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COMPARATIVE STUDY OF SOME PHYSICO-CHEMICAL CHARACTERISTICS OF WHEAT, RICE, AND CORN FLOURS

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Abstract: *A comparative study of the oil and water absorption and swelling capacity of wheat, rice, and corn flours was performed in the context of possible utilization of the latter two materials as partial substitutes for wheat in various types of dough for producing pastries and other food products to meet the growing popularity of low-gluten dietary solutions. Since rice and corn contain less gluten, these substitutions can be beneficial for gluten-free and/or low-gluten dietary courses.*
It was found that the water absorption capacities of all flours are quite close, while their oil/grease absorption capacities vary. The swelling of rice/corn flour mixtures is not lower than that of wheat, which should not deteriorate the porosity and texture of the items baked with a flour in which wheat was partially substituted with rice or corn. However, a higher grease absorption by corn flour should be taken into account when making adjustments to pastry recipes.

Keywords: *wheat flour, rice flour, corn flour, swelling, water absorption capacity, grease absorption capacity*

1. Introduction

Wheat flour is one of the oldest and most traditional, yet still highly consumed valuable source of carbohydrates, vegetable proteins, mineral compounds, and many other nutritional components. It is used widely in various pastry, bakery, confectionery products, and a wide variety of other foods. Wheat flour ensures good taste and high calorific value of foods, but, on the other hand, it has comparatively high gluten content, which is adverse for individuals with gluten intolerance. Among others, this flaw is a reason to put some restrictions on the consumption of wheat flour-rich products by customers aged below 2 and over 45 years [1-5].

That is why, despite strong tradition of consuming wheat flour, there is a growing topicality of its partial or complete replacement with other, less-gluten-containing types of flour.

There are many materials to be used as substitutes for wheat flour: potato powder [6], quinoa [5, 7], pumpkin seed flour [8], and others. Substantial attention is paid to the research on the influence of the replacement of wheat flour with rice and corn flours [9-12] since they can affect the rheological properties, texture, appearance, taste, and other consumer qualities of the pastry and other items made of the blended dough. As reported in [9], upon incorporation of the rice flour, the swelling capacity and bulk density of the blended flour increase, while its oil absorption capacity, solubility index, foaming capacity and stability decrease. Additionally, the pasting capacity of the mixed flour also increases, perhaps due to

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the higher starch content in the added rice flour. All these changes affect the rheological properties of the dough and require some readjustments in the settings of the dough processing equipment. A more detailed investigation of the rheological properties of the rice/corn/wheat blended dough [10] showed closeness between the properties of pure wheat and wheat/rice types of dough, while the properties of pure wheat and corn/wheat types of flour were found to be more different at the same contents of rice or corn additives.

Mixed wheat/corn flour exhibits higher water and oil holding capacity, better emulsifying activity, while its foaming capacity also decreases with an increase in the content of raw or defatted corn flour in the mixture [11]. An admixture of different types of corn flour also affects the blended dough rheological and sensorial properties, resulting in a less structured and more broken gluten matrix, slower hardening with storage time, darker color, larger specific volume, and better overall sensorial perception score [10, 12]. Therefore, it seems interesting to study and compare some of the abovementioned parameters of wheat, corn, and rice flour to improve the understanding of the effect of the latter two components on the properties of wheat flour in the context of possible partial substitution of wheat with such less-gluten-containing components. Both possible substituents are widely cultivated and easily available in Ukraine, which facilitates their utilization as additional components of various types of dough.

Dough is a dispersed system that can absorb some water and/or oil, which affects the technological settings for its transportation, processing, and storage. Depending on the dough composition, its water/oil absorption capacity and rheological properties may change; therefore, it is important to study these characteristics for various flour blends in the context of their possible use in producing low-gluten items, which are gaining popularity among customers in many countries.

2. Materials and methods

All flour materials used in this study were purchased from a regular grocery store and were standard packages of flour used for various homemade food products, such as bread, pastries, pancakes, etc.

This study was done on the following samples:

An unbranded sample of wheat flour of the highest grade. It is a finely ground, off-white powder with a weak, characteristic smell and a specific taste, with no bitterness or acid notes. The content of mineral compounds was 2.1 wt%, water content – 15 %.

An unbranded sample of rice flour. It is a finely ground white powder with a characteristic smell and a specific taste, with no bitterness or acid notes. The content of mineral compounds was 2.9 wt%, water content – 12.5 %.

An unbranded sample of corn flour. It is a finely ground light-yellowish powder with a characteristic smell and a specific taste, without bitter or acidic taste. The content of mineral compounds was 0.8 wt%, water content – 9.8 %. Determination of the water absorption capacity (WAC, %) of a sample was conducted by the following method. 1 g of a sample was mixed with 30 mL of water for 1 min and then placed in a pre-weighed centrifuge tube (weight A, g). The residual flour and water were washed off the mixing device with 5 mL of water, which was added to the same tube. The tube with all added materials was weighed again (weight B, g). The tube was centrifuged for 15 min at 8000 rpm. After that, the supernatant liquid was decanted, and the tube was turned upside down and left for 10 min to let the residual not-absorbed liquid leak out of the tube. Finally, the sample with some absorbed liquid was weighed (weight C, g), and WAC was calculated by the formula

$$WAC = \frac{C - B}{B - A} * 100 \qquad \text{Eq. (1)}$$

Determination of the grease absorption capacity (GAC) was performed in a similar way, but using a 5 g sample of the flour and 30 mL of refined sunflower oil with two 1-minute-long mixing sessions separated by a 5-minute-long pause. Then the sample was centrifuged under the same conditions, and GAC was calculated by the formula

$$GAC = \frac{C - B}{B - A} * 100 \qquad \text{Eq. (2)}$$

All the terms here have the same meanings as in the above case of calculating WAC.
To determine the swelling capacity, the samples of 1, 2, 3, 4, 5, and 6 g were taken from thoroughly mixed flour and placed in the beakers. 5-6 mL of water was added to each beaker, and the mixture was kneaded with a glass rod until it formed a viscous dough-like material. Each material was then placed in a graduated cylinder, and some amount of water was added until the volume reached the zero mark.
The samples were left at 20 °C, and their volumes were checked after 3, 24, 48 and 72 h. All experimental determinations mentioned above were repeated at least five times to ensure that the relative error was 10 % or less.

3. Results and discussion

WAC and GAC of wheat, rice, and corn flour

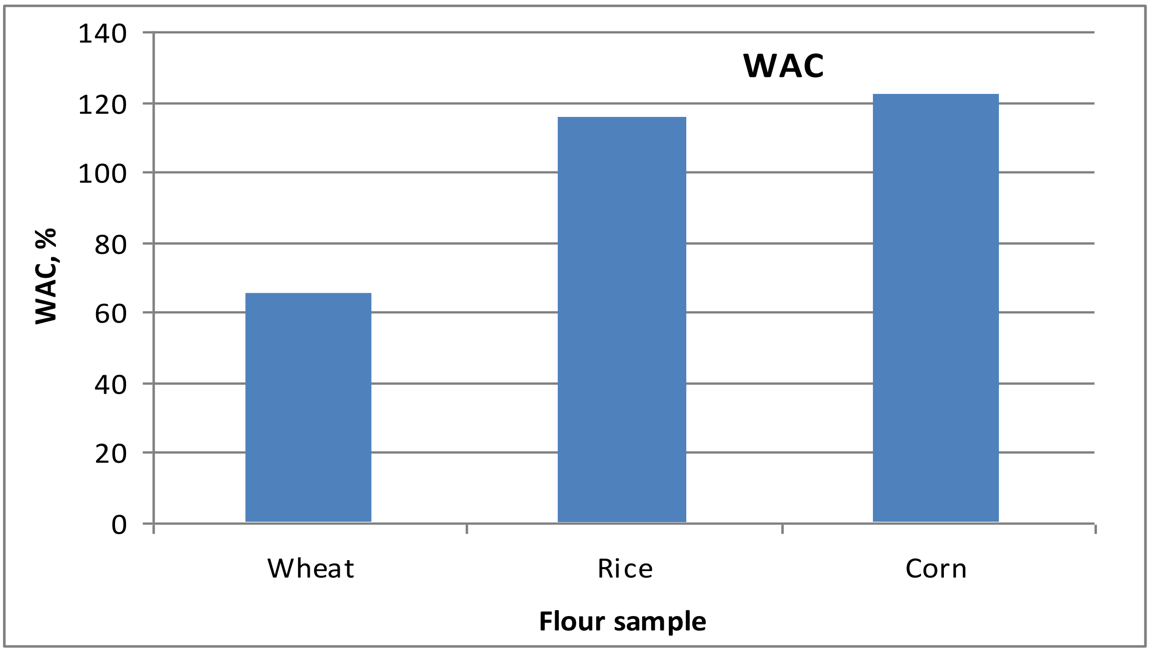
As seen in Fig. 1, the WAC and GAC of all flour samples involved in this investigation differ. This variation arises from different surface hydrophilicity, inner pore diameter, and granulometric composition of wheat, rice, and corn flours. Wheat flour is more highly dispersed but also more hydrophobic [15, 16]. That is why the WAC of rice and corn flour samples is higher than that of wheat (Fig. 1). The particles of corn and rice flour can better absorb and hold moisture on their surface and in the interparticle space. All three types of flour form a pseudo-solid phase after centrifugation – the absorbed water does not get separated and remains held inside the pores and on the particle's surface. The GAC value of the flour samples varies less between rice, wheat, and corn than their WAC value. It can be caused by a bigger physical size of the molecules of grease compounds, which also have comparatively long hydrophobic chains. As a result, the formation of an adsorption layer on the flour particle surface is impeded due to spatial obstacles and weaker interactions between the grease molecules and the hydrophilic adsorption centers on the surface. As seen in Fig.1, in the context of GAC, wheat and rice flour are very close to each other, while corn flour absorbs oil materials more intensively, and approximately 0.75 g of corn flour absorbs the same amount of oils as 1 g of wheat.

Swelling of the flour samples

The rheological properties of disperse systems are significantly affected by the amount of free disperse medium that contains the dispersed phase particles, and ensures their more or less free motion.
It was found that the dry bulk volume and swelling capacity of the samples were different. The bulk volume of the flours ranges between 1.4 and 2.1 cm^3/g (compare the first bars of the '1 g' series of wheat, rice, and corn flour in Fig. 2-4):

wheat (2.1 cm^3/g) > corn (1.8 cm^3/g) > rice (1,4 cm^3/g)

This difference is based on various granulometric compositions of the samples and the differences among their surface structures, leading to weaker or stronger interparticle interaction and more or less dense packing of the flour particles.



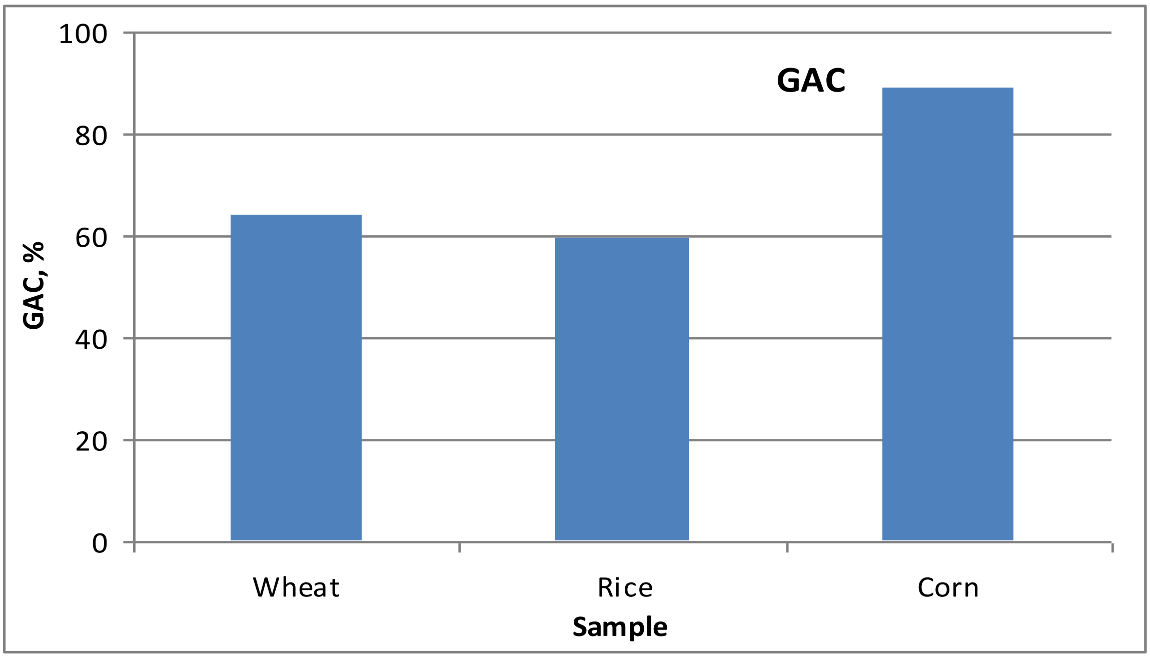


Fig 1. WAC (upper) and GAC (lower) of wheat, rice, and corn flour.

The addition of water leads to the swelling of all samples (see Fig. 2-4), which evidences the emergence of some spatial structure. The particles capture and adsorb water, forming bonds between their surface and the adsorbed water molecules, and build an inner framework that maintains its geometry for a certain time.

It was found that this period of inner framework stability lasts for at least 24 h for all types of flour involved in this investigation.

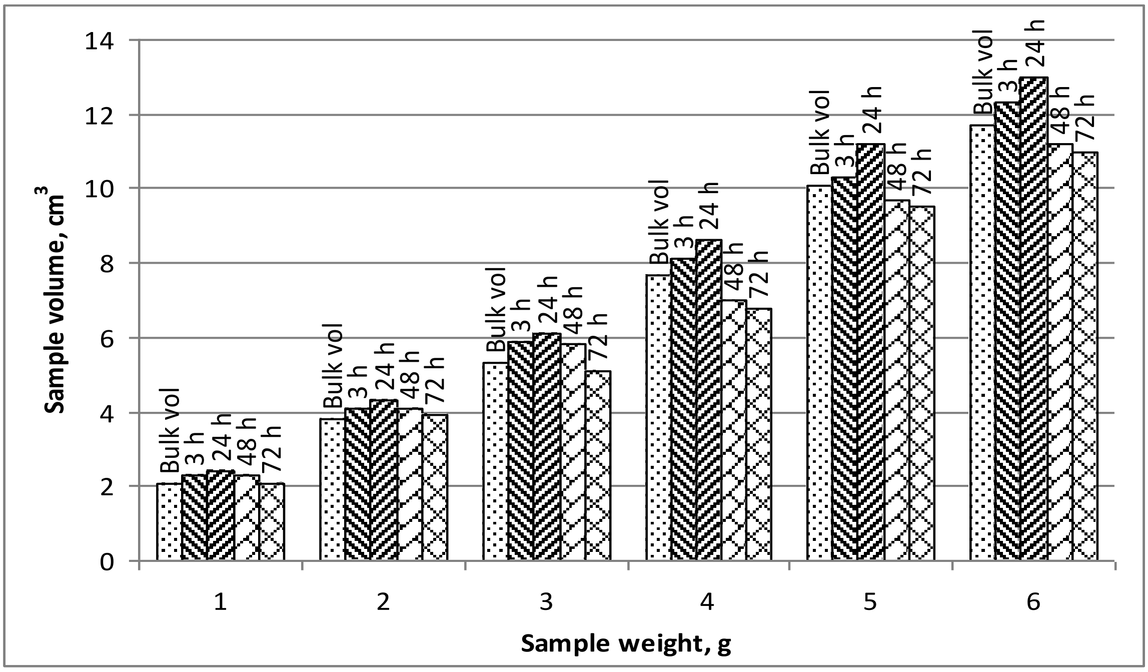


Fig. 2. Dynamics of swelling of wheat flour for the samples of 1, 2, 3, 4, 5, and 6 g: bulk volume and sample's volume after 3, 24, 48, and 72 h.

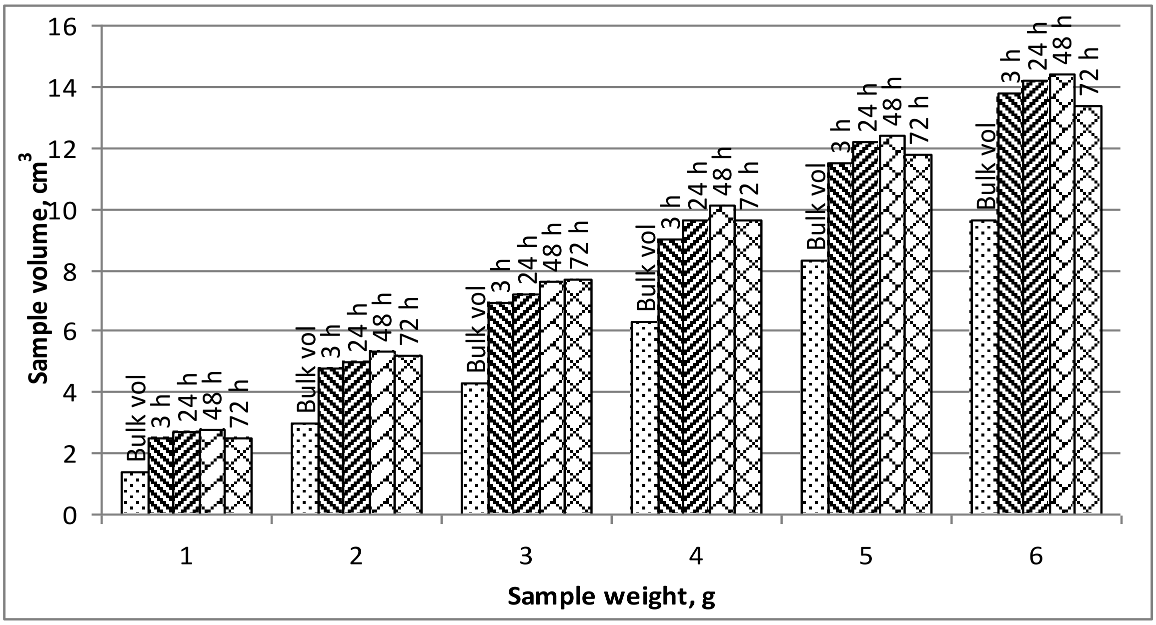


Fig. 3. Dynamics of swelling of rice flour for the samples of 1, 2, 3, 4, 5, and 6 g: bulk volume and sample's volume after 3, 24, 48, and 72 h.

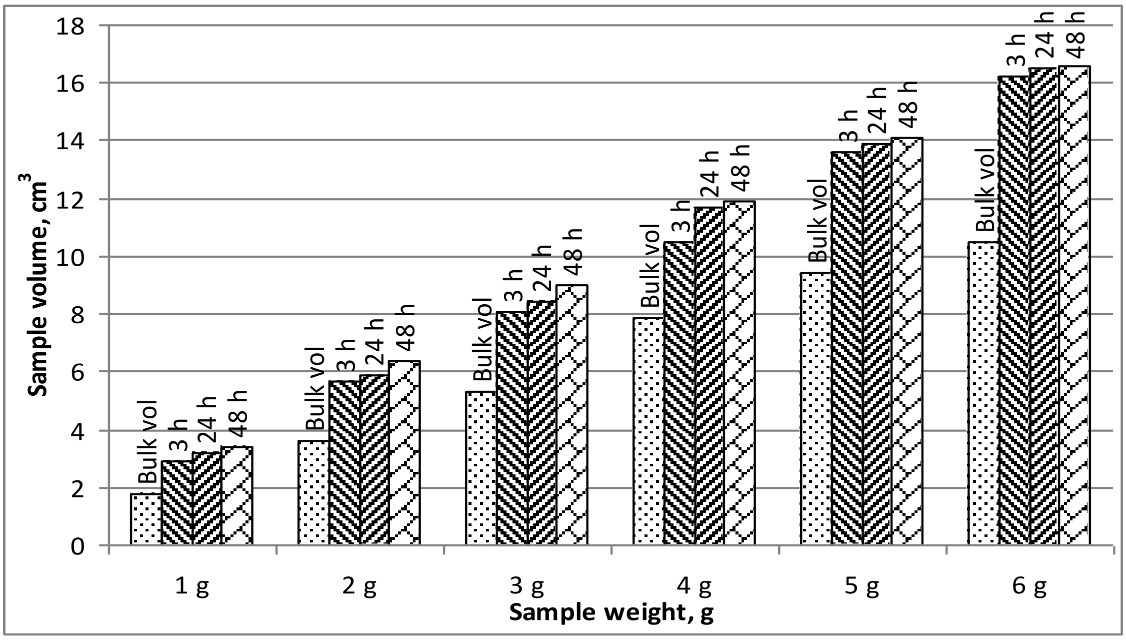


Fig. 4. Dynamics of swelling of corn flour for the samples of 1, 2, 3, 4, 5, and 6 g: bulk volume and sample's volume after 3, 24, and 48 h.

After that, the structure gradually degrades, causing the mixture to become cloudy and its volume to decrease. In our opinion, this process occurs due to the proliferation of microorganisms in the wet flour, which manifests itself by the appearance of turbidity in the liquid and a characteristic smell of fermentation. As seen in Figures 2-4, such degradation of the structure and subsidence in the initially swollen mixture starts after 24 h for wheat flour and after 48 h for rice. In the case of corn flour, this process could take place after 48 h, but the experiment was stopped due to the very intense fermentation and decaying of the mixture. Comparing swelling of similar samples of wheat, rice, and corn flour in a 24-h series, one can see that corn flour shows the most intense swelling, followed by rice, and then wheat flour. The lowest swelling of wheat flour can be caused by finer grinding of this type of grain, which causes the highest specific surface of the flour material. As a result, finer ground particles adhere to each other more tightly, leading to a lower capacity to retain the liquid phase necessary for swelling.

A comparison of our results with those reported in [9-12] proves that WAC and GAC measured in our project exhibit the same trends as in other similar works. A detailed quantification of these parameters and a comparative explanation of swelling dynamics for different types of flour presented here can be used to adjust recipes and technological settings of the production of pastry items made with blended doughs.

4. Conclusion

Corn and rice flour can be used to substitute wheat flour in the context of a low-gluten nutritional line. Both of these replacement materials have higher swelling capacity, which would not deteriorate the texture and sensorial properties of the end products. However, a less stable gluten matrix and changes in the pastry structure, color, and odor should be considered when adjusting recipes for pastry and other products based on corn/rice/wheat blends.

Since the oil absorption capacities of rice and wheat are very close, replacement of wheat flour with rice is not supposed to affect oil consumption in the technological processes, while adding extra oil can be required in the case of replacing wheat with corn, since its GAC is higher than that of wheat by approximately 25 %.

5. Acknowledgement

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