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Black cumin-fortified flat bread: formulation, processing, and quality

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RESEARCH ARTICLE

Abstract

Black cumin (BC) (*Nigella sativa*) defatted meal was added at 5, 10, and 15% to whole wheat flour (WWF) in flat bread formulation so that to deliver daily intake of zinc, potassium, phosphorous, iron, and copper as well as high protein content. BC is known for its anticancer activities, immune stimulation, anti-inflammation, anti-hypertensive, anti-microbial, anti-parasitic, antioxidant and hypoglycemic. Although the water holding capacity of BC was twice as much as WWF, BC has minimal effect on the water absorption of WWF. The farinograph mixing tolerance index of the WWF dough has increased up to 133%, whereas dough stability has decreased by 41%. The extensibility of the control dough was not significantly ($P \leq 0.05$) affected by BC, but the resistance to extension was reduced. The higher amylograph gelatinisation temperature indicates delay on starch granule swelling, but the peak viscosity dropped as a function of BC content, while the final viscosity was unchanged. By consuming one piece of this bread, one can receive the USA Food and Drug Administration recommended daily allowance of phosphorous, iron, copper, zinc, and potassium in addition to other therapeutic benefits of BC.

Keywords: black cumin, bread, farinograph, extensograph

1. Introduction

The seed of *Nigella sativa* have been used for many years to protect against disease and promote health in the Middle East where it is called Alhabatu Alswada. In South Asia it is known as Kalonji, and in English as black cumin. The plant is cultivated in a wide range of environments all over the world. This seed has been the focus of research for centuries for its chemical constituents as well as several traditional applications.

Investigators have reported the composition of black cumin (black seed) as 3.8-7.0% moisture, 22.0-40.35% oil, 20.85-31.2% proteins, 3.7-4.7% ash, and 24.9-40.0% total carbohydrates (Atta, 2003; Takruri and Dameh, 1998). Minerals such as iron, calcium, and phosphorus were reported to be in significant amounts, while copper, calcium, magnesium, manganese and zinc in small amounts (Abu Jadayil *et al.* 1999; Ali and Blunden, 2003; Haq *et al.* 1996; Khan, 1999; Nergiz and Ötles, 1993). The quantities of iron, copper, sodium, potassium, calcium, zinc, phosphorous and magnesium lie in the range of 9.1-15.40, 1.5-3.75, 41.2-55.0, 442.3-675.0, 154.4-305.0, 3.36-6.6, 378.12-576.9 and 134.92-147.05 mg/100 g of black cumin whole meal, respectively (Ashraf *et al.* 2006; Cheikh-Rouhou *et al.* 2008). Similarly, Takruri and Dameh (1998) reported the quantities of iron, copper, sodium, potassium, calcium, zinc and phosphorous to be 105, 18.4, 496.0, 5257, 1859, 60.4 and 5265 mg/kg, respectively.

N. sativa flour can increase the nutritional value of wheat flour by adding more fibre, minerals, lysine, and antioxidants. The ratio of the seed flour to wheat flour may influence dough rheological properties and consequently consumer acceptance for the final baked product. In addition, the presence of components with extreme water-holding capacity can negatively affect farinograph value of wheat flour, such as water absorption, dough mixing, rheological properties and bread quality, such as loaf volume, crumb texture and colour (Holas and Tipples, 1978; Jelaca and Hylnka, 1971; Kim and D'Appolonia, 1977; McCleary, 1986; Michmiewicz *et al.*, 1990; Shelton and D'Appolonia, 1985).

The Food and Nutrition Board of the Institute of Medicine (IOM, 2004) established the minimum required potassium intake levels sufficient for lowering blood pressure, reduce salt sensitivity, and limits the risk of kidney stones. These average levels were 4,200 mg/day and 5,100 mg/day for breast-feeding mothers (IOM, 2004). The objectives of this work were to develop yeast-fermentable bread formulations with high levels of black cumin content without compromising bread quality characteristics. This product is expected to assist consumers in meeting their daily recommended intake of, zinc, phosphorus, iron, copper, and potassium and other health benefits by consuming bread.

2. Materials and methods

Materials

Hard wheat grown in Saudi Arabia was donated by the Saudi Grain Silos and Flour Mill Association. The grains were milled and used as whole wheat flour (WWF). Active dry instant yeast (DSM, Heerlen, the Netherlands) was purchased from a local supermarket. Bread improver containing ascorbic acid, α-amylase was donated by Bakemate (Bakemate, Factory for Bread and pastry Mixes, Riyadh, Saudi Arabia). Shortening was purchased from local supermarket (Goody, Knoxville, TN, USA). Locally grown black cumin (BC) seeds were purchased from a local market. Seeds were ground to pass through 60 mesh and defatted using n-hexane in a Soxhlet apparatus. The defatted BC was added as replacement of WWF at 5, 10, and 15% based on the flour.

Water holding capacity

Water holding capacity (WHC) of wheat flour/blends was done according to Traynham *et al.* (2007) with minor modifications. Whole wheat flour or blends (1.5 gram) were placed in a centrifuge tube and 28.5 ml of distilled water was added. Samples were shaken for 10 min, allowed to rest for 1 h, and centrifuged at 4,500 rpm for 30 min. The supernatant was decanted and tubes were weighed. The WHC (g of water/g flour) was calculated as follows:

WHC = ((weight of tube after decanting – weight of dry tube) – total flour weight) / total flour weight

Dough properties

Physical dough properties for the control and the blends were determined using the following methods: farinograph AACCI method no. 54.21, extensograph AACCI method no. 54.10, and amylograph AACCI method no. 22.10 (American Association of Cereal Chemists International (2000), Approved Methods, St. Paul, MN, USA).

Flat-bread baking

Flat-bread formulation was prepared by mixing a total of 700 g of flour, defatted BC, and other ingredients as shown in Table 1. Dough was fermented for 30 min at 35 °C and 55% relative humidity followed by proofing for 20 min, molding, and placed in pans (22×6×7 cm). The dough was let to proof for another 30 min followed by baking at 220 °C for 20 min in a rotary oven (National Manufacturing Company, Lincoln, NE, USA). Bread was allowed to cool on racks and sensory evaluated.

Bread chemical analysis

Bread samples were analysed for crude fibre, crude fat, crude proteins, and moisture according to AACCI Approved methods No. 46-12, 50-20, 35-15, 08-01, 44-15, and 54-21, respectively (AACCI, 2000).

Taste panel evaluation

The multiple comparison test was conducted (Larmond, 1977) to compare bread with and without BC by using a number of criteria used for flat bread. These included desired colour, flavour, chewiness, uniformity, and complete separation of upper and lower crust, as well as overall acceptability. Whole wheat bread was used as a control. Each panellist was given a tray with a control and the three samples and was asked to compare based on the characteristics mentioned above. The sample rating was given 1 to 9 score, where no difference from the control was given 5, superior to control = 9, inferior to control = 1. Analysis of variance was done and Duncan's multiple range tests was used to identify significant difference at $P \leq 0.05$ using SAS (PASW® Statistics 18; Quarry Bay, Hong Kong).

Table 1. Flat bread recipe.

Ingredients[1]	Parts	Weight (g)
Flour	100.0	700.0
Sugar	5.0	35.0
Yeast	3.0	21.0
Salt	2.0	14.0
non-fat dry milk	3.0	21.0
Shortening	3.0	21.0
Water[2]	73.6	515.0
Bread improver	0.03	0.21

[1] Flour or flour blends.
[2] Water was adjusted to 500 Brabender units on the farinograph.

3. Results and discussion

Reports in the literature indicated that defatted BC flour contains 43% protein, 1% oil, and 40% carbohydrates, where the same components for BC protein isolate were 86.9%, 0.04%, and 7.36%, respectively (Osman and Al-Jasser, 2004). The WHC of the 100% whole wheat flour, 5% BC blend, 10% BC blend, and 15% BC blend showed 1.024, 0.942, 0.976, and 1.010 g water/g flour or blend, respectively, whereas 100 BC exhibited 1.890 g water/g BC. Although WHC of the 100% BC was 85% higher than the 100% WWF, the presence of BC has minimal effect on WHC of the blends as shown above. In fact, BC reduced WHC of the WWF by 8.2, 4.6, and 1.4% for the 5, 10, and 15% BC blends, respectively. It appears that WWF has faster water absorption rate than BC which resulted in minimum effect of BC on the WHC of the WWF. This phenomenon is obvious in the farinograph data as well.

In general, seeds contain appreciable amount of fibre plus other components. Fibre has negative effect on wheat gluten functionality for two reasons; due to its high water holding capacity which leaves less free water for gluten to develop, in addition to lack of viscoelasticity. Dough development requires mixing flour with appropriate amount of water and specific mixing time, which is the most critical step of dough formation. The significance of dough mixing step is obvious in the formation of disulphide bonds between gluten (wheat proteins) fractions. This leads to gluten film formation which is necessary for holding dough components together, thus develops to a viscoelastic mass. Farinograph was used to determine the effect of defatted black cumin flour on the water absorption of the control flour and the mechanical properties of the formed dough.

The presence of BC decreased the farinograph water absorption of the control by 0.6% (Table 2). Usually, the addition of high fibre content ingredient to wheat flour is known to increase water absorption (Mohamed *et al.*, 2005, 2010) because of competition for water between flour and fibre. The drop in water absorption due to BC could be due to low hydration rate of BC relative to WWF. These findings agree with Karaoğlu (2006) who reported drop in water absorption with the addition of *Cephalaria* flour. Although the high water holding capacity of BC should have increased the water absorption of the blends, but the opposite was noted. This could be attributed to the slow hydration rate of BC flour compared to WWF.

The dough mixing tolerance index (MTI) is the difference in Brabender units (BU) between the top of the Farinograph-profile peak and 5 min later, where larger differences indicate a more negative effect of BC on increasing the control. MTI of WWF had increased in the presence of BC, where MTI of the 5, 10, and 15% BC had increased MTI by 66, 100, and 133% (Table 2). Dough stability is the difference in min between the time when the top of the curve arrives at the 500 BU and the time where it departs. Generally, addition of BC flour reduced the dough stability time compared with the control, which is consistent with the finding of El-Dawy (1997), who reported lower stability time with the addition of sesame products to wheat flour. The reduction in stability was also confirmed by an increase in MTI as mentioned above. Dough stability was reduced as a function of BC content added to blends, where 5, 10, and 15% BC reduced the dough stability by 7, 19, and 41%. The influence of BC on MTI and dough stability is due to their ability to weaken the gluten network needed for dough formation.

The extensograph is designed to measure the balance between viscous and elastic characteristics of wheat flour dough, where the curve gives a measure of the resistance to extension and the extensibility of the dough. The height of the resulting curve from stretching the dough is associated with dough's resistance-to-extension. Extensibility is the total length of the curve at the base line in centimetres which reflects the extent to which dough was stretched. Dough resistance is measured at the maximum curve height in BU and reflects the maximum force applied and indicates dough resistance to extension. In general, for good bread dough a balance of these two factors is desired. The procedure calls for stretching the dough after three resting times 45, 90 and 135 min. Extensograph test can also

Table 2. Farinographic parameters of defatted black cumin fortified wheat flours.

BC level	WA (%)	PT (min)	AT (min)	DT (min)	DST (min)	TI (BU)
Whole wheat flour	73.6	5.5	3.0	16.5	13.5	30.0
5%	73.0	6.0	3.5	16.0	12.5	50.0
10%	73.0	6.0	3.5	14.0	11.0	60.0
15%	73.0	6.5	4.0	13.0	9.0	70.0

BC = defatted black cumin seed flour; WA (%) = water absorption; PT (min) = peak time; AT (min) = arrival time; DT (min) = departure time; DST (min) = dough stability time; TI (BU) = tolerance index; BU= Brabender units.

evaluate the effects of baking ingredients and fermentation time on dough viscoelasticity. The addition of dietary fibre was observed to either negatively or positively influence wheat flour dough performance. Fibre is much less elastic than gluten, but in some cases where the molecular weight of the fibre is high, it might allow for better interaction with gluten-starch complex which could improve dough properties. The addition of water-insoluble fibre was proven to decrease dough extensibility (Kulp and Bechtel, 1963). Conversely, water-soluble fibre increased both extensibility and resistance to extension similar to the action of dough improvers (Bloksma, 1971). The effects of BC on the extensograph characteristics of WWF are shown in Table 3. The extensibility of the WWF dough was not significantly ($P≤0.05$) affected by BC at all three different testing times except for the 15% BC at 90 and the 10 and 15% BC at 135 min, where significantly lower ($P≤0.05$) extensibility was noted. These results were confirmed by Özer *et al.* (2010) and Miś *et al.* (2012). The resistance to extension was reduced as well by BC addition, but the ratio of resistance at 5 cm and extensibility (R_{5cm}/E_t) has dropped as a function of BC level and dough resting time (Table 3).

The amylograph primarily measures starch gelatinisation and pasting properties. It can give indications on the mechanism of starch gelatinisation such as swelling and amylose leaching steps. The amylograph data of the WWF and the blends indicated a much higher gelatinisation temperature in the presence of BC without any change in the temperature at maximum viscosity (Table 4). The maximum viscosity for the control and the 5, 10, and 15% BC exhibited 180, 160, 140, and 120 BU, respectively. The higher gelatinisation temperature indicates the delay in starch granule swelling which possibly due to BC covering starch granules and postpones hydration or granule to granule interaction. Since WWF was replaced with BC that means BC replaced starch which is the main component responsible for the amylograph viscosity. One can calculate the drop in viscosity according to the replaced amount of starch with the assumption that BC does not take part in the viscosity of the system. Based on these results, the drop in the peak viscosity for the 5% could be calculated by subtracting 5% of the final viscosity as a predicted viscosity for the blend. For instance, the 5% replacement should have been 171 BU rather than 160 BU (180 – (5/100 × 180)) (Table 4). The 10 and 15% replacements exhibited similar trend.

The protein content, crude fat, ash, and crude fibre of the control bread were significantly lower than the blend, where blends with higher BC exhibited higher levels of these components (Table 5). Obviously, the nitrogen free extract decreased as a function of higher BC content. In general, the effect of 5% BC on the bread composition was not as noticeable as the other two BC levels. All the sensory properties presented in Table 6 are significantly affected ($P≤0.05$) by increasing the level of black cumin powder. The crust and crumb colour of the control and even at 5% level of BC powder has decreased from 8.56±0.88 to 6.33±1.00 and 8.78±0.67 to 5.67±1.00, respectively. This can be attributed to the dark colour of the BC powder. The overall acceptability of the bread was significantly lower than the control, where the 10 and 15% BC showed similar acceptability values, while the 5% was closer to the control (Table 6). Based on the recommended daily intake by the USA Food and Drug Administration, consuming at least one piece of this product (700 g) a day will meet the

Table 3. Extensographic parameters of defatted black cumin fortified wheat flours.[1]

Dough resting time	BC level	E_T (mm)	E_M (mm)	R_M (BU)	R_{5cm} (BU)	Ratio no.
45 min	0%	137.67±11.68^a	81.67±2.87^b	410.00±10.00^a	386.67±5.77^a	2.82±0.26^a
	5%	132.67±4.62^a	88.33±2.87^a	403.33±5.77^a	380.00±10.00^a	2.87±0.17^a
	10%	130.00±0.00^a	76.67±2.87^b	376.67±5.77^b	360.00±10.00^b	2.77±0.80^a
	15%	127.33±8.33^a	75.00±5.00^b	376.67±5.77^b	363.33±5.77^b	2.86±0.18^a
90 min	0%	134.33±7.23^a	91.67±2.89^a	533.33±23.09^{ab}	486.67±11.55^a	3.63±0.18^b
	5%	123.33±2.89^a	86.67±2.89^{ab}	546.67±5.77^a	500.00±0.00^a	4.06±0.09^b
	10%	121.33±11.72^a	81.67±5.77^b	536.67±15.28^{ab}	496.67±5.77^a	4.12±0.36^b
	15%	104.67±7.51^b	61.67±5.77^c	506.67±20.82^b	500.00±17.32^a	4.79±0.36^a
135 min	0%	128.67±3.51^a	86.67±2.87^a	645.00±30.41^a	586.67±11.55^a	4.55±0.22^a
	5%	125.33±4.51^a	86.67±2.88^a	683.33±47.28^a	606.67±41.63^a	4.85±0.50^a
	10%	103.33±4.73^b	70.00±0.00^b	653.33±30.55^a	606.67±23.09^a	5.87±0.07^b
	15%	90.00±6.00^c	49.33±1.15^c	543.33±5.77^b	526.67±11.55^b	5.86±0.51^b

[1] Mean values within the same column per dough resting time followed by the same superscript letters are not significantly different.
DBC level = defatted black cumin seed powder level; E_T (mm) = total extensibility; E_M (mm) = extensibility at maximum resistance; R_M (BU) = maximum resistance; R_{5cm} (BU) = resistance at 5 cm of extension; BU = Brabender units; Ratio no. = R_{5cm}/E_T.

Table 4. Amylographic parameters of defatted black cumin (BC) fortified wheat flours.

BC level	Temperature at start of gelatinisation (°C)	Temperature at max. viscosity (°C)	Max. viscosity (BU)
Whole wheat flour	59.5	85.0	180.0
5%	65.6	86.5	160.0
10%	73.0	86.5	140.0
15%	74.0	86.5	120.0

BU = Brabender units.

daily recommended intake of phosphorous, iron, copper, zinc, and potassium.

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Conflict of interest

The authors declare that they have no conflict of interest

Table 5. Chemical composition of defatted black cumin (BC) fortified flat bread.[1]

BC level	Crude protein	Crude fat	Ash	Crude fibre	Nitrogen free extract
Whole wheat flour	15.10±0.21^{d}	5.27±0.10d	3.75±0.10c	2.65±0.06c	73.27±0.10a
5%	15.60±0.01^{c}	5.49±0.02^{c}	3.87±0.01^{c}	2.32±0.27^{c}	73.28±1.03^{a}
10%	16.94±0.11^{b}	5.70±0.01^{b}	4.11±0.06^{b}	3.41±0.01^{b}	69.81±0.10^{b}
15%	17.73±0.03^{a}	6.06±0.09^{a}	4.26±0.00^{a}	4.86±0.08^{a}	66.82±0.10^{c}

[1] Mean values within a column followed by different superscript letters are significantly different.

Table 6. Sensory parameters of defatted black cumin (BC) fortified flat breads.[1]

BC level	Crust colour	Symmetry	Break and shred	Crumb colour	Grain and texture	Overall quality
Whole wheat flour	8.56±0.88^{a}	8.56±1.00^{a}	8.78±0.66^{a}	8.78±0.67^{a}	8.33±1.14^{a}	8.78±0.67^{a}
5%	6.33±1.00^{b}	6.78±1.20^{b}	7.00±1.00^{b}	5.67±1.00^{b}	6.67±1.41^{b}	6.22±1.2^{b}
10%	4.78±0.97^{c}	4.78±0.97^{c}	5.11±1.16^{c}	4.67±1.32^{c}	5.33±1.32^{c}	4.67±1.00^{c}
15%	4.22±0.44^{c}	4.22±0.33^{c}	4.11±0.33^{c}	4.22±0.44^{c}	4.67±1.65^{c}	4.22±0.44^{c}

[1] Mean values within a column followed by different superscript letters are significantly different.

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