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Comparative Study on Rheological Properties of Wheat Flour Types for Industrial Usage

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Abstract

Wheat, *Triticum aestivum* is one of the grains consumed worldwide as a staple food used in a variety of processed commodities. The rheological properties of the raw commodity will define the end product's characteristics, whether it is of high quality or not. Moreover, the processes of, e.g., grinding, crushing, etc., of grain will also determine the flour's content, which will further go on for other processes and be delivered to the consumer in the end product. To that end, the properties and effects of different wheat flour contents were analyzed for different types of flour 550, 1050 and whole grain flour available in Germany. These samples were analyzed to select the best-suited commodity for industrial purposes. Falling number, gluten percentage, starch content, viscosity and farinograph were determined for flour during baking test and bread volume for its products. Three types of flour with different content percentages were tested for comparison to find the best-suited type for the baking purpose among them. Among the types 550, 1050 and whole grain flour, the parameters are fitter for bread baking process is 550 type as the results show falling number = 450.25; 334; 296.87; starch (%) = 75.45; 69.72; 64.75; gluten (%) = 38.65; 31.84 and 21.44, and bread volume is 400, 340 and 300 ml respectively. This study suggested that flour with more starch content and a falling number will produce a reasonable volume and more appealing bread regarding sensory attributes.

Keywords: amylolytic activity; elasticity; gelatinization; gluten; viscosity

INTRODUCTION

Wheat is a major food crop in production and staple food in global consumption, while the central part of many end products in the food system is vital for industrialists (Šramkováa et al., 2009). Wheat flour quality depends on many factors such as cultivar, harvesting time, crop, planting area, after-crop treatment and condition of storage. Moreover, different contents of various types of flour cause changes in its properties and end products, i.e., baked products. Due to this, control of mill products is required for the flour products that can be further used in other end products. Before using the flour in industry, the rheological properties of flour were predetermined, like the amount of damaged starch, immanent enzyme activity, and quantity and quality of storage proteins. The baking process determines this flour baking value by step-by-step rheological apparatus usage (Hrušková and Švec, 2009). Each country has different criteria set by millers for the production of various fractions of flour. Germany has diverse wheat flours having other ash contents according to their purpose of utilization. Type 550 is all-purpose flour with 0.51% to 0.63% ash content on dry basis that is best suited for baking and home usage.

Similarly, the 1050 type is 0.91% to 1.20% ash content and is a high gluten (protein) flour. It can be used for pizza crust or mixing with other

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flours for better texture. Whole wheat flour, or 1600 type, is the one that is obtained from all wheat kernels having 1.21% to 1.80% ash content (Zanirato, 2013). For utilization of wheat flour, its quality is determined by various tests that help in its approval or rejection for product formation. Despite other flour properties, one of the essential characteristics examined is amylolytic activity which significantly affects the product, such as the fermentation strength of the dough. Whether the amylolytic in the flour is too low or too high compared to the required value, both can result in a low-quality product (Ostasiewicz et al., 2009). A way to determine this is by the falling number based on the changes that occurred due to damaged starch due to enzymatic activity. This value is affected considerably by the extent of starch damage and the granules' size (Zarzycki and Sobota, 2015). The falling number shows the activity of α-amylase enzyme or damaged starch in wheat flour. A low falling number value means high α-amylase activity and a high falling number value means low α-amylase activity.

Falling number represents the starch properties and water bound to the starch. High α-amylase activity concerns higher sprouting levels in raw wheat and vice versa (Hrušková et al., 2013). Wheat flour contains different types of proteins such as albumin (water soluble), globulin (water-NaCl solution soluble), prolamin (ethanol soluble) and glutelin (alkali solution soluble). Gluten is responsible for visco-elastic properties in the dough. It consists of gliadins (monomeric) and glutenins (polymeric), known as wheat's main storage proteins, i.e., 60% to 85% of the total grain proteins. They have a high amount of glutamine, asparagine, proline or arginine. In contrast, it lacks essential amino acids such as tryptophan, lysine and methionine. The gliadins are soluble in 70% alcohol and separate into α, β, γ and ω gliadins. At the same time, glutenins can be categorized into two groups, the high molecular weight (HMW) and the low molecular weight (LMW) subunits. Disulfide bonds of polypeptides join both proteins to produce heterogeneous polymer mixtures (Zilic, 2013).

Starch has two components: amylose and amylopectin. Amylose is easily soluble in water, while amylopectin is not. Both of these compounds will swell in hot water. Thus, this process primarily affects the flour's ability to rush when cooked. Starch plays an essential role in the gelatinization of the flour during dough formation, which causes viscous and gelatinous properties.

Furthermore, micro-scale baking is one of the best methods for testing the properties of wheat flour in baked goods (Blazek and Copeland, 2008). Amylo-graph measures the flour starch properties and enzyme activity, which results from the sprout damage (α-amylase enzyme activity). It is used to predict the cooking properties at the temperature applied to the product. This study is specifically designed to determine the rheological properties of wheat flour types and to make a micro scale comparison between the flour types available in the market according to its contents for bread baking. Further, to determine the contents or factors involved in attaining the final product's best quality that consumers will prefer.

MATERIALS AND METHOD

Procurement of material

The three types of flour, whole wheat, 1050 and 550 with the brand name Bauk Hof (13% moisture) were purchased at a Gottingen, Germany supermarket.

Determination of rheological properties of flour

Falling number

The falling number was checked by the methods described by AACC (2010b). Kasten Muller's falling number machine was utilized to determine the falling number. A sample weight was taken in the viscometer tube with 25 ml of water for that purpose. For uniform suspension, vigorously shake it and scrap down the residues from the tube walls with the viscometer stirrer's help. A viscometer tube with a stirrer was put in the boiling water bath and started the machine. The slurry was mixed for 55 seconds with a viscometer stirrer then the stirrer was released. The process proceeded until the micro switch signaled the completion of the test and the reading was recorded.

Gluten content

Gluten content was checked by AACC (2010a) method through sample washing with a 2% solution of NaCl to make a dough ball. The dough ball was then washed with a 2% NaCl solution before being washed with water to remove starch and water-soluble protein components. Gluten was pressed between the two glass plates to remove water from the gluten. That pressed gluten was weighed on the weighing machine and % gluten content was calculated using Equation 1.

$$\text{Gluten content \%} = \frac{\text{Wet gluten (g) x 100\%}}{\text{Flour (g) x [100-moisture \%]}} \text{ x } 100 \quad (1)$$

Starch content

Starch content was determined by using the polarimetry method described by Peris-Tortajada (2004). As much as 2.5 g of each sample with 50 ml HCl was taken in the 100 ml volumetric flask for starch content. Flasks were immersed in the boiling water bath for 15 minutes and with vigorous shaking followed by volume makeup up to 90 ml with the addition of cold water, 5 ml of tungstophosphoric acid was added. Further filtration and optical rotation of filtrate were measured using a polarimeter at 589 nm and calculations were done using Equation 2.

$$\text{Starch content \%} = \left[\text{c x Vext x } \frac{100}{\text{W}}\right] \div \frac{\text{DM}}{100} \quad (2)$$

Where:

$$*c = \frac{\alpha}{182.7Xl}$$

L = 1.901; α = optical rotation; Vext = 100 ml; DM = 100 – moisture % of flour.

Viscosity

Viscosity was determined by Brabender Micro Visco-Amylo-Graph (Brabender, Germany) following the method described by Mitrus et al. (2020). Wheat flour's measurement profile is heating rate = 7.5 °C $minute^{-1}$, measurement range = 300 cmg, speed = 250 $minute^{-1}$, temperature profile = 30 to 92 °C (1 minute constant at 92 °C). Water and flour were taken in an erlenmeyer flask and shaken vigorously, then put this homogeneous suspension in the bowl on the Brabender Micro Visco-Amylo-Graph apparatus. Measurement started and ended automatically with a graph as a result.

Micro-scale baking test

As much as 50 g wheat flour of each type 550, 1050 and whole flour was taken in replicates. Then all the weighed ingredients: 5% yeast, approximately 2.46 to 2.50, 1% peanut fat, 1.5% NaCl, 1% sucrose and water were added to each pot. Mixing, intensive kneading, proofing and baking at 175 °C for 35 minutes were done and slices of bread were obtained from each sample. After baking, the rapeseed displacement method evaluated the loaf volume (AACC, 2010c). Furthermore, crust color and crumb formation were also assessed visually.

Statistical analysis

All experiments were conducted in triplicates. Obtained data for each parameter were analyzed statistically by analysis of variance represented in Tables 1, 2 and 3.

RESULTS AND DISCUSSION

The falling number value is the determination of wheat flour quality depending on the enzyme activity on the starch content of that flour. It is a significant quality forecaster with a significant economic impact (Shao et al., 2019). An extent of α-amylase activity is considered beneficial for bread baking, while a lower or higher value affects its quality. During the study (represent in Table 1), the falling number of type 550 flour was 450.25±2.4 followed by the type-1050 flour 334±2.1. The lowest value 296.87±1.4 obtained was for whole wheat flour, which shows that it has more enzyme activity than the other two types of starch, resulting in lower dough volume and grain formation. Kiszonas et al. (2018) showed during their studies that bran removal by roller milling impacted the α-amylase activity e.g., lowering the activity. An inverse relationship was seen between the action of the α-amylase enzyme and the falling number.

Similarly, in types 550 and 1050, the bran content is lower than the whole wheat flour, so there is lower activity of α-amylase, resulting in higher falling number values in these two types. Another study by Zarzycki and Sobota (2015) showed that the storage temperature of wheat significantly affects the falling number value and α-amylase activity. The falling number increases with the rise in storage temperature and decreases by lowering storage temperature e.g., inverse relation. So, according to the study results, type 550 is best for a higher volume of bread and type 1050 is also a good option for baking purposes.

The starch percentage was high in type 550, 75.45%, while the lowest in whole wheat flour 64.75. Type 1050 has 69.72% starch content. Starch is the main component of wheat grains compared to the other constituents as it is 70% to 80% of the grain dryly. Starch plays an essential

Table 1. Mean values for rheological properties of flour types

Type	Falling number (seconds)	Starch (%)	Gluten (%)
550	450.25±2.40	75.45±0.3	38.65±0.98
1050	334.00±2.10	69.72±0.0	31.84±1.08
Whole wheat	296.87±1.45	64.75±0.0	21.44±1.88

Note: Values are mean ±standard deviation for samples analyzed in triplicates

role in the gelatinization of the flour during dough formation which causes it viscous and gelatinous properties. The baking and baked products' quality primarily depend on the percentage of starch content, which helps in the crumb formation, crust color and staling kinetics and is significant in the volume attainment (Khurana and Sharma, 2021). The type 550 and 1050 have more percentages of starch which are more appropriate for bread production. During a study, another factor rather than starch percentage of flour is that the starch obtained from different cultivars could impact the quality of the final product as they showed other physiochemical properties (Majzoobi et al., 2011). Gluten is the complex protein in wheat flour that provides visco-elastic properties to the dough. It can form a dough with the rheological properties necessary to manufacture leavened bread. The amount of gluten content in the flour increases the kneading time and firmness of the dough. Its two components control the visco-elastic properties as gliadin is responsible for dough viscosity and glutenin helps in the elastic characteristics. For bread making, it is essential to have a particular balance between viscosity (extensibility) and elasticity (dough strength), or in other words, a glutenin to gliadin ratio (Zilic, 2013). In this study, the gluten percentage in type 550 is the highest 38.65%±0.98 while for type 1050 its quantity is 31.84%±1.08. The lowest rate for gluten is obtained by whole wheat flour which is 21.44%±1.88. The former types have more elasticity and viscosity than the latter, showing that bread or dough prepared by type 550 or 1050 can have better results than whole wheat flour. Studies show that gluten proteins are responsible for mixing dough, the rheological properties of optimally mixed dough and fermenting dough's gas retention properties (Rosell, 2011).

Different flour components affect the physical, chemical and biochemical changes that occur in bread making process. For better results, there should be a specific proportion of other constituents such as carbohydrates, proteins, lipids, water and proper interaction (Kuktaite, 2004). In the case of this study, researchers have three flours with different proportions of each constituent based on their extraction during the milling process. After baking all these types, researchers get different results based on their volume, crust color and crust hardness. Table 2 shows that the mean values for bread volumes produce significant results. The highest volume 400±0.0 was attained by bread baked of type 550 while the lowest volume 300±0.7 was whole wheat flour. Type 1050 has volume in between both other types, which is 340±0.7.

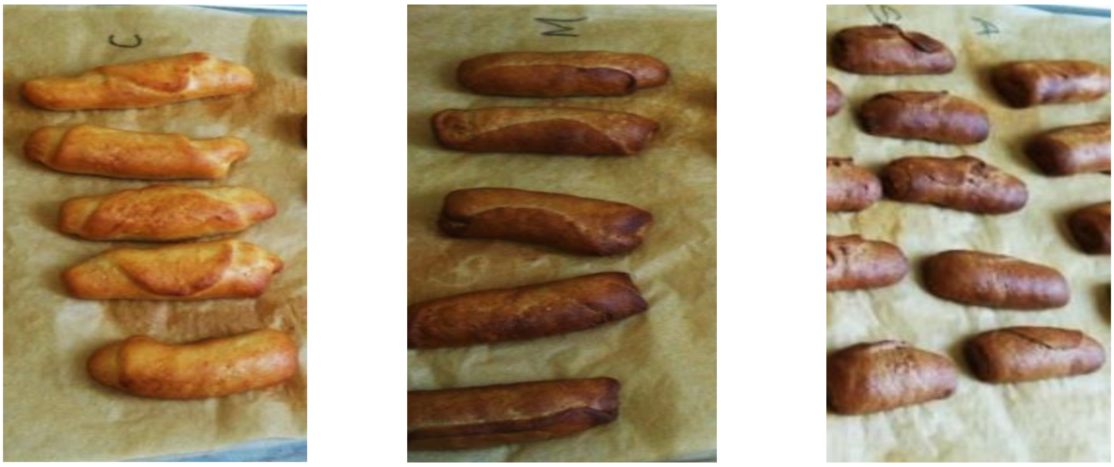
Table 2. Mean values for volume of bread after baking test

Flour type	Volume (ml)
550	400±0.0
1050	340±0.7
Whole wheat	300±0.7

Note: Values are mean ±standard deviation for samples analyzed in triplicate

The principal components of wheat flour are starch (70% to 75%), water (14%) and proteins (10% to 12%). Around 2% lipids and 2% to 3% non-starch polysaccharides (arabinoxylans) are essential to the bread manufacturing process and end product quality (Goesaert et al., 2005). Shewry (2007), stated that wheat gluten is a necessary factor in bread production in terms of its percentage, quality, type or source and visco-elastic properties. Gluten proteins determine gas retention in fermenting dough, which ultimately affects the bread's loaf volume and crumb structure (Ortolan and Steel, 2017).

Furthermore, in the appearance of baked bread, the crust color is a significant factor determining the quality and consumer acceptance of that good. In this study, the crust color (Figure 1) is lighter in color and most anticipated among all the baked bread is of type 550.



a. b. c.

Figure 1. Baked breads by type, a) types 550, b) 1050 and c) whole wheat flour

Table 3. Micro Visco-Amylo-Graph mean ±standard deviation

Flour type	Maximum viscosity torque (BE)	Minimum viscosity torque (BE)	Maximum viscosity-temperature (°C)
550	924±0.11	670±0.14	91.5
1050	677±0.24	400±1.00	91.8
Whole wheat	603±0.18	339±0.22	91.5

While the type 1050 has a bit dark crust color, this is also acceptable and desired by consumers. For whole wheat flour, the bread has dark crust color due to the high ash or fiber contents.

Micro Visco-Amylo-Graph is applied to determine the viscosity and stability of the flour dough used in baking. Peak or maximum viscosity is significant property to illustrate the characteristics of starch present in that flour (Ali et al., 2014). There is a difference in the pasting properties of different starches during differences in cooking rates and stirring speeds (Suh and Jane, 2003). In this study (represent in Table 3), the type 550 showed the highest viscosity 924 BE with higher dough stability time. Type 1050 had a peak viscosity 677 BE which is in the middle of both types. Whole wheat flour had the lowest peak viscosity of 603 BE and the most inadequate dough stability. So, in this case, types 550 and 1050 are more suitable for baking than whole wheat flour due to more starch contents and better results achievement.

CONCLUSIONS

Both the quality and quantity of constituents present in the flour determine the purpose of that flour in making a specific kind of end product. Moreover, the quality of the product is also destined by them. The types of flour are meant for different purposes based on their constituents. For bread making, the type 550 is the best fit owing to all the parameters it meets for required product followed as it gives a good loaf volume and specific bread characteristics. Type 1050 is primarily suitable for products that require more elasticity, such as pizza dough. Whole wheat flour is also essential as it contains nutrients and flavor. It can be dense when baked, so used for other purposes, but in industrial usage for baked products, the two different types are more efficient. Further, whole wheat flour can be used for industrial purposes if it can blend with other flours.

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