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Effect of selected Rwandan wheat varieties on the physicochemical characteristics of whole wheat flour

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Effect of selected Rwandan wheat varieties on the physicochemical characteristics of whole wheat flour

Abstract: The present study aimed to evaluate the effect of the wheat varieties newly introduced in Rwanda on the physicochemical characteristics of their whole wheat grains in order to know their potentials for processing. Gihundo wheat grain variety had the highest values for extraction yield (99.20 %), contents of ash (1.47 %) and total dietary fiber (15.97 %), water absorption capacity (89.00 %), dough development time (7.62 min) and brightness (84.67 %). For the same physicochemical characteristics, whole flour from Nyaruka wheat variety showed the lowest values for extraction yield (96.20%), water absorption capacity (80.00 %), dough development time (6.33 min) and brightness (80.33), while whole flour from Reberaho wheat variety exhibited the lowest values for the contents of ash (0.98 %) and total dietary fiber (12.44 %). The protein content ranged between 10.00 % and 10.85 % for whole flours from all wheat varieties. The results showed that whole flour from Gihundo wheat grain variety exhibited high values for most of the physicochemical characteristics determined in comparison to the other three varieties. It is important to select grains or flour from these wheat varieties newly introduced in Rwanda based on the individual cultivar because their derivative products could have a more desired quality.

Key words: physicochemical characteristics; whole wheat flour; wheat varieties

Vpliv izbranih ruandskih sort pšenice na fizikalno-kemijske lastnosti polnozrnate pšenične moke

Izvleček: Cilj raziskave je bil proučiti vpliv v Ruandi na novo vpeljanih sort pšenice na fizikalno-kemijske lastnosti pripadajočih celih zrn z namenom prepoznave njihovega potenciala za nadaljnjo predelavo. Zrna iz pšenice sorte Gihundo so imela največji izplen moke pri mletju (99,20 %), polnozrnata moka je vsebovala največ pepela (1,47 %), največ skupne prehranske vlaknine (15,97 %), imela je najboljšo sposobnost vezave vode (89,00 %), najdaljši razvoj testa (7,62 min) in bila je najbolj svetla (84,67). Za iste fizikalno-kemijske lastnosti je polnozrnata moka iz sorte Nyaruka dosegla najmanjši izplen meljave (96,20 %), najslabšo sposobnost vezave vode (80,00 %), najkrajši razvoj testa (6,33 min) in bila je najbolj temna (80,33), medtem, ko je polnozrnata moka iz sorte Reberaho vsebovala najmanj pepela (0,98 %) in skupne prehranske vlaknine (12,44 %). Vse štiri pšenične polnozrnate moke so vsebovale med 10,00 % in 10,85 % beljakovin. Rezultati so pokazali, da je imela polnozrnata moka iz pšenice sorte Gihundo v primerjavi z mokami iz zrn ostalih treh sort boljše vrednosti za večino fizikalno-kemijskih parametrov. Pomembno je izbrati pšenična zrna ali moko iz tistih zrn na novo vpeljanih sort v Ruandi, ki imajo najboljše lastnosti, saj lahko to vodi k večji kakovosti izdelkov.

Ključne besede: fizikalno-kemijske lastnosti; polnozrnata pšenična moka; sorte pšenice

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1 INTRODUCTION

Whole wheat flours have been gaining an increase in demand and utilization for their nutritive value and health benefits in different food products for human consumption worldwide. AACC (2000) defines whole grain flour as flour which consists of the intact, ground, cracked or flaked caryopsis, whose principal anatomical components (the starchy endosperm, germ, and bran) are present in the same relative proportions as they exist in the intact caryopsis. Whole grain flour contains more vitamins, minerals, antioxidants, bioactive phytochemicals and dietary fiber than refined flour (Chung et al., 2009; Adom and Sorrells, 2005; Slavin, 2004). Due to health promoting effects of phytochemicals and dietary fiber, an increased consumption of whole grains is recommended (Seal, 2015).

While the extraction yield affects the (dough) farinograph test properties of whole wheat flours, these phytochemical compounds can also affect the quality of the end-use products such as low loaf volume and dense crumb structure, grainy, nutty and bitter flavors (Heinio, 2009; Chang and Chambers, 1992), and darker crumb and crust color (Lebesi and Tzia, 2011). Among the phytochemicals, carotenoids and phenolic compounds such as anthocyanins can act as antioxidants and impact the color and flavor of the food product (Rao and Rao, 2007). On average, the total carotenoid content was 2.57 mg kg^{-1} for the whole wheat grain, 1.92 mg kg^{-1} for the endosperm, 9.11mg kg^{-1} for the germ and 0.74 mg kg^{-1} for the bran. Those values for the endosperm, the germ and the bran were calculated based on seed fraction mass proportions to whole grain (Ndolo and Beta, 2013). Therefore, depending on the varieties, the physicochemical characteristics of whole wheat grains would significantly differ and influence the processing and quality of end-products. Some physicochemical attributes of the grains and flours of these new wheat varieties released in Rwanda in 2017 have not yet been determined so far in order to provide industries and consumers wheat with preferred specific quality traits and functionality (MINAGRI, 2017; Newtimes, 2017; RAB, 2017). This may often result in promising wheat cultivars that can be rejected by a farmer, seller, processor or consumer (Battenfield et al., 2016). With regard to this, the present study aimed to determine the physicochemical characteristics of whole wheat grains which can influence the quality of their based products.

2 MATERIALS AND METHODS

2.1 COLLECTION OF THE SAMPLES

Four (4) dry wheat grain varieties namely TAI, EN161, Eagle10 and Korongo with their 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 in RAB farms at the same location and under the same agro ecological conditions in the crop year 2019.The wheat grains were sampled in the same year, packed in high density polyethylene bags and stored at room temperature prior to milling.

2.2 PREPARATION OF THE RAW SAMPLES

2.2.1 Wheat grains milling

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) in order to get a fine particle size whole wheat flour. AACC (2003) method was used to calculate the amount of water to be added for wheat grains tempering:

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

The conditioned wheat grains of each variety were wholly milled for 15 min by using a laboratory hammer mill (CM 1090 Cemotec, 2009, China). All bran and germ were mixed with the flour. The flour was packed in high density polyethylene envelop and stored at -20 °C until the day of analysis.

2.3 DETERMINATION OF PHYSICOCHEMICAL CHARACTERISTICS

2.3.1 Moisture content of whole wheat flour

Moisture content of the whole wheat flour was determined using moisture analyser (Model: HE 53/01, Mettler Toledo, China).

2.3.2 Ash content of whole wheat flour

Ash content of the whole wheat flour was determined by AOAC (2005) method using a muffle furnace (Lindberg/Blue 1100°C Box furnace BF 51800 series Ashville, NC).

2.3.3 Total fat content of whole wheat flour

Total fat content was determined by AOAC (2005) method using Soxhlet extraction procedure.

2.3.4 Total protein content of whole wheat flour

Total protein content was determined by AOAC (2005) method using the Kjeldahl procedure.

2.3.5 Total dietary fiber content of whole wheat flour

Total dietary fiber content was determined by AOAC (2005) method where the extraction was done using petroleum ether.

2.3.6 Total carbohydrate content of whole wheat flour

Total carbohydrate was determined by AOAC (1990) method.

$$Total\ carbohydrate = 100 - (Protein\ \% + Fat\ \% + Ash\ \% + Moisture\ \%).$$

2.3.7 Bulk density of whole wheat flour

The bulk density was determined as described by Khalid et al. (2017). The flour samples were gently filled into 10 ml graduated plastic cylinders. The bottom of the cylinder was gently tapped on a laboratory bench covered with foam several times until there was no further diminution of the sample level. The mass of the sample was calculated and the bulk density was calculated as mass of sample per unit volume of sample (g ml^{-1}).

2.3.8 Oil absorption capacity of whole wheat flour

The oil absorption capacity was determined as described by Khalid et al. (2017). Each sample of 0.5 g was mixed with 6 ml of mustard oil in pre-weighed centrifuge tubes. The contents were vortexed for 1 min to disperse the sample in the oil. The samples were then kept for 30 min in vertical positions and then subjected to centrifugation of 3000 rpm for 15 min (3-18KS, Sigma Laborzentrifugen GmbH, Germany). The layer of the oil was removed by pipette and the tubes were kept in inverted position for 10 min to drain the oil before reweighing. The gain in mass was expressed as grams of oil absorbed per gram of flour.

2.3.9 Wheat grain hardness

The wheat hardness was determined as described by Manley (1995).The ground grain samples were obtained by passing the whole wheat grain (15.5 % moisture content) through a Model 3100 hammer mill (Falling Number AB, Huddinge, Sweden) equipped with 1mm screen. The wheat hardness was calculated as the % of ground wheat grain (10 g) forcing through 75 micrometer air jet sieve in 90 s. The mass less than 4.0 g indicated a hard wheat, while 4.0 g or more indicated a soft wheat.

2.3.10 Extraction yield of whole wheat flour

The flour extraction yield was determined as a percentage of all bran and germ mixed with the flour from the mass of grains milled (AACC, 2000):

$$\%\ flour\ yield = \frac{Mass\ of\ whole\ wheat\ flour\ collected}{Mass\ of\ wheat\ milled}\ X\ 100$$

2.3.11 Farinograph test of whole wheat flour

The farinograph parameters were determined using CW Brabender Instruments, inc., Germany following the AACC method (AACC, 2000). The flour sample was placed into a mixing bowl and distilled water was added up to the optimum dough consistency (500 BU). The water absorption, dough development time, dough stability time and mixing tolerance index during mixing were evaluated from the farinograph.

2.3.12 Color of whole wheat flour

The color was determined by a color reader (CR-10, Konica Minolta,inc. Japan) on the basis of L*, a* and b* values.

2.4 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 the Tukey post hoc test and least significant difference was accepted at $p \leq 0.05$.

3 RESULTS AND DISCUSSION

3.1 EFFECT OF WHEAT VARIETY ON GRAIN HARDNESS, EXTRACTION YIELD AND ON THE PROXIMATE COMPOSITION OF WHOLE WHEAT FLOURS

The extraction yield was between 96.20 % and

Table 1: Effect of wheat variety on grain hardness, extraction yield and on the proximate composition of whole wheat flours

Wheat variety grains	Grain hardness (g)	Extraction yield (%)*	Moisture content (%)	Total protein content (% dmb)	Ash content (% dmb)	Total fat content (% dmb)	Total carbohydrate content (% dmb)	Total dietary fiber content (% dmb)
Gihundo	$3.03^{a} \pm 0.10$	$99.20^{c} \pm 0.12$	$11.73^{b} \pm 0.25$	$10.85^{a} \pm 0.15$	$1.47^{c} \pm 0.31$	$1.61^{c} \pm 1.11$	$74.34^{a} \pm 1.19$	$15.97^{c} \pm 0.99$
Kibatsi	$3.36^{b} \pm 0.01$	$97.70^{b\pm}$ 0.04	$11.56^{a} \pm 0.02$	$10.45^{a} \pm 1.03$	$1.31^{b} \pm 0.98$	$1.76^{d} \pm 0.23$	$74.92^{b} \pm 1.56$	$14.97^{b} \pm 0.22$
Nyaruka	$3.86^{c} \pm 0.02$	$96.20^{a} \pm 0.10$	$12.07^{c} \pm 0.10$	$10.00^{a} \pm 0.61$	$1.38^{b} \pm 0.93$	$1.46^{b} \pm 0.01$	$75.09^{c} \pm 0.99$	$15.01^{bc} \pm 0.11$
Reberaho	$3.82^{c} \pm 0.21$	$96.50^{a} \pm 0.13$	$12.09^{c} \pm 0.01$	$10.30^{a} \pm 0.95$	$0.98^{a} \pm 0.22$	$1.38^{a} \pm 2.09$	$75.28^{d} \pm 0.19$	$12.44^{a} \pm 0.04$

Values are means ±SD of 3 replications. Treatment means followed by different letters in the same column are significantly different at $p \leq 0.05$. dmb: Dry mass basis. *Percentage of all bran and germ mixed with the flour from the mass of grains milled.

99.20 % and grain hardness was from 3.03 g to 3.86 g. The results for extraction yield were in the range with those reported by Cauvain (2015). As the product was the whole wheat flour, the wheat milling extraction was supposed to be 100 %. However, the flour yield was not 100 % due to that some quantities of the flour were held, disappeared in parts of the mill and were not collected into the vessel. During brushing the flour off the parts of the hammer mill, some few quantities of it were also transported/conveyed by air. The highest flour yield of Gihundo variety may be due to the low grain hardness (Table 1), producing a lower quantity of damaged starch and tailings during the milling process. The extraction yields of Nyaruka and Reberaho wheat varieties were not significantly different ($p > 0.05$) and were the lowest. The level of extraction yield indicated the particle size of the wheat flour. This means that when the yield was high, the particle size of the flour was small. The results showed that all wheat grains were possibly hard as their results were below 4 g or 40 % (Manley ,1995).

The results for total protein content were between 10.00 % and 10.85 %. There was no significant difference in protein content ($p > 0.05$) among whole wheat flours from the four wheat varieties, may be because they were grown at the same location and under the same agro ecological conditions. Wheat flours from all varieties could possibly fall under all purpose flour category as their protein contents were not below 9 % or above 12 % (Chu, 2004). Moisture content ranged from 11.56 % to 12.09 %. The moisture contents of the wheat flours from Nyaruka and Reberaho varieties were not significantly different ($p > 0.05$) and were higher than those from the other two wheat varieties. Increase in moisture content could have been associated with increase in fibre (Maneju and Udobi, 2011). Excess moisture content above 12 % may be detrimental as it can lead to mould growth, toxin formation, insect infestation, sprouting in storage (Ezeama , 2007) and has the effect of reducing the protein content as a percentage of total mass. On the other hand, grain with excessively low moisture would result in a hard grain with low flour yield (Mishra, 2016).

The content for ash was between 0.98 % and 1.47 % and the content for total dietary fiber was from 12.44 % to 15.97 %. The ash content results were in line with 0.42 % found by Khalid (2017) and from 1.46 to 1.56 % reported by Mishra (2016). Khalid et al. (2017) worked on the proximate composition of the native and irradiated whole wheat flour from wheat grains var. WH-1021, while Mishra (2016) compared the proximate composition of whole wheat flours and wheat flours made from five wheat cultivars (Advance, Prevail, Select, Brick and Forefront). The results for dietary fiber levels were similar to those found by Bressiani et al. (2016), where they were between 12.45 % and 15.95 % in the study done on the effect of particle size on the damaged starch content, proximate composition, gluten content, phenolic content and free sulfhydryl groups of fine whole wheat flour, medium whole wheat flour and coarse whole wheat flour from BRS Guabiju, wheat variety. There was a significant difference ($p \leq 0.05$) of the ash and dietary fiber contents among whole wheat flours from all wheat varieties. The ash content may have differed due to mineral content which varied according to wheat cultivar (Bressiani et al.,2016) and the amount of minerals in flour which increases with extraction rate (Scade, 1975). The extraction yield may have influenced the levels of ash and dietary fiber of whole wheat flour because generally when extraction yield is high, the ash and dietary fiber contents are high as well. It is explained by the fact that the bran portion which is the main source of ash and dietary fiber could be highly concentrated in flour when there was a high extraction yield. Therefore, it could be the reason why the whole wheat flour from Gihundo variety had the highest ash and dietary fiber contents, while the whole wheat flour from Reberaho variety had the lowest ash and dietary fiber contents. The high ash content of the flour indicates that whole grain flour could be an important source of minerals. Increased dietary fibre content of the flour has several health benefits; it aids in the digestion of the bread in the colon and reduces constipation often associated with bread produced from white wheat flour (Jideani, 2009). Dietary fibre plays a significant role in the prevention of several diseases such as cardiovascular diseases, diverticulosis, constipation, irritable colon, cancer and diabetes (Slavin, 2005).

The minimum and maximum total fat contents were 1.38 % and 1.76 %, respectively. Fat content differed significantly ($p \leq 0.05$) from one type of whole wheat flour to another one. Flour from Kibatsi had the highest fat content, while flour from Reberaho wheat variety had the lowest fat content. Wheat grains with a high amount of germ could have given whole wheat flours with a high amount of fat (Mishra, 2016). Fat plays a significant role in the shelf life of food products and as such relatively high fat content could be undesirable in food products. This is because fat can promote rancidity in foods, leading to development of unpleasant and odorous compounds. Bread loaf volume can increase with free polar fat contents that are naturally present in a particular cultivar, mostly when utilized samples are from pure wheat breeding lines (Chung et al.,1982). In the study of investigating the relationships between textural qualities of noodles and flour lipids, Qiyu and Siyuan (2009) found that as the free lipid content of the flour was increased, hardness of noodles linearly increased, reaching a maximum at a level of 1.84 g 100 g^{-1} flour, thereafter falling to a low value. The same author reported that cohesiveness of noodles was significantly ($p \leq 0.05$) decreased due to removal of free lipid while the highest cohesiveness value was obtained at a free lipid content of 1.24 g 100 g^{-1} flour. A higher free lipid content in flour would reduce cohesiveness of noodles. According to these findings, whole wheat breads made from the analysed wheat varieties would be harder and less cohesive.

Total carbohydrate content ranged between 74.34 % and 75.28 %. There was a significant difference ($p \leq 0.05$) in carbohydrate contents among whole wheat flours from all wheat varieties, where whole wheat flours from Reberaho and Gihundo varieties had the highest and the lowest carbohydrate contents, respectively. B-vitamins and minerals from the wheat bran and germ of the whole wheat breads avail carbohydrate for proper assimilation in humans (Connection, 2017). Whole wheat flour from Reberaho wheat variety could be a good source of metabolisable energy and could assist also in fat metabolism because of its high carbohydrate content (Ifie, 2011).

3.2 EFFECT OF WHEAT VARIETY ON THE PHYSICAL PROPERTIES OF WHOLE WHEAT FLOURS

The range for oil absorption capacity was from 1.24 g g^{-1} to 1.45 g g^{-1}. These results were in line with the ones obtained by Khalid et al. (2017). Oil absorption capacity changed with the types of whole wheat flour, where Gihundo and Nyaruka varieties gave whole wheat flours with the highest and the lowest oil absorption capacity, respectively. The high amount of dietary fiber in Gihundo wheat flour (Table 1) might have been responsible for the high oil absorption capacity of the flour (Chou and Huang, 2003). The high oil absorption capacity makes the flour suitable in facilitating enhancement in flavor and mouthfeel when used in food preparations (Kaushal and and Kumar, 2012).

The results for bulk density of the whole wheat flours were between 0.32 g ml^{-1} and 0.56 g ml^{-1}. These results were near to those found by Offia et al. (2015). The bulk density of whole wheat flours from Kibatsi, Nyaruka and Reberaho did not differ significantly ($p > 0.05$). Flour from Gihundo wheat variety could be dense in comparison to flours from other wheat varieties, and it meant that Gihundo grain endosperm could be filled out better than the endosperm from the other variety grains. The high bulk density of flours suggests their suitability such as thickener in food products and for use in food preparations since it helps to reduce paste thickness which is an important factor in convalescent and child feeding (Kaushal and Kumar, 2012). In contrast, low bulk density would be an advantage in the formulation of complementary foods (Akpata and Akubor, 1999).

The results for least gelation concentration were in the range of 40.36 % and 70.23 %. Whole wheat flours

Table 2: Effect of wheat variety on the physical properties of whole wheat flours

Wheat variety grains	Oil absorption capacity (g g^{-1})	Bulk density (g ml^{-1})	Least gelation concentration (%)
Gihundo	$1.45^{d} \pm 0.01$	$0.56^{b} \pm 0.13$	$70.23^{d} \pm 0.03$
Kibatsi	$1.31^{c} \pm 0.10$	$0.35^{a} \pm 0.09$	$56.23^{c} \pm 0.02$
Nyaruka	$1.24^{a} \pm 0.12$	$0.34^{a} \pm 0.01$	$40.36^{a} \pm 0.15$
Reberaho	$1.28^{b} \pm 0.01$	$0.32^{a} \pm 0.02$	$47.42^{b} \pm 0.21$

Values are means ± SD of 3 replications. Treatment means followed by different letters in the same column are significantly different at $p \leq 0.05$.

from Gihundo and Nyaruka varieties were the highest and the lowest in least gelation concentration, respectively. The lower the least gelation concentration, the better is the gelating ability of the protein ingredient and the swelling ability of the flour is enhanced (Kaushal and Kumar, 2012). The low least gelation concentration of wheat flour may be an asset as an additive to other gel forming materials in food products.

3.3 EFFECT OF WHEAT VARIETY ON THE FARINOGRAPH TEST PROPERTIES OF WHOLE WHEAT FLOURS

The range for water absorption capacity was between 80 % and 89 %. The range for those results included 0.85 g g^{-1} (85 %) found by Khalid et al. (2017) for wheat grains var. WH-1021 in the study on physico-chemical properties of native and irradiated whole wheat flour. Gihundo variety followed by Kibatsi variety gave whole wheat flours with high values of water absorption capacity in comparison to Nyaruka and Reberaho varieties. The last two were not significantly different ($p > 0.05$) in water absorption capacity. Maghirang et al. (2006) reported that an increase or decrease in water absorption capacity may be explained by differences in flour extraction yield and presumably higher starch damage content as well, after finding that some wheat varieties with differences in grain protein content had similar water absorption requirement. Similarly, to this report, the total protein contents of whole wheat flours from all wheat varieties (Table 1) were not significantly different ($p \le 0.05$), but the flours with high extraction yield (Table 1) showed high water absorption capacity. Sluimer (2005) also showed that water absorption increased with increasing extraction rate. It could be the reason why the high extraction yield (Table 1) impacted the whole wheat flours from Gihundo and Kibatsi varieties to require a high amount of water to center the farinograph curve on the 500-Brabender Unit (BU) line compared to flours from other remaining wheat varieties. The small particle size of bran and high amount of fiber in the flour might have been responsible for high water absorption capacity as reported by Chou and Huang (2003). Water absorption is a key parameter in the purchase of flour for breadmaking (Webb and Owens, 2003).The high water absorption capacity of the flours may assure product cohesiveness (Houson and Ayenor, 2002).

The time for dough development was between 6.33 min and 7.62 min and for stability, it was between 10.72 min and 11.65 min. Gihundo variety followed by Kibatsi variety produced whole wheat flours with long development time in comparison to Nyaruka and Reberaho varieties. The last two were not significantly different ($p > 0.05$) in development time. As the dough development time is the time taken from when water is added up to when the dough reaches maximum consistency, the results indicated that whole wheat flours from Nyaruka and Reberaho varieties took short time for optimum mixing compared to flours from Gihundo and Kibatsi varieties. The stability time shows the maximum consistency for a dough and is a good indication of its strength. Flours from Nyaruka and Gihundo varieties took the longest and the shortest time, respectively, for dough stability. Thus, the dough obtained from Nyaruka wheat variety lasted long with high consistency, while similar consistency for the dough from Gihundo wheat variety lasted a short time. The results for dough development time (DDT) and dough stability time ranged in the results found by Bressiani et al. (2016). In the time evaluation of the effect of particle size on mixture properties, extensional properties and paste properties of refined flour and whole grain wheat flour from BRS Guabiju, wheat variety, those authors reported between 7.60 min and 12.93 min for DDT, between 11.6 min and 12.8 min for dough stability for fine whole grain wheat flour, medium whole grain wheat flour and coarse whole grain wheat flour. For the flours which showed low dough development and stability time, they could have been affected by weakened gluten network with fiber-rich bran particles (Bae et al., 2014).

Table 3: Effect of wheat variety on the farinograph test properties of whole wheat flours

Wheat variety	Water absorption capacity (%)	Dough development time (min)	Dough stability time (min)	Mixing tolerance index (BU)
Gihundo	$89.00^{c} \pm 0.09$	$7.62^{c} \pm 0.07$	$10.72^{a} \pm 0.03$	$22.88^{d} \pm 0.11$
Kibatsi	$85.00^{b} \pm 0.03$	$6.73^{b} \pm 0.12$	$12.09^{c} \pm 0.02$	$24.73^{c} \pm 0.01$
Nyaruka	$80.00^{a} \pm 0.10$	$6.33^{a} \pm 0.01$	$13.12^{d} \pm 0.10$	$20.17^{a} \pm 0.25$
Reberaho	$81.00^{a} \pm 0.15$	$6.79^{a} \pm 0.04$	$11.65^{b} \pm 0.12$	$21.02^{b} \pm 0.02$

Values are means ± SD of 3 replications. Treatment means followed by different letters in the same column are significantly different at $p \le 0.05$.

Mixing tolerance index (MTI) was from 20.17 BU to 22.88 BU. Mixing tolerance index highly differed ($p \leq 0.05$) in whole wheat flours obtained from all wheat varieties. Whole wheat flour from Gihundo and Kibatsi varieties showed the highest and the lowest values of mixing tolerance index, respectively. This indicated that dough from Gihundo variety whole wheat flour was hard and dough from Kibatsi variety whole wheat was soft during mixing. The hardness of dough mixing could contribute to firm product texture. Mishra (2016) who compared the farinograph parameters among ground whole wheat flours and flour incorporated with treated bran, found the results in same range, where MTI was between 18.13 BU for ground whole wheat flours from five wheat cultivars (Advance, Prevail, Select, Brick and Forefront).

3.4 EFFECT OF WHEAT VARIETY ON THE COLOR OF WHOLE WHEAT FLOURS

The color ranged between 80.33 and 84.67, 1.4 and 2.30 and 10.14 and 10.67 for L*, a* and b* values, respectively. Gihundo variety followed by Kibatsi variety produced whole wheat flours with high L*values in comparison to Nyaruka and Reberaho varieties. The last two were not significantly different ($p > 0.05$) in L* values. The results indicated that whole wheat flour from Gihundo variety was brighter than the remaining flours. The whole wheat grain with high flour extraction yield produces a fine size flour containing high amounts of bran and germ, which later can make the flour to be less bright (Maghirang et al., 2006). This assumption was not the case for whole wheat flours from Gihundo and Kibatsi varieties which demonstrated the highest yield extraction (Table 1). Thereby, the flour brightness was considered to mainly be caused by the wheat cultivar (Maghirang et al., 2006). Redness (a*) and yellowness (b*) values were not significantly different in whole wheat flours from all wheat varieties ($p > 0.05$). Anthocyanins and carotenoids, located mainly in the germ and bran, may have contributed to the colors of the whole wheat flour (Schwinn, 2004; Rao and Rao, 2007). Anthocyanins are phenolic compounds (flavonoids), responsible for most blue to blue-black, and red to purple colors of diverse plant organs (Schwinn, 2004). Meanwhile, carotenoids are responsible for the yellow, orange and red colors in various plants (Rao and Rao, 2007). The beneficial effect of wheat bran against colon cancer is attributed to the presence of a high concentration of polyphenolic compounds, which are likely released into the colon as a result of bacterial fermentation (Monica and Whole Grain Connection, 2017). The obtained L*, a* and b*values were very close to those found by Mishra (2016). The author obtained 82.08, 1.71 and 10.64 for L*, a* and b* average values, respectively, for whole grain flour from five hard red spring wheat cultivars.

4 CONCLUSION

The results showed that the wheat varieties affected the extraction yield and other qualities of their whole wheat grain flours. The proximate composition was significantly different among whole wheat flours from the wheat grain varieties, except protein content. Gihundo and Nyaruka wheat grain varieties have the highest and the lowest extraction yields, respectively. The farinograph test parameters of the doughs were impacted by wheat varieties. The whole wheat flour brightness was considered to mainly be caused by the wheat cultivar. Beyond the quantity and economic reasons that most of bakeries qualify wheat grains by their extraction yields, it is also important to consider other qualities such farinograph (dough) test characteristics, color and proximate composition to select grains or flour from these wheat varieties newly introduced in Rwanda based on the individual cultivar because their derivative products could have a more desired quality for competitive markets. For their nutritive value and health benefits, whole wheat flours have been gaining an increase in demand and utilization in different food products for human consumption worldwide.

Table 4: Effect of wheat variety on the color of whole wheat flours

Wheat variety grains	Extraction yield (%)	L*	a*	b*
Gihundo	$99.20^{c}\pm1.40$	$84.67^{c}\pm1.04$	$1.50^{a}\pm3.01$	$10.67^{a}\pm 3.07$
Kibatsi	$97.70^{b}\pm0.22$	$82.67^{b}\pm 2.08$	$1.90^{ab}\pm0.27$	$10.23^{a}\pm 0.54$
Nyaruka	$96.20^{a}\pm1.01$	$80.33^{a}\pm1.04$	$2.10^{b}\pm 1.04$	$10.47^{a}\pm1.50$
Reberaho	$96.50^{a}\pm1.82$	$80.52^{a}\pm 3.03$	$2.30^{b}\pm0.58$	$10.14^{a}\pm1.04$

Values are means ± SD of 3 replications. Treatment means followed by different letters in the same column are significantly different at $p \leq 0.05$. % Percentage of all bran and germ mixed with the flour from the weight of grains milled.

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