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Traditional flatbread with sorghum supplementation influences quality attributes of weight, volume, colour and texture

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RESEARCH ARTICLE

Abstract

Trials were carried out to assess the effect of white sorghum (WS) and red sorghum (RS) supplementation on the physical attributes of traditional wheat flour (WF) flat bread. Flat breads were prepared with varying amounts of refined WF and (30, 40 and 50% of) commercial wholegrain WS or RS flours and measurements were taken of the physical attributes (weight, volume, colour and texture) of the resulting combinations. Addition of WS and RS flour reduced the weight of the flat bread by 7.42 and 6.72%, respectively, and volume by 21.31 and 16.60%, respectively, compared with the 100% WF flat bread. The addition of WS flour resulted in a significantly harder (0.58%) flat bread compared with the 100% WF flatbread, with 'noticeable' and 'appreciable' ΔE*ab colour differences compared with the 100% WF flat bread. Adding RS flour resulted in comparable flat bread texture, however it produced a 'discernibly' ΔE*ab darker flat bread when compared to the 100% WF flat bread. This work indicates that supplementing WS and RS flour results in lower quality physical attributes in relation to the 100% WF flat bread.

Keywords: baking, colour, flatbread, flour, sorghum, texture, volume, weight, wheat

1. Introduction

Eastern style traditional 100% wheat flour (WF) flatbread is widely consumed as part of the human diet in many parts of the world. Flatbread is a carbohydrate based food product, which supplies large amounts of energy and in combination with other refined carbohydrate foods can contribute to the current obesity epidemic in western society (Deitel, 2006).

Sorghum is a cereal grain with desirable functional food attributes, such as slow digestible starch and polyphenol antioxidants (Awika and Rooney, 2004; Dykes and Rooney, 2006; Rooney and Awika, 2005). The nutritional advantage of sorghum is elucidated by Yousif *et al.* (2012) who observed that flatbread that incorporated 40% whole grain sorghum exhibited a reduced level of rapidly digestible starch and an increase in the total phenolic content and antioxidant capacity. Sorghum is currently underutilised for human nutrition and is considered a 'poor man's cereal' (Anderson and Martin, 1949), mostly used as animal feed in developed countries (Ryley *et al.*, 2008). In order to improve the functional and nutritional quality of flatbread, and to add value to sorghum as a food grade cereal grain, there is potential to use sorghum flour in traditional flatbread formulations.

Around the world sorghum has been traditionally used in various food products such as porridge, unleavened bread, cookies, cakes, couscous and malted beverages (US Grains Council, 2010). However, the addition of sorghum flour to leavened foods, such as bread, has been reported to affect the colour, texture, weight and volume (Rooney and Waniska, 2000) of the final product. Changing the ingredients of a traditional staple, such as flatbread, may result in consumer rejection of the new value added product, due to changes in texture and colour. Furthermore the newly developed flatbread formulation may have negative implications from a food processing and production point of view.

The objective of this study is to better understand the physical quality changes of weight, volume, texture and colour that occur as a consequence of adding sorghum flour to WF for the production of eastern style traditional flatbread.

2. Materials and methods

Flatbread formulations and preparation

Flour samples

Commercial white sorghum (WS) and red sorghum (RS) (*Sorghum bicolour*) wholegrain flour produced in Australia were purchased from a retail store (JK International, Rocklea, Australia). WF used in this trial is commercial white bread flour 'maximus' brand provided by Weston Milling (Melbourne, Australia). All samples were stored in airtight, light proof and moisture proof packaging at room temperature (20 °C) for up to six months prior to use. The proximate analysis of the raw flour (mean g/100 g dry basis ± standard deviation (SD)) (Yousif *et al.*, 2012) is given in Table 1.

Flatbread formulation

The control formulation consisted of 700.0 g WF, 10.5 g salt and 7.0 g yeast (Tandaco dry yeast, Cerebos foods, Seven Hills, Australia). WS and RS flour was used to replace 30, 40 and 50% of the WF in the control formulation. Optimal water addition (weight for weight) for each formulation (control = 66%; 30% WS = 62.5%; 40% WS = 61.2%; 50% WS = 58.7%; 30% RS = 62.8%; 40% RS = 61.7%; 50% RS = 60.3%) was determined in duplicate using a Farinograph (American Association of Cereal Chemists International method 54-21.01; AACCI, 2010). Optimal water absorption (also called dough arrival time) is an arbitrary point of dough resistance (500 Brabender units) chosen to achieve a required dough consistency for optimal dough processing behaviour (Wheat Marketing Center, 2008). Each formulation was prepared in duplicate.

Flatbread preparation

Dough preparation followed the method of Morad *et al.* (1984). Flour, salt, yeast and water were mixed by hand to form dough. The dough was proofed for 75 minutes in an air conditioned room at 21 °C and a relative humidity of 45%, then divided into seven equal portions (control = 170.15 g; 30% WS = 166.56 g; 40% WS = 165.23 g; 50% WS = 162.67 g; 30% RS = 166.87 g; 40% RS = 165.74 g; 50% RS = 164.31 g). Each portion was manually shaped using a pin roller to a thickness of 3 mm and a diameter of 15-20 cm. The dough circles were immediately baked in a fan-forced oven (Combi-Steamer Oven VPE-102, 230 V electric model; Fagor Australia, Dee Why, Australia) at 300 °C at 'low' fan speed for 5.5 min. The flatbread was cooled on a rack to room temperature (20 °C) then placed in labelled plastic resealable bags and stored frozen at -18 °C.

Prior to physical testing, flatbread (in plastic resealable bags) was thawed for a period of 24 hours at 4 °C and then equilibrated to ambient room temperature of 20 °C for 4 hours.

Analytical procedures

Flatbread weight

Flatbread weight was measured with a conventional laboratory balance (model XS-310D; Denver Instrument Company, Bohemia, NY, USA). Three breads for each treatment were measured and results are reported as mean ± SD.

Flatbread volume

A seed displacement method (El-Soukkary, 2001) was used to assess flatbread volume (ml). A round, deep baking dish (204 mm internal diameter and 68 mm deep) was filled with rapeseed (*Brassica napus*). Excess rapeseed was removed via running a ruler twice at 90° angle along the rim of the baking dish. The baking dish was then emptied of rapeseed, the flatbread placed at the bottom of the baking dish and

Table 1. Analysis of the raw flour (mean g/100 g dry basis ± standard deviation).

	Wheat flour	White sorghum	Red sorghum
Protein (%)	13.56±0.61	11.61±0.12	9.47±0.20
Lipid (%)	1.72±0.03	1.69±0.37	1.58±0.38
Ash (%)	0.75±0.05	1.22±0.09	1.33±0.01
Total dietary fibre (%)	3.44±0.15	4.09±0.14	3.50±0.12
Available carbohydrates	81	81	84

the rapeseed placed on top of the bread filling the baking dish to capacity. Excess rapeseed was removed as above and weighed. The rapeseed weight was measured with a conventional laboratory balance (model XS-310D; Denver instrument company), three breads for each treatment were measured and the results are reported as mean ± SD.

Rapeseed weight was converted to flatbread volume via a canola weight/volume standard curve. Rapeseed was weighed at 25 ml volume intervals and a standard curve was created.

Flatbread texture

Flatbread texture analysis was conducted via a Stable Micro Systems (Godalming, UK), model TA-XT Plus, texture analyser with a probe (SMS P/36R) used to measure firmness in grams force. The texture analyser settings are given in Table 2. The texture (compression) measurement of each bread sample was repeated three times and the results are reported as mean ± SD.

Flatbread colour analysis

L* (degree of lightness: 100 = perfect white, 0 = black), a* (green (-) to red (+), gray when zero) and b* (blue (-) to yellow (+), gray when zero) was measured using a Konica Minolta CR series Chroma Meter 400, with a Cr-400 light projection tube (Konica Minolta Sensing Americas Inc., Ramsey, USA).

Colour difference index (ΔE^*ab) was also calculated as:

$\Delta E^*ab = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$ (Kato and Meguro, 1998).

Where ΔL = L* colour value difference; Δa = a* colour value difference; Δb = b* colour value difference.

According to Yamauchi (1989), the ΔE^*ab difference is an index for visual colour differences. ΔE^*ab is described in terms of related visual colour difference as follows:

- 0-0.5: trace difference;
- 0.5-1.5: slightly discernible, hard to detect with the human eye;
- 1.5-3.0: noticeable, detectable by trained people;
- 3.0-6.0: appreciable, detectable by ordinary people;
- 6.0-12.0: large; large difference in the same colour group;
- >12: extreme; another colour group.

The colour measurement was taken three times from triplicate bread samples for each bread preparation and the results are reported as mean ± SD.

Table 2. The texture analyser settings.

Test mode	compression
Pre-test speed	2 mm/sec
Test speed	1 mm/sec
Post-test speed	1 mm/sec
Target mode	distance
Distance	3 mm
Trigger type	auto
Trigger force	5 g

Statistical analysis

A one way analysis of variance with the Tukey post-hoc test was used to compare: (1) properties of WF, WS and RS; and (2) the effect of flatbread formulation weight, volume, texture and colour. The level of significance in this work is $P<0.05$ unless otherwise stated. Statistical analysis was carried out via SPSS (version 17.0 for Windows, patch 14.0.2; IBM Corporation, New York, NY, USA).

3. Results and discussion

Bread weight

Comparison between the control (100% WF flatbread) and the WS and RS containing (30, 40 or 50%) flatbread formulations showed a significant reduction in flatbread weight (Figure 1). Flatbread prepared from 100% WF was significantly heavier (145.08 g) than all other flatbread formulations. The addition of 30% WS and RS flour resulted in a significant reduction in flatbread weight of 5.27% and 4.34%, respectively, when compared to the weight of the 100% WF flatbread (Figure 1).

Data also indicated an inverse relationship between the addition of WS and RS flour and flatbread weight. As the amount of sorghum flour added increased, (30, 40 and 50%) flatbread weight decreased significantly by 5.1 and 4.9% for WS and RS, respectively (Figure 1). The addition of 50% WS and RS flour to the flatbread formulation resulted in the greatest decrease in weight by 10.1 and 9.0%, respectively, when compared with the 100% WF.

The inverse relationship between sorghum levels and flatbread weight is due to the functional characteristics of hydrophilic (protein, starch) and hydrophobic (fibre) levels in the flatbread formulations; with higher flatbread weight being an indication of higher dough water absorption. This is supported by flatbread farinograph physical analysis (Yousif *et al.*, 2012); confirming that the control flatbread (100% WF) formulation exhibited higher levels of water absorption in comparison to all WS and RS containing (30, 40 and 50%) flatbreads. This finding is further supported

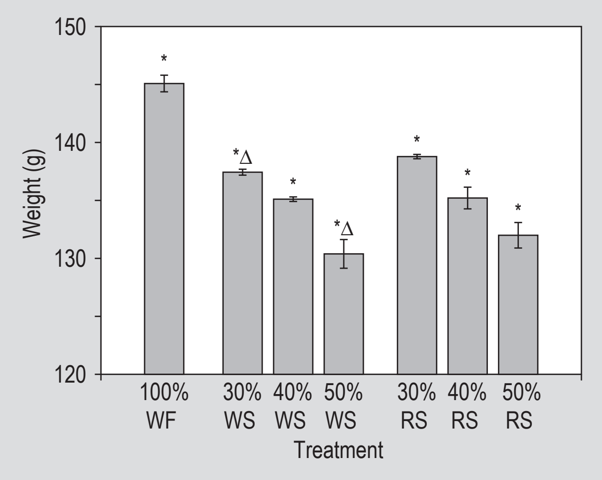

Figure 1. Effect of white (WS) and red sorghum (RS) flour addition (30, 40 and 50%) to 100% wheat flour (WF) on flatbread weight in grams. Bars indicate standard error of the mean (n=3). * = significant difference between 100% WF, WS and RS containing flatbread formulations; Δ = significant difference between WS flatbread formulations (30 and 50%).

by the work of Salim-Ur-Rehman *et al.* (2006) and Elkhalifa and El-Tinay (2002).

The ability of protein to bind and hold water is especially significant in baked products where it is important for the sensory acceptability of the food (Damodaran, 2008). In WF baked products, gluten can absorb and retain on average three times its weight in water (Carson and Edwards, 2009). This is supported by proximate analysis which has indicated that the WF contained a significantly higher level of protein compared with the WS and RS (Yousif *et al.*, 2012). As a consequence, the 100% WF flatbread exhibited significantly the highest level of protein content (15.30%) in comparison to WS and RS flatbread formulations: 30% (14.56 and 13.51%, respectively), 40% (14.26 and 13.39%, respectively), and 50% (14.15 and 12.92%, respectively) (Yousif *et al.*, 2012). This outcome indicated that higher sorghum addition results in lower flatbread protein content. In addition the major sorghum endosperm proteins (kafirins) are hydrophobic (Belton *et al.*, 2006). Therefore increased levels of WS and RS (30, 40 and 50%) in the flatbread formula results in a gradually reduced capacity for dough water absorption and retention (Yousif *et al.*, 2012).

Furthermore, Yousif *et al.* (2012) observed that in comparison to the control flatbread (100% WF) total dietary fibre content increased significantly with increased addition of WS and RS flour to the flatbread formulations: 30% (7.62 and 9.06%, respectively), 40% (10.81 and 16.37%, respectively), and 50% (11.53 and 22.04%, respectively). Due to the high level of the insoluble component of sorghum dietary fibre, which is hydrophobic in nature (Licata *et al.*, 2014); high sorghum flour presence in the flatbread formula is expected to reduce water absorption and retention ultimately resulting in the reduction of the flatbread weight (Figure 1).

Flatbread volume

Flatbread 100% WF volume was significantly higher (250.6 ml) in comparison to the WS and RS containing formulations. With increased WS and RS flour levels (30, 40 and 50%) a consistent reduction in flatbread volume was observed resulting in a significant average reduction of 21.6 and 11.2%, respectively (Figure 2). This is indicative of an inverse relationship between WS and RS levels and flatbread volume. The addition of 30% WS and RS to the 100% WF flatbread resulted in a significant reduction in flatbread volume of 12.84 and 10.52%, respectively.

Furthermore, 30% WS addition exhibited a significant reduction in flatbread volume in comparison to the 40 and 50% WS flour addition, a reduction of 7.58 and 21.58%, respectively.

A further significant reduction of 10.81% in flatbread volume was observed between 30 and 50% RS flour addition. The WS 50% flatbread also exhibited a significantly greater reduction in volume of 13.94%, in comparison to RS 50% flatbread. Comparison between the WF (100%) and the 50% WS and RS flour flatbread exhibited a 31.65 and 20.58%, respectively, reduction in flatbread volume.

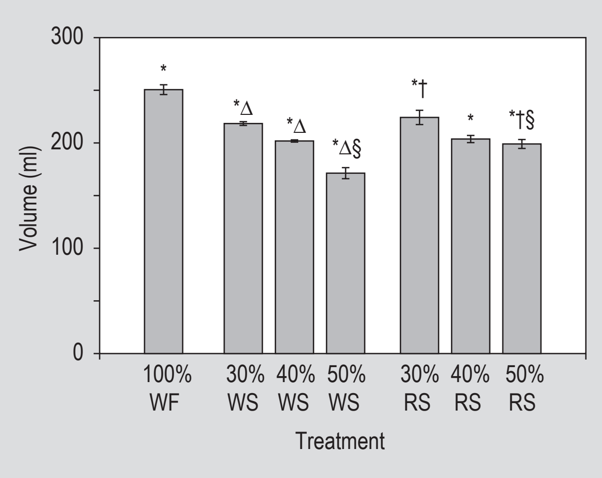

Figure 2. Effect of white (WS) and red sorghum (RS) flour addition (30, 40 and 50%) to 100% wheat flour (WF) on flatbread volume. Bars indicate standard error of the mean (n=3). * = significant difference between 100% WF, WS and RS containing flatbread formulations (30, 40 and 50%); Δ = significant difference between WS flatbread formulations (30, 40 and 50%); † = significant difference between RS flatbread formulations (30 and 50%); § = significant difference between WS and RS flatbread formulations at 50%.

The reduction of bread volume is due to the fact that sorghum flour is devoid of gluten (Liu, 2009; Suhendro *et al.*, 2000). Gluten is a protein present in wheat dough which forms a network that entraps gases such as carbon dioxide produced by yeast fermentation and steam during baking (Kent and Evers, 1994). Furthermore, gluten reduction has been found to reduce dough development time (Sroan *et al.*, 2009) and dough stability (Sugden and Osborne, 2001) due to the disruption of the continuous gluten network and reduced dough viscoelastic resistance. This is supported by farinograph physical analysis, which indicated the WF (100%) flatbread formula dough development time and stability decreased (Elkhalifa and El-Tinay, 2002; Yousif *et al.*, 2012) with increased sorghum addition.

It is therefore acceptable to conclude that increased sorghum flour levels, reduced gluten in the flatbread dough, disruption of the protein network and related reduction of dough stability, results in reduction of the amount of trapped gases and produces a consistent loss of flatbread volume (Figure 2).

Flatbread texture analysis

Flatbread objective texture analysis indicated that compared with the 100% WF flatbread, the addition of WS flour (30 and 50%) significantly increased the textural strength (resistance to force compression). Whereas addition of RS flour resulted in comparable flatbread textural strength in comparison to the 100% WF flatbread (Figure 3), with the level of RS flour (30, 40 and 50%) addition to the flatbread formula not exhibiting an effect on the objective texture measurement (Figure 3).

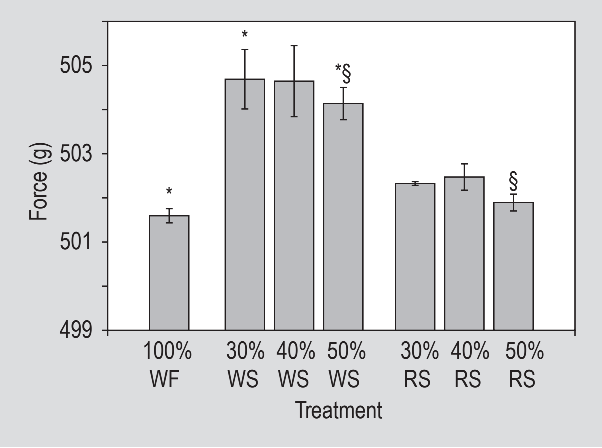

Figure 3. Change of flatbread objective texture in relation to the addition of white (WS) and red sorghum (RS) flour (30, 40 and 50%) to 100% wheat flour (WF). Bars indicate standard error of the mean (n=9). * = significant difference between 100% WF, WS and RS containing flatbread formulations (30, 40 and 50%); § = significant difference between WS and RS flatbread formulations at 50%.

Addition of WS flour resulted in significantly higher texture measurements compared with the addition of RS flour, with the 50% WS flatbread exhibiting a significantly higher textural strength than the 50% RS (an increase of 0.45%) (Figure 3). Higher textural strength of WS flatbread in comparison to the RS flatbread may be related to the lower volume of the WS flatbread in comparison to the RS flatbread (Figure 2). Bearing in mind that in this trial compression was used as a measure of texture, therefore we may surmise that a lower flatbread volume is indicative of higher density which is expected to equate to a higher textural strength (Figure 3).

Increased flatbread objective textural strength is reflected in reduced subjective hedonic sensory acceptability, as observed by the work of Yousif *et al.* (2012) who reported that sorghum addition reduced flatbread consumer acceptability.

Flatbread colour

Flatbread L* colour value

Addition of RS flour (30, 40 and 50%), resulted in a significant reduction in the flatbread L* colour value compared with the 100% WF and the WS (30, 40 and 50%) flatbread formulations (Figure 4). Flatbread L* colour value decreased significantly with increased RS addition resulting in an inverse relationship between RS flour level (30, 40 and 50%) and the flatbread L* colour value. Comparison between the 100% WF flatbread and the 30% RS flatbread

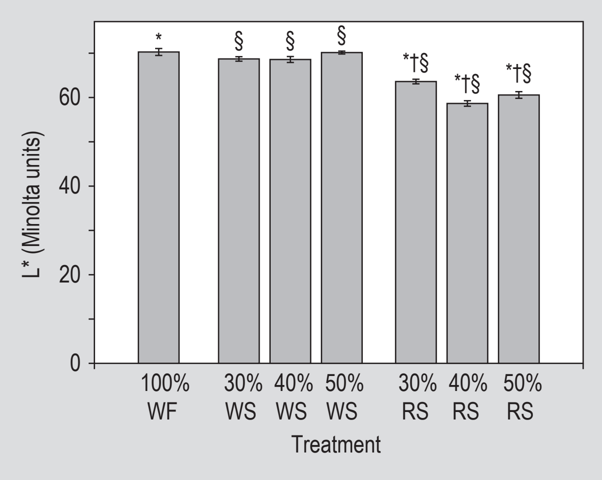

Figure 4. Effect of white (WS) and red sorghum (RS) flour addition (30, 40 and 50%) to 100% wheat flour (WF) on flatbread degree of lightness (L*). Bars indicate standard error of the mean (n=9). * = significant difference between 100% WF and RS containing flatbread formulations (30, 40 and 50%); † = significant difference between RS (30%) and RS (40 and 50%) flatbread formulations; § = significant difference between WS and RS flatbread formulations at 30, 40 and 50%.

exhibited a 9.49% reduction in flatbread L* colour value. The greatest decrease is exhibited by the 40% flatbread treatment, resulting in a 16.54% reduction in L* colour value. Further addition of RS flour at 50% exhibited similar bread L* colour value in comparison to the RS 40% flatbread.

Furthermore, 40 and 50% RS levels exhibited a significant reduction in the L* colour value in comparison to 30% RS the (7.78 and 4.76%, respectively). The consistent decrease in RS flatbread L* colour value, with increased RS addition is indicative of the flatbread becoming darker.

The reason for the inverse relationship between the reduced L* colour value and increased flatbread RS flour addition is that RS flour has a higher total phenolic (anthocyanins) content than WF (3.7 and 0.59 mg GAE/g, respectively) (Yousif *et al.*, 2012). This finding is supported by Awika and Rooney (2004) who reported that darkening is due to the presence of phenols (anthocyanins) in the sorghum flour. These phenols are dark red in nature and therefore would result in darker flatbread. Furthermore, Yousif *et al.* (2012) reported the total phenol content of the 40% RS flatbread formula (2.02 mg GAE/g) is significantly higher than the 100% WF flatbread (0.65 mg GAE/g).

Phenols are also present in WS flour (2.3 mg GAE/g), but to a lesser extent than in RS flour (Yousif *et al.*, 2012). This finding was supported by Dykes *et al.* (2005), who observed that darker sorghum grain contained higher level of phenolic compounds. Therefore, all WS flatbread formulations (30, 40 and 50%) exhibited a similar flatbread L* colour value to each other and to the 100% WF (Figure 4).

Despite the fact that the bread is darker, which may result in reduced consumer acceptance, it may be argued the presence of phenols in the flatbread would add additional health benefits due to the ability of sorghum phenols to act as antioxidants (Awika and Rooney, 2004).

Flatbread a* colour value

Addition of WS and RS flour to the 100% WF flatbread resulted in a significant increase in a* colour value (red-blue). The 30, 40 and 50% WS formulas resulted in a 290.5, 409.5 and 528.6% increase in a* colour value, respectively (Figure 5).

However, addition of RS flour resulted in a significantly larger increase in a* colour value compared to the WS flour. In comparison with the 100% WF flatbread, addition of 30 and 40% RS flour, resulted in a 1,361.9, and 1,676.2% increase in a* colour value, respectively. As discussed in section 'Flatbread L* colour value', this is due to the RS flour having a higher levels of polyphenolic content (Yousif *et al.*, 2012), which are known to exhibit high levels of anthocyanins (Awika and Rooney, 2004), compared with WS flour. Further addition of RS flour at 50% exhibited similar flatbread a* colour value in comparison to the RS 40% flatbread.

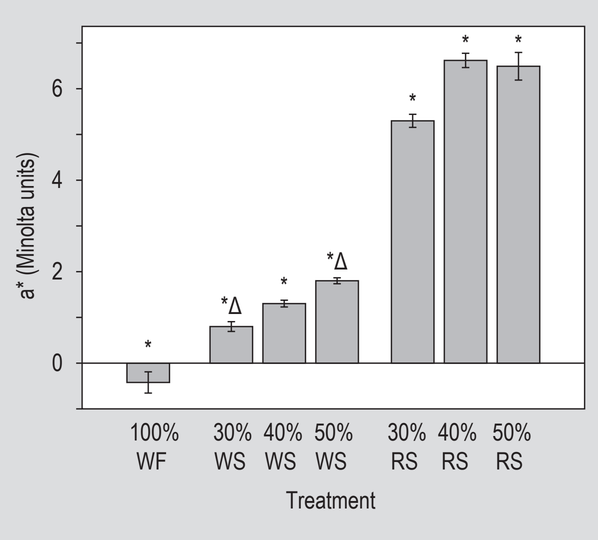

Figure 5. Effect of white (WS) and red sorghum (RS) flour addition (30, 40 and 50%) to 100% wheat flour (WF) on flatbread colour a* value. Bars indicate standard error of the mean (n=9). * = significant difference between 100% WF, WS and RS containing flatbread formulations (30, 40 and 50%); Δ = significant difference between WS (30 and 50%) flatbread formulations.

Flatbread b* colour value

Flatbread (100% WF) exhibited similar b* colour value in comparison to all other flatbread (WS and RS) formulations (30, 40 and 50%). Both WS and RS exhibited a similar effect on the flatbread b* colour value with addition of increasing amounts of WS and RS having a relatively small effect on the b* colour value results.

Colour difference index

The L*, a* and b* colour system is a three dimensional standardised and approved method used to describe and rate the colour of food samples (Moyano *et al.*, 2008). However, ΔE*ab is an alternative and a more practical one-dimensional scale of colour difference (Kato and Meguro, 1998). This method presents a clearer illustration of changes in colour of the WF/WS and RS (30, 40 and 50%) flatbread (Figure 6).

All ΔE*ab results are calculated relative to the 100% WF flatbread and presented in Figure 6. WS 30 and 40% flatbread formulations exhibited a noticeable (detectable by trained people) difference in colour index of 2.83 and 2.96, respectively, whereas the 50% WS flatbread exhibited an appreciable difference of 3.30 which is deemed detectable

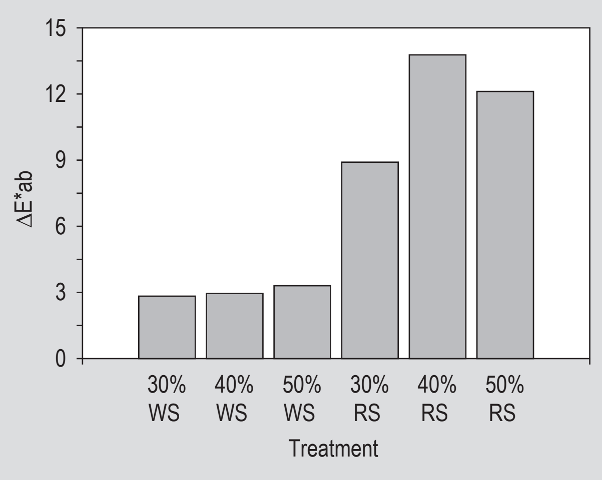

Figure 6. Change of flatbread colour difference index (ΔE*ab) in relation to the addition of white (WS) and red sorghum (RS) flour (30, 40 and 50%) to 100% wheat flour.

by ordinary people, such as consumers. Based on the ΔE*ab scale it is expected therefore, that consumers may notice minor colour differences produced by the addition of 50% WS, but would be unlikely to notice significant differences in formulations containing less than that.

In comparison to WS; RS addition resulted in large ΔE*ab index differences. The 30% RS flatbread formulation resulted in a reddish hue to the flatbread with large ΔE*ab index differences of 8.91 indicating a large, discernible difference in colour (darkening) within the same colour group. This colour difference is easily detected by the consumer. The addition of the 40 and 50% RS resulted in an extreme colour ΔE*ab index difference of 13.77 and 12.11, respectively; indicating that flatbread incorporating 40 and 50% RS may be considered to be within another colour group. The intense colour change exhibited by the RS flatbread formulations indicates the RS flour flatbread is much darker compared with the 100% WF flatbread. This outcome is likely due to the higher levels of anthocyanins found in RS varieties in comparison to WS varieties (Awika and Rooney, 2004).

The physical quality outcomes of loss of bread weight, reduced volume, increased texture and RS related darkening of the flatbread is likely to result in decreased consumer demand due to reduced consumer acceptability (Yousif *et al.*, 2012) and will ultimately have a negative financial effect on the processor (baker).

4. Conclusions

Addition of WS and RS flour resulted in flatbread with lower volume and weight than 100% WF flatbread. Addition of WS flour resulted in a harder flatbread with colour quality comparable to the 100% WF. RS flour had minimum effect on flatbread texture; however, produced a darker flatbread with a ΔE*ab value detectable by consumers. The outcome of this work is that addition of sorghum flour (WS and RS) to WF for the production of traditional flatbread using formulations and processing methods described in this study is expected to result in inferior sensory quality of texture and colour as well as processing difficulties such as reduced flatbread weight and volume. These quality and processing difficulties may be overcome with further product development work leading to formulation and process optimisation.

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