Influence of doum (*Hyphaene thebaica* L.) flour addition on dough mixing properties, bread quality and antioxidant potential

Waleed Aboshora^{1,3,4} · Zhang Lianfu^{1,2,3} · Mohammed Dahir¹ · Meng Qingran^{1,3} ·
Abubakr Musa¹ · Mohammed A. A. Gasmalla^{1,2} · Khamis Ali Omar¹

Revised: 25 September 2015 / Accepted: 7 October 2015 / Published online: 12 October 2015
© Association of Food Scientists & Technologists (India) 2015

Abstract In this covenant of functional foods, the world seeks for new healthier food products with appropriate proportions of bioactive constituents such as fiber, mineral elements, phenols and flavonoids. The doum fruit has good nutritional and pharmaceutical properties; therefore, its incorporation in breads could be beneficial in improving human health. In the current study, partial substitution of wheat flour (WF) with doum fruit flour (DFF) at levels of 5 %, 10 %, 15 % and 20 % were carried out to investigate the dough viscoelastic properties, baking performance, proximate compositions and antioxidant properties of the breads. Partial substitution of WF with DFF increased the water absorption and developing time of dough ($P \leq 0.05$), while, the dough extensibility, resistance to extension and the deformation energy were reduced. Bread supplemented with DFF resulted in a reduction in quality in terms of specific loaf volume, conferred softness, hardness, cohesiveness and gumminess to the bread crumbs. DFF up to 15 % could partially replace WF in bread; increase its nutritional value in terms of fiber content and minerals, with only a small depreciation in the bread quality. Sensory evaluation showed that breads supplemented up to 15 % DFF were acceptable to the panelists and there was no significant

difference in terms of taste, texture and overall acceptability compared to the control. The incorporation of DFF increased the total phenolic contents, total flavonoids contents and antioxidant properties compared to the control (for both flour and bread).

Keywords Doum fruit flour (DFF) · Wheat flour (WF) · Dough viscoelastic properties · Bread quality · Sensory evaluation · Antioxidant properties

Introduction

Recently, consumer demands for healthy and convenient diet has led to development of a huge room for functional food ingredients market. Functional foods, besides providing the basic nutrition and energy, also exert some additional health benefits as they contain biologically active ingredients. Food fortification has emerged as one of the major techniques, currently being implemented in development of functional food products (Abdel-Salam and Buraidah 2010).

Doum (*Hyphaene thebaica* L.) is an African palm tree which is commonly found alongside the River Nile in Egypt and Sudan, and also in the Inner Niger Delta. In Sudan it has remained in use to prepare activated carbon from its by-products via chemical activation method (Elnasri et al. 2013). Nutritionally, doum fruit is an excellent source of carbohydrate and fiber. Additionally, micronutrients such as vitamins (especially B vitamins) and minerals including K, Na, Ca, Mg, and P also help to regulate the biological process in body and impart health benefits (Aboshora et al. 2014; Admassu et al. 2013). Various studies have revealed the fact that doum fruit extracts contain high levels of phenols and flavonoids, which possess significant antioxidant and antibacterial activities (Aboshora et al. 2015; Hsu et al. 2006).

✉ Zhang Lianfu
lianfu@jiangnan.edu.cn

¹ State Key Laboratory of Food Science and Technology, Jiangnan University, Wuxi 214122, China

² School of Food Science and Technology, Jiangnan University, Wuxi 214122, China

³ National Engineering Research Center for Functional Food, Jiangnan University, Wuxi 214122, China

⁴ Department of Food Processing, Faculty of Engineering, University of Elemam Elmahadi, P. O. Box 209, Kosti, Sudan

Wheat flour is considered as a universal ingredient in bread making in many countries around the globe. In previous studies (Peressini and Sensidoni 2009; Sudha et al. 2007), the Brabender farinograph has been successfully used as a sensitive tool for the study of characterization of dough properties; particularly for the modifications caused by fiber at the stage of developing and mixing of bread dough. While, the Brabender extensograph allows indirect investigation of the extension behavior of the dough at further stages of bread production (Koletta et al. 2014). Ever increasingly consumer demand for nutritious breads has opened up new horizons of research to develop breads with both significantly high health benefits and sensorial properties. In recent years, the stakeholders associated with bread making are focusing more importantly on the use of high fiber and low caloric breads and other related bakery products (Indrani and Rao 2000; Koletta et al. 2014; Menon et al. 2015). Keeping in view the above rationale, the incorporation of various fiber-rich ingredients into breads is a need of hour. The use of doum fruit in breads and confectioneries formulation may provide essential nutrients and may also be used as functional food to address metabolic syndrome diseases like diabetes and hypertension. However, the influence of doum fruit flour on dough mixing properties and bread quality has not been well reported previously. The aim of the present study was to investigate the effect of partial substitution of wheat flour with doum flour on the dough properties and bread making, and estimation of its proximate composition, bread quality, sensorial properties and antioxidant capacity.

Materials and methods

Raw materials

Doum fruit (*Hyphaene thebaica* L.) was purchased from local market in Aljazeera Aba, Sudan. Doum fruit were allowed to dry using direct sun light for a week after removing seeds. Pre-dried doum fruit was brought to the National Engineering Research Center of the Functional Food, at Jiangnan University, Wuxi, China. Doum flours (according to our previous work average ash content 5 %, protein 2.4 % and fiber 20 %) (Aboshora et al. 2014) were obtained after grinding the doum fruit by using a laboratory scale hammer mill (Debarker Co Ltd., Beijing, China). High-gluten wheat flour (average ash content 0.82 %, protein 13.9 % and moisture content 14 %) was purchased from China Oil and Food Import and Export Corporation Co. Ltd. (Beijing, China).

Dough characteristics

The effect of the doum fruit flour on dough mixing and stretching properties was determined by a farinograph and

extensograph instruments (Brabender, Duisburg, Germany) following the AACC (2000) Method. The parameters determined were: water absorption or percentage of water required to yield dough consistency of 500 BU (Brabender Units), dough development time (DDT, time to reach maximum consistency in minutes), stability (time dough consistency remains at 500 BU) and Degree of softening (BU). The parameters obtained from the extensograph curves were expressed as: extensibility (E_x), which is the distance travelled by the recorder paper from the moment in which the hook touches the test piece until rupture of the test piece; resistance to constant deformation after 50 mm stretching (R_{50}); energy (E_a) (the work applied for stretching the dough in cm^2); the ratio between the parameters R_{50} and E_x (R_{50}/E_x).

Bread making

The basic recipe for bread production as follows (ICC-Standard No.131): 500 g flour (wheat flour as control or wheat flour substituted with DFF 5, 10, 15 or 20 %), was first mixed in the mixer bowl for 1 min. Afterwards, 3 % sugar, 1 % salt, 1.5 % fresh compressed yeast, previously dissolved in water, were added followed by the addition of water up to 500 BU consistency. Dough kneading process was continued for 5 min thereafter 5 % shortening was added and kneaded for further 3 min. The kneaded dough was placed in baking pans and proofed at 30 °C with 85 % relative humidity. After 1 h fermentation, the dough was punched down to remove gases, proofed for further 1 h and baked at 205 °C for 30 min. Four breads were randomly selected from each treatment subsequently freeze dried, grinded, sieved through an 80-mesh screen and stored at −20 °C prior to analysis.

Instrumental analyses

Two hours after baking, instrumental analysis of the breads were performed. Loaves were mechanically cut into slices of 12.5 mm thickness each by a bread slicer (Sinmag Bakery Equipment, Wuxi Co., Ltd., Wuxi City, Jiangsu, China). Texture profile analysis (TPA) including Hardness, Resilience, Cohesiveness, Springiness and Chewiness were carried out on a Texture Pro CT V 1.4 Build 17 (Brookfield Engineering Laboratory, Middleboro, MA, USA) equipped with an aluminum 25 mm diameter cylindrical probe. Bread slices taken from the center of each loaf were used to evaluate the crumb texture. A stack of two slices (25 mm total) was prepared and compressed to 50 % of its original thickness. The test conditions were pretest speed, 2 mm/s; test speed, 0.5 mm/s; return speed, 0.5 mm/s; and trigger load, 7 g.

Bread quality parameters included weight, volume (determined by seed displacement in a loaf volumeter) and specific volume were determined.

Hunter color values of bread crumb and crust

Hunter color values of both crumb and crust were measured with a Minolta colorimeter (Lab Scan XE, Hunter Association Laboratory, Reston, VA, USA). Before measuring, the colorimeter was calibrated using a standard white plate. The color was measured from three different positions, on the bread surface (crust) and inside (crumb). Color intensity was measured and expressed based on the values of L, a and b. Where L represents whiteness (value 100) or blackness (value 0), a represents red (+a) or green (−a), and b represents yellow (+b) or blue (−b).

Sensory evaluation

The sensory analysis was conducted on the breads 12 h after baking. Breads samples were sliced into equal sizes (3 cm × 3 cm) and presented to the panelist on a color coded plates. 20 students (11 female; 9 male) from the Faculty of Food Science and Technology aged 18–30 years old were chosen for the sensory evaluation. Sensory evaluation was carried out in a laboratory under normal (daylight) illumination and at ambient temperature. The panelists were required to score the appearance, flavor, taste, texture and overall acceptability of the bread using a nine point hedonic scale, where 9 indicates extremely like and 1 extremely dislike (Ihekoronye and Goddy 1985).

Chemical analysis

Moisture content, ash content, total protein and fat content of the breads were carried out according to ICC standard methods (Williams et al. 2008), while the crude fiber was determined by AOAC (2000) method. Carbohydrate content was determined by difference. All the measurements of the analyzed samples were done in triplicate.

Minerals composition in the breads samples was determined from the ash which was prepared and dissolved in 10 ml of concentrated HNO₃ and made up to 25 ml. Calcium content was estimated by the titrimetric method. Potassium, phosphorus and sodium contents were determined using atomic absorption spectroscopy (Shimadzu AA 6701F, Atomic Absorption Flame Emission Spectrophotometer equipped with hollow cathode lamps) (AOAC 2000).

Extraction process

The total phenolic and flavonoid contents were extracted by the method of Aboshora et al. (2015) with slight modifications. The extracts of composite flour and bread were prepared

by continuous shaking of ground samples with methanol (80 %, v/v) (sample-to solvent ratio of 1:10) for 1 h in ultrasonic bath at 40 °C. Afterwards, 4 M NaOH was added to hydrolyse the solid residue by shaking for 90 min in the dark at room temperature to involve bounded phenols. Then centrifuged at 3500 × g for 30 min at 4 °C and the supernatant was used for experiments.

Determination of total phenolic content (TPC)

Total phenolic content (TPC) was estimated colorimetrically using Folin-Ciocalteu reagent according to Paško et al. (2009) with some modifications. Total phenols assay was conducted by mixing 15 ml of de-ionized water, 0.5 ml of extracts, 3.75 ml 20 % sodium carbonate and 1.25 ml undiluted Folin-Ciocalteu reagent. After incubation for 30 min at room temperature, the absorbance was measured at 760 nm using an UV-Vis spectrophotometer (Unico Equipment Co, Ltd., Shanghai, China). A standard curve was prepared with gallic acid. Final results were given as gallic acid equivalents (GAE) in mg/g DW (dry weight of the sample).

Determination of total flavonoid content (TFC)

Total flavonoid content (TFC) was determined by a colorimetric method as described previously (Biglari et al. 2008). Briefly, 2.5 ml of the methanolic extract was diluted with 10 ml of distilled water. Then 0.75 ml of 5 % NaNO₂ solution was added to the mixture and after 6 min, 0.75 ml of 10 % AlCl₃.6H₂O solution was added. The mixture was allowed to stand for 5 min, then 5 ml 1 M NaOH was added and the total volume was made up to 25 ml with distilled water. The solution was mixed well and the absorbance was measured immediately against the blank at 510 nm using UV-Vis spectrophotometer (Unico Equipment Co, Ltd., Shanghai, China). The results were expressed as mg of rutin equivalents (RE)/g (g) DW.

Antioxidant activities

The capacity to scavenge the “stable” free radical 2,2-diphenylpicrylhydrazyl (DPPH) was determined by the method of Baydar and Baydar (2013) with some modifications. Based on the total phenolic content, (0.1 ml) of each extracts (composite flours and breads) at different concentrations (1, 2, 4, 6 and 8 mg/ml) was mixed with (3.5 ml) of DPPH methanolic solution (0.2 mM). These concentrations were chosen as a geometric progression to calculate the EC₅₀ values. The mixtures were left in the dark at room temperature for 30 min. The control was prepared as above without the addition of extract. The absorbance of the mixtures was measured at 517 nm against methanol and DPPH radical scavenging

activity was calculated using the following equation proposed by Aboshora et al. (2015):

$$\% \text{ inhibition} = [(A_c - A_s)/A_c] \times 100 \quad (1)$$

where A_s is the absorbance of the sample extract and A_c is the absorbance of the control. The activities were expressed as EC_{50} -extract concentration required to provide 50 % of activity based on dose-dependent mode of action.

The reducing power of the extracts was determined by method of Xiang and Ning (2008). 100 μ l of various concentrations of extract were mixed with 2 ml of sodium phosphate buffer (0.2 M, pH 6.6) and 2 ml of 1 % (w/v) potassium ferricyanide. The mixture was incubated for 20 min at 50 °C in a water bath followed by addition of 2 ml of 10 % trichloroacetic acid. The mixture was centrifuged at 3000 $\times$ g for 10 min. The upper layer fraction (2 ml) was mixed with 2 ml of distilled water and 0.5 ml of 0.1 % ferric chloride. The absorbance was measured at 700 nm. EC_{50} value (mg/ml) is the effective concentration at which the absorbance was 0.5 for reducing power and was obtained by interpolation from linear regression analysis.

Statistical analysis

The experimental data were subjected to an analysis of variance using the SPSS statistical software, version 16.0 (SPSS, Chicago, Illinois, USA). All data were represented as the means $\pm$ standard deviation (SD) of triplicate analyses, except for the sensory evaluation ($n = 20$) and color measurements ($n = 6$). Duncan's test was used to determine the significant differences amongst the samples means at the level of ($P \leq 0.05$).

Results and discussion

Effect of DFF incorporation on dough farinograph properties

The addition of doum fruit flour (DFF) to wheat flour (WF) brought about some differences on the dough mixing behavior as measured by the farinograph. Farinograph results of WF and WF-DFF composite, at 5, 10, 15 or 20 % DFF are shown in Fig. 1. Substitution of wheat flour with doum flour significantly ($P \leq 0.05$) had increased water absorption at all substitution levels compared with the control (Fig. 1A) and this was more obvious at 20 % DFF substitution. The amount of added water is considered to be very important for the distribution of the dough materials, hydration and the gluten protein network improvement (Mohammed et al. 2012). In the present study, the composite flours involving the doum flour showed high levels of water absorption and this could be associated with a high fiber content. It is known that the amount of water absorption of the flour containing bran from different sources

does not decrease, whatever the level of replacement, might be due to a high water-binding capacity of the fibers (Nindjin et al. 2011; Sudha et al. 2007). This is probably caused by the large number of hydroxyl groups present in the fiber structure, which let more water interactions through hydrogen bonding (Rosell et al. 2001). The development times of composite dough made from the DFF were drastically increased with the WF replacement that could be due to low protein content as well as to a higher water uptake by the DFF (Fig. 1B). Gluten is the main protein in the wheat flour dough and plays a significant function in gas retention which makes leavened products light. According to the previous work replacement of a portion of the wheat flour with the flours containing no-gluten-forming proteins reduced the overall weight of the wheat protein, and the outcome is a weaker skeleton than that of 100 % white wheat flour dough (Nindjin et al. 2011). The development of gluten gives an elastic structure for the wheat dough that allows it to be worked in a variety of ways (Aboaba and Obakpolor 2010; Nindjin et al. 2011). As shown in Fig. 1C, the control sample has a high stability while formulate 20 % DFF exhibited the lowest stability value. Stability for all DFF-WF composite doughs was gradually decreased with increasing the replacement of wheat flour. This finding was supported by the work of Nindjin et al. (2011) who reported that, the decrease in stability could be due to a weakening of the gluten network when wheat flour replacement was increased. Dough softening degree for all doum-wheat blends was decreased along with the increasing substitution level of the wheat flour (Fig. 1D). This might be due to exist of fiber into viscous mass of the dough which pointed the viscosity breakdown at over-mixing time.

Extensograph properties of composite doum-wheat flours

Extensograph measurements are providing information about the viscoelastic behavior of dough. Extensograph measurements were used in order to assess the impact of the substitution of WF with DFF. The effect of incorporation of DFF at varying levels on the extensograph characteristics throughout 135 min of proofing time are presented in Table 1. Extensograph characteristics of DFF enriched doughs were found to be dependent on level of addition and proving time when compared to the control. The extensibility (E_x) of control sample was recorded at 168 mm (45 min resting time), which finally dropped to 109 mm with increase in the level of DFF to 20 %. The extensibility of DFF-added samples decreased with the increase of proving time, where further decrease was observed during extended proving time of 135 min. The lowest extensibility (89 mm) was recorded at 20 % DFF level and after 135 min proving time. The results indicated R_{50} and E_a decreased with increasing rate of DFF when compared to the control; meanwhile these factors (R_{50} and E_a) were increased with proving time. According to Patel

Fig. 1 Farinograph characteristics of composite doum-wheat flours: **A** water absorption, **B** dough development time, **C** stability, and **D** degree of dough softening

et al. (2012) rheological properties of dough and gluten during mixing are considerably affected by the flour composition. In our study; the R_{50}/E_x value which gives information about the elastic resistance and extensibility equilibrium of the dough, was gradually increased with proving time. This may likely due to the high content of fiber in the doum fruit, which tends a strong interaction between fiber and the flour proteins; consequently affects the elasticity of dough matrix. It is interesting to note that, very little differences were observed among

the DFF contained samples in term of R_{50}/E_x and are significant ($P \leq 0.05$) than that of control (Table 1).

Influence of DFF incorporation on bread texture

Bread texture characteristics were evaluated using a texture profile analysis in terms of hardness; resilience; cohesiveness; springiness and chewiness. Along with appearance, taste and flavor, the perception by the consumer of the texture of the

Table 1 Extensograph properties of composite doum- wheat flour

DFF: WF	0: 100	5: 95	10: 90	15: 85	20: 80
Dough extension properties (45 min)					
E_x (mm)	168.00 ± 1.73 ^a	151.00 ± 1.00 ^b	135.00 ± 0.87 ^c	122.00 ± 1.00 ^d	109.00 ± 1.73 ^e
R_{50} (B)	577.00 ± 1.53 ^a	407.00 ± 1.18 ^b	375.00 ± 1.56 ^c	323.00 ± 1.30 ^d	283.00 ± 1.00 ^e
E_a (cm ²)	116.00 ± 1.00 ^a	88.00 ± 1.74 ^b	69.00 ± 2.11 ^c	59.07 ± 1.84 ^d	37.00 ± 1.18 ^e
R_{50}/E_x	3.43 ± 0.04 ^a	2.69 ± 0.01 ^{bc}	2.78 ± 0.03 ^b	2.65 ± 0.01 ^{cd}	2.60 ± 0.05 ^d
Dough extension properties (90 min)					
E_x (mm)	147.00 ± 1.73 ^a	139.00 ± 1.00 ^b	123.00 ± 0.87 ^c	109.00 ± 1.00 ^d	98.00 ± 1.73 ^e
R_{50} (BU)	643.00 ± 2.65 ^a	455.00 ± 2.11 ^b	412.00 ± 3.46 ^c	361.10 ± 2.74 ^d	312.00 ± 2.65 ^e
E_a (cm ²)	121.03 ± 1.78 ^a	93.00 ± 1.80 ^b	75.00 ± 2.65 ^c	64.00 ± 1.00 ^d	44.33 ± 2.08 ^e
R_{50}/E_x	4.37 ± 0.05 ^a	3.27 ± 0.04 ^{bc}	3.35 ± 0.03 ^b	3.31 ± 0.08 ^b	3.18 ± 0.10 ^c
Dough extension properties (135 min)					
E_x (mm)	130.00 ± 2.65 ^a	126.00 ± 1.00 ^a	111.00 ± 2.00 ^b	99.00 ± 2.43 ^c	89.00 ± 1.83 ^d
R_{50} (BU)	696.00 ± 2.46 ^a	500.00 ± 2.00 ^b	462.00 ± 1.87 ^c	407.00 ± 1.73 ^d	341.00 ± 1.23 ^e
E_a (cm ²)	128.00 ± 1.25 ^a	101.00 ± 1.73 ^b	81.00 ± 1.87 ^c	68.53 ± 2.35 ^d	51.00 ± 1.50 ^e
R_{50}/E_x	5.35 ± 0.11 ^a	3.97 ± 0.05 ^{bc}	4.16 ± 0.08 ^b	4.11 ± 0.12 ^b	3.83 ± 0.08 ^c

Mean values within a row followed by a different letter are significantly different ($P \leq 0.05$); Mean ($n = 3$) ± standard deviation

product governs how often the product might be purchased. The assessment of a product quality through the texture analysis is an essential tool for bread products development and establishes a link between eating qualities, flavor and shelf life. The results of texture analysis on DFF-WF breads are presented in Table 2. In the present study, hardness was directly proportional to the amount of DFF added; this may be as a result of low moisture levels and higher fiber content in the DFF-WF breads. The firmness of the product depends on the resilience value, whenever was small can recover faster from deformation (Bhol and Bosco 2014). The results were revealed that the bread sample with 20 % DFF was more firm than the other bread samples. Chewiness was increased as the amount of doum flour increased from 3.9 (control) to 8.8 (20 % DFF).

Influence of DFF incorporation on loaf characteristics

A significant decrease in breads volume that corresponded to the increasing percentage of doum fruit flour replacement was shown in Table 3. This effect began at 5 % up to 20 % of replacement of WF by DFF. The reduction in loaf volume seems to be related to the high amount of fiber present in the doum fruit, which diluted the gluten content and interfered with the optimal gluten matrix formation during fermentation and baking. Moreover, the resulting gluten with fiber addition became stiffer and less extensible, and this led to a lower ability of the dough to retain the gas (Wang et al. 2004). Specific volumes (volume/weight) of the breads were 4.87, 4.22, 3.94, 3.67 and 3.32 (ml/g) for 0 %, 5 %, 10 %, 15 % and 20 % respectively of the replacement of WF by DFF. Lin et al. (2009) reported that, the specific volume of standard bread is supposed to be within the range of (3.5–6.0) ml/g. From our results, all the breads met the passing standard of specific volumes excepting the 20 % DFF breads.

Influence of DFF incorporation on color properties of breads

Color of the bread is one of the most important parameter for the consumer acceptability of a product. All color data were expressed by Hunter L, a, and b values corresponding to

lightness, redness, and yellowness, respectively. The color results of the bread were shown variation based on the replacement of WF with the DFF (Table 4). In the crumb, the L values which correspond to lightness were gradually decreased with an increase the addition ratio of DFF. Moreover, the crumb color, as the level of DFF was increased, the a and b values increased, indicating that a redder and more yellow crumb was obtained as a result of DFF addition. The crumb of the control was lighter and less yellow than any of the other sample. In the crust, an increase in substitution with the DFF was resulted in a reduction in the L and b. In the bread made at replacement levels of 15 % and 20 %, the lightness (L) and yellowness (b) values of the crust were significantly different from the others. However, no significant differences ($P \leq 0.05$) were observed for the redness (a) among the samples. The impact in the crust color increased in the enriched bread for higher replacement levels of the DFF than 10 %. Mohammed et al. 2012 reported that the darkening of crust and crumb might have been attributed to high content of TPC as well as the Maillard reaction during baking due to higher lysine content. In our study, darkness in both crust and crumb could be related to the lysine content (92.2 mg/100 g) (Admassu et al. 2013) and/or higher TPC in doum flour.

Sensory analysis

Sensory characteristics of baked products have been widely studied over the years. The results of sensory properties on DFF-WF breads are shown in Fig. 2. Sensorial properties (appearance, flavor, taste and texture) of the breads were tested on a nine-point hedonic scale in range (5.15–7.7) indicating that these breads were moderately acceptable. No significant differences ($P \leq 0.05$) were found between the breads (5 % and 10 % DFF-WF) and the control (100 % WF) in terms of flavor, taste, texture and overall acceptability. The breads enriched with 15 % and 20 % DFF were much darker in appearance than the control (significant difference $P \leq 0.05$) and had negatively influence on bread acceptability. Higher levels of the doum fruit flour addition, especially 20 % DFF had caused an unpleasant taste and worst appearance. DFF addition up to 10 % had no statistically significant influence on bread texture. Higher levels of the doum fruit addition had

Table 2 Texture profile characteristics of control bread and bread made from wheat–doum composite flour

DFF: WF	0: 100	5: 95	10: 90	15: 85	20: 80
Hardness (N)	1.21 ± 0.02 ^c	1.36 ± 0.04 ^d	1.45 ± 0.03 ^c	1.61 ± 0.04 ^b	2.84 ± 0.03 ^a
Resilience	0.50 ± 0.00 ^a	0.50 ± 0.01 ^a	0.47 ± 0.02 ^b	0.46 ± 0.02 ^b	0.44 ± 0.00 ^c
Cohesiveness	0.94 ± 0.04 ^a	0.92 ± 0.03 ^a	0.86 ± 0.03 ^b	0.8 ± 0.03 ^c	0.75 ± 0.02 ^c
Springiness (mm)	3.77 ± 0.03 ^a	3.76 ± 0.02 ^a	3.68 ± 0.03 ^b	3.59 ± 0.02 ^c	3.56 ± 0.02 ^c
Chewiness (mj)	3.90 ± 0.20 ^c	4.80 ± 0.21 ^b	4.80 ± 0.20 ^b	4.90 ± 0.17 ^b	8.80 ± 1.21 ^a

Mean values within a row followed by a different letter are significantly different ($P \leq 0.05$); Mean ($n = 3$) ± standard deviation

Table 3 Loaf characteristics of wheat flour and doum–wheat composite flour

DFF: WF	0: 100	5: 95	10: 90	15: 85	20: 80
Loaf weight (g)	77.38 ± 0.74 ^b	79.36 ± 0.53 ^a	79.55 ± 0.99 ^a	79.11 ± 0.78 ^a	79.37 ± 0.40 ^a
Loaf volume (ml)	376.67 ± 2.89 ^a	335.00 ± 5.00 ^b	313.33 ± 2.89 ^c	290.00 ± 5.00 ^d	263.33 ± 2.87 ^e
Loaf specific volume (ml/g)	4.87 ± 0.06 ^a	4.22 ± 0.04 ^b	3.94 ± 0.04 ^c	3.67 ± 0.03 ^d	3.32 ± 0.03 ^e

Mean values within a row followed by a different letter are significantly different ($P \leq 0.05$); Mean ($n = 3$) ± standard deviation

negative influence on this parameter. The hedonic properties linking results indicated that a partial replacement of wheat flour in breads with up to 10 % DFF gave satisfactory overall consumer acceptability. However, breads containing 15 % and 20 % DFF were rated comparatively lower, which might be due to excessive amounts of the DFF negatively affecting appearance, taste and texture.

Chemical composition of DFF-WF composite breads

The proximate compositions of the control and DFF-WF breads are presented in (Table 5). Moisture contents were in the order: 20 % > 15 % > 10 % > 5 % DFF > control (100%WF). The variation in the moisture contents were consistent with varied water amounts used in the substitution of the different ratios of the doum flour. Increase in moisture content in the DFF-WF blends has been associated with increase in fiber content (Akhtar et al. 2008; Elleuch et al. 2011). It is noteworthy that DFF-WF breads contained much less protein than the control bread; possibly due to the relatively low level of protein in doum flour (Aboshora et al. 2014). The fat content of DFF-WF breads ranged from 2.56 to 3.01 %. DFF-WF had significantly ($P \leq 0.05$) higher ash and fiber content compared to the control. Recently food processors have investigated ways of improving the overall nutritional balance of carbohydrate rich foods by focusing on increasing their dietary fiber contents at the expense of readily digestible carbohydrates (Foschia et al. 2013). A small but statistically significant varietal effect on crude fiber content of the wheat-doum breads was observed, related to the differences in crude fiber of the doum fruit previously reported (Aboshora et al.

2014), so it was found that the fiber content in DFF-WF (20 %) breads was fourfold that of the control bread. Recently, many researches indicated that numerous health benefits are associated with an increased intake of dietary fiber, including a reduced risk of coronary heart disease, diabetes, obesity, and some forms of cancer, as well as a reduction in cholesterol and fat (Anderson et al. 2009; Brownlee 2011). All ratios of the DFF-WF breads had significantly high carbohydrates content than the control.

The mineral composition of the breads supplemented with different percentages of the doum flour is presented in (Table 5). It is well known elsewhere that a doum fruit is a rich source of minerals such as Na, K, Ca and P (Aboshora et al. 2014; Admassu et al. 2013). The incorporation of doum flour to the formulation significantly increased K, Ca and P content of composite breads compared to that of control ($P \leq 0.05$). Calcium is necessary for supporting bone formation, growth and indeed phosphorus works closely with calcium to build strong bones and teeth. For Na there was a significant difference ($P \leq 0.05$) between the control and all the substitutions made; however, there was no significant differences between some of them. In this study, the DFF-WF breads were found to be rich sources of essential minerals which in most instances exceed the recommended dietary allowance (RDA), thus may keep the balances and ratios between those in need. In view to this study, the ratio of sodium to potassium in the all blended breads was in agreement with the work of Aremu et al. (2006) who reported that the Na/K ratio less than one has a great importance in the human body for the control of high blood pressure.

Table 4 Color measurements of control bread and bread made from wheat–doum composite flour

DFF: WF	Crust color			Crumb color		
	<i>L</i>	<i>a</i>	<i>b</i>	<i>L</i>	<i>a</i>	<i>b</i>
0: 100	58.74 ± 5.84 ^a	15.35 ± 2.13 ^a	35.89 ± 1.28 ^a	79.86 ± 2.59 ^a	−0.87 ± 0.12 ^c	14.66 ± 0.06 ^d
5: 95	56.56 ± 5.49 ^{ab}	15.15 ± 1.79 ^a	34.57 ± 1.67 ^{ab}	68.30 ± 1.32 ^b	2.05 ± 0.15 ^d	17.55 ± 0.46 ^c
10: 90	56.38 ± 6.36 ^{ab}	14.26 ± 2.33 ^a	32.81 ± 1.91 ^{bc}	60.77 ± 1.49 ^c	5.17 ± 0.38 ^c	21.55 ± 0.78 ^b
15: 85	51.50 ± 5.29 ^b	15.34 ± 2.00 ^a	31.19 ± 2.13 ^c	54.79 ± 1.01 ^d	7.28 ± 0.35 ^b	23.07 ± 0.54 ^a
20: 80	50.89 ± 4.79 ^b	15.51 ± 1.21 ^a	30.96 ± 1.71 ^c	51.79 ± 1.25 ^e	8.25 ± 0.28 ^a	23.46 ± 0.33 ^a

Mean values within a column followed by a different letter are significantly different ($P \leq 0.05$); Mean ($n = 6$) ± standard deviation

Fig. 2 Hedonic sensory evaluation scores of control bread and bread made from wheat–doum composite flour. Results are expressed as mean $\pm$ standard deviation (SD) ($n = 20$). Same-colored columns with different letters indicate significant difference ($P \leq 0.05$) using Duncan's Test

TPC, TFC and antioxidant properties of DFF-WF (flour and bread)

Partial substitution of wheat flour with the doum fruit flour had caused an increase of phenolic compounds content. The whole doum fruit contains relatively high levels of phenols (Aboshora et al. 2015). The phenolic contents (TPC) for both flour and breads were expressed as mg gallic acid per gram of dry weight (Fig. 3A). The lowest TPC was found in the wheat flour whereas the highest was in the flour with 20 % DFF (6.86 mg GAE/g DW and 33.4 mg GAE/g DW, respectively). Consistently with our results, phenolic content in flour was about 3–4 fold higher when compared to the breads in all cases. The phenols content in bread samples was gradually increased with increasing the DFF levels, and the maximum

phenols content of 8 0.17 mg GAE/g DW was found in bread supplemented with 20 % DFF. The lowest phenol contents were presented in control bread. These results of phenolic contents of wheat flour and control bread were similar to those reported by Chlopicka et al. (2012). It is interesting to note that the flavor changes in bread supplemented with DFF might be correlated to the high levels of phenolic compounds; this finding has agreement with Menon et al. (2015). According to the researches of Leenhardt et al. (2006) and Holtekjølén et al. (2008) bioactive compounds existing in flour might be destroyed or lost during baking.

In this study, the TFC in both the flour and breads of DFF-WF composite was measured and expressed as mg of rutin equivalents (RE)/g (g) DW. As shown in (Fig. 3B), the substitution of wheat flour with the doum flour significantly ($P \leq 0.05$) increased the total flavonoids content (TFC) in both flour and breads compared with the control, and this was more obvious at 20 % DFF. The TFC varied from 0.065 to 9.48 mg RE/grams DW for flour extracts and 0.019 to 2.33 mg RE/grams DW for bread extracts. The TFC ranked for both flour and bread samples in descending order, as follows: 20 % DFF, 15 % DFF, 10 % DFF, 5 % DFF and 0 % DFF (control); whatever the substitution ratio, the flavonoids content in the flours was higher than in the breads. Processing stages including mixing, kneading, and heating affects the flavonoids content of the bread (Holtekjølén et al. 2008; Leenhardt et al. 2006).

The antioxidant activities were measured by DPPH (2, 2-diphenylpicrylhydrazyl) and reducing power are summarized in (Fig. 3C, D) and the results were expressed as EC_{50} values (milligram dry weight of various extracts per milliliter). Efficiency of the antioxidant activities was inversely associated with their EC_{50} values (the most effective as indicated by its lowest EC_{50} values) which were obtained by interpolation from linear regression analysis. The R^2 for all samples ranged

Table 5 Chemical composition and minerals of control bread and bread made from wheat–doum composite flour

DFF: WF	0: 100	5: 95	10: 90	15: 85	20: 80
Chemical composition (%)					
Moisture	31.93 $\pm$ 0.03 ^e	32.33 $\pm$ 0.03 ^d	32.54 $\pm$ 0.03 ^c	32.81 $\pm$ 0.02 ^b	33.03 $\pm$ 0.10 ^a
Protein	13.86 $\pm$ 0.26 ^a	11.50 $\pm$ 0.13 ^b	10.78 $\pm$ 0.04 ^c	10.11 $\pm$ 0.02 ^d	9.49 $\pm$ 0.02 ^e
Fat	3.17 $\pm$ 0.05 ^a	3.01 $\pm$ 0.02 ^b	2.83 $\pm$ 0.02 ^c	2.71 $\pm$ 0.04 ^d	2.56 $\pm$ 0.02 ^e
Ash	1.27 $\pm$ 0.21 ^c	1.33 $\pm$ 0.02 ^c	1.68 $\pm$ 0.01 ^b	1.78 $\pm$ 0.04 ^b	2.03 $\pm$ 0.01 ^a
Crude fiber	1.23 $\pm$ 0.02 ^e	2.07 $\pm$ 0.03 ^d	2.74 $\pm$ 0.04 ^c	3.71 $\pm$ 0.03 ^b	4.70 $\pm$ 0.03 ^a
*CHO	80.47 $\pm$ 0.32 ^d	82.01 $\pm$ 0.08 ^a	81.97 $\pm$ 0.09 ^a	81.69 $\pm$ 0.05 ^b	81.22 $\pm$ 0.01 ^c
Minerals (mg/100 g)					
Na	1.93 $\pm$ 0.07 ^c	4.00 $\pm$ 0.02 ^b	4.37 $\pm$ 0.02 ^b	4.86 $\pm$ 0.02 ^{ab}	5.61 $\pm$ 0.03 ^a
K	169.72 $\pm$ 0.20 ^e	184.26 $\pm$ 0.40 ^d	189.33 $\pm$ 0.20 ^c	198.38 $\pm$ 0.10 ^b	212.14 $\pm$ 0.40 ^a
Ca	20.24 $\pm$ 0.35 ^e	35.80 $\pm$ 0.21 ^d	38.47 $\pm$ 0.22 ^c	43.55 $\pm$ 0.37 ^b	50.28 $\pm$ 0.34 ^a
P	57.10 $\pm$ 0.05 ^e	69.74 $\pm$ 0.24 ^d	71.61 $\pm$ 0.29 ^c	77.86 $\pm$ 0.52 ^b	92.56 $\pm$ 0.40 ^a

Mean values within a row followed by a different letter are significantly different ($P \leq 0.05$); Mean ($n = 3$) $\pm$ standard deviation

Fig. 3 Total phenolic content, total flavonoids content and antioxidant capacity of DFF-WF flour and their breads. **A:** TPC; **B:** TFC; **C:** EC₅₀ in DPPH; **D:** EC₅₀ in Reducing Power. Results are expressed as mean $\pm$ standard deviation (SD) ($n = 3$). Same-graphics columns with different letters indicate significant difference ($P \leq 0.05$)

from 0.975 to 0.996 in DPPH and from 0.989 to 0.999 in reducing power (data not shown). The DPPH radicals were scavenged by 50 % for both flour and breads with different levels of composite DFF-WF as shown in (Fig. 3C). The addition of doum flour at all levels were enhanced the composite DFF-WF bread comparing to the control.

Reducing power of flour and bread made with different levels of substitution of WF with DFF was shown in (Fig. 3D). It was noted that, when the substitution levels of WF with the DFF increased in both flour and breads, the EC₅₀ (is the effective concentration at which the absorbance was 0.5 for reducing power) decreased, which indicated that the antioxidant activity was increased. As shown in the (Fig. 3D) the antioxidant capacity as measured by reducing power was higher for all substitution levels (flour and breads) extracts compared to control.

Conclusion

From the overall results, it could be concluded that the partial substitution of wheat flour with doum flour was modified the rheological properties of the dough to different extent. Inclusion of DFF in bread formula; increase its nutritional value, with only a small depreciation in bread quality. Organoleptic properties shown that the loaf supplemented up to 15 % DFF was acceptable and has no significant difference

with control in terms of taste, texture and overall acceptability. TPC, TFC and antioxidant activities in flour were higher than the breads in all substitution levels. Regardless to this, addition of DFF improved TPC and TFC contents, hence led to higher antioxidant activity.

Acknowledgments This work was supported by grants from the Natural Sciences Foundation of China (31171724), the Fundamental Research Funds for the Central Universities (JUSRP51501) and the Specialized Research Fund for the Doctoral Program of Higher Education (SRFDP 20130093110008).

References

- AACC (2000) Approved methods of American association of cereal chemists, 10th edn. AACC Int, St. Paul
- Abdel-Salam A, Buraidah AQ (2010) Functional foods: hopefulness to good health. Am J Food Technol 1-14
- Aboaba O, Obakpolor E (2010) The leavening ability of baker's yeast on dough prepared with composite flour (wheat/cassava). Afr J Food Sci 4(6):325–329
- Aboshora W, Lianfu Z, Dahir M, Gasmalla MA, Musa A, Omer E, Thapa M (2014) Physicochemical, nutritional and functional properties of the epicarp, flesh and pitted sample of doum fruit (*Hyphaene Thebaica*). J Food Nutr Res 2(4):180–186
- Aboshora W, Lianfu Z, Dahir M, Qingran M, Qingrui S, Jing L, Ammar A (2015) Effect of extraction method and solvent power on polyphenol and flavonoid levels in *Hyphaene Thebaica* L Mart (*Arecaceae*) (doum) fruit, and its antioxidant and antibacterial activities. Trop J Pharm Res 13(12):2057–2063

- Admassu M, Bekele A, Kim JC (2013) Nutritional composition of balanites aegyptiaca (desert date) and hyphaene thebaica (dour palm) fruits consumed by Hamadryas Baboons (*Papio hamadryas hamadryas*) in Awash National Park, Ethiopia. *J Nutr Ecol Food Res* 1(3):198–206
- Akhtar S, Anjum F, Rehman SU, Sheikh MA, Farzana K (2008) Effect of fortification on physico-chemical and microbiological stability of whole wheat flour. *Food Chem* 110(1):113–119
- Anderson JW, Baird P, Davis RH, Ferreri S, Knudtson M, Koraym A, Williams CL (2009) Health benefits of dietary fiber. *Nutr Rev* 67(4):188–205
- AOAC (2000) Official methods of analysis, 17th edn. Association of Official Analytical Chemists, Washington DC
- Aremu MO, Olaofe O, Akintayo TE (2006) A comparative study on the chemical and amino acid composition of some Nigerian underutilized legume flours. *Pak J Nutr* 5(1):34–38
- Baydar NG, Baydar H (2013) Phenolic compounds, antiradical activity and antioxidant capacity of oil-bearing rose (*Rosa damascena* Mill.) extracts. *Ind Crop Prod* 41:375–380
- Bhol S, Bosco SJD (2014) Influence of malted finger millet and red kidney bean flour on quality characteristics of developed bread. *LWT Food Sci Technol* 55(1):294–300
- Biglari F, AlKarkhi AF, Easa AM (2008) Antioxidant activity and phenolic content of various date palm (*Phoenix dactylifera*) fruits from Iran. *Food Chem* 107(4):1636–1641
- Brownlee IA (2011) The physiological roles of dietary fibre. *Food Hydrocoll* 25(2):238–250
- Chlopicka J, Pasko P, Gorinstein S, Jedryas A, Zagrodzki P (2012) Total phenolic and total flavonoid content, antioxidant activity and sensory evaluation of pseudocereal breads. *LWT Food Sci Technol* 46(2):548–555
- Elleuch M, Bedigian D, Roiseux O, Besbes S, Blecker C, Attia H (2011) Dietary fibre and fibre-rich by-products of food processing: characterisation, technological functionality and commercial applications: a review. *Food Chem* 124(2):411–421
- Elnasri NA, Elsheik MA, Eltayeb MA (2013) Physico-chemical characterization and freundlich isotherm studies of adsorption of Fe (II), from aqueous solution by using activated carbon prepared from dour fruit waste. *Arch Appl Sci Res* 5(5):149–158
- Foschia M, Peressini D, Sensidoni A, Brennan CS (2013) The effects of dietary fibre addition on the quality of common cereal products. *J Cereal Sci* 58(2):216–227
- Holtekjølén AK, Bævre A, Rødbotten M, Berg H, Knutsen SH (2008) Antioxidant properties and sensory profiles of breads containing barley flour. *Food Chem* 110(2):414–421
- Hsu B, Coupar IM, Ng K (2006) Antioxidant activity of hot water extract from the fruit of the dour palm, *hyphaene thebaica*. *Food Chem* 98(2):317–328
- Ihekoronye AI, Ngoddy PO (1985) Integrated food science and technology for the tropics: Macmillan
- Indrani D, Rao GV (2000) Effect of chemical composition of wheat flour and functional properties of dough on the quality of south Indian parotta. *Food Res Int* 33(10):875–881
- Kolettta P, Irakli M, Papageorgiou M, Skendi A (2014) Physicochemical and technological properties of highly enriched wheat breads with wholegrain non wheat flours. *J Cereal Sci* 60(3):561–568
- Leenhardt F, Lyan B, Rock E, Boussard A, Potus J, Chanliaud E, Remesy C (2006) Wheat lipoxygenase activity induces greater loss of carotenoids than vitamin E during breadmaking. *J Agric Food Chem* 54(5):1710–1715
- Lin L-Y, Liu H-M, Yu Y-W, Lin S-D, Mau J-L (2009) Quality and antioxidant property of buckwheat enhanced wheat bread. *Food Chem* 112(4):987–991
- Menon L, Majumdar SD, Ravi U (2015) Development and analysis of composite flour bread. *J Food Sci Technol* 52(7):4156–4165
- Mohammed I, Ahmed AR, Senge B (2012) Dough rheology and bread quality of wheat–chickpea flour blends. *Ind Crop Prod* 36(1):196–202
- Nindjin C, Amani G, Sindic M (2011) Effect of blend levels on composite wheat doughs performance made from yam and cassava native starches and bread quality. *Carbohydr Polym* 86(4):1637–1645
- Paśko P, Bartoń H, Zagrodzki P, Gorinstein S, Fołta M, Zachwieja Z (2009) Anthocyanins, total polyphenols and antioxidant activity in amaranth and quinoa seeds and sprouts during their growth. *Food Chem* 115(3):994–998
- Patel M, Ng J, Hawkins W, Pitts K, Chakrabarti-Bell S (2012) Effects of fungal α -amylase on chemically leavened wheat flour doughs. *J Cereal Sci* 56(3):644–651
- Peressini D, Sensidoni A (2009) Effect of soluble dietary fibre addition on rheological and breadmaking properties of wheat doughs. *J Cereal Sci* 49(2):190–201
- Rosell C, Rojas J, De Barber CB (2001) Influence of hydrocolloids on dough rheology and bread quality. *Food Hydrocoll* 15(1):75–81
- Sudha M, Vetrmani R, Leelavathi K (2007) Influence of fibre from different cereals on the rheological characteristics of wheat flour dough and on biscuit quality. *Food Chem* 100(4):1365–1370
- Wang M, van Vliet T, Hamer RJ (2004) How gluten properties are affected by pentosans. *J Cereal Sci* 39(3):395–402
- Williams P, Lindhauer MG, Poms RE, Wehling RL, Berghaller W, Gaines CS (2008) The joint AACC international-ICC methods harmonization project. *Cereal Foods World* 53(2):99–102
- Xiang Z, Ning Z (2008) Scavenging and antioxidant properties of compound derived from chlorogenic acid in south-China honeysuckle. *LWT Food Sci Technol* 41(7):1189–1203