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Effect of different sources of starch on Sudanese wheat flour bread quality

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ABSTRACT

Sudanese wheat flour (Imam) of 72% extraction rate and decorticated lentil flour were used in the study. Ratios of starch used in wheat flour for making bread was 5, 10 and 15%, whereas ratios of lentil flour was 5%. Proximate composition and mineral content were carried out for wheat flour extraction rate 100%, 72% and lentil flour. Loaf bread specific volume and sensory evaluation of the produced bread were investigated. From the results it could be observed that quality attributes of sensory evaluation of the blends of bread was found to be very good in spite of low bread Specific volume.

Keywords: *Loaf bread specific volume, proximate composition, sensory evaluation, starch, wheat flour.*

INTRODUCTION

Starch is a large polysaccharide, of considerable industrial importance particularly to the food and is mainly compose of amylose and amylopectin **(**Englyst and Hudson, 1997). It occurs in seeds and fruits, in tubers and pithy stems and in leaves, although in the last instance its presence is only transitory, the starches present in, or obtained from, cereals, tubers and roots are of sufficient interest to warrant detailed consideration. These include the cereal starches of corn, wheat, rice etc… and the non-cereal starches finding application to various degrees in baking, such as tapioca starch, potato starch, arrowroot starch, etc. these starches, while similar in their over-all characteristics, differs nevertheless in many essential properties which govern their suitability for certain specialized applications (Pyler,1973). Wheat starch makes up to 80% of wheat meal and has a great impact on the functionality of wheat products. Sorghum starch plays an important role in the production of many sorghum-based food products, including bread (Schober *et al.,* 2005). Starch is the main carbohydrate component of pearl millet grain and is smooth with a gel viscosity (Burton *et al.*, 1972). Rice is an excellent source of energy, in the form of starch, and it gives the benefit of providing proteins with a higher nutritional quality than those of other cereal grains (Moldenhauer *et al.*, 1998). It contains up to 75% starch depending on the variety. Starch is the main constituent of cassava, about 25% starch may be obtained from mature good quality tubers, about 60% starch may be obtained from dry cassava chips and about 10% dry pulp may be obtained per 100 kg of cassava roots. Cassava starch has many remarkable characteristics including high paste viscosity, high paste charity and high freeze-thaw stability, which are advantageous to many industries. Breads, sweet-dough products, biscuits, cookies, crackers and cakes are common bakery products that are widely consumed throughout the world. Bakery products are no longer considered fancy or luxury teatime snacks, but have become essential and significant components of the dietary profile of the population (Chavan and Kadam, 1993). Bread baking quality is dependent not only on protein quantity but also on its quality. Therefore many extensive works were performed on gluten protein and the real ability of crude gluten as an indicator of flour strength for baking products. Technological quality of wheat is strongly related to the storage proteins (gliadin and glutenin) and characteristics of both of these proteins must be considered when attempting to explain the quality variation observed among different wheat Anjum and Walker (2000). Starch is another important bio-component of cereal products and its gelatinization induces major structural changes during baking. It was found that the swollen and partially solubilized starch granules act commonly with wheat proteins as essential structural elements of baking products (Baszczak *et al.*, 2000 and Fornal, 1998). Composite flour may be considered a combination of wheat and non-wheat flour for the production of leavened bread, other baked products and pastas, or wholly non-wheat flour prepared from mixture of flours from cereals, root tubers, legumes raw materials, to be used for traditional or novel products (Dendy**,** 1992). The composite flours containing wheat flour usually consisted of 70% wheat flour, 25% maize/cassava starch and 5% soy flour. But there were tests in which the composite flour contained no wheat flour at all for example 70% cassava flour or starch and 30% peanut and/ or soy flour. When bakery products are made from composite flour; their overall quality (odor and flavor, chewing properties, appearance, shelf life) should be as similar as possible to those of products made from wheat, to achieve this, the wheat flour contained in the composite flour must be suitably treated. Flour milled from local crops is used with imported wheat supply to save some of the foreign currency. This arrangement is particularly appropriate for developing countries which do not grow wheat. Satisfactory bread can be made from such composite flour, a blend of wheat flour with flour of either cereals such as maize, sorghum, millet or rice, or with flour from roots crops such as cassava (Kent and Evers, 1994). A more economical blend, producing acceptable bread, is 50%, 10% and 40% wheat, rice and cassava respectively. Rice starch used at 25% with 75% wheat flour yielded acceptable bread (Bean and Nishita, 1985). Perten (1995) stated that quality factors such as loaf volume and water absorption are related to gluten quality and quantity, higher gluten quantity values generally give a greater bread volume. Basically, strong flours must be used for making good bread. If weak flour is used, loaves of small volume are produced. Kaldy and Rubenthaler (1987) reported that a fine uniform crumb texture that is tender and moist is one of the main criteria for good bread quality. Generally, flour with high protein content or strong gluten or both, produces a coarse or heavy crumb texture. The objective of this study was studying the effect of starch on bread quality and Sensory evaluation of the produced products.

Material and methods:

Samples were brought from Agricultural Research Corporation. Chemicals and reagents were obtained from Food Research Center and local market.

Preparation of starch:

Wheat, Sorghum, Millet, Rice and Cassava were cleaned from impurities and foreign matter and prepared for extraction of starch by using Wet Milling process.

Preparation of wheat flour and lentil flour:

Wheat was cleaned manually using 2.8 micron sieve for removing of impurities. The sample of wheat was tempered for 17 hours to obtain 14.5% grain moisture, and then milled in a Chinese flour mill with the capacity of 5tons/day (GFY-5). The flour was adjusted to 72% extraction rate by sifting using 180 micron sieve. The sample was well mixed and placed in air-tight plastic container, then stored under appropriate conditions (Deep freezer). Lentil (Abu Gibbaa) was decorticated using Stone Mill at Omdurman Local Market. The decorticated seeds were ground into flour using an efficient universal pulverizer, (GF 300, serial number 69578, and powder fineness 90 – 120 mesh – Shanghai).

Preparation of Composite Flour Blends:

The starch of each sample of wheat, sorghum, millet, rice and cassava was added to wheat flour with three different percentages 5%, 10% and 15%with5% of lentil flour added to each of the three blends in order to compensate for the loss of protein content expected from starch addition.

Analytical Methods:

Analysis was carried out for wheat and lentil flours. The Moisture content was determined according to the method of A.A.C.C (2000) by using Buhler Rapid Moisture Tester (Model ML 11000). The ash content of the sample was measured according to the A.O.A.C method (2000) using the muffle furnace (Carbolite Company). Protein was determined according to A. O. A. C. method (2000) by micro Kjeldahl technique. Total fat was determined according to the A.O.A.C method (2000). Mineral contents were determined according to Pearson (1970).

Processing of the bread samples

The bread-baking test for assessing the quality of wheat flour and blends were carried out according to the method of Badi *et al.*, (1978). Bread flour sample (100% wheat flour) and blends of wheat flour (5%, 10% and 15% starch) with 5% lentil flour were prepared into bread. The ingredients used in bread making were as follows:

Item	Quantity (g)
Flour	250
Yeast	2.5
Salt	1.5
Sugar	2.5
Improver (Banda) (Hemicellulose, Fungal alpha amylase , pentosanase, lipase, oxidase glucose and ascorbic acid)	0.025

The amount of water used for the wheat flour and blends was added according to water absorption of the farinograph. All the ingredients were weighed and mixed to form dough in mono- universal laboratory dough mixer for 5 minutes at medium speed. The dough was allowed to rest for 10 minutes at room temperature (30 C°) then it was scaled to three portions of 120g each. The three dough portions were made into round balls and allowed to rest for another 15 minutes. Then molded up, put into pans, placed in the fermentation cabinet for final proof between 50 – 60 minutes. The fermented dough samples were baked in a Simon Rotary Test Oven at 220 – 250 C° with saturation of steam for 20 – 55 minutes. The loaves were then left to cool. The loaves were sliced with an electric knife, part of the slices were kept in polyethylene bags at room temperature for sensory evaluation in the same day.

Evaluation of bread quality

The bread made from wheat flour and different blends were cooled at room temperature (38±2C°) for an hour after baking and quality measures were made on triplicate loaves as follows:

Bread volume

The loaf volume expressed in cubic centimeters was determined by Seed Displacement Method according to pyler (1973). The loaf was placed in a container of a known volume into which small seeds (millet seeds) were run until the container is full. The volume of seeds displaced by the loaf is equal to the loaf volume.

Bread weight

The loaf weight of bread was taken in grams.

Bread specific volume

The bread specific volume of the loaf was calculated according to the AACC method (2000) by dividing the loaf volume by its weight (g).

Sensory evaluation of loaf bread

Loaf bread samples were assessed organoleptically according to procedure described by Ihekovonye and Ngoddy (1985). Sensory evaluation (color, odor, taste, crumb texture, crumb grain uniformity, and preference) was carried out by fifteen panelists. The evaluation depends on the range of 8 – 9 as excellent, 6 – 7 is very good, 4 – 5 is good, 2 – 3 is fair and 1 is poor.

Method of statistical analysis

The data were statistically analyzed by the Completely Randomized Design as described by Montgomery ((2001) and the mean differences were tested by Duncan Multiple Range Test (DMRT).

Results and discussion

Chemical composition of wheat flour extraction rate (100 and 72%) and lentil flour

The Chemical composition of wheat flour extraction rate (100 and 72%) and lentil flour is shown in table (1).

Moisture content

The moisture content of the whole wheat flour (100% extraction rate) and wheat flour (72% extraction rate) were found to be 8.73 and 11.81% respectively. These results were in a good agreement with the results obtained by Ahmed (2005), Mohamed (2000), Badi *et al.*, (1976) and Pareds – Lopez (1978) who found the values ranging between 7.00 to 7.90, 7.65 to 7.90, 10.00 to 11.00 and 11.20 % respectively. The moisture content of lentil is 7.97%. The value of moisture content of lentil flour agreed with values obtained by Sulieman (2007) who reported the range from 6.40 to 10.40% and similar to that reported by Muehlbauer *et al.*, (1985). Statistical analysis showed significant ($P \leq 0.05$) differences among the three samples.

Ash content

Ash content of wheat flour (100% extraction rate) and wheat flour (72% extraction rate) were found to be 1.66 and 1.00% respectively. These results are Comparable with results obtained by Ahmed (2005) and Mohamed (2000) who found the ranges were between 1.44 to 1.60 and 1.20 to 1.84% respectively. Abdalla (2002) found ash content as 1.50% .The ash content of lentil flour was found to be 3.53%. The result of ash content of lentil flour agreed with what was reported by Sulieman (2007) who found the ash content ranged between 2.70 to 3.80% and similar to that reported by Adsule *et al.*, (1989) and Muehlbauer *et al.*, (1985). Analysis of variance showed significant ($P \leq 0.05$) differences among the samples.

Protein content

The protein content of 100% extraction rate and 72% extraction rate wheat flours were found to be 14.87 and 13.87% respectively. These results are justified by results obtained by Ahmed (2013), Ahmed (2005), Yasar (2002), Abdalla (2002) and Mohamed (2000) who reported the protein content as 11.73, 10.44 to 14.97, 7.84 to 14.11 and 12.10% respectively. The protein content of lentil flour was found to be 29.60%. Adsule *et al.*, (1989) reported that the protein content of lentil ranged between 22.00 to 33.60%. Duke (1981) reported one hundred grams of decorticated lentil seeds contained 25.80 grams of protein**.** Sulieman (2007) found the protein content of lentil flour grown in Sudan ranged between 32.30 to 35.60% and Abd Elhady (2005) found that the protein content of lentil was 26.00%

Statistical analysis showed significant ($P \leq 0.05$) differences between the three different flour samples. The protein content of wheat is very highly influenced by environmental conditions, grain yield and available nitrogen as well as the variety genotypes reported by George (1973).

Fat content

Fat content of 100% extraction rate and 72% extraction rate wheat flour were found to be 2.30 and 1.82% respectively as shown in table (7). These results are in a good agreement with what was reported by Morrison (1978), El Agib (2002) and

Quisenberry and Reitz (1967) who found that the fat content of wheat flour was 2.90, 1.80 to 2.00 and 1.20 to 2.00% respectively. Fat content of lentil flour was found to be 1.07%. This result is lower than that reported by Duck (1981) and Hulse (1990). Decorticated lentil seeds contain 1.83g fat/100gm decorticated seeds (Hulse, 1990). Sulieman (2007) found that the fat content of lentil ranged from 1.95 to 2.40%. Hundred grams of dried lentil seeds contain 0.6g fat (Adsule *et al.*, 1989).

Statistical analysis showed significant ($P \leq 0.05$) differences between the results of wheat flour extraction rate 100%, 72% and lentil flour.

Carbohydrates

Carbohydrates content of the whole wheat flour (100% extraction rate) and white wheat flour (72% extraction rate) were found to be 72.44 and 71.50% respectively. The results were supported by Ahmed (2013) who reported the range between 70.30 to 72.78%. Ahmed (2005) found that the carbohydrate of wheat flour (100% and 72% extraction rate) of Debaira, Elnielain and Sasaraib ranged from 71.70 to 74.64%. El Agib (2002), Abdalla (2002) and Mohamed (2000) reported that the carbohydrates of Sudanese wheat cultivars were ranged between 72.20 to 80.60%. The carbohydrate of lentil flour was found to be 57.84%. One hundred grams of dried lentil seeds contain 65.00 grams total carbohydrate (Adsule *et al.*, 1989). Hulse, (1990) reported that one hundred grams of decorticated lentil seeds contain 58.90 grams of total carbohydrate. Sulieman (2007) found the carbohydrate content of lentil ranged from 47.04 to 52.63%.Statistical analysis showed highly significant ($P \leq 0.05$) differences between the results of different flours.

Mineral content

Table (2) showed the mineral content of wheat flour extraction rate 72% and lentil flour. Wheat flour extraction rate 72% was found to contain 63.33 mg/100g Sodium (Na), 483.33 mg/100gm potassium (K), 67.00 mg/100gm calcium (Ca), 106.67 mg/100gm phosphorous (P) and 2773.33 μ/g iron (Fe). The values obtained in this study are higher than that obtained by Lorenz (1994) and Hassan (2007) for hard and soft wheat.

Betschart (1988) found that many factors influence mineral concentration which include; type and variety of wheat, field location, milling methods, and analytical methods. Lentil flour mineral content were 51.67mg/100 g sodium (Na), 303.33 mg/100 g potassium (K), 40.68 mg/100g calcium (Ca), 120.00 mg/100 g phosphorus (P) and 1733.33 μ/g iron (Fe) respectively. From the results it could be observed that the wheat flour contains higher level of sodium (Na), potassium (K), calcium (Ca) and iron (Fe) compared to lentil flour which contains high level of phosphorous. Statistical analysis showed significant ($P \leq 0.05$) difference between the two types in their calcium and phosphorus. On the other hand showed highly significant ($P \leq 0.05$) differences in their Sodium, potassium and iron content.

Baking test

Three percentages of five types of starch from different sources (5, 10 and
15%), (wheat, sorghum, millet, rice and cassava) with 5% lentil flour were used for baking test.

Specific loaf volume of wheat flour and wheat flour blends:-

Baking characteristics of wheat flour and wheat flour blends were shown in table (3) to (5) .From the results obtained, the loaf volume decreased significantly from 366.67, 380.00 and 435.00cc for control wheat flour bread to the range from 335.00 to 348.33cc for 5% starches blends bread. And decreased to the range from 300.00 to 336.67cc for 10% starches blends bread and to the range from 328.33 to 388.30cc for 15% starches blends bread respectively.

15% sorghum starch blend bread gave the highest volume of loaf bread, whereas 10% rice starch blend bread gave the lowest value compared to the other blends of starch bread. For 5% starches blends bread, the highest value of loaf volume was observed in 5% rice starch blend bread, while the lowest value was in 5% millet starch blend bread. 10% starches blends bread the highest loaf volume was observed in 10% wheat starch blend bread, while the lowest value was observed in 10% rice starch blend bread and for 15% starches blends bread the highest value of loaf volume was observed in 15% sorghum starch blend bread, while the lowest volume was in 15% rice starch blend bread.

Bread specific volume (cm^3/g) values of 10% starches blends bread ranged from 2.83 to 3.10 (cm^3/g). 10% wheat starch blend bread gave the highest value, while 10% cassava starch blend bread gave the lowest value of specific volume. Bread specific volume (cm^3/g) values of 15% starches blends bread ranged from 3.10 to 3.64 (cm^3/g). The highest value of specific volume was observed in 15 % sorghum starch blend bread, while the lowest value was in15% rice starch blend bread. These values were significantly lower than the specific volume of control wheat flour bread (3.49, 4.05 cm^3/g).

From these results, it can be concluded that the bread specific volume decreased with increasing level of starch percentage in blends, and 15% sorghum starch blend bread gave the highest value of bread specific volume compared to other starches blends percentages, whereas 10% cassava starch blend bread gave the lowest value.

Statistical analysis showed significant ($P \leq 0.05$) differences between wheat flour and wheat flour blends in their bread specific volume. These findings agreed with the results obtained by Mustafa *et al.*, (1986) who found that beyond 10% replacement of wheat flour by cowpea flour, the specific volume of the bread decreased. Mustafa (1976) also obtained similar results with 5% soy flour in bread. Dilution of gluten with the addition of non-wheat flours to wheat flour has been reported to be associated with loaf volume depression effect of composite flours **(**Deruiter, 1978, Chavan and Kadam (1993). Hassan (2007) reported that the use of decorticated pigeon pea flour beyond 10% has a negative effect on the loaf bread specific volume and incorporation of pigonpea protein isolate shows significant increase and higher volumes of loaf bread specific volume. Youssef and Bushuk (1986) mentioned that the proportion of non-wheat flour depends on the inherent strength of the wheat flour. These findings are supported by results reported by Mohamed (2000) and Ahmed (2005). These results were confirmed by data reported by Ahmed (1995) who showed that the bread specific volume of Sudanese wheat cultivars ranged between 3.25 to 3.95(cm^3/g). Ahmed (2005) found similar results that the bread specific volume decreased with increasing level of wheat bran in the blends. Mohamed (2000), Siddiq (1999) and Sid Ahmed (2003) reported that the bread specific volume ranged between 3.66 to 4.05 cm^3/g, 2.50, and 2.20(cm^3/g) respectively. High values of bread volume were reported by Hestangen and Frolish (1983) and Lukour (1990) 355 to 376(cm^3/g) and 376 (cm^3/g) respectively for Canadian wheat flour bread. Ahmed (2013) obtained bread specific volume for Sudanese wheat flour 2.89 (cm^3/g) without improver and 3.49 (cm^3/g) with improver. In general, the flours from stronger wheat cultivars can carry a higher percentage of the non-wheat products.

Organoleptic evaluation of loaf bread containing different levels of starchs:

Tables from (6) to (8) showed the sensory evaluation of bread from wheat flour and wheat flour blends. The control wheat flour (Imam) was found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and preference. Wheat flour bread with 5% and 15% wheat starch were found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and preference. Wheat flour bread with 10% wheat starch was found to be good in color, odor, taste, crumb texture, crumb grain uniformity and preference. This means that addition of wheat starch was having positive effect on quality attributes of sensory evaluation.

Bread with 5% and 10% of sorghum starch was found to be excellent in color and very good in odor, taste, crumb texture, crumb grain uniformity and preference by panelists. Wheat flour blends with 15% sorghum starch was found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and preference. This means that sorghum starch was having positive effect on color, odor, taste, crumb texture, crumb grain uniformity and preference.

Bread with 5% millet starch was found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and preference. Wheat flour bread with 10% millet starch was found to be excellent in color, odor, taste, crumb texture, and very good in crumb grain uniformity and preference. Bread with 15% millet starch was found to be very good in color, odor, taste, crumb texture, preference and good in crumb grain uniformity. This means that addition of millet starch was having positive effect and it is better than control in quality attribute of sensory evaluation and overall quality. Bread with 5% rice starch was found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and good in preference. Wheat flour bread with 10% and 15% rice starch were found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and preference. Also addition of rice starch has a good effect on quality attributes of sensory evaluation. Bread with 5% cassava starch was found to be good in color, odor, taste, crumb texture, crumb grain uniformity and preference. Bread with 10% cassava starch was found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and preference. Wheat flour bread with 15% cassava starch was found to be very good in color, taste, crumb texture, crumb grain uniformity and good in odor and preference. In general, also addition of cassava starch has positive effect on quality attributes of sensory evaluation similar to other starches.

Statistical analysis showed significant (P≤0.05) difference between 5% starches bread blends in their color, odor, crumb texture and preference. Also there is no significant difference between these blends in their taste and crumb grain uniformity

Analysis of variance showed significant (P≤0.05) difference between 10% starches blends bread in their quality attributes of sensory evaluation. On the other hand statistical analysis showed no significant difference in taste and crumb texture of 15% starches blends bread, and significant difference in color, odor, crumb grain uniformity and preference of the same blends. These results are in good agreement with the results obtained by Ahmed (2013) who found that the improver have a positive effect on quality attributes of the sensory evaluation.

From these results, it could be observed that starch has positive effect on taste; odor, crumb texture and crumb grain uniformity and has negative effect on bread specific volume.

Suielman (2005) found that 10% level of chick pea odor was dominated in the loaf. Hassan (2007) found that the high level of protein (25%) in the blends gave the lowest quality attributes of sensory evaluation and overall quality. Gur and Janette (1988) reported that the dark crumbs were related to the presence of high ash content. Michael *et al.,* (1989) observed a gritty texture when cereal brans were added to the formulation of baked goods.

Physiochemical properties of cassava starch are suitable for supplementation of wheat flour in bread-making without compromising its sensory attributes (Eduardo *et al.,* 2013). Sim (2001) reported that the intake of bread is often enhanced by taste. Color of bread crust is important sensory attribute, which can enhance acceptability. The local populating thinks that pale colored bread crust is indicative of improper baking. Besides it is assumed that the brown color is what imparts nutrients, especially iron on the product. Browning of bread crust is an origin of Millard reactions during baking in the presence of amino acids, reducing sugars, temperature, time of baking and moisture levels of the fermented dough (Dendy, 2013).

Eduardo *et al.,* (2013) obtained that food texture sometimes embraces appearance. Udofia *et al.,* (2013) found that high supplementation of non-wheat flour showed low scores on texture, also reduces elastic properties of wheat flour dough rendering the dough incapable of retaining the gas emanating from fermentation. Preference is often influenced by prejudices, religious principles, group conformance, status value and snobbery, in addition to the quality of the food. People have preferences, no matter how illogical they may appear. Therefore, the parameters are difficult parameters to determine in a new product development (Sim, 2001). According to Giami *et al.,* (2004) and Akobudu (2006), up to 20% substitution of cassava flour had no adverse sensory and organoleptic effect on bread, while more development was still being expected.

Eddy *et al., (*2007) found that bread baked with 10% and 20% supplementation with cassava composite flour was not significantly different in most sensory attributes, acceptability and readiness to buy from the control.

Conclusion

- 15% sorghum starch blend bread showed high specific volume, while panelists prefer 10% millet starch blend bread.
- The use of different starches for bread making has a positive effect on taste, odor, crumb texture and crumb grain uniformity.
- The best bread was produced by adding 15%sorghum starch and 5% lentil flour.
- 15% starches of wheat, sorghum and millet with 5% lentil flour are suitable for making bread.

Table 1. Chemical composition (%) of wheat flour (extraction rate 100% and 72%) and Lentil flour

Samples	Moisture content	Ash content	Crude protein	Fat content	Carbohydrates
Wheat flour (100%)	8.73±0.12^{b}	1.66±0.00^{b}	14.87±0.06^{b}	2.30±0.11^{a}	72.44±0.13^{a}
Wheat flour (72%)	11.81±0.06^{a}	1.00±0.00^{c}	13.87±0.12^{c}	1.82±0.19^{b}	71.50±0.28^{b}
Lentil flour	7.97±0.03^{c}	3.53±0.03^{a}	29.60±0.14^{a}	1.07±0.10^{c}	57.84±0.04^{c}
$Lsd_{0.05}$	0.1548*	0.0006318*	0.2189*	0.2754*	0.3574**
SE±	0.04472	0.0001826	0.06325	0.07958	0.1033

Values are mean±SD.

Any mean value(s) having same superscript(s) in a column are not different significantly (P≤0.05).

NS = not significant

* = significant

** = highly significant

Table 2. Minerals content of wheat flour extraction rate (72%) and lentil flour

Type of flour	Na (mg/100g)	K (mg/100g)	Ca (mg/100g)	P (mg/100g)	Fe (µ/g)
Wheat flour (72%)	63.33±15.28[a]	483.33±76.38[a]	67.00±1.00[a]	106.67±11.55[b]	2773.33±94.52[a]
Lentil flour	51.67±1.53[b]	303.33±25.17[b]	40.68±3.06[b]	120.00±10.00[b]	1733.33±152.75[b]
$Lsd_{0.05}$	10.6653**	160.5753**	15.2579*	12.0694*	990.2989**
SE±	2.915	0.40.1325	2.6718	1.3162	152.7653

Values are mean±SD.
Any mean value(s) having same superscript(s) in a column are not different significantly (P≤0.05).
NS = not significant
* = significant
** = highly significant

Table 3. Loaf bread specific volume of wheat flour with 5% starch and 5% lentil flour

Flour blends	Bread volume $(cc)^3$	Bread weight (g)	Bread specific volume (cc/g)
100% wheat flour (control)	366.67±18.93[a]	104.93±1.12[c]	3.49±0.16[a]
5% wheat starch + 5% lentil flour	345.00±0.00[b]	106.47±0.31[ab]	3.24±0.01[b]
5% sorghum starch + 5% lentil flour	340.00±5.00[b]	105.93±0.32[bc]	3.21±0.04[b]
5% millet starch + 5% lentil flour	335.00±5.00[b]	107.27±0.35[a]	3.12±0.06[b]
5% rice starch + 5% lentil	348.33±12.58[ab]	105.47±0.57[bc]	3.30±0.13[b]
5% cassava starch + 5% lentil flour	336.67±10.41[b]	105.40±0.44[bc]	3.20±0.11[b]
$Lsd_{0.05}$	18.87*	1.046*	0.1779*
SE±	6.124	0.3396	0.05774

Values are mean±SD.
Mean values having different superscripts in a column are significantly different (P≤0.05).

Table 4. Loaf bread specific volume of wheat flour with10% starch and 5% lentil flour

Flour blends	Bread volume $(cc)^3$	Bread weight (g)	Bread specific volume (cc/g)
100% wheat flour (control)	380.000±13.23[a]	108.93±0.42[a]	3.49±0.13[a]
10% wheat starch + 5% lentil flour	336.67±36.17[b]	108.77±1.17[a]	3.10±0.36[b]
10% sorghum starch + 5% lentil flour	328.33±7.64[bc]	106.50±0.66[c]	3.08±0.09[b]
10% millet starch + 5% lentil flour	318.33±7.64[bc]	108.60±0.80[ab]	2.93±0.08[b]
10% rice starch + 5% lentil flour	300.00±10.00[c]	105.20±0.52[d]	2.85±0.11[b]
10% cassava starch + 5% lentil flour	303.33±11.55[bc]	107.37±0.31[bc]	2.83±0.11[b]
$Lsd_{0.05}$	31.10**	1.254*	0.3132*
SE±	10.09	0.407	0.1017

Values are mean±SD.
Mean values having different superscripts in a column are significantly different (P≤0.05).

Table 5. Loaf bread specific volume of wheat flour with15% starch and 5% lentil flour

Flour blends	Bread volume $(cc)^3$	Bread weight (g)	Bread specific volume (cc/g)
100% wheat flour (control)	435.00±5.00[a]	107.40±0.85[b]	4.05±0.04[a]
15% wheat starch + 5% lentil flour	363.30±15.28[c]	106.00±0.60[c]	3.43±0.13[c]
15% sorghum starch + 5% lentil flour	388.30±2.89[b]	106.60±0.40[bc]	3.64±0.04[b]
15% millet starch + 5% lentil flour	351.70±10.41[cd]	109.10±0.15[a]	3.22±0.09[d]
15% rice starch + 5% lentil flour	328.33±2.89[e]	106.0±0.76[c]	3.10±0.05[d]
15% cassava starch + 5% lentil flour	343.33±11.55[de]	109.20±0.59[a]	3.15±0.11[d]
$Lsd_{0.05}$	16.51**	1.078**	0.1488*
SE±	5.358	0.3498	0.0483

Values are mean±SD.
Mean values having different superscripts in a column are significantly different (P≤0.05).

Table 6. Acceptability of bread from wheat flour containing 5% starch with 5% Lentil flour

Source of starch in wheat Flour blends	Quality attributes					
	Color Scores	Odor	Taste	Crumb texture	Crumb grains uniformity	Preference
wheat flour bread (control)	5.93±1.53[bc]	5.67±1.59[ab]	5.60±1.40[a]	5.47±1.41[ab]	5.60±1.30[a]	5.80±1.08[ab]
wheat starch bread	6.40±2.56[abc]	6.67±1.88[a]	6.00±2.10[a]	6.47±1.85[ab]	6.13±1.73[a]	6.33±1.95[a]
sorghum starch bread	7.80±0.86[a]	6.47±1.73[a]	6.00±1.96[a]	6.13±2.13[ab]	6.27±1.98[a]	6.47±1.85[a]
millet starch bread	5.27±2.09[c]	5.67±2.09[ab]	5.93±2.22[a]	5.07±2.31[b]	5.73±2.09[a]	5.47±1.68[ab]
rice starch bread	7.00±1.83[ab]	5.50±1.51[ab]	5.75±1.95[a]	6.63±1.54[a]	5.88±1.63[a]	5.13±1.31[ab]
cassava starch bread	5.43±2.10[c]	5.00±2.00[b]	5.07±2.09[a]	5.07±1.94[b]	5.00±2.08[a]	4.91±2.02[b]
$Lsd_{0.05}$	1.38*	1.311*	1.431[ns]	1.369*	1.318[ns]	1.217*
SE±	0.4906	0.4661	0.509	0.487	0.4688	0.4327

Values are mean±SD.Any two scores having different superscripts in a column are significantly different (P≤0.05).

Table 7. Acceptability of bread from wheat flour containing 10% starch with 5% Lentil flour

Source of starch in wheat Flour blends	Quality attributes					
	Color Scores	Odor	Taste	Crumb texture	Crumb grains uniformity	Preference
wheat flour bread (control)	6.47±1.64[a]	6.00±1.73[b]	5.40±1.59[c]	6.67±1.29[a]	6.47±1.60[a]	6.73±1.43[a]
wheat starch bread	4.93±2.05[b]	5.40±2.38[b]	5.20±2.21[c]	4.53±1.92[b]	4.67±1.99[b]	4.93±1.73[b]
sorghum starch bread	7.13±2.00[a]	6.73±1.94[ab]	6.73±1.67[ab]	7.00±1.60[a]	6.27±2.43[a]	6.60±1.80[a]
millet starch bread	7.13±1.46[a]	7.53±0.74[a]	7.33±1.05[a]	7.13±1.19[a]	6.93±1.22[a]	7.00±1.07[a]
rice starch bread	6.94±1.44[a]	5.50±1.75[b]	5.75±1.84[bc]	6.13±1.36[a]	6.81±2.14[a]	6.63±1.63[a]
cassava starch bread	6.64±1.74[a]	5.71±1.77[b]	5.50±1.29[bc]	5.93±1.59[a]	5.64±2.02[ab]	6.14±1.70[a]
$Lsd_{0.05}$	1.258*	1.30*	1.204*	1.096*	1.41*	1.147*
SE±	0.4474	0.4622	0.4279	0.3899	0.5013	0.4079

Values are mean±SD.Any two scores having different superscripts in a column are significantly different ($P \leq 0.05$).

Table 8. Acceptability of bread from wheat flour containing 15% starch with 5% Lentil flour

Source of starch in wheat Flour blends	Quality attributes					
	Color Scores	Odor	Taste	Crumb texture	Crumb grains uniformity	Preference
wheat flour bread (control)	6.33±2.29[ab]	5.80±2.21[ab]	6.07±2.25[a]	6.13±2.33[a]	6.20±2.27[ab]	6.33±2.32[ab]
wheat starch bread	6.53±2.00[ab]	7.00±2.00[a]	7.00±1.81[a]	6.53±1.73[a]	6.47±1.96[a]	6.93±1.71[a]
sorghum starch bread	5.93±1.62[ab]	6.07±1.28[ab]	6.00±1.41[a]	6.00±1.20[a]	6.07±1.03[ab]	5.80±1.26[ab]
millet starch bread	5.07±1.67[b]	5.53±1.73[ab]	5.93±1.71[a]	5.47±1.30[a]	4.87±1.25[b]	5.67±1.72[ab]
rice starch bread	6.81±1.83[a]	6.63±1.89[ab]	6.56±2.03[a]	6.50±1.79[a]	6.63±1.67[a]	6.69±1.70[a]
cassava starch bread	6.07±1.98[ab]	5.14±2.07[b]	6.42±2.03[a]	6.00±1.88[a]	5.57±2.06[ab]	5.07±1.98[b]
$Lsd_{0.05}$	1.351*	1.369*	1.375[ns]	1.266[ns]	1.277*	1.312*
SE±	0.4806	0.4868	0.4889	0.45	0.4542	0.4666

Values are mean±SD.Any two scores having different superscripts in a column are significantly different ($P \leq 0.05$)

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