was repeated 5 times in order to increase the purity. The mixture was freeze-dried (Alpha 1-2 LD plus, Christ, Saxony, Germany; Vacuumbrand vacuum pump, Germany) and then micronized with a planetary ball mill (PM-100 type micronizer (Retsch GmbH, Haan, Germany)). The obtained powder was sealed in aluminum foil and kept in desiccators for further analysis.

Farinographic characteristics

Five blends of flour were prepared by blending the wheat flour with Doum dietary fiber (DDF) at a level of 0, 2.5, 5, 7.5 and 10% using a blender with a spiral. The dough development time (DDT), dough stability (DS), water absorption (WA) and mixing tolerance index (MTI) were measured using a farinograph (Brabender, Duisburg, Germany) in accordance with the AACC (2000).

Preparation of biscuit dough

Initially, formulae for biscuits as presented in Table 1 were prepared by substituting the wheat flour with DDF at different levels following the method described by Leelavathi and Haridas Rao (1993). Vegetable oil and sugar were mixed thoroughly in a Hobart mixer (N-50) with a shortening beater for 3 min at 61 rpm. Other ingredients were pre dissolved in water and then added to the above mixture. The mixture was mixed for 6 min at 125 rpm to get a uniformly mixture. Later, flour was added to the mixture and mixed for 2 min at 61 rpm. The dough was pressed to 3.5 mm sheet using a rolling pin, an aluminum platform and a frame. The dough was further formed with a cutter of 51-mm diameter and baked into biscuits on aluminum trays at 205 °C for 9 min and cooled to 25 °C. The polypropylene pouches were used to pack the biscuits until further analysis.

Physical characteristics

The Diameter (D) and Thickness (T) of biscuits were measured; thereafter, the spread ratio was calculated according to the method of Gandhi et al. (2001) modified by Ajila et al. (2008). The breaking strength force of the biscuits was measured using a Texture Analyzer (TA-

Table 1 Dough formula of biscuits supplemented with different levels of DDF

Ingredients	Weight (g)
Flour blend (prepared by substituting the wheat flour with DDF at a level of 0, 2.5, 5, 7.5 and 10%)	100
Sugar	30
Shortening	25
Skim milk powder	2.0
Dextrose	2.0
Sodium bicarbonate	0.5
Ammonium bicarbonate	2.0
Sodium chloride	1.0
Water (ml)	35–40 ml

XT2i, Stable Micro Systems, Godalming, UK) according to the method reported by Choudhury et al. (2015).

Biscuits color parameters

Hunter color parameters of biscuits were measured using a Minolta colorimeter (Lab Scan XE, Hunter Association Laboratory, Reston, VA, USA) after being calibrated using colorimeter standards. The color intensity was measured from the bottom and central point of biscuits and expressed based on the values of L^* , a^* and b^* .

Sensory evaluation

Sensory characteristics of biscuits were conducted followed the method of Sharma et al. (2016) modified by Rathod and Annapure (2017). Sensory attributes of biscuits supplemented with DDF were measured after 3 days of baking. Twenty students (8 male and 12 female) from the School of Food Science and Technology (Jiangnan University, China) aged 18–30 years were selected to evaluate the sensual attributes and the overall acceptability accordance to ISO guidelines (ISO 2007). Biscuits were presented in a sealed pouch encoded with different numbers and the panelists were required to assess each sample based on the following attributes: appearance, mouth feel, taste/flavor, crust color, crumb color, texture and overall acceptability on a 9-point Hedonic scale (ISO 8589:2007). Panelists scores were defined as follows: a maximum score for like extremely (9 scores), like very good (8 scores), like good (7 scores), like moderately (6 scores), neither like nor aversion (5 scores), aversion moderately (4 scores), aversion fairly (3 scores), aversion very much (2 scores) and aversion extremely (1 score).

Chemical analysis

The chemical analysis of DDF and biscuits were determined following the AOAC standard methods (AOAC 2000); official methods: moisture (method No. 925.09), ash (Method No. 942.05), protein (Method No. 955.04) and fat (Method No. 920.39). The conversion factor of nitrogen used for calculation of total protein was 6.25. Dietary fiber content (DFC) of DDF and obtained biscuits was analyzed by enzymatic–gravimetric method (AOAC 1992).

Minerals in the DDF and biscuits samples were determined according to AOAC standard methods (AOAC 2000) which was modified by Aboshora et al. (2016).

Extraction of antioxidant

For the determination of the polyphenol content and the antioxidant activity of DDF and biscuits, 3 g of each

sample was extracted with 30 ml of methanol (80%) for 2 h in an ultrasonic cleaner bath at 60 °C. Afterwards, the mixtures were cooled to ambient temperature and then centrifuged at $5000 \times g$ for 15 min. The supernatants were clarified and methanol was eliminated using the rotary evaporator at 50 °C to dryness. The dried extract was re-dissolved in absolute methanol (25 ml) and kept at -4 °C till use (Aboshora et al. 2014b).

Total polyphenol

Total polyphenol content of extracts was assessed colorimetrically using Folin–Ciocalteu reagent method (Aboshora et al. 2014b). Polyphenol analysis was performed by mixing 0.1 ml of sample extract, 3 ml of distilled water, 0.75 ml of 20% Na_2CO_3 and 0.25 ml of concentrated Folin–Ciocalteu reagent. UV–Vis spectrophotometer at 760 was used to measure the absorbance of the mixture after incubation in the dark for 30 min at 25 °C. Final results of total polyphenol were presented as mg gallic acid equivalents per g dry basis (mg GAE/g db) depending on the linear equation of the gallic acid standard curve at (0.0125–0.125) mg/ml, $R^2 = 0.998$.

Antioxidant activity by the ABTS

In vitro radical cation scavenging capacity of DDF and biscuits extracts against ABTS was determined according to Zhang et al. (2014) with some changes. A stock solution of radical cation was prepared by mixing 7 mmol ABTS and 2.45 mmol potassium persulfate in a volume ratio of 1:0.5; thereafter, the mixture was maintained at ambient temperature in the dark for 16 h. Working solution of the ABTS was prepared by diluting 7 mmol ABTS radical cation stock solution with PBS (pH 7.4) to an absorbance of 0.68 ± 0.02 at 734 nm. Extract (0.15 ml) of each sample was mixed with 3 ml of ABTS^+ working solution. The mixture was kept at 25 °C for 10 min and the absorbance was recorded at 734 nm. The antioxidant activity of the extract DDF and the biscuits were presented as mM Trolox equivalent (TE) per 100 g dry basis (TE mM/100 g db) by a linear equation of the standard curve for Trolox. The linearity range of the calibration curve was 0.00 to 0.09 mmol ($R^2 = 0.998$).

DPPH free radical scavenging capacity

The DPPH· scavenging effect (DPPH–SE) of DDF and biscuits was determined according to Aboshora et al. (2016). Based on the total phenolic content (0.15 ml) of each extract at different concentrations was treated with a 3 ml of DPPH· methanolic solution (6×10^{-5} mmol/ml). The absorbance after 30 min was measured at 517 nm and

the % DPPH-SE was calculated using the following equation:

$$\%DPPH-SE = \left(\frac{A_C - A_S}{A_C} \right) \times 100 \quad (1)$$

where A_C is the absorbance of the control; A_S is the absorbance of the sample extract. The half maximal effective concentration (EC_{50}) of DPPH-SE was calculated using Microsoft Excel 2016.

Data analysis

One-way ANOVA analysis using SPSS software (SPSS, Chicago, Illinois, USA, version 17.0) was conducted to analyze the data. The data were presented as mean $\pm$ SD. Duncan's test was performed to determine the significance ($P < 0.05$) (Aboshora et al. 2016). The EC_{50} values were calculated using Microsoft Excel 2016.

Results and discussion

Effect of DDF on Farinographic properties

The influence of DDF on rheological measurements of the dough was carried out using farinographic equipment. As shown in Fig. 1 partial substitution of wheat flour with DDF at different levels (0, 2.5, 5, 7.5 and 10%) displayed a significant difference in farinograph parameters. Incorporation of DDF into wheat flour at different levels significantly ($P \leq 0.05$) increased the water absorption properties from 61% in control dough to 68.5% at 10% DDF blended dough (Fig. 1A); similar findings showed that, the incorporation of mango peels into flour increase the water absorption (Ajila et al. 2008). It's well known that the DF contains pectins, lignin, β -glucans, cellulose and hemi-cellulose; therefore, the interaction of water and hydroxyl groups of these compounds resulted in high water absorption (Chaplin 2003; Dikeman and Fahey 2006; Singh et al. 2016c). Dough development time was increased from 4.5 min (control) to 7.8 min with the incorporation of 10% DDF (Fig. 1A). On the other hand, the dough stability was reduced from 7.4 min (control) to 4.1 min with the incorporation of 10% DDF (Fig. 1B). Increasing in dough development time and reduction in dough stability could be attributed to the dilution of the gluten in wheat flour upon addition of DDF; similar observation was reported by Sudha et al. (2007b). Significant effects ($P \leq 0.05$) were detected on the mixing tolerance index values (MTI). The poor dough stability of 10% DDF was reflected in significantly higher MTI (Fig. 1B). The MTI increased as a result of the increase in the percentage of the DDF possibly due to decreased elasticity of the dough as influenced by Doum dietary fiber.

Influence of DDF powder on the physical characteristics of biscuits

The physical characteristics of biscuits prepared by using the blended flour were evaluated. Results in Table 2 revealed that the incorporation of DDF into biscuits resulted in decreased the diameter from 42.47 to 41.56 mm with slight effect on the thickness. The spread ratio was decreased from 10.73 in control to 10.65 of 10% DDF biscuit sample. Based on these results, increased levels of DDF in the flour led to decrease in diameter and thickness of biscuits possibly due to dilution of gluten. Comparable findings were described with bamboo shoot biscuit (Choudhury et al. 2015), mango peel biscuit (Ajila et al. 2008) and biscuit supplemented with different cereal brans (Sudha et al. 2007b), but reverse findings were observed for coconut meal biscuit (Srivastava et al. 2010) due to high content of fat in the coconut meal.

The results of the study further revealed that the hardness of biscuits was increased with the addition of DDF (Table 2). Biscuits prepared from flour containing 10% DDF had higher hardness value (1.52 kg) compared with the control biscuits (0.74 kg). The results are consistent with previous findings in which biscuits prepared with bamboo shoot powder, mango peel powder and cereal bran (Ajila et al. 2008; Choudhury et al. 2015; Sudha et al. 2007b) were also found with higher breaking strengths than the control. Previously Ajila et al. (2008) reported that increase in breaking strength of biscuits might be due to increased water content in the dough.

Biscuits color parameters

The color of any product has a major impression on their perception by consumers; therefore, it is a needful to assess how adjustment of the formula affected values of this parameter. Hunter color parameters of biscuits measured by using L^* , a^* and b^* values representing to brightness, redness, and yellowness, respectively. Results as shown in Table 2 show that the control biscuit had the highest values for L^* (lightness) as compared to the DDF blended biscuits. On the other hand, the L^* values gradually reduced with the increase in the levels of DDF possibly due to browning effect of Doum dietary fiber. It was also found out that b^* (yellowness) was decreased progressively with increasing levels of DDF, implying that less yellow color was achieved as a result of DFF addition. In contrast, no specific trend was found regarding the change in a^* values upon addition of DDF. Previously, low values of L^* and b^* have been reported for biscuits supplemented with bamboo shoot and mango peel powder compared to control (Ajila et al. 2008; Choudhury et al. 2015). A number of studies have proven that the darkness of the color could be due to a

Fig. 1 Farinographic characteristics of wheat flour-DDF blends; **A** water absorption (%) and dough development time (min); **B** dough stability (min) and mixing tolerance index (BU)

Table 2 Influence of Doum dietary fiber on the physical parameters and color values of biscuits

	Control	2.5% DDF	5% DDF	7.5% DDF	10% DDF
Diameter (D, mm)	42.47 ± 0.045 ^a	42.31 ± 0.085 ^b	42.19 ± 0.140 ^c	41.79 ± 0.025 ^d	41.56 ± 0.046 ^e
Thickness (T, mm)	3.96 ± 0.044 ^a	3.95 ± 0.032 ^a	3.94 ± 0.032 ^a	3.92 ± 0.025 ^a	3.90 ± 0.010 ^a
Spread ratio	10.73 ± 0.107 ^a	10.72 ± 0.087 ^a	10.70 ± 0.069 ^a	10.67 ± 0.066 ^a	10.65 ± 0.015 ^a
Hardness (kg)	0.74 ± 0.047 ^c	0.83 ± 0.053 ^d	0.96 ± 0.083 ^c	1.24 ± 0.082 ^b	1.52 ± 0.089 ^a
L*	65.34 ± 0.731 ^a	56.025 ± 0.705 ^b	54.88 ± 0.701 ^{bc}	53.39 ± 0.519 ^c	51.02 ± 0.796 ^d
a*	10.37 ± 0.471 ^a	10.45 ± 0.399 ^a	10.33 ± 0.439 ^a	9.37 ± 0.297 ^b	9.53 ± 0.276 ^b
b*	28.18 ± 0.414 ^a	18.58 ± 0.580 ^b	16.75 ± 0.515 ^c	14.21 ± 0.293 ^d	13.21 ± 0.617 ^d

Values are mean ± SD (n = 3). Mean followed by different letters in the same row differs significantly ($P \leq 0.05$)

high content of total polyphenol besides the Maillard reaction during baking (Ajila et al. 2008; Jan et al. 2015; Singh et al. 2016c; Takeungwongtrakul and Benjakul 2017).

Sensory evaluation

Results from sensory evaluation of the biscuits are given in Fig. 2. According to the Fig. 2, the taste/flavor and

mouthfeel of biscuits containing DDF were acceptable up to 7.5% DDF level.

The addition of DDF improved taste and flavor of the biscuits attributed to pleasant flavor of Doum fruit. However, at the 10% DDF level, the biscuits were found with a dry mouthfeel and a slightly bitter taste possibly due to increased polyphenol content. On the other hand, crumb and crust of biscuits were rated low in terms of color with increasing the level of DDF. Above 5% level of Doum

Fig. 2 Influence of DDF powder on the sensory acceptability of biscuits

dietary fiber, the biscuits turned dark as evidenced from the decreased L values (Fig. 2). Furthermore, the incorporation of DDF up to 5% had no statistically significant effect on the texture of the biscuit. Above 5% level, the biscuits became comparatively harder than the control, therefore, less acceptable. The progress of biscuits hardness may be due to increased water absorption of the blended flour (Ajila et al. 2008). The increase in the hardness was also consistent with results obtained by using a Texture analyzer (Table 3). Based on results from the attributes (taste/ flavor, mouthfeel, crumb color and appearance), the incorporation of DDF up to 7.5% resulted in development of biscuits with satisfactory properties and overall acceptability.

Chemical composition of Doum dietary fiber and biscuits

The proximate compositions of the Doum dietary fiber (DDF), control biscuit and DDF fortified biscuits are presented in Table 3. The results of DDF showed that the moisture content was 7.09%, ash content 2.24%, protein content 1.26% and the fat content was 2.21%. On the other hand, the moisture content of biscuits increased from 2.87 in control to 3.71% in 10% DDF fortified biscuits. The variation in the moisture contents of the biscuits could be due to increased water requirement in order to prepare the dough by using the fiber rich flour (Ajila et al. 2008;

Choudhury et al. 2015). Results also showed that protein and fat content of biscuits were decreased from 9.76 to 8.94% and from 16.25 to 15.72%, respectively, with increased levels of DDF possibly due to low levels of protein and fat in DDF as reported above. Whereas, the ash content was increased gradually from 1.17 to 1.45% with increased levels of DDF. Recently, Jan et al. (2015) reported that the high content of ash is correlated to the high content of mineral.

The TDF in DDF was 86.83%, of which IDF content was 72.50% and SDF content was 14.33%. Latterly, Zhu et al. (2015) reported that the SDF plays a major role in the body by absorbing water and participating in gel formation which slows down the digestive processes; thus delaying pangs of hunger. In addition, SDF also, assists in weight control and consequently helps in the management of blood cholesterol, blood glucose and insulin levels (Singh et al. 2016c). These rules imply that SDF is capable of mitigating health related dysfunctions, thus considered an important component of the diet. In contrast, Zhu et al. (2010, 2015) had reported that a balanced DF composition must have approximately 10% SDF contents. Previously, Sudha et al. (2007b) reported that the SDF content in barley bran, oat bran and wheat bran was 10.8, 8.9 and 5.01% respectively, which is less than that of DDF. As shown in Table 4 biscuits developed from DDF were found with increased total dietary fiber content and a good balance of soluble dietary fiber and insoluble dietary fiber.

Table 3 Proximate composition (% dry basis) and minerals content (mg/100 g) of biscuits supplemented with different levels of DDF

	DDF	Control	2.5% DDF	5% DDF	7.5% DDF	10% DDF
Moisture (%)	7.09 ± 0.015 ^a	2.87 ± 0.032 ^f	3.09 ± 0.025 ^e	3.31 ± 0.015 ^d	3.49 ± 0.026 ^c	3.71 ± 0.025 ^b
Protein (%)	2.21 ± 0.020 ^f	9.76 ± 0.046 ^a	9.54 ± 0.030 ^b	9.34 ± 0.025 ^c	9.15 ± 0.026 ^d	8.94 ± 0.031 ^e
Fat (%)	1.2 ± 0.036 ^e	16.25 ± 0.056 ^a	15.94 ± 0.036 ^b	15.87 ± 0.031 ^c	15.79 ± 0.030 ^d	15.72 ± 0.031 ^d
Ash (%)	2.2 ± 0.075 ^a	1.17 ± 0.021 ^f	1.24 ± 0.021 ^e	1.31 ± 0.029 ^d	1.36 ± 0.017 ^c	1.45 ± 0.025 ^b
SDF (%)	14.33 ± 0.312 ^a	1.28 ± 0.015 ^f	1.58 ± 0.026 ^e	1.92 ± 0.025 ^d	2.25 ± 0.04 ^c	2.57 ± 0.056 ^b
IDF (%)	72.50 ± 0.732 ^a	0.44 ± 0.031 ^f	2.29 ± 0.055 ^e	4.05 ± 0.061 ^d	5.82 ± 0.074 ^c	7.66 ± 0.075 ^b
TDF (%)	86.83 ± 0.420 ^a	1.72 ± 0.036 ^f	3.87 ± 0.08 ^e	5.97 ± 0.067 ^d	8.07 ± 0.102 ^c	10.23 ± 0.115 ^b
Na (mg/100 g)	26.30 ± 0.347 ^a	0.83 ± 0.036 ^e	1.02 ± 0.023 ^d	1.41 ± 0.038 ^c	2.53 ± 0.046 ^b	2.99 ± 0.068 ^a
K (mg/100 g)	256.04 ± 0.974 ^a	60.90 ± 0.345 ^f	65.05 ± 0.421 ^e	75.96 ± 0.467 ^d	93.02 ± 0.523 ^c	105.99 ± 0.617 ^b
Ca (mg/100 g)	111.09 ± 0.583 ^a	23.90 ± 0.214 ^f	27.81 ± 0.233 ^e	35.93 ± 0.247 ^d	42.52 ± 0.251 ^c	47.45 ± 0.279 ^b
P (mg/100 g)	70.30 ± 0.469 ^a	16.25 ± 0.123 ^f	18.66 ± 0.132 ^e	23.64 ± 0.139 ^d	27.61 ± 0.147 ^c	31.01 ± 0.153 ^b

All data are the mean ± SD of three replicates. Mean followed by different letters in the same row differs significantly ($P \leq 0.05$)

Table 4 TPC and free radical scavenging activity as determined by ABTS and DPPH-SE (EC₅₀) of biscuits supplemented with different levels of DDF

	TPC (mg GAE/g db)	ABTS (mM TEA/100 g db)	EC ₅₀ from DPPH (mg/ml)
DDF	72.31 ± 0.417 ^a	88.76 ± 0.313 ^a	0.20
0%	0.52 ± 0.050 ^b	2.65 ± 0.749 ^b	31.46
2.5%	1.74 ± 0.057 ^c	6.00 ± 0.360 ^c	13.77
5%	2.18 ± 0.056 ^d	9.11 ± 0.544 ^d	11.09
7.5%	2.52 ± 0.051 ^e	13.9 ± 0.715 ^e	8.37
10%	2.92 ± 0.046 ^f	18.34 ± 0.544 ^f	5.36

All data are the mean ± SD of three replicates. Mean followed by different letters in the same column (except for EC₅₀) differs significantly ($P \leq 0.05$)

The content of total dietary fiber was increased from 1.72 to 10.23%, soluble dietary fiber from 1.28 to 2.57% and the insoluble dietary fiber from 0.44 to 7.66% with the addition of DDF. The ratio of IDF/SDF, which is nutritionally significant, increased from 0.34 to 2.98 (data not shown). The findings of this study showed that there was a significant increase in the TDF content of DDF fortified biscuits, possibly due to the high content of this component in the DDF.

Essential minerals play a major role in promoting good health. Minerals content of DDF is presented in Table 3. The results exhibited that the sodium content was 26.3 mg/100 g, potassium content 256.04 mg/100 g, calcium content 111.09 mg/100 g and phosphorus content was 70.3 mg/100 g. These findings are in agreement with previous results of Aboshora et al. (2014a) in which Doum fruit was found with higher levels of minerals. According to results as shown in Table 3, the incorporation of DDF increased the content of minerals in the biscuits. Thus biscuits formulated with DDF blended flour had significantly higher levels of Na, K, Ca and P content than the control. The increased levels of minerals especially

calcium implies that, the biscuits prepared from DDF blended flour could enhance bone formation and growth since it was reported previously that calcium and phosphorus are an important component required for the development of strong bones and teeth (Aboshora et al. 2016). It was found out further that the enriched biscuits had even higher levels of essential minerals beyond the recommended dietary allowance (RDA), thus could be useful for those experiencing mineral deficiencies. The ratio of Na/K in the fortified biscuits according to this study was inconsistent with the findings reported by Aboshora et al. (2016) who found that the Na/K ratio less than one is recommended for the control of hypertension.

TPC, ABTS and DPPH- free radical scavenging activity of DDF and biscuits

The content of total polyphenol and in vitro antioxidant capacity assay, such as the ABTS and DPPH assays, represent convenient methods for identification of potential sources of antioxidant compounds in food products. TPC of DDF and biscuit extracts are presented in Table 4. As

expected, DDF showed a high content of total polyphenol (72.31 mg GAE/g db), these could be due to a rise of TPC in the Doum fruit (Aboshora et al. 2014b). The addition of DDF influenced the TPC contents of the biscuit significantly ($P \leq 0.05$). The content of polyphenols in biscuits increased with increased levels of DDF, thus, the highest content was found in biscuits developed from 10% DDF blended flour, followed by 7.5% DDF, 5% DDF and 2.5% DDF while, the control biscuit had the lowest TPC of 0.52 mg GAE/g db. The fortification of wheat flour by DDF was a necessary strategy for increasing TPC in the biscuits, since previous studies have reported that polyphenols in wheat are lost through refining of white flour that was used for biscuit making (Shafi et al. 2016; Yu and Nanguet 2013).

The antioxidant capacity as assessed by ABTS and DPPH was examined and the results were presented in Table 4. The ABTS^{•+} created by potassium persulfate, is considered as one of the best assay methods for measuring the antioxidant capacity of hydrogen-donating antioxidants (Singh et al. 2015, 2016b). According to the results in Table 4 the DDF extract exhibited a high ABTS^{•+} antioxidant activity (88.76 mM TEA/100 g db) as the consequence of a high polyphenolic content in DDF. The results of biscuits showed that the antioxidant activity by ABTS^{•+} radical assay varied considerably, ranging from 2.65 to 18.34 mM TEA/100 g db. These results revealed that higher antioxidant capacity by ABTS^{•+} were found in 10% DDF biscuit, followed by 7.5% DDF, 5% DDF and 2.5% DDF respectively, whereas, the control sample had the lowest score of ABTS^{•+} value. The increase in antioxidant activity by ABTS^{•+} could be due to increase in total phenolic contents through the supplementation biscuits with DDF.

DPPH free radical Scavenging activity is another technique that is extensively used to assess the antioxidant capacity (Singh et al. 2016b). The reduction in absorbance at 517 nm signifies the scavenging potential of antioxidants present in the extract through a donation of hydrogen atoms (Aboshora et al. 2014b; Ajila et al. 2008; Singh et al. 2015, 2016b). Results for DPPH were normalized and expressed as EC₅₀ values. Efficiency of antioxidant capacity was inversely correlated with the EC₅₀ value which was obtained by interpolation from linear regression analysis. The half maximal effective concentration (EC₅₀) value of the DDF extract was 0.20 mg/ml. It was found out that the blending of DDF in the wheat flour at all levels increased DPPH anti radical activity as evidenced from decreasing EC₅₀ values. As shown in Table 4, the concentration needed to obtain 50% DPPH radical scavenging activities of biscuits prepared with 2.5%, 5, 7.5% and 10% levels of DDF were 13.75, 11.09, 8.37 and 5.36 mg/ml, respectively, while the control had the highest EC₅₀ of

31.46 mg/ml. These results indicate that, when the supplementation levels with DDF increased in biscuits, the EC₅₀ decreased, which implied that the antioxidant capacity was increased.

Conclusion

The results of the present study showed that DDF is a good source of dietary fiber (DF), essential minerals and polyphenols with high antioxidant activity. Incorporation of DDF into biscuit dough improved dough development time, water absorption and mixing tolerance index, while causing reduction in dough stability. Biscuits supplemented with DDF showed higher levels of DF, essential minerals, total phenolics and antioxidant activities. Supplementation of biscuits with 10% DDF increased the antiradical activity sixfold as compared to the control. Substituting wheat flour with DDF up to 7.5% level increased the overall quality of biscuits. Overview, supplementation of DDF improved nutritional profile and quality attributes of biscuits. The present findings will be helpful for the development of functional foods and nutraceuticals tailored to enhance good health.

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