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Rheological properties of composite flours fortified by adding chickpea flour and oat fiber

Ramona Carmen Romînescu[1*], Sylvestre Dossa[1], Ersilia Alexa[1], Mariana-Atena Poiana[1], Adrian Riviș[1]

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

Abstract

This paper presents the study of the rheological properties of composite flours with functional potential in bakery obtained by replacing wheat flour with chickpea flour and adding fiber from oats.

Chickpea flour has been used for the partial substitution of wheat flour in percentages of 10-25%, adding certain percentages of oat fibers (2-5%) to further increase the functional potential. The rheological properties of composite flours were analysed using MIXOLAB system by CHOPIN. The results shown that the higher the quantities of fiber and chickpeas, the lower the stability time of the dough and the stability times obtained for the different flours ranged from 7.97 to 6.55 min. Also, it was suggested that the gradual addition of chickpeas to wheat flour would weaken its protein quality. Even if there are some changes in the rheological behavior of chickpea-based composite flours, the present study indicates the possibility of successfully using this flour in bakery in order to increase the nutritional and functional value of the products.

Keywords: Chickpea flour, oat, MIXOLAB, water absorption, dough stability

1. Introduction

Chickpea flour is an excellent source of nutrients and has multiple health benefits. Being obtained from ground chickpeas, it retains a large part of its properties [1].

Interest in the consumption of chickpea flour is increasing, especially due to its functional properties. such as foaming, emulsifying, gelatinizing, texture and viscosity properties, water and oil absorption capacity [2].

Here are the main nutritional properties of chickpea flour:

1. High protein content

Chickpea flour contains about 22-25% protein, making it a great option for vegetarians and vegans, as well as anyone looking to add plant-based protein to their diet [2].

2. Rich in fiber

It contains soluble and insoluble dietary fiber, which helps maintain digestive health and control blood sugar levels. A 100 g portion of chickpea flour contains about 10 g of fiber [1].

3. Low in fat

Chickpea flour is relatively low in fat (about 6-7%), most of which is unsaturated fat, beneficial for heart health [3].

4. Source of vitamins and minerals

Chickpea flour is a good source of vitamins and minerals, especially iron, magnesium, phosphorus and B vitamins (especially folate). For example, 100 g of chickpea flour can contain up to 6 mg of iron.

5. Low glycemic index

It has a low glycemic index, which means it is suitable for people with diabetes or those who want to control their blood sugar.

6. Gluten free

Chickpea flour is naturally gluten-free, making it a great option for people with celiac disease or those following a gluten-free diet [3].

7. Antioxidants

Chickpea flour contains antioxidants such as polyphenols, which help protect cells from oxidative stress and may help reduce the risk of chronic disease [1-3].

Chickpea flour is increasingly used in bakery products, due to its nutritional and functional properties. Incorporating chickpea flour into bread, biscuits, cakes and other bakery products brings many benefits, but also technical challenges [4-6].

*Corresponding author: ramona_rominescu@yahoo.com

High nutrient potential of chickpea flour used in bakery is due in large part to the high content of protein and fiber. According to the results shown in Table1, the average of the protein content for the tested chickpea flour is 21.9% and 9.9 % for the fiber content; these results show, that comparatively with the wheat flour, the protein content of the chickpea flour is 2.5 times higher, while the fiber content is 16.6 times higher than the wheat flour (type 650) [7].

However, chickpea presents higher content of lipids content up to 7% [5](5). In pulses, lipids are usually present in the form of sterols, phospholipids (PhL), triacylglycerol (TAG), steryl esters, and free fatty acids (FFA). The phospholipids (PhL) content of chickpeas was around 17–20% and TAG content was 56–67% as reported by Zia-Ul-Haq et al. [8].

Some benefit of chickpea flour added in bakery products are presented below.

1. Improving the nutritional profile

Chickpea flour adds high protein, fiber and minerals to baked goods. This helps to increase the nutritional value of the products, making them healthier and more filling. For example, adding chickpea flour to bread can increase the protein and fiber content, providing a healthier option over traditional wheat bread [4].

2. Improving structure and texture

Chickpea flour can influence the structure and texture of baked goods. Although it does not contain gluten, the combination with other flours or leavening agents can produce a pleasant texture and an acceptable volume in products such as bread or cakes. However, due to the lack of gluten, in breads with a high percentage of chickpea flour, a binding agent such as xanthan gum or guar is required [5].

3. Distinct flavor and color

Chickpea flour adds a slightly nutty flavor and a yellowish color to baked goods. These characteristics can improve the taste and appearance of products, but must be balanced in recipes to suit consumer preferences [4].

4. Potential for gluten-free products

Chickpea flour is ideal for bakery products intended for those with gluten intolerance or for those following a gluten-free diet. Products such as biscuits, cakes and pancakes can be made with chickpea flour, offering a texture and taste comparable to traditional, but gluten-free [5].

Chickpeas are a very good source of dietary fiber. So is chickpea flour, especially if it is used instead of some types of refined flour, emptied of nutrients and with a low fiber content.

Chickpeas have been found to be a good vehicle for selenium enrichment [2]. When chickpeas are germinated using sodium selenite, the concentration of isoflavonoids increased. Therefore, this may be a desirable method for using chickpeas as flour [3] Chickpea proteins are considered suitable source of dietary protein due to excellent balance of essential amino acid composition [4].

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Table 1. Chemical parameters for wheat flour, chickpea flour [7]

Parameter	Wheat flour (WF)	Chickpea Flour (CF)
Moisture, g%	12.7	8.9
Ash, g%	0.67	3.24
Crude protein, g%	8.9	21.9
Total lipids, g%	1.8	6.3
Crude fibre g%	0.6	9.9

Impact on recipes and processing techniques

Incorporating chickpea flour into baking recipes requires adjustments to recipes and processing techniques. For example, chickpea flour absorbs more water than wheat flour, which requires adjusting the amount of liquids in the recipe. Also, to compensate for the lack of gluten, it is necessary to add binding agents [6].

Oat fiber is used in bakery products to improve their nutritional and functional profile. Adding oat fiber has multiple benefits, including increased fiber content, improved texture, and extended shelf life.

1. Increasing fiber content

The addition of oat fiber to bakery products contributes significantly to increasing dietary fiber intake. This is beneficial for digestive health and the prevention of chronic conditions such as cardiovascular disease and type 2 diabetes. Oat fiber in particular contains beta-glucans, which have been associated with lowering blood cholesterol levels [9].

2. Improving texture and structure

Oat fiber can improve the texture and structure of baked goods, providing a more pleasant chew and better moisture retention. This can result in softer, fluffier bread with a greater ability to stay fresh for a longer period of time [10].

3. Weight and satiety control

Oat fiber can help with weight control by inducing a faster and longer-lasting feeling of satiety. These fibers slow the digestion and absorption of

carbohydrates, which can help stabilize blood sugar levels and prevent overeating [11].

4. Functionality and extension of validity period

Due to their ability to absorb water, oat fibers can help retain moisture in products, extending their shelf life. They can also act as thickeners and stabilizers in baking recipes [12].

Incorporating oat fiber into baking recipes requires recipe adjustments. Oat fiber can interfere with gluten development, which can affect the volume and texture of the final product. Therefore, it is important to find a balance between the amount of added fiber and the other ingredients in the recipe.

In this paper, the rheological and technological properties of wheat flour enriched with chickpea flour in different proportions and in combination with oat fibers were studied.

2. Materials and method

The chickpea flour, oat fiber and wheat flour were purchased from Solaris shop, Romania.

Four composite flours were obtained:

CFWF1 - flour with 10% chickpea flour, 2% fiber and 88% Wheat flour

CFWF2 - flour with 15% chickpea flour, 3% fiber and 82% Wheat flour

CFWF3 - flour with 20% chickpea flour, 4% fiber and 76% Wheat flour

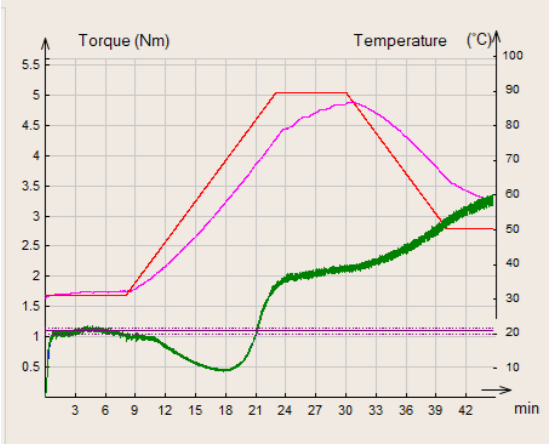
CFWF4 - flour with 25% chickpea flour, 5% fiber and 88% Wheat flour

The rheological profile of composite flours was performed using MIXOLAB system according the methodology presented in the Handbook of rheological and enzymatic analysis provided by Chopin Applications Laboratory, France [13].

3. Results and discussion

3.1. Rheological profiles

The rheological profiles of the flour samples were analyzed using the MIXOLAB equipment. The rheological profile of each sample is shown in the figures 1-4.



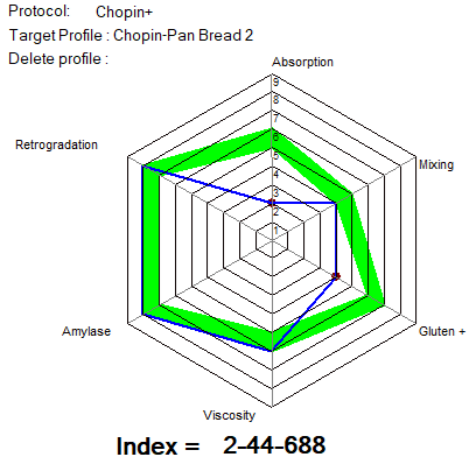
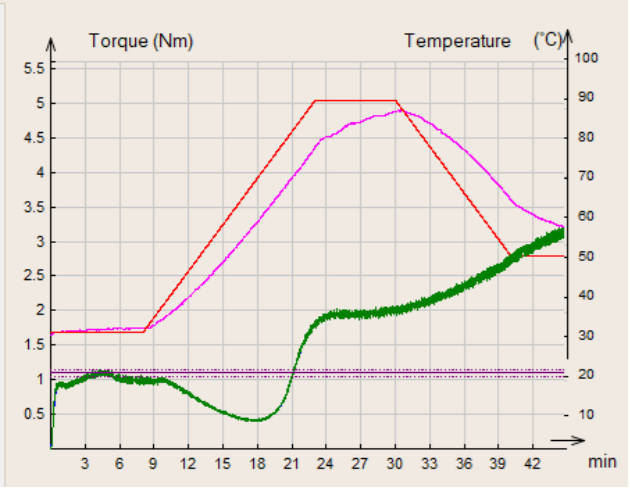


Figure 1. Mixolab rheological profiles of the analyzed sample of composite flour with 10% chickpea flour, 2% fiber and 88% Wh eat flour (CFWF1).



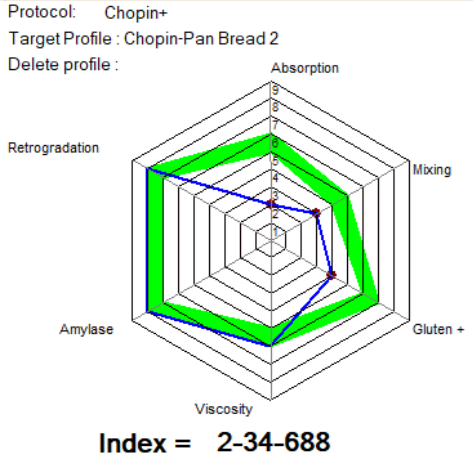
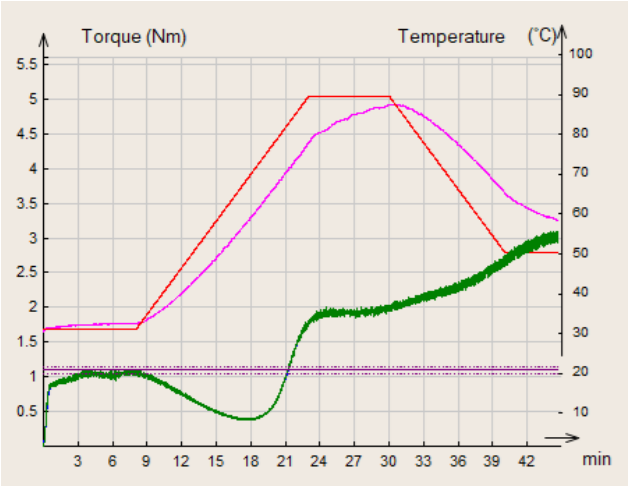


Figure 2. Mixolab rheological profiles of the analyzed sample of composite flour with 15% chickpea flour, 3% fiber et 82% Wheat flour (CFWF2)



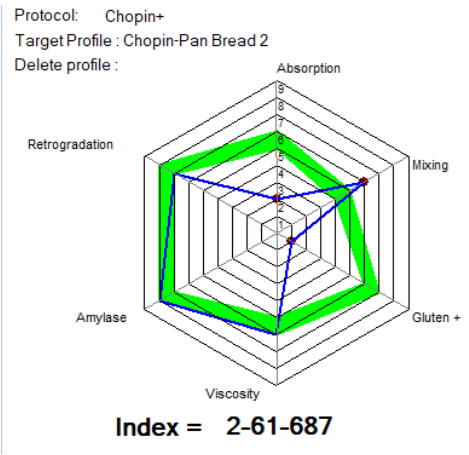
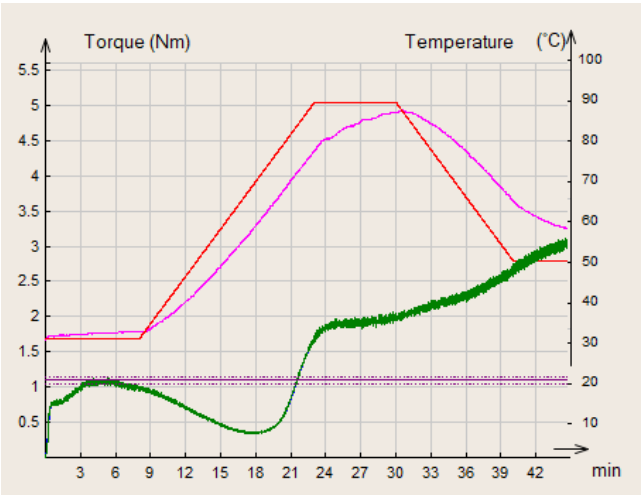


Figure 3. Mixolab rheological profiles of the analyzed sample of composite flour with 20% chickpea flour, 4% fiber et 76% Wheat flour (CFWF3).



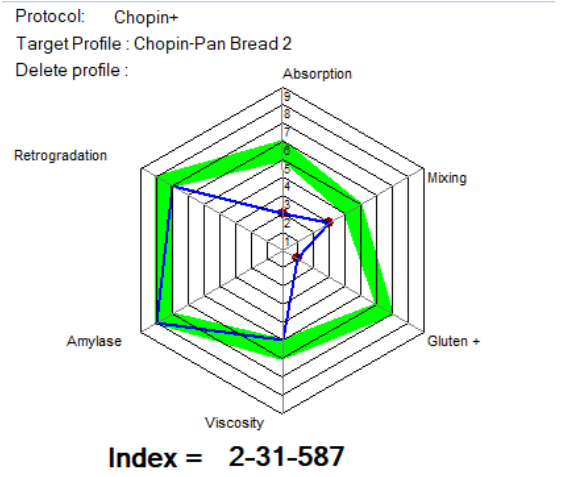


Figure 4. Mixolab rheological profiles of the analyzed sample of composite flour with 25% chickpea flour, 5% fiber et 70% Wheat flour (CFWF4)

The figures 1-4 show the curves obtained from Mixolab for the different samples. They also show the different quality indices of the flours studied in this study, compared with the standard index for making good bread using Mixolab.

Analysis of the results of these different figures shows that the absorption index, although lower than that required for flour used to produce bread, remained stable from one sample to the next, regardless of whether the quantity of chickpea flour and fiber increased from one sample to the next. Indeed, according to Mixolab, normal bread flour should have a water absorption index of between 5 and 6, whereas in this study the water absorption index (WA) was 2 for the different samples. As the water absorption of flour is related to the water capacity of its dough [14], it follows that doughs made from various wheat/chickpea/fiber flours would have a low water absorption capacity and therefore require special attention when formulating bread. According to the Mixolab Chopin manual, the mixing index is the rheological parameter that provides key information on dough stability, development time, and weakening of the dough during kneading at a temperature corresponding to 30°C [13].

According to Mixolab, the normal value for the mixing index of flour used to produce bread should be between 4 and 5. In the present study, only the sample with 10% chickpea and 2% fiber falls within this range. The result is that, among compound flours, the best composition for flour with good stability and development time would be that with 10% chickpea, 2% fiber, and 88% wheat flour (CFWF1).

As far as the gluten index (GI) is concerned, for good bread its value should be between 6 and 7. In this study, the GI obtained for the different composite flours was below the normal value for

good bread. Indeed, maximum values (4) were obtained for CFWF1 and CFWF2 (containing respectively 10% chickpea / 2% fiber and 15% chickpea / 3% fiber). On the other hand, the minimum values (1) were obtained for samples CFWF3 and CFWF4 (containing large quantities of chickpeas and fiber). Thus, the higher the quantity of chickpea and fiber in the composition of composite flours, the lower the gluten index. Similar results were obtained by Dossa et al., 2023; Plustea et al., 2022 when replacing wheat flour with lupin and baobab flour respectively [15,16]. Referring to the Mixolab Chopin handbook [13], GI is a parameter that not only provides information on the attitude of gluten during dough heating but also shows a high resistance of gluten to heat when its value is high. This suggests that the various composite flours produce doughs with low gluten heat resistance as the quantities of chickpea and fiber increase.

The viscosity index (VI) represents the increase in viscosity on heating [13,14]. In the present study, the values obtained for VI were in the range required to obtain good bread (between 5 and 6). Amylolysis index (AI) and retrogradation index (RI) represent, respectively, the starch's ability to resist amylolysis and the characteristics of the starch and its hydrolysis during the test [13,14].

For each of the flours studied in the present study, the AI and RI obtained were within the range proposed by Mixolab for bread production. This shows that chickpea flour and fiber did not hurt viscosity, amylose, and retrogradation indices.

3.2. Primary parameters

Table 2 shows the primary parameters obtained for the different flours studied.

Table 2. Primary parameters

Primary parameters	WA	Stability	C1	C2	C3	C4	C5
Sample	(%)	min	Nm	Nm	Nm	Nm	Nm
CFWF1	55.0	7.97	1.134	0.446	1.826	2.132	3.290
CFWF2	55.0	7.58	1.096	0.413	1.799	2.009	3.133
CFWF3	55.0	6.62	1.067	0.389	1.769	1.986	3.047
CFWF4	55.0	6.55	1.080	0.350	1.676	1.979	3.049

Analysis of the results in this table reveals that the stability times obtained for the different flours ranged from 7.97 to 6.55 min. The maximum value (7.97 min) was obtained for CFWF1, while the minimum value (6.55 min) was obtained for CFWF4. In addition, it was found that the higher the quantities of fiber and chickpeas, the lower the stability time of the dough obtained. Similar results were obtained by Cingöz & Yörükoğlu, 2022 [17]. In their study, stability time fell from 10.2 min to 5.33 min between the sample with 10% chickpeas and the one with 50%. Chickpea would therefore be responsible for the drop-in time required for the dough obtained from each of the composite flours to withstand kneading.

For C1, the values obtained in this study were 1.134, 1.096, 1.067, and 1.080 respectively for CFWF1, CFWF2, CFWF3, and CFWF4. Similarly, for C2, the values obtained were respectively 0.446; 0.413; 0.389; 0.350 for CFWF1, CFWF2, CFWF3 and CFWF4. Analysis of these results reveals that the higher the chickpea and fiber content in the composition of the various flours, the lower the value of the C1 and C2 torques. These results are in line with those of Cingöz & Yörükoğlu, 2022 [17]. Indeed, in their studies the values obtained for the C2 couple varied between 0.45 and 0.33 from the sample with 10% chickpea to the sample with 50% [17]. Moreover, according to Ozturk et al., 2008, a high C1-C2 value indicates the protein quality of the flour used [18]. All this information suggests that the gradual addition of chickpeas to wheat flour would weaken its protein quality.

Couples C3, C4, and C5 adopted the same behavior as couples C1 and C2. This means that the greater the quantity of chickpea and fiber in the composition of blended flours, the lower the value of C3, C4, and C5 pairs. Not only was the same finding made by Cingöz & Yörükoğlu, 2022 [17], but the values obtained in that study were close to those of the present study. Given that high values for the C3, C4, and C5 torques indicate good flour quality [18], this suggests that chickpea affects the quality of compound flours.

4. Conclusions

Considering the important nutritional properties, especially the protein and fiber content, chickpea flour stands out as a good substitute for wheat flour in bakery products. Even if there are some changes in the rheological behavior of chickpea-based composite flours, the present study indicates the possibility of successfully using this flour in bakery in order to increase the nutritional and functional value of the products. The addition of up to 20% chickpea flour and even 25% corroborated with the addition of 5% oat fiber does not negatively influence the rheological parameters of the bakery dough determined by the Mixolab system, which recommends the use of these functional composite flours in the usual practice of the bakery industry.

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