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Rheological characteristics of composite flour substituted by moringa leaf flour (*Moringa oliefera*) for bread-making

Sylvestre Dossa[1*], Christine Dragomir[1], Monica Negrea[1], Ileana Cocan[1], Ersilia Alexa[1] and Adrian Rivis[1]

[1]*Faculty of Food Engineering, University of Life Sciences "King Mihai I" from Timisoara, Calea Aradului No. 119, 300645 Timisoara, Romania*

Corresponding author:sylvestredossa04@gmail.com

Abstract

Moringa oleifera is a multi-purpose plant that is a major benefit to nutrition and health. Thanks to its nutritional properties, it can be used as a functional ingredient in bakery products. To achieve this, it is important to know the impact that this flour could have on the rheological and technological characteristics of bakery products. Thus, this study aimed to evaluate the rheological characteristics of four (4) types of moringa/wheat composite flours compared to wheat flour. The four composite flours formulated contained 2.5%, 5%, 7.5%, and 10% moringa flour respectively. Rheological analysis was carried out using the Mixolab according to the Chopin protocol. The results showed that the composite flour had better water absorption (60%) than wheat flour (55.8%). On the other hand, the higher the moringa content in the composition of the composite flours, the shorter the dough stability time. The water absorption index was higher in composite flour than in wheat flour. On the other hand, wheat flour had better gluten and mixing indices than composite flours. It was also found that maximum viscosity during heating, starch stability, and starch retrogradation were better for wheat flour than for composite flours. Given all this information, it should be noted that the substitution of wheat flour with different percentages of moringa flour improved certain rheological properties of the doughs, but also had an impact on other properties. However, the composite flour with 2.5% moringa was the best composite flour, with values close to those of wheat flour. It should therefore be remembered that moringa can be used as a substitute for wheat flour in bread products, but with a substitution rate of no more than 2.5% to retain their rheological properties.

Keywords: Reological characteristics, bakery products, Moringa flour

1. Introduction

Bakery products are a globally accessible commodity due to their low price point. They are consumed daily and are accepted by all age groups due to their exceptional organoleptic characteristics [1, 2]. Wheat flour is the traditional ingredient used in the production of bakery products, which are rich in complex carbohydrates but low in dietary fiber and certain minerals and trace elements [1].

At the same time, consumers are increasingly interested in foods that not only satisfy their nutrient requirements but also have health benefits [3]. To fulfill this growing demand, numerous researchers have embarked on researching and developing novel ingredients that are more nutrient- and bioactive-rich than wheat flour about moringa leaf flour.

Moringa Oleifera is a nutritious and multifunctional plant native to India. Because of its many uses in nutrition and medicine, it has been dubbed the "miracle plant" or "tree of life" [4]. This plant is often used as a food fortifier in many parts of the world, particularly in Africa. It is a plant endowed with several nutrients that play a crucial role in human nutrition [5]. Its leaves, whether fresh or not, are used in the diets of many sub-Saharan and East African countries [6]. They

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are an abundant source of vitamins, minerals, and essential phytochemicals [7]. Moringa leaves are rich in minerals such as calcium (Ca), magnesium (Mg), potassium (K), zinc (Zn), copper (Cu), and iron (Fe). They are also abundant in vitamins A, B, C, D, and E [8, 9]. They contain anti-cancer agents (isothiocyanates, glucosinolates, glycoside compounds, etc.) [10, 11]. Moringa oleifera is also a medicinal plant as it improves immunity and has an effect against certain diseases such as diabetes, cancer, and obesity [9, 12].

Given the above information, moringa is undoubtedly an ingredient for fortifying bakery products. The question is whether the partial replacement of wheat flour by moringa leaf flour while improving nutritional characteristics, would have no impact on rheological properties. This question will be addressed in the present study, which will compare the rheological properties of wheat flour with those of wheat/moringa composite flours.

2. Materials and Methods

2.1. Biological materials

The wheat flour used was type 650 and had been purchased from the Profi supermarket (Timisoara/Romania). Moringa leaves were harvested in southern Benin. After separating the stems from the leaves, the latter were dried at room temperature in a ventilated room until completely dry. They were then ground to powder using the Retsch GmbH mill No.128120236G (Rheinische, Germany).

2.2. Preparation of composite flour

Four (4) types of composite flours were prepared by the previous article entitled “The use of moringa oleifera as a value-added ingredient in bakery industry” [13], namely MWF1 (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).

2.3. Rheological analysis

To determine the effect of the partial replacement of wheat flour with moringa flour on the rheological properties, an analysis of these properties was carried out using the "Chopin+" protocol of the Chopin Mixolab [14]. To achieve this, it was first necessary to measure the moisture content of each sample using the standard ICC (2003) method [15]. Depending on the moisture content obtained, the samples were weighed (between 42 and 50 g) and placed in the Mixolab bowl. There were three bowls, the characteristics of which are shown in the table below. The mixing speed was 80 rpm.

Table 1. Mixolab parameters used to determine the rheological profile of different flours

Plateau	Temperature	Time	Gradient
First plateau	30°C	8min	4 °C/min
Second plateau	90°C	7min	4 °C/min
Third plateau	50°C	5min	-

The parameters evaluated in this analysis were: water absorption, dough development time and stability (resistance of the dough to kneading). The maximum torque (C1) during kneading, protein weakening (C2), starch gelatinization rate (C3), minimum torque (C4) and torque after cooling (C5) were also measured. In addition, the Mixolab also evaluated baking stability, heat-induced protein weakening, starch gelatinization rate, enzyme degradation rate, and starch retrogradation on cooling.

3. Results and discussion

3.1. Rheological profiles and primary parameters

Each of the flour samples was subjected to rheological analysis using the Mixolab apparatus. The rheological profiles of the samples analyzed with different proportions of Moringa flour (0%, 2.5%, 5%, 7.5%, and 10%) are presented in the figures below.

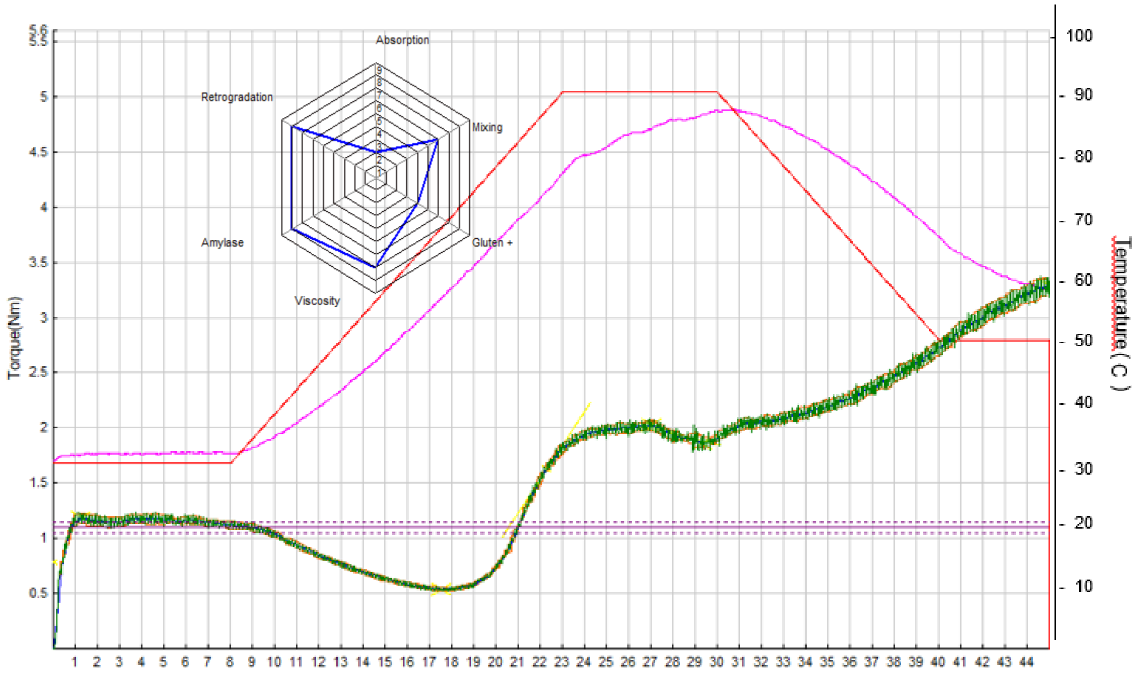

Figure 1. Mixolab rheological profiles of analyzed sample of Wheat flour WF

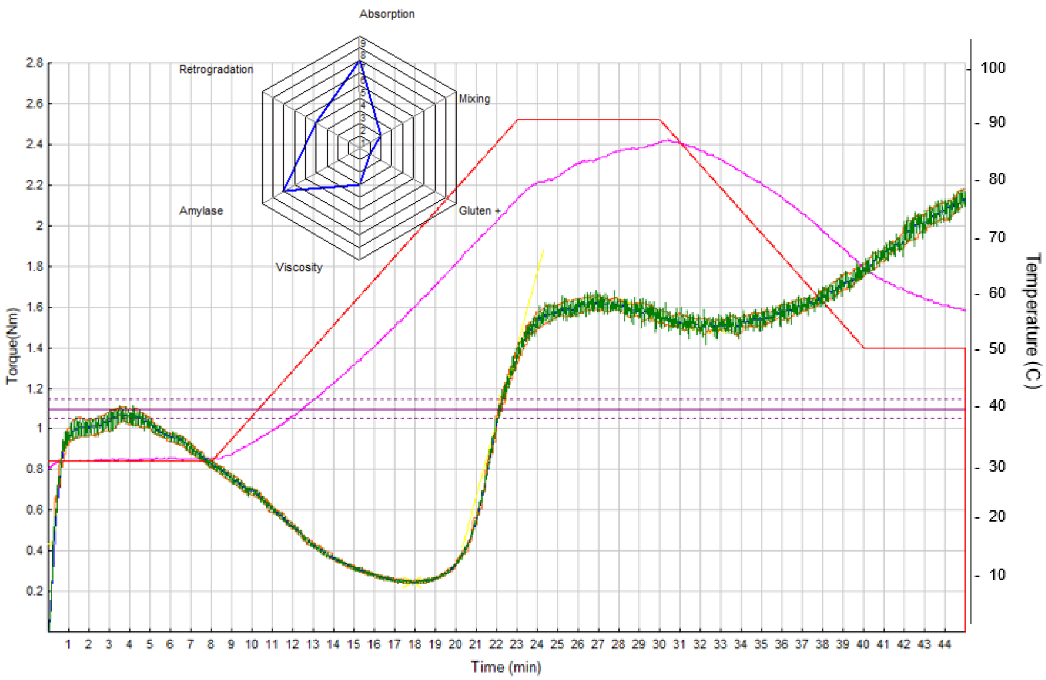

Figure 2. Mixolab rheological profiles of the analyzed sample of composite flour with 2.5% moringa (MWF1)

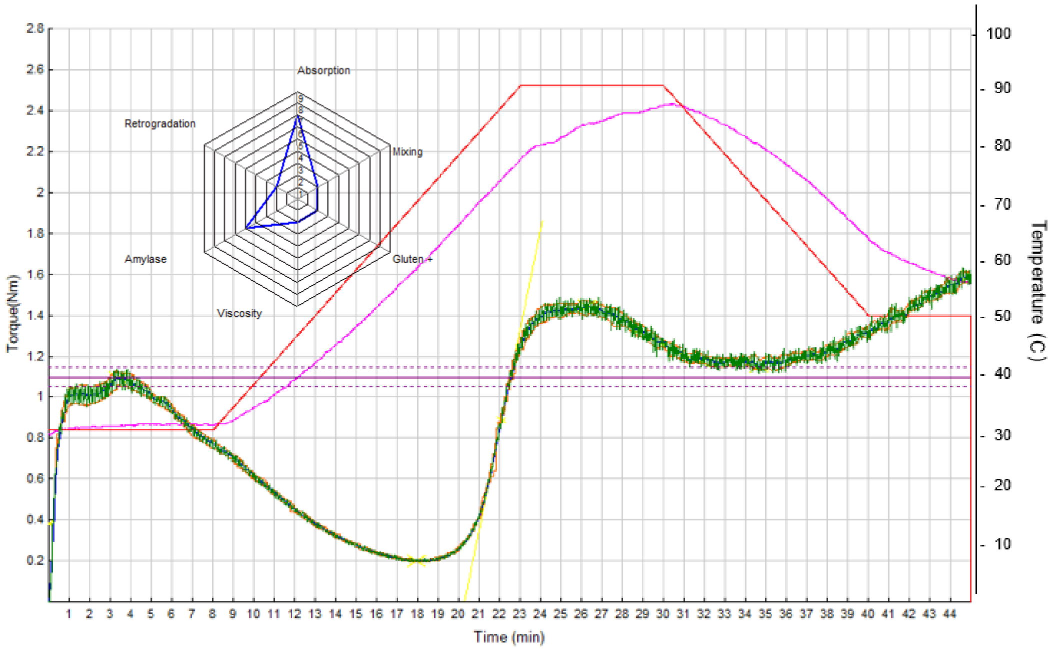

Figure 3. Mixolab rheological profiles of the analyzed sample of composite flour with 5% moringa (MWF2)

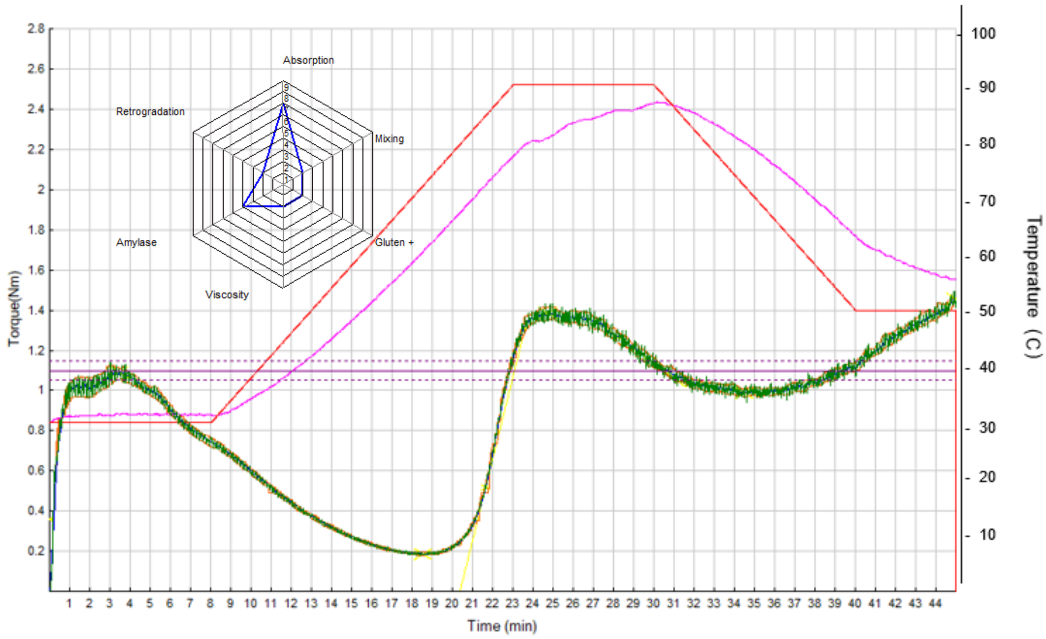

Figure 4. Mixolab rheological profiles of the analyzed sample of composite flour with 7.5% moringa (MWF3)

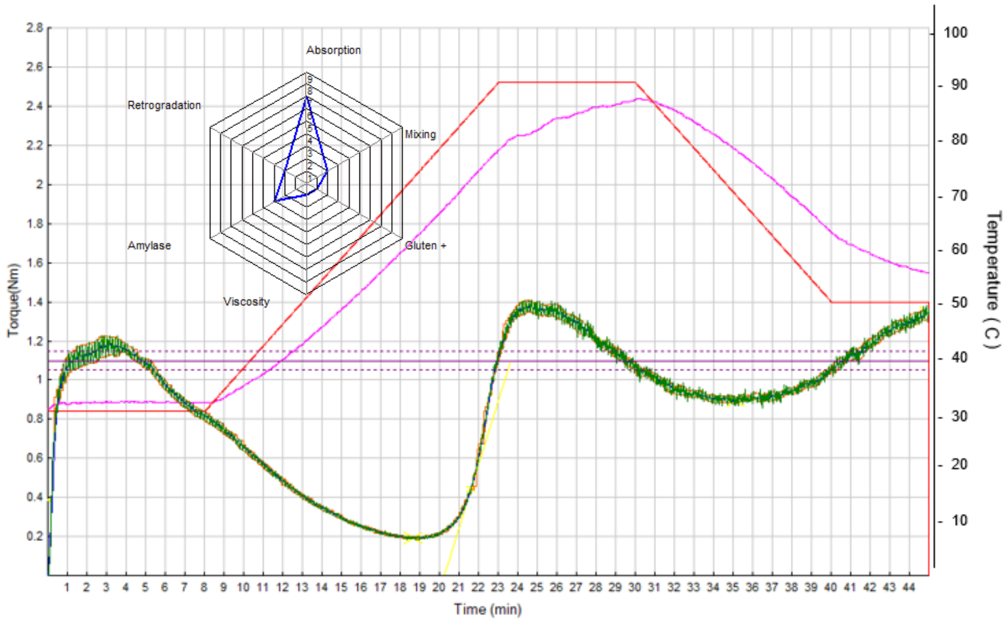

Figure 5. Mixolab rheological profiles of the analyzed sample of composite flour with 10% moringa (MWF4)

Table 2 presents the primary parameters of the various Moringa samples. These parameters include water absorption (WA, %), stability (ST, min), as well as torques C1 to C5 (Nm), which represent mechanical weakening, minimum torque, maximum torque, baking stability, and recoil, respectively. Additionally, the primary parameters included the angles between the ascending and descending curves (α, β, γ, and δ), which correspond to the tangent arc of the four curve angles [14].

Table 2. Primary parameters

Primary parameters	Water Absorption	Stability	C1	C2	C3	C4	C5	α	β	γ
Samples	(%)	(min)	(Nm)	(Nm)	(Nm)	(Nm)	(Nm)	(Nm/min)	(Nm/min)	(Nm/min)
WF	55.8	9.52	1.189	0.538	2.027	1.860	3.289	-0.074	0.306	-0.046
MWF1	60.0	5.82	1.076	0.247	1.622	1.496	2.138	-0.072	0.368	-0.042
MWF2	60.0	5.17	1.095	0.200	1.445	1.150	1.593	-0.066	0.490	-0.046
MWF3	60.0	4.85	1.092	0.186	1.385	0.988	1.456	-0.058	0.406	-0.074
MWF4	60.0	4.82	1.187	0.193	1.374	0.893	1.345	-0.058	0.324	-0.074

Analysis of the combined results of the figures and Table 2 shows that the addition of moringa flour to wheat flour had an impact on the rheological properties of the composite flours obtained. Water absorption improved from 55.8% for wheat flour to 60% for the various composite flours. We can therefore conclude that the partial replacement of moringa flour with wheat flour would improve the water absorption capacity of the composite flours. Similar conclusions were reached by Dachana et al, [16] in their study entitled "Effect of dried moringa (*Moringa oleifera*lam) leaves on rheological, microstructural, nutritional, textural and organoleptic characteristics of cookies". In this study, the incorporation of 15% moringa flour improved water absorption capacity from 59.2 to 66.7%. It should be noted that water absorption is a parameter that should be given particular attention to obtaining good-quality baked products [17]. It is considered to be the hydration required to obtain a maximum dough consistency of 1.1 Nm. It is also the amount of water to be absorbed by enzyme degradation rate, and starch the flour

to reach a given consistency during the constant temperature phase [14].
Stability time is the time required for the dough to resist kneading. According to the results of the present study, this time obtained for wheat flour is well above those obtained for flours with different proportions of moringa. The values obtained were as follows: 9.52; 5.82; 5.17; 4.85 and 4.82 for WF, MWF1, MWF2, MWF3 and MWF4 respectively. The higher the moringa content in the composite flours, the lower the stability times obtained. Moringa flour would therefore reduce the resistance of composite flour doughs during kneading. The same observation was made by [16], who also noted a reduction in dough stability time with the addition of moringa flour.
For C1 torque, the values obtained for composite flours (between 1.076 and 1.187 Nm) were below those obtained for wheat flour (1.189 Nm). The same observation was made for the C2 couple. From 0.538 Nm for WF, C2 fell to 0.193 Nm for the sample with 10% moringa (MWF4). This shows that the higher the moringa content in composite flours, the lower the C2 value. Given that a high C1-C2 value indicates the protein quality of the flour used [18], we can deduce that moringa flour reduces protein quality when incorporated into composite flours.

One of the factors for recognizing the good quality of cookie flour is that it has high C3 and C4 values, indicating the importance of the starch phase [18]. In our study, maximum C3 and C4 values were obtained for WF and minimum values for MWF4. Furthermore, C4 and C5 values decreased with increasing moringa content in composite flours. The values obtained for couple C3 were 2.027; 1.622; 1.445; 1.385 and 1.374 respectively for WF, MWF1, MWF2, MWF3 and MWF4. For C4 torque, the values were 1.860; 1.496; 1.150; 0.988 and 0.893 Nm respectively for WF, MWF1, MWF2, MWF3 and MWF4. As with C3 and C4, the higher the moringa content in composite flours, the lower the C5 value. Bearing in mind that for better flour quality, C5 values should be high [18], and taking into account the above information and the results of the present study, we deduce that adding high quantities of moringa flour to wheat flour could affect the good quality of the composite flours obtained.

3.2. Mixolab Profiler index

The following table presents the different scores for the indices defined by the Mixolab Profiler. These are: Water Absorption Index (WAI), Mixing Index (MI), Gluten + Index (GI), Viscosity Index (VI), Amylolysis Index (AI), and Retrogradation Index (RI).

Table 2. Mixolab Profiler index

Samples	WAI	MI	GI	VI	AI	RI
WF	2	6	4	7	8	8
MWF1	7	2	1	3	7	4
MWF2	7	2	2	2	5	2
MWF3	7	2	2	2	4	2
MWF4	7	2	1	1	3	2

Analysis of the results in this table reveals that composite flours have a higher absorption index than wheat flour. This being the case, we can deduce that moringa flour has a better absorption index than wheat flour, and contributes to the increase in the latter in composite flours. As a high value of the water absorption index is synonymous with a high-water absorption capacity of the dough [14, 19], our previous results and those of [16] regarding the high-water absorption capacity of moringa compared with wheat flour are confirmed.

The mixing index is a very important rheological parameter, as it not only provides information on dough stability but also on development time and dough weakening during kneading at 30°C [14]. According to the Mixolab Chopin handbook, a high MI value corresponds to high dough stability during kneading [14]. In the present study, MI being higher for WF (6) than for composite flours (2), we deduce not only that WF is more stable than composite flours, but also that the addition of moringa flour is the cause of the lower stability of composite flours.

Similar results were obtained by [16], who revealed a decline in dough stability and strength with the addition of increasing quantities of moringa flour to wheat flour.
The gluten index provides information on the attitude of gluten during dough heating [14]. In this study, GI was highest for WF (4) and lowest for MWF4 (1). Since a high GI value corresponds to high gluten resistance to heat [14], it can be deduced that WF produces a dough with an excellent gluten network, unlike the other flours (MWF1, MWF2, MWF3, and MWF4). The same observation was made by [16], who reported a break in gluten continuity with the addition of increasing quantities of moringa flour. Moringa would thus have affected the behavior of the gluten network in composite flours.
The viscosity index (VI), amylolysis index (AI), and retrogradation index (RI) represent, respectively, the increase in viscosity on heating, the ability of the starch to resist amylolysis and the characteristics of the starch and its hydrolysis during the test [14, 19]. In this study, VI is maximal in WF (7) and minimal in BWF4 (1). Also, the higher the amount of moringa flour in the composite flours, the lower the VI values. Since a high VI value corresponds to high dough viscosity during heating, we deduce that WF would produce doughs with better viscosity compared to composite flours. Dachana et al., 2010 [16] also reported a decrease in the ability of starch granules to swell and therefore a decrease in dough viscosity with the addition of moringa flour to wheat flour.
AI and RI values were highest for WF (AI: 8 and RI: 8) and lowest for MWF4 (AI: 3 and RI: 2). It was also found that as the amount of moringa increased, the AI and RI values decreased. Since low AI and RI values correspond to a good shelf life of the final product [16], it can be deduced that the higher the moringa content in composite flours, the better the shelf life of the final products derived from these flours. It can therefore be deduced that moringa increases the shelf life of bakery products.

4. Conclusion

This article aimed to evaluate the rheological properties of moringa leaf and wheat flour composites, to explore the potential of moringa leaf flour as a functional ingredient in bread-making. The study determined the rheological profile, the primary Mixolab parameters, and the Mixolab profiler index. These analyses showed that moringa increased the water absorption capacity of composite flours. It also had a positive impact on improving the shelf life of bakery products. On the other hand, moringa flour reduced the resistance of composite flour doughs during kneading. It also reduced protein quality when incorporated into composite flours. A low gluten index was observed, causing a break in gluten continuity following the addition of increasing quantities of moringa flour. Moringa would thus have affected the behavior of the gluten network in composite flours. The study also revealed a reduction in the swelling capacity of starch granules, and hence in dough viscosity, with the addition of moringa flour to wheat flour. This study's results show that adding large quantities of moringa flour to wheat flour could affect the quality of the composite flours obtained. Still, they would increase water absorption capacity and shelf life. Moringa flour can therefore be used as a substitute for wheat flour in bread-making products, but with a substitution rate not exceeding 2.5% to preserve their rheological properties.

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