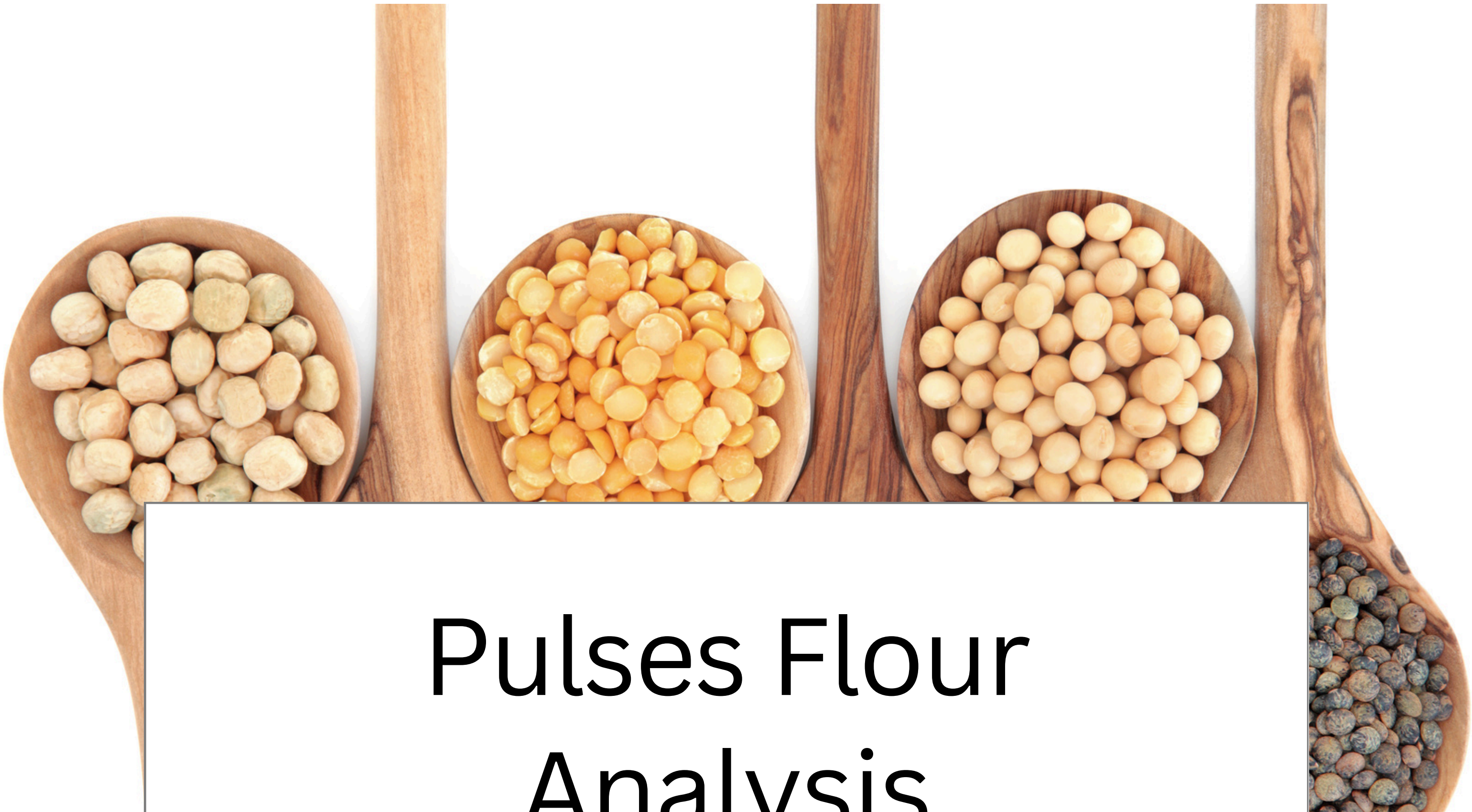


Pulses Flour Analysis

Current health trends have caused the rise of novel ingredients in baked goods. One of the most important ones due to their health, environmental, and nutraceutical functionalities are pulses. Pulses or legumes, as they are also known, are the dry seeds of leguminous plants. They are recognized due to their high fiber, and high protein content, and as good sources of vitamins and minerals such as iron, zinc, magnesium, folate, and potassium.

This paper addresses the available alternatives to replace or partially substitute wheat flour for nutritious pulse flour alternatives, and how to analyze the quality of the flours to help you find the solutions that fit your needs.

Introduction

Keto and gluten-free trends have been surging in the last few decades, and one of the building blocks of this health trend is the use of pulses or legume flours as partial or total substitutes for wheat flour in baked goods.[1]

Aside from the nutritional benefits of pulses, some environmental benefits can also be considered. Pulses help restore soil fertility by fixing atmospheric nitrogen into nitrogen compounds such as ammonia.[1,2]

All of the potential benefits of the usage of pulses instead of traditional wheat flour present a drawback, and it is the functional challenges presented by the usage of this type of flour due to the absence of gluten. Baked goods made with partial or total substitution of wheat flour for pulse flour tend to have a higher water absorption, lower volume, higher density, and colors and flavors that may be unacceptable to some consumers. Recent studies have researched the effect of different pulse flour substitutions in bread, and other baked goods. It's of the utmost importance to verify flour quality and establish procedures to objectively classify them, and thus provide bakers around the globe with high-quality consistent products that satisfy consumer demands.[4]

The current pulses flour market is valued at USD 19.3 billion for 2023, and it's expected to grow with a compound annual growth rate (CAGR) of 7.0% in the 2023 - 2033 period. By the year 2033, it is expected to have a valuation of USD 38.0 billion.[3]

What are Pulses?

Pulses also commonly known as legumes are the dry seeds of leguminous plants. They are differentiated from leguminous oil seeds due to their low fat content. Pulses flour is the fine ground powder obtained from the milling of dry legumes. The process begins with cleaning the seeds to remove impurities, followed by pre-treatment processes like dehulling, roasting, or germination, which enhance the flour's functionality and sensory attributes.[1]

Functional Properties of Legume Flour

Replacing wheat flour in gluten-free baked goods is a technological challenge confronted by researchers and bakers around the world. Usually, partial replacement of wheat flour is made to improve the nutritional profile of baked goods. Total substitution requires the use of other ingredients to mimic gluten performance on the baked goods, and other processing parameters or processing should be applied.

The most important functionalities of pulse flour in bakery systems are:

Solubility

Solubility is the result of the interaction between hydrophilic and hydrophobic groups present on the surface of the protein with water or other solvents. Legume proteins in general are characterized by a high solubility of up to 80-90% at pH levels lower than 3, and higher than 7.5, but with a decreased solubility at pH values ranging from 4-6. This property is important for other protein functionalities like gelation, emulsification, and foaming.[5,6]

Water holding capacity (WHC)

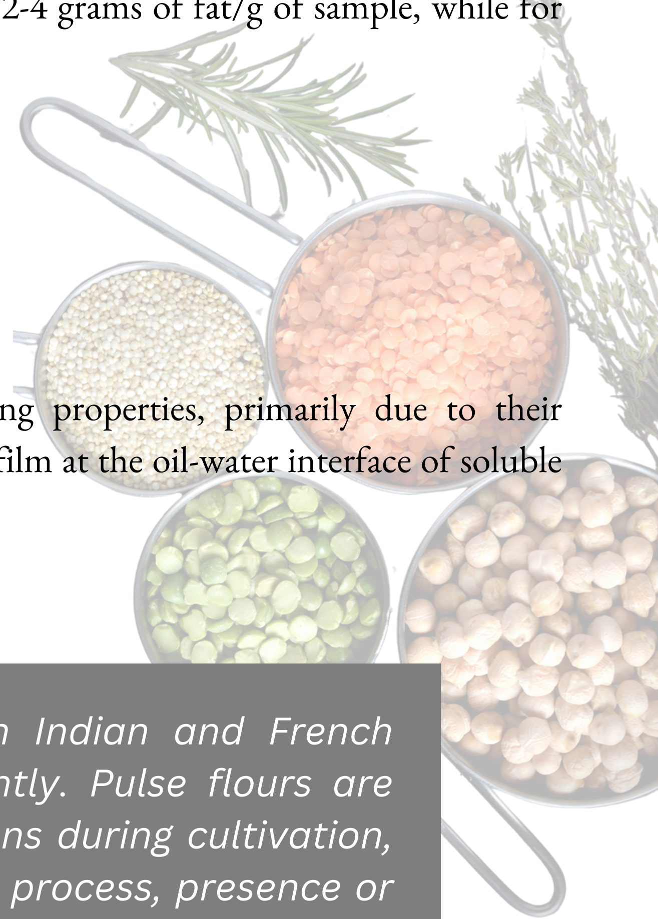
Water holding capacity is the amount of water that can be absorbed per gram of ingredient. It ranges from 0.6 to 2.7 grams of water/grams of dry mater for chickpeas, lentils, faba bean, soybean, and pea protein. This parameter influences the stalling rate of the baked goods, as well as dough performance, and batter viscosity.[5,6]

Fat absorption capacity (FAC)

Fat absorption capacity is the mass of oil absorbed per mass of pulse flour. It influences the texture of the final product, giving that the affinity of the protein to bind fat improves the texture of baked goods. FAC of legumes ranges from 2-4 grams of fat/g of sample, while for wheat gluten is 1.1-1.7 g/g.[5,6]

Emuslfying and foaming

Pulses flours exhibit strong emulsifying and foaming properties, primarily due to their amphiphilic characteristics and their ability to form a film at the oil-water interface of soluble proteins.[5,6]



No two pulse flours are alike, an Indian and French chickpea flour will behave differently. Pulse flours are affected by environmental conditions during cultivation, soil conditions, genetics, the milling process, presence or absence of additional treatments.

Quality of Pulse Flours

Pulses flour quality doesn’t have established methods of analysis like its wheat flour counterparts. However, by taking advantage of Mixolab versatility, it was possible to develop dedicated protocols for various pulses. This study on pure pulse flour demonstrate significant variability, even among samples of the same variety. This highlights the need for systematic control of pulse flour quality parameters.[7,8]

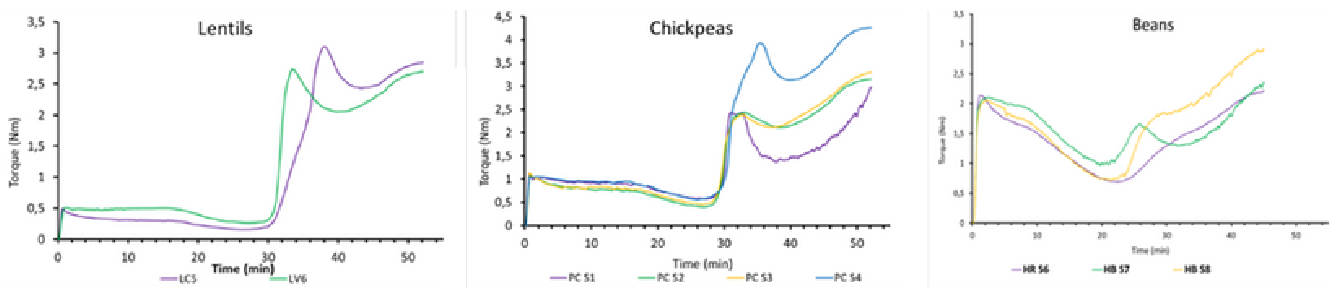


Figure 1. Results obtained for various pulses, analyzed pure with the Mixolab

The potential of pulse flour in bread-making can be explored by blending it with wheat flour. Modifications of conventional wheat flour methods can be used to assess different pulse flour quality parameters such as water absorption capacity, mixing behavior, protein weakening, starch gelatinization, amylase activity, and starch retrogradation.

The obtained parameters can be correlated with sensory, and physical parameters such as loaf volume, and crumb density of bread formulated with different pulses of flour to evaluate the performance of each pulse and the substitution level of them.

Several researches have been conducted using the Mixolab 2 to determine the quality of pulse flour used for baked products. Aguiar et al (2022) for example conducted a study to assess the acceptability, softness, and emotional response to gluten-free bread using rice and bean flour. Bojnanska et al (2021) also studied the rheological response of adding legume flours to breadmaking properties.[9]

Research conducted by KPM Analytics with its Mixolab 2 has shown that the usage of pulses such as green lentils, chickpeas, kidney beans, coral lentils, and white beans significantly increases the water absorption capacity of the dough with increasing substitution levels, except for coral lentils. Consistency of the dough at cold temperatures of 30 $^{\circ}$C (86 $^{\circ}$F) also increased. A delay in starch gelatinization time was also observed in comparison with wheat flour control dough.[7]

In general, the addition of different pulses of flour at different levels shows different rheological behavior. Thus, the importance of controlling and evaluating the quality of them to reach the ideal performance of each alternative available for the desired usage.

Effect of Pulse Flour on Bread Making

Adding pulses flour can cause a wide variety of changes in the rheological behavior of the dough, ranging from an increment of the water absorption capacity, and an increase in the development time to reach dough weakening. Bread made with partial substitution of wheat flour with pulse flour can obtain lower overall scores than their wheat flour counterparts.

They also present a decrease in the loaf volume and an increase in bread density. Depending on the use of pulse flour significant differences in the acceptability of the color or flavor of the bread can also be observed.[7]

Why is the Mixolab 2 Important in Understanding Pulses in Breadmaking?

The Mixolab 2 is dough testing equipment used to assess the baking quality and performance of hydrated cereal flours. It's used to characterize the rheological behavior and pasting properties of flour/water doughs and starch/water mixtures when subjected to the simultaneous action of mixing and heat transfer.

The Mixolab 2 helps millers and bakers to:

- Adjust dough mixing parameters
- Detect excessive enzymatic activity in wheat due to sprout damage
- Evaluate starch damage
- Adjust flour's alpha-amylase activity
- Predict product behavior during thermal processing
- Assess the cold/hot functionality of starches and gums
- Study the effect of dough conditioners on dough mixing properties
- Study the effect of different flours on the rheological behavior of the dough

In Figure 1 a typical graph made by the Mixolab 2 can be seen. Following the Chopin+ Protocol **(ICC-173-1/AACC 54-60.01/ ISO 17718)** a blend of pulse flour can be successfully analyzed, to analyze pure pulse flour some adaptations need to be taken into account for each pulse type. Some relevant parameters can be extracted from Figure 2. Derived parameters such as water absorption, maximum consistency at 30 °C (86 °F) **(C1)**, dough weakening **(C2)**, time to reach dough weakening **(TC2)**, peak torque **(C3)**, stability of hot dough at 90 °C (194 °F) **(C4)**, and final torque **(C5)** can be determined.[7]

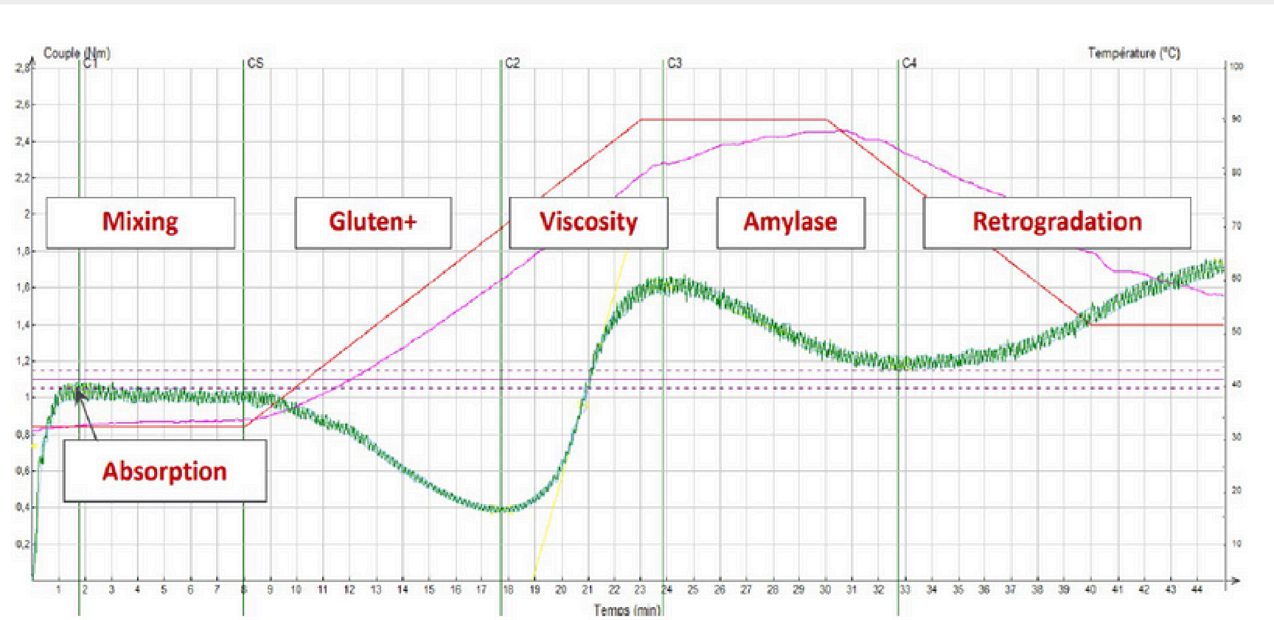


Figure 2.Mixolab 2 Analysis Graph

Water absorption capacity is affected by the addition of pulses flour, increasing levels of substitution cause an increase in the water absorption capacity of the doughs as seen in Figure 3, except for coral lentils in which a decrease was found. Zhang et al (2021) found that adding pulses increases the dough's water absorption capacity. This can be associated with the larger particle size and the non-dehulled coat. Some studies indicate that water absorption is strongly related to particle size, surface area, protein content, fiber content, and starch and damaged starch content. The variability of the previously mentioned parameters may explain the decrease in water absorption of coral lentil flour.[7,10]

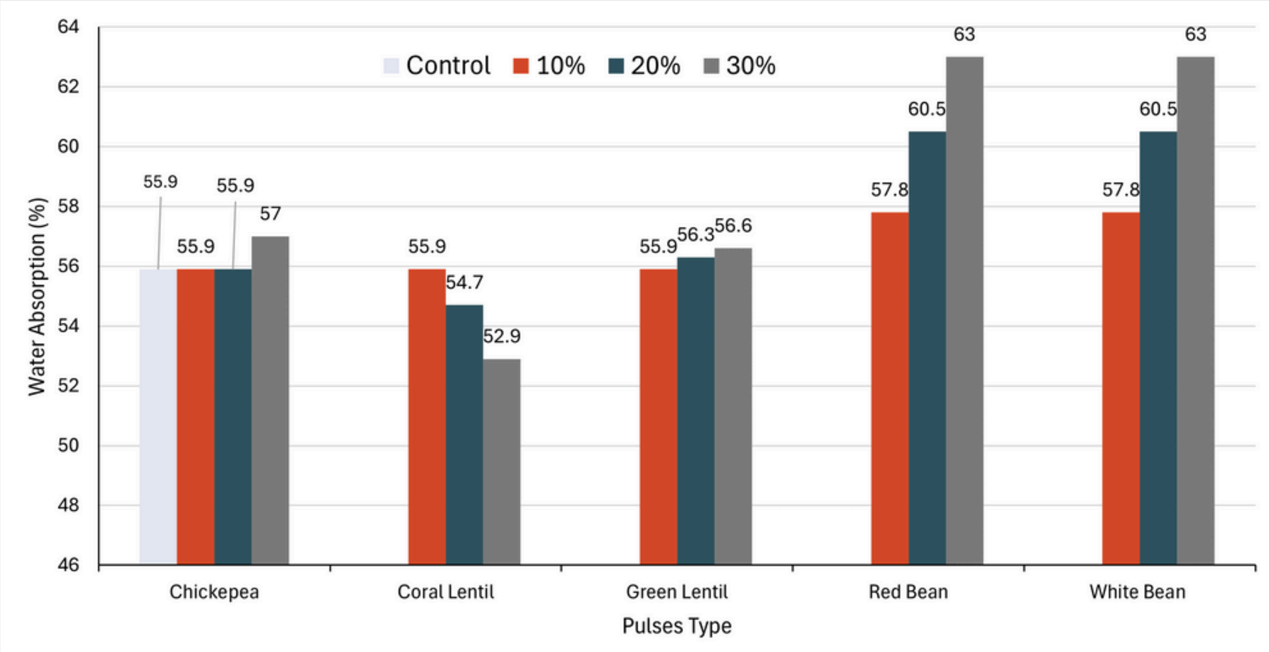
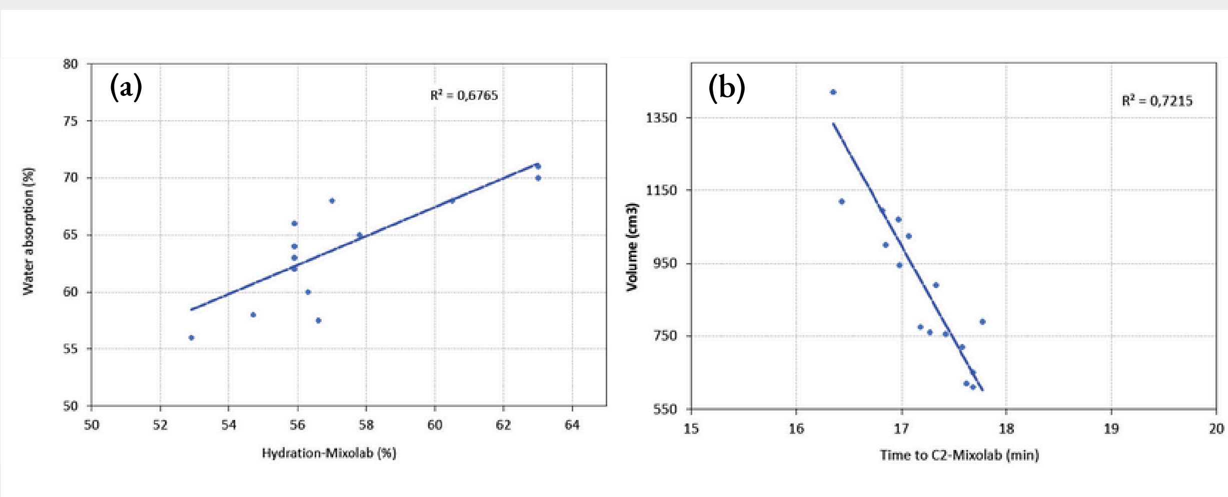


Figure 3. Water absorption of wheat-pulses blends at the substitution levels of 10, 20 and 30

Mixolab 2 parameters can be associated with baking-test parameters to observe its correlation as seen in Figure 4. Water absorption in the bread-making process is correlated with the hydration parameter of the Mixolab 2. Sensory parameters like total evaluation score correlate with the parameter **TC2**, corresponding to the time required to reach dough weakening. A similar behavior can be seen for loaf density and volume.[7]



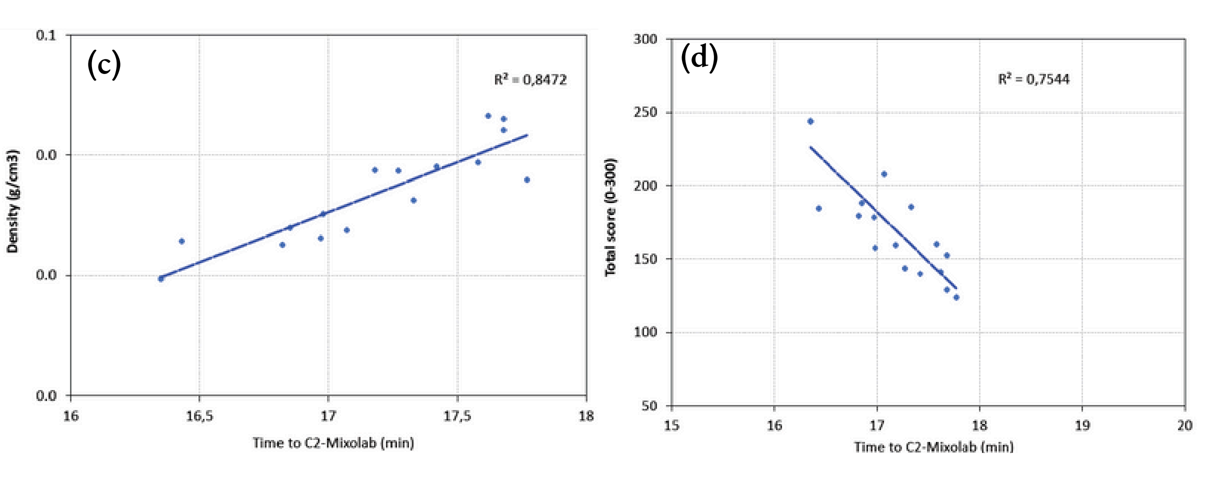


Figure 4. Correlation between bread-making tests and Mixolab 2 Data (a) Water absorption vs Hydration, (b) Volume vs Time, (c) Density vs Time and (d) Total score vs Time

In Figure 5 , breads manufactured with a variety of pulses flour can be appreciated.

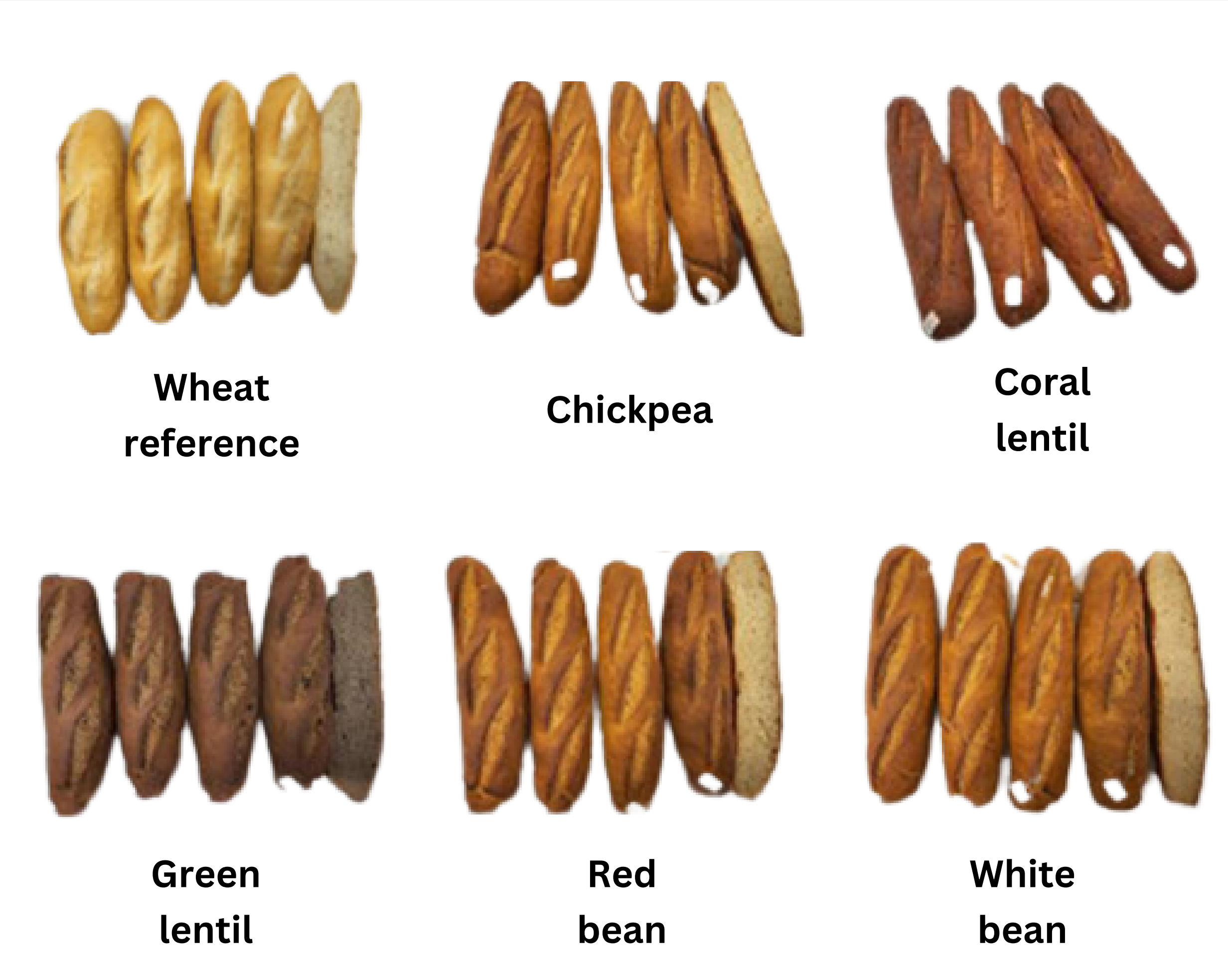


Figure 5. Bread produced with a variety of pulse flours

Replacing wheat flour with legume flour leads to :

- Excessive dough firmness.
- Lower extensibility.
- Lower development.
- Lower fermentation and baking resistance.
- Decrease in bread appearance.
- Lack of volume.
- Very dark, dense crumb with a strong taste of legume at high concentration.
- Increase in cold dough consistency regardless of legume origin.
- Increased hydration for all legumes except coral lentils.
- Increased dough development time for all pulse flours, except chickpea.
- A decrease in the resistance of the protein network (C2) to kneading and heating.
- A time delay is required to reach parameter C2.
- Increase in paste consistency during heating for all legumes, except chickpeas

Mixolab 2 Study Conclusions

- Different legume flours have very different rheological properties (as measured by Mixolab 2).
- Different levels of legume incorporation show different rheological properties (as measured by Mixolab 2).
- The characteristics of the finished products were strongly correlated with the Mixolab 2 data, particularly the time to reach C2 and the C2 and C3 torques.
- The Mixolab 2 can be used to select raw materials, eliminate unsuitable ones, and not keep only the most promising.
- The Mixolab 2 can also predict the properties of end products such as bread.

Summary

Pulses are novel nutritional-improving alternatives for bakers worldwide. However, from all the alternatives present today, it's extremely important to choose the right one according to the needs of the baked good to produce. Choosing the right alternative requires a feasibility testing analysis just like any new development. Considering the needs of the producer, and finding the right tools to conduct a quick and effective analysis of the material would allow bakers to make the best choice for their products.

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