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THE USE OF *Moringa oleifera* AS VALUE-ADDED INGREDIENT IN BAKERY INDUSTRY

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Abstract

In this study, the nutritional, physicochemical, phytochemical and sensory potential of Moringa flour, composite Moringa/wheat flours in different proportions, and bread obtained from these flours were examined. The nutritional analysis revealed an increase in the mineral content of the bread with the addition of 10% Moringa flour, as well as an increase in protein and fat content. The results obtained show that the maximum mineral and fat contents were recorded in the case of bread with 10% Moringa flour and are 3.89% and 4.93%, respectively. They also show that the addition of moringa flour results in an abundance of micro- and macro-nutrients in composite flour samples and breads depending on the percentage added. The bread containing 2.5% of Moringa flour has values close to the control bread in terms of physical properties: 83.88%, 250.57 cm^3/100 g, 93.66% and 0.717 respectively for porosity, volume, elasticity and H/D ratio. The total polyphenol content was between 191.87 and 279.83 mg/100 g and flavonoids between 6.18 and 9.76 mg EQ/100 g. The sensory analysis showed a reluctance of consumers to bread with more than 2.5% of moringa flour. This study reveals that the addition of moringa leaf flour up to 2.5% allows obtaining an elastic bread, acceptable from an organoleptic point of view while improving the nutritional quality without negative effects on the physicochemical characteristics.

Key words: *flavonoids, Moringa, nutrition, organoleptic, polyphenols.*

INTRODUCTION

From ancient times to the present day, people around the world have relied on the major cereal grains of wheat, rice, and maize for their diets. The lack of dietary diversity justifies the current state of global nutrition (Petcu et al., 2019; Matthews & Ghanem, 2020), which poses a threat to nutritional security. To alleviate this, diverse food crops as well as underutilized or orphan crops rich in protein, dietary fiber, phenolic antioxidants, and micronutrients improving nutritional quality should be part of the diet (Savu & Petcu, 2002; Goncearov et al., 2004; FAO, 2010; Khoury et al., 2014).
Indeed, *Moringa oleífera* or tree of life is one of the plants containing many bioactive compounds and which strengthens the immune system (Oyeyinka & Oyeyinka, 2016). It is a miracle plant in the sense that all its parts (leaves, seeds, flowers, etc.) can be used as a food supplement, medicine, water purifier and animal fodder (Daba, 2016).

Moringa leaves contain significant amounts of micro and macronutrients including calcium, potassium, magnesium, iron etc. also they are an important source of protein, β-carotene, and vitamins A, B1, C and E (Sanchez-Machado et al., 2010; Hekmat et al., 2015; Gonzalez-Burgos et al., 2021). A study by Manzo et al. in 2016 on the composition of *Moringa oleifera* dry leaf powder in three regions of Niger shows that Moringa dry leaf powder produced in Niger was found to be rich in protein with an average of 24.8% with micronutrient values ranging from 21.58% and 28.72%. Depending on the region, the composition varies for iron between 51.9 and 55.12 mg/100 g; 0.45 and 1.58 mg/100 g for zinc, 1192.5 and 1957.5 mg/100 g for calcium, 414.37 and 714.37 mg/100 g for magnesium, 1587 and 2037 mg/100 g for potassium, 207.75 and 326.25 mg/100 g for sodium, 32 and 61 mg/ 100 g for phosphorus Several authors have reported the antioxidant properties of *Moringa oleifera* leaves as well as a good level of polyphenol and flavonoids (Siddhuraju &

Becker 2003; Sreelatha & Padma 2009; Belhi et al., 2018).

Several scientific studies have shown that supplementation of dried Moringa leaves to staple foods such as bread, cheese, yogurt and cookies improves their nutritional properties (Dachana et al., 2010; Hekmat et al., 2015; Salem et al., 2013; Sengev et al., 2013; Hedhili et al., 2021). Indeed, in their study on the effect of *Moringa oleifera* leaf powder supplementation on some quality characteristics of wheat bread in 2013, Sengev et al, revealed that addition of Moringa leaf powder significantly increased fiber (2.10% to 3.28%), ash (1.10% to 1.65%), protein (9.07% to 13.97%), and ether extract (1.51% to 2.59%), while decreasing moisture content (35.20% to 27.65%). Also, this study reveals that there was a significant increase in magnesium (Mg), calcium (Ca) and beta-carotene contents from 0.76 to 1.27 mg/100 g, 3.67 to 6.07 mg/100 g and 0.02 to 3.27 mg/100 g, respectively.

Not only does moringa have effects on the sanitary quality of the products to which it is added, but it also acts on the textural quality of the product (Sengev et al., 2013; Hernandez-Aguilar et al., 2021). In 2013 the studies of Sengev et al. showed that supplementation with moringa leaf powder significantly decreased the volume, weight and height of bread. The specific volume of the bread decreased from 796.70 to 496.70 cm 3, and the height from 7.00 to 5.83 cm. Studies by Hernandez-Aguilar et al on photoacoustic characterization of wheat bread mixed with Moringa oleifera revealed that the addition of moringa in bread making slows down textural changes (hardness, elasticity, cohesion, resilience, and chewing) during storage.

Although there are several studies on the addition of moringa in bread making, none of these studies made a comparison between the nutritional, organoleptic and physicochemical parameters of the composite flours to the finished products. All these studies only addressed the characteristics of the final products.

The objective of this paper is to study the nutritional, physicochemical and organoleptic potential of Moringa flour and Moringa/wheat composite flour in different proportions. Thus, breads with different proportions of Moringa flour will be characterized from a nutritional, physicochemical and organoleptic point of view.

MATERIALS AND METHODS

Preparation of composite flours

Moringa flour (MF) was purchased in Benin, and wheat flour (WF) type 650 at Profi supermarket, Timisoara (Romania). Four types of composite moringa flours were made: MWF 1 (2.5% moringa flour and 97.5% wheat flour); MWF 2 (5% moringa flour and 95% wheat flour); MWF 3 (7.5% moringa flour and 92.5% wheat flour); and MWF 4 (10% moringa flour and 90% wheat flour).

Sample preparation

The breads were prepared according to Hernandez-Aguilar C. et al, (2021) and Plustea L. et al (2022) with some modifications. All ingredients (honey, wheat flour type 650, salt, oil and Pakamaya yeast) used to produce the bread apart from Moringa flour were purchased from local supermarkets Profi and Auchan, Timisoara, Romania. Four experimental breads (MWB1, MWB2, MWB3 and MWB4) were prepared by supplementing a control bread (WB) with different amounts of MF (WB - wheat bread, MWB 1 - Moringa/wheat bread 2,5%, MWB 2 - Moringa/wheat bread 5%, MWB 3 - Moringa/wheat bread 7.5% and MWB 4 - Moringa/wheat bread 10%).

The breads obtained from this study are presented in Figure 1.

Figure 1. Final products. WB - wheat bread, MWB1 – Moringa/wheat bread 2.5%, MWB 2 - Moringa/wheat bread 5%, MWB3 - Moringa/wheat bread 7.5% and MWB 3 - Moringa/wheat bread 10%

Table 1. Recipe for bread with composite Moringa flours

Samples	Ingredients						
	Moringa flour (g)	Wheat flour type 650 (g)	Yeast (g)	Salt (g)	Honey (g)	Oil (mL)	Water (mL)
WB	-	1000	50	20	30	80	800
MWB1	25	975	50	20	30	80	800
MWB2	50	950	50	20	30	80	800
MWB3	75	925	50	20	30	80	800
MWB4	100	900	50	20	30	80	800

After its fermentation in 800 g of warm water (30°C), the yeast was incorporated to the mixture of flour, honey and salt. They were then mixed for 5 minutes, in a mixer with a spiral hook at the first speed. At the second speed, which also lasted 5 minutes, the oil was added gradually. The obtained dough is then placed in a covered plastic bowl for 1 hour at a temperature of 20°C. Then the dough was kneaded and placed in a greased bread pan, where it increased its volume for 30 min at a temperature of 35°C. The doughs were simultaneously baked in an electric oven preheated to 230°C, for 24 min. After baking, the loaves will be left to cool at room temperature for 24 h and then cut into slices with a knife. The technological scheme for obtaining bread is presented in Figure 2.

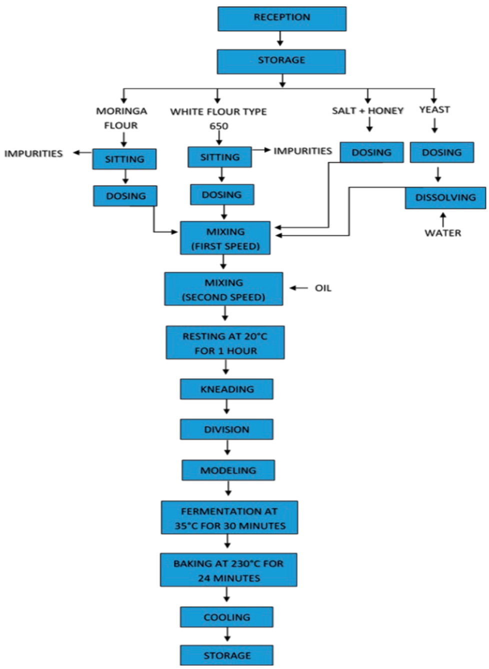

Figure 2. The technological scheme for obtaining bread

Determination of mineral content

3 g of each sample (weighed on an analytical balance: KERN ALT 220-4NM, series WL 074130, Germany) in a porcelain capsule were calcined for 6 to 8 hours in a calcination kiln (Naberthem GmbH, series 190945, Lilienthai/Bremen, Germany) heated to 550°C and then cooled down and weighed as soon as it reached room temperature. The ash content is calculated with the relation:

Ash (%) = $[(m_2-m_0)/(m_1-m_0)] \times 100$,

where: m_2 - mass of the crucible after calcination, in (g); m_1 - mass of the crucible containing the sample before calcination, in (g); m_0 - mass of the empty crucible (g).

Determination of lipid content

The determination of the lipid content was carried out in a practical way, by hot extraction using the Soxhlet apparatus (Raypa Espinar, S.L., series 31454, mode SX-6). The fat content is calculated using the formula:

$$\text{Fat} = \frac{m}{m_1} 100\ (\%)$$

where:

m - is the amount of fat extracted; m_1- is the amount of sample taken.

Determination of carbohydrate content

The carbohydrate content is obtained by subtracting 100 from the sum of the protein, fat, moisture and ash contents of the sample.

Determination of protein content

The protein composition was determined following SR EN ISO 8968-1:2014.

Determination of the energy value

The energy value was calculated by adding the caloric intake of fats, carbohydrates and proteins, taking into account the following composition:

1 g of fat = 9 kcal,
1 g of protein = 4 kcal,
1 g of carbohydrates = 4 kcal

Determination of moisture content

5 g of each sample was weighed with an analytical balance (KERN ALT 220-4NM, series WL 074130, Germany) to the nearest 0.0002 g into a glass vial with a lid. The vial was then placed in an oven (Binder GmbH, Tuttingen/Germany) at 105°C where it was held for 1 hour, then removed and allowed to cool. Then it was weighed. The moisture content was calculated using the formula:

$$\text{Moisture (\%)} = \frac{m_1 - m_2}{m_1} \times 100$$

where: m_1 - mass of the sample before drying, in (g); m_2 - mass of the sample after drying (g).

Macro and microelements

Determination of the content of macro- and microelements was determined by atomic absorption spectroscopy (AAS) using the Varian 220 FAA equipment according to the method described by Plustea et al. (2022). The results were expressed in ppm.

Physico-chemical properties

For each type of bread, the following physicochemical characteristics were used to assess quality: volume, porosity, core elasticity, height/diameter ratio, moisture and acidity. All analytical methods used were in accordance with STAS 91/83. The results are the arithmetic mean of three parallel determinations.

Evaluation of the total phenolic content

The methods used here are those of Folin-Ciocâlteu with some modifications according Obistioiu et al. (2021). The total phenolic content of MF, WF, composite flours and bread with different percentages of Moringa flour was analyzed. The absorbance of the samples was read at 750 nm with the Specord 205 spectrophotometer (Analytik Jena AG, Jena, Germany) using ethanol (Sigma-Aldrich; Merck KgaA, Darmstadt, Germany) as a blank sample. Results were expressed as mg gallic acid equivalent (GAE) per 100 g sample based on the calibration curve (concentration range: 2.5-250 μg/mL). All the determinations were performed in triplicate.

Sensory analysis

The panel consisted of 36 ISO 6658:2017 trained raters, aged 21-56 years, non-smokers, with no known cases of food allergies. A 1 cm thick slice of each type of bread was presented on cardboard plates, coded with two numbers and served randomly, under normal lighting conditions and at room temperature. To assess consumer acceptance, a five-point hedonic scale was used [ISO 6658:2017], with the following rates: 1 = extremely disliked; 2 = slightly disliked; 3 = neither liked nor disliked; 4 = slightly liked; 5 = extremely liked.

Each panelist was asked to rate the sensory attributes of each sample: appearance, color, texture, flavor, taste, and overall acceptability. The score and acceptability level ranges were as follows: 1.00-1.49 = Not Acceptable; 1.5- 2.49 = Slightly Acceptable (SA); 2.50-3.49 = Moderately Acceptable; 3.5-4.49 = Acceptable; 4.5-5.00 = Very Acceptable.

Statistical analysis

All determinations were made in triplicate and the results are reported as mean values ± standard deviation (SD). Differences between means were analyzed by t-test (two-sample assuming equal variances) using Microsoft Excel 365. Differences were considered significant when p-values < 0.05.

RESULTS AND DISCUSSIONS

Proximate composition

The results presented in Table 2 illustrate the nutritional characteristics of the wheat/Moringa composite flours as well as the breads made from these flours.

Table 2. Proximate composition of Moringa composite flours and breads

Samples	Nutritional parameters					
	Moisture (%)	Ash (%)	Protein (%)	Lipids (%)	Carbohydrates [g/100 g]	Energy value [kcal/ 100 g]
COMPOSITE FLOURS						
WF	10.80 ± 0.04[a]	0.33 ± 0.03[a]	11.26 ± 0.02[a]	1.33 ± 0.03[a]	76.28 ± 0.04	362.13 ± 0.16
MF	9.79 ± 0.01[b]	9.97 ± 0.10[b]	37.55 ± 0.3[b]	3.31 ± 0.03[b]	39.38 ± 0.35	337.51 ± 0.53
MWF1	10.59 ± 0.04[c]	0.79 ± 0.08[c]	12.28 ± 0.2[c]	1.40 ± 0.05[a,c]	74.94 ± 0.32	361.48 ± 0.74
MWF2	10.40 ± 0.13[c,d]	1.34 ± 0.02[d]	12.97 ± 0.05[c]	1.60 ± 0.15 [c,d]	73.69 ± 0.08	361.04 ± 1.32
MWF3	10.20 ± 0.13[d,e]	1.84 ± 0.01[e]	13.77 ± 0.07[d]	1.77 ± 0.05 [d,e]	72.42 ± 0.17	360.69 ± 0.76
MWF4	10.05 ± 0.14[e]	2.32 ± 0.04[f]	14.35 ± 0.08[e]	1.96 ± 0.06 [e]	71.32 ± 0.18	360.32 ± 0.57
COMPOSITE BREAD						
BW	35.65 ± 0.03[a]	1.33 ± 0.02[a]	10.87 ± 0.02[a]	3.19 ± 0.01[a]	48.97 ± 0.01	268.09 ± 0.16
MWB1	34.89 ± 0.05[b]	2.94 ± 0.04[b]	11.47 ± 0.09[b]	3.76 ± 0.06[b]	46.98 ± 0.1	267.65 ± 0.44
MWB2	34.67 ± 0.09[b,c]	3.62 ± 0.05[c]	11.78 ± 0.07[b]	4.15 ± 0.18[c]	45.78 ± 0.17	267.59 ± 1.09
MWB3	34.35 ± 0.02[c,d]	4.63 ± 0.02[d]	12.83 ± 0.03[c]	4.61 ± 0.04[d]	43.59 ± 0.04	267.16 ± 0.32
MWB4	34.22 ± 0.03[d]	5.34 ± 0.02[e]	13.82 ± 0.03[e]	4.93 ± 0.02[e]	41.68 ± 0.08	266.41 ± 0.1

[a–e]data within the same column sharing different superscripts are significantly different ($p < 0.05$) according to t-test.

The results of Table 2 show that MF is a good source of minerals (9.97 ± 0.10%), proteins (37.55 ± 0.3%) and lipids (3.31 ± 0.03%). These results are close to those obtained through the metanalysis made by Witt in 2013 on 49 scientific articles on the nutritional composition of dried Moringa leaves (Witt, 2013). In this study, on 100 g of dried Moringa leaves, 24 ± 5.8 g of protein, and 6 ± 2.5 g of lipids are found. These results are also close to those of Manzo et al. (2013), where the protein content of moringa leaves ranged from 19.34- 30.24% and Ndong et al. (2007), where the protein concentration was 39.69%.

These results also show that MF is more than twice as concentrated in protein as WF (37.55 ± 0.3% against 11.26 ± 0.02% for WF). On the other hand, WF is about 2 times richer in carbohydrates than MF (76.28 ± 0.04% against 39.38 ± 0.35% for MF). These results are similar to those of Sengev et al. (2013), in their studies on the effect of Moringa oleifera leaf powder supplementation on some quality characteristics of wheat bread. In their studies, MF had a protein concentration of 27.82 ± 0.06 % against 11.20 ± 0.04% for WF. Concerning carbohydrates MF had a concentration of 38.20 ± 0.02% against 69.70 ± 0.04% for WF.

WF provides more energy than MF (362.13 ± 0.16% against 337.51 ± 0.53% for MF). The same thing was observed for the breads obtained. Thus, the more the quantity of MF increases in the composition of the breads, the more the rate of carbohydrates and energy values decrease. For the carbohydrate rate we have respectively 48.97 ± 0.01%; 46.98 ± 0.1%; 45.78 ± 0.17%; 43.59 ± 0.04% and 41.68 ± 0.08% for WB, MWB1, MWB2, MBW3 and MBW4. As for the energy value of 267.65 ± 0.44 kcal/ 100 g for MWB1, it increased to 266.41 ± 0.1 kcal/ 100 g for MWB4.

MF being more than 30 times more concentrated in mineral substances than WF, the more its quantity increases in the composition, the more the quantity of mineral substances increases in both flours and breads. We have respectively for the flours 0.33 ± 0.03%; 9.97 ± 0.10%; 0.79 ± 0.08%; 1.34 ± 0.02%, 1.84 ± 0.01% and 2.32 ± 0.04 for WB, MWB1, MWB2, MBW3 and MBW4 For breads the mineral content increased from 2.94 ± 0.04% (MWB1) to 5.34 ± 0.02% (MWB4). The same was observed for lipids and proteins. That is, the higher the amount of MF, the higher the lipid or protein content in the composite flours and in the breads.

Significant differences ($p < 0.05$) according to t-test were recorded between the samples for most of all analysed parameters.

These results show that the partial substitution of wheat flour by moringa would increase the level of minerals, proteins and lipids in both the composite flours and the breads produced with these flours. There is a significant difference between the values obtained for the control samples (WF for flours and WB for breads) and the other samples for each of the parameters studied (moisture, ash, proteins and lipids.

Macro and microelements

Table 3 shows the macro- and micro-nutrient content of the moringa flour composites and breads. The experimental results obtained show that the addition of moringa flour leads to an increase in the contribution of micro and macro elements in both composite flour samples and breads depending on the percentage added. The same finding was made in the studies of Sengev et al. (2013) on the effect of *Moringa oleifera* Leaf Powder Supplementation on Some Quality Characteristics of Wheat Bread. In this study, as the amount of MF increased, the micro and macronutrients (Fe, Mg, Ca and Cu) were more abundant. The most abundant macronutrient in the analyzed samples is calcium (Ca). It varied between 2875.58± 20.61 and 475.44±1.15 mg/kg in the flour samples while in the bread samples it varied between 128.65±0.38 and 386.75±0.49 mg/kg. Similar results were obtained in the studies of Sengev et al. (2013), where calcium was the most abundant macroelement.

Statistically significant differences were found both in terms of Ca content in moringa, wheat and composite flours, but also in the resulting bread.

Table 3. Macro and micro-elements content of moringa flour composites and bread

Samples	Macro- and Microelements Content (mg/kg)							
	Cu	Ni	Zn	Fe	Mn	Ca	Mg	K
Composite flours								
MF	5.42± 0.02 ^{a}	0.76±0.006 ^{a}	29.58± 0.01 ^{a}	93.553± 0.02 ^{a}	32.89± 0.01 ^{a}	2875.58± 20.61 ^{a}	742.06±1.14 ^{a}	975.31±0.95 ^{a}
WF	2.40± 0.002 ^{b}	nd	11.40± 0.01 ^{b}	12.13±0.03 ^{b}	8.69±0.02 ^{b}	166.22±0.99 ^{b}	273.15±1.28 ^{b}	65.29±0.09 ^{b}
MWF1	2.79± 0.04 ^{b,c}	0.103± 0.005 ^{b}	12.26± 0.04 ^{c}	14.23±0.04 ^{c}	8.87±0.03 ^{b,c}	228.30±0.90 ^{c}	280.47±1.31 ^{c}	114.61± 0.51 ^{c}
MWF2	2.93± 0.02 ^{c,d}	0.257± 0.003 ^{c}	12.43± 0.02 ^{c}	16.96±0.01 ^{d}	9.01±0.02 ^{c}	325.43±0.74 ^{d}	286.81±0.85 ^{c,d}	144.98± 0.68 ^{d}
MWF3	3.00± 0.01 ^{d}	0.366± 0.005 ^{d}	13.04± 0.04 ^{d}	19.49±0.04 ^{e}	9.31±0.06 ^{c,d}	391.93±0.56 ^{e}	289.20±0.68 ^{d,e}	172.18± 1.15 ^{e}
MWF4	3.10± 0.05 ^{d}	0.430± 0.026 ^{e}	14.63± 0.07 ^{d}	21.21±0.02 ^{f}	10.01± 0.01 ^{d}	475.44±1.15 ^{f}	292.38±1.01 ^{e}	198.08± 0.75 ^{f}
Composite Breads								
WB	1.85± 0.02 ^{a}	0.014± 0.005 ^{a}	4.08±0.05 ^{a}	11.21±0.04 ^{a}	2.97±0.05 ^{a}	128.65±0.38 ^{a}	244.77± 0.68 ^{a}	62.31±0.91 ^{a}
MWB1	2.12± 0.03 ^{b}	0.087± 0.003 ^{b}	5.64±0.02 ^{b}	13.80±0.05 ^{b}	4.08±0.03 ^{b}	220.22±1.35 ^{b}	266.27± 0.95 ^{b}	102.03± 1.12 ^{b}
MWB2	2.41± 0.01 ^{c}	0.136± 0.004 ^{c}	6.09±0.02 ^{c}	14.71±0.01 ^{c}	4.65±0.03 ^{b}	275.61±0.66 ^{c}	271.47± 1.20 ^{b}	167.21± 1.52 ^{c}
MWB3	2.65± 0.02 ^{c,d}	0.173± 0.002 ^{c,d}	6.40±0.06 ^{c}	15.49±0.03 ^{d}	5.62±0.01 ^{c}	357.38±0.82 ^{d}	286.54± 2.52 ^{c}	174.91± 0.89 ^{c,d}
MWB4	2.87± 0.01 ^{d}	0.205± 0.005 ^{d}	7.60±0.06 ^{d}	16.85±0.03 ^{e}	6.21±0.02 ^{d}	386.75±0.49 ^{e}	296.47± 1.47 ^{d}	182.22± 0.38 ^{d}

$^{a–f}$ data within the same column sharing different superscripts are significantly different ($p < 0.05$) according to t-test

It should be noted that calcium is a mineral that plays an essential role in the optimal functioning of the organism, particularly in the growth of the skeleton during childhood and ensures the necessary bone mineral mass during adult life; it is also involved in cell permeability, neuromuscular excitability, cardiac function and in blood coagulation. These different functions of calcium explain why the needs are rigorously covered in young growing children (Dansou et al., 2000). The FAO and WHO, quoted by Dansou et al. (2000), recommend that the daily calcium intake of the healthy population should be between 500 and 800 mg per day.

Potassium is the second most abundant element and increases with the amount of MF added. Thus, in both composite flours and breads, it is more abundant in the sample with 10% moringa.

We have respectively 198.08± 0.75 mg/kg for MWF4 (flour) and 182.22± 0.38 mg/kg (bread). There is a significant difference not only between the different composite flour samples but also between the bread samples.

The magnesium (Mg) content of the composite flour samples MWF1 (280.47±1.31 mg/kg), MWF2 (286.81±0.85 mg/kg), MWF3 (289.20±0.68 mg/kg) and MWF4 (292.38±1.01 mg/kg) showed significant differences from WF (273.15±1.28 mg/kg). MWF recorded the highest Mg content (742.06±1.14 mg/kg). The same was true for the bread samples, which means that there was a significant difference between WB and other bread samples containing moringa. The WB content was 244.77± 0.68 mg/kg, lower than the other bread samples which recorded values between 266.27± 0.95 mg/kg (MWB1) and 296.47± 1.47 mg/kg (MWB4).

The content of iron (Fe) varies between 12.13±0.03 mg/kg (WF) and 21.21±0.02 mg/kg (MWF4) for the composite flour samples and between 11.21±0.04 mg/kg (WB) and 16.85±0.03 mg/kg (MWB4) for bread samples with significant difference between them. MF recorded the highest Fe content (93.553± 0.02 mg/kg). Also, as in the case of the previous nutrients, the higher the amount of MF the more abundant the iron content is. This observation will remain the same for the other nutrients (Cu, Ni and Zn). Also, for each of these nutrients MF has the highest rate. Finally, there is a significant difference between the values obtained for the control samples (WF for flours and WB for breads) and the other samples for each of the remaining nutrients (Cu, Ni and Zn). These different findings are in agreement with the results obtained by Sengev et al. in 2013.

Bread properties

For each bread samples it was determined according to STAS 91/1983, the volume, porosity, elasticity, height/diameter ratio (H/D) and moisture. The results obtained are presented in Table 4.

Table 4. Bread quality indicators for WB, MWB1, MWB2, MWB3 and MWB4

Indicator	M.U.	WB	MWF1	MWF2	MWF3	MWF4
Volume	cm^3/100 g	251.09±0.05	250.57±0.01	234.96±0.02	231.05±0.01	230.32±0.33
Porosity	%	85.67±0.06	83.88±0.02	83.15±0.05	81.77±0.06	80.81±0.01
Elasticity	%	91.67±1.15	93.33±0.58	93.67±1.15	94±1.00	94.33±1.53
H/D	-	0.752±0.002	0.717±0.003	0.702±0.009	0.653±0.001	0.598±0.002
Acidity	Acidity/ 100 g	3.33±0.02	6.33±0.01	7±0.4	7.66±0.2	8.33±0.05

From the analysis of the data obtained from the Table 4, it can be seen that the volume of the control sample (251.09±0.05 cm^3/100 g) is higher compared to the other bread samples with different proportions of Moringa flour (between 250.57 and 230.32). However, the products were not excessively flattened (Table 3). Thus, as the amount of moringa increases in the bread composition, the volume decreases. The same observation was made by Sengev et al. in 2013 where the volume decreased from 4.70 ± 0.03 cm^3/g for the control sample to 2.65 ± 0.09 cm^3/g for the sample with 5% MF.

The control sample (wheat flour, without addition of moringa) recorded the highest values in terms of volume (251.09±0.05 cm^3/100 g), H/D ratio (0.752), porosity (85.67%) compared to the samples with addition of moringa, which recorded lower values for these different parameters analyzed. On the other hand, the more the quantity of Moringa increases in the recipe, the more the elasticity of the bread increases. Thus, MWB4 recorded the highest percentage in terms of elasticity (80.81%). These results are consistent with Bourekoua et al. (2018), who revealed that the addition of moringa in the bread formulation decreases its volume but increases its elasticity.

MWB1 has a good presentation and well smooth with a volume of 250.57±0.01 cm^3/100 g, soft and flat pores for a porosity of 83.88±0.02%, with 94.33±1.53% elasticity, the H/D ratio is 0.717±0.003. MWB1 recorded the best scores closest to the control sample compared to other breads containing Moringa.

As far as acidity is concerned, it is observed that it increases with the addition of moringa flour in the composition. From 3.33 grades of acidity/100 g of bread in the standard bread (WB), it increases to 6.33 grades of acidity/ 100 g of bread for MWB1, to 7 grades of acidity/100 g of bread for MWB2, to 7.33 grades of acidity/100g of bread for MWB3 and to 3 grades of acidity per 100 g of bread for MWB4. We can therefore conclude that Moringa powder has a higher acidity than wheat flour. This parameter must then be taken into consideration in the production of bread with Moringa flour in order to have bread with better physicochemical properties.

Phytochemical proprieties

The following figures show the polyphenol content for the different flours (Figure 3) and for the different breads (Figure 4).

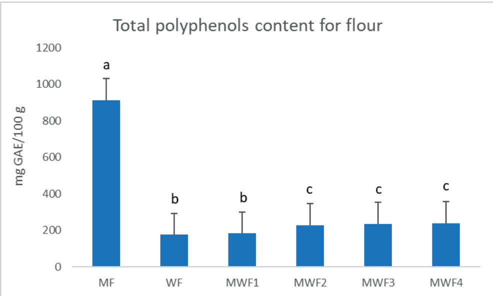

Figure 3. Polyphenol content for the different flours
[a–e]data within the same column sharing different superscripts are significantly different ($p < 0.05$) according to t-test

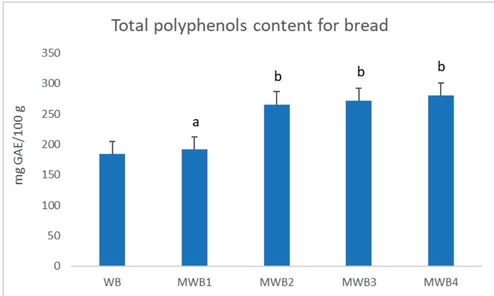

Figure 4. Polyphenol content for the different bread
[a–e]data within the same column sharing different superscripts are significantly different ($p < 0.05$) according to t-test

The analysis of the data obtained shows that the polyphenol content in moringa flour is 5 times higher than in wheat flour. Thus, it can be seen that the polyphenol content increases with the increase of the moringa flour content in the sample. Then, in the case of flour samples, it is found that the lowest PT content is observed in the control sample WF (176.70±0.693 mg GAE/100 g), while the highest value is observed for the control sample MWF4 (239.40±0.346 mg GAE/100 g). This is due to the high polyphenol content in moringa leaves (Siddhuraju & Becker, 2003; Sreelatha & Padma, 2009; Belhi et al., 2018).

It is also found that the TP content of the bread samples is higher than the TP content of the flour. This observation would be due to the presence of polyphenols in the honey used as an ingredient to obtain the bread samples (Dico et al., 2019). Thus, as for the fava samples, the higher the amount of moringa powder, the higher the polyphenol content in the bread samples. We have 183.800±6.059 mg GAE/ 100 g; 191.870±1.198 mg GAE/100 g; 265.503±3.593 mg GAE/100 g; 271.580±1.920 mg GAE/100 g and 279.833±9.469 mg GAE/100 g, respectively for the samples WB, MWB1, MWB2, MWB3 and MWB4. Similar results were found by Hayat et al, in 2017 in their studies on the evaluation of physical, sensory and antioxidant properties of gluten-free bread enriched with *Moringa oleifera* leaf powder. In this study with the same proportions of moringa (2.5%, 5%, 7.5% and 10%) the polyphenol content varied between 212 and 239 mg GAE/100 g. On the other hand, the level of polyphenols for dry moringa leaves was 331.3 mg GAE/100 g against 912.7 mg GAE/100 g in our study. This difference would probably be due to the fact that the composition of moringa leaf varies from one region to another (Manzo et al., 2016). As such, the polyphenol level was 236.5 mg GAE/100 g for moringa leaf powder in the study conducted by Belhi et al. in 2018 on the chemical properties and anti-nutritional factors of *Moringa oleifera*.

Table 5 presents the flavonoid composition of the composite flours as well as the breads resulting from these flours.

Table 5: Flavonoid composition of the composite flours as well as the breads resulting from these flours

Sample		Flavonoids (mg QE/100 g)	
Flours composites		Breads composite	
WF	1.72±0.08 [a]	WB	2.90±0.05 [a]
MF	12.40±0.07 [b]	-	-
MWF1	4.28±0.05 [c]	MWB1	6.18±0.22 [b]
MWF2	4.78±0.03 [c,d]	MWB2	7.95±0.00 [c]
MWF3	5.16±0.16 [d]	MWB3	9.72±0.01 [d]
MWF4	5.91±0.00 [e]	MWB4	9.76±0.01 [d]

[a–e]data within the same column sharing different superscripts are significantly different ($p < 0.05$) according to t-test

From the analysis of the results in this table, it can be seen that moringa flour is richer in flavonoid than wheat flour (12.40 ±0.07 mg EQ/100 g versus 1.72 ±0.08 mg EQ/100 g). Approximately similar results were obtained by Sulastri et al. in 2018 in a study on total phenolic, total flavonoid, quercetin content and antioxidant activity of the standardized extract of *Moringa oleifera* leaf from regions at different altitudes. In this study, the values found for flavonoids varied between 8.9 and 9.6 mg EQ/100 g.
Also, we notice the increase of the flavonoid rate with the increase of the Moringa flour (4.28 mg EQ/100 g for MWF1 and 5.91 mg EQ/100 g for MWF4). This same observation was made in the composition in flavonoids of the obtained breads where we have respectively 6.18 mg EQ/100 g; 7.95 mg EQ/100 g; 9.72 mg EQ/100 g and 9.76 mg EQ/100 g for MWB1, MWB2, MWB3 and MWB4. It should be noted here that the concentration of flavonoids in breads is higher than in flours. This finding would be due to the presence of flavonoid in the honey used as an ingredient to obtain the breads (Silva et al., 2021).

Sensory analysis

Consumer acceptability of the bread samples with different proportions of moringa and the standard bread was performed by sensory evaluation with a panel of 36 raters using a five-point hedonic scale. Figure 5 shows the mean scores for the sensory attributes (appearance, color, texture, taste, aroma and overall acceptability) of the different breads. Recall here that WB, is the control wheat bread; MWB1, the one with 2.5% moringa flour; MWB2; MBWB3 and MBWB4 respectively the breads with 5%; 7.5% and 10% moringa flour.
The control sample (WB) had the highest scores regardless of the evaluation criteria (color: 4.61±0.80; taste: 4.56±0.80; appearance: 4.47±0.94; texture: 4.72±0.74; flavor: 4.47±0.84 and overall acceptability: 4.53±0.77).

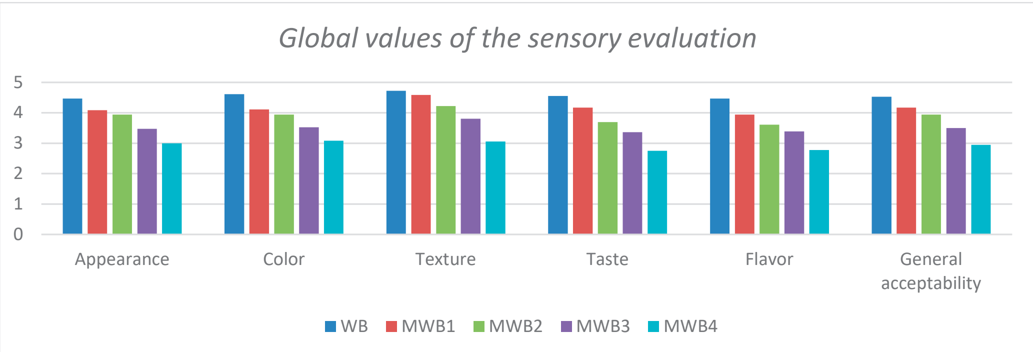

Figure 5: Global values of the sensory evaluation (consumer acceptance) of bread with Moringa (MWB1, MWB2, MWB3 and MWB4; WB (control bread) by using 5-point hedonic scale (n = 36)

Among the bread samples with different proportions of Moringa flour (MWB1, MWB2, MWB3 and MWB4), MWB1 was the most liked by the raters followed by MWB2, MBWB3 and MWB4 respectively. Not only was MWB1 the most appreciated among the Moringa composite flour samples, it also scored close to the control sample (WB). For texture, it was very acceptable having obtained a score of 4.53±0.55. It scored 4.08±0.97; 4.11±0.95; 4.17±0.85; 3.94±0.89 and 4.17±0.70 for appearance, color, taste, flavor and overall acceptability respectively. These different scores being in the range of 3.5 to 4.49 then these criteria are classified in the acceptable level by the consumers. Concerning the sample MWB2 all the scores being between 3.5 and 4.49 (3.94; 3.94; 4.22; 3.69; 3.61 and 3.94 respectively for the aspect, the color, the texture, the taste, the flavor and the overall acceptability), we retain that they are classified acceptable by the consumers. Concerning the two other samples (MWB3 and MWB4), similar to the two previous ones, the higher the quantity of moringa, the lower the acceptability level of the products. The results of this evaluation show us that the addition of a significant amount (more than 2.5%) negatively affects the acceptability of bread by consumers (Bourekoua et al., 2018).

CONCLUSIONS

In this study, it was discussed the production of bread with different levels of substitution of wheat flour by moringa leaf flour in order to evaluate the nutritional, physicochemical and organoleptic potential of the flours and finished products.

The results indicate that the incorporation of MF increased significantly the nutritional quality of the composite flours and breads obtained. On the other hand, the addition of moringa in the bread formulation affected its physicochemical characteristics: its volume was decreased but its elasticity was increased. As for the acidity, it is observed that it increases with the addition of moringa flour in the composition. These parameters must be taken into account in the production of bread with Moringa flour in order to have a bread with better physicochemical characteristics.

The results of these studies also reveal that the addition of MF significantly increased the total polyphenols and flavonoids of the bread obtained. The results of the organoleptic evaluation indicate that the addition of a significant amount (more than 2.5%) negatively affects the acceptability of the bread by consumers (Hayat et al., 2017).

Finally, our results allow us to conclude that substitution with a small amount of moringa flour in bread allows to obtain a smooth bread with soft and flat pores, an elastic core, acceptable from the organoleptic point of view while improving the nutritional quality without negative effects on the technological and physicochemical characteristics. MF is therefore, in small quantities, an excellent product for enriching wheat flour bread.

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