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Effect of substitution of wheat flour with chickpea flour on their physico-chemical characteristics

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Abstract

Purpose – The major objective of this research work was to evaluate various physico-chemical characteristics, such as, chemical composition, antioxidant capacity, objective color and texture profile analysis (TPA) of the wheat flour/chickpea flour (CF) blends, so that nutritious baked products could be consumed by the type-2 diabetic persons.

Design/methodology/approach – Wholegrain wheat flour (WGF) and white wheat flour (WWF) were substituted with CF at 0 to 40% levels. These wheat flour/CF blends were analyzed for proximate composition, the prepared dough and baked breads were tested for objective color, antioxidant capacity as trolox equivalent antioxidant capacity (TEAC), malondialdehyde (MDA) and total phenolic content (TPC) and TPA.

Findings – WGF had the highest TEAC (117.42 mM/100g) value, followed by WWF (73.98 mM/100g) and CF (60.67 mM/100g). TEAC, MDA and TPC values varied significantly among all the three flour samples.

Research limitations/implications – Inclusion of whole chickpea (without dehulling) flour in such type of blends would be another interesting investigation during the future research studies.

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Authors' contribution statement: Jiwan S. Sidhu: Conceptualization, methodology development, obtained funding, project administration. Tasleem A. Zafar: Investigation, visualization, writing-original draft preparation. Abdulwahab S. Almusallam: Data curation, supervision. Muslim Ali: Supervision, provision of reagents, methodology development for antioxidant analyses. Amani R.A. Al-Othman: Data curation, visualization, statistical analysis of research data and preparation of data tables.

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Practical implications – These research findings have a great potential for the production of these baked products for human consumption on an industrial scale.
Social implications – Production of breads using wheat flour and CF blends would benefits the consumers.
Originality/value – Production of Arabic and pan breads using wheat flour and CF blends would, therefore, combine the benefits of both the needed proteins of plant origin and the health-promoting bioactive compounds, in a most sustainable way for the consumers.

Keywords Wheat and chickpea flours, Dough, Antioxidants, Phenolics, Objective color, Nutritional value
Paper type Research paper

Introduction

Recently many health organizations and health professionals are advising consumers to change their diets to plants-based foods, such as whole grains, legumes and nuts, because of the presence of various health-promoting bioactives, such as, phenolics (Xing, Dekker, Kyriakopoulou, Boom, & Schutyser, 2020). Consumption of higher amounts of plant proteins in place of meat proteins has been recommended as the most sustainable approach not only to improve the physical health and wellbeing of older adults but also to limit the greenhouse gases emissions (Grasso *et al.*, 2021). Consumption of plant-based varied diet have been reported to influence microbiome which ultimately improve human health, reducing the incidences of noncommunicable diseases, such as, type-2 diabetes (Lee-Sarwar & Ramirez, 2022). Legumes are rich in both soluble and insoluble dietary fiber too, especially the resistant starch (RS), which retains its functionality even after cooking (Summo, Angelis, Riccardi, Caponio, & Pasqualone, 2019). The benefit of dietary fiber for the prevention of obesity, cardiovascular diseases, type-2 diabetes and colon cancer is attracting a great interest lately. Among the legumes, chickpea is not only rich in many vitamins, minerals, bioactive compounds (e.g. ferulic acid, resistant starch), proteins (25.3–28.9%) but also rich in lysine and arginine and can improve the nutritive value of wheat-based products (Nasir & Sidhu, 2013; Bai, Nosworthy, House, & Nickerson, 2018; Moreno-Valdespino, Luna-Vital, Camacho-Ruiz, & Mojica, 2020). Chickpea is also reported to be a rich source of many phenolic antioxidant compounds (Ferreira, Bubolz, da Silva, Dittgen, & de Oliveira, 2019).

Type-2 diabetes is emerging as one of the major clinical and public-health problems in many of the Gulf Cooperation Council (GCC) countries. The number of persons suffering from type-2 diabetes (21.4% in 2008) in Kuwait is predicted to go up to double by the year 2025 (Alkhalaf, Eid, Najjar, Doi, & Thalib, 2010). The current expenses (374 million United States (US)$) on treating diabetic patients in Kuwait is expected to be 924 million US$ by 2030. Type-2 diabetics are 285 million worldwide and are expected to reach 438 million by 2030. Many reasons, such as, genetics, obesity, sedentary lifestyle and unhealthy eating habits could be assigned to this problem. As the digestibility of chickpea starch is much slower than that of cereal starch, it can be utilized for attenuating the abnormal sugar spikes in blood after consuming baked products produced from chickpea-wheat flour blends (El-Sohaimy, Brennan, Darwish, & Brennan, 2020).

Chickpea being rich in proteins and certain essential amino acids which are lacking in cereals, thus can improve the nutritive value of wheat-based products (Suhasini & Malleshi, 2003; Summo *et al.*, 2019; Sharma, Dar, Sharma, & Singh, 2021). Garcia-Valle, Bello-Perez, and Tovar (2021) have enriched pasta products using chickpea flour (CF) rich in nondigestible carbohydrates (resistant starch) to improve the dietary fiber intake thus providing help in fighting obesity and many diet-related noncommunicable diseases. Santos, Fratelli, Muniz, and Capriles (2018) have developed chickpea-based gluten-free bread with acceptable technological, sensory and nutritional quality with 2-fold increase in ash and protein, 3-fold increase in total dietary fiber contents. A detailed review on the composition and nutritional value of chickpeas with special reference to bakery and snack products has been published (Rachwa-Rosiak, Nebesny, & Budryn, 2015). The nutritional quality, chemical composition, phenolics and total antioxidant activity in chickpeas is affected by a number of food processing operations, such as soaking, sprouting, cooking, roasting and dehydration (Dragicevic, Kratovalieva, Dumanovic, Dimov, & Kravic, 2015; Bai *et al.*, 2018; Xing *et al.*, 2020).

The increased inflammation due to higher oxidative stress, lower level of antioxidant defense enzymes has been proposed to contribute to vascular disfunction in type-2 diabetes (Azul *et al.*, 2020). In a number of recent studies, the role of consuming antioxidant-rich foods in improving the renal perfusion and glomerular filtration rates (Zitouni *et al.*, 2020), antioxidant-rich propolis and bee pollen extracts for glycemic control in type-2 diabetes has been reported (Afsharpour, Javadi, Hashemipou, Koushan, & Khadem Haghighian, 2019; Laaroussi *et al.*, 2020). In addition to the role of oxidative stress, intake of a type of proteins has also been implicated in the development of type-2 diabetes. The intake of red meats as a possible biomarker and a risk factor for type-2 diabetes (Yang *et al.*, 2020); inverse relationship between total meat, red meat as well as processed meat intake with insulin sensitivity mediated through body-mass index (Clapham, Root, & Ekker-Runde, 2020); reduced intake of animal foods with increased consumption of plant-based diets and reduced incidence of type-2 diabetes (Adeva-Andany *et al.*, 2019; Kahleova *et al.*, 2020); for the prevention and treatment of type-2 diabetes, higher intake of plant-based proteins for reduced oxidative stress have been extensively reported (Pivovarova-Ramich *et al.*, 2020). As the specific nutritional needs of type-2 diabetics can differ from those of healthy individuals, it is now suggested that medical foods (functional foods) specifically designed for tackling such disease conditions can fill the needs (Holmes, Biella, Morck, Rostorfer, & Schneeman, 2021). The rheological characteristics of wheat chickpea composite flour dough made with amla fruit powder (*Phyllanthus emblica* L.) have already been published by Zafar, Allafi, Alkandari, and Al-Othman (2020). Microstructure of wholegrain wheat flour (WGF), white wheat flour (WWF) and CF blends, including the effect on glycemic response of the pan bread made therefrom, have also been reported recently by Zafar, Aldughpassi, Almusallam, and Al-Othman (2020).

Keeping this in view, the importance of chickpea-based foods in the diet of the type-2 diabetic patients, important information related to chemical composition, antioxidant capacity, objective color and texture profiles of the chickpea-wheat flour blends has been studied and presented here. The rheological, nutritional and sensory quality of baked products from wheat flour/chickpea blends have been reported in another publications (Zafar, Allafi *et al.*, 2020, Zafar, Aldughpassi *et al.*, 2020). The major objective of the present study was to make available useful data for producing superior quality pan and Arabic flat breads to make these available in abundance for consumption by the diabetic consumers, who may then be able to effectively manage their diabetes without the use of medicine.

Materials and methods

Materials

Commercially available CF was obtained from the local market. This chickpea grains are dehusked to remove the seed coat, thus only the cotyledons are pulverized to obtain fine flour passing through 10XX sieve (100μ opening). The WGF and WWF were procured from Kuwait flour mills & bakeries company. All the chemicals used for analysis were of analytical grade.

Flour blends

WGF and WWF were substituted by CF at different levels (0, 10, 20, 30 and 40%), mixing them thoroughly in dry condition, in minimum batches of five Kg. These flours and their blends were analyzed for moisture (Method 44-19), crude protein (Method 46-12), crude fat (Method 30-25), crude fiber (Method 32-10) and ash (Method 08-01) contents by standard American Association of Cereal Chemists methods (AACC, 2000) as reported by Alkandari, Sarfraz, and Sidhu (2019) and the results are expressed on % dry basis (d.b.).

Methods

Total antioxidants capacity (as mM TEAC/100g)

For the determination of total antioxidant capacity, the modified method of Rice-Evans and Miller (1994) described by Drobiova *et al.* (2009) was used. Consistent with the original method of Rice-Evans and Miller (1994), the modified method is based on the ability of 2, 2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) to form a radical cation intermediate ($ABTS^{•+}$). The reaction series that results in the production of $ABTS^{•+}$ starts with the activation of metmyoglobin (MetMb) by hydrogen peroxide, generating Ferryl Mb which in turn reacts with ABTS to produce $ABTS^{•+}$ radical. The blue-green color of $ABTS^{•+}$ radical is characterized by long wavelength absorption maxima and is measured at 660, 734 and 820 nm in a spectrophotometer (Model: Genesys 5, Make: Thermo, United States of America (USA)). All analyses were done in triplicates. More details about the total antioxidants' methodology are given in supplementary file (Appendix-A: supplementary file Figure 1).

Total phenolics content (as mg gallic acid equivalent/g)

Reagents used in the study: methanol (Sigma Aldrich Company, USA); Folin-Ciocalteau reagent (Sigma Aldrich Company, USA); sodium carbonate, 100mg/ml distilled water; gallic acid standard (Sigma Aldrich Company, USA). Prepared 6 different concentrations of gallic acid (1, 2, 3, 4, 5, 6μg/mL in methanol) for the standard curve. One gram in 10 mL 70 % methanol was extracted, centrifuged at 3000 x g, supernatant was used for total phenolics with appropriate dilutions according to the gallic acid standard curve.

Exactly 0.5 mL of the extract solution/standard was mixed with 0.5 mL of Folin Ciocalteau reagent in an opaque flask. After 2 min, added sodium carbonate solution, tubes allowed to stand for 2hr in dark, centrifuged and the optical density of the supernatant was measured at 734 nm in a spectrophotometer (Model: Genesys 5, Make: Thermo, USA). Total phenolic content (TPC) was calculated from the standard curve. All analyses were done in triplicates. More details about the total phenolics methodology are given in supplementary file (Appendix-A: supplementary Figure 2).

Malondialdehyde (MDA as mM/g)

For all the samples, 1g weighed and extracted with 5ml distilled water. It was centrifuged at 2000 x g for 15min at 4°C. The supernatant with appropriate dilutions was used for analysis and results were calculated from the extinction coefficient. One ml of the sample was mixed with 1mL of TCA-TBA reagent, boiled for 15 min in a water bath, cooled, centrifuged at 2000 x g, collected the supernatant, and the absorbance was read at 535nm in a spectrophotometer (Model: Genesys 5, Make: Thermo, USA). All analyses were done in triplicates. Further details about the MDA methodology are given in supplementary file (Appendix-A).

Objective color measurement

The objective color of WWF, WGF, CF and their blends was measured with hunter lab portable spectrophotometer (model Miniscan-EZ, USA) as CIE L* a* b* tristimulus values. Under this tristimulus color coordinate system, the L* value is a measure of lightness and range from 0 (black) to 100 (white); a* values from −100 (green) to +100 (red), and the b* value from −100 (blue) to +100 (yellow). As the values for a* and b* rise, the color becomes more saturated or chromatic, but these values approach zero for neutral colors (white, gray or black). The instrument settings were illuminant D50, display L*a*b*, observer angle 34° and was calibrated with a white primary tile (100) and with black primary tile (zero), supplied by the manufacturer. Twelve readings were taken in different areas of the samples, after discarding the two extreme reading on both side of the spectrum; the remaining ten readings were recorded for each sample. Objective color measurements were made on the WWF, WGF, CF, blends of wheat flour and CF as well as the crust and crumb color of the pan breads made from these flours and blends.

Additional color attributes, such as, whiteness value, RI, saturation index (SI) and total color difference (ΔE), were also calculated as explained by Al-Hooti, Sidhu, and Al-Saqer (2000). Whiteness was calculated by the equation: $100 - [(100-L^*)^2 + a^{*2} + b^{*2}]^{1/2}$. The a*/b* ratio was taken as an index of apparent change in redness (RI); the SI representing the color purity or color intensity, was calculated by the equation: $(a^{*2} + b^{*2})^{1/2}$. Total color difference, ΔE, was calculated from the equation: $[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$, representing ΔE between the wheat flours and wheat flour-CF blends.

Texture profile analysis

Using farinograph water absorption values, dough was made from blends prepared, in duplicates, by replacing wheat flour (WWF, WGF) with CF at 0, 10, 20, 30 and 40 % levels in Mixograph (National manufacturing Co., Lincoln, Nebraska, USA) to optimum dough development, covered with paraffin film and given a rest time of 25 min at 30°C. Six cylindrical pieces of 2 cm di and I cm height were cut from these dough pieces, were given a rest period of 10 min at 20°C. The effect of this replacement was evaluated through texture profile analysis (TPA) using TATX2plus texture analyzer (Stable Micro System Ltd, United Kingdom (UK)) as per the procedure reported by Ponzio, Ferrero, and Puppo (2013). Three observations were made on all dough samples and mean ± standard deviations are reported. The following measurements were obtained from the TPA observations:

Hardness: is defined as the maximum force (in Newton) registered during the first compression cycle of the dough.

Compressibility/Spreadability: also known as the elasticity was calculated as the distance between the beginning and the maximum force of the second compression cycle of the dough.

Adhesiveness: is the negative area obtained during the first cycle of dough when the probe was returning back after achieving the desired penetration into the dough.

Cohesiveness: is determined as the ratio between the positive area of the second cycle and the positive area of the first cycle of dough compression.

Statistical analysis

Research data were analyzed for analysis of variance, for statistical significance ($P = 0.05$) using Duncan’s new multiple range test (SPSS (Statistical Package for Social Sciences) Program for Windows, version 17), and the inferences are reported at the appropriate places. For the results, mean values ± standard deviations are reported.

Results and discussion

Chemical composition

The WGF, WWF and CF had moisture contents of 10.58, 10.54 and 7.61%, respectively. The proximate analyses (% dry basis) for WGF, WWF and CF were, crude protein (Nx6.25), 13.30, 15.20 and 26.99%; crude fat, 4.52, 2.94 and 7.15%; crude fiber, 0.43, 1.69 and 1.72%, and ash were 1.28, 0.64 and 2.47%, respectively. The data presented here shows CF to be an excellent source of proteins (26.99%) with higher amounts of lysine and threonine amino acids, which are low in cereals (Sharma *et al.*, 2021). The chickpeas, if consumed have been shown to assist in the management of blood sugar levels among persons having type-2 diabetes (Kahleova *et al.*, 2020). Moreover, intake of red meat or processed meat when substituted with proteins from plant origin have been shown to reduce the development and prevention of type-2 diabetes, in some cases by affecting the insulin sensitivity (Adeva-Andany *et al.*, 2019; Yang *et al.*, 2020; Clapham *et al.*, 2020). Only the proximate composition of these blends is presented in Table 1. The protein content in WGF:CF blends increased from 13.31 to 18.78% as the CF replacement level was increased from zero to 40%. The protein content in WWF:CF blends also increased from 15.20 to 19.91% as the CF replacement level was increased from zero to 40%. As the CF used in this study was obtained from the cotyledons (thus lacking seed coats), it showed lower crude fiber contents than the whole chickpeas seeds as reported by other workers (Sharma *et al.*, 2021). In another study, Demir, Bilgigli, Elguen, and Demir (2010) have reported the substitution of wheat flour with CF up to 100% on the technological, nutritional and sensory qualities of couscous, and found beyond 50% replacement level with CF, the couscous was not acceptable in sensory quality. Quazib, Dura, Zaidi, and Rosell (2016) have studied the partial replacement of wheat flour with only 10 and 20% of germinated, toasted and cooked chickpea on breadmaking quality. According to them, the replacement with germinated CF gave the best performance in improving the bread quality.

In a recent review, higher protein intake has been reported to be reasonably beneficial for type-2 diabetic persons (Malaeb, Bakker, Chow, & Bantle, 2019). In another review, higher protein consumption (1.0 to 1.5 g/kg/day) in older adults has been reported to increase muscle mass with improvements in glycemic control (Beaudry & Devries, 2019). Ke *et al.* (2018) have reported that the association between protein intake and Type-2 diabetes (T2DM) changes with the dietary pattern. They found the extreme quartile of plant protein intake in the legumes and seafood group was inversely related to T2DM. However, the total protein intake and the animal protein intake was positively related with T2DM in red meat group.

Total antioxidant capacity

The WGF, WWF, CF and their blends were analyzed for total antioxidant capacity in terms of trolox equivalent antioxidant capacity (TEAC mM/100g), MDA (mmoles/g) and TPC (mg Gallic acid equivalent (GAE)/g), and the results are presented in Table 2. The TEAC, MDA and TPC values varied significantly among all these samples. The TEAC values were the highest for WGF (117.42 mM/100g), followed by WWF (73.98 mM/100g) and CF (60.67 mM/100g). The TPC content also followed the same trend for GAE values with WGF having the highest (8.67 mg GAE/g), followed by WWF (5.65 mg GAE/g) and CF (3.45 mg GAE/g).

Flour/Blends	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Total ash (%)
WWF-CF 100:0	15.20 ± 0.08^{a}	5.94 ± 0.15^{b}	0.43 ± 0.07^{a}	2.13 ± 0.01^{a}
WWF-CF 80:20	17.56 ± 0.1^{c}	6.87 ± 0.1^{c}	0.69 ± 0.1^{b}	2.51 ± 0.01^{b}
WWF-CF 70:30	18.73 ± 0.06^{d}	7.21 ± 0.09^{ac}	0.82 ± 0.09^{c}	2.69 ± 0.06^{c}
WWF-CF 60:40	19.91 ± 0.07^{e}	7.51 ± 0.12^{a}	0.96 ± 0.06^{d}	2.87 ± 0.06^{d}
WGF-CF 100:0	13.31 ± 0.15^{b}	7.52 ± 0.08^{a}	1.69 ± 0.12^{e}	2.71 ± 0.17^{d}
WGF-CF 80:20	16.04 ± 0.07^{c}	8.04 ± 0.12^{d}	1.65 ± 0.16^{e}	3.02 ± 0.07^{e}
WGF-CF 70:30	17.42 ± 0.04^{c}	8.34 ± 0.07^{d}	1.71 ± 0.06^{e}	2.89 ± 0.16^{e}
WGF-CF 60:40	18.78 ± 0.01^{d}	8.72 ± 0.14^{d}	1.71 ± 0.06^{e}	3.26 ± 0.11^{f}

Note(s): Data is presented as mean ± SD, (n = 12); the different superscript letters represent significant difference between the samples in a column at significance level of P = 0.05. Protein factor (Nx6.25). Legends: WWF = White wheat flour; WGF = Wholegrain wheat flour; CF = Chickpea flour; 0, 20, 30, and 40 suggest the ratio of 0 % (Control), 20%, 30% and 40% replacement of wheat flour with the CF

Table 1. Nutritional composition of the control wholegrain wheat flour, white wheat flour doughs and composite flour blends with various ratio of chickpea flour (% dry basis)

Table 2.
Antioxidant capacity, malondialdehyde and total phenolic content (% dry basis)

Sample description	Trolox equivalent antioxidant capacity (TEAC mM/100g)	Malondialdehyde (Mm/g)	Total phenolic content (mg GAE/g)
White Wheat flour (WWF)	73.98 ± 3.2[e]	0.87 ± 0.03[e]	5.65 ± 1.9[d]
WWF:CF 80:20	71.3 ± 3.4[e]	0.98 ± 0.014 [d]	5.21 ± 0.45 [d]
WWF:CF 70:30	69.7 ± 3.2 [e]	1.05 ± 0.013 [c]	4.99 ± 0.44 [de]
WWF:CF 60:40	68.7 ± 2.5 [d]	1.11 ± 0.013 [b]	4.78 ± 0.42 [e]
Wholegrain wheat flour (WGF)	117.42 ± 2.2[a]	0.43 ± 0.04[h]	8.67 ± 1.2[a]
WGF:CF 80:20	106.07 ± 3.5 [b]	0.63 ± 0.010 [g]	7.62 ± 1.17 [ab]
WGF:CF 70:30	100.4 ± 3.0 [b]	0.74 ± 0.008 [f]	7.10 ± 1.02 [bc]
WGF:CF 60:40	94.7 ± 2.5 [c]	0.84 ± 0.005 [e]	6.58 ± 0.88[cd]
Chickpea flour (CF)	60.67 ± 3.2[d]	1.47 ± 0.06[a]	3.45 ± 0.9[f]

Note(s): Mean values (n = 3) with different superscripts in a column differ significantly (p = 0.05)
Legends: WWF = White wheat flour; WGF = Wholegrain wheat flour; CF = Chickpea flour; 0, 20, 30 and 40 suggest the ratio of 0 % (Control), 20%, 30% and 40% replacement of wheat flour with the CF

In case of MDA, CF had the highest values (1.47mM/g) and was followed by WWF (0.87 mM/g) and WGF (0.43 mM/g). Most of the phenolics have been shown to be present in seed coat of chickpea grains (Giusti, Capuano, Sagratini, & Pellergrini, 2019). The reason for lower values of TPC for CF is this differential distribution of phenolics because the seed coat is completely separated during the production of CF that comes from the cotyledons only. Likewise, wheat bran is reported to be a richer in phenolics than the endosperm of wheat grain (Alkandari *et al.*, 2019), thus, WGF gave higher values for phenolics than the WWF. Because MDA measures the amount of lipid peroxidation, it has inverse relationship with the TEAC as well as TPC values. Obviously, higher the amounts of antioxidant capacity of a compound, lower will be the MDA production for that compound.

The whole wheat flour was shown to be a significantly superior source of antioxidants when compared with WWF or CF. However, the contribution of higher protein content of CF combined with its health-promoting antioxidants would provide significant benefits to consumers of breads made from wheat flour and CF blends, as shown recently by Pivovarova-Ramich *et al.* (2020). A significant increase in TEAC during roasting of chickpea seeds has been reported by Acar, Gokmen, Pellegrini, and Fogliano (2009), mainly due to the generation of Maillard reaction products during the roasting process. Microwave cooking of chickpea seeds is reported not only to improve the nutritional quality (by reducing the anti-nutritional factors and improving digestibility) but also needs lower cooking time (Alajaji & El-Adawy, 2006; Bai *et al.*, 2018). Apparently, most of the variations in the results reported above may arise out of the type of cultivars, and the processing conditions employed by these researchers.

In one of the earlier studies, consumption of diet rich in vitamin E and other antioxidants has been reported to reduce the development of type-2 diabetes (Montonen, Knekt, Jarvinen, & Reunanen, 2004). Hyperglycemia has been shown to promote auto-oxidation of glucose to generate free radicals which result in macro- and micro-vascular dysfunction (Bajaj & Khan, 2012; Matough, Budin, Hamid, Alwahaibi, & Mohamed, 2012). They had suggested the intake of diets rich in various antioxidants, such as, vitamin C and α-lipoic acid to reduce the diabetic complications. In a recent review, the use of various antioxidants, such as, vitamin C and E have been reported to enhance the antioxidant capacity of the body as a valuable strategy to control the diabetic complications (Balbi *et al.*, 2018). In another review, Rajendiran, Packirisamy, and Gunasekaran (2018) have suggested that antioxidant therapy which defends the beta-cells in the pancreas against the oxidative stress-induced apoptosis and preserves the function of the beta-cells. In a very recent review, Park and Park (2021), have also reported a close association between oxidative stress and insulin resistance. This discussion clearly brings out the importance of consuming more antioxidant vitamins, and the results presented in the study are important contributions in tackling the type-2 diabetes using dietary approaches based on healthy baked products.

Objective color

WWF and WGF were taken as control, for two reasons. First, WWF pan bread as well as Arabic bread are very well accepted by the Kuwaiti consumers. Second, both the WWF and WGF are being replaced at varying levels (0 to 40%) with CF, and this replacement is expected to affect the color attributes of these flour blends. The CIE L*, a*, b* values and the other color properties of WWF, WGF and CF are presented in Table 3. The WWF showed the lightest color among these samples with L*, a*, b*, whiteness value and RI of 66.3, 0.4, 7.6, 65.4 and 0.06, respectively. The CF had a strong yellow hue with the highest value for b* (16.9) and SI (17.0). Compared with WWF and CF, the WGF having all the bran particles showed a dark red hue which is evident from the significantly higher RI (1.9). Compared with WGF (0.18), the significantly lower RI values for WWF and CF (0.06) reflected a color change in WWF and CF samples towards yellowness. As compared with WWF and CF, the highest a* value (1.9) for WGF, reflected a color change to redness. Sopiwnyk, Young, Frohlich, Borsuk, and Malcolmson (2020) have also reported that addition of CF at 20% replacement level to WWF significantly affected the flour color (decreased L* value) and the darker bread crumb color (increased a* value).

When WWF and WGF were replaced with different levels of CF (i.e. 0, 10, 20, 30 and 40%), significant differences in L*, a*, b* values among most of these flour blends were observed (Table 4). In case of WWF, as the CF replacement level increased from 0 to 40%, the L* values showed a significant decrease from 66.3 to 60.9, making the flour blends look darker. Similarly, both the a* and b* values for WWF and CF also showed a significant increase from 0.44 to 0.69 and 7.6 to 13.9, respectively. This data shows that the WWF flour blends with higher levels of CF tended to show a darker red and yellow hue. Chickpea cotyledons have been reported to be rich in many carotenoids which is responsible for the yellow to reddish color to the flour derived from this legume (Ashokkumar *et al.*, 2015a, b). These workers suggested the use of breeding programs to improve carotenoid content of chickpea through biofortification, to tackle vitamin A deficiency and age-related macular degeneration in many developing countries.

However, in case of WGF (having higher bran constituents), the replacement with CF from 0 to 40% did not show a definite trend in the L* values, but the a* and b* values were affected significantly. In contrast to WWF, the addition of CF to WGF decreased the a* value from

CIE L* a* b* values and color properties	WWF	WGF	CF
L* value	66.3 ± 1.2^{a}	60.4 ± 0.4^{b}	60.8 ± 1.0^{b}
a* value	0.4 ± 0.1^{a}	1.9 ± 0.1^{b}	1.1 ± 0.1^{c}
b* value	7.6 ± 0.4^{a}	10.1 ± 0.2^{b}	16.9 ± 0.7^{c}
Total Color Difference, ΔE	0.0^{a} (control)	6.5 ± 1.4^{b}	10.9 ± 1.4^{c}
Whiteness value	65.4 ± 1.2^{a}	59.1 ± 0.4^{b}	57.2 ± 1.0^{c}
Redness Index	0.06 ± 0.005^{a}	0.18 ± 0.01^{b}	0.06 ± 0.004^{a}
Saturation Index	7.7 ± 0.4^{a}	10.3 ± 0.18^{b}	17.0 ± 0.7^{c}

Note(s): For all color attributes, mean values (n = 10) with different superscripts in a row differ significantly (p = 0.05)

Table 3. CIE L* a* b* values and color properties (mean ± S.D.) of white wheat flour (WWF), wholegrain wheat flour (WGF) and chickpea flour (CF)

1.86 (WGF) to 1.13 (at 40% level), indicating the red hue of WGF:CF blend has decreased. On the other hand, the yellowness hue (b* value) of these blends increased from 10.1 (WGF) to 14.1 at 40% level of CF replacement. The increased b* values of WGF with the addition of CF could be attributed to the higher concentrations of β-carotenes, lutein, xanthophylls and zeaxanthin pigments in *desi* chickpeas (*Cicer arietinum* L.) as reported by Ashokkumar *et al.* (2015a, b).

Based on the L*, a*, b* values, whiteness, RI, SI and color difference values were calculated for all the flour blends ($n = 60$) made with WWF and WGF (0 to 40% replacement level with CF) and the results are presented in Figure 1. Compared with control (WWF with no CF), the total color difference (ΔE) increased significantly as the level of CF replacement increased from 10 to 40%, but, with no significant ΔE in case WGF-CF blends. This could be explained on the basis of higher bran constituents already present in WGF showing some masking effects. Similarly, the whiteness values for WWF showed a significant reduction with higher level of CF replacement, meaning the color becoming darker. The reduction in whiteness value of WWF:CF blends may be explained due to the carotenoid pigments being contributed by the CF component added to this blend (Ashokkumar *et al.*, 2015a, b).

The WGF-CF flour blends showed insignificant difference in whiteness values, as the WGF already has a brown color due to the presence of higher amounts of bran particles. In case of WWF-CF blends, no significant increase in the RI was observed. However, in case of WGF-CF blends, the RI decreased significantly as the level of CF increased from 0 to 40%. This may be explained due to the dilution of bran content with the increased levels of CF, as the wheat bran has been shown to be responsible for the higher RI of WGF (Ponzio *et al.*, 2013). The purity (indicated by SI) of color for the WWF-CF as well as WGF-CF flour blends increased significantly as the level of CF increased from 0 to 40%. It can be concluded that the addition of CF to both the WWF and WGF blends significantly affected the various color properties. As it was expected to affect the crumb color of Arabic as well as pan breads produced from such blends, it may affect the consumer acceptability of these baked products. Clearly, the tristimulus system can effectively be utilized in evaluating the color of these flour blends and the baked products prepared therefrom.

The crumb color and crumb grain of pan bread samples for the WGF:CF blends and WWF:CF blends are presented pictorially in Figures 2 and 3, respectively. The CIE L* a* b* color values (Mean ± S.D.) for crust and crumb of control as well as WGF:CF and WWF:CF pan breads have been presented in Supplementary Tables 3A and 3B, respectively. As can be seen from the data in these Supplementary Tables, the crumb and crust CIE L*, a* b* color values were significantly darkened as the replacement level of WWF or WGF with CF was

Table 4.
CIE L* a* b* values and color properties (mean ± S.D.) of white wheat flour (WWF), and wholegrain wheat flour (WGF) as affected by the addition of varying levels of Chickpea Flour (CF)

Type of wheat flour	CF level, %	L* value	A* value	B* value
WWF	0	66.3 ± 1.2^{a}	0.44 ± 0.1^{a}	7.6 ± 0.4^{a}
	10	65.5 ± 0.6^{a}	0.55 ± 0.1^{b}	9.3 ± 0.2^{b}
	20	63.1 ± 0.9^{b}	0.63 ± 0.1^{bc}	10.2 ± 0.3^{c}
	30	60.6 ± 0.9^{c}	0.59 ± 0.1^{cd}	10.9 ± 0.2^{d}
	40	60.9 ± 0.5^{c}	0.69 ± 0.02^{d}	13.9 ± 0.3^{e}
WGF	0	60.4 ± 0.4^{a}	1.85 ± 0.1^{a}	10.1 ± 0.2^{a}
	10	58.6 ± 0.2^{b}	1.52 ± 0.1^{b}	9.9 ± 0.3^{a}
	20	58.7 ± 0.8^{b}	1.40 ± 0.2^{b}	10.5 ± 0.3^{b}
	30	60.9 ± 0.4^{a}	1.14 ± 0.1^{c}	11.7 ± 0.4^{c}
	40	59.4 ± 0.3^{c}	1.13 ± 0.1^{c}	14.1 ± 0.4^{d}

Note(s): For WWF and WGF based samples, mean values ($n = 10$) with different superscripts in a column differ significantly ($p = 0.05$)

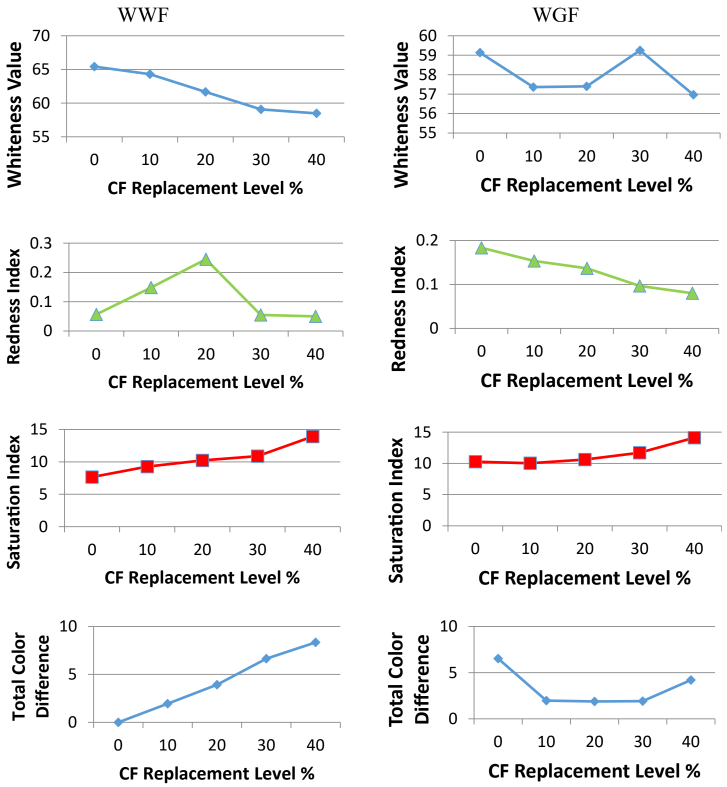

Figure 1.
Effect of adding CF to white wheat flour (WWF) and wholegrain wheat flour (WGF) on the color properties of flour blends

Key: A = WGF control (100:0), B = WGF:CF 80:20, C = WGF:CF 70:30, D = WGF: CF 60:40

Figure 2.
Crumb color and crumb grain of wholegrain wheat flour (WGF): chickpea flour (CF) breads

increased to 40% level. In case of WWF bread control (80.58 ± 0.29), the bread crumb color (L* lightness value) became significantly darker (75.78 ± 0.38) as the CF addition was increased from zero to 40% level. As the addition of CF to WWF increased to 40% level, the crumb became slightly red, i.e. higher a* value (5.22 ± 0.23), but the yellowness (b* value) increased significantly (40.29 ± 0.74). Compared with WWF, the WGF breads did not show significantly darkening in crumb color (L* lightness values; a*, redness value; b*, yellowness value), when the CF replacement level was increased from zero (control) to 40%, but became slightly lighter in crumb color (67.49) than the control with no CF (64.22) mainly due to the dilution of bran particles, though still much darker than the bread made from WWF:CF blends. On the other hand, WGF already being much darker in color due to bran particles, the replacement with CF did not have significant darkening effect on the crust color among these bread samples.

The importance of color, texture and flavor in relation to sensory quality that determines the overall acceptability of food products has been highlighted by many workers (Granato & Masson, 2010; Spence, 2019). Next to flavor, color and texture of baked products is of utmost importance affecting the sensory quality of these products. As reported by Zafar *et al.* (2020a, b), the flavor of pan as well as Arabic breads made from chickpea-wheat flour blends was found to be much stronger than those of control samples made from wheat flour alone. Interestingly, the objective color and instrumental texture values did not affect the overall acceptability sensory scores of these breads to any significant degree. Addition of *amla* (Indian gooseberry) powder improved the color and flavor of bread samples, thus making these samples more acceptable. All the samples of breads were found to be acceptable to the panelists, even up to 40% level of replacement of wheat flour with CF.

Texture profile analysis

The WWF, WGF and their blends were made into dough using Farinograph water absorption and the results of TPA are presented in Tables 5 and 6, respectively. The hardness values differed significantly when WWF was replaced with different levels of CF (Table 5). The decreased hardness value may be due to the dilution of wheat gluten by the CF proteins

Key: A = WWF control (100:0), B = WWF:CF 80:20, C = WWF:CF 70:30, D = WWF: CF 60:40

Figure 3. Crumb color and crumb grain of white wheat flour (WWF): chickpea flour (CF) breads

Table 5. TPA analysis values of dough made from white wheat flour (WWF), and WWF: CF blends

Sample description	Hardness N force	Compressibility/ Spreadability, N-mm, area F-D 1:2	Adhesiveness, N-mm, area F-D 2:3	Area F-D 3:4 N.mm	Cohesiveness
WWF:CF 100:0	2.2 ± 0.05[a]	37.55 ± 1.2[a]	−24.75 ± 0.43[a]	31.77 ± 0.76[a]	−11.27 ± 0.42[a]
WWF:CF 90:10	1.53 ± 0.03[b]	27.37 ± 0.44[b]	−18.38 ± 0.37[b]	23.13 ± 0.3[b]	−11.99 ± 0.22[ab]
WWF:CF 80:20	1.69 ± 0.6[b]	29.07 ± 0.44[b]	−22.13 ± 0.14[c]	24.99 ± 1.22[c]	−13.14 ± 0.22[bc]
WWF:CF 70:30	1.53 ± 0.02[b]	26.86 ± 0.54[b]	−21.59 ± 0.86[c]	23.59 ± 0.29[b]	−14.15 ± 0.46[c]
WWF:CF 60:40	1.40 ± 0.22[c]	17.53 ± 2.85[c]	−16.69 ± 0.18[d]	17.72 ± 026[d]	−12.81 ± 2.3[abc]

Note(s): Mean values (n = 3) for WWF and blends with different superscripts in a column differ significantly at p = 0.05

which had weakened the wheat gluten network during the dough mixing. Compared with control WWF, lower values for the adhesiveness of dough were observed when the CF replacement levels were increased from 0 to 40%. A few of the typical TPA graphs have been shown in supplementary figures 3A and 3B. The wheat gluten proteins are reported to have excellent adhesiveness properties as these make films stretching over the starch granules to produce dough suitable for making excellent quality bread (Mohammed, Ahmed, & Senge, 2012). According to their results, the adhesiveness property of wheat gluten was gradually weakened when the level of CF in their blends was increased from 0 to 30%.

The cohesiveness values for WGF and their blends with CF did not show a definite trend and differed only insignificantly. Similar trends were observed in the hardness and compressibility values for WGF and their blends (Table 6), as it was observed in the WWF and CF blends. The adhesiveness and cohesiveness values for WGF and CF blends did not show any significant differences with the increased levels of CF replacements. This can be explained again by the findings of Mohammed *et al.* (2012), the wheat gluten proteins in WGF are already diluted by the bran particle and so further dilution by the addition of CF did not make any difference in adhesiveness values. When WWF and WGF controls were compared with each other, only the hardness and compressibility values differed significantly, but the adhesiveness and cohesiveness values showed nonsignificant differences.

Conclusions and recommendations

When the level of replacement of WWF, WGF with CF was increased from 0 to 40%, it significantly affected the chemical composition and total antioxidant capacity values. Addition of CF to wheat flour not only enhanced the protein content of blends but also increased the total antioxidant capacity. However TPA values obtained for WWF, WGF and their blends with CF showed significant variations in hardness and compressibility values. Thus, consuming diets rich in good quality proteins and antioxidants would be good strategy to decrease the harmful complications of type-2 diabetes.

Production of breads using wheat flour and CF blends would combine the benefits of both the extra proteins of plant origin and the health-promoting antioxidant compounds, in a most sustainable way. The development of functional foods (Arabic flat bread and pan bread) containing chickpea-wheat flour blends will greatly benefit the diabetic patients to control their blood sugar levels without the use of unnecessary medicines, but the technological challenges of retaining the bread making qualities of these wheat flour : CF blends must be addressed properly. To overcome the deleterious effects of adding CF to WWF and WGF on these rheological properties will be an interesting challenge for the future studies.

Sample description	Hardness N force	Compressibility/ Spreadability N-mm, area F-D 1:2	Adhesiveness, N-mm, area F-D 2:3	Area F-D 3:4 N.mm	Cohesiveness
WGF	1.62 ± 0.02^{a}	32.26 ± 0.05^{a}	$-21.98 \pm 2.42_{a}^{ab}$	26.04 ± 3.33^{a}	-13.62 ± 1.66^{a}
WGF:CF 90:10	1.58 ± 0.08^{a}	32.22 ± 3.05^{a}	-20.93 ± 5.12^{b}	29.27 ± 1.98^{a}	-13.2 ± 2.89^{ab}
WGF:CF 80:20	1.28 ± 0.03^{b}	25.46 ± 0.23^{b}	-20.16 ± 1.16^{ab}	22.90 ± 0.23^{b}	-15.77 ± 0.68^{bc}
WGF:CF 70:30	1.11 ± 0.03^{c}	21.48 ± 0.17^{c}	-18.97 ± 0.33^{a}	20.44 ± 0.29^{b}	-17.02 ± 0.1^{c}
WGF:CF 60:40	1.40 ± 0.11^{d}	22.96 ± 0.35^{d}	-20.33 ± 0.14^{ab}	22.20 ± 0.16^{b}	-14.59 ± 1.13^{ab}

Note(s): Mean values (n = 3) for WGF and CF blends with different superscripts in a column differ significantly at p = 0.05

Table 6. TPA analysis values of dough made from wholegrain wheat flour (WGF) and WGF: CF blends

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Appendix

The supplementary material for this article can be found online.

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