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The effect of wheat variety, fermentation and incorporation of ingredients on the texture profile, colour and sensory attributes of whole wheat bread

Bernard Rwubatse[1*], Michael W. Okoth[1], Angela A. Andago[1], Sophia Ngala[1], Anastase Kimonyo[2], Clement Bitwayiki[2]

[1]*University of Nairobi, Department of Nutrition, Food Science and Technology*
[2]*University of Rwanda, Department of Food Science and Technology*

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ABSTRACT

Whole grain flour is gaining an increase in demand for its nutritive and health promotion values in different food products for human consumption worldwide. Whole flour from wheat grain varieties (Gihundo, Kibatsi, Nyaruka and Reberaho), spent coffee grounds (SCG), juices of lemon fruit (L) and rosemary leaves (R), and dough fermentation were assessed for their impact on the texture profile, colour and sensory attributes of bread. Wheat grains (sampled from the stores of Rwanda Agriculture and Animal Resources Development Board, Kinigi, Rwanda) were conditioned to 15.5% moisture content and were wholly milled. The mixture of 200 g whole wheat flour, 4% spent coffee grounds, 1% juice of lemon fruit and 1% juice of rosemary leaves were fermented by using 2% instant dry yeast at 34 °C, 60% relative humidity (RH) for 60 min and at 39 °C, 85% RH for 120 min, separately. The dough was baked at 180 °C for 20 min. Data were subjected to one-way analysis of variance using SAS System. Treatment means were separated using Tukey's test and the least significant difference was accepted at $p \leq 0.05$. The control bread was made for 60 min of fermentation without incorporation of SCG and LR. The control bread was harder than the bread containing SCG and SCG+LR with the same time of fermentation. The long fermentation and the inclusion of SCG and SCG+LR in doughs, caused the supplemented bread to have lower L*, a* and b* values than control bread. Low L*, a* and b* values indicate minimum darkness, redness and yellowness of bread. Aroma, taste and appearance of SCG+LR bread from doughs fermented for 120 min were the most liked. Whole wheat bread obtained satisfied consumers' preferences. Therefore, the application of spent coffee grounds, juices of lemon fruit and rosemary leaves in bread making represents a good opportunity at low cost.

Introduction

The scientific evidence and increasing campaigns on health-promoting compounds of whole grain have gained the attention of consumers for the consumption of whole grain based-foods (van der Kamp et al., 2014). The United States dietary guidelines for Americans explicitly recommend adults the consumption of at least three ounce-equivalents of whole grain per day, and that at least half of the grains consumed should be whole grains (van der Kamp et al., 2014). The increasing awareness on consuming functional foods, foods which provide additional health benefits to those coming from normal nutrients, has led the bakeries to produce bread from whole wheat grains, as well as white bread (Ndife et al., 2013). Physical, texture profile and sensory characteristics of bread are generally the basis for liking this wheat product by consumer. Physico-chemical characteristics of raw materials and ingredients, and fermentation time are among other major factors which influence the quality of bread. Demirkesen et al. (2010) demonstrated that the increase in high crumb hardness

[*]Corresponding author E-mail: brwubatse@students.uonbi.ac.ke

was associated with high amount of bran dietary fibre in whole wheat bread. High and low lightness of bread can be caused by strong and weak enzymatic browning of carotenoids, respectively, during dough fermentation (Leenhardt et al., 2006b). Aroma and taste of bread are affected by aromatic compounds from the raw material and ingredients incorporated in the product formulation (Allegrone et al., 2006).
Products from rosemary leaves and lemon fruit have been used in food preparation for their health promoting compounds and preservative properties (Bozˇin et al., 2007; Salim-ur-Rehman et al., 2007). These parts of the plants are well known to be a rich source of phytochemicals and possess anti-microbial potential (Bozˇin et al., 2007; Salim-ur-Rehman et al., 2007). Spent coffee grounds (SCG), as a by-product from coffee brewing, has recently been tested as a new ingredient in food preparation. It was found that SCG has some chemical substances that are beneficial to consumers and was reported to be safe to be applied in food preparation (Martinez-Saez et al., 2017). SCG was used in the making of biscuit and bread. Few studies have worked on the application in the combination of juices from rosemary leaves (R) and lemon fruit (L), and SCG in food preparation. Consumers like white wheat bread more than whole wheat bread due to less appealing organoleptic, physical and textural characteristics of whole bread (Maneju et al., 2011). Consequently, it leads to the low acceptance and economic loss of whole wheat bread. Bakeries need to fulfil the increasing consumers' preferences for healthier and tastier whole wheat bread (Banu et al., 2012). High bran dietary fibre contained in whole wheat flour was reported to increase crumb hardness (Demirkesen et al., 2010) and dough fermentation duration influences enzymatic browning of carotenoids, thereby affects colour of bread (Leenhardt et al., 2006b). The inclusion of products from herbs in baking recipe can affect the crust and crumb, taste, texture and aroma of bread (Salim-ur-Rehman et al., 2007). In the previous study, different wheat varieties, fermentation time, together with the addition of juices from rosemary leaves and lemon fruit, and SCG, were used to evaluate their effects on the acrylamide formation and microbial quality of whole wheat bread (Rwubatse et al., 2020).
It is in this regard that the present study aimed at furthering this research by using the same raw material, ingredients and processing conditions to evaluate their effects on the physical quality of whole wheat bread in order to satisfy consumers' preferences regarding the texture, colour and sensory characteristics.

Materials and methods

Collection of the samples

Four (4) dry wheat grain varieties, namely TAI, EN161, Eagle10 and Korongo with the local names Gihundo, Kibatsi, Nyaruka, and Reberaho, respectively, were collected from the stores of Rwanda Agriculture and Animal Resources Development Board (RAB), located at Kinigi, Musanze district, Rwanda. These wheat varieties were grown on Kinigi RAB farms. They were packed in high-density polyethylene bags and stored at room temperature prior to milling. The wastes, known as spent coffee grounds, were directly taken after brewing coffee (Coffea Arabica var. bourbon) in a coffee shop in Musanze town, Rwanda and stored in a transparent plastic bottle in a freezer at -40 °C prior to analysis. Fresh green lemon fruits (var. African rough lemon) and raw green rosemary leaves (Var. Arp rosemary herb) were bought from the market in Musanze town, Rwanda, packed in plastic sachets and stored at 5 °C in the refrigerator (Hisense, HBM17158SS, 2015, China) prior to processing. Coffee, lemon and rosemary were all grown in Rwanda.

Preparation of the raw samples

Milling of wheat grains

Before milling, the wheat grains were conditioned to 15.5% moisture content by the addition of distilled water and were left for at least 24 h at ambient conditions in a closed plastic container for the absorption of the moisture (Mishra, 2016). AACC Approved Method 26-95.01 (AACC, 2003) was used to calculate the amount of water to be added for wheat grains tempering:

$$\boldsymbol{mL} = \left(\left(\frac{100 - \%moisture}{100 - 15.5\%}\right) - 1\right) x\ grams\ of\ wheat\ grains$$

The conditioned wheat grains of each variety were wholly milled by using a laboratory hammer mill (CM 1090 Cemotec, 2009, China). The obtained flour contained all bran and germ. The whole wheat flour was packed in high-density polyethylene envelop and stored at -20 °C in a freezer (SM302NW, SM302NW1014009, 2010/08) prior to analysis and baking.

Preparation of juices from lemon fruits and rosemary leaves

The lemon fruits and rosemary leaves were blended separately by using a laboratory blender (Moulinex, LM241, Genuine, 2017, France). The obtained juices were kept in transparent plastic bottles and stored at -20

°C in a freezer (SM302NW, SM302NW1014009, 2010/08) prior to analysis.

Baking

The dough comprised 200 g whole wheat flour from each of the wheat variety grains (TAI, EN161, Eagle10 and Korongo), 2% instant dry yeast (GB Ingredients, Dordrecht, 2019, Holland), 2% sodium chloride and potable water (125 mL) (Fredriksson et al., 2004). The amounts of 4% spent coffee grounds (Martinez-Saez et al., 2017), 1% lemon fruit juice and 1% rosemary leaf juice were added. The electric balance (Explorer EX 223, version 2.00/2.00. SN B 333687045, IR Sensor, OHAUS) was used. The mixture was fermented and proofed in a fermenter (Manz Backtechnik GmbH, Creglingen, Germany) at 34 °C, 60% relative humidity for 60 min and at 39 °C, 85% relative humidity for 120 min after being mixed in a dough mixer (Combisteel Dough Mixer Liter, 7455.1400, 2011, China) (Surdyk et al., 2004). The rotation of the mixer was 54 rotations per minute (rpm) for 3 min until the dough came together and then switched to 104 rpm for 6 min. Each fermented dough was covered with a lid and baked at 180 °C for 20 min in an oven (Electric baking oven, Lemarkz, Model: LGO-24A, 2010, India).

The control bread from each wheat variety was made for 60 min of fermentation without incorporation of SCG and LR. The loaves were taken out of the oven and cooled for 2 h, packed in unperforated low-density polythene bags, closed and stored at -20 °C in a freezer (SM302NW, SM302NW1014009, 2010/08) prior to analysis.

Determination of weight, specific volume and density of bread

The weight was determined using an electronic balance (JA2002, Yhequipment, China, 2017). Volume, specific volume and density were determined by an AACCI approved method 10-05-01 (AACC, 2003). Specific volume (cm^3/g) was calculated as the loaf volume divided by its weight. The bread density (g/cm^3) was calculated as its weight divided by loaf volume.

Assessment of colour and texture profile of bread

The bread was kept at room temperature for 1 day. The colour of the bread crumb was measured by a colour reader (CR-10, Konica Minolta, inc. 2016, Japan). The texture profile of bread crumb was analysed by a texture analyser (TA.XT.Plus, stable micro systems, 2015, London) with a compression probe (SMSP/75) with the following settings and parameters: Sequence Title: TPA1, T.A. Variable No. 1: Compression, Pre-Test Speed: 1.00 mm/sec, Test speed: 5.00 mm/sec, Post-Test Speed: 5.00 mm/sec, T.A Variable No: 5:0.0 g, Distance: 10.000 mm, Strain: 75.0%, Trigger type: Auto (Force), Trigger Force: 5.0 g.

Evaluation of the sensory characteristics of bread

The bread samples from the four wheat varieties were evaluated for sensory attributes of texture, colour, taste, aroma, appearance and overall acceptability by a trained 10-member panel, using a 7-point Hedonic scale (Eleazu et al., 2014). Sensory evaluation was carried out in a sensory evaluation laboratory under white light.

Statistical analysis

Data in triplicate were subjected to one-way analysis of variance (ANOVA) using SAS System for Windows (version 9.3, SAS Institute, Cary, NC). Treatment means were separated using Tukey's test and the least significant difference was accepted at $p \leq 0.05$.

Results and discussion

The values for the hardness of the bread were between 1338 g and 6881 g. The hardness of 100% wheat flour bread that was fermented for 60 min from the Nyaruka followed by Kibatsi varieties was higher than that of bread from the Gihundo and Reberaho ($p \leq 0.05$). Regarding ingredients, the control bread was harder than bread containing SCG and SCG+LR. The substitution of whole wheat flour as a rich source of bran dietary fibre (Wang et al., 2014) with SCG and SCG+LR reduced the dietary fibre content of the resultant bread compared to control bread (100% whole wheat flour). The results are in agreement with the report of Demirkesen et al. (2010) who demonstrated that the increase in crumb hardness was associated with a high amount of bran dietary fibre in whole wheat bread. The W: SCG+LR bread from the dough fermented for 120 min were much harder than those fermented for 60 min ($p \leq 0.05$). This was possibly due to the long fermentation of dough with low pH that was enhanced by the addition of lemon juice. The latter could have lowered the pH to the optimum for the yeast's activity to release more gas (Table 2). With low pH values, there is a net positive charge, and proteins become more soluble (Komlenić et al., 2010). Bread hardness determines its mechanical strength and deformation behaviour which in turn decides people's texture perception and swallowing threshold during human oral processing (Gao et al., 2014). The springiness values of the bread were between 0.716 and 0.940 (Table 1). The springiness of bread from the Gihundo variety was higher than those of the bread made from the remaining varieties. The bread from the Nyaruka and Reberaho varieties had the least springiness (p≤0.05) as shown in Table 1. The incorporation of SCG and SCG+LR decreased and increased respectively the springiness of the control bread when fermentation of the dough was extended to 120 min (p≤0.05). Springiness is a measure of how much the bread crumb springs back after being compressed once and it can be defined as the elasticity of the bread crumb. It is an important parameter to determine the staling degree of bread (Boz and Karaoğlu, 2013). The minimum and maximum cohesiveness of the bread were 0.500 and 0.757 (Table 1), respectively. The control bread processed from the Nyaruka variety had the lowest, while the bread from the Gihundo had the highest value of cohesiveness (p≤0.05). The separate incorporation of SCG and SCG+LR decreased and increased respectively the cohesiveness of the control bread when fermentation duration was prolonged from 60 min to 120 min. The decrease in cohesiveness indicates increased susceptibility of the bread to fracture or crumble. The range for the resilience of the bread was 0.160 and 0.351 (Table 1). The resilience of the bread was not significantly different (p>0.05) among the control bread from all the varieties. An increase and decrease in resilience were observed when whole wheat flour was mixed with SCG+LR and SCG, respectively.

When fermentation duration was prolonged from 60 to 120 min, the resilience of control bread decreased with the supplementation of whole wheat flour with SCG and increased with SCG+LR incorporation (p≤0.05). Resilience is correlated with the extent of staling. Typically, the fresher the bread, the higher is its resilience value, while stale bread shows little or no resilience. Staling makes the crumb structure or internal matrix stiffer or firmer and more brittle (crumbly) over time (Cauvain, 2004). The resilience of bread is directly proportional to its springiness (Zhang, 1999).

Table 1. Effect of wheat variety, ingredient incorporation and fermentation time on the texture profile of whole wheat bread crumb

Wheat variety	Ingredients	Fermentation (min)	Hardness (g)	Cohesiveness*	Springiness*	Resilience*
Gihundo	W	60	5717^{k}	0.646^{df}	0.843^{fg}	0.253^{bcd}
	W:SCG		3360^{c}	0.730^{h}	0.940^{efg}	0.240^{bcd}
	W:SCG+LR		1468^{b}	0.610^{c}	0.716^{a}	0.276^{abc}
	W	120	5706^{k}	0.632^{def}	0.820^{de}	0.233^{abc}
	W:SCG		3343^{c}	0.696^{g}	0.720^{a}	0.230^{abc}
	W:SCG+LR		1444^{b}	0.620^{cd}	0.793^{c}	0.320^{f}
Kibatsi	W	60	6651^{l}	0.620^{cde}	0.840^{efg}	0.226^{abc}
	W:SCG		3205^{h}	0.720^{gh}	0.890^{i}	0.213^{ef}
	W:SCG+LR		3012^{g}	0.566^{b}	0.723^{a}	0.230^{ab}
	W	120	6613^{l}	0.513^{a}	0.860^{gh}	0.200^{a}
	W:SCG		3105^{f}	0.610^{c}	0.800^{cd}	0.160^{bcd}
	W:SCG+LR		1518^{c}	0.613^{c}	0.736^{ab}	0.256^{bcd}
Nyaruka	W	60	6881^{m}	0.610^{c}	0.730^{ab}	0.226^{abc}
	W:SCG		5245^{j}	0.730^{h}	0.833^{ef}	0.210^{de}
	W:SCG+LR		5043^{i}	0.646^{def}	0.730^{ab}	0.243^{ef}
	W	120	6866^{m}	0.500^{g}	0.876^{hi}	0.223^{abc}
	W:SCG		5220^{j}	0.720^{gh}	0.783^{c}	0.200^{bcd}
	W:SCG+LR		1338^{a}	0.646^{f}	0.750^{b}	0.263^{cd}
Reberaho	W	60	6872^{m}	0.617^{c}	0.725^{ab}	0.241^{abc}
	W:SCG		5222^{j}	0.757^{h}	0.817^{ef}	0.239^{de}
	W:SCG+LR		2351^{e}	0.637^{def}	0.741^{ab}	0.333^{ef}
	W	120	6847^{m}	0.604^{g}	0.851^{hi}	0.247^{abc}
	W:SCG		5012^{i}	0.710^{gh}	0.771^{c}	0.217^{bcd}
	W:SCG+LR		1955^{d}	0.634^{f}	0.747^{b}	0.351^{cd}

*Means with different superscript within a column are significantly different at p ≤ 0.05. W: Whole wheat grain bread (Control bread), W: SCG: Whole wheat grain bread supplemented with spent coffee grounds, W: SCG+LR: Whole wheat grain bread supplemented with spent coffee grounds, juice of lemon fruit and juice of rosemary leaves. *Dimensionless*

Table 2. Effect of wheat variety, ingredient incorporation and fermentation time on colour of whole wheat bread crumb

Wheat variety	Ingredients	Fermentation (min)	L*	a*	b*	Yield extraction (%)*	pH of whole wheat bread
Gihundo	W	60	71.77[j]	7.633[a]	21.43[j]	99.2[c]	5.83[b]
	W:SCG		65.60[e]	8.500[ab]	18.63[h]		5.83[b]
	W:SCG+LR		68.23[h]	8.033[ab]	18.50[h]		4.49[a]
	W	120	74.37[l]	8.567[b]	24.37[k]		5.82[b]
	W:SCG		69.50[i]	10.900[c]	17.73[g]		5.81[b]
	W:SCG+LR		72.50[k]	8.300[ab]	17.73[g]		4.48[a]
Kibatsi	W	60	69.77[i]	8.567[b]	17.33[f]	97.7[b]	5.5b[a]
	W:SCG		65.77[e]	8.567[b]	17.70[g]		5.52[b]
	W:SCG+LR		68.40[h]	8.300[ab]	16.30[d]		4.47[a]
	W	120	67.23[g]	12.633[d]	20.50[i]		5.50[b]
	W:SCG		63.23[c]	12.367[d]	16.53[de]		5.44[b]
	W:SCG+LR		65.77[e]	8.633[b]	16.77[e]		4.36[a]
Nyaruka	W	60	65.63[e]	8.333[ab]	12.80[a]	96.2[a]	5.59[b]
	W:SCG		61.17[a]	8.433[ab]	16.23[d]		5.55[b]
	W:SCG+LR		63.10[c]	8.367[ab]	17.53[fg]		4.50[a]
	W	120	64.83[d]	10.400[c]	13.83[b]		5.51[b]
	W:SCG		62.73[b]	10.900[c]	14.60[c]		5.47[b]
	W:SCG+LR		63.57[c]	7.833[ab]	16.37[d]		4.43[a]
Reberaho	W	60	67.12[g]	8.790[ab]	12.18[a]	96.5[a]	5.57[b]
	W:SCG		64.20[d]	8.110[ab]	16.26[d]		5.52[b]
	W:SCG+LR		65.41[e]	8.270[ab]	17.33[fg]		4.53[a]
	W	120	66.24f	10.370[c]	13.71[b]		5.50[b]
	W:SCG		62.11[b]	10.190[c]	14.47[c]		5.48[b]
	W:SCG+LR		64.48[d]	7.440[ab]	16.14[d]		4.44[a]

*Means with different superscript within a column are significantly different at p≤ 0.05. W: Whole wheat grain bread (Control bread), W: SCG: Whole wheat grain bread supplemented with spent coffee grounds, W: SCG+LR: Whole wheat grain bread supplemented with spent coffee grounds, juice of lemon fruit and juice of rosemary leaves. (%)*Percentage of whole wheat flour from the weight of wheat grains milled.*

The ranges for bread colour were 61.17 and 74.37 for L* values, 7.440 and 12.633 for a* values and 12.18 and 24.37 for b* values (Table 2). The L* values were significantly different ($p \leq 0.05$) in the control bread from all the wheat varieties. The control bread from the Gihundo and Nyaruka varieties had the highest and lowest L* values, respectively. The higher L* value means that bread from the Gihundo variety was brighter than the bread from the varieties which had lower L* values. The relationship between darkness and bran size of bread was reported by Zhang (1999) in which bread with higher extraction yield and fine bran had darker crumb colour than bread with lower extraction yield and coarse or medium size bran. However, this study was not in agreement with what was revealed by Zhang (1999) in that the whole wheat bread from the Gihundo and Kibatsi varieties had the highest yield extraction, while showing the highest L* values (71.77 and 69.77), respectively, among other control bread (Table 2). Therefore, the bread crumb brightness in this study was considered to be mainly caused by the wheat cultivar. The control bread from all the wheat variety doughs fermented for 60 min had higher L* values of crumb colour than the ones from the doughs with fermentation extended to 120 min that the high and low L* values were probably caused by strong and weak enzymatic browning of carotenoids, respectively, during fermentation. Some of the individual components of carotenoids were reported to be responsible for the bright yellow colour of pasta (Beleggia et al., 2011). Leenhardt et al. (2006a) reported that the carotenoid content decreased during the process of making whole grain French bread where the greatest loss (66%) of carotenoids occurred in the dough. Carotenoids are concentrated in the aleurone layer of wheat. Kneading leads to the incorporation of water and oxygen in the dough, therefore fostering the lipoxygenase (LOX)-mediated oxidation of polyunsaturated fatty acids, which in turn causes the oxidation of carotenoids (Beleggia et al., 2011). A strong correlation between LOX and carotenoids decline during dough kneading was reported by Sui et al. (2015). Lipoxygenase and peroxidase could lead to carotenoid oxidation in the presence of oxygen and water in the dough. However, during fermentation, the consumption of oxygen by yeast prevents further oxidation by oxidative enzymes (Leenhardt et al., 2006a). Dough fermented longer could undergo low oxidation and later has more carotenoid content than the dough fermented for a shorter time. Hence, in the present study, the dough obtained after 120 min of fermentation had lower enzymatic browning of carotenoids with lower L* values after baking compared to dough fermented for 60 min. The a* and b* values of the bread increased when the dough fermentation time increased from 60 to 120 min. Thus, the dough fermentation had significant effect on the a* and b* colours of the bread. The anthocyanin, which is responsible for redness (a* values) and yellowness (b* values), was higher in the dough fermented for 120 min than in the ones fermented for 60 min. The anthocyanin seemed to undergo low degradation rates in 120 min fermentation when compared to 60 min fermentation of the dough, most likely due to the protective effect of high volume of CO_2 generated by yeast during 120 min fermentation (Sui et al., 2015). The inclusion of SCG and SCG+LR in doughs caused the supplemented bread to have lower L*, a* and b* values than the control bread. The W: SCG+LR bread had higher L* values than W: SCG bread. This was probably due to the synergy of the pH lowering the capacity of LR and the antioxidant capacity of SCG to mitigate during fermentation and baking, respectively, the enzymatic and non-enzymatic (Maillard reactions) browning which could otherwise increase L*, a* and b* values of the bread. The lemon juice lowered the pH (Table 2) to the optimum (4.50-5.00) preferred by yeast to possibly scavenge more oxygen for the reduction of enzymatic browning of carotenoids and to release more gas for the protection against the degradation of anthocyanins. Also, lowering the pH of the dough by the addition of lemon juice could have discouraged the formation of dark colour of bread. Gökmen et al. (2007) reported that the reduced pH of the dough affected the colour of bakery products by reducing the formation of Maillard reaction products. On the other hand, SCG was incorporated in the bread as a source of antioxidant fibre to minimize the level of the Maillard reaction products which could favour the darkness, redness and yellowness of the bread (Martinez-Saez et al., 2017).

The bread weight was in the range of 136.7 g and 142.7 g (Table 3). The weight of the bread which was not significantly different ($p>0.05$) from the control bread from the Kibatsi and Nyaruka wheat varieties, was lower than the weight of the control bread from the Gihundo variety. The W: SCG and W: SCG+LR bread had higher weight than the control bread. The decrease in weight may be due to an increase in crude fibre content of the supplemented bread samples. The control and W: SCG bread from doughs fermented for 120 min were heavier than the same bread from doughs fermented for 60 min ($p>0.05$). However, fermentation duration did not significantly ($p>0.05$) affect the weight of W: SCG+LR bread.

Table 3. Effect of wheat variety, ingredient incorporation and fermentation time on the physical characteristics of whole wheat bread

Wheat variety	Ingredients	Fermentation (min)	Weight (g)	Specific volume (cm^3/g)	Density (g/cm^3)
Gihundo	W	60	140.3^{ab}	3.067^{abc}	0.480^{a}
	W:SCG		142.0^{b}	2.933^{a}	0.483^{a}
	W:SCG+LR		141.7^{b}	2.967^{ab}	0.490^{a}
	W	120	138.7^{ab}	3.233^{abc}	0.513^{a}
	W:SCG		141.3^{ab}	3.167^{abc}	0.513^{a}
	W:SCG+LR		141.9^{b}	3.000^{ab}	0.516^{a}
Kibatsi	W	60	139.3^{ab}	2.967^{ab}	0.520^{a}
	W:SCG		141.0^{ab}	3.000^{ab}	0.523^{a}
	W:SCG+LR		141.0^{ab}	3.033^{abc}	0.520^{a}
	W	120	138.3^{ab}	3.300^{abc}	0.526^{a}
	W:SCG		141.0^{ab}	3.267^{abc}	0.533^{a}
	W:SCG+LR		141.7^{b}	3.067^{abc}	0.523^{a}
Nyaruka	W	60	138.7^{ab}	3.033^{abc}	0.530^{a}
	W:SCG		140.3^{ab}	3.067^{abc}	0.536^{a}
	W:SCG+LR		140.7^{ab}	3.133^{abc}	0.526^{a}
	W	120	137.7^{a}	3.400^{c}	0.533^{a}
	W:SCG		140.3^{ab}	3.333^{bc}	0.540^{a}
	W:SCG+LR		141.0^{ab}	3.140^{abc}	0.541^{a}
Reberaho	W	60	137.7^{ab}	3.050^{abc}	0.522^{a}
	W:SCG		142.3^{ab}	3.090^{abc}	0.511^{a}
	W:SCG+LR		142.7^{ab}	3.110^{abc}	0.540^{a}
	W	120	136.7^{a}	3.410^{c}	0.501^{a}
	W:SCG		141.3^{ab}	3.300^{bc}	0.513^{a}
	W:SCG+LR		142.0^{ab}	3.133^{abc}	0.542^{a}

Means with different superscript within a column are significantly different at $p \leq 0.05$. W: Whole wheat grain bread (Control bread), W: SCG: Whole wheat grain bread supplemented with spent coffee grounds, W: SCG+LR: Whole wheat grain bread supplemented with spent coffee grounds, juice of lemon fruit and juice of rosemary leaves.

The specific volume ranged between 2.933 cm^3/g and 3.410 cm^3/g (Table 3). The specific volume was significantly different ($p \leq 0.05$) among the control bread, where bread from the Gihundo and Nyaruka varieties showed the highest and lowest specific volume, respectively. The wheat variety which exhibited high extraction yield after milling (Table 2) resulted in bread with low specific loaf volume (Tables 3). The small size bran flour may have contributed to the low specific volume. The same was reported in another study: namely, bread containing fine bran resulted in a lower specific loaf volume than bread containing coarse or medium size bran (Tamanna and Mahmood, 2015). The control bread from all the wheat varieties had a high specific volume compared to W: SCG and W: SCG+LR bread. The decrease in specific volume may have been caused by fibre from SCG which reduced the gluten network that is required for good gas-holding properties (Noort et al., 2010). When dough fermentation time was increased from 60 min to 120 min, there was a higher increase in the specific volume for W: SCG+LR bread in comparison to that of other bread due to the fact that fermenting yeasts were in a favourable environment of acidic conditions for longer time. In this case, the addition of lemon fruit juice (L) could have reduced the dough pH to the extent the yeasts became more active.

The density of the bread was in the range of 0.480 g/cm^3 and 0.542 g/cm^3 (Table 3). The density was not significantly different ($p>0.05$) between the control bread from the Gihundo and Nyaruka varieties which was lower than that of the bread from the other varieties ($p \leq 0.05$). The W: SCG and SCG+LR bread were less dense than the only wheat (control) bread. The addition of SCG increased the dietary fibre content of the control bread, therefore reduced its density (Park et al., 1997). The dough fermentation duration did not affect the density of control bread ($p>0.05$). The W: SCG+LR bread and W: SCG bread from the doughs fermented for 60 min were denser than the similar bread from the doughs fermented for 120 min ($p \leq 0.05$).

The range of values for colour, aroma, taste, texture, appearance and general acceptability were respectively between 4.2 and 5.7, 4.5 and 6.2, 4.5 and 5.9, 4.3 and 5.6, 4.5 and 5.7, and 4.5 and 5.7. The control bread from the Gihundo variety had higher colour and appearance scores than the other control bread ($p \leq 0.05$), (Table 4). The bread from the Kibatsi, Nyaruka and Reberaho varieties showed non-significant differences ($p>0.05$) in colour.

Table 4. Effect of wheat variety, ingredient incorporation and fermentation time on sensory attributes of whole wheat grain bread

Wheat variety	Ingredients	Fermentation (min)	Crust colour	Aroma	Taste	Texture	Appearance	General acceptability
Gihundo	W	60	5.7^{c}	5.9^{de}	5.5^{c}	5.1^{a}	5.5^{b}	5.7^{c}
	W:SCG		5.2^{b}	5.2^{b}	5.1^{b}	5.0^{a}	5.1^{b}	5.1^{b}
	W:SCG+LR		5.1^{b}	6.2^{f}	5.9^{d}	5.0^{a}	5.2^{b}	5.3^{b}
	W	120	5.4^{c}	5.5^{d}	5.3^{b}	5.6^{b}	5.7^{bc}	5.4^{b}
	W:SCG		5.0^{b}	5.0^{b}	4.8^{a}	5.3^{ab}	5.1^{b}	4.8^{a}
	W:SCG+LR		4.7^{a}	5.3^{b}	5.2^{b}	5.6^{b}	5.1^{b}	5.1^{b}
Kibatsi	W	60	5.5^{c}	5.7^{d}	5.5^{c}	5.2^{ab}	5.1^{b}	5.2^{b}
	W:SCG		4.8^{ab}	5.2^{c}	5.0^{a}	4.8^{a}	4.7^{a}	4.8^{a}
	W:SCG+LR		4.7^{a}	5.5^{d}	5.4^{c}	4.9^{a}	4.6^{a}	5.0^{a}
	W	120	5.4^{b}	5.4^{d}	5.3^{bc}	5.5^{b}	5.2^{b}	5.0^{b}
	W:SCG		4.5^{a}	5.0^{b}	5.0^{b}	5.1^{a}	4.7^{a}	4.5^{a}
	W:SCG+LR		4.2^{a}	5.4^{d}	5.7^{d}	5.4^{abc}	4.5^{a}	5.3^{b}
Nyaruka	W	60	5.3^{bc}	5.8^{de}	5.7^{c}	5.2^{a}	5.3^{b}	5.3^{b}
	W:SCG		4.7^{a}	5.2^{b}	5.1^{a}	4.7^{a}	4.7^{a}	4.9^{a}
	W:SCG+LR		4.7^{a}	5.5^{d}	5.4^{b}	4.7^{a}	4.8^{a}	5.0^{a}
	W	120	5.0^{b}	5.5^{d}	5.5^{c}	5.4^{a}	5.4^{b}	5.0^{a}
	W:SCG		4.5^{a}	5.0^{b}	5.0^{a}	5.0^{a}	4.9^{a}	4.7^{a}
	W:SCG+LR		4.4^{a}	5.5^{d}	5.3^{b}	5.3^{ab}	5.0^{b}	5.3^{b}
	W							
Reberaho	W:SCG	60	5.2^{b}	4.7^{a}	4.6^{a}	4.5^{a}	4.6^{a}	4.7^{a}
	W:SCG+LR		4.5^{a}	4.5^{a}	4.5^{a}	4.3^{a}	4.6^{a}	4.5^{a}
	W		4.6^{a}	5.0^{b}	5.0^{b}	4.9^{b}	4.8^{a}	4.9^{b}
	W:SCG	120	5.0^{b}	5.2^{b}	4.6^{a}	4.6^{a}	4.7^{a}	4.6^{a}
	W:SCG+LR		4.4a	5.0^{b}	4.7^{a}	4.5^{a}	4.9^{a}	4.7^{a}

Means with different superscript within a column are significantly different at $p \leq 0.05$. W: Whole wheat grain bread (Control bread), W: SCG: Whole wheat grain bread supplemented with spent coffee grounds, W: SCG+LR: Whole wheat grain bread supplemented with spent coffee grounds, juice of lemon fruit and juice of rosemary leaves.

The control bread from the Gihundo varieties were preferred the most (p≤0.05) probably due their crust colour which was the brownest (Table 2). The W: SCG and W: SCG+LR bread (Table 4) received a lower score for colour than the control (p≤0.05), possibly because their colour was not brown enough (Table 2). On the other hand, the aroma and taste of W:SCG+LR bread were preferred the most (p≤0.05), probably due to the aromatic compounds from these ingredients (Allegrone et al., 2006). The W: SCG+LR bread from doughs fermented for 120 min scored higher in texture, aroma, taste, appearance and general acceptability, but lower in colour in comparison to the other bread from doughs fermented either for 60 min or 120 min. This could be related to the SCG+LR incorporation in the doughs and their long fermentation that may have favoured bread to become more porous and to have a pronounced flavour (Allegrone et al., 2006).

Conclusion

The wheat varieties, dough fermentation and incorporation of spent coffee grounds, lemon fruit juice and juice of rosemary leaves into dough, significantly affected the texture profile, colour, physical characteristics and sensory attributes of whole grain bread. The control bread from doughs fermented for 60 min were harder than the supplemented bread with the same time of fermentation. The long fermentation and the inclusion of spent coffee grounds, juice of lemon fruit and juice of rosemary leaves in doughs influenced low L*, a* and b* values and high general acceptability of the resulting bread in comparison to control bread. The obtained whole wheat bread satisfied consumers' preferences on the texture profile, colour and sensory attributes. Therefore, the application of spent coffee grounds, juices of lemon fruit and rosemary leaves in bread making represents a good opportunity at low cost.

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