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Comparing the quality of wheat flour produced by roller mill and Astrié stone mill

KATALIN KÓCZÁN-MANNINGER*, IVETT JAKAB, LEVENTE ILLÉS, ILDIKÓ SZEDLJAK, ANIKÓ LAMBERT-MERETEI and KATALIN BADAK-KERTI

Department of Grain and Industrial Plant Processing, Hungarian University of Agriculture and Life Sciences, Villányi str. 29-43, H-1118, Budapest, Hungary

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ABSTRACT

An alternative to roller mills, a French-designed stone mill, was evaluated and compared with traditional laboratory roller mills through grinding performance. Developed by the Astrié brothers in the 1950s, the stone mill's slow-rotating granite stones purportedly preserve the full nutritional value of the grain. This study, conducted in collaboration with the Csoroszlya farm, compared flour from the same wheat batch ground by both an Astrié stone mill and a laboratory roller mill. Evaluations included the Pekar test for bran content, sieve analysis, measuring wet gluten content, and gluten index to assess protein quality. Rheological properties of the doughs were analyzed using Farinograph and Mixolab equipment, which indirectly also measured amylase enzyme activity. Results indicated that the stone mill produced flour with finer grain size, higher protein content, and higher enzyme presence, although challenges remain in achieving optimal gluten index and dough stability.

KEYWORDS

roller mill, stone mill, grinding, Farinograph, Mixolab, flour quality

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* Corresponding author. E-mail: koczan.gyorgyne@uni-mate.hu

1. INTRODUCTION

Wheat is one of the most important cereal crops in both Europe and our country, with over five million tons harvested annually in Hungary (Awika et al., 2011). The flour produced from wheat is a fundamental ingredient in many products, making the quality and nutrient content of the raw material crucial. There are several mills in Hungary, varying in age and capacity. Roller mills are popular and frequently utilized in the grain industry for grinding (Finnie and Atwell, 2016b), and modern mills attain a flour output exceeding 80%. This high yield means that very few components of the grain are excluded from the white flour. However, the properties of the flour significantly affect the processability of dough and the quality of the final products (Finnie and Atwell, 2016c).

Currently, mills have tasks beyond just grinding; they operate within a much more complex system. According to Posner and Hibbs (2005), this system can be divided into four parts:

1. Removing the germ and bran from the endosperm,
2. Separating small bran particles from larger endosperm portions,
3. Isolating the flour-sized fraction from the ground endosperm,
4. Removing fibre from the endosperm obtained through the other three processes.

As an alternative to roller mills, there is a French-designed stone mill. The Astrié brothers perfected the technology of grinding between slow-rotating granite stones in the 1950s. According to their claim, the ground meal preserves the full content value of the grain (Le moulin astrié, n.d.).

The most significant difference between the Astrié mill and modern roller mills is that in the stone mill the two granite stones are positioned horizontally. The gap between them can be adjusted using a spring mechanism. The lower stone is stationary, while only the upper stone rotates slowly, preventing the flour from heating, thus eliminating the need for cooling and avoiding oxidation processes. During grinding, the germ is not removed, and the aleurone layer beneath the bran remains in the ground product. The finely cut granite stones and flute designs have a major impact on the mill's efficiency. As a result, the wheat grains are not crushed but cut by the millstone. The grains are passed between the two granite discs through a hole in the middle of the upper stone. The grains move outward through the narrowing gap, resulting in the grinding of all released materials, including the germ. The mill operates with an approximate yield of 80% (Astrié and Fritsch, 2006).

In this research, flour milled with a stone mill at an organic farm is compared with flour milled using a laboratory mill from the same batch of wheat grain. The laboratory mill has a flour yield of around 70%, which does not match the yield of modern commercial mills but is a highly efficient tool designed for experimental purposes. Various methods were employed to examine the flours, with the aim of determining and comparing their properties. These values provide insights into the quality differences resulting from the different milling technologies. A similar study has been made earlier, in the article of Magyar et al. (2020), but they were more interested in the mechanical side of milling with roller mills, stone mill and disc mills. In this paper, we focused on the technofunctional parameters of the flours.

The flour milled with the granite stones of the Astrié mill retains the nutrient content of the whole-wheat grain, a feature not characteristic of conventional mills (Cappelli et al., 2020). Our goal was to explore further benefits of utilizing the Astrié stone mill. Therefore, in our study we evaluated the quality of flour samples produced by a typical laboratory mill and by a stone mill from the same batch of mixed French wheat varieties. To conduct the comparison, the following analyses were performed: determination of moisture content and wet gluten content, gluten index test, and farinograph analysis to determine the water absorption capacity of the flours and the rheological properties of the dough made from them. Additionally, we conducted a comprehensive dough analysis using a Mixolab device, which not only describes the water absorption capacity and rheological properties of the flour but also tracks changes due to heat treatment and enzyme activity.

2. MATERIALS AND METHODS

The wheat grain was provided by Csoroszlya Farm. The grain was a seed mix composed of French varieties (specific variety names were not known). The stone mill flour from the grain was prepared using the Astrié stone mill owned by the farm, while in the case of roller milled flour samples the grain was milled into flour using the laboratory mill in the Department of Grain and Industrial Plant Processing at the Hungarian University of Agriculture and Life Sciences (MATE). Flour was obtained from the French variety mix by milling with laboratory mill in 100g batches. The grain mix was not conditioned (wetted) before milling.

2.1. Laboratory mill and the Astrié mill

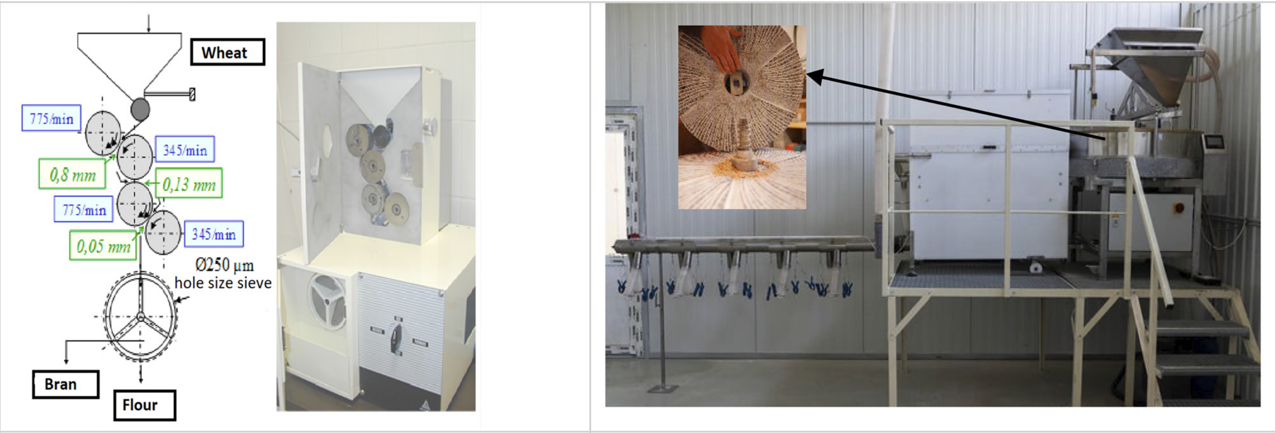
The laboratory mill (Fig. 1) contains four fluted rollers rotating in opposite directions. The rotational speeds of the two opposing rollers differ. The first roller is a so-called high-speed roller with a speed of 775 revolutions per minute (rpm). Opposite this is a slow-speed roller with a speed of 345 rpm. The subsequent rollers rotate at the aforementioned speeds, with the third roller being fast (775 rpm) and the fourth roller being slow (345 rpm). The gap between the rollers decreases progressively, starting from an initial gap of 0.8 mm, reducing to 0.13 mm between the second and third rollers, and finally to 0.05 mm at the last roller. The laboratory mill also includes a drum sieve with a pore size of 250 μm. The ground product is fed into the drum sieve, where the sieved residue is bran, while the sifted flour collects in the container below.

2.2. Sieve analysis

For the sieve analysis, a laboratory sieve is required, consisting of stacked sieve frames with different mesh sizes. These sieves are connected to a shaking mechanism. To conduct the analysis, 50g of the sample is evenly distributed on the topmost sieve, and the sieve stack is shaken for 10 min. After this, the residue on each sieve is measured, which is the flour retained on each sieve. The total passing refers to the amount that remains on the given sieve and all the sieves above it. This analysis allows us to determine the most frequent particle size, which we can calculate using the mode, and the theoretical sieve size at which 50% of the flour mass would pass, calculated using the median.

2.3. Moisture measurement

The moisture content of the wheat was measured using a Sartorius MA50 automatic moisture analyzer. An electric coffee grinder was used, with multiple pauses to ensure the temperature did



(a)

(b)

Fig. 1. Pictures of the lab mill (a) and Astrié mill (b) (Own source/creation)

not rise, to gently crush the grains. The crushed sample was then evenly spread on the sample tray, and the measurement was initiated. The measurement was done by thermogravimetric method using Sartorius MA50, and infrared heating to 105 °C. The loss on drying (LOD) technique was applied, which measures the weight of a sample before and after a drying procedure and uses the weight delta to determine the percentage of moisture as the weight removed by the drying process in comparison to the initial weight of the sample.

2.4. Gluten analysis

Wet gluten content, gluten index, and gluten spreadability were measured as follows.

2.4.1. Wet gluten content. The wet gluten content is a measure of the amount of gluten proteins present in wheat flour, expressed as a percentage. It is determined by washing the dough with a salt solution to remove starch and other soluble components, leaving behind the gluten. The remaining gluten is then weighed. This process can be performed using the Glutomatic system, which automates the washing and weighing steps for more consistent results (AACC International, 2000a, Method 38-12.02).

2.4.2. Gluten index. The gluten index is a measure of the quality of gluten. It is determined by centrifuging the wet gluten obtained from the Glutomatic system. The gluten is separated into two fractions: a firm, cohesive gluten and a softer, more extensible gluten. The index is calculated as the percentage of the firm gluten fraction. A higher gluten index indicates stronger, more elastic gluten, which is desirable for bread-making (ICC, 1995; Standard No. 155).

2.4.3. Gluten spreadability. The gluten spread test measures the extensibility of the gluten. After obtaining the wet gluten, it is placed in a special mould and allowed to rest for a specific period. The diameter of the gluten disc is then measured. The spread of the gluten provides information on the viscoelastic properties of the gluten network. Greater spread indicates more extensible gluten, which affects the dough's handling and baking properties (AACC International, 2000b, Method 38-10.01).

2.5. Pekar test

In the Pekar (slick test), the sample flour is slicked alongside the standard sample and their colours compared visually in dry and in wet state. This procedure is also useful to determine if the sample is contaminated with bran. Any colour differences between the samples can then be evaluated using a table (Lásztity and Törley, 1987).

2.6. Farinograph analysis

The Farinograph is an essential tool in assessing the rheological properties of dough made from flour. This instrument measures the resistance of dough to mixing, providing key insights into the water absorption capacity, dough development time, stability, and mixing tolerance index. The main steps of the Farinograph analysis are:

1. **Sample Preparation**: A flour sample is mixed with a specific amount of water to form dough. The exact water amount is adjusted to achieve a consistent dough consistency, typically around 500 Brabender units (BU).

2. **Mixing and Measurement**: The farinograph records the resistance of the dough against the mixing blades over time. The resulting curve, called a Farinogram, displays the dough's behaviour during mixing.
3. **Data Interpretation**: Key parameters extracted from the Farinogram include:
    - **Water Absorption (%)**: The amount of water required to reach the desired dough consistency.
    - **Dough Development Time (DDT, min)**: The time taken to reach maximum dough consistency.
    - **Stability (min)**: The duration for which the dough maintains maximum consistency.
    - **Mixing Tolerance Index (MTI)**: The difference in BU between the top of the curve at peak development and the top of the curve measured five minutes after peak.

Farinograph analysis helps in understanding the dough's behaviour during mixing and provides crucial information for optimizing bread-making processes (AACC International, 2000c, Method 54-21.02; Bock, 2022).

In our study flour samples were compared using the DDT (dough development time), water absorption, and dough stability characteristics.

2.7. Mixolab 2 analysis

The Chopin Mixolab 2 is an advanced rheological device used to analyze the dough behaviour during mixing and heating, providing comprehensive data on flour quality and dough properties (Dubat, 2009). This instrument also measures the rheological properties of dough, but it provides much more comprehensive results than the Farinograph. The mixing bowl can be not only tempered but also heated to 90 °C and then cooled back to the specified temperature while continuously mixing. Due to this capability, it provides information not only on the dough's water absorption capacity, dough development, and stability time but also on starch gelatinization and retrogradation, as well as amylase enzyme activity. Heating affects not only starch but also proteins, and interactions between these substances can be studied.

The device measures torque as a function of time and temperature, yielding valuable information through various phases, referred to as C values (C1, C2, C3, C4, and C5). These phases correlate with the dough's behaviour under specific conditions, reflecting protein quality, starch properties, and overall dough stability (Rosell et al., 2007; Bloksma, 1990).

2.7.1. Phases of the Mixolab 2 measurement. **C1 (Development Phase)** – This phase assesses the initial dough formation and hydration characteristics. It starts with the mixing of flour and water, continuing until the dough reaches its maximum consistency. The peak torque (C1 value) indicates the water absorption capacity and initial dough development, which is influenced by the protein content and quality of the flour.

C2 (Stability Phase) – This phase evaluates dough stability and protein network strength. The dough is subjected to continuous mixing, and the torque decreases as the dough undergoes mechanical breakdown. The minimum torque (C2 value) measures protein weakening, providing insight into the dough's tolerance to mixing and its stability under mechanical stress.

C3 (Starch Gelatinization Phase) – During this phase, the dough is heated, leading to starch gelatinization. The torque increases as the starch granules swell and gelatinize. The peak torque

(C3 value) in this phase reflects the gelatinization properties of the starch, which are critical for baking performance and product texture.

C4 (Amylase Activity Phase) – As the temperature continues to rise, the torque starts to decrease due to the enzymatic activity of amylases breaking down the gelatinized starch. The minimum torque (C4 value) in this phase indicates the extent of starch degradation and the activity of amylase enzymes, affecting the dough's viscosity and structure.

C5 (Retrogradation Phase) – In this final phase, the dough is cooled, and the starch undergoes retrogradation. The torque increases again as the gelatinized starch reassociates. The final torque (C5 value) measures the retrogradation properties of the starch, which are important for the shelf-life and textural qualities of the final baked product.

2.7.2. Evaluation of C values. The C values provide a comprehensive assessment of flour quality and dough performance:

- **C1 Value**: Higher C1 values indicate strong water absorption and protein quality, essential for good dough development and baking strength.
- **C2 Value**: Lower C2 values suggest better dough stability and less susceptibility to mechanical breakdown, which is favourable for industrial processing.
- **C3 Value**: Higher C3 values denote superior starch gelatinization properties, contributing to desirable texture and volume in baked products.
- **C4 Value**: Lower C4 values reflect higher amylase activity, which can influence the final product's structure and moisture retention.
- **C5 Value**: Higher C5 values are associated with better starch retrogradation properties, enhancing the shelf-life and quality of the baked goods.

The Mixolab profiler aids in quick evaluation (Fig. 2), displaying water absorption, mixing properties, gluten strength, viscosity, amylase activity, and retrogradation on a spider diagram (Finnie and Atwell, 2016a; CHOPIN Technologies, n.d.).

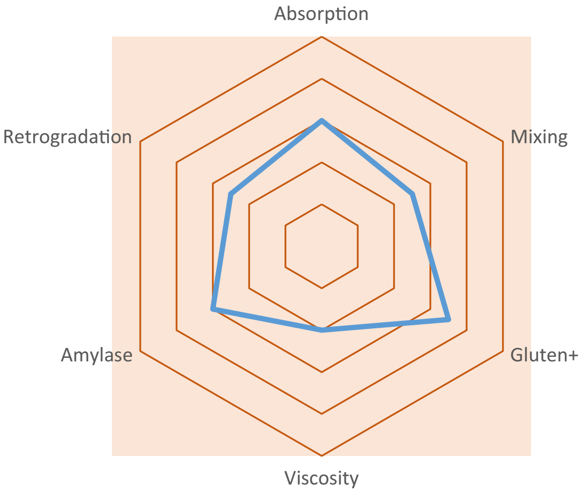


Fig. 2. General picture of Mixolab 2 profiler (based on CHOPIN Technologies, n.d.)

3. RESULTS AND DISCUSSION

3.1. Results of sieve analysis

By touch and visual inspection, it is possible to establish that the flour ground in the Astrié mill has a much finer particle size, resembling a powder that is comparable in texture to starch. Interestingly, though, this observation was not supported by the results of the sieve analysis.

For the flour milled with the Astrié mill, clumping was observed on the intermediate sieves. Since larger particles should have remained on the previous sieve, it can be concluded that the particles clumped together on the given sieve due to the shaking action. Additionally, flour that should have passed through the 250 µm sieve was also observed clogging the sieve openings. The moisture content of the flour was low, so the adhesion was not caused by moisture content. The adhesion may be caused by two factors: the presence of the non-endosperm materials (the bran, the aleurone layer and the germ), and the high degree of milling. The high oil content of the germ alone would not cause such a problem, as we did not remove the germ from the grain milled with the lab mill either. However, when milling oil-containing grain parts, excessive fine grinding can cause significant oil release from the plant tissue, leading to particle adhesion. Therefore, the finer particle size obtained with the Astrié mill is currently supported only by sensory observations, and further investigation is needed to determine the exact particle size. Laser diffraction combined with microscopy is a suitable method to determine the exact particle size and particle composition, which was unavailable at the time of our study.

The data obtained were plotted on a diagram, and an average particle size for both flours was calculated using the modus of the distribution curve, showing almost no difference between the two, further proving that the measurement does not reflect the actual results. The theoretical sieve size at which 50% of the flour would pass was calculated using the median. The sieve residues were also plotted on a diagram, shown in Fig. 4. There is a difference between the two flours in the theoretical sieve size (Fig. 3), in the case of the Astrié mill it was 121 µm, for the laboratory mill it was 133 µm.

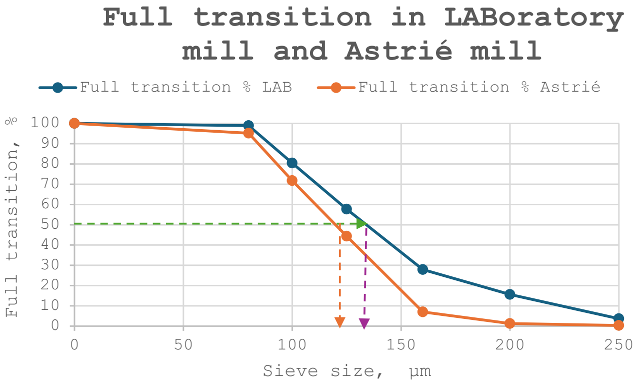


Fig. 3. Full transition and theoretical sieve size of flour samples ground with laboratory (roller) mill and Astrié mill (Own source/creation)

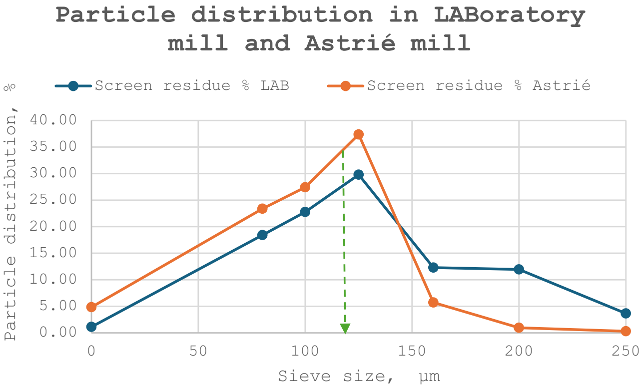


Fig. 4. Particle distribution flour samples ground with laboratory (roller) mill and Astrié mill (Own source/creation)

In earlier studies, there were conflicting results in case of Tartary buckwheat flour. Liu et al. (2018) found that the stone mill produced flour with narrower particle size distribution and a more uniform particle size, whereas Kihlberg et al. (2004) stated the opposite in the case of Swedish winter wheat, as they found that the stone milled flour had wider particle size distribution in the range of 400–800 µm.

3.2. Results of gluten analysis

The gluten washing results indicate that the flour from the Astrié stone mill has a higher gluten content. This supports the manufacturers' claim that the aleurone layer's valuable components enrich the flour rather than being relegated to the bran, thus achieving a higher protein content. The wet gluten content of the wheat ground with the lab mill is slightly lower, but both cases show good gluten content. The wet gluten content of the flour from the Astrié stone mill is 42.4%, while the laboratory mill flour is 39.1% (Table 1).

However, high gluten content alone is not sufficient; the gluten index must also be good, which means a value between 60% and 90% according to Hungarian standards (MSZ 6369/5-1987) This is not achieved, for lab mill the gluten index was 33.7 % and the flour from the Astrié mill, despite having a much better gluten index, still falls short at 45.5%. The low gluten index means that the dough made from this flour will rise, but cannot maintain the formed gluten structure, causing the product to collapse.

Table 1. Result of Gluten washing (Own creation)

	Total gluten content	Wet gluten content %	Gluten index
Astrié stone milled flour	4.24 g	42.4%	45.51%
Lab (roller) milled flour	3.91 g	39.1%	33.67%

Gluten spreadability was in the case of the laboratory-milled sample 7.0 mm, whereas for the Astrié milled flour it was 6.5 mm. These two values are acceptable according to the Hungarian standards (the range is 2–8 mm, MSZ 6369/5-1987).

Evaluating the gluten tests based on the obtained data is challenging, as some tests show good values, such as wet gluten content and gluten spreadability, but the gluten index result is below the Hungarian standards (MSZ 6369/5-1987). However, it can be stated that the type of the mill is not negligible, as the flour from the Astrié stone mill consistently resulted in better values. The gluten test results are more attributable to the wheat's properties, which the mill could improve, but it could not bring the gluten index into the expected range. This suggests that a batch of grain with lower quality can – theoretically – still produce a final product of better quality using the appropriate machine.

3.3. Farinograph results

Three parallel measurements were conducted for both flour samples, and the averages of these measurements were compared. The moisture content, as previously measured (for flour samples from the laboratory mill 6.5%, from the Astrié mill 9.5%), remained unchanged, as did the flour's water absorption capacity and corrected water absorption values in both evaluations. For simplicity and clarity, the evaluations are presented according to international standards (Bock, 2022).

The results show that the water absorption of the flour from the Astrié mill is much higher, with a difference of over 10%. This is due to higher bran content, as proven in the Pekar test (Fig. 5), where the two flour samples were compared in dry and in wet state. Bran absorbs moisture more effectively, causing it to swell slightly.

Another factor not proven by sieve analysis is that the Astrié mill flour has a much finer particle size, which affects the dough development time. However, the dough development time also correlates with water absorption. Another previously proven fact is that the flour from the Astrié mill has higher protein content, as confirmed by the wet gluten content test. The Farinograph test corroborated this, as dough development time depends on raw protein content. The dough development time, rounded to the nearest half minute, is 2.0 min for the laboratory mill flour and 2.5 min for the Astrié mill flour. A combined farinogram was created, displaying both the Astrié flour and the laboratory mill flour on a single diagram, shown in Fig. 6. The burgundy bars in the diagram represent the Astrié flour, while the grey boundary line with a green centre

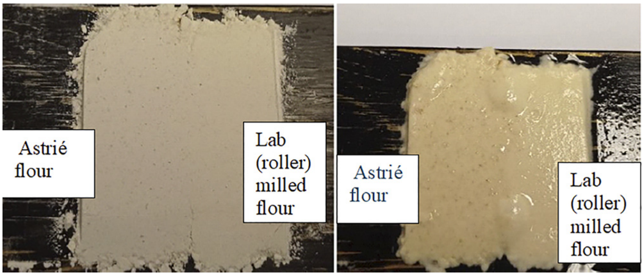


Fig. 5. Results of the Pekar test (left dry samples and right wet samples). Astrié milled flour shows more bran particles (black dots in the sample) (Own source/creation)

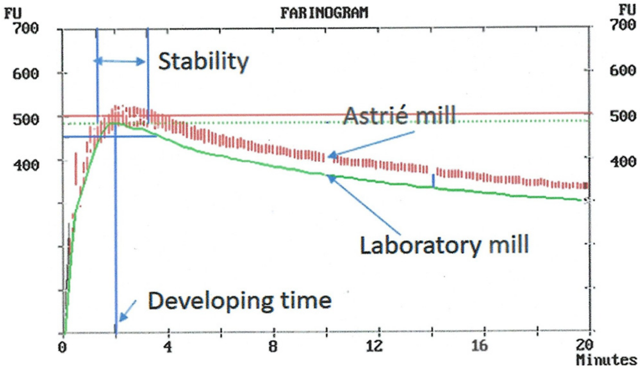


Fig. 6. Farinograms of Astrié (stone mill) and lab (roller) mill flours (Own source/creation)

line represents the lab mill flour. This clearly indicates that the lab mill flour has more modest rheological properties than the Astrié flour.

The stability time, which indicates the dough's tolerance to kneading, can also be read from the farinogram. Although experiments have not shown a correlation between flour composition and stability, it can be inferred about dough strength. The higher the stability, the stronger the dough. Both flours studied have low stability (2.5 min for Astrié, 1.5 min for lab mill), leading to rapid softening of the dough and thus low Farinograph values for both flours. However, it is noticeable that the Astrié flour scored higher than the laboratory mill flour, though still below the expected value. This can be attributed to the wheat's characteristics, as noted in the gluten analysis. In this comparison the flour from the Astrié mill produced better values than the flour from the laboratory mill.

3.4. Mixolab 2 results

Three parallel measurements were performed with the Mixolab device, averaged, and these values compared. The first eight minutes of the measurement are similar to the Farinograph test. During this period, information is obtained about dough development and stability time, as well as water absorption capacity. All three parameters show some differences compared to the Farinograph values, but the proportional differences between the two flours remain, as illustrated in Table 2. The data confirm the Farinograph results, showing that the Astrié flour has higher water absorption and better dough stability than the laboratory mill flour.

Table 2. Comparison of Farinograph and Mixolab values (Own creation)

	Lab flour		Astrié flour	
	Farinograph	Mixolab	Farinograph	Mixolab
Dough development time (min)	2 min	2.84 min	2.3 min	2.98 min
Dough stability (min)	1.5 min	1.7 min	2.2 min	2.7 min
Water absorption (%)	54.80%	52.60%	62.50%	61.20%

The Mixolab measures torque in accordance with the developed dough's resistance. The C1 value relates to dough development, while the CS value shows softening measured at the eighth minute.

After the eighth minute, the machine begins to warm up the dough, initially to a temperature between 55 and 60 °C, where the instrument measures protein weakening due to mixing and heat, shown as the minimum mixing resistance in the C2 row. The heating of the kneading cup continues to 90 °C, with the dough approaching but not quite reaching this value. At this temperature, the proteins denature, and the starch gelatinizes, shown in the C3 row. However, in all three parallel measurements, the intermediate measurement was skipped, and the machine measured mixing resistance only at the end of the test. In this phase, the device examines the viscosity due to starch gelatinization. Analyzing the diagrams, in case of laboratory milled flour, there was no decrease in mixing resistance above 80 °C (Fig. 7), but a continuous increase. This suggests lower activity of the amylase enzyme, meaning it does not liquefy a large amount of starch. There are two possible reasons: either the starch exhibits resistance to the action of the enzyme, or the enzyme is present in smaller amounts in the laboratory milled flour sample.

Since the C3 phase start is detectable for the flour from the Astrié mill, it suggests not starch resistance but the presence of more enzymes in the flour. The C4 phase starts at the dough's maximum temperature and measures the resistance increase due to starch gelatinization.

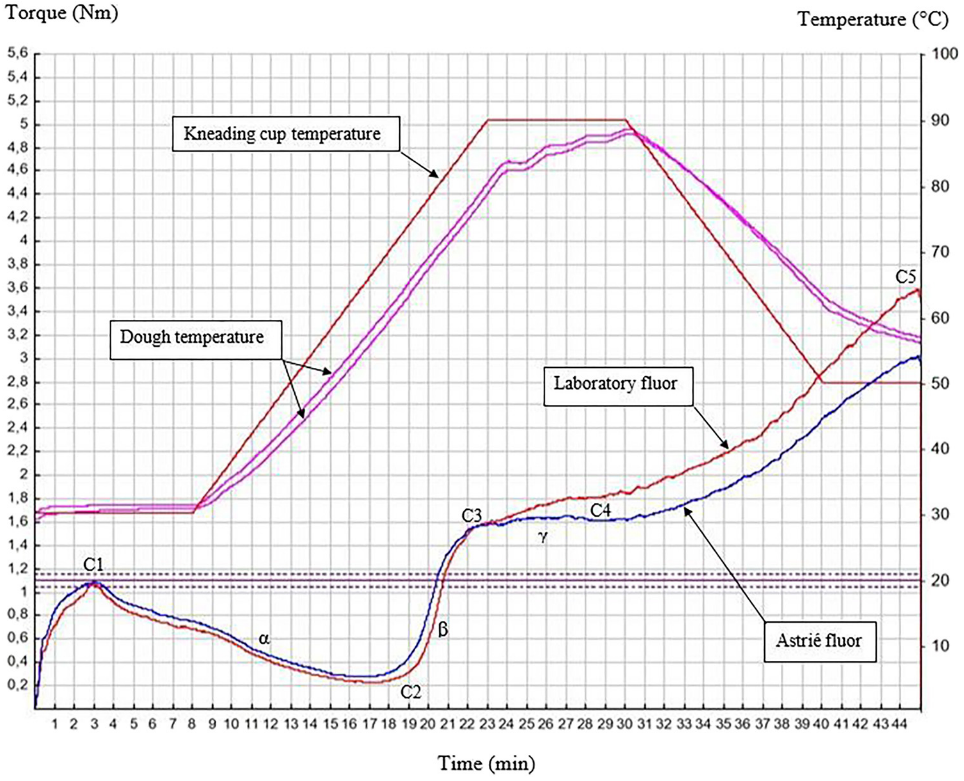


Fig. 7. Mixolab diagrams for laboratory (roller mill) milled and Astrié (stone milled) flours (Own source/creation)

The previous phase data indicate that very little starch was broken down due to low amylase enzyme presence. The final phase measures starch retrogradation, based on the principle that if little starch is broken down, the mixing resistance will be high due to gelatinization. The less gelatinous the starch is, the less water can be excreted during starch rearrangement and crystallization.

The α, β, γ values on the diagrams show slopes indicating process speeds. The α slope shows protein weakening speed from the end of the 30 °C phase to the C2 phase. The β indicates starch gelatinization speed between C2 and C3, while the γ shows enzyme reduction based on the slope between C3 and C4. For Astrié flour, the average is positive, but this is due to a measurement, where the local maximum was not detected, distorting the result. Overall, for both flours, these slopes indicate slow processes, but β and γ values are influenced by amylase enzyme presence. The enzyme presence naturally belongs to wheat properties, and the studies only proved that different amounts end up in the flour depending on the milling type.

Based on the profile (Fig. 8), the Farinograph analysis confirmed that the flour milled with the Astrié mill can absorb more water, but it shows minimal resistance to mixing. The Gluten + value indicates the gluten's resistance to heat, thus there is almost no difference between the two flours since this property cannot be influenced by milling. The differences in viscosity and amylase values can only be affected by milling, as such a significant variation cannot exist within the same batch of wheat. Retrogradation provides information on starch aging, which is also closely related to the enzymatic breakdown of starch. The diagram clearly shows that some properties of the flours are identical or nearly identical, which can be attributed to the characteristics of the wheat itself, while the differences are related to the milling process.

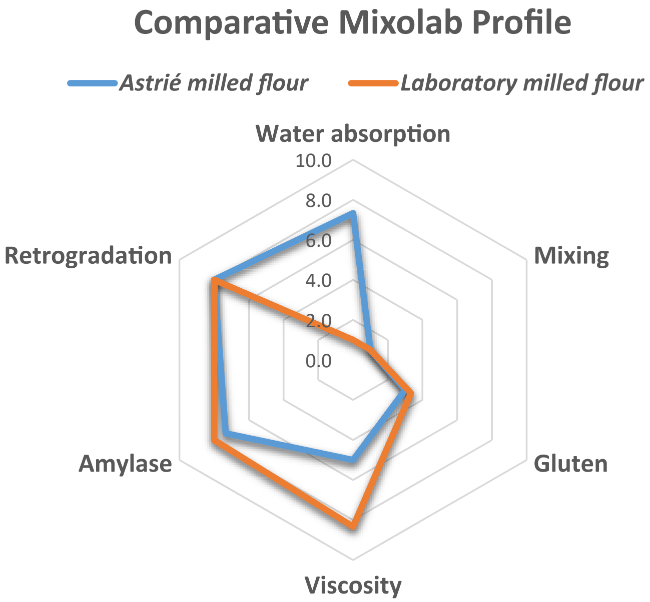


Fig. 8. Mixolab profiles of Laboratory (roller mill) milled and Astrié stone milled flour samples (Own source/creation)

4. CONCLUSIONS

The study aimed to compare the characteristics of flour samples ground using the Astrié mill and ground using a conventional laboratory mill, focusing on particle size distribution, gluten content, Farinograph results, and Mixolab measurements. The findings reveal significant differences in flour properties attributable to the milling process.

Despite sensory observations indicating a finer particle size for the Astrié-milled flour, sieve analysis did not reflect this difference accurately. Clumping on intermediate sieves suggested adhesion due to factors other than moisture content, such as the presence of whole grain components and a high degree of milling. The theoretical sieve size calculation and median analysis confirmed almost no difference in average particle size between the two flour types, indicating that the current methods may not fully capture the nuances of particle size distribution.

The gluten analysis highlighted that flour from the Astrié stone mill had a higher wet gluten content (42.4% compared to 39.1% for the lab mill flour), supporting the manufacturer's claim regarding the retention of valuable components from the aleurone layer. However, the gluten index of the Astrié-milled flour (45.5%) was below the optimal range, indicating potential issues with dough stability. While the milling process appears to enhance certain gluten properties, the gluten index remains influenced by the inherent characteristics of the wheat.

Farinograph tests showed that the Astrié-milled flour had a higher water absorption capacity and longer dough development time, correlating with its higher protein content. However, both flours exhibited low dough stability times, suggesting rapid softening. The Astrié-milled flour demonstrated better overall Farinograph values, though still below the expected standards, emphasizing the influence of wheat properties alongside milling techniques.

Mixolab measurements confirmed the Farinograph results, showing higher water absorption and better dough stability for the Astrié-milled flour. The tests also revealed differences in starch gelatinization and enzyme activity, with the Astrié flour exhibiting signs of higher enzyme presence. These results suggest that the milling process affects not only flour composition but also its enzymatic activity and starch behaviour.

The study demonstrates that the Astrié milling process can produce flour with higher gluten content and water absorption capacity, though challenges remain in achieving optimal gluten index and dough stability. The higher enzyme presence in the Astrié-milled flour indicate potential benefits for certain baking applications such as biscuit manufacturing, but further research is needed to refine measurement techniques and fully understand the impact of milling on flour properties.

In conclusion, the type of mill used significantly influences flour characteristics, affecting baking quality and performance. The Astrié mill, with its ability to produce higher-protein flour, shows promise for specific uses, though additional investigation is required to optimize its application and address the observed inconsistencies in particle size measurements and gluten index results. Based on our results, the mixing of the flours would be a good solution to have a good quality general purpose flour, but this is not an everyday practice in small artisanal bakeries, which are the main targets for stone milled flours.

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