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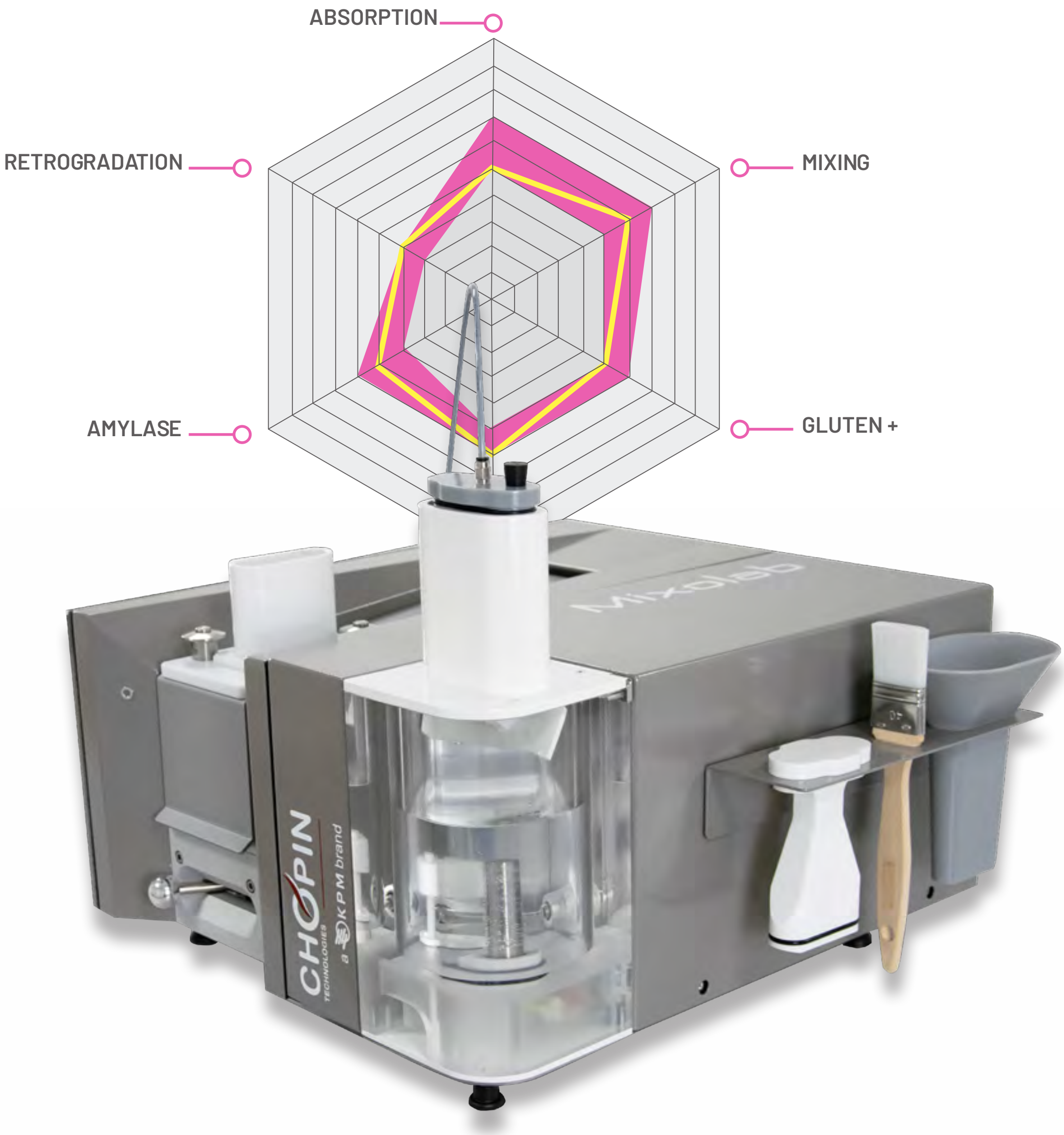
MIXOLAB APPLICATIONS HANDBOOK

Rheological and Enzyme Analyses
Analysis Methods - Studies and Applications

May 2012 Edition



Foreword

In a perpetually changing world, we naturally considered that CHOPIN Technologies could provide its users with more than analytical instruments for grains and powders. Every day, we deal with industrial realities at an international level. It convinced us that, beyond manufacturing high-end and standardized instruments, CHOPIN Technologies had to put all the experience of the technical teams at the service of the users.

This idea was bolstered further when the Mixolab® was launched onto the market. In 2006, we decided to pool the best of our technical expertise within an entity specifically dedicated to meeting the challenges set by our customers: the CHOPIN Technologies applications laboratory. Our analytical specialists offer you a complete range of solutions to get the best from your instruments.

This document presents the main applications available for the Mixolab® at a given time. It is constantly changing, however, and we recommend that you contact us regularly to get the latest updates.

Most of the applications in this document were developed in our Applications Laboratory, most frequently directly in conjunction with the cereal industry (cooperatives, millers, 2nd transformation, additives and ingredients manufacturers, etc.).

In other cases (highlighted in the document), they were provided to us by international research centers working alongside CHOPIN Technologies to achieve optimum Mixolab® use and to discover other possible fields of application.

We hope with this document you will discover the great variety of possible applications on the Mixolab®. Though it is in no way exhaustive, the document will give you an idea of what is possible with the Mixolab®. Thus, we think you will identify potential solutions to your questions... Don't hesitate to contact our experts!

A. Dubat
Directeur Marketing et Applications

N. Boinot
Responsable Applications

CONTENTS

1 ❖ TERMS AND DEFINITIONS

1.1 ▶ Definitions

✦ Water content

The water content (sometimes referred to as moisture) is the amount of water contained in flour. This content varies on the basis of various parameters (wheat conditioning prior to milling, storage conditions, etc.), but is generally between 7% and 15%.

✦ Hydration

The hydration is the amount of water contained in dough for a given consistency. One part of this water comes from the flour itself (variable proportion based on flour water content), with the other part added by the operator. Hydration is always linked with a hydration base.

✦ Hydration base

The hydration base is the reference system used to express hydration. The most commonly used bases are:

- The 14% base (b14)
- The 15% base (b15)
- The dry matter base (dm)
- The "as is" base (As-is)

In this way, to prepare a dough with 55% b14 hydration:

- If the water content of the flour is equal to 14%: it is necessary to mix 100g of this flour and 55g of water.
- If the water content of the flour is less than 14% (e.g. 12.3%): it is necessary to mix 100g of the flour, 55g of water, plus the amount of water required to increase the flour water content from 12.3% to 14%.
- If the water content of the flour is greater than 14% (e.g. 15.6%): it is necessary to mix 100g of the flour, 55g of water, less the amount of water required to reduce the flour water content from 15.6% to 14%.

Hydration can be expressed using any base, just as temperature can be expressed in degrees Celsius, degrees Fahrenheit or degrees Kelvin. The equations for converting from one hydration base to another are given in section 1.2.

However, it is important to note that, unlike the b14, b15 and dm bases, the As-is base does not account for the water content of the flour used to form the dough, making it very difficult to make comparisons.

As a reminder, the formula for converting from the As-is base to the dm base is:

$$\text{As-is} = \text{dm} \times (100-\text{moisture})/100$$

✦ Flour water absorption capacity

The water absorption capacity of a flour is the hydration required to bring a dough to a given maximum consistency. This consistency is equal to 1.1 Nm (+/- 0.05 Nm) with the Chopin+ protocol (equivalent to 500 Farinograph® units). It is generally expressed with a 14% base.

✦ Dough temperature

The dough temperature is measured by a patented system ensuring excellent measurement repeatability and reproducibility. The measurement probe is located as close to the dough as possible inside the dough mixer unit.

✦ Critical Difference (CD)

The critical difference is the acceptable deviation between 2 averages of results obtained in the course of tests conducted under repeatability conditions.

➧ *Comparison of 2 sets of measurements from the same laboratory*

The critical difference to compare 2 averages of results obtained from tests conducted under repeatability conditions within the same laboratory is equal to:

$$CD = 2{,}8S_r\sqrt{\frac{1}{2n_1}+\frac{1}{2n_2}} = 2{,}8S_r\sqrt{\frac{1}{2}} = 1{,}98S_r$$

Where S_r : Repeatability standard deviation
n1 and n2 : Number of results used for each average of results to be compared

➧ *Comparison of 2 sets of measurements from 2 different laboratories*

The critical difference to compare 2 averages of results obtained from tests conducted under repeatability conditions in 2 laboratories is equal to:

$$CD = 2{,}8\sqrt{S_R^2 - S_r^2\left(1-\frac{1}{2n_1}-\frac{1}{2n_2}\right)} = 2{,}8\sqrt{S_R^2 - 0{,}5S_r^2}$$

Where S_r : Repeatability standard deviation
S_R : Reproducibility standard deviation
n1 and n2 : Number of results used for each average of results to be compared

1.2 ▶ Formulas for converting from one hydration base to another

from b14 to dm	$Hyd.dm\% = \frac{(Hyd.b14+14)\times 100}{86}$
from b15 to dm	$Hyd.dm\% = \frac{(Hyd.b15+15)\times 100}{85}$
from b15 to b14	$Hyd.b14\% = \left[\frac{(Hyd.b15+15)\times 86}{85}\right]-14$
from b14 to b15	$Hyd.b15\% = \left[\frac{(Hyd.b14+14)\times 85}{86}\right]-15$
from dm to b14	$Hyd.b14\% = \left[\frac{Hyd.dm\times 86}{100}\right]-14$
from dm to b15	$Hyd.b15\% = \left[\frac{Hyd.dm\times 85}{100}\right]-15$

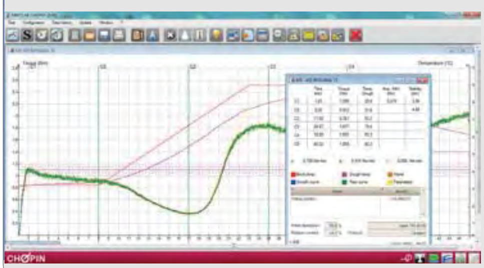
1.3 ▶ Abbreviations

AACC .... American Association of Cereal Chemistry
AFNOR .... Association Française de NORmalisation (French Standardization Association)
BIPEA .... Bureau InterProfessionnel d'Etudes Analytiques (International Bureau for Analytical Studies)
b14 .... 14% base
b15 .... 15% base
CD .... Critical Difference
CEN .... European Committee for Standardization
CV_r .... Repeatability coefficient of variation
CV_R .... Reproducibility coefficient of variation
H_2O .... Water content
ICC .... International Association for Cereal Science and Technology
ISO .... International Organization for Standardization
ERM .... External Reference Materials
dm .... dry matter base
nd .... not determined
R^2 .... Correlation coefficient
rpm .... Revolutions per minute
S_r .... Repeatability standard deviation
S_R .... Reproducibility standard deviation
Dev time .... Development time
As-is .... As is base
FU .... Farinograph® unit
WA .... Water absorption capacity

2 ❖ MIXOLAB® SYSTEM

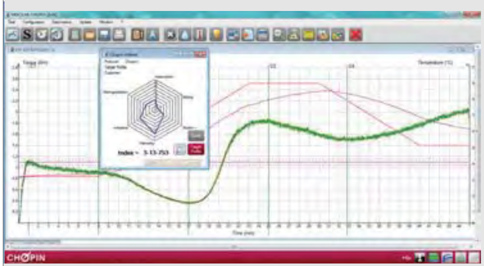
Comprehensive tool for research and quality control

✦ Mixolab® Standard



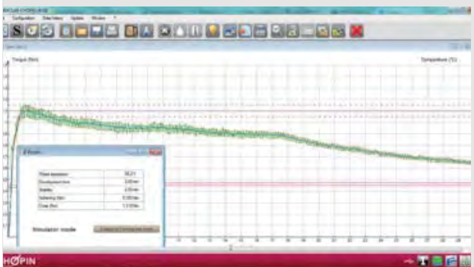
The Mixolab® Standard is the ideal application for R&D. It is the only system for a complete flour characterization (protein, starch, enzymes, etc.) in a single test, on a single tool.

✦ Mixolab® Profiler



The Mixolab® Profiler can be used to test and select your wheat varieties and flours completely reliably, since it is based on an exhaustive analysis of the flour, its constituents and their interactions. The Mixolab® Profiler is the ideal tool for raw material quality control and can be used to set up a common vocabulary for customer-supplier relationships.

✦ Mixolab® Simulator

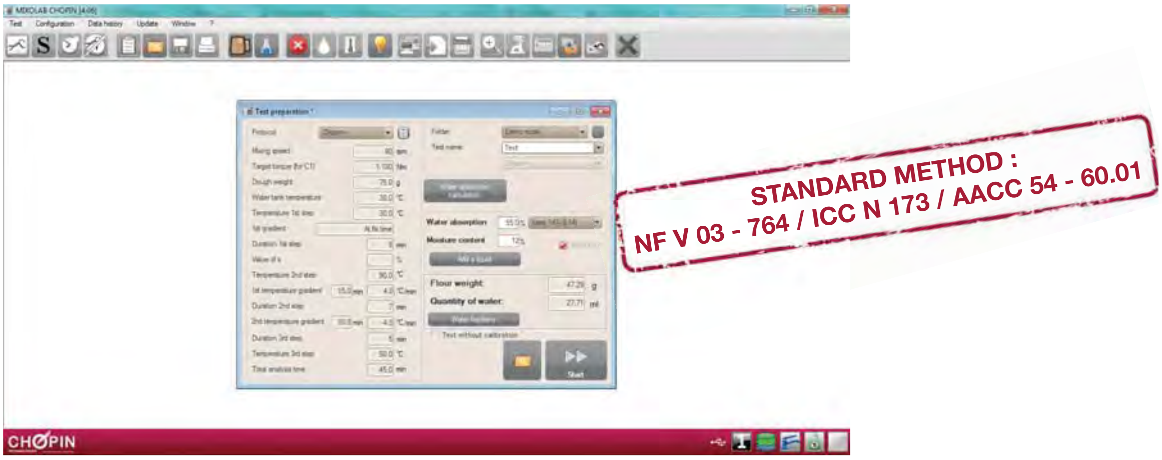


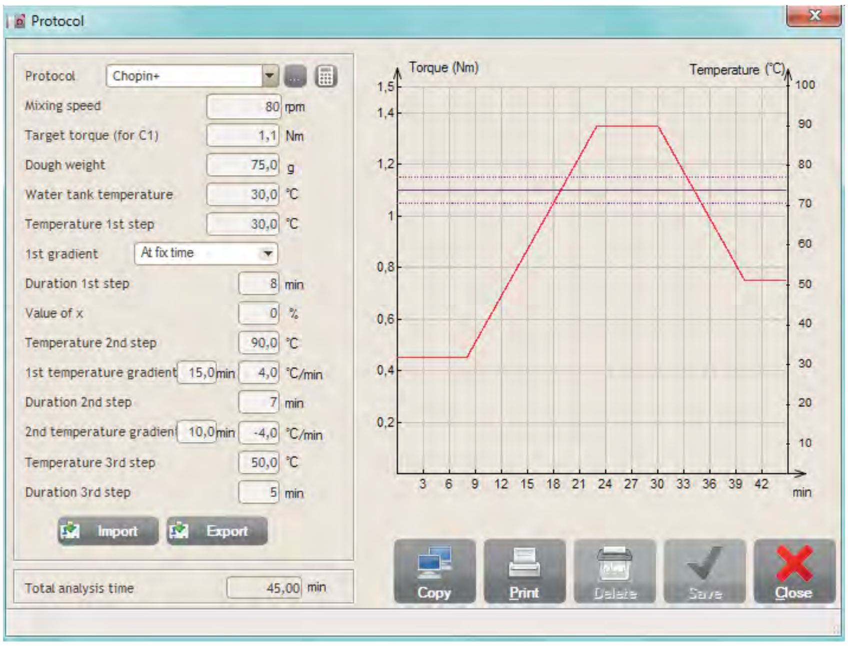
The Mixolab® Simulator has been specifically developed to be able to obtain data with Mixolab® that are fully comparable (values and units) to those obtained with a Farinograph®. With the Mixolab® Simulator you can still dialog with business partners who are using conventional analysis methods.

2.1 ▶ Mixolab® Standard

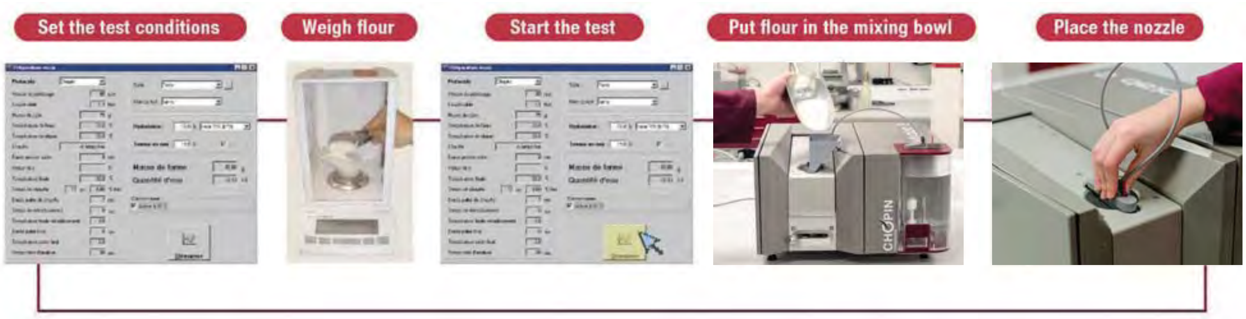
2.1.1 Principle

The Mixolab® is a recording dough mixer used to measure the rheological properties of doughs subject to the dual stress of mixing and temperature changes. It measures the torque (in Nm) produced by the dough between two mixing blades. The test is based on the preparation of a constant weight dough sample hydrated to obtain a target consistency during the first test phase. In the “Chopin+” protocol, the dough weight is 75 grams and the target consistency is 1.1 Nm (+/- 0.05 Nm).





2.1.2 Method



- Select the desired protocol.
- Specify the sample moisture and approximated hydration (by default, use 55% for white flour and 60% for whole grain).
- Select a hydration base (“As-is”, “15% base”, “14% base”, “dry matter”).
  It is recommended to work with a 14% base.
- Weigh the quantity of sample specified by the Mixolab® software.
- Position the dough mixer in its housing, close the lid.
- Start the test.
- Introduce the sample using the specially provided funnel.
- Position the water injection nozzle.
- If the consistency C1 is outside the tolerances, stop the test, clean the dough mixer and put it back in place.
- Use the integrated calculation tool to predict the actual hydration of the sample, accounting for the results of the previous test (hydration used, C1 torque obtained and moisture).
- Restart the test and let it run until the end.

NB: The test follows the same procedure on flour and whole grains.
For more information on the influence of the type of mill, see chapter 4.

2.1.3 Results

Point	Explanation	Associated parameters	
C1	Used to determine water absorption	T°C 1 and T1	Dough temperature and time corresponding to the occurrence of the various torques
C2	Measures protein weakening as a function of mechanical work and temperature	T°C 2 and T2	
C3	Measures starch gelatinisation	T°C 3 and T3	
C4	Measures hot gel stability	T°C 4 and T4	
C5	Measures starch retrogradation in the cooling phase	T°C 5 and T5	

Parameter	Calculation method	Explanation
Water absorption (%)	Amount of water required to obtain C1 = 1.1 Nm +/- 0.05 Nm	Amount of water that a flour can absorb to obtain a given consistency during the phase at constant temperature
Time for C1 (min)	Time required to obtain C1	Dough development time, the stronger the flour, the longer the development time
Stability (min)	Time during which the upper frame is > C1 – 11% (phase at constant temp)	Mixing resistance of dough, the longer this time is, the more the flour is said to be “strong”
Amplitude (Nm)	Width of curve to C1	Dough elasticity, the higher the value, the greater the elasticity of the flour

Parameter	Calculation	Explanation
Slope α	Slope of curve between end of period at 30°C and C2	Protein weakning speed under the effect of heat
Slope β	Slope of curve between C2 and C3	Starch gelatinisation speed
Slope γ	Slope of curve between C3 and C4	Enzyme degradation speed

NB: These parameter calculations are the calculations by defaut. The user can combine them after having exported the test to excel. It is thus possible to calculate the C3-C4 viscosity drop (hot gel stability) to compare it with the amylase activity as determined in the Falling Number® (see section 3).

2.1.4 Precision of the method

▶ Repeatability and reproducibility

An international inter-laboratory test (Ring test) was organized in March 2006. The goal was to measure the precision data (repeatability and reproducibility) for the Mixolab® with a dozen users in order to submit the results to the competent organizations (ISO, CEN, ICC, AACC, AFNOR, etc.) and have the mixolab standards.

The results are given in the following tables and apply both to white wheat flours and whole grain.

The first table gives the ranges and standard deviations for the various parameters.

	Type	Range	S_r	S_R	CV_r (%)	CV_R (%)
Absorption	Constant	51.6-63.4 (%)	nd	0.9	nd	2
C2	Constant	0.37-0.63 (Nm)	0.01	0.03	3	5
C3	Constant	1.59-2.27 (Nm)	0.02	0.08	1	4
C4	Constant	0.95-2.12 (Nm)	0.03	0.09	2	5
C5	Constant	1.46-3.73 (Nm)	0.08	0.19	3	7
Stability	Variable	4.69-11.42 (min)	--	--	--	--
Dough development time	Variable	0.99-7.36 (min)	--	--	--	--
T°C at C1	Constant	29.7-33.9 (°C)	0.57	0.97	2	3
T°C at C2	Constant	52.2-57.7 (°C)	0.65	1.59	1	3
T°C at C3	Constant	75.2-86.2 (°C)	0.78	1.69	1	2
T°C at C4	Constant	83.5-88.7 (°C)	0.77	1.72	1	2
T°C at C5	Constant	58.1-60.6 (°C)	0.74	2.72	1	5

The second gives the precision limits (maximum deviation accepted between 2 measurements).

	Type	Range	r	R
Absorption	Constant	51.6-63.4 (%)	nd	0.9 x 2.77 = 2.49
C2	Constant	0.37-0.63 (Nm)	0.01 x 2.77 = 0.04	0.03 x 2.77 = 0.08
C3	Constant	1.59-2.27 (Nm)	0.02 x 2.77 = 0.05	0.08 x 2.77 = 0.20
C4	Constant	0.95-2.12 (Nm)	0.03 x 2.77 = 0.08	0.09 x 2.77 = 0.24
C5	Constant	1.46-3.73 (Nm)	0.08 x 2.77 = 0.22	0.19 x 2.77 = 0.53
Stability	Variable	4.69-11.42 (min)	(-0.0902 x average + 1.2762)*2.77	(-0.1513 x average + 2.2014)*2.77
Dough development time	Variable	0.99-7.36 (min)	(0.0814 x average + 0.1252)*2.77	(0.1716 x average + 0.1147)*2.77
T°C at C1	Constant	29.7-33.9 (°C)	0.57 x 2.77 = 1.58	0.97 x 2.77 = 2.69
T°C at C2	Constant	52.2-57.7 (°C)	0.65 x 2.77 = 1.80	1.59 x 2.77 = 4.39
T°C at C3	Constant	75.2-86.2 (°C)	0.78 x 2.77 = 2.16	1.69 x 2.77 = 4.47
T°C at C4	Constant	83.5-88.7 (°C)	0.77 x 2.77 = 2.13	1.72 x 2.77 = 4.55
T°C at C5	Constant	58.1-60.6 (°C)	0.74 x 2.77 = 2.05	2.72 x 2.77 = 7.55

The results for the Mixolab® in terms of repeatability and reproducibility are excellent. The permissible deviations noted here apply both to white wheat flour and whole grain (not valid for other matrices).

▶ Blind repetitions

In the ring test organized in March 2006, it was decided to double 2 blind samples. Each laboratory received the same sample of wheat twice under two different codes. In this way, they analyzed, without knowing it, the same sample on different days.

The table below gives the average results obtained by all the laboratories on these samples.
Note that these samples have been grinded by each laboratory separately.

	Duplicate 1		Duplicate 2	
	B3	B7	B9	B12
Absorption (%b14)	61.6	61.2	60.4	59.9
Dough development time (min)	5.15	5.27	7.15	7.15
Stability (min)	10.27	10.38	11.28	11.3
C2 (Nm)	0.47	0.48	0.58	0.6
C3 (Nm)	1.76	1.79	2.1	2.13
C4 (Nm)	1.24	1.32	1.95	1.99
C5 (Nm)	1.86	1.99	2.92	2.99
T°C at C1 (°C)	31.3	31.4	31.6	31.9
T°C at C2 (°C)	56.9	56.9	56.3	56.1
T°C at C3 (°C)	77.5	78	79.2	79.1
T°C at C4 (°C)	85.1	85.8	86.5	86.6
T°C at C5 (°C)	58.9	59.2	59.6	59.7

The results show very good reproducibility for:

- The water absorption value.
- The dough development time value.
- The stability value.
- All the torque values (C1…C5).
- All the dough temperature values (T°C at C1… T°C at C5).

These values, in addition to the ring test results given above in this document, demonstrate the excellent repeatability and reproducibility of the Mixolab®.

In terms of repeatability, note that two results are significantly different when they differ by more than:

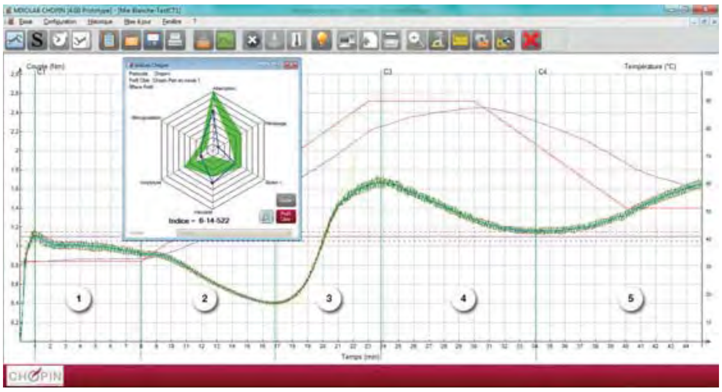
Parameter	Average limit of repeatability
Torques	0.1 Nm
Dough temperature	2 °C
Dough development time	Variable according to average value
Stability	Variable according to average value

When comparing 2 average results (e.g.: average of 2 tests conducted in one laboratory and average of 2 results obtained in another laboratory), the difference is not considered to be significant if it is less than the critical difference of the method (definition of critical difference available in section 1).

2.2 ▶ Mixolab® Profiler

2.2.1 Principle

The Mixolab® Profiler is a feature of the Mixolab®. It uses the standardized protocol (ICC N°173, AACC 54 -60.01 and NF V 03 -764) for a complete flour characterization (protein network, starch and enzyme activity) and provides a simplified graphic interpretation of the results.



The Mixolab® Profiler converts the standard curve into 6 indexes rated from 0 to 9. It profiles flour on the basis of 6 fundamental criteria, i.e.:

- **Absorption potential or *Water Absorption Index*:**
  This is dependent on the flour composition (protein, starch, fibre, etc.). It influences the dough yield (profit).

  The higher the index, the more water is absorbed by the flour.

- **Mixing properties or *Mixing Index*:**
  This represents the properties of the flour during mixing at 30°C. It accounts for the stability, dough development time, weakening, etc.

  The higher the index, the greater the stability of the flour during mixing.

- **Gluten strength or *Gluten+ Index*:**
  This represents the properties of the gluten when the dough is heated.

  The higher the index, the higher the resistance of the gluten to heating.

- **Maximum viscosity or *Viscosity Index*:**
  This represents the increase in viscosity during the heating phase. It is dependent both on the amylase activity and the starch quality.

  The higher the index, the higher the viscosity of the dough when hot.

- **Amylase activity or *Amylase Index*:**
  This is dependent on the ability of the starch to “resist” amylolysis.

  The higher the index, the lower the amylase activity.

- **Retrogradation or *Retrogradation Index*:**
  This is dependent on the characteristics of the starch and its hydrolysis during the test.

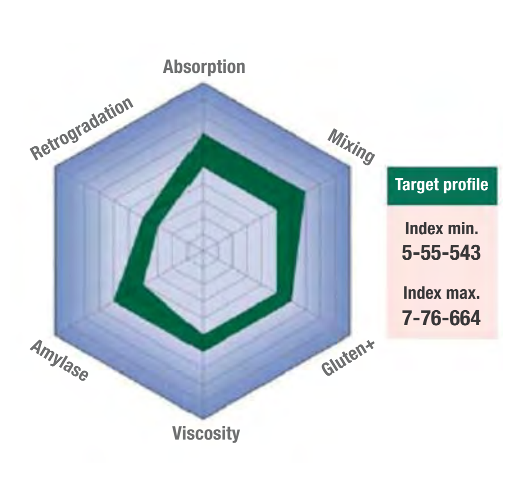
  The higher the index, the shorter the product shelf-life.

2.2.2 Key steps

✦ Step 1: Create or select a Target Profile based on the selected application

The ***Target Profile*** of an application is an area characterized by min/max values on each of the 6 ***Mixolab® Profiler*** axes, rated from 1 to 9. The axes represent the water absorption, mixing properties, gluten strength, maximum viscosity, amylase activity and retrogradation.

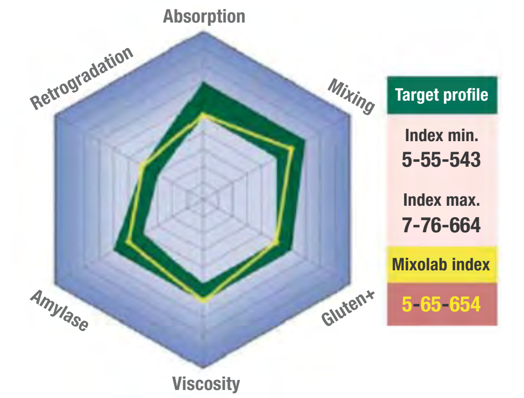
The ***Mixolab®*** software allows you to choose one of the standard profiles provided by CHOPIN Technologies or select them in a customized database (the user can create as many profiles as required, associating them for example with flour types, customers or suppliers).



✦ Step 2: Measure the Mixolab® indexes of a flour and compare it to a Target Profile

During sample analysis, the results for each of the 6 indexes are displayed in real time on the ***Mixolab® Profiler***. The user instantaneously knows whether the test sample matches the desired profile.

The curve obtained is characterized by a 6-digit ***Mixolab® index*** corresponding to the value measured on each of the 6 axes. If all the points of the ***Mixolab® index*** of the flour match the ***Target Profile***, then the flour is suitable for the selected application.

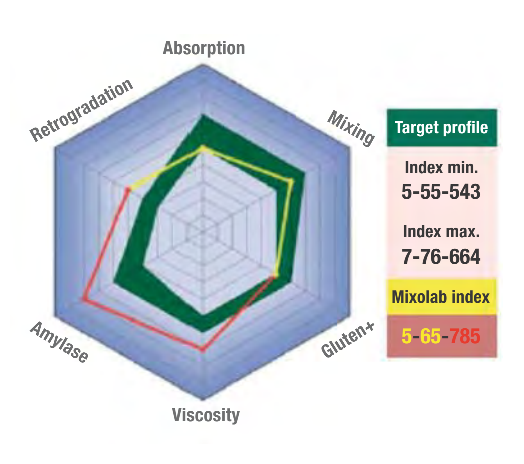


✦ Step 3: Accept, adapt or redirect...

If the ***Mixolab® index*** of the flour only partially matches the ***Target Profile***, the ***Mixolab® Profiler*** offers the user 2 options:

❶ The ***Mixolab® Guide*** suggests a possible correction of the flour characteristics to the user, based on the deviations observed.

❷ The ***Mixolab® Research Tool*** analyses the database to find the closest standard profile to the flour tested, making it possible to redirect the flour to a different application or customer if applicable.

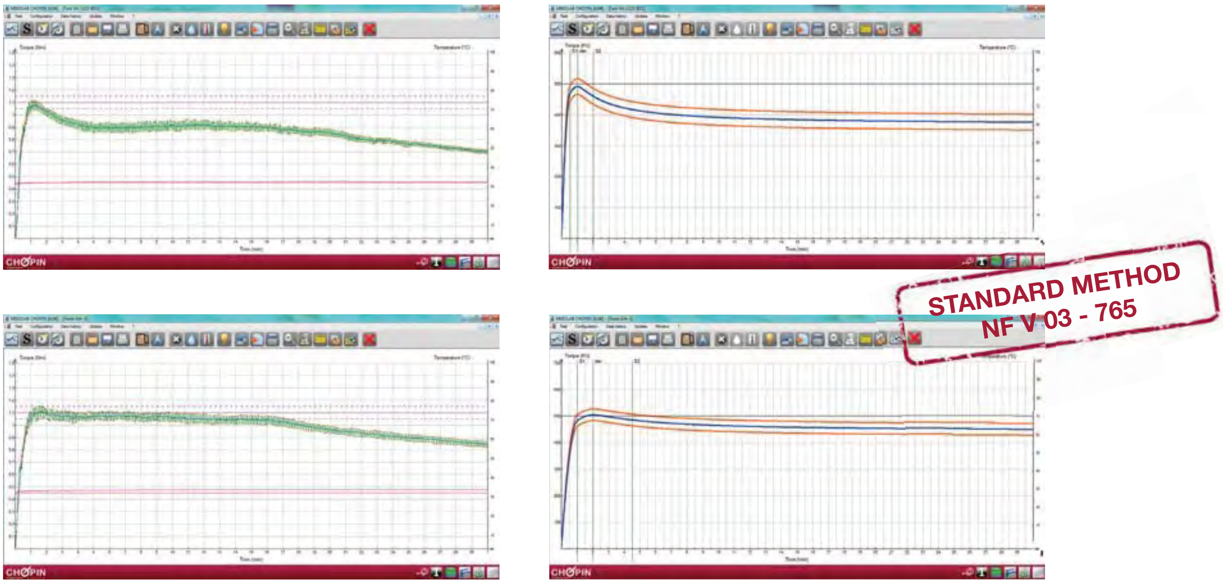


Ideal tool for raw material quality control, the Mixolab® Profiler can be used to test, select and improve your flours completely reliably, since it is based on an exhaustive analysis of the flour, its constituents and their interactions.

2.3 ▶ Mixolab® Simulator

2.3.1 Principle

The Simulator protocol has been specifically developed to be able to get the data with the Mixolab® that are fully comparable (values and units) to those obtained with a Farinograph®.



Although the curves obtained with the Simulator have the same general shape as those obtained with a Farinograph® (see curves above), there is no direct relationship between these two instruments (different dough mixer configurations, different units, etc.). The Simulator includes a calculation algorithm for automatically converting Mixolab® data into Farinograph® data.

The Simulator consists of 2 components integrated in the standard Mixolab® application:

- ❑ **A specific protocol (Chopin S)**
  - ➮ Constant test temperature: 30°C
  - ➮ Test time: 30 minutes
  - ➮ Running speed: 80 rpm
  - ➮ Target value 1.1 Nm
- ❑ **A calculation algorithm**
  - ➮ The Farinograph® equivalents are calculated accounting for several points of the curve.
  - ➮ The results are given in Farinograph® units (Time, FU, etc.).
  - ➮ Each user can optimize the values predicted by the Simulator by adjusting the correlations based on in-house tests.

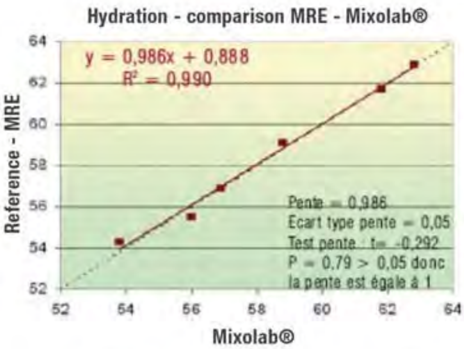
The Mixolab® is a perfect alternative for current Farinograph® users looking for a modern system while retaining their usual references.

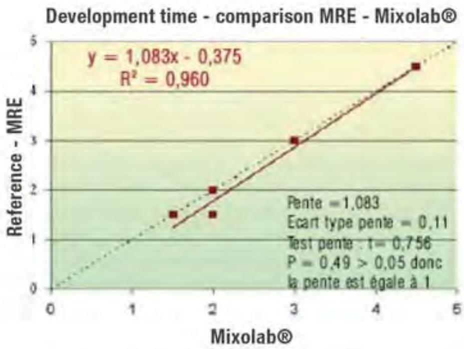
2.3.2 Precision of the method

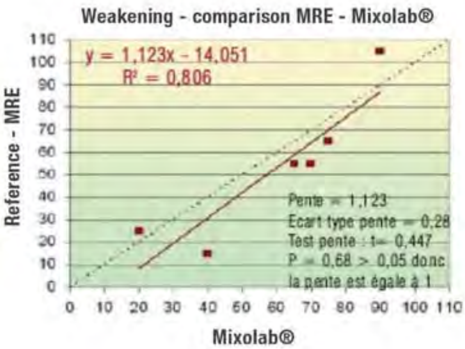
An inter-laboratory test conducted as per the standard NF ISO 5725 was initiated with 12 participants (Argentina, Australia, Belgium, France, USA) in order to assess performances (accuracy, repeatability, reproducibility) of the Simulator.

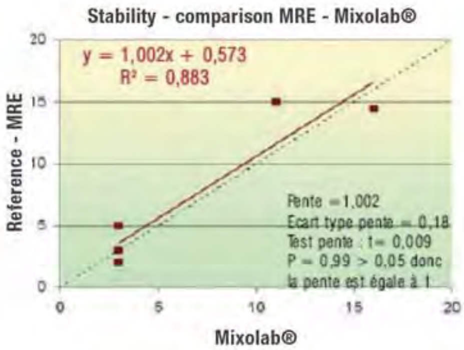
8 wheat samples including 6 External Reference Materials (BIPEA circuit No. 25 –Farinograph® / Mixolab®) were selected to cover a wide range on the 4 parameters: hydration, development time, stability and weakening. All the laboratories used the same Chopin S protocol, on all the samples. The repeatability and reproducibility standard deviations were determined using a single-factor analysis of variance after eliminating the deviant average (Dixon test) and variances (Cochran test). The accuracy of the method was assessed by comparing the average values obtained with the Mixolab® with the ERM sample reference values.

The average values obtained with the Mixolab® compared to the ERM results are not different:









For each parameter, the precision values are independent from the calculated average level. The constant repeatability (r) and reproducibility (R) limits are as follows:

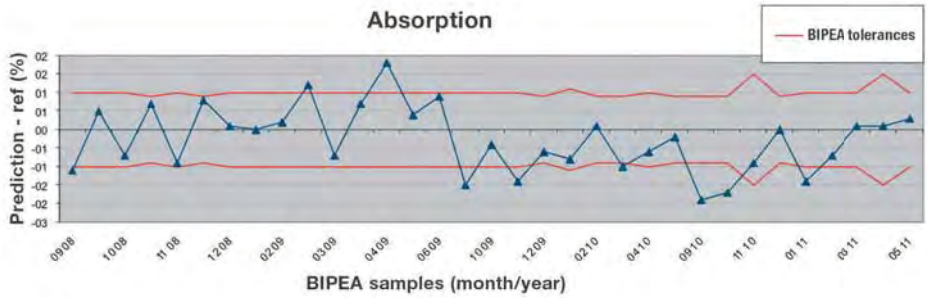
	Test range	r	R
Hydration ratio	51.7 – 62.8%	0.8%	2.1%
Development time	1 – 4.4 min	0.6 min	0.8 min
Stability	2 – 16 min	1.5 min	2 min
Weakening	22 – 100 FU	11 FU	20 FU

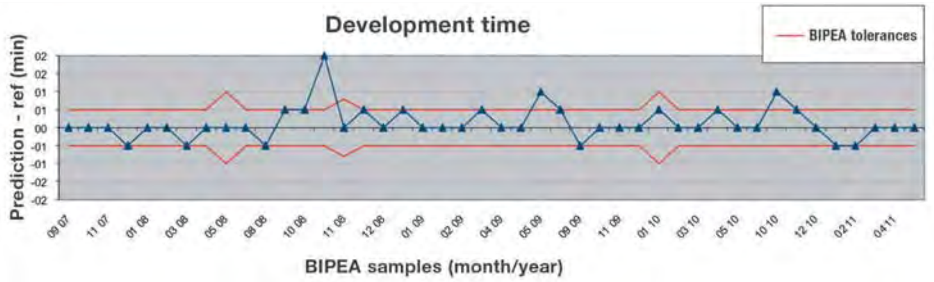
The results confirm that the Mixolab® (Chopin S protocol) is suitable for determining the water absorption ratio of flours and the rheological characteristics (development, weakening, stability) of doughs during mixing.

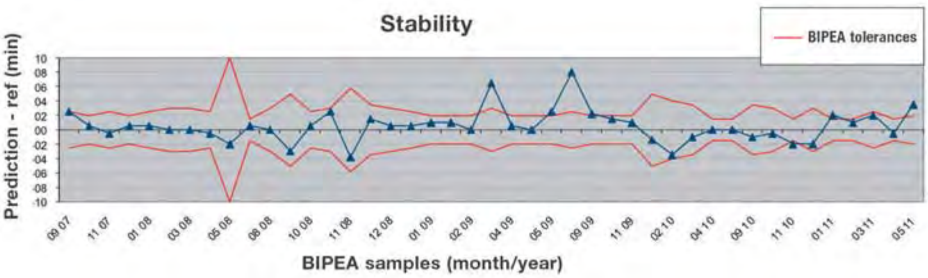
For more information: LE BRUN J., GEOFFROY S., DUBAT A. and SINNAEVE G. (2007): Niveau de performances de la mesure du taux d'adsorption d'eau des farines et des caractéristiques rhéologiques de la pâte pendant le pétrissage avec le Mixolab® Chopin. Industries des céréales. Vol.154, 20 - 27.

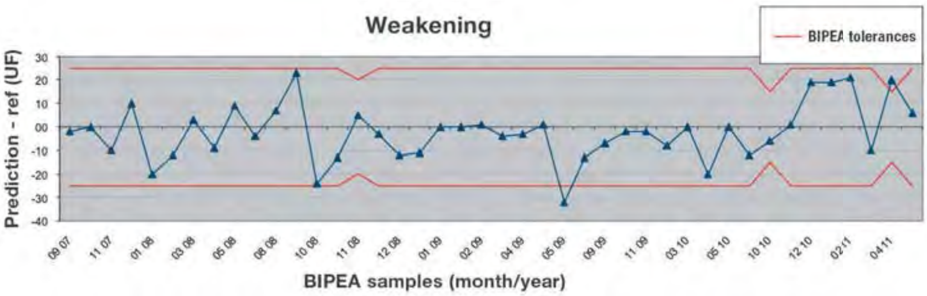
2.3.3 Accuracy of method

In order to monitor the performances of our prediction models over time, the Mixolab® (Simulator protocol) has been participating to the BIPEA "Farinograph®/Mixolab®" inter - comparison circuit (circuit No. 25) since 2003.









The above figures represent, for each of the samples analyzed and for each of the 4 parameters selected from the 2007/2008 to 2010/2011 campaigns:

- The deviation between the value predicted by the Simulator and the BIPEA reference value (blue dots).
- The tolerances allowed by BIPEA (red lines).

On all the circuits and on the 4 parameters, it is noted that the Simulator is always (apart from some very rare exceptions) within the tolerances allowed by BIPEA. Moreover, the Simulator value is very often found to be similar to the reference.

It is important to note that the specific variations of the Farinograph® on the “development time”, “stability” and “weakening” parameters are very broad. An example of the rules used by BIPEA for calculating the tolerances allowed is given below:

	Tolerances
Water absorption (%)	0.02 x WA - 0.2
Development time (min)	0.35 x DEVT
Weakening (FU)	25
Stability (min)	0.85 x STAB

NB: The Mixolab® Simulator is recognized by BIPEA. Official BIPEA documents now offer the various participants in BIPEA “Farinograph® / Mixolab®” circuit No. 25 the option of specifying the type of equipment used: Mixolab® or Farinograph®.

3 ❖ COMPARISON WITH OTHER LABORATORY SYSTEMS

3.1 ▶ Alveograph®

3.1.1 Constant hydration

▶ Standard protocol

✦ Comparison of parameters in pairs

The table opposite shows the best correlations (r^2) obtained by comparing Mixolab® results (Chopin+ protocol at adapted hydration) with CHOPIN Alveograph® results at constant hydration.

It is important to note:

- The correlations between water absorption and the parameters P, W and P/L. These correlations are normal since P has a considerable influence on the W value (r^2 W vs. P = 0.65). The correlation between P and the absorption capacity is also known (starch damage, flour strength, etc.).
- The correlation Stability vs. W means that: the "stronger" the flour, the higher the W value and the greater the mixing stability (the elasticity index is also involved).

However, it is not possible to "predict" alveographic values directly on the basis of the Mixolab® test (and vice-versa). Both systems give complementary information.

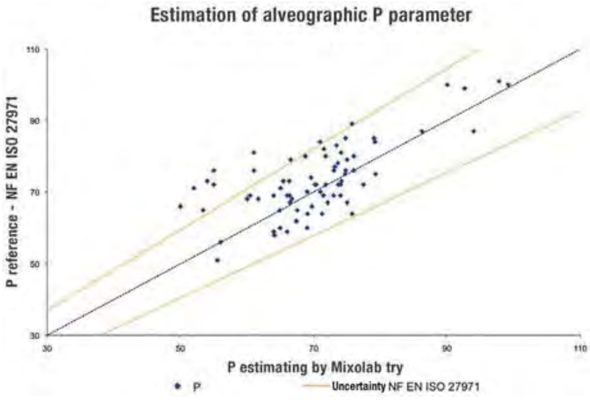
Furthermore, it is noted that alveographic values are not very predictive of the dough properties during the Mixolab® "hot" phase (C2, C3, C4 and C5). These data thus provide very useful additional information.

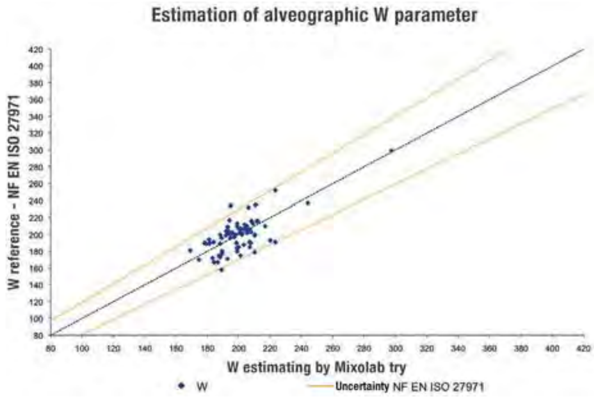
Correlation coefficient r^2				
	P	W	Ie	P/L
Absorption	0.78	0.49		0.5
C2		0.26		0.29
C3		0.23		0.43
C5				0.42
Stability		0.58	0.30	

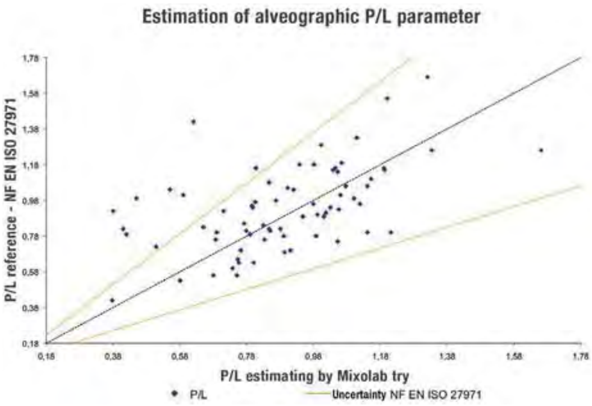
Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30 °C
Temperature 1st step	30 °C
Duration 1st step	8 min
Temperature 2nd step	90 °C
1st temperature gradient	4 °C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4 °C/min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	45 min

✦ Comparison via use of multi-parameter equations

A mathematical study is used to establish multi-parameter equations to estimate the alveographic results of flours based on the results obtained with Mixolab® (the results shown below are taken from a study conducted with one of our partners).







The models (based on 75 samples) demonstrate a high percentage of results within the uncertainty of the alveographic method (ISO 27971):

- 88% of estimated parameter P results.
- 95% of estimated parameter W results.
- 87% of estimated parameter P/L results.

The Alveograph® at constant hydration and the Mixolab® standard are two different, perfectly complementary, tests. The alveographic results can be estimated with multi-parameter equations based on the Mixolab® results.

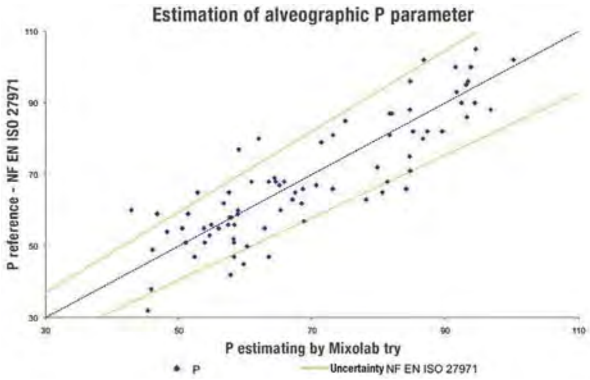
▶ Rapid protocol

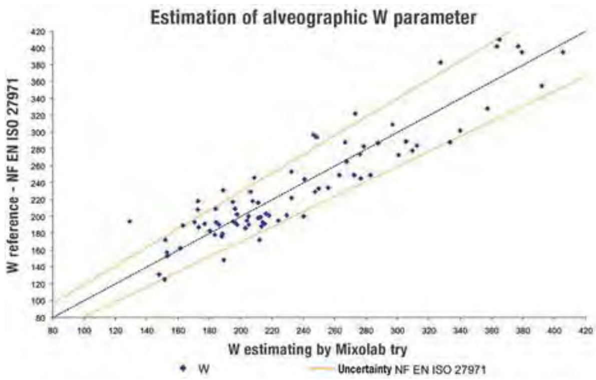
It is possible when using the Mixolab® Rapid wheat+ protocol to estimate the quality of the wheat at reception.

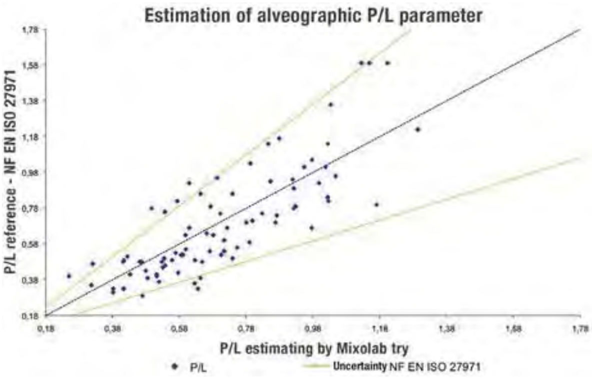
The mathematical study of the Mixolab® curve gives multi-parameter equations used to calculate the alveographic results of the samples tested.

The results obtained with one of our partners are given as an example below.

Rapid wheat+ protocol	
Mixing speed	180 rpm
Constant hydration	60% b14
Dough weight	75 g
Tank temperature	45 °C
Temperature 1st step	45 °C
Duration 1st step	3 min
Temperature 2nd step	90 °C
1st temperature gradient	8 °C/min
Duration 2nd step	5 min
2nd temperature gradient	- 8 °C/min
Temperature 3rd step	50 °C
Duration 3rd step	2 min
Total analysis time	20.6 min







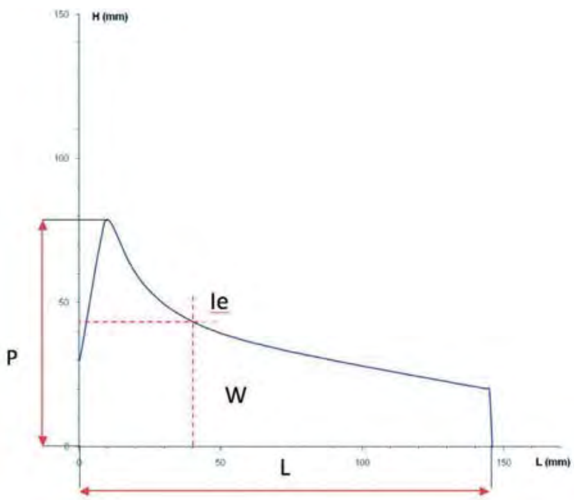
The models developed (based on 84 samples) demonstrate a high percentage of results within the uncertainty of the alveographic method (ISO 27971):

- 77% of estimated parameter P results.
- 82% of estimated parameter W results.
- 87% of estimated parameter P/L results.

The lower performance of these results with respect to those obtained with Mixolab® standard can be explained by the difference in the matrix analyzed with the Alveograph® (white flour) and Mixolab® (whole grain flour).

The Rapid wheat+ protocol (20.6 min) can be shortened by removing the dough cooling phase, such that the "rapid wheat" protocol runs for only 13.6 minutes. Combined with the sample water content determination with Infraneo NIR, it is possible to estimate the alveographic parameters in less than 15 minutes.

Using Mixolab® with the Rapid wheat+ protocol (constant hydration = a single test) to analyze unconditioned whole grain gives an estimation of the alveographic results in less than 20 minutes when multi-parameter equations based on the mathematical study of the comparison of the Alveograph® and Mixolab® are used.



3.1.2 Adapted hydration

The table below shows the best correlations (r^2) obtained by comparing, in pairs, Mixolab® results (Chopin+ protocol at adapted hydration) with Alveograph® results at adapted hydration.

Correlation coefficient r^2						
	T	Ex	A	Fb	Iec	T/A
Absorption				0.33		
C2				0.16		
C3				0.20		
C4	0.19					
C5	0.36			0.20		
Stability		0.49	0.47	0.59	0.57	0.21

Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30 °C
Temperature 1st step	30 °C
Duration 1st step	8 min
Temperature 2nd step	90 °C
1st temperature gradient	4 °C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4 °C/min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	45 min

It is important to note:

- The correlation Absorption vs. Fb (not as strong as the correlation Absorption vs. W since the impact of the factor T is reduced by the use of adapted hydration).
- The correlations between stability and various alveographic parameters (Ex, Fb, Iec, etc.) show that the stability of a dough is the resultant of several components (which are interconnected).

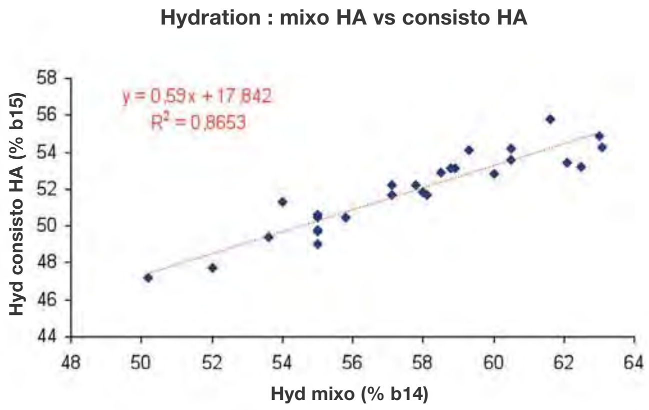
However, it is not possible to “predict” alveographic values directly on the basis of the Mixolab® test (and vice-versa). Both systems give complementary information. Furthermore, it is noted that alveographic values are not very predictive of the dough properties during the Mixolab® “hot” phase (C2, C3, C4 and C5). These data provide very useful additional information.

The analysis techniques are very different:

- Expansion of a bubble vs. torque measurement during mixing subject to temperature stress.
- Alveograph® rest time not required on Mixolab®.
- Test temperature.

The Alveograph® at adapted hydration and Mixolab® are two different, non-redundant and perfectly complementary tests.

3.2 ▶ Consistograph®



Important: Feasibility study obtained on a limited number of samples

The CHOPIN Consistograph® also measures dough consistency during mixing. Consequently, it is able to measure the water absorption capacity of a flour. The above graph shows the correlation between the Consistograph® (test at adapted hydration) and Mixolab® (Chopin+ protocol and adapted hydration) on the water absorption parameter.

- The correlation between the two systems is excellent. The correlation of Mixolab® vs. Farinograph® is established at $r^2 = 0.95$. The correlation of Consistograph® vs. Farinograph® is established at $r^2 = 0.92$. It is thus logical to obtain such a value between Consistograph® and Mixolab®.
- The hydration values for the Consistograph® are always lower than those obtained with Mixolab® (average deviation approximately 6%) because:
  - The target consistency with the Consistograph® is firmer than with the Mixolab®:
  - The hydration with the Mixolab® shown here is calculated with a 14% H2O base and with a 15% H2O base on the Consistograph®.

Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30 °C
Temperature 1st step	30 °C
Duration 1st step	8 min
Temperature 2nd step	90 °C
1st temperature gradient	4 °C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4 °C/min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	45 min

The correlation on the determination of the absorption capacity between Mixolab® and Consistograph® is excellent.

The only correlation between Consistograph® and Mixolab® on the other parameters applies to Stability. The correlation coefficients are altogether relatively modest and do not show any redundancy between the systems. The type of measurement (Mixolab® torque vs. Consistograph® pressure) primarily explains why it is impossible to have strong correlations between the dough development time, weakening (D250 and D450) parameters, etc. This is in line with the Consistograph® vs. Farinograph® comparison tests, which give identical results.

Correlation between the other parameters for the Consistograph® (adapted hydration) and Mixolab® stability (27 industrial flour samples):

R^2	TPrmax	Tolerance	D250	D450
Mixolab stability	0.44	0.38	0.46	0.50

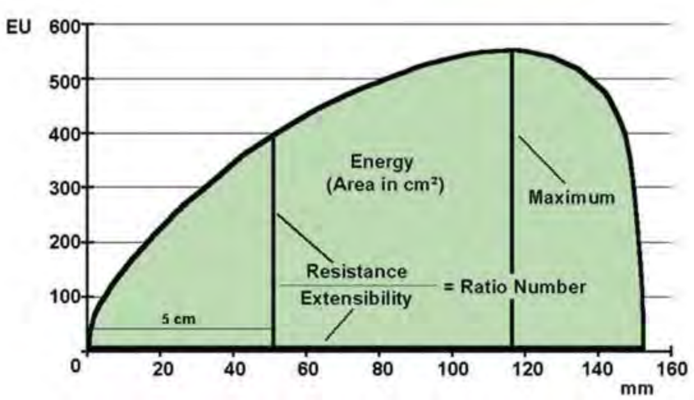
The information produced by the Consistograph® and the Mixolab® is complementary, since the Mixolab® measures torque and the Consistograph® measures the pressure on a wall of the dough mixer.

The Mixolab® gives a more comprehensive analysis, by incorporating a sample heating phase.
The Consistograph® is suitable for working alongside the Alveograph® (tests at adapted hydration).

3.3 ▶ Extensograph®

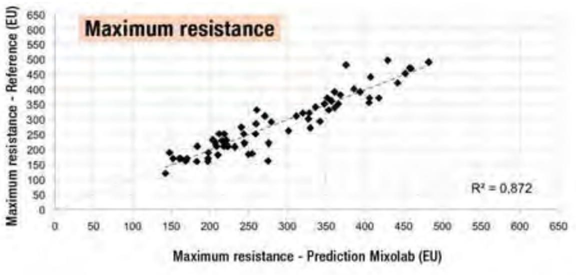
The Brabender Extensograph® measures the resistance of a dough to stretching (uniaxial deformation). The force/extension curves recorded, referred to as Extensograms, are used to evaluate various characteristics of the doughs analyzed, including extensibility (curve length in mm), maximum resistance, energy equivalent to the area under the curve and the ratio between the resistance at 5 cm and the extensibility.

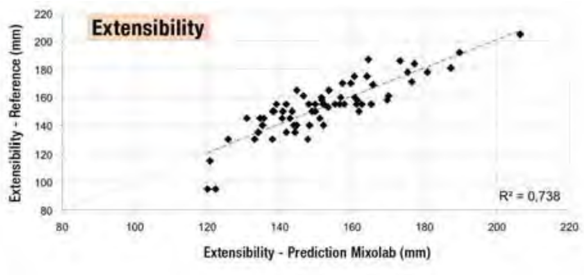
The spectral analysis of the Mixolab® curve and the use of suitable statistical tools (multiple linear regression) demonstrate it is possible to estimate Extensograph® values using Mixolab® data. The first mathematical models show good performances on all the parameters (see graphs below).

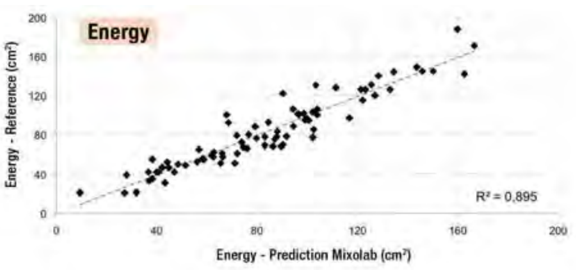


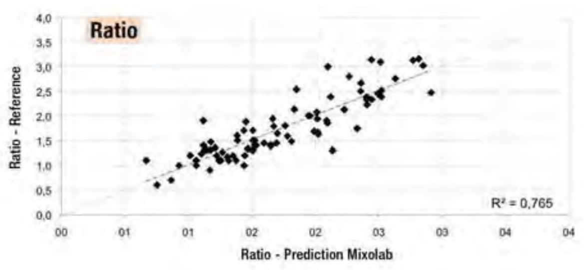
Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30 °C
Temperature 1st step	30 °C
Duration 1st step	8 min
Temperature 2nd step	90 °C
1st temperature gradient	4 °C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4 °C/min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	45 min

	Maximum resistance	Extensibility	Energy	Ratio
r^2	0.88	0.74	0.90	0.77
Average |Pred – Ref|	22	7	9	0.2









These initial results confirm the high versatility and strong potential of the Mixolab®. However, further analyses need to be conducted to optimize the performances and have stronger models.

3.4 ▶ Falling Number®

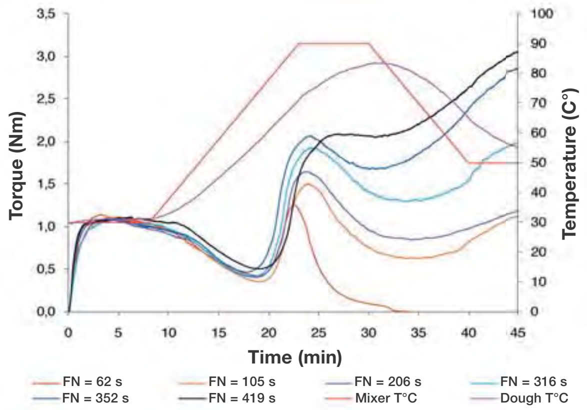
Due to their technological importance, α-amylases are among the most extensively studied flour enzymes: if insufficient amounts are present, the starch hydrolysis is insufficient to provide enough sugar for the yeast. If excess amounts are present (which occurs with germinated wheat), the amylose and amylopectin chains are liquefied at the start of baking and the dough becomes sticky and rubbery, resulting in bread that is not good for consumption (FEILLET, 2000)*.

Various viscosimetric and empirical methods (RVA, Visco-Amylograph®, etc.) can be used to determine the diastase activity of a flour. The most commonly used is the Perten (or Hagberg) Falling Number®. This method consists in evaluating the consistency of a flour suspension by measuring the time (in seconds) taken by a plunger rod with a perfectly defined geometry to fall by a fixed distance into the flour suspension: in this case, the α-amylase content is inversely proportional to the falling number of the plunger rod.

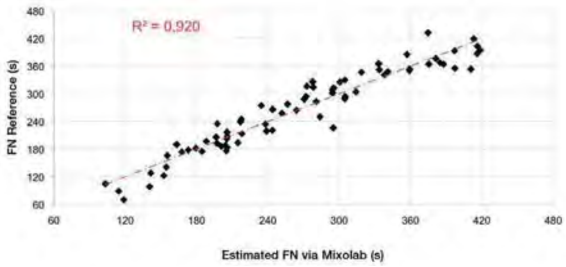
Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30 °C
Temperature 1st step	30 °C
Duration 1st step	8 min
Temperature 2nd step	90 °C
1st temperature gradient	4 °C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4 °C/min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	45 min

FEILLET P. (2000): Le grain de blé. Composition et utilisation, Éditions INRA, 308 p.

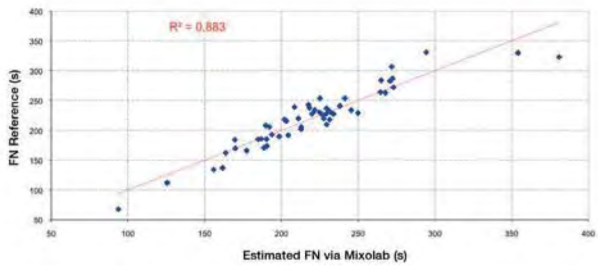
During the Mixolab® analysis, the decrease in the falling number is generally seen as a decrease in the torque C4 and an increase in the difference C3-C4 (see graph opposite). Moreover, the spectral analysis of the curve and the use of suitable statistical tools (multiple linear regression) can be used to refine the correlation between the falling number and the data provided by Mixolab®. The first mathematical models show good performances (see graph below), on wheat (white flour or whole grain wheat) and on rye.



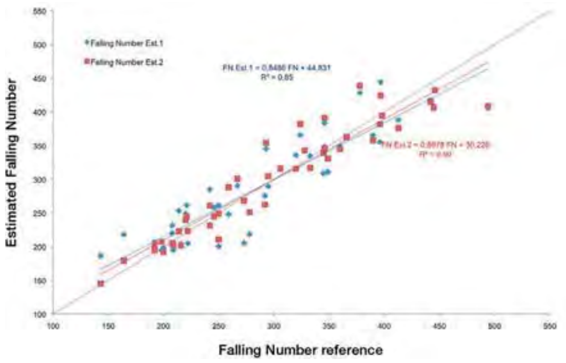
FN	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	C3-C4 (Nm)
62	1.12	0.42	1.26	nd	nd	nd
105	1.14	0.35	1.5	0.62	1.13	0.88
206	1.08	0.4	1.65	0.85	1.19	0.8
316	1.09	0.41	1.93	1.29	1.99	0.64
352	1.09	0.47	2.06	1.67	2.88	0.39
419	1.11	0.5	2.09	2.04	3.05	0.05



Wheat - Whole grain



Rye - Flour



Wheat - White flour

Therefore, these initial results confirm the existence of strong correlations between the Falling Number® and Mixolab® on wheat or rye. However, further analyses need to be conducted to optimize the performances and have stronger models.

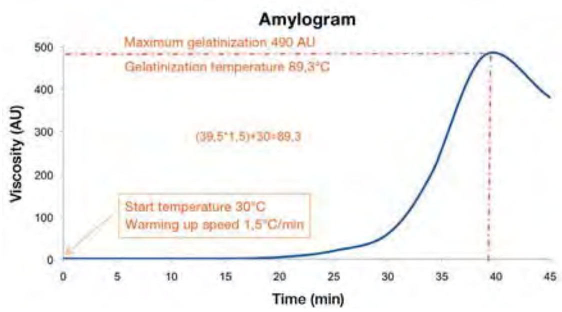
Acknowledgments: CRA Gembloux (Belgium))

NB1: The Falling Number® determines the endogenous amylase activity. To determine the activity of added enzymes (fungal amylases) using this type of system, it is necessary to use a specific protocol and a specific instrument model.

NB2: The Falling Number is not only dependent on the α-amylase content of the flour. It is also dependent on the starch damage content: the greater it is, the quicker starch is hydrolyzed and the lower the falling number.

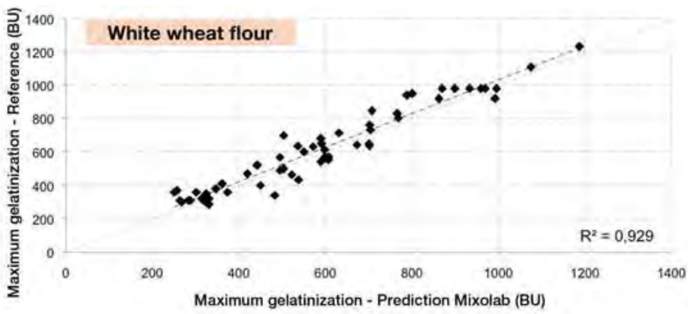
3.5 ▶ Amylograph®

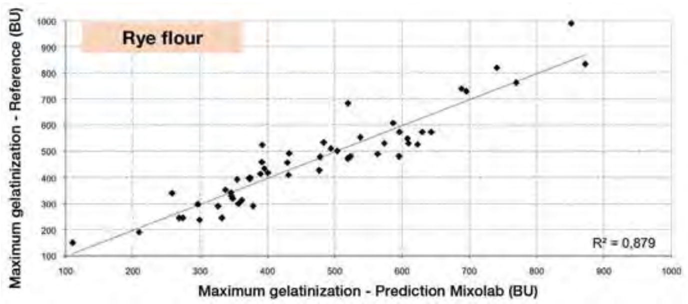
The Brabender Amylograph® continuously measures the consistency of a starch (or flour) paste as a function of time and temperature. It determines the starch gelatinization properties, particularly the maximum viscosity achieved.



During the Mixolab® analysis, the significant increase in the torque measured after the point C2 is generally associated with starch gelatinization and can easily be compared to that observed on an amylogram.

Moreover, the shape of the Mixolab® curve and the use of suitable statistical tools (multiple linear regression) show strong correlations between these two systems. The first mathematical models defined show good performances (see graph below), on wheat flours or on rye flours.



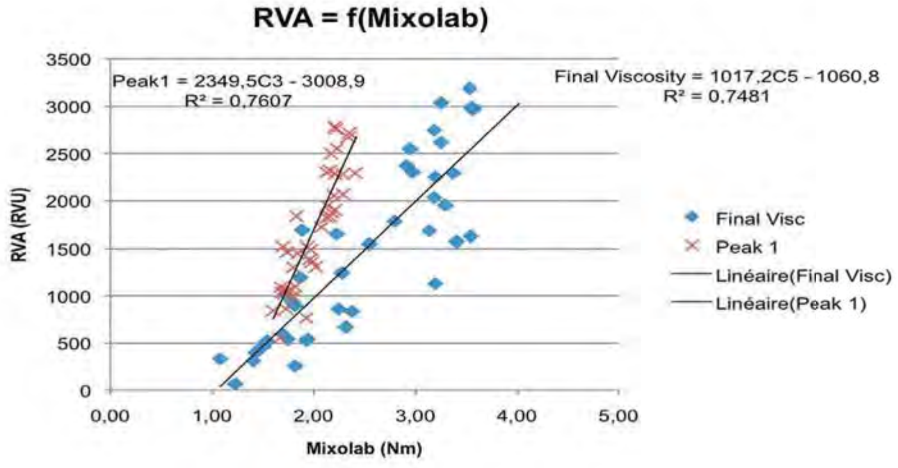


Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30 °C
Temperature 1st step	30 °C
Duration 1st step	8 min
Temperature 2nd step	90 °C
1st temperature gradient	4 °C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4 °C/min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	45 min

However, it should be noted that the Mixolab® works on a dough (limited availability of water) and the Amylograph ® on a suspension (excess of water). This difference may explain the slight differences observed between the Mixolab® and the Amylograph® results.

These initial results confirm the existence of strong correlations between the Amylograph® and the Mixolab®, (on wheat or rye). However, further analyses need to be conducted to optimize the performances and have stronger models.

3.6 ▶ Rapid Visco Analyser®



The second part of the Mixolab® curve (gelatinization, hot stability, gelling) looks like the curves obtained on systems such as the RVA® (Perten) or Viscograph® (Brabender).

The example above shows the correlations between tests conducted on white flour with the RVA and with Mixolab®. The results are very comparable and clearly demonstrate that the information obtained on both systems is consistent, both in terms of the gelatinization capacity and in terms of the retrogradation measurement.

However, it should be noted that the Mixolab® results are based on measurements made on a dough and not on a suspension.

Mixolab® and RVA® results may differ slightly but the Mixolab® results have more credit. Measurments on dough show the availability of water with respect to starch and any interactions between gluten and starch, deserve more merit.

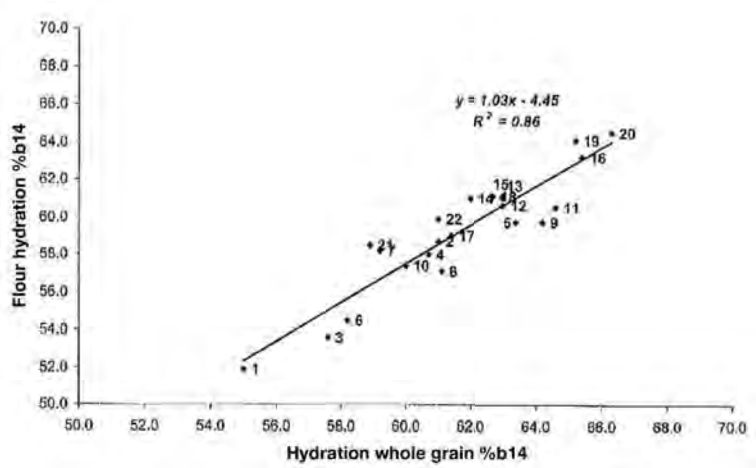
Therefore, the Mixolab® is able to measure on the dough, in a single test, the characteristics of the starch in the sample (and the associated enzymes).

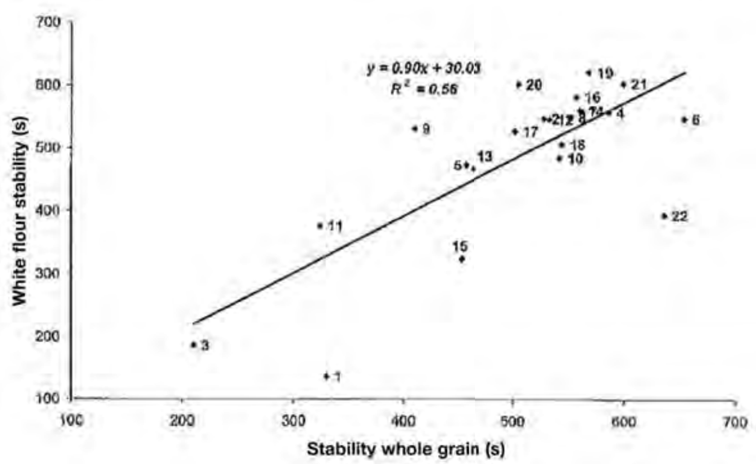
Acknowledgments: CRA Gembloux (Belgium)

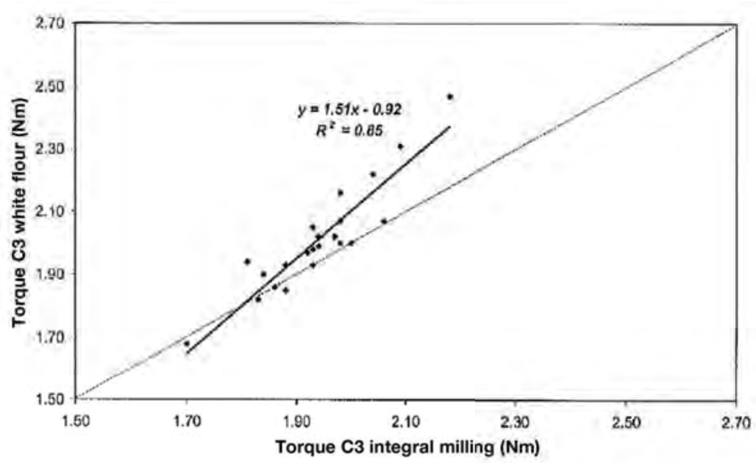
4 ❖ WHOLE GRAIN FLOUR VS. WHITE FLOUR

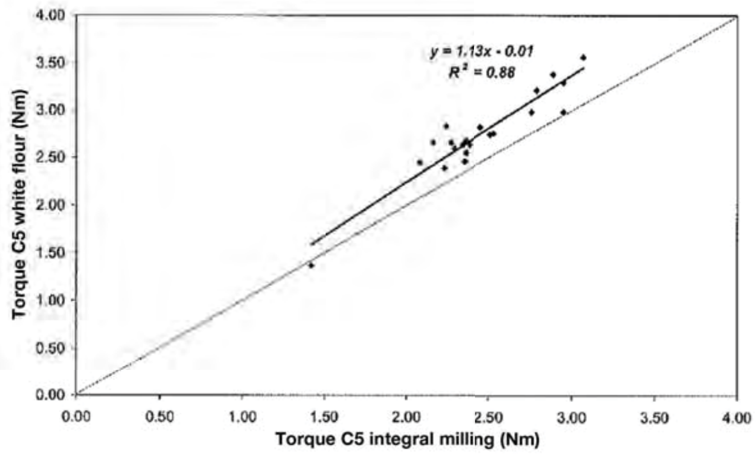
4.1 ▶ Comparison of industrial milling vs. laboratory grinder

The ability of the Mixolab® to work on whole grain flour (without prior grain tempering) gives a quick characterization of wheat at reception.









Tests were conducted comparing the results obtained with the Mixolab® (Chopin+ protocol) on industrial milling (white flours) intended for bread-making and on the corresponding whole grain flour. The above results show:

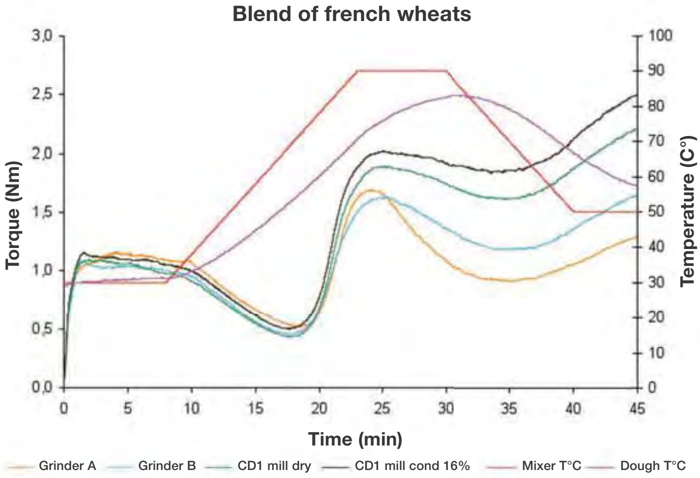
- An excellent correlation for water absorption capacity measurement. The values obtained are logically and systematically higher with [1]$\text{Absorption}_{\text{white flour}} = \text{Absorption}_{\text{whole grain flour}} - 4.5$.
- An interesting estimation of stability (whole grain flour has lower stability).
- A very good estimation of the torque C3 flour.
  In this case, the following conversion formula should be used: $C3_{\text{white flour}} = 1.51 \times C3_{\text{whole grain flour}} - 0.92$.
- A very good estimation of C5 with $C5_{\text{white flour}} = C5_{\text{whole grain flour}} + 0.4$.

It is possible to predict the quality of an industrial flour based on a Mixolab® analysis of the corres-ponding grinded wheat. This gives a quick analysis with no need for conditioning.

Acknowledgments: CRA Gembloux (Belgium)

[1] *All the formulas given only apply to these specific tests since they are dependent on the type of mill used and the industrial mill setting.*

4.2 ▶ Use of various types of laboratory grinders and mills



	Grinder A	Grinder B	Mill CD1 dry	Mill CD1 cond. 16%
Hydration % (14% base)	62.7	59.5	54.6	54.6
C2 (Nm)	0.52	0.46	0.43	0.5
C3 (Nm)	1.69	1.64	1.89	2.02
C4 (Nm)	0.91	1.18	1.61	1.83
C5 (Nm)	1.29	1.64	2.22	2.51

Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30 °C
Temperature 1st step	30 °C
Duration 1st step	8 min
Temperature 2nd step	90 °C
1st temperature gradient	4 °C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4 °C /min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	45 min

The same wheat sample was tested with the Mixolab® (Chopin+ protocol) after grinding on 2 types of grinders and on a Chopin CD1 laboratory mill (with and without conditioning).

A/ Various grinders

The differences observed between grinders A and B (water absorption, C2, C3, C4, C5) give the impression that 2 different types of wheat are being analyzed. Grinder A is characterized by very high absorption and a C3-C4 drop of 0.78 nm (as opposed to 0.46 Nm for Grinder B). This is characteristic of a very though violent grinder, generating more starch damage.

B/ Laboratory grinder vs. mill

The curves obtained after CD1 milling show higher C3, C4, C5 values than those after grinding, accompanied by lower water absorption. This is characteristic of more limited starch damage and of the absence of bran particles rich in enzymes (amylases).

While it is possible to anticipate the properties of industrial flours based on the whole grain flour, the type and condition of the grinder are of primary importance. For the use of laboratory mills, conditioning has a noteworthy impact.

5 ❖ BLEND LAW

Wheat and flour blends represent one method to ensure consistent flour quality.

To test the potential of the Mixolab® as a blending decision-making help tool, we studied 2 flour samples with significantly different characteristics using the Simulator protocol and using the CHOPIN standard protocol.

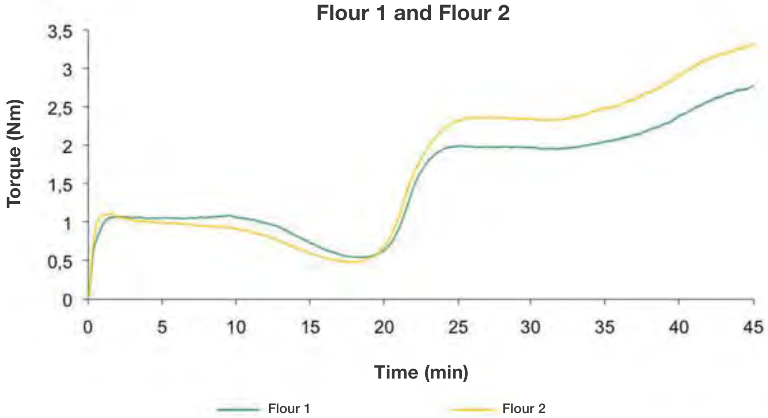
We then produced 3 blends (75% / 25%, 50% / 50%, 25% / 75%) of these two flours.

The pink curve is the theoretical value obtained by calculating the weighted algebraic average for each of the points of the curve. The blue curve is the actual test conducted with Mixolab®.

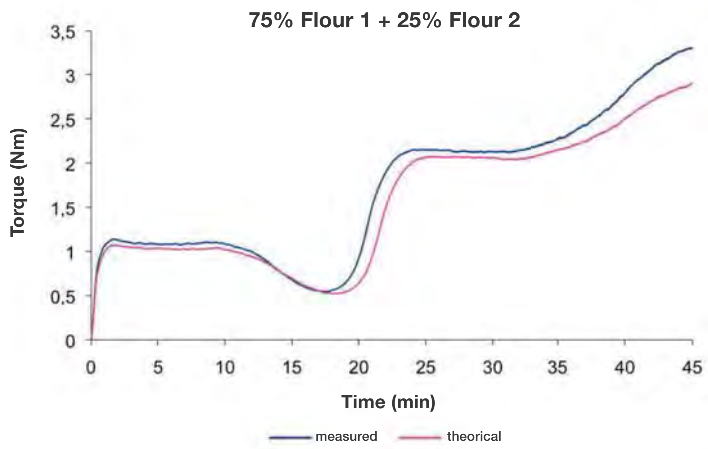
*Theoretical value = % flour blend 1 * Value of torque 1 + % Flour blend 2 * Value of torque 2*

5.1 ▶ Mixolab® Standard

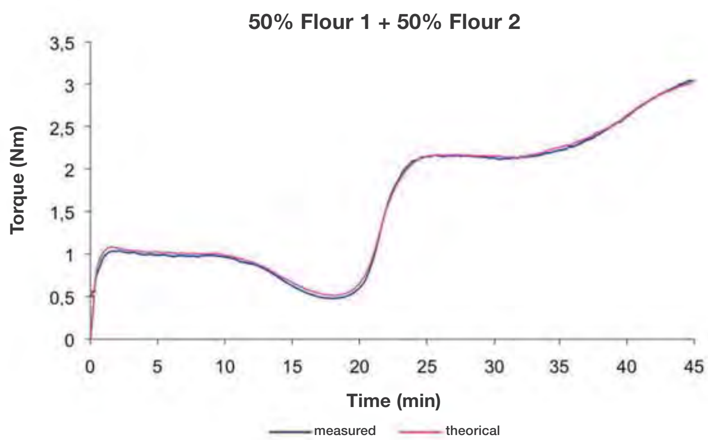
Pure product (100%)	Flour 1	Flour 2	Difference Flour 1 - Flour 2	Repeatability limit (NF V03-764)
WA (%)	60.6	53.1	7.5	nd
C2 (Nm)	0.54	0.49	0.05	0.04
C3 (Nm)	1.99	2.37	-0.38	0.05
C4 (Nm)	1.95	2.33	-0.38	0.08
C5 (Nm)	2.78	3.32	-0.54	0.22



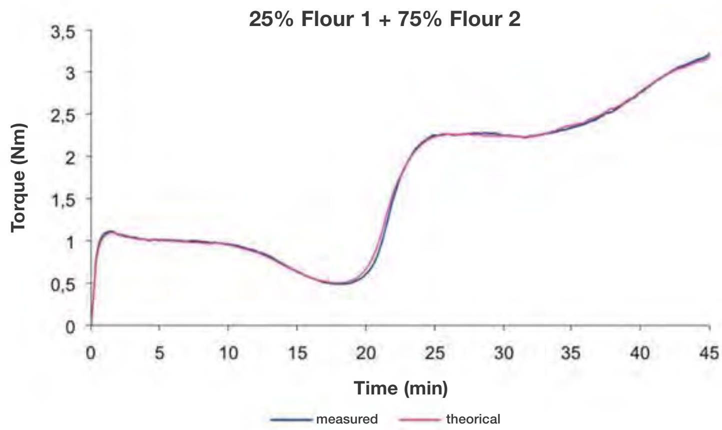
75% Flour 1 / 25% Flour 2	Measured	Theoretical	Difference measured - theorical	Repeatability limit (NF V03-764)
WA (%)	57.6	58.7	-1.10	nd
C2 (Nm)	0.55	0.53	0.02	0.04
C3 (Nm)	2.14	2.08	0.06	0.05
C4 (Nm)	2.08	2.00	0.08	0.08
C5 (Nm)	3.10	2.91	0.19	0.22



50% Flour 1 / 50% Flour 2	Measured	Theoretical	Difference measured - theorical	Repeatability limit (NF V03-764)
WA (%)	57.6	56.9	0.7	nd
C2 (Nm)	0.48	0.52	-0.04	0.04
C3 (Nm)	2.17	2.18	-0.01	0.05
C4 (Nm)	2.12	2.14	-0.02	0.08
C5 (Nm)	3.06	3.05	0.01	0.22



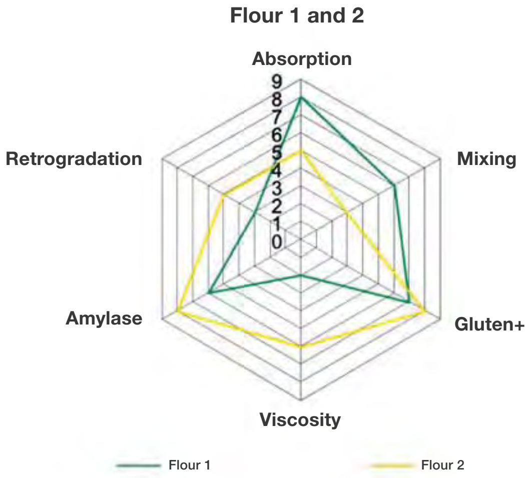
25% Flour 1 / 75% Flour 2	Measured	Theoretical	Difference measured - theorical	Repeatability limit (NF V03-764)
WA (%)	55.1	55.0	0.1	nd
C2 (Nm)	0.49	0.50	-0.01	0.04
C3 (Nm)	2.29	2.27	0.02	0.05
C4 (Nm)	2.22	2.23	-0.01	0.08
C5 (Nm)	3.23	3.18	0.05	0.22

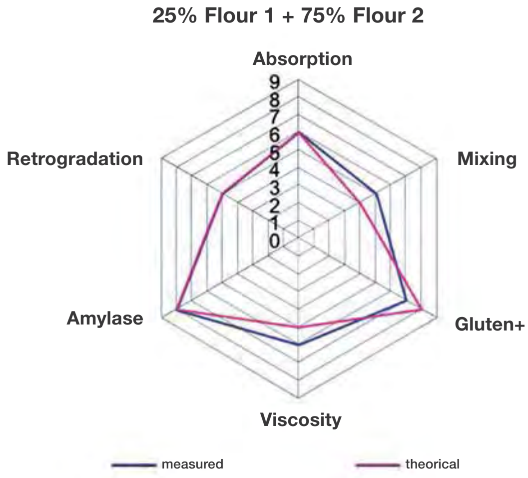


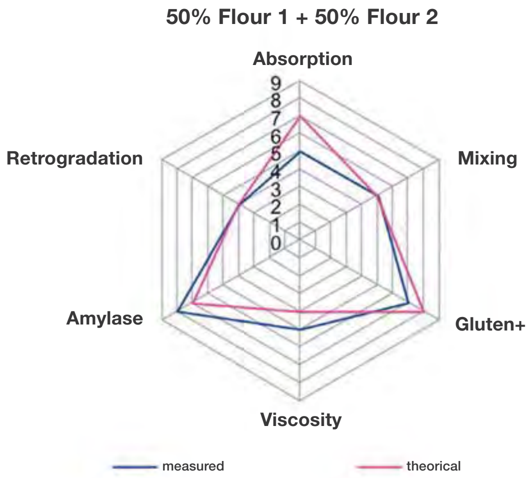
The blend law perfectly applies to the Mixolab® analysis using the standard protocol. The deviations observed between the blend curves measured and the theoretical curves are less than the repeatability limits of the measurement.

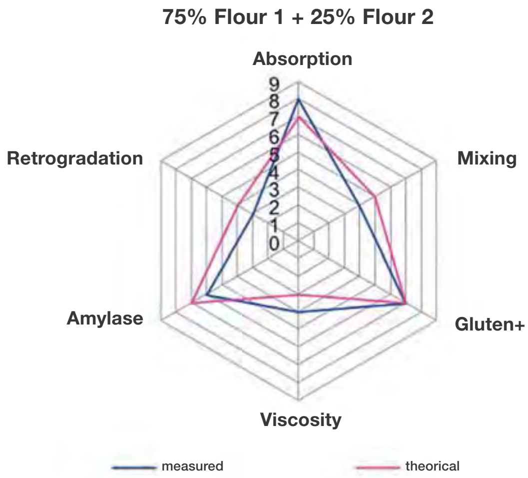
The Mixolab® Standard can be used to test the properties of the raw materials (wheat or flour) and deduct the properties of the blends.

5.2 ▶ Mixolab® Profiler









The Mixolab® Profiler is a simplified interpretation of the standard protocol curve. The indexes are systematically rounded to the nearest unit. A difference of 1 point on the Profiler is not asignificant difference.

The blend law is observed for the Mixolab® Profiler analysis. The deviations observed between the blend curves measured and the theoretical curves calculated on the basis of the curves of the raw materials only are not greater than 1 point.

Mixolab® Profiler can be used to anticipate the properties of a wheat flour blend using the blend law.

5.3 ▶ Mixolab® Simulator

Pure product (100%)	Flour 1	Flour 2	Difference Flour 1 - Flour 2	Repeatability limit (NF V03-765)
Absorption (%b14)	60.5	54.2	6.3	0.8
Development time (min)	3.50	1.50	2	0.6
Stability (min)	11.00	3.50	7.5	1.5
Weakening (Nm)	0.07	0.14	-0.07	0.02

75% Flour 1 / 25% Flour 2	Measured	Theoretical	Difference measured - theorical	Repeatability limit (NF V03-765)
Absorption (%b14)	58.10	58.90	-0.8	0.8
Development time (min)	3.50	3.00	0.5	0.6
Stability (min)	10.00	9.10	0.9	1.5
Weakening (Nm)	0.08	0.10	-0.02	0.02

50% Flour 1 / 50% Flour 2	Measured	Theoretical	Difference measured - theorical	Repeatability limit (NF V03-765)
Absorption (%b14)	56.7	57.4	-0.7	0.8
Development time (min)	2.50	2.50	0.0	0.6
Stability (min)	5.00	7.30	-2.3	1.5
Weakening (Nm)	0.11	0.11	0.00	0.02

25% Flour 1 / 75% Flour 2	Measured	Theoretical	Difference measured - theorical	Repeatability limit (NF V03-765)
Absorption (%b14)	55.7	55.8	-0.1	0.8
Development time (min)	2.00	2.00	0.0	0.6
Stability (min)	3.50	5.40	-1.9	1.5
Weakening (Nm)	0.14	0.12	0.02	0.02

The blend law perfectly applies to the Mixolab® analysis using the Simulator protocol. The deviations observed between the blend curves measured and the theoretical curves are less than the repeatability deviations of the measurement.

The Mixolab® Simulator can be used to test the properties of the raw materials and deduct the properties of the blends.

The Mixolab® curve of a flour blend can be anticipated using the blend law on the Simulator protocol, on the CHOPIN Standard protocol and on the Profiler:

*Theoretical value = % Flour blend 1 * Value of torque 1 + % Flour blend 2 * Value of torque 2*

6 ❖ PROTOCOL ADAPTATION

The Mixolab® is a very versatile instrument. A large number of protocol parameters can be customized (amount of dough in mixer, mixing speeds, temperature gradients and profiles, etc.) to reproduce the process conditions of various finished products as accurately as possible.

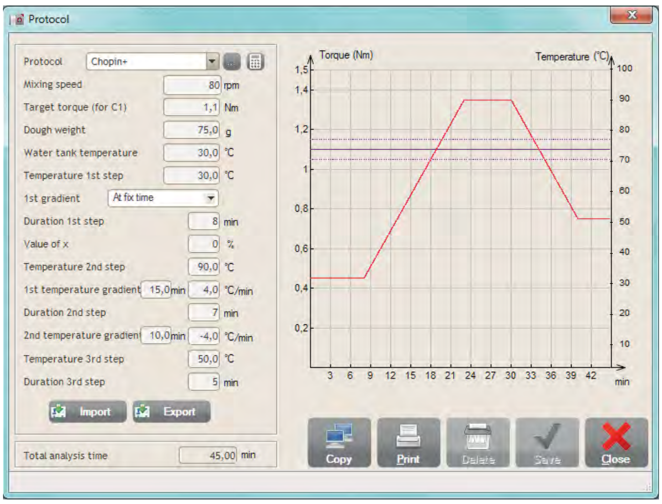
The table below contains the minimum and maximum values that can be assigned to programmable parameters on the Mixolab®.

Settings	Minimum	Maximum
Mixing speed	30 rpm	250 rpm
Torque	0.1 Nm	7 Nm
Water temp	10°C	60°C
Mixer temp	10°C	90°C
Heating gradient	2°C/min	12°C/min
Cooling gradient	2°C/min	12°C/min
Time	0 min	545 min
Maximum test time: 545 min		

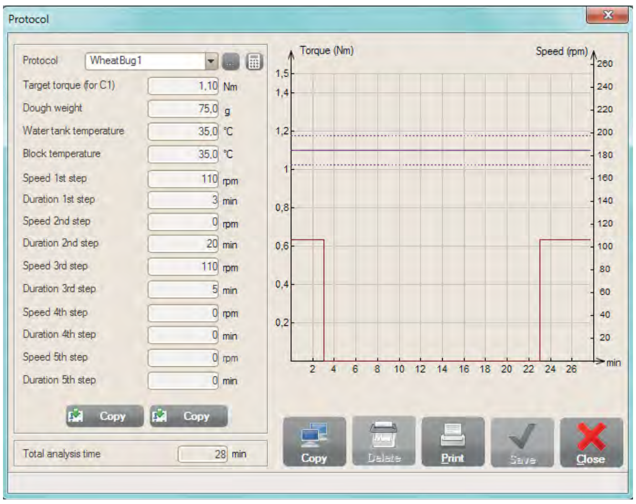
It is important to note that the Mixolab® can operate at “Variable temperature” or at “Variable speed”:

➲ In the first case (Variable temperature), the user sets the mixing speed for the duration of the test, and varies the mixer temperature. The “Chopin+” protocol is an example of a “Variable temperature” protocol.

➲ In the second case (Variable speed), the user sets the mixing speed for the duration of the test, and varies the mixing speed. The “WheatBug1” protocol is an example of a “Variable speed” protocol.

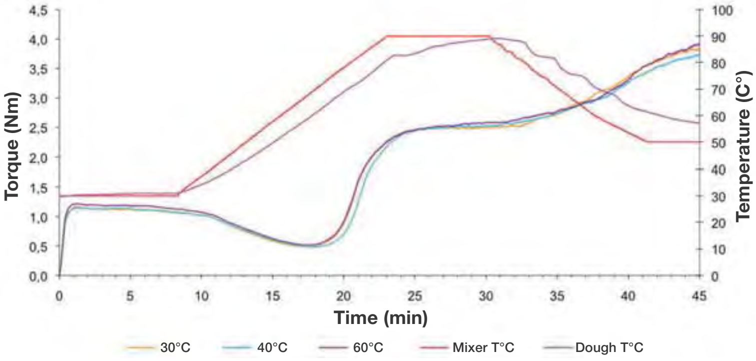


Creating a variable temperature protocol



Creating a variable speed protocol

6.1 ▶ Hydration water temperature



Tank water temp	30 °C	40 °C	60 °C
Hydration (%) (14% base)	52.9	52.9	52.9
C2 (Nm)	0.49	0.48	0.52
C3 (Nm)	2.26	2.25	2.26
C4 (Nm)	2.51	2.60	2.55
C5 (Nm)	3.82	3.74	3.92
Stability (min)	9.8	10.2	9.77

Protocols	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30 / 40 / 60 °C
Temperature 1st step	30 °C
Duration 1st step	8 min
Temperature 2nd step	90 °C
1st temperature gradient	4 °C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4 °C/min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	45 min

Hydration water temperature can be changed on the Mixolab®. Tests were conducted with the Chopin+ protocol to determine the influence of this factor on Mixolab® results (in the following tests, only the hydration water temperature changes).

In the Mixolab®, the effects of the hydration water temperature are characterized by:

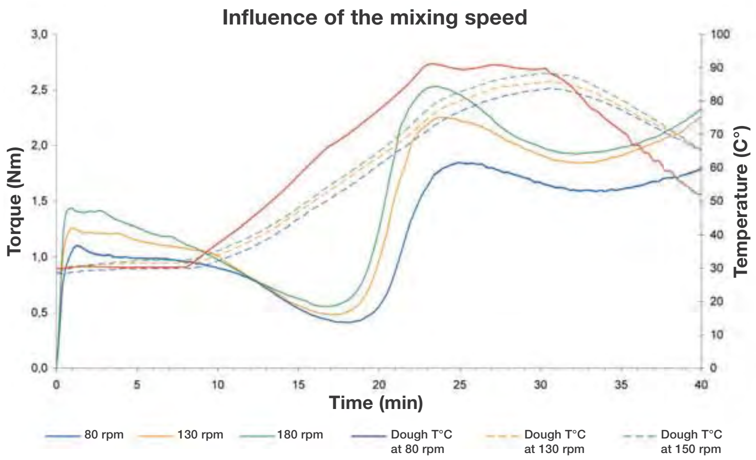
- Practically no substantial modification of the results obtained despite a wide water temperature variation range in the container.

This is explained as follows:

- The mixer temperature remains set to 30°C.
- The flour is at 20°C (laboratory temperature).
- On a total dough sample of 75 g, 47.13 g of flour and the Mixolab® introduces 27.87 ml of water (the heat supply from the water only represents 37% of the total).

The dough temperature is the most important parameter. It is controlled with the Mixolab®. Although the hydration water temperature does not have a major effect on the rheological properties of the dough, we recommend, when creating protocols, watching the mixer temperature and the water tank.

6.2 ▶ Mixing speed



Mixing speed (rpm)	80	130	180
C1 (Nm)	1.11	1.26	1.43
C2 (Nm)	0.41	0.48	0.56
Dough temp for C2 (°C)	54.1	53.4	53.8
Time for C2 (min:s)	00:18:07	00:16:59	00:16:42
C3 (Nm)	1.85	2.25	2.53
C4 (Nm)	1.58	1.84	1.92
C5 (Nm)	1.82	2.27	2.34
Stability (min:s)	07:32	05:49	04:42
C1-C2 (Nm)	0.7	0.78	0.87
C3-C2 (Nm)	1.44	1.77	1.97
C3-C4 (Nm)	0.27	0.41	0.61
C5-C4 (Nm)	0.24	0.43	0.42

Protocols	
Mixing speed	80 / 130 / 180 rpm
Hydration	55% b14
Dough weight	75 g
Tank temperature	30 °C
Temperature 1st step	30 °C
Duration 1st step	8 min
Temperature 2nd step	90 °C
1st temperature gradient	4 °C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4 °C/min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	45 min

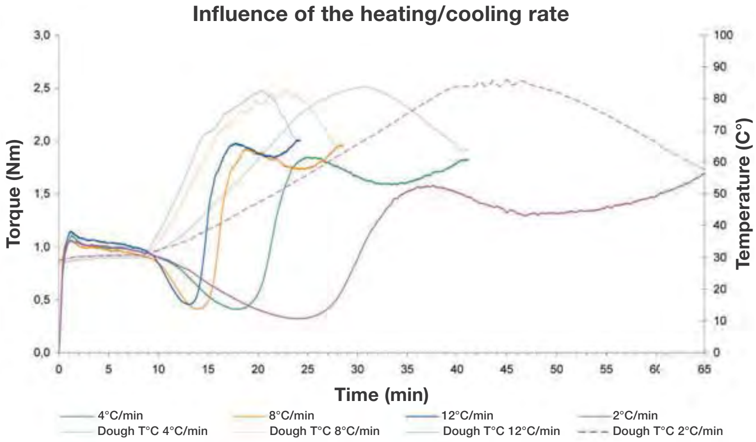
A study was conducted with the Chopin+ protocol to determine the influence of the mixing speed on the results (in the following tests, only the mixing speed changes).

On the Mixolab®, the effect of increasing the mixing speed is characterized by:

- An increase in the C1 torque.
- An increase in the C2-C1 drop.
- A decrease in stability.
- An increase in the maximum viscosity (C3) and C3-C2, an increase in the C3-C4 drop and the C5-C4 retrogradation.
- A quicker dough temperature rise relative to the mechanical heating associated with the mixing intensity. The only valid comparison is when comparing the dough temperatures, not the mixer temperatures.

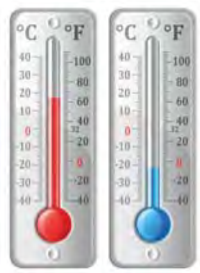
Changing of the mixing speed modifies significantly all the parameters. It is not possible to compare results obtained with different mixing speeds.

6.3 ▶ Temperature rise



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30 °C
Temperature 1st step	30 °C
Duration 1st step	8 min
Temperature 2nd step	90 °C
1st temperature gradient	4 °C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4 °C/min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	45 min

Temperature gradient	2 °C/min	4 °C/min	8 °C/min	12 °C/min
Hydration (%) (base 14%)	55	55	55	55
C1 (Nm)	1.07	1.11	1.07	1.14
C2 (Nm)	0.32	0.41	0.41	0.46
Dough temperature for C2 (°C)	54.1	54.1	56.4	57.9
C3 (Nm)	1.58	1.85	1.92	1.98
Dough temperature for C3 (°C)	80.1	76.6	75.7	77.1
C4 (Nm)	1.29	1.58	1.73	1.84
Dough temperature for C4 (°C)	85.4	80.4	79.7	79.6
C5 (Nm)	1.67	1.82	1.95	2
Stability (min:s)	08:57	07:32	07:45	07:30
C1-C2 (Nm)	0.75	0.7	0.66	0.68
C3-C2 (Nm)	1.26	1.44	1.51	1.52
C3-C4 (Nm)	0.29	0.27	0.19	0
C5-C4 (Nm)	0.38	0.24	0.22	0.02



On the Mixolab® the heating/cooling rate can be changed.

A study was conducted, modifying the temperature increase and decrease gradients, with all other parameters being equal.

On the Mixolab®, the effect of the heating/cooling rate is characterized by:

- A decrease in the C1-C2 drop and a higher dough temperature at C2.
- A decrease in stability.
- An increase in the maximum viscosity (C3) and C3-C2, a decrease in the C3-C4 drop and the C5-C4 retrogradation.

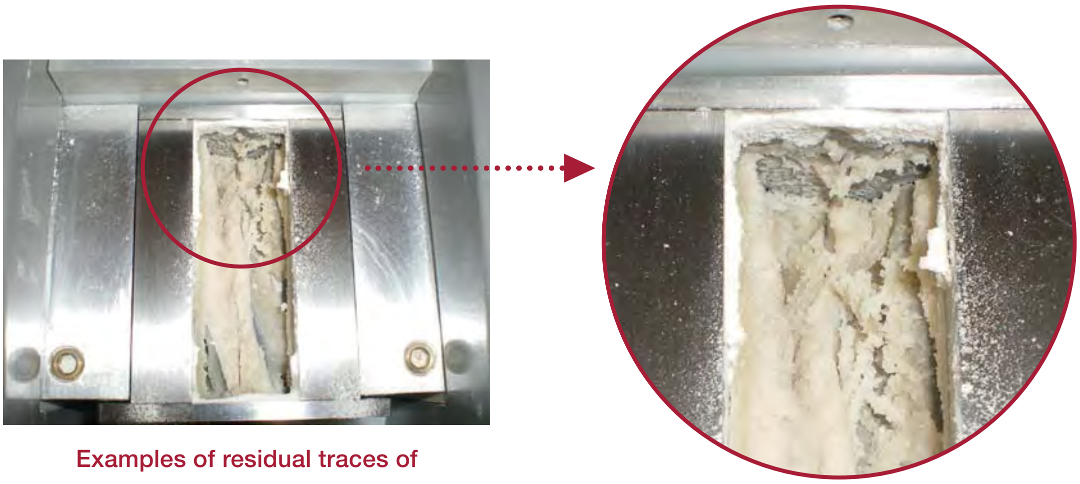
Changing the heating/cooling rate modifies significantly all the parameters. It is not possible to compare results obtained with different test conditions.

6.4 ▶ Dough sample size

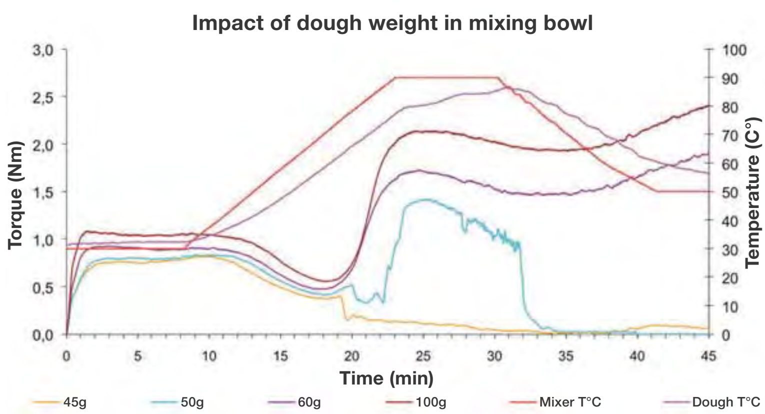
If the dough sample in the Mixolab® is too small, dough separates in 2 parts during mixing. This phenomenon can be avoided by increasing the amount of dough in the mixer.

The standard protocol uses 75 g of dough. Tests were run with 45 g, 50 g, 60 g and 100 gof dough.

To avoid errors in results, it is important to ensure that the flour is completely hydrated if the amount of dough is increased significantly.



Examples of residual traces of non-hydrated flour in the mixer



Protocols	
Mixing speed	80 rpm
Hydration	60,6%
Dough weight	45 / 50 / 60 / 100 g
Tank temperature	30 °C
Temperature 1st step	30 °C
Duration 1st step	8 min
Temperature 2nd step	90 °C
1st temperature gradient	4 °C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4 °C/min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	45 min

In the Mixolab®, increasing the amount of dough in the mixer is characterized by:

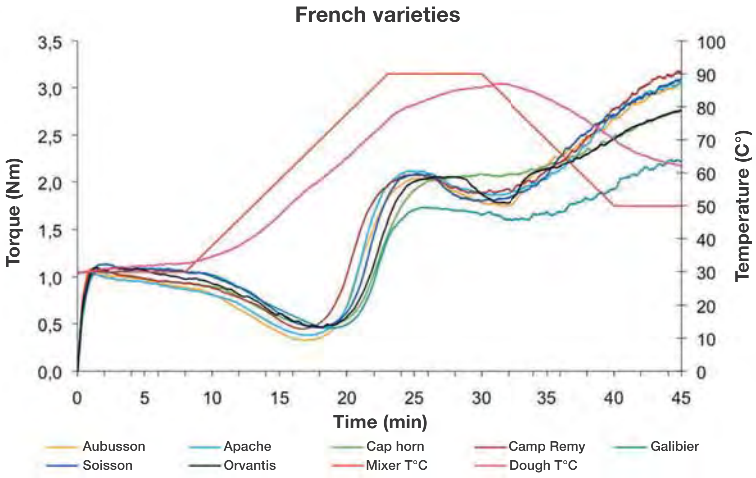
- A higher C1 torque at constant hydration.
- A greater C3-C2 difference.

It is not possible to compare results obtained with different dough sample sizes.

7 ❖ WHEAT APPLICATIONS

7.1 ▶ Wheat analysis

7.1.1 French varieties



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

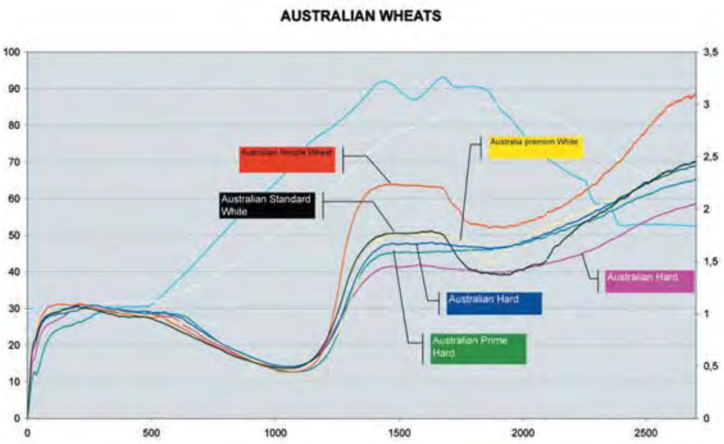
	Soisson	Orvantis	Aubusson	Galibier	Camp remy	Caphorn	Apache
Hydration % (14% base)	53.4	56.6	51.9	57.7	54.6	56.8	52.8
C2 (Nm)	0.46	0.46	0.33	0.46	0.44	0.46	0.38
C3 (Nm)	2.09	2.06	2.04	1.74	2.08		2.12
C4 (Nm)	1.80	1.78	1.75	1.60	1.88		1.86
C5 (Nm)	3.11	2.77	3.04	2.24	3.17	2.77	3.07
Development time (min)	2	1.30	1	5.50	1.30	1.60	1.30
Stability (min)	9.50	8.60	5.10	10.5	5.50	7.80	6.40

Various types of French wheat were tested with the Mixolab® (Chopin+ protocol).
These types of wheat have:

- A relatively broad water absorption capacity range (between 51.9% and 57.7%).
- Relatively short dough development times (< 2 minutes), except for Galibier (= 5.5 minutes).
- Moderate C2 torques (except for Aubusson and Apache, which has a low C2).
- Relatively high C3, C4 and C5 torques (except for Galibier).
- A relatively broad stability range, from 5 to over 10 minutes.

The Mixolab® can be used to characterize French wheat varieties.

7.1.2 Australian varieties



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	Australian Prime Hard	Australian Hard	Australian Hard	Australian Noodle Wheat	Australian Premium White	Australian Standard White
Hydration % (14% base)	65	61.7	63.1	53.5	60.3	57.7
C2 (Nm)	0.45	0.5	0.48	0.44	0.48	0.48
C3 (Nm)	1.6	1.68	1.47	2.24	1.77	1.79
C4 (Nm)	1.6	1.62	1.39	1.82	1.48	1.37
Development time (min)	5.28	4.26	3.3	3.29	4.46	4.46
Stability (min)	8.2	9.34	8.11	8.16	9.36	7.44

Various types of Australian wheat were tested with the Mixolab® (Chopin+ protocol).

- Australian Prime Hard is characterized by a high water absorption capacity and long development time; it is a strong variety.
- Australian Hard is characterized by a high C2, indicating high protein quality.
- Australian Noodle Wheat is characterized by a low water absorption capacity, a short development time, a very high gelatinization (C3) and a very high C5. Note the very characteristic drop after C3.
- Australian Standard White and Australian Premium White also show this drop, Australian Premium White is particularly suitable for noodle production.

The analysis of the various Australian wheat varieties works very well with the Mixolab®. The data obtained are very consistent with current evaluation methods (Farinograph®, Amylograph®, etc.).

Wheat varieties for noodles have a very high hot viscosity and a drop between C3 and C4 which has not been explained yet (studies in progress).

Acknowledgments: Australian Wheat Board Ltd

7.1.3 Argentine varieties

Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	Region 1	Region 2 north	Region 2 south	Region 3	Region 4	Region 5 north	Region 5 south	NEA/NOA region
Hydration % (14% base)	59.6	58.8	58.1	59.1	58.1	61.2	60.7	62
C1 (Nm)	1.11	1.06	1.07	1.08	1.11	1.11	1.14	1.13
C2 (Nm)	0.53	0.50	0.46	0.45	0.49	0.47	0.54	0.39
C3 (Nm)	2.03	2.07	2.01	1.97	1.95	1.83	1.95	1.56
C4 (Nm)	1.85	2.00	1.92	1.89	1.57	1.64	1.79	1.06
C3-C4 (Nm)	0.18	0.07	0.09	0.08	0.38	0.19	0.16	0.50
C5 (Nm)	3.01	3.16	2.92	2.88	2.24	2.48	2.99	1.56
Stability (min)	16.3	14.5	13.6	10.8	13.3	12.7	14.7	10.3

Argentine wheat varieties are classified according to the region where they are grown.

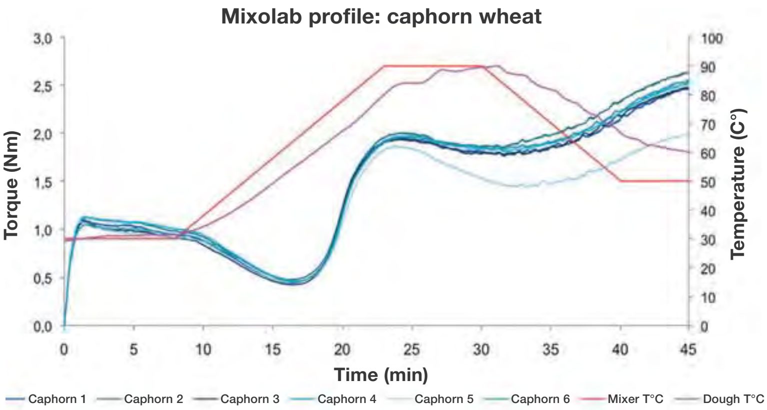
- Region 1 wheat varieties are characterized by high stability.
- Region 2 wheat varieties are characterized by relatively low water absorption and relatively high cold viscosity (retrogradation).
- NEA/NWA region wheat varieties are characterized by higher absorption but lower stability and C2 than other regions. The C3, C4 and C5 values are also relatively low.

On the Mixolab®, it is possible to characterize the differences induced by the regions where Argentine wheat varieties are grown.

Acknowledgments: Granotec Argentina

7.1.4 Caphorn variety

Within the same wheat variety, a significant diversity in properties associated with environmental factors may be observed. Using the Mixolab®, it is possible to analyze variations in quality within the same wheat variety.



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

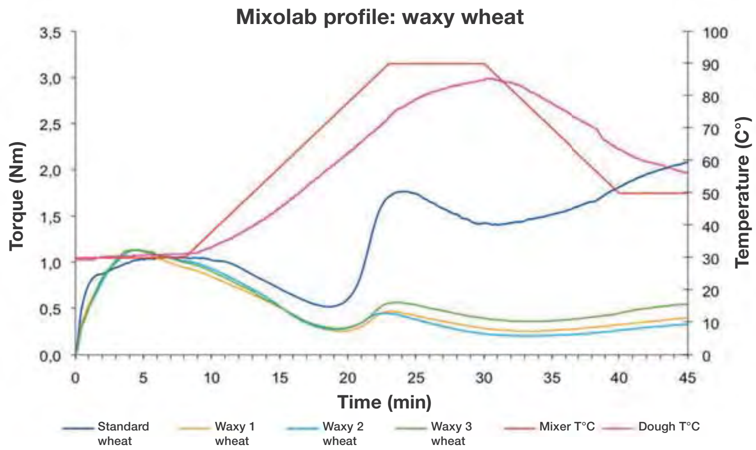
	WA (% b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Stability (min)	C1-C2 (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Caphorn 1	57.2	0.44	1.95	1.77	2.48	7.4	0.66	1.51	0.18	0.71
Caphorn 2	56.2	0.48	2.01	1.85	2.65	8	0.65	1.53	0.16	0.8
Caphorn 3	56.5	0.42	1.94	1.76	2.48	6.6	0.66	1.52	0.18	0.72
Caphorn 4	55.9	0.46	1.98	1.81	2.54	8.3	0.67	1.52	0.17	0.73
Caphorn 5	56.7	0.45	1.87	1.44	2.01	6.9	0.63	1.42	0.43	0.57
Caphorn 6	57	0.45	1.97	1.83	2.55	9	0.6	1.52	0.14	0.72

The most significant differences in quality on these Caphorn samples grown in different regions of France are essentially measured after dough heating (C3-C2, C3-C4 and C5). Differences in the starch gelatinization, enzyme activity and retrogradation properties are observed.

Within the same wheat variety, it is possible to determine the differences in quality with the Mixolab®.

7.1.5 Waxy wheat varieties

The Mixolab® has an extensive analysis potential. It is able to work with any type of cereal, on flour or grinded wheat. The Mixolab® can be used to assess the rheological properties of Waxy wheat varieties (low-amylose wheat varieties).



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	WA (% b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Stability (min)	TC2 (°C)	C1-C2 (Nm)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Standard wheat	69.1	0.52	1.77	1.4	2.09	9.8	57.1	0.54	1.25	0.37	0.69
Waxy 1	78.5	0.25	0.47	0.25	0.4	nd	59.6	0.89	0.22	0.22	0.15
Waxy 2	78.8	0.28	0.45	0.2	0.33	nd	60.5	0.86	0.17	0.25	0.13
Waxy 3	77.5	0.28	0.57	0.36	0.55	nd	60.6	0.86	0.29	0.21	0.19

Compared to regular soft wheat, Waxy wheat varieties are characterized by:

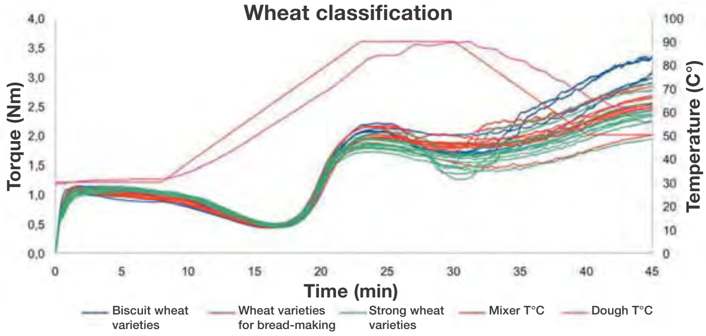
- A much higher hydration content.
- A lower dough development time.
- A much lower C2 torque with a larger C1-C2 drop.
- A lower max viscosity peak (C3 and C3-C2).
- A higher hot stability (C3-C4).
- A lower retrogradation (C5-C4).

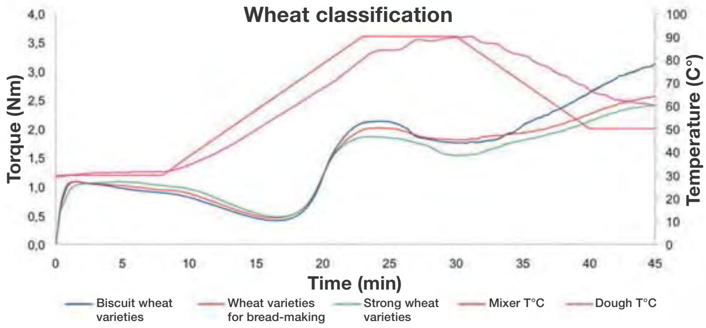
Waxy wheat varieties are characterized by a much higher Amylopectin/amylose ratio (amylose free). They are used to improve the shelf-life of products by limiting starch retrogradation. This effect is particularly observed on the second part of the curve (C3, C4 and C5).

It is possible to analyse the quality of Waxy wheat varieties with Mixolab®.

Acknowledgments: University of Nebraska USDA-ARS

7.1.6 Wheat classification

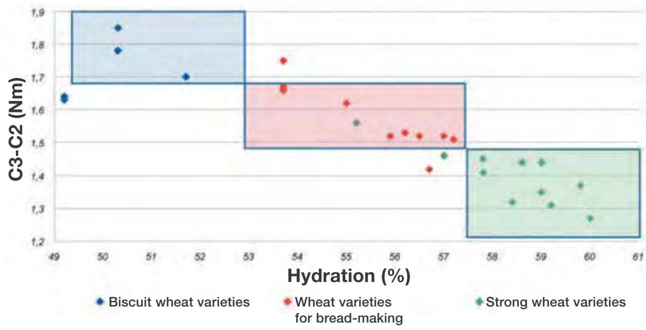


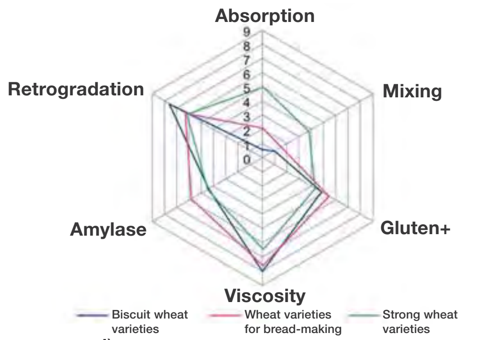


Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

The results shown here are the average results obtained for each wheat category.

	Biscuit wheat varieties	Wheat varieties for bread-making	Strong wheat varieties
Hydration % (14% base)	50.1	55.6	58.3
C2 (Nm)	0.43	0.45	0.47
C3 (Nm)	2.06	2.03	1.87
C3-C2 (Nm)	1.63	1.58	1.4
C4 (Nm)	1.68	1.77	1.5
C5 (Nm)	3.34	2.57	2.41
Stability (min)	4.9	7.3	9





Various types of wheat were tested with the Mixolab® (Chopin+ protocol).

- Biscuit wheat varieties are characterized by a lower water absorption capacity, a lower mixing stability and a high gelatinization (C3-C2) and a very high C5.
- Strong wheat varieties are characterized by a high water absorption capacity, a high stability, a lower starch gelatinization (C3-C2) and a low C5 (low retrogradation).
- Wheat varieties for bread-making have intermediate properties between biscuit wheat and strong wheat varieties.

The Mixolab® can be used to classify wheat varieties based on their water absorption capacity and the gelatinization properties (C3-C2).

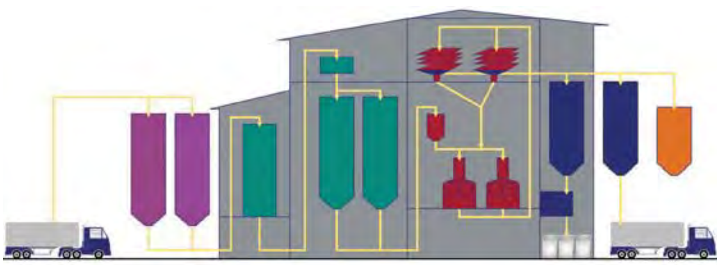
7.2 ▶ Flour analysis

7.2.1 Flour mill streams

The study presented below was conducted in partnership with an industrial mill in order to:

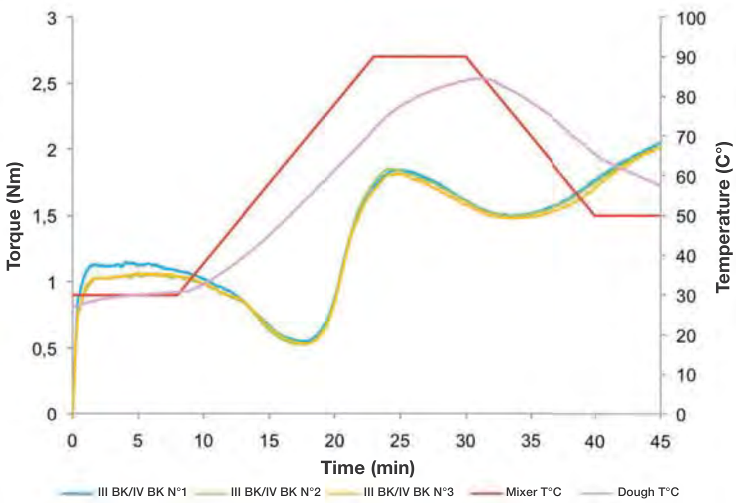
- Show the relevance of the Mixolab® analysis on flours with a very rich mineral content.
- Check that the various mill streams sampled on the same milling process produce a similar flour, thus ensuring consistency in production.
- Study the complete milling process.
- Predict the quality of flours obtained from blending various mill streams (blending law).

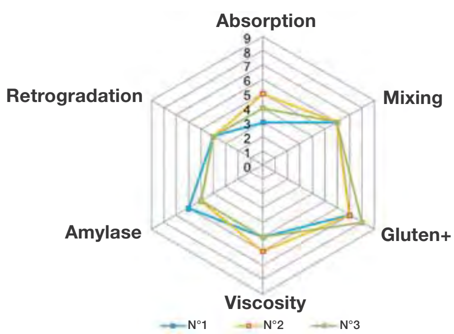
All the flour streams in the milling process were analyzed on the Mixolab®.



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

■ III BK/IV BK flour streams

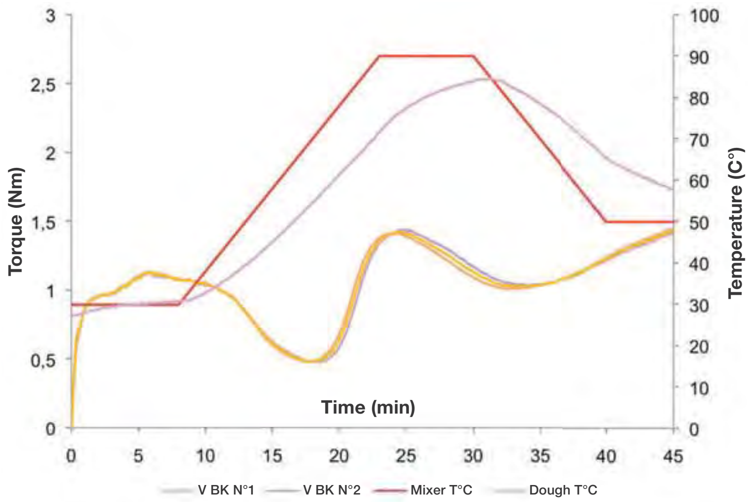


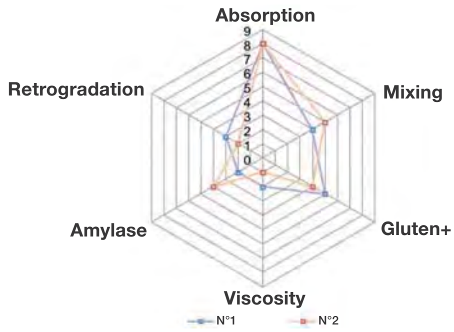


	N°1	N°2	N°3
Hydration % (14% base)	56.8	58	57.2
C2 (Nm)	0.54	0.52	0.53
C3 (Nm)	1.84	1.85	1.82
C4 (Nm)	1.49	1.49	1.48
C5 (Nm)	2.06	2.02	2.03
Profiler indexes	3-67-564	5-67-654	4-68-554
Stability (min)	9.8	10.3	10.3

These three III BK/IV BK flour streams are very similar in terms of Mixolab® data.

V BK flour stream

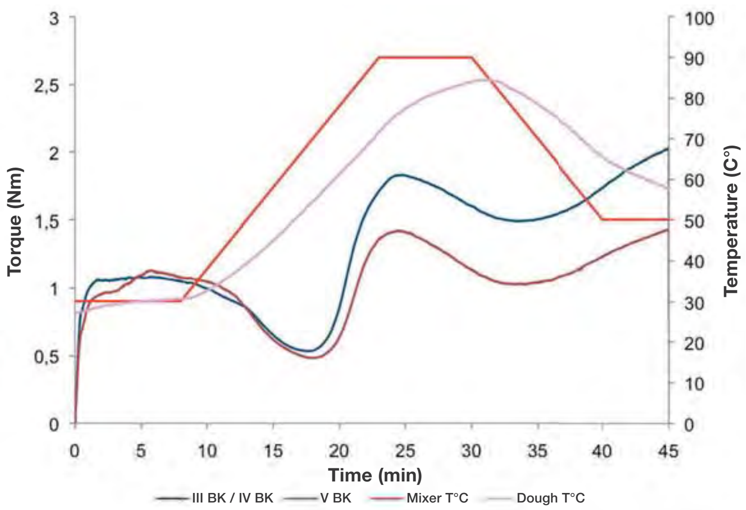




	N°1	N°2
Hydration % (14% base)	64.6	63.9
C1 (Nm)	1.13	1.13
C2 (Nm)	0.48	0.48
C3 (Nm)	1.42	1.44
C4 (Nm)	1.01	1.03
C5 (Nm)	1.45	1.42
Profiler indexes	8-45-223	8-54-142
Stability (min)	8.5	8.7

Flour from V BK stream are also very similar. Their Profiler show a high water absorption and moderate mixing and Gluten+ indexes. The viscosity, amylolytic resistance and retrogradation are low, which may indicate a higher damaged starch content, but also a higher amylase content.

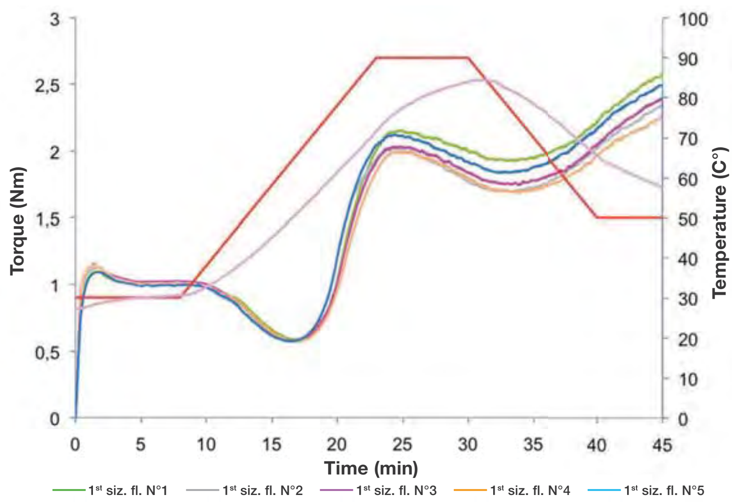
Comparison of III BK / IV BK and V BK streams

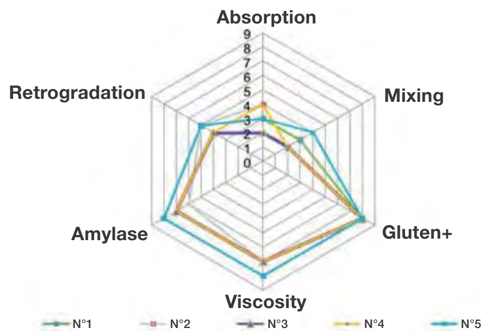


	III BK / IV BK	V BK
Hydration % (14% base)	57.3	64.2
C2 (Nm)	0.53	0.48
C3 (Nm)	1.83	1.43
C4 (Nm)	1.48	1.02
C5 (Nm)	2.04	1.43
C3-C2 (Nm)	1.30	0.95
C3-C4 (Nm)	0.35	0.41
C5-C4 (Nm)	0.56	0.41
Profiler indexes	4-67-554	8-54-132
Stability (min)	10.1	8.6

Flour from V BK have a greater water absorption than flours from III BK / IV BK. Flours from III BK / IV BK are more stable during mixing and have a higher gelatinization peak (C3 and C3-C2).

■ 1st sizings flour

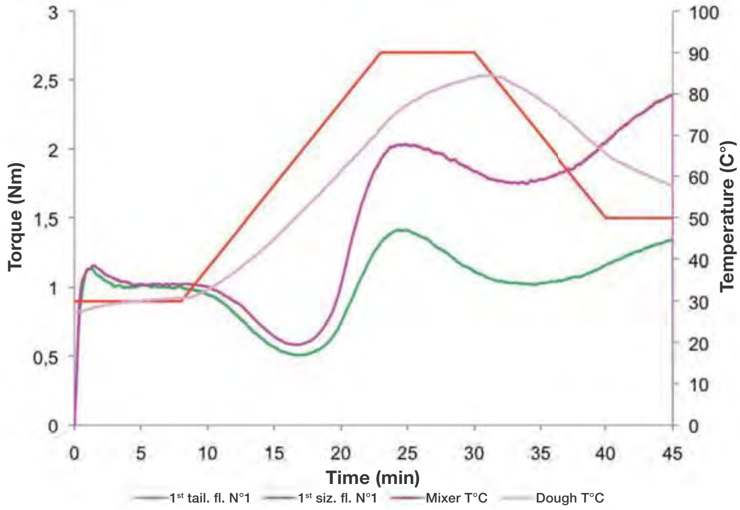




	N°1	N°2	N°3	N°4	N°5
Hydration % (14% base)	56.7	57.8	56.3	57.4	56.4
C2 (Nm)	0.59	0.58	0.58	0.57	0.58
C3 (Nm)	2.15	2.02	2.03	1.99	2.12
C4 (Nm)	1.92	1.69	1.74	1.69	1.84
C5 (Nm)	2.59	2.34	2.39	2.26	2.5
Profiler indexes	3-38-885	4-28-765	2-28-774	4-28-774	3-48-885
Stability (min)	10.5	9.5	9.5	9.2	10.2

These five 1st sizings flours have a very high stability, indicated by a high gluten+ index. For the starch-related phases, variations are more pronounced between the flours. Ash contents have excellent reproducibility of results which, under blind measurement conditions, also demonstrate the similarity of the flours obtained from these five 1st sizings flours.

■ Comparison between 1st sizings and 1st tailings

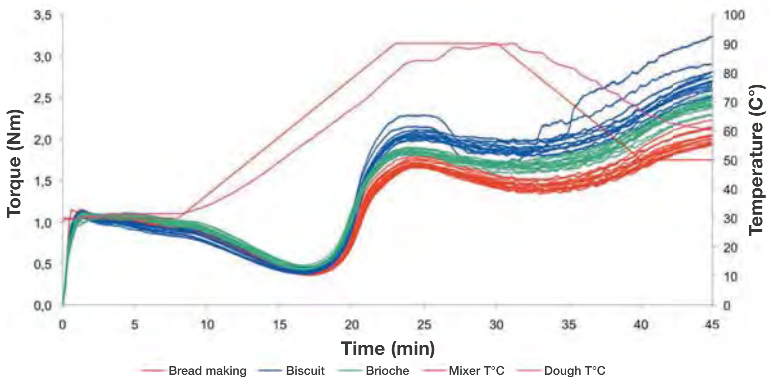


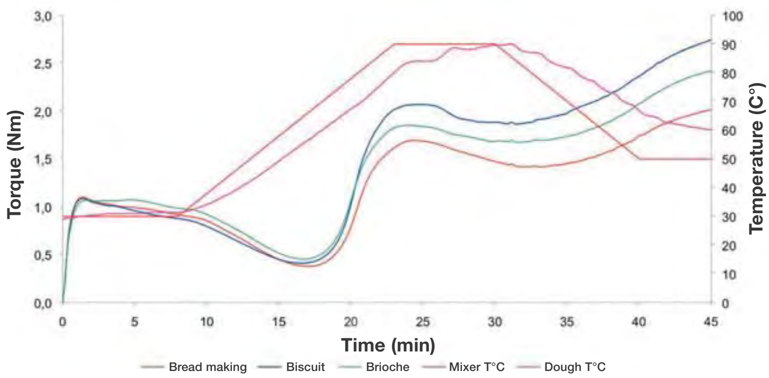
	1st tailings	1st sinzings
Hydration % (14% base)	64	56.3
C2 (Nm)	0.51	0.58
C3 (Nm)	1.42	2.03
C4 (Nm)	1.02	1.74
C5 (Nm)	1.35	2.39
C3-C2 (Nm)	0.91	1.45
C3-C4 (Nm)	0.4	0.29
C5-C4 (Nm)	0.33	0.65
Profiler indexes	8-26-122	2-28-774
Stability (min)	8.6	9.5

Flours from the start (1st sinzings) and end of clapping (1st tailings) show significant differences. The 1st sinzings and 1st tailings flour qualities are similar during mixing. However, the differences are much greater when the dough is heated. A superior heating resistance in the gluten of the 1st sinzings flours is observed. The viscosity, amylolytic resistance and retrogradation are superior on the 1st sinzings flour. The flour from the start of clapping 1st sinzings has a lower ash content and starch damage than the end flour 1st tailings.

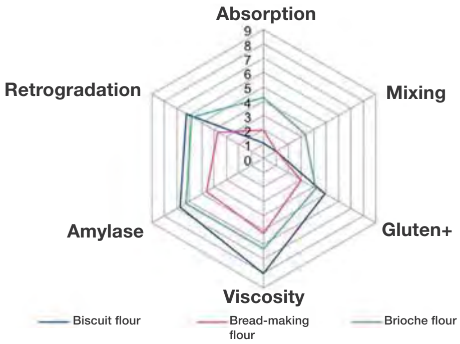
The Mixolab® gives a good differentiation between flour mill streams by analyzing not only the protein phase (mixing) but also the amylolysis/retrogradation phase, which provides a lot of additional information. It is possible to check that the various mill streams produce a similar flour and study the complete milling process.

7.2.2 Flour classification





Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min



The results shown in the graphs above and the table below are the average results from each flour category.

	Biscuit flours	Flours for bread-making	Brioche flours
Hydration % (14% base)	54	55.8	57.7
C2 (Nm)	0.41	0.37	0.45
C3 (Nm)	2.08	1.7	1.86
C3-C2 (Nm)	1.67	1.33	1.41
C4 (Nm)	1.84	1.41	1.65
C5 (Nm)	2.75	2.05	2.43
Stability (min)	4.80	6	8.6

Differents types of flour were tested with the Mixolab® (Chopin+ protocol).

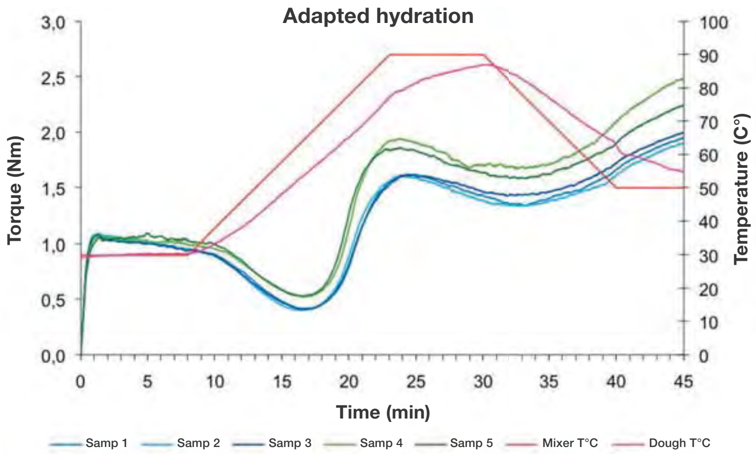
- Biscuit flours are characterized by a lower mixing stability, a high gelatinization capacity (C3, C3-C2) and a high C5.
- Flours for bread-making have intermediate properties with respect to biscuit and brioche flours on the mixing phase, a lower gelatinization capacity (C3, C3-C2) and a low C5.
- Brioche flours have a higher water absorption capacity, a higher mixing stability and intermediate properties between flours for bread-making and biscuit flours during heating and retrogradation.

The Mixolab® can be used to classify flours based on their water absorption capacity, stability, the gelatinization capacity (C3-C2) and the starch retrogradation rate.

7.2.3 Example of puff pastry flour

Conventional flour analysis methods are not always discriminatory enough to meet industry expectations (flours identical in the laboratory may show different properties on an industrial scale). Therefore, the purpose of this study is to demonstrate that the Mixolab® can offer effective new solutions for industrial issues.

Five flour samples intended for puff pastry production are analyzed on the Mixolab® (Chopin+ protocol). These samples are not differentiated using conventional analysis techniques, but show different properties on the production line. The purpose of this study is to determine how the Mixolab® is capable of differentiating them.



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

The results obtained on the Mixolab® demonstrate that the samples tested are broken down into 2 groups (Group 1: Sample 1, Sample 2, Sample 3; Group 2: Sample 4, Sample 5):

- The dough development time is the same for all the samples.
- The samples in Group 1 show:
  - A lower stability.
  - A lower C2.
  - Lower C3, C4 and C5 values.

The information from our industrial partner confirms that one of the groups consists of the samples showing satisfactory production line properties whereas the other contains the "defective" samples. For confidentiality reasons, it is not possible to specify which of the 2 groups contains the quality samples.

The Mixolab® can be used to analyze flour for puff pastry and identify samples liable to have problems on production lines.

7.2.4 Profiler examples on various types of products

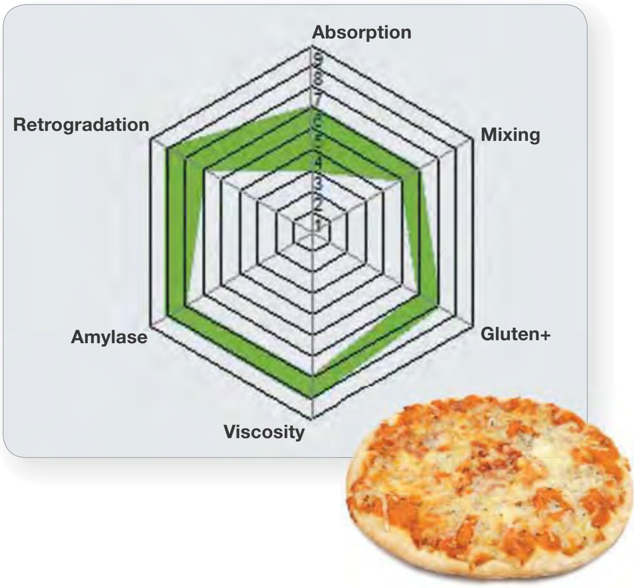
Different flour qualities are required depending on the type of finished product.

For example, the characteristics required to make cookies or bread are not the same.

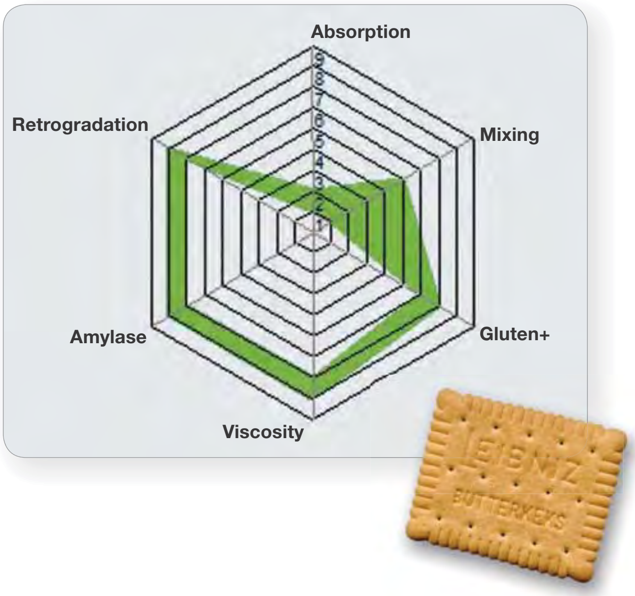
In the case of a cookie, the hot gluten strength and thus its ability to retain gas during baking will not be of primary importance for the finished product, unlike leavened products like bread. However, a flour with a low retrogradation capacity will be appreciated, in order to ensure a longer product shelf-life.

You will find below examples of target profiles defined with manufacturers (specificities of the associated industrial processes) from different countries.

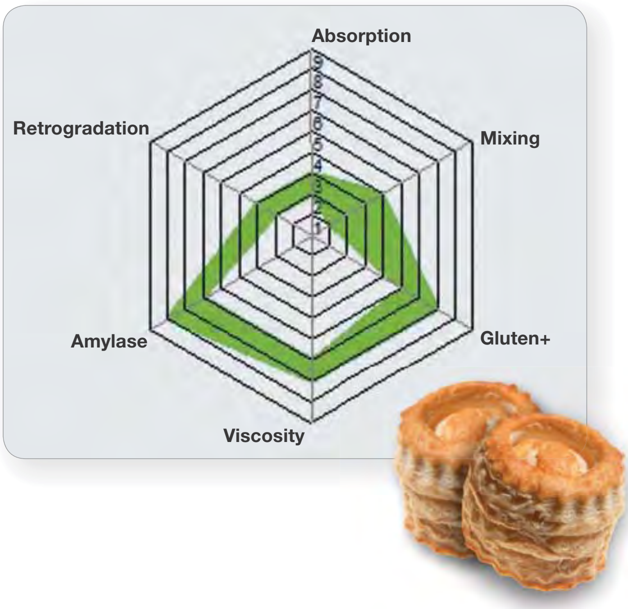
Pizza profile



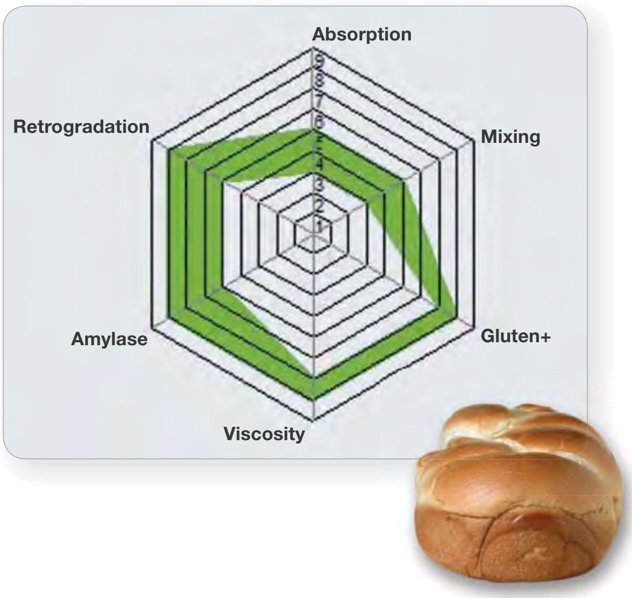
Cookie profile



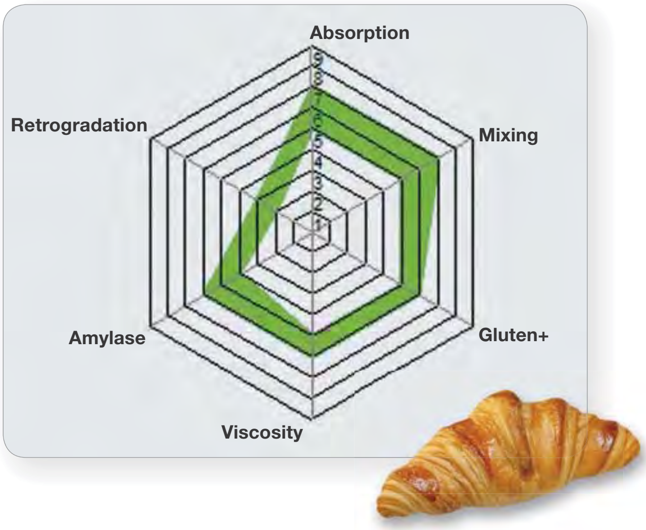
Puff pastry profile



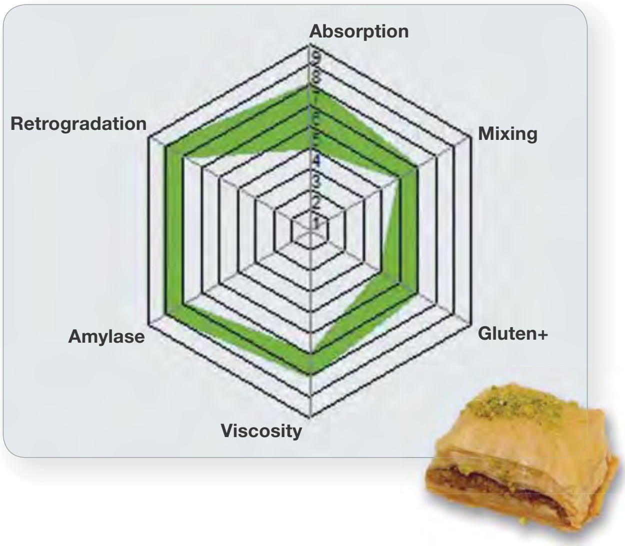
Brioche profile



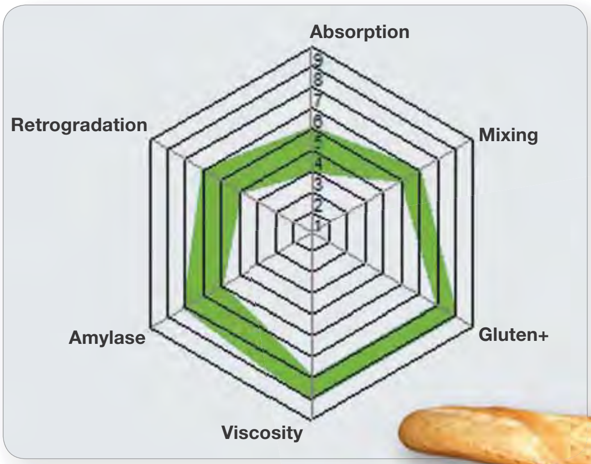
Viennese pastry profile



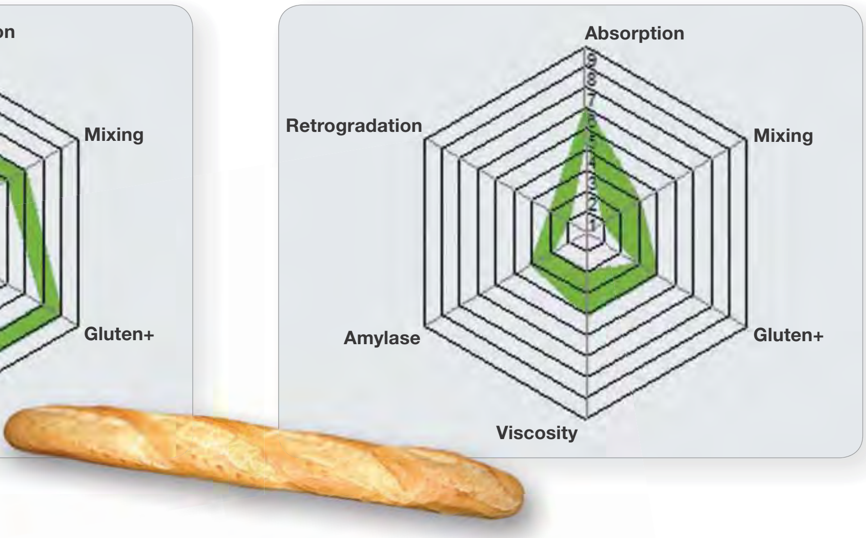
Baklava profile



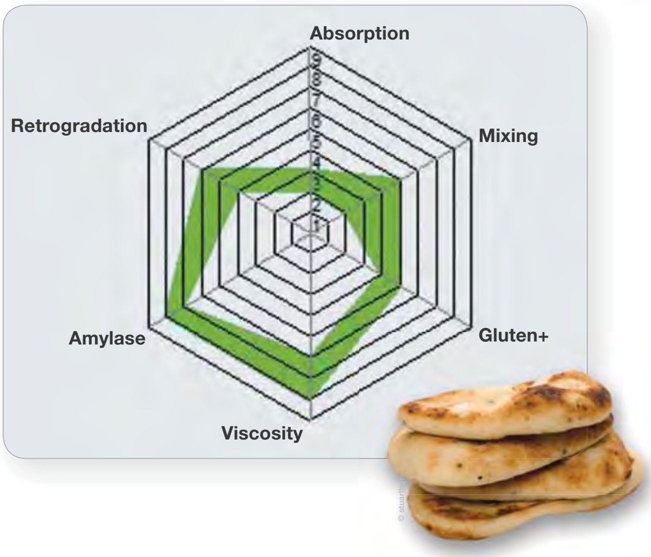
T55 baguette profile



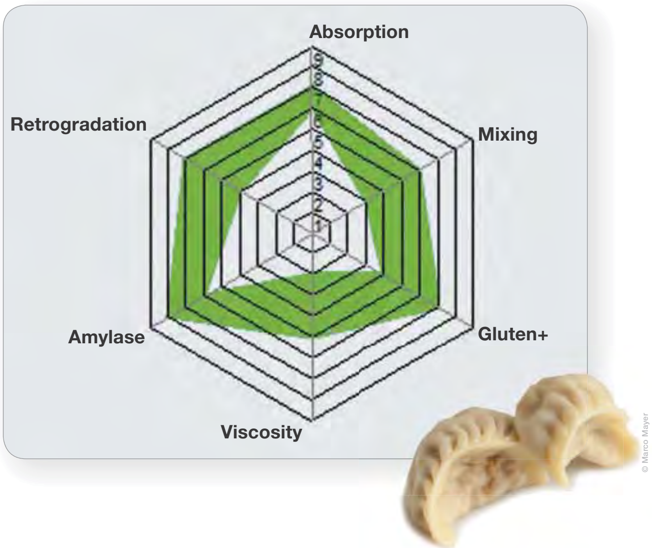
T65 baguette profile



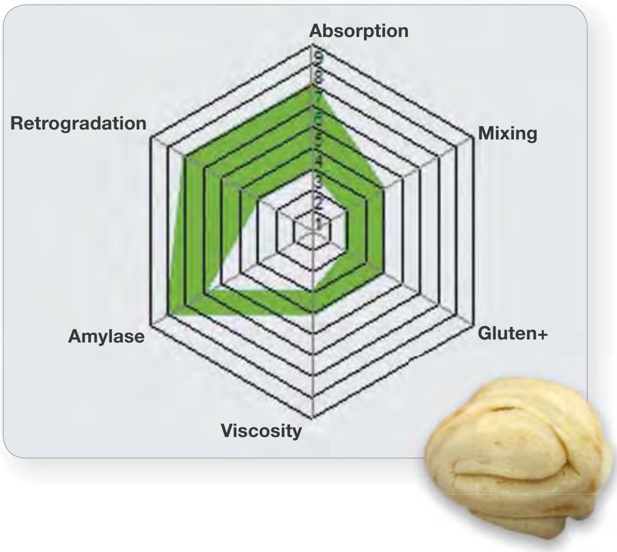
Baladi bread profile



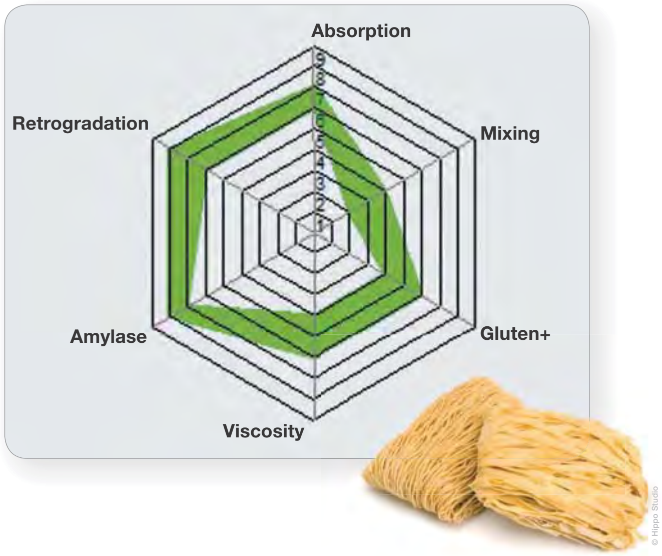
Chinese dumpling profile



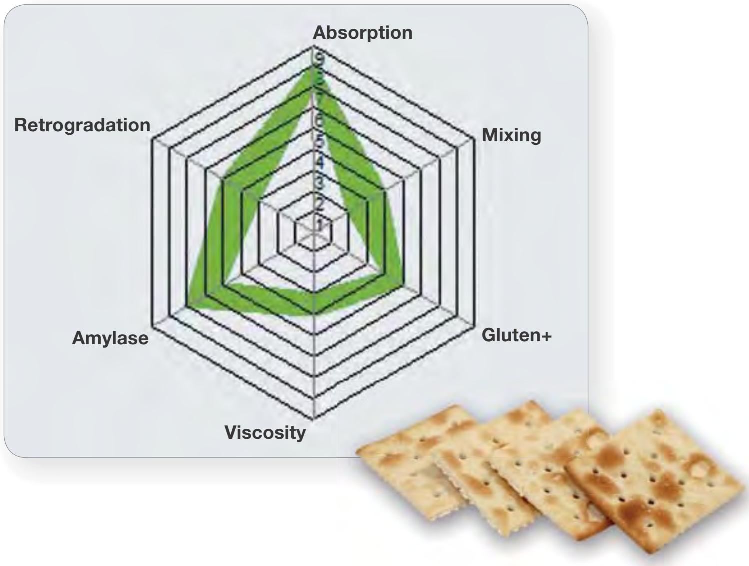
Steam bread profile



Chinese noodle profile

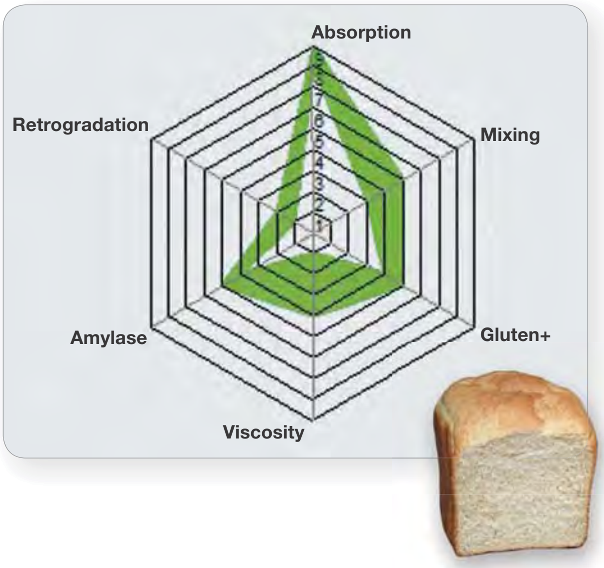


Cracker profile

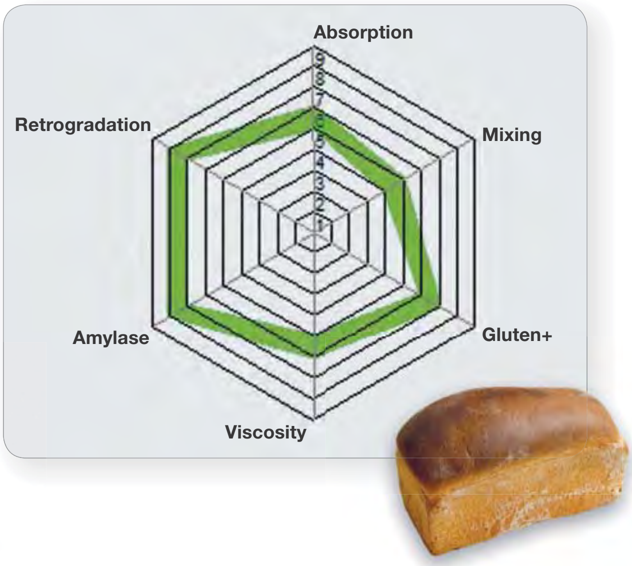


7.2.5 Profiler examples on various types of processes

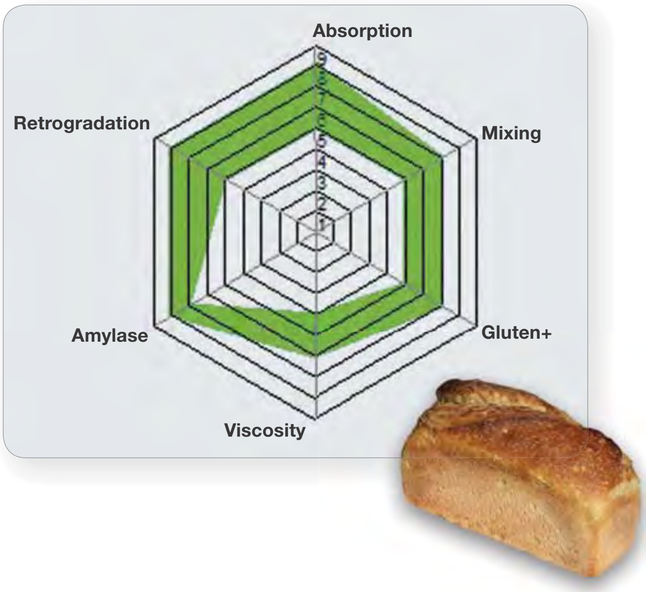
Loaf bread 1



Loaf bread 2



Loaf bread 3



For the same product, different flour qualities may be required depending on the process used. Using the Profiler tool, it is possible to identify profiles for each process and ensure consistency in quality.

8 ❖ ABOUT DURUM WHEAT

Durum wheat (Triticum durum) is a tetraploid hybrid (2 x seven homeologous chromosome pairs) of Triticum monococcum and Aegilops speltoides. In comparison, common wheat (Triticum aestivum) is a hexaploid hybrid (3 x seven homeologous chromosome pairs) of Triticum monococcum, Aegilops speltoides and Aegilops squarrosa. Please note that durum wheat (Triticum durum) should not be confused with “hard wheat”, the term used in North America to refer to some types of common wheat.

Durum wheat differs from common wheat by its vitreous albumen grain and its higher protein content. More sensitive to the cold than common wheat, and more resistant to drought, durum wheat was first farmed in Ancient times in the Mediterranean region, particularly in Egypt and in Greece.

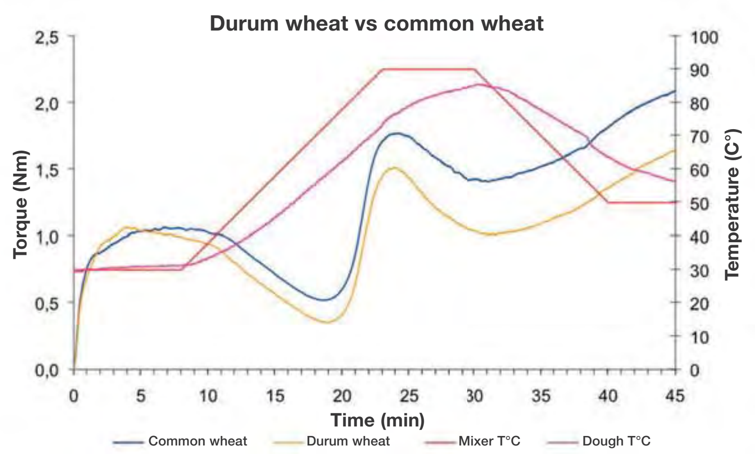
Worldwide durum wheat production reached 40 million metric tonnes in 2009. Europe (excluding the CIS) produced 26% of global production on average over the last 10 years. It is followed by North and Central America (24%), the Middle East (particularly Turkey and Syria) (18%), and the CIS (12%) and North Africa (11%).

Durum wheat production is subject to two variabilities: very irregular harvests in North Africa, as they are dependent on winter and spring rains, and production in North America arising from sowing decisions on economic and agronomic bases (with few alternatives in arid regions).

The overall Mediterranean region consumes 62% of global durum wheat production and is the world's primary importing region. North and Central America is the world's primary exporting region. It produces 72% of the world's exports. Canada is the world's leading exporter of durum wheat and Algeria is the leading importer.

8.1 ▶ Durum wheat – Whole grain flour

The Mixolab® is able to analyse a wide range of products. It can easily assess the rheological properties of whole grain durum wheat flour.



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	WA (% b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Stability (min)	Time C1 (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	69.1	0.52	1.77	1.4	2.09	9.8	6.8	1.25	0.37	0.69
Durum wheat	67.6	0.35	1.51	1.01	1.64	8.5	4.1	1.16	0.5	0.63

The comparative analysis of two whole grain flours (see graph above) demonstrates that durum wheat and common wheat have overall the same Mixolab® curve shape.

In this example, durum wheat is characterized by:

- A lower hydration capacity.
- A shorter dough development time.
- A lower C2 torque.
- A lower viscosity peak (C3 and C3-C2).
- A lower hot stability (C3-C4).
- A similar retrogradation (C5-C4).

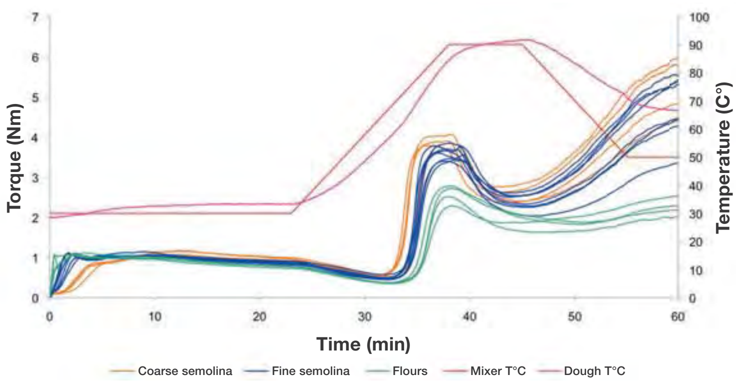
It is possible to test the quality of durum wheat with the Mixolab®.

8.2 ▶ Milling products

Durum wheat is not generally consumed as is. It requires prior processing into semolina or flour. Semolina is essentially used to make pasta and couscous. It can also be used in other Oriental products (tabbouleh) or in pastries. Flour is essentially added in the production of bread. In Morocco, the primary use of durum wheat is bread-making. In Greece, traditional farmhouse bread contains durum wheat flour.

The Mixolab® analysis of 12 semolinas (4 coarse, 8 fine) and 6 flours from a Moroccan semolina factory reveal the specific features of each product category:

- The flours absorb more water than the semolinas.
- The coarse semolinas have a much longer dough development time than the fine semolinas. The fine semolinas have a longer dough development time than the flours.
- The flours have a less intense gelatinization (C3-C2) and a greater hot stability (C3-C4) than the semolinas.



	Hydration b14%	Development time (min)
Coarse semolina	61-62	10-13
Fine semolina	60-66	3-9
Flours	68-75	2-4

Couscous protocol	
Mixing speed	250 rpm
Target torque (for C1)	1,10 Nm
Dough weight	90 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	23 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	60 min

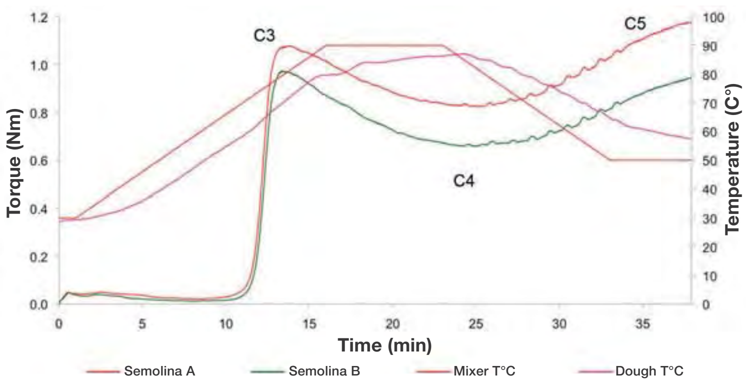
It is important to note the differences between categories are more pronounced, but there are also significant between products in the same category. These differences are particularly visible on the starch part (second part of the curve).

NB: The Couscous protocol is suitable for all durum wheat-based products, from the finest to the coarsest. It has high mixing speed and long initial mixing phase at 30°C.

8.3 ▶ Blend optimization and monitoring

Pasta is generally produced using durum wheat semolina and water, two basic ingredients. Salt and fresh eggs are sometimes added. Therefore, the quality of the semolina needs to be beyond reproach and suitable for each type of pasta.

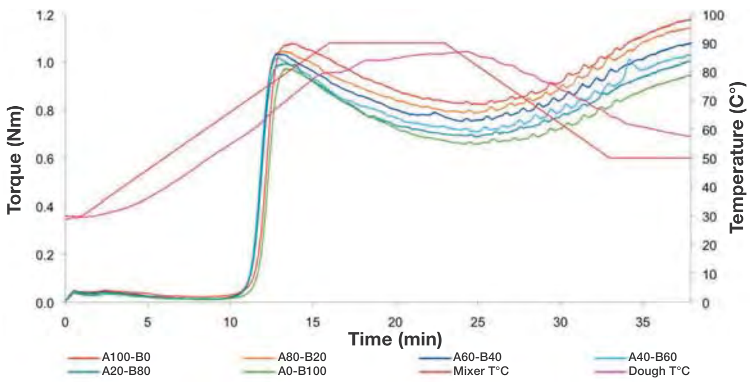
Our partner is a semolina-pasta manufacturer producing different types of pasta (ranging from farfalle to spaghetti) from two types of semolina (A and B), incorporated in different proportions. Our partner needs a laboratory device to control the quality (observance of proportions) of the initial semolina blend. Therefore, a study was initiated to determine how the Mixolab® is capable of meeting this partner's need.

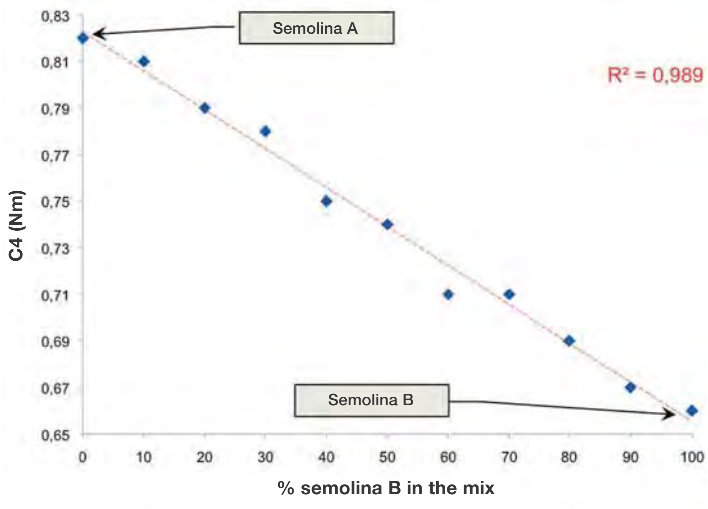


1min Chopin+ protocol	
Mixing speed	80 rpm
Hydration	100% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	1 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	38 min

First, the protocol 1 min Chopin+ was designed to get optimum differentiation of both types of basic semolina (A and B), 9 blends (A10-B90 / A20-B80 / … / A80-B20 / A90-B10) were prepared and analyzed on the Mixolab® with this protocol.

The results obtained demonstrate that the greater the proportion of semolina B in the blend, the greater the decrease in the second part of the Mixolab® curve. There is a very strong linear correlation (r = 0.99) between the Mixolab® C4 value and the proportion of semolina B in the blend.

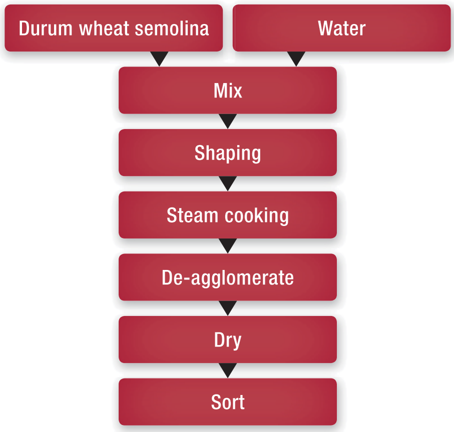




This study demonstrates that the Mixolab® can be used to control semolina blend quality.

NB: the two initial types of semolina (A and B) used by this partner have very similar basic characte-ristics (grain size distribution, protein content, ash content, etc.). Therefore, this type of parameter cannot be used to qualify blends.

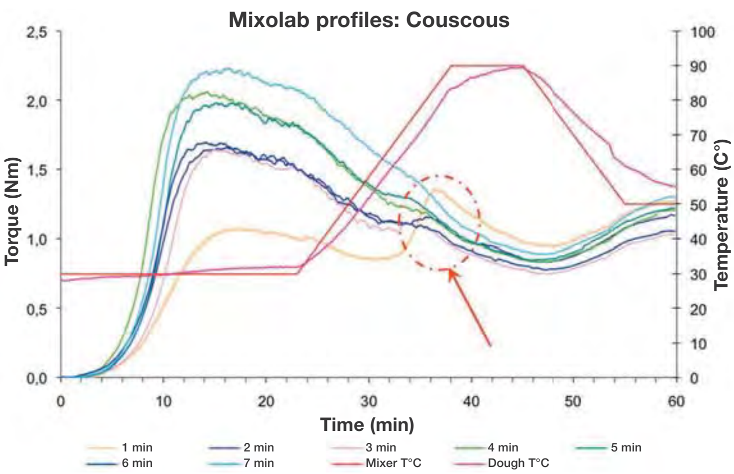
8.4 ▶ Couscous



8.4.1 Influence of cooking time

Couscous grains are spherical granules obtained by the aggregation of durum wheat semolina. Their quality depends on the gelatinization state of the starch contained. Naturally, this degree of gelatinization depends on the size of the couscous milling, their moisture, but also the duration of the cooking phase.

Our partner, an industrial couscous manufacturer needs a laboratory device to monitor and optimize the production process, particularly the cooking phase.This phase needs to be long enough to gelatinize a maximum amount of starch, and short enough so as not to increase production costs. A study was conducted on the Mixolab® to identify couscous cooking problems.



Couscous protocol	
Mixing speed	250 rpm
Hydration	120% bAi
Dough weight	90 g
Tank temperature	30 °C
Temperature 1st step	30 °C
Duration 1st step	23 min
Temperature 2nd step	90 °C
1st temperature gradient	4 °C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4 °C/min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	60 min

Samples were taken every minute during the production process, and analyzed with the Mixolab®. The results obtained show:

- An increase in the maximum torque with the cooking time.
- A decrease in the development time with the cooking time.
- A progressive disappearance of the gelatinization peak (arrow).

The Mixolab® is easy to use to monitor the degree of starch gelatinization during the cooking (steaming) of couscous. It also can be used to detect other rheological modifications caused by cooking, such as an increase in the maximum torque and decrease in the development time.

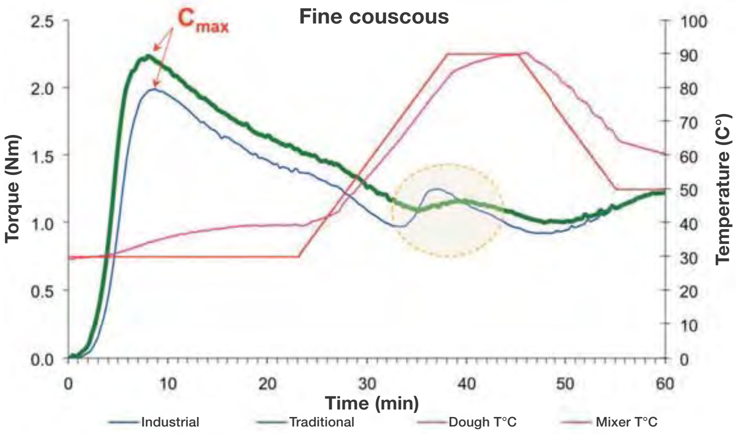
8.4.2 Industrial couscous vs traditional couscous

There are currently two production modes, traditional and industrial, on the couscous market.

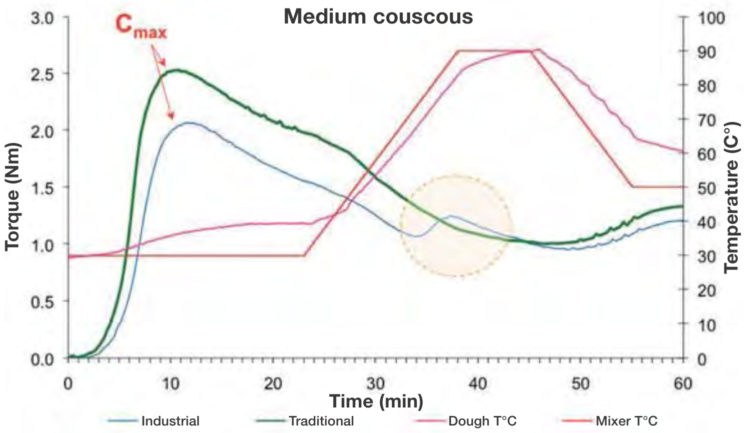
Considerable differences in quality are observed between both types of couscous: consumers have a preference for traditional couscous. The purpose of the study is to assess the ability of the Mixolab® to detect the differences in quality between traditional and industrial couscous.

Two samples of industrial couscous and two samples of traditional couscous of different grain sizes, obtained using the same semolina, were analyzed on the Mixolab® using the “Couscous” protocol.

	Cmax
Industrial fine couscous	1.99 Nm
Traditional fine couscous	2.23 Nm



	Cmax
Industrial medium couscous	2.07 Nm
Traditional medium couscous	2.53 Nm



Samples	
1	Industrial fine couscous
2	Traditional fine couscous
3	Industrial medium couscous
4	Traditional medium couscous

Couscous protocol	
Mixing speed	250 rpm
Hydration	120% bAi
Dough weight	90 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	23 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	60 min

The results show two major differences between industrial and traditional couscous:

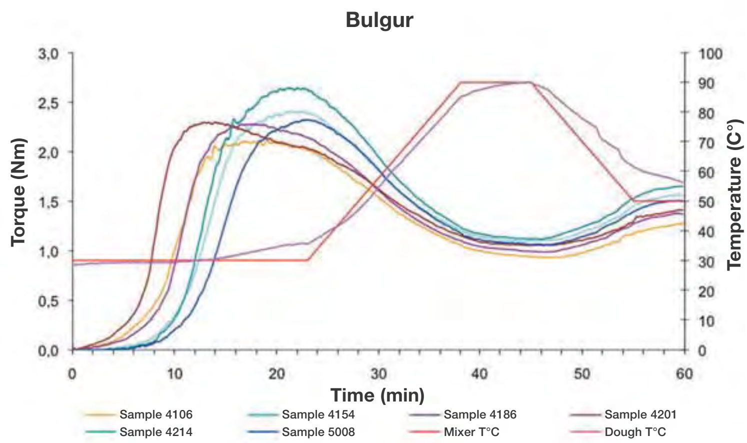
➲ Industrial couscous has a lower water absorption capacity (lower Cmax) than traditional couscous. This difference is more pronounced on medium couscous than on fine couscous.

➲ Industrial couscous shows incomplete starch gelatinization. This incomplete gelatinization is conveyed by a significant increase in the torque measured when the dough temperature reaches approximately 65°C (rebound observed after approximately 35 minutes of mixing). Traditional couscous has complete starch gelatinization (no rebound).

The results prove that the “Couscous” protocol clearly shows differences in quality between industrial couscous and traditional couscous. Therefore, the Mixolab® is an excellent tool for monitoring quality and optimizing the couscous production process.

8.5 ▶ Bulgur

Bulgur is durum wheat with its bran removed. It is pre-steamed, dried and finally crushed. It is the base product in traditional Turkish cuisine.



Couscous protocol	
Mixing speed	250 rpm
Hydration	110% b14
Dough weight	90 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	23 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	60 min

The Mixolab® analysis of 6 industrial bulgur samples, 3 fine (4106, 4186 and 4201) and 3 coarse (4154, 4214 and 5008) shows:

- A longer dough development time for “coarse” samples.
- A higher maximum torque for “coarse” samples.
- No gelatinization for all the samples.
- A greater (but limited) retrogradation for “coarse” samples.

The Mixolab® is able to test coarse or fine bulgur. Moreover, the lack of a rebound around 50-60°C demonstrates that the gelatinization of the bulgur samples tested is complete (the bulgur production process includes a cooking phase in excess of water).

NB: A liquid flow may be observed at the start of the test on the mixing blade bearings. In the event of an excessive flow, reduce the hydration.

9 ❖ APPLICATIONS FOR FLOURS FROM VARIOUS SOURCES

According to the FAO, the Food and Agriculture Organization of the United Nations, global cereal production was almost 2.28 billion tonnes in 2010. The most common cereal crops are rice, corn, wheat, barley and sorghum. However, other types of milling (cereals, pseudocereals, legumes, etc.) are also used in human consumption.

The current trend for healthy products and problems with allergens (such as gluten) have brought some of these grains in the light. They were previously only consumed by local populations.

Quinoa-based pastries or breads produced with legume flour such as lupin bread are now available on the market.

The Mixolab® can be used to study the quality of these flours regardless of their source and whether they contain gluten or not.

It should be noted that the flours tested in this study are provided as examples and are not necessarily representative of the variability of their species.

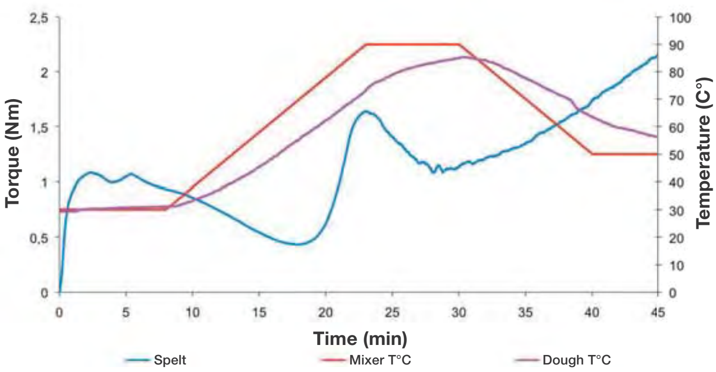
9.1 ▶ Cereals and pseudocereals

9.1.1 Cereals containing gluten

✦ SPELT ✦

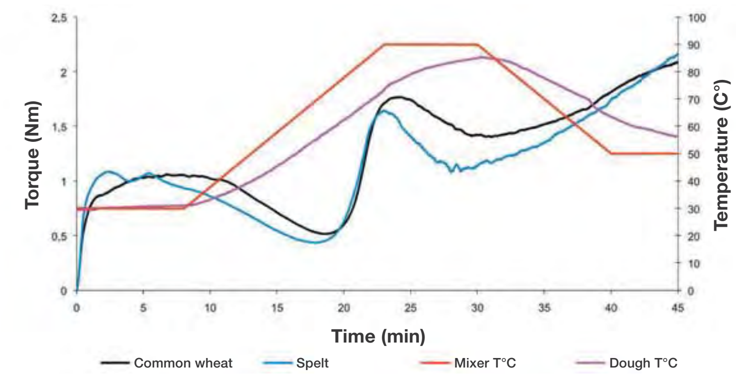
TECHNICAL DATA	
Category	Cereal (wheat variety)
Crop region	Northern Europe and Italy
Diet type	All
Benefits	Very high protein content Rich in vitamins and minerals Nutty flavour
Main form of consumption	Flour for breads, pastries, cookies and pasta

Test conducted with Chopin+ protocol on pure whole grain flour



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	WA (% b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	69.1	0.52	1.77	1.4	2.09	9.8	1.25	0.37	0.69
Spelt	58	0.44	1.64	1.08	2.17	6.8	1.2	0.56	1.09

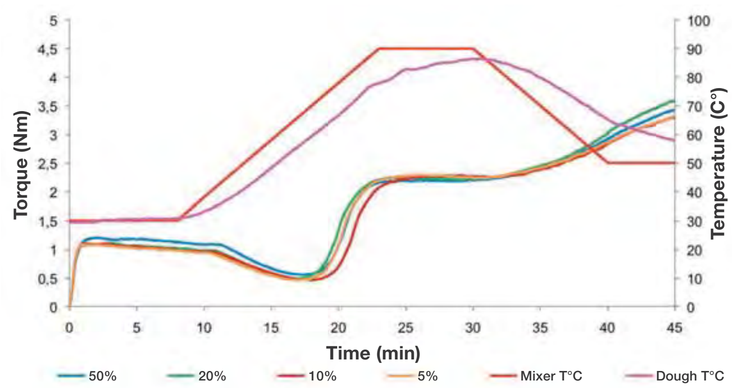


The general shape of the curve for spelt is identical to common wheat. However, a few special points exist:

- Double peak at 30°C during mixing.
- Low weakening acceleration during heating.
- Very pronounced gelatinization peak and high rise during cooling.

Test conducted with Chopin+ protocol on flour blend.

Spelt flour incorporated with common wheat flour (5%, 10%, 20% and 50%) was analyzed at constant hydration (53.3% base 14) with the Chopin+ protocol.



Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	53.3% b14
Dough weight	75 g
Tank temperature	30 °C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50 °C
Duration 3rd step	5 min
Total analysis time	45 min

	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
5%	1.09	0.46	2.29	2.23	3.32	1.03	9.87	1.83	0.06	1.09
10%	1.10	0.47	2.29	2.25	3.31	2.67	10.22	1.82	0.04	1.06
20%	1.10	0.49	2.20	2.22	3.59	2.92	10.50	1.71	-0.02	1.37
50%	1.20	0.56	2.15	2.20	3.45	1.92	10.82	1.59	-0.04	1.25

Incorporating spelt flour brings:

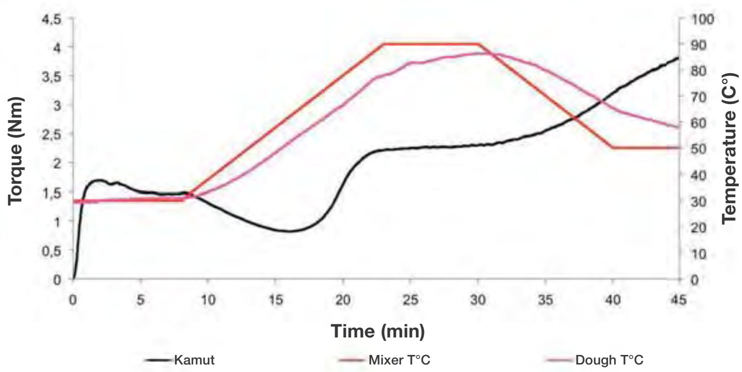
- An increase in the water absorption capacity (C1 increases at high incorporation rates).
- A declining viscosity peak (C3 and C3-C2 decrease).
- A superior hot stability (C3-C4).

Based on the results obtained, the impact of spelt flour on dough rheology remains limited and can only be observed for high incorporation rates.

KAMUT

TECHNICAL DATA	
Category	Ancestor of durum wheat
Crop region	United States and Canada
Diet type	All
Benefits	Rich in protein Remarkable bread-making qualities Slight hazelnut flavour
Main form of consumption	Flour for breads, pastries, pasta, bulgur, semolina

Test conducted with Chopin+ protocol on pure flour



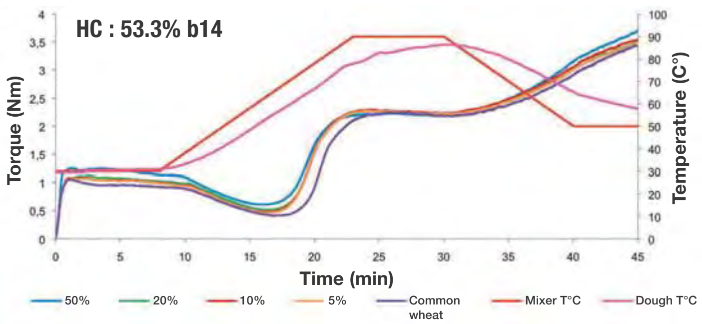
Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	53.3% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

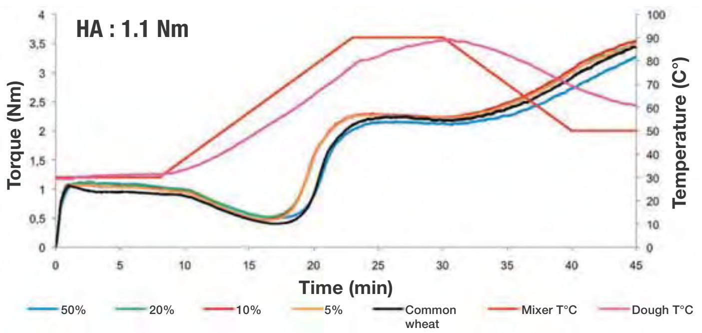
WA (%b14)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
53.3	1.70	0.82	2.21	2.30	3.83	1.97	5.32	1.39	- 0.09	1.53

Blend: common wheat - kamut at constant and adapted hydration

Kamut flour incorporated with common wheat flour (5%, 10%, 20% and 50%) was first analyzed at constant hydration (53.3% base 14) with the Chopin+ protocol.

	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	1.06	0.41	2.25	2.17	3.45	1.1	7.27	1.84	0.08	1.28
5%	1.07	0.46	2.27	2.21	3.50	1.25	9.85	1.81	0.06	1.29
10%	1.08	0.47	2.29	2.23	3.55	1.07	9.90	1.82	0.06	1.32
20%	1.12	0.51	2.28	2.18	3.51	2.53	9.93	1.77	0.10	1.33
50%	1.25	0.61	2.23	2.19	3.71	1.18	9.75	1.62	0.04	1.52





Chopin+ protocol	
Mixing speed	80 rpm
Constant / adapted hydration	53.3% b14 / 1.1 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Blends in the same proportions (kamut / common wheat) were also analyzed at adapted hydration (1.1 Nm) to better study the rheological properties of the flour.

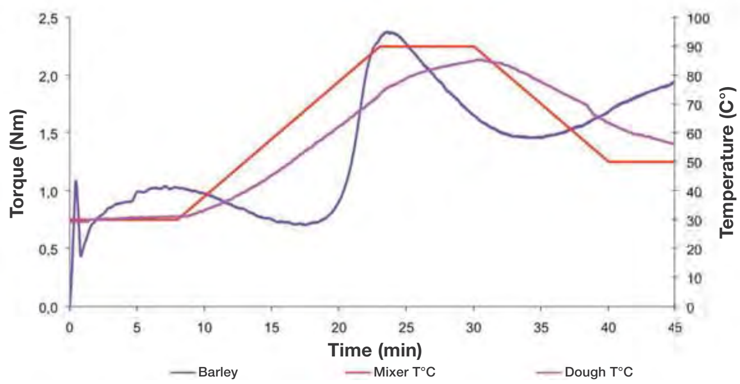
	WA (%b14)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	53.3	1.06	0.41	2.25	2.17	3.45	1.1	7.27	1.84	0.08	1.28
5%	53.3	1.07	0.46	2.27	2.21	3.50	1.25	9.85	1.81	0.06	1.29
10%	53.3	1.08	0.47	2.29	2.23	3.55	1.07	9.90	1.82	0.06	1.32
20%	53.3	1.12	0.51	2.28	2.18	3.51	2.53	9.93	1.77	0.10	1.33
50%	54	1.25	0.61	2.23	2.19	3.71	1.18	9.75	1.62	0.04	1.52

Based on the results obtained, incorporating kamut flour mainly influences the first part of the Mixolab® curve (protein part). It creates an increase in the water absorption capacity and the stability at 30°C. The intensity of these modifications remains limited and probably varies between kamut samples. The results show similarity between common wheat and kamut on the dough cooling part.

✦ BARLEY ✦

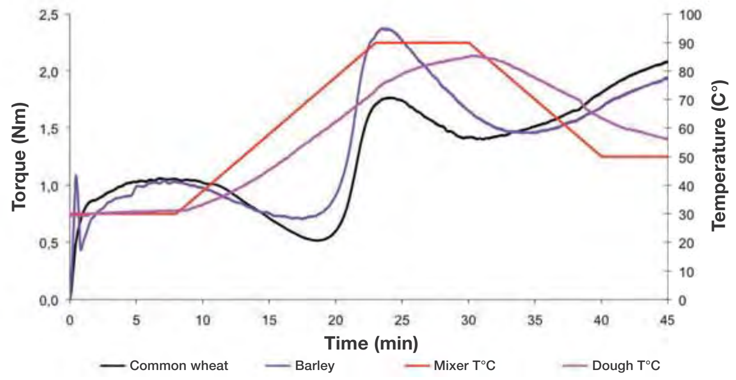
TECHNICAL DATA	
Category	Cereal characterized by its long-bearded ears
Crop region	Russia, Europe, Canada, United States and Australia
Diet type	All
Benefits	Rich in fibre, vitamins and minerals Low in protein
Main form of consumption	Beer, cakes, pancakes and animal feed

Test conducted with Chopin+ protocol on pure whole grain



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	WA (% b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	69.1	0.52	1.77	1.4	2.09	9.8	1.25	0.37	0.69
Barley	75.3	0.71	2.37	1.46	1.94	11.3	1.66	0.91	0.48



The general shape of the curve for barley is identical to common wheat. The sample tested is characterized by:

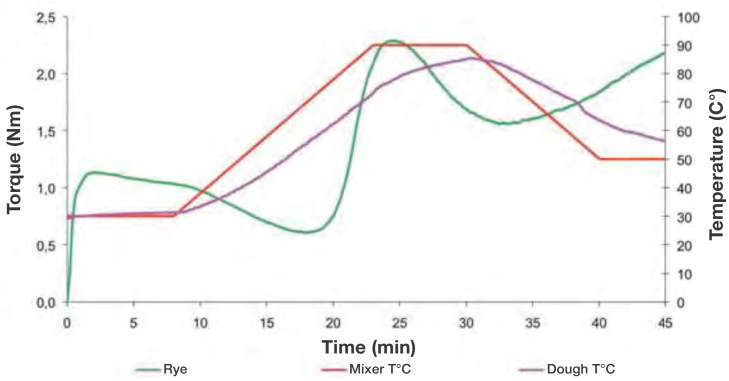
- A much higher hydration content probably associated with the presence of larger amounts of fibre.
- The presence of an absorption peak.
- A much higher C2 torque with a smaller C1-C2 drop.
- A higher viscosity peak (C3 and C3-C2).
- A lower hot stability (C3-C4).
- A lower retrogradation (C5-C4).

Barley is characterized by a very high water absorption capacity. This absorption is preceded by an absorption peak. The gelatinization capacity is high and the C3 peak reaches a high value. This peak is followed by a drop in hot consistency which may be attributed to a high amylase activity. The retrogradation is lower than for wheat, indicating a different type of starch.

✦ RYE ✦

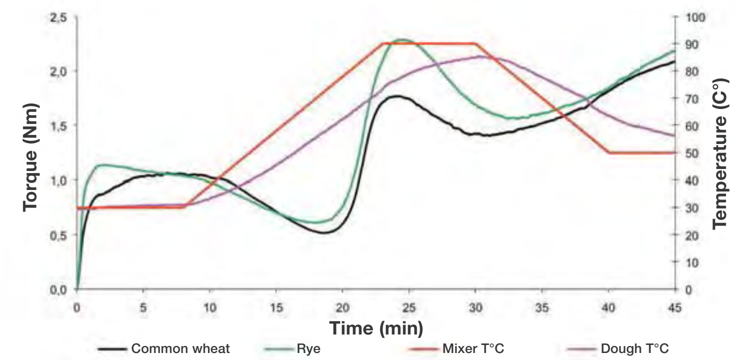
TECHNICAL DATA	
Category	Cereal
Crop region	Russia, Poland, Germany, France and Scandinavia
Diet type	All
Benefits	Low in gluten Rich in fibre
Main form of consumption	Flour for breads, pastries, cookies and pasta Animal feed

Test conducted with Chopin+ protocol on pure whole grain



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	WA (% b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	69.1	0.52	1.77	1.4	2.09	9.8	1.25	0.37	0.69
Rye	65.0	0.61	2.29	1.56	2.18	9.1	1.68	0.73	0.62



The general shape of the curve for rye is identical to common wheat. The sample tested is characterized by:

- A lower hydration content.
- A much shorter dough development time.
- A higher viscosity peak (C3 and C3-C2).
- A lower hot stability (C3-C4).
- A slightly lower retrogradation (C5-C4).

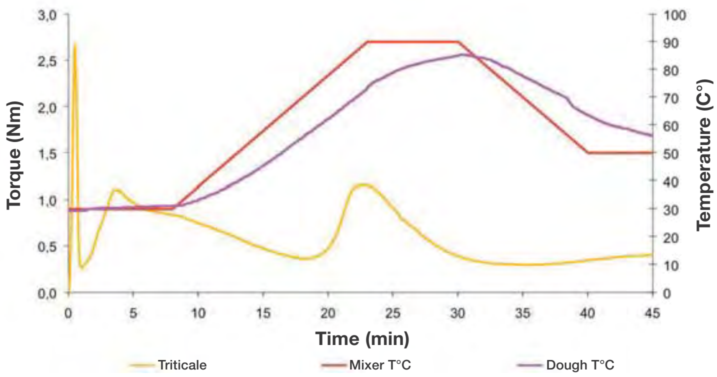
Rye has a lower water absorption capacity than common wheat. Dough development is very rapid and the dough stability is similar to common wheat.

No modifications in the slope when the heating phase starts are observed, as for common wheat. This may be explained by a different composition and different properties in rye protein. In the “hot” phase, rye has a conventional curve with a high viscosity (C3) and a much lower hot stability than common wheat. The retrogradation is practically equivalent for both types of cereal.

✦ TRITICALE ✦

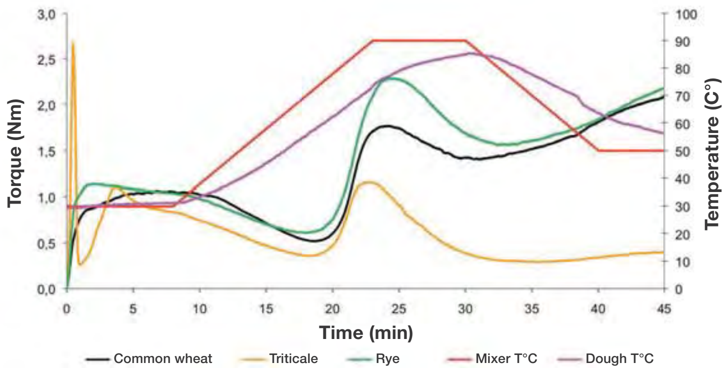
TECHNICAL DATA	
Category	Hybrid of rye and wheat
Crop region	Europe, Russia, China and Australia
Diet type	All
Benefits	Rich in gluten Rich in fibre
Main form of consumption	Flour for breads, tortillas, pastries and pasta

Test conducted with Chopin+ protocol on whole grain



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	WA (% b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	69.1	0.52	1.77	1.40	2.09	9.8	1.25	0.37	0.69
Triticale	68.0	0.36	1.16	0.31	0.41	4.70	0.80	0.85	0.10
Rye	65.0	0.61	2.29	1.56	2.18	9.1	1.68	0.73	0.62



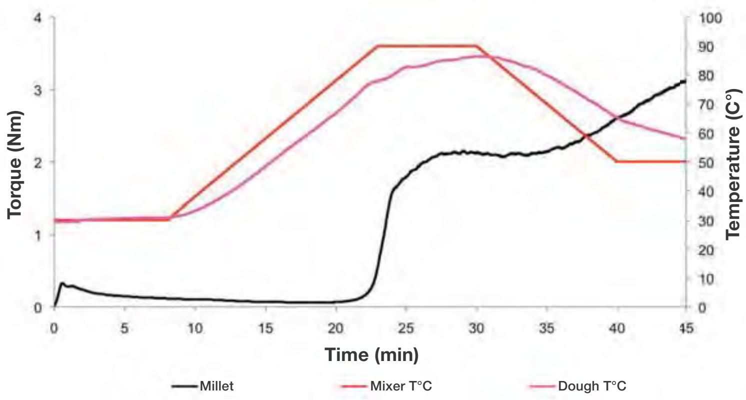
Triticale is a hybrid of common wheat and rye. Triticale does not show any of the specific qualities of common wheat or rye (high cold stability and high hot viscosity). The absorption capacity is similar to wheat but the low cold stability demonstrates a very insufficient plasticity, which is very difficult to work with. The “hot” part is closer to the properties of a Waxy wheat with, in particular, a very low hot viscosity (C3). The starch in triticale may be similar to Waxy wheat (amylose/amylopectin ratio).

9.1.2 Gluten-free cereals

✦ MILLET ✦

TECHNICAL DATA	
Category	Food cereal
Crop region	Europe and America
Diet type	All (gluten-free)
Benefits	Rich in vitamin A and minerals High-energy food
Main form of consumption	Breads, pastries, pancakes

Test conducted with Chopin+ 90 g protocol on pure flour



Chopin+ 90 g protocol	
Mixing speed	80 rpm
Constant hydration	55% b14
Dough weight	90 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

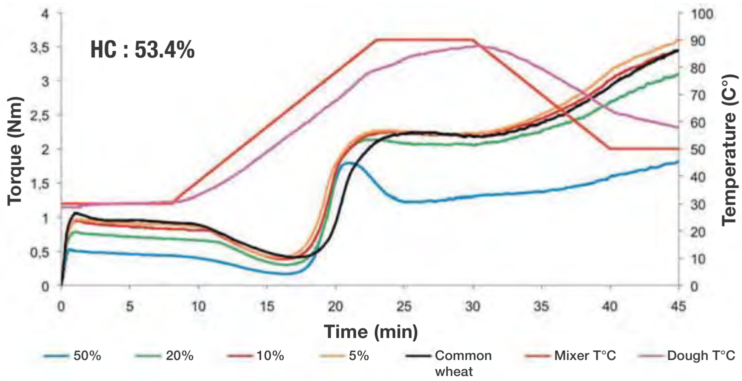
WA (%b14)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Tps de dvt (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
55	0.33	0.06	2.15	2.06	3.12	0.58	1.02	2.09	0.09	1.06

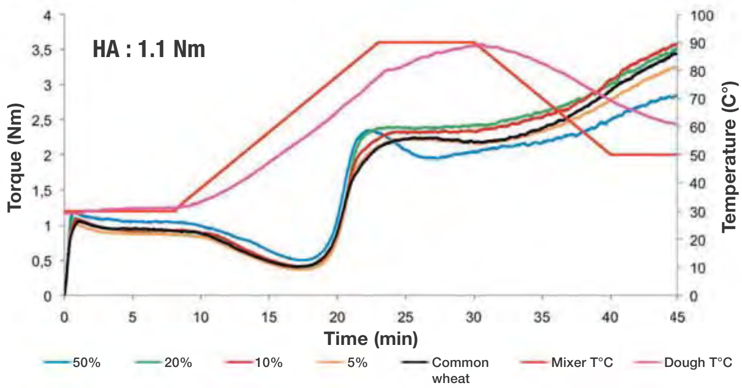
An atypical curve shape (very low consistency) is observed until the gelatinization temperature is reached. An adaptation of the protocol to analyze millet flour is currently under development.

Blend: common wheat-millet at constant and adapted hydration

Millet flour incorporated with common wheat flour (5%, 10%, 20% and 50%) was analyzed at constant hydration (53.3% base 14) with the Chopin+ protocol.

	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	1.06	0.41	2.25	2.17	3.45	1.1	7.27	1.84	0.08	1.28
5%	0.98	0.41	2.28	2.2	3.61	1.1	10.1	1.87	0.08	1.41
10%	0.95	0.39	2.25	2.19	3.45	1.07	8.67	1.86	0.06	1.26
20%	0.79	0.3	2.14	2.05	3.1	1.02	8.22	1.84	0.09	1.05
50%	0.53	0.17	1.79	1.22	1.82	0.63	5.2	1.62	0.57	0.6





Chopin+ protocol	
Mixing speed	80 rpm
Constant / adapted hydration	53.4% b14 / 1.1 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Blends in the same proportions (millet/common wheat) were also analyzed at adapted hydration (1.1 Nm) to better study the rheological properties of the flour.

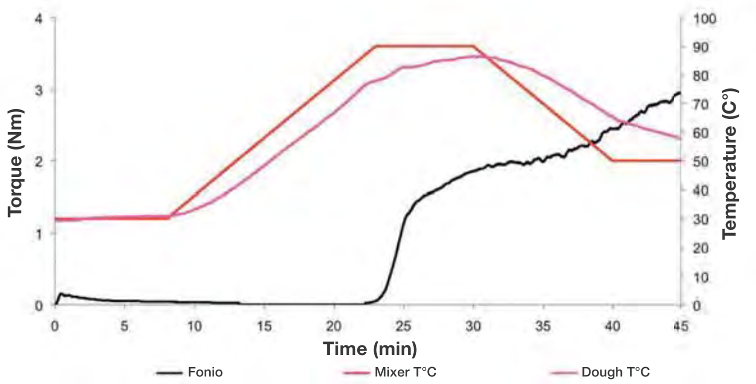
	WA (%b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	53.4	0.41	2.25	2.17	3.45	1.1	7.27	1.84	0.08	1.28
5%	51.3	0.37	2.23	2.15	3.25	0.90	4.05	1.86	0.08	1.10
10%	49.0	0.41	2.22	2.33	3.59	1.02	3.00	1.81	-0.10	1.27
20%	48.0	0.39	2.37	2.42	3.52	0.82	3.05	1.98	-0.05	1.10
50%	44.5	0.51	2.35	1.95	2.85	0.68	8.82	1.84	0.40	0.90

With the exception of the water absorption capacity, the impact of millet flour in common wheat flour starts to be noticeable at 20% and becomes very significant at 50%.

✦ FONIO ✦

TECHNICAL DATA	
Category	Cereal
Crop region	Africa – Sahel
Diet type	All (gluten-free) Recommended for diabetics
Benefits	Very rich in carbohydrate (84%) compared to other cereals Rich in fibre
Main form of consumption	Breads, couscous, doughnuts

Test conducted with Chopin+ 90 g protocol on pure flour



Chopin+ 90 g protocol	
Mixing speed	80 rpm
Constant hydration	55% b14
Dough weight	90 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

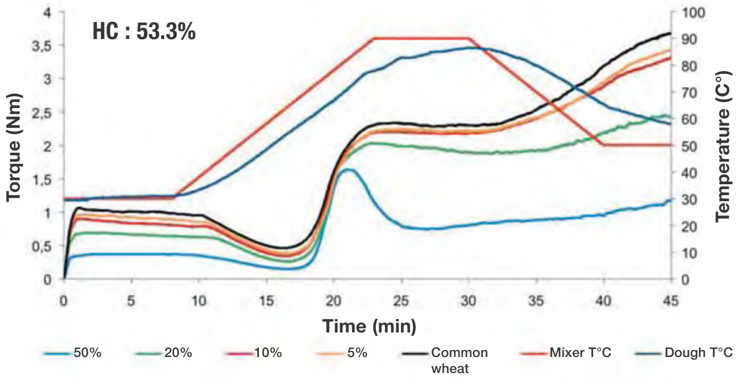
WA (%b14)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
55	0.16	0.1	1.43	1.94	2.94	0.48	0.33	1.33	-0.51	1.00

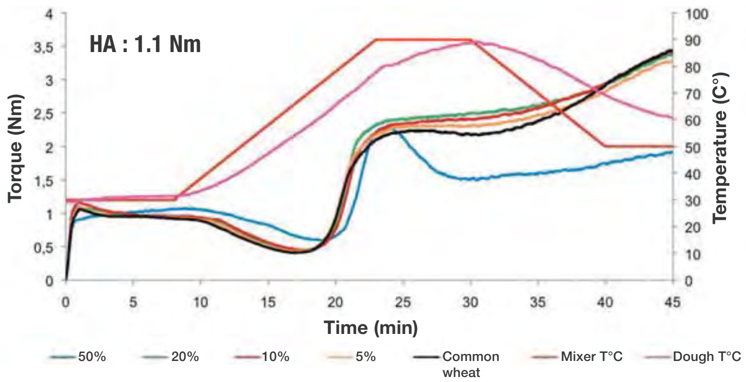
An atypical curve shape (very low consistency) is observed until the gelatinization temperature is reached. This curve is similar to millet flour (fonio is also known as “African millet”). An adaptation of the protocol to analyze fonio flour is currently under development.

Blend: common wheat - fonio at constant and adapted hydration

Fonio flour incorporated with common wheat flour (5%, 10%, 20% and 50%) was first analyzed at constant hydration (53.3% base 14) with the Chopin+ protocol.

	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	1.07	0.46	2.34	2.28	3.68	1.18	9.9	1.88	0.06	1.4
5%	0.96	0.38	2.25	2.19	3.44	1.15	10.20	1.87	0.06	1.25
10%	0.95	0.39	2.25	2.19	3.45	1.07	8.67	1.86	0.06	1.15
20%	0.69	0.26	2.03	1.87	2.43	1.87	10.83	1.77	0.16	0.56
50%	0.37	0.15	1.64	0.74	1.17	3.27	10.53	1.49	0.90	0.43





Chopin+ protocol	
Mixing speed	80 rpm
Constant / adapted hydration	53.3% b14 / 1.1 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Blends in the same proportions (fonio/common wheat) were also analyzed at adapted hydration (1.1 Nm) to better study the rheological properties of the flour.

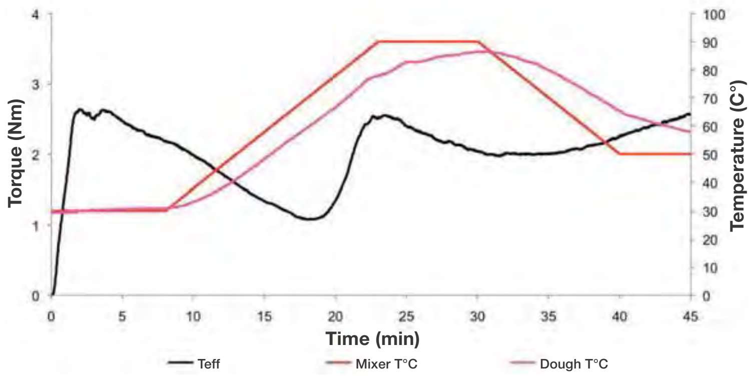
	WA (%b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	53.3	0.41	2.25	2.17	3.45	1.10	7.27	1.84	0.08	1.28
5%	52.0	0.43	2.17	2.31	3.30	0.98	5.97	1.74	-0.14	0.99
10%	50.0	0.45	2.19	2.41	3.44	0.98	3.80	1.74	-0.22	1.03
20%	47.0	0.41	2.32	2.50	3.38	1.00	6.30	1.91	-0.18	0.88
50%	42.0	0.59	2.29	1.49	1.93	8.92	11.90	1.70	0.80	0.44

Incorporating fonio impacts the dough rheology, both on the protein part (decrease in water absorption capacity, increase in stability) and on the starch part (hot stability, retrogradation). However, when the incorporation rate remains low (5%, 10%), these modifications are moderate. These effects are comparable to millet flour.

✦ TEFF ✦

TECHNICAL DATA	
Category	Cereal
Crop region	Africa – Ethiopia
Diet type	All (gluten-free)
Benefits	Rich in protein (methionine) Very rich in calcium Rich in iron and soluble fibre
Main form of consumption	Sweet and savory pancakes, cookies, breads

Test conducted with Chopin+ 90 g protocol on pure flour



Chopin+ 90 g protocol	
Mixing speed	80 rpm
Constant hydration	55% b14
Dough weight	90 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

WA (%b14)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
55	2.64	1.08	2.54	2.5	2.57	2.02	5.22	1.46	0.04	0.07

The general shape of the curve for teff is similar to common wheat. However, a few special properties exist:

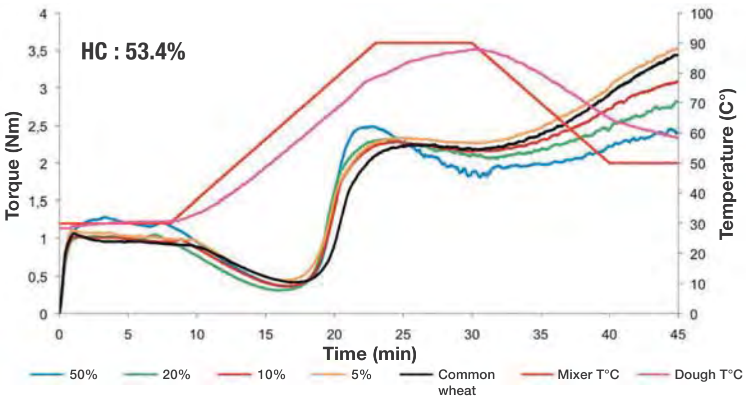
- Double peak at 30°C.
- Low weakening during heating.

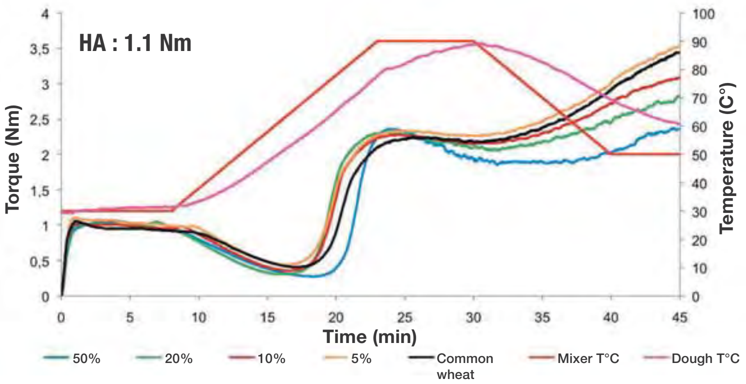
The rheological properties of teff are similar to those of spelt.

Blend: common wheat teff at constant and adapted hydration

Teff flour incorporated with common wheat flour (5%, 10%, 20% and 50%) was first analyzed at constant hydration (53.4% base 14) with the Chopin+ protocol.

	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	1.06	0.41	2.25	2.17	3.45	1.1	7.27	1.84	0.08	1.28
5%	1.10	0.44	2.34	2.26	3.53	0.97	9.55	1.90	0.08	1.27
10%	1.02	0.36	2.28	2.14	3.10	1.33	9.15	1.92	0.14	0.96
20%	1.03	0.31	2.31	2.05	2.82	2.42	8.12	2.00	0.26	0.77
50%	1.28	0.36	2.49	1.86	2.41	3.28	7.62	2.08	0.46	0.47





Chopin+ protocol	
Mixing speed	80 rpm
Constant / adapted hydration	53.4% b14 / 1.1 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Blends in the same proportions (teff/common wheat) were also analyzed at adapted hydration (1.1 Nm) to better study the rheological properties of the flour.

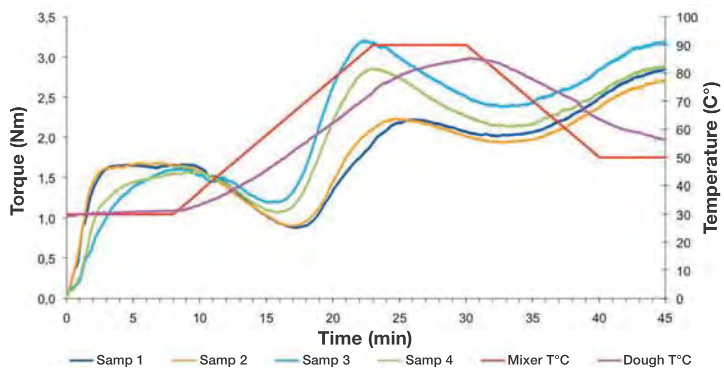
	WA (%b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	53.4	0.41	2.25	2.17	3.45	1.1	7.27	1.84	0.08	1.28
5%	53.4	0.44	2.34	2.26	3.53	0.97	9.55	1.90	0.08	1.27
10%	53.4	0.36	2.28	2.14	3.10	1.33	9.15	1.92	0.14	0.96
20%	53.4	0.31	2.31	2.05	2.82	2.42	8.12	2.00	0.26	0.77
50%	52.5	0.28	2.36	1.90	2.37	3.93	7.82	2.08	0.46	0.47

Incorporating teff impacts the dough rheology on the starch part of the curve (low retrogradation). This impact is even more important for high incorporation rates.

✦ RICE ✦

TECHNICAL DATA	
Category	Cereal
Crop region	East Asia, South America
Diet type	All (gluten-free)
Benefits	Very good source of complex carbohydrates, and low in fat
Main form of consumption	Flour for pancakes, breads, cookies, pastries, quenelles and pasta

Test conducted with Chopin+ protocol on whole grain (husked rice)



Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	55% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	WA (% b14)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
sample 1	55	1.66	0.88	2.22	2.01	2.87	9.50	1.34	0.21	0.86
sample 2	55	1.68	0.90	2.24	1.93	2.70	9.30	1.34	0.31	0.77
sample 3	55	1.61	1.19	3.20	2.38	3.19	7.70	2.01	0.82	0.81
sample 4	55	1.57	1.07	2.86	2.13	2.87	8.50	1.79	0.73	0.74

The curves obtained with the Mixolab® on whole grain husked rice can be separated in 2 groups:

- The first group includes samples 1 and 2.
- The second group includes samples 3 and 4.

The samples in group 2 are characterized by:

- A long development time.
- A high C2.
- A high gelatinization (high C3 and C3-C2).
- A high diastase activity (high C3-C4).

The general shape of the curve for rice is similar to common wheat. However, significant variability in properties (protein and starch) from one rice to another exists.

✦ CORN ✦

TECHNICAL DATA	
Category	Cereal
Crop region	United States, China, European Union, Brazil, Mexico
Diet type	All (gluten-free)
Benefits	Rich in starch Benefit for potassium, phosphorus and magnesium Low in fat
Main form of consumption	Breads, pastries, tortillas, tacos, polenta, cornstarch (cornflour), fermented drinks (chicha)

▶ Corn

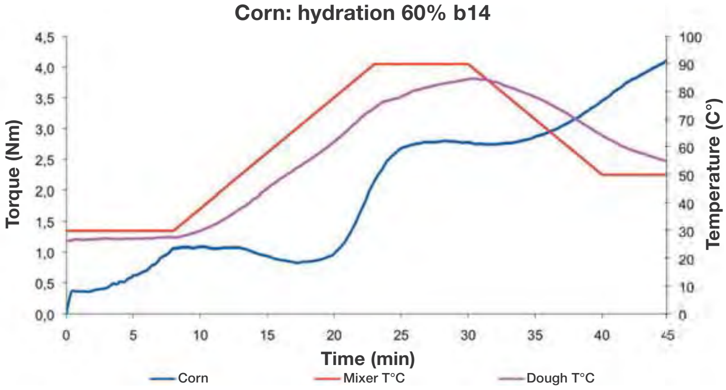
Test conducted with Chopin+ 100g protocol on pure flour

The protocol used for these tests is based on Chopin+ with the following modifications:

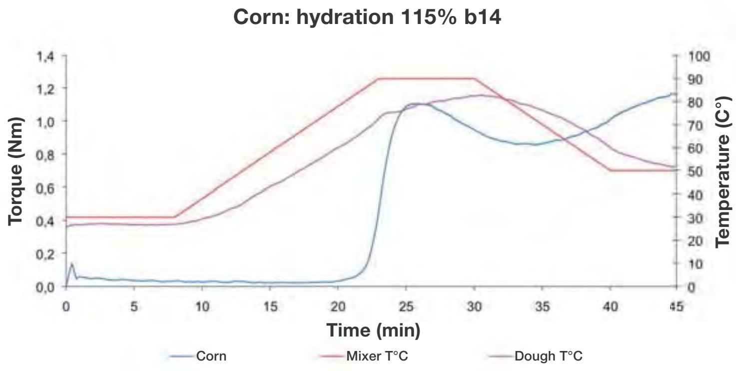
- Dough weight set to 100 grams.
- Two different hydrations: 60% b14 and 115% b14.

The results obtained demonstrate that the Mixolab® is perfectly able to analyse corn flours.

Corn: hydration 60% b14



Chopin+ 100g protocol	
Mixing speed	80 rpm
Hydration	60% ou 115% b14
Dough weight	100 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min



The results also demonstrate that adapting the hydration provide different information on the same sample:

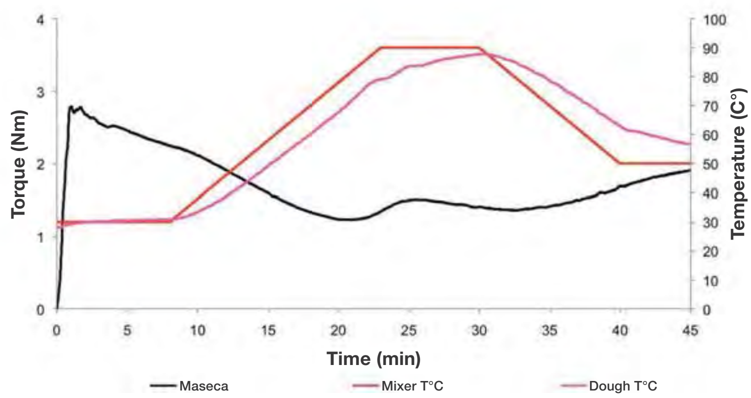
- Using a low hydration (approximately 60% b14), the user will get information on the "dough development at 30°C" phase.
- Using a high hydration (approximately 115% b14), the user will get more detailed information on the starch phase (gelatinization, liquefaction, gelling).

▶ Maseca

Maseca brand flour is a Mexican superior white corn flour used extensively in the production of pancakes, tortillas, etc. This flour is obtained via nixtamalization.

In a nixtamalization process, corn milling are soaked and cooked in an alkaline solution (usually limewater). It weakens the outer layer of the grain, making it easier to grind.

Test conducted with Chopin+ 90g protocol on pure flour



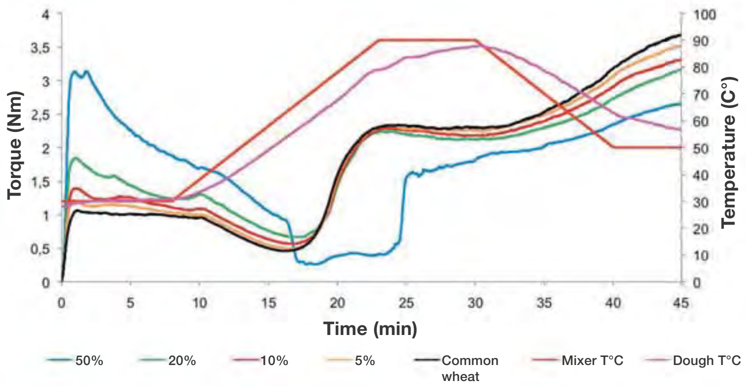
Chopin+ 90g protocol	
Mixing speed	80 rpm
Constant hydration	80% b14
Dough weight	90 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

The general shape of the curve for maseca differs from common wheat in the following aspects: a double peak at 30°C, low weakening acceleration at the start of heating and almost no gelatinization. This behavior may be a consequence of the nixtamalization process.

The first part of the curve (protein part) is similar to teff flour.

Blend: common wheat - maseca at constant hydration

Blends of maseca and common wheat flour (5%, 10%, 20% and 50%) were analyzed at constant hydration (53.3% base 14) with the Chopin+ protocol.



Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	53.3% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	1.06	0.41	2.25	2.17	3.45	1.1	7.27	1.84	0.08	1.28
5%	1.21	0.49	2.33	2.24	3.52	0.92	7.07	1.84	0.09	1.28
10%	1.39	0.57	2.29	2.17	3.31	1.05	5.30	1.72	0.12	1.14
20%	1.85	0.67	2.24	2.11	3.18	1.00	2.52	1.57	0.13	1.07
50%	3.14	0.26	1.64	1.57	2.66	1.83	2.47	1.38	0.07	1.09

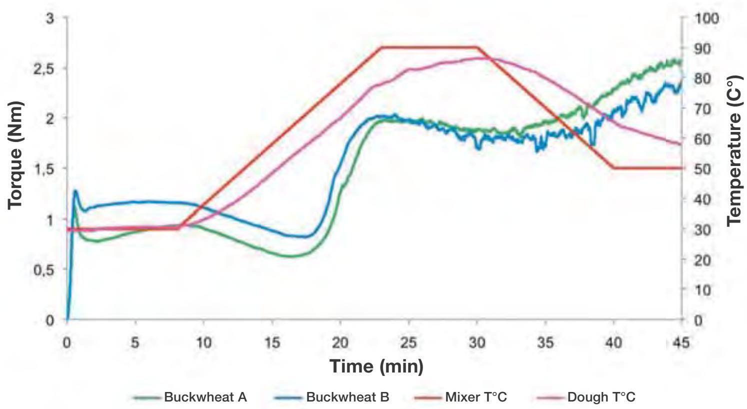
The drop observed at 50% between 17 and 25 minutes confirms the need to increase the amount of dough in the mixer (CHOPIN+ 90g protocol) for high maseca incorporation rates.

Incorporating maseca impacts the protein part significantly (weakening of the protein network). The impact on the starch part is less significant.

BUCKWHEAT

TECHNICAL DATA	
Category	Pseudocereal
Crop region	France, China
Diet type	All (gluten-free)
Benefits	Rich in protein Excellent source of minerals and vitamins
Main form of consumption	Flour for pancakes, breads, pasta

Test conducted with Chopin+ protocol on pure flour



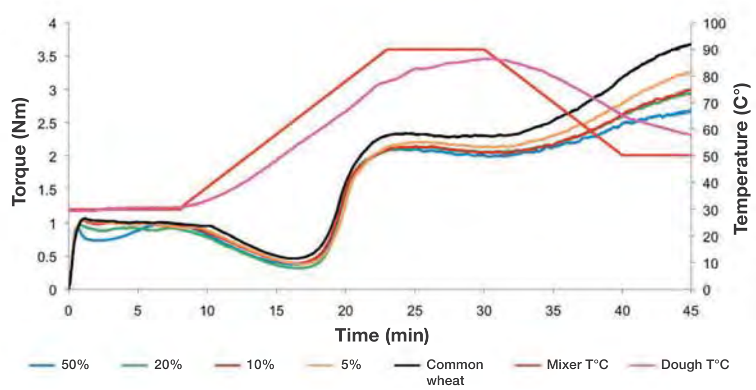
The general shape of the curve for buckwheat is similar to common wheat. However, the samples tested are characterized by a long dough development time (with a hydration peak in the first minute).

Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	53.3% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	WA (%b14)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Buckwheat A	53.3	0.94	0.63	1.98	1.85	2.57	8.22	11.52	1.35	0.13	0.72
Buckwheat B	53.3	1.16	0.82	2.03	1.89	2.36	5.88	11.85	1.21	0.14	0.47

Blend: common wheat – buckwheat A at constant hydration

Buckwheat flour A, incorporated with common wheat flour (5%, 10%, 20% and 50%) was analyzed at constant hydration (53.3% base 14) with the Chopin+ protocol.



Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	53.3% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	1.07	0.46	2.34	2.28	3.68	1.18	9.90	1.88	0.06	1.4
5%	1.04	0.38	2.21	2.13	3.28	0.98	9.25	1.83	0.08	1.15
10%	1.03	0.39	2.14	2.02	2.99	1.05	8.97	1.75	0.12	0.97
20%	0.96	0.31	2.13	2.04	2.95	0.85	8.83	1.82	0.09	0.91
50%	0.99	0.37	2.09	1.99	2.70	6.97	9.22	1.72	0.10	0.71

Incorporating buckwheat flour brings:

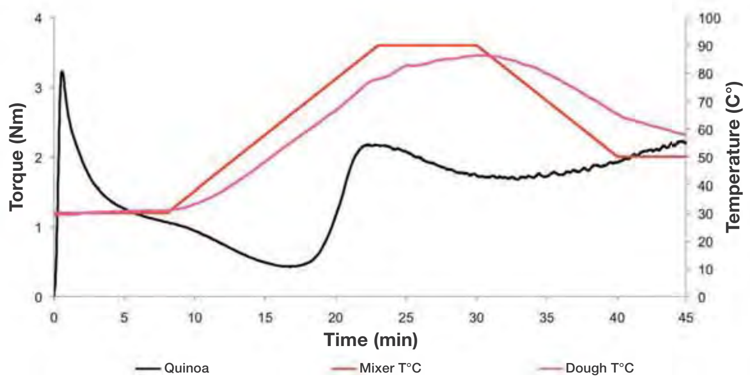
- A slightly lower hydration value (C1 decreases). At 50%, an absorption peak and a long development time are observed.
- A declining viscosity peak (C3 and C3-C2).
- A lower hot stability (C3-C4).
- A lower retrogradation (C5 and C5-C4).

Incorporating buckwheat flour mainly influences the first part of the curve with a relatively long dough development time (the initial hydration peak may be associated with a very low particle size of the flour).

✦ QUINOA ✦

TECHNICAL DATA	
Category	Pseudocereal
Crop region	South America (Peru, Bolivia, Ecuador)
Diet type	Not recommended for children under 2 years. Gluten-free
Benefits	Rich in protein and iron Excellent mineral supplement
Main form of consumption	Beer, pancakes Needs to be blended with wheat in preparations (high absorption capacity)

Test conducted with Chopin+ 90g protocol on pure flour



The general shape of the curve for quinoa is quite similar to common wheat with, however, a significant difference at the beginning of the curve (high hydration peak).

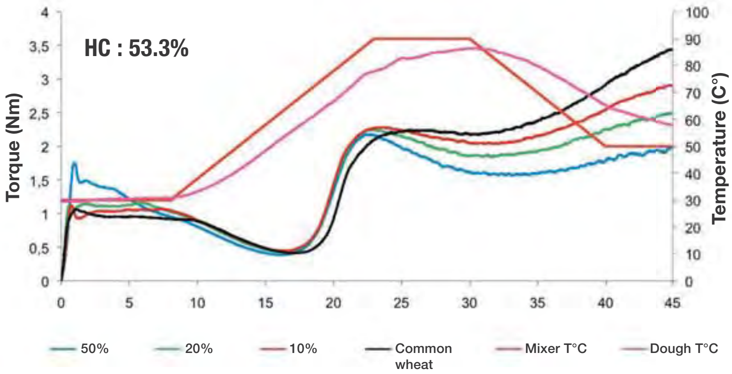
Chopin+ 90g protocol	
Mixing speed	80 rpm
Constant hydration	55% b14
Dough weight	90 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

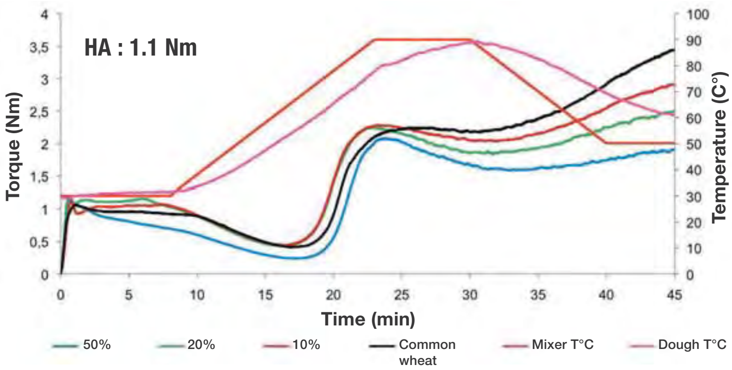
WA (%b14)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
55	3.22	0.43	2.17	1.67	2.22	0.58	0.5	1.74	0.5	0.55

Blend: common wheat - quinoa at constant and adapted hydration

Quinoa flour incorporated with common wheat flour (10%, 20% and 50%) was first analyzed at constant hydration (53.3% base 14) with the Chopin+ protocol.

	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	1.06	0.41	2.25	2.17	3.45	1.1	7.27	1.84	0.08	1.28
10%	1.12	0.45	2.28	2.04	2.90	0.73	0.75	1.83	0.24	0.86
20%	1.12	0.43	2.25	1.83	2.49	0.67	8.62	1.82	0.42	0.66
50%	1.75	0.39	2.18	1.56	1.95	0.97	0.62	1.79	0.62	0.39





Chopin+ protocol	
Mixing speed	80 rpm
Constant / adapted hydration	53.3% b14 / 1.1 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Blends in the same proportions (quinoa/common wheat) were also analyzed at adapted hydration (1.1 Nm) to better study the rheological properties of the flour.

	WA (%b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	53.3	0.41	2.25	2.17	3.45	1.1	7.27	1.84	0.08	1.28
10%	53.4	0.45	2.28	2.04	2.90	0.73	0.75	1.83	0.24	0.86
20%	53.4	0.43	2.25	1.83	2.49	0.67	8.62	1.82	0.42	0.66
50%	56	0.24	2.08	1.58	1.91	0.60	1.28	1.84	0.50	0.33

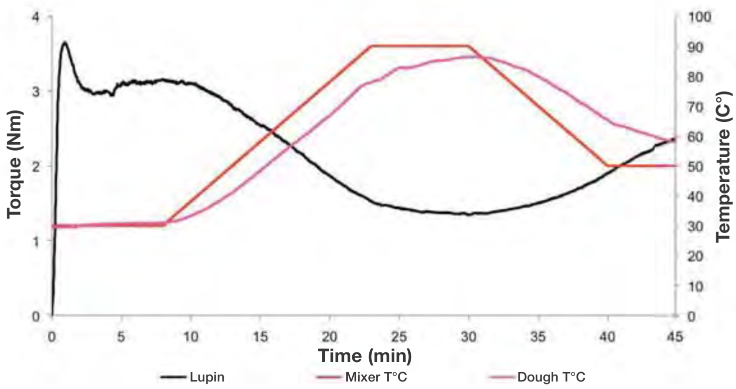
The impact of incorporating quinoa flour can be seen on the first part of the curve (hydration and stability when the incorporation rate is greater than 20%) and the second part of the curve (essentially the hot stability and retrogradation).

9.2 ▶ Legumes

✦ LUPIN ✦

TECHNICAL DATA	
Category	Legume
Crop region	Central Europe
Diet type	All (gluten-free)
Benefits	Very rich in protein and fibre Very good emulsifying capacity (partial or total replacement of eggs in brioches)
Main form of consumption	Viennese-style pastries, cookies, high-protein breads, brioche, cakes, pancakes

Test conducted with Chopin+ 90g protocol on pure flour



The general shape of the curve for lupin is different from common wheat flour. It is characterized by a big protein weakening at the start of heating and a lack of gelatinization. These properties (attributed to the lack of starch in lupin) are also observed in amaranth flour.

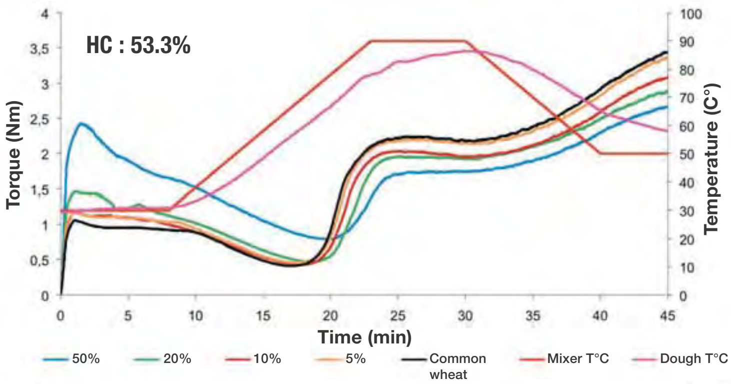
Chopin+ 90g protocol	
Mixing speed	80 rpm
Constant hydration	53.3% b14
Dough weight	90 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

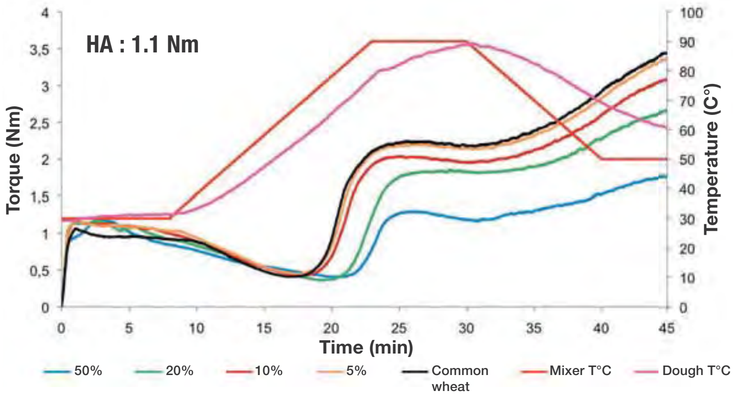
WA (%b14)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
53.3	3.65	2.97	3.14	1.38	2.37	0.93	1.40	0.17	1.76	0.99

Blend: common wheat - lupin at constant and adapted hydration

Lupin flour incorporated with common wheat flour (5%, 10%, 20% and 50%) was first analyzed at constant hydration (53.3% base 14) with the Chopin+ protocol.

	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	1.06	0.41	2.25	2.17	3.45	1.10	7.27	1.84	0.08	1.28
5%	1.18	0.45	2.20	2.13	3.38	1.10	8.42	1.75	0.07	1.25
10%	1.18	0.43	2.04	1.94	3.10	1.02	7.00	1.61	0.1	1.16
20%	1.47	0.47	1.96	1.92	2.90	1.18	3.28	1.49	0.04	0.98
50%	2.43	0.79	1.37	1.74	2.67	1.50	2.70	0.583	-0.36	0.93





Chopin+ protocol	
Mixing speed	80 rpm
Constant / adapted hydration	53.3% b14 / 1.1 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Blends in the same proportions (lupin/common wheat) were also analyzed at adapted hydration (1.1 Nm) for a better study of the rheological properties of the flour.

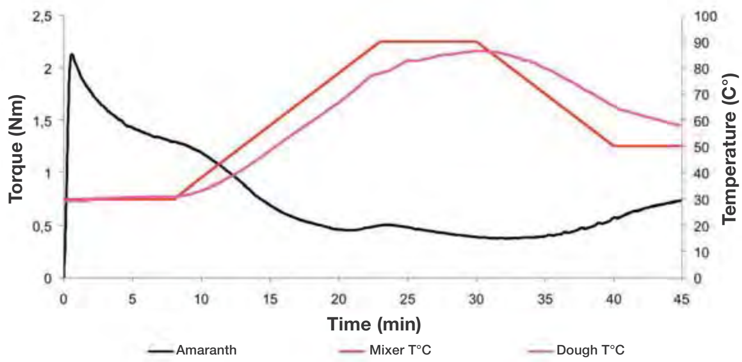
	WA (%b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	53.3	0.41	2.25	2.17	3.45	1.1	7.27	1.84	0.08	1.28
5%	53.3	0.45	2.20	2.13	3.38	1.10	8.45	1.75	0.07	1.25
10%	53.3	0.43	2.04	1.94	3.10	1.02	7.00	1.61	0.10	1.16
20%	56.0	0.36	1.85	1.81	2.68	2.75	5.80	1.49	0.04	0.87
50%	66.0	0.41	1.30	1.16	1.76	2.57	3.28	0.89	0.14	0.60

Incorporating lupin flour influences both the first part of the curve (much higher water absorption capacity and slower dough development time) and the second part (very pronounced decrease in gelatinization C3-C2 and a shift of C2 over time when the amount of flour is greater than 20%). This impact on the starch part may be explained by a decrease in the overall starch content in the blend, since lupin does not contain starch.

AMARANTH

TECHNICAL DATA	
Category	Legume
Crop region	Central and South America
Diet type	All (gluten-free)
Benefits	Rich in protein, iron and calcium Hazelnut flavour
Main form of consumption	Pastries, cookies and breads

Test conducted with Chopin+ protocol on pure flour



The general shape of the curve for amaranth is different from common wheat flour. It is characterized by a high protein weakening and a low/non-existent gelatinization (very slight rebound at 23 minutes). This type of curve is very similar to lupin flour.

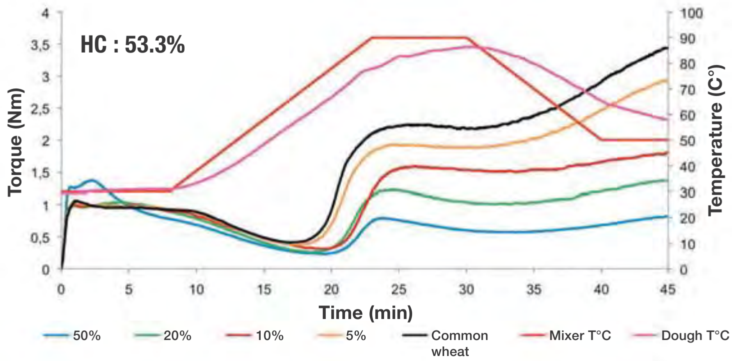
Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	53.3% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

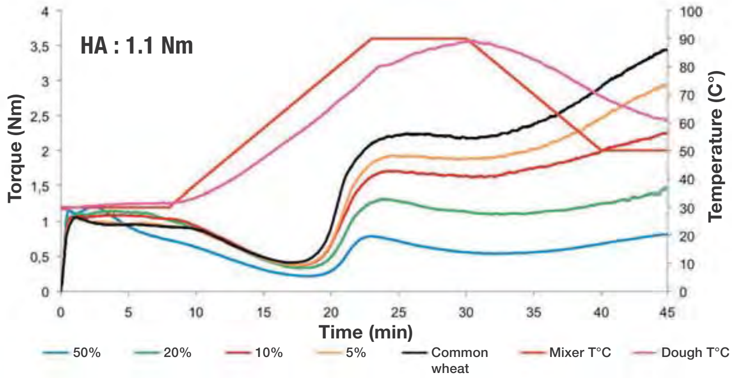
WA (%b14)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
53.30	2.13	0.37	0.50	0.39	0.74	0.58	1.17	0.13	0.11	0.36

Blend: common wheat - amaranth at constant and adapted hydration

Amaranth flour incorporated with common wheat flour (5%, 10%, 20% and 50%) was first analyzed at constant hydration (53.3% base 14) with the Chopin+ protocol.

	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	1.06	0.41	2.25	2.17	3.45	1.1	7.27	1.84	0.08	1.28
5%	1.05	0.37	1.93	1.88	2.94	1.15	9.15	1.56	0.05	1.06
10%	1.00	0.31	1.59	1.50	1.82	0.93	9.20	1.28	0.09	0.32
20%	1.03	0.26	1.23	1.00	1.38	4.20	7.52	0.97	0.23	0.38
50%	1.37	0.24	0.79	0.57	0.83	2.23	3.22	0.55	0.22	0.26





Chopin+ protocol	
Mixing speed	80 rpm
Constant / adapted hydration	53.3% b14 / 1.1 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Blends in the same proportions (amaranth/common wheat) were also analyzed at adapted hydration (1.1 Nm) to better study the rheological properties of the flour.

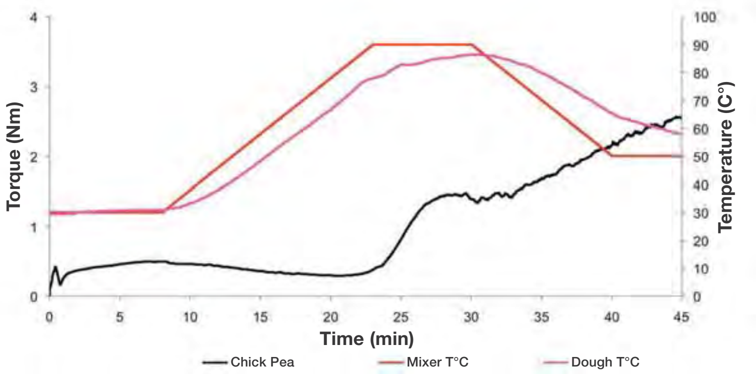
	WA (%b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	53.3	0.41	2.25	2.17	3.45	1.1	7.27	1.84	0.08	1.28
5%	53.3	0.37	1.93	1.88	2.94	1.15	9.15	1.56	0.05	1.06
10%	52.0	0.37	1.71	1.61	2.27	3.43	9.32	1.34	0.10	0.66
20%	52.0	0.33	1.32	1.10	1.49	3.73	7.95	0.99	0.22	0.39
50%	54.5	0.22	0.79	0.54	0.83	0.57	3.28	0.57	0.25	0.29

Incorporating amaranth impacts significantly the second part of the Mixolab® curve (starch part). This effect is proportional to the amount of amaranth incorporated. It could be explained simply by a lower overall starch content in the blend. The impact on the first part of the curve is more variable: at low levels, it tends to reinforce the protein network stability; however, at high levels, the opposite effect is observed.

✦ CHICK PEA ✦

TECHNICAL DATA	
Category	Legume
Crop region	India, Spain, Turkey, Maghreb, Southern France, Canada
Diet type	All (gluten-free)
Benefits	High carbohydrate and plant protein content Rich in vitamin B, minerals and dietary fibre
Main form of consumption	Pastries, breads, pancakes

Test conducted with Chopin+ 90g protocol on pure flour



The general shape of the curve for chick pea is different from common wheat flour. This atypical curve is characterized by:

- A hydration peak at 30°C.
- A low consistency.
- A long development time.
- A high rise during cooling.

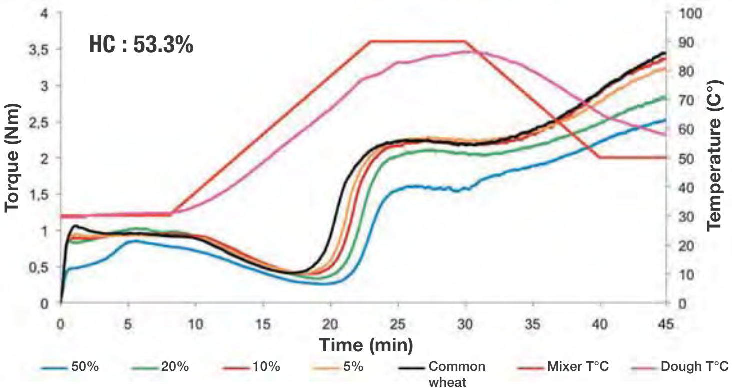
Chopin+ 90g protocol	
Mixing speed	80 rpm
Constant hydration	55% b14
Dough weight	90 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

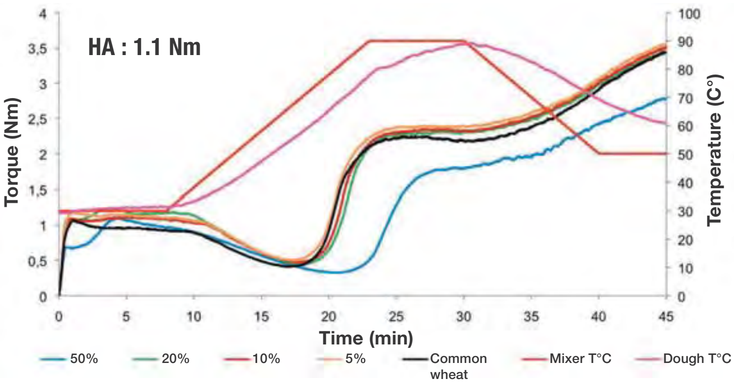
WA (%b14)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
55	0.5	0.3	1.43	1.36	2.53	6.97	11.73	1.13	0.07	1.17

Blend: common wheat – chick pea flour at constant and adapted hydration

Chick pea flour incorporated with common wheat flour (5%, 10%, 20% and 50%) was first analyzed at constant hydration (53.3% base 14) with the Chopin+ protocol.

	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	1.06	0.41	2.25	2.17	3.45	1.10	7.27	1.84	0.08	1.28
5%	0.95	0.41	2.28	2.22	3.25	1.02	11.17	1.87	0.06	1.03
10%	0.96	0.40	2.24	2.17	3.37	6.42	11.33	1.84	0.07	1.2
20%	1.02	0.34	2.11	2.03	2.84	5.70	7.75	1.77	0.08	0.81
50%	0.85	0.26	1.61	1.53	2.53	5.58	5.38	1.35	0.08	1.00





Chopin+ protocol	
Mixing speed	80 rpm
Constant / adapted hydration	53.3% b14 / 1.1 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Blends in the same proportions (chick pea/common wheat) were also analyzed at adapted hydration (1.1 Nm) to better study the rheological properties of the flour.

	WA (%b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	53.3	0.41	2.25	2.17	3.45	1.10	7.27	1.84	0.08	1.28
5%	51.5	0.50	2.22	2.39	3.58	0.95	10.60	1.72	-0.17	1.18
10%	51.5	0.47	2.13	2.33	3.52	5.45	10.95	1.66	-0.19	1.19
20%	50.0	0.44	2.10	2.30	3.45	0.67	11.35	1.66	-0.20	1.15
50%	49.0	0.32	1.71	1.79	2.79	4.35	5.50	1.39	-0.08	0.99

The impact on the protein part is seen after adding low chick pea levels whereas, on the starch part, the influence is seen at high levels.

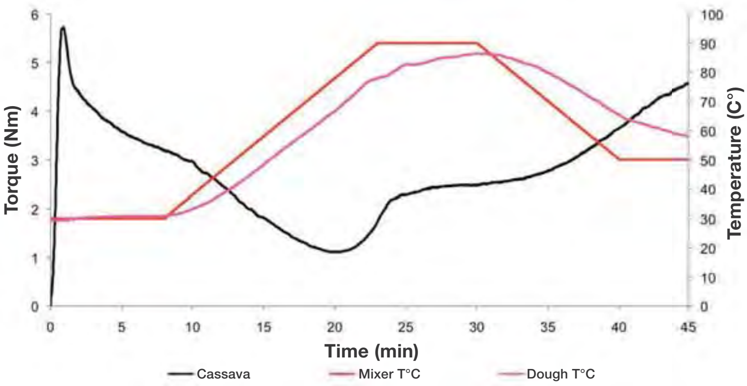
As a general rule, the effect of chick pea appears to be less pronounced in blends compared to the other legumes previously studied (lupin and amaranth).

9.3 ▶ Roots

✦ CASSAVA ✦

TECHNICAL DATA	
Category	Root
Crop region	Africa, Asia and Central America
Diet type	All (gluten-free)
Benefits	Rich in starch Low in protein
Main form of consumption	Breads, pancakes, semolina, tortillas, beer, pastries

Test conducted with Chopin+ 90g protocol on pure flour



The general shape of the curve for cassava differs from common wheat at the beginning of the curve (water absorption peak) and on the starch part (a low gelatinization capacity (C3-C2)). This type of curve is similar to quinoa flour.

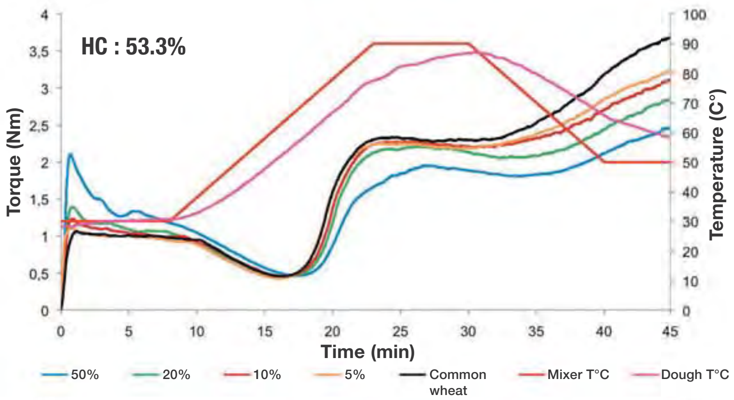
Chopin+ 90g protocol	
Mixing speed	80 rpm
Constant hydration	55% b14
Dough weight	90 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

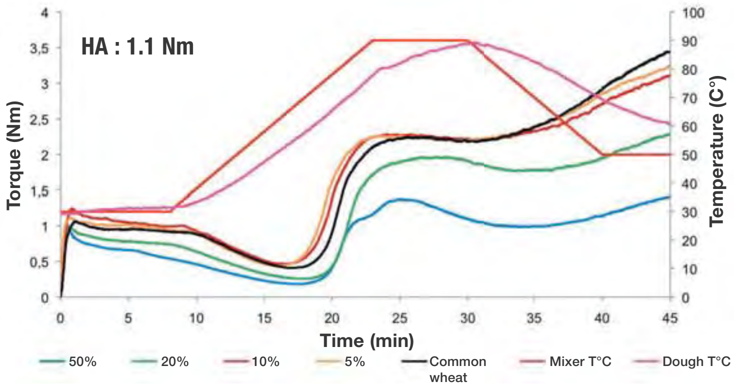
WA (%b14)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
55	5.73	1.11	2.29	2.49	4.57	0.92	0.87	1.18	-0.2	2.08

Blend: common wheat – cassava flour at constant and adapted hydration

Cassava flour incorporated with common wheat flour (5%, 10%, 20% and 50%) was first analyzed at constant hydration (53.3% base 14) with the Chopin+ protocol.

	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	1.06	0.41	2.25	2.17	3.45	1.10	7.27	1.84	0.08	1.28
5%	1.11	0.43	2.26	2.18	3.25	0.75	7.17	1.83	0.08	1.07
10%	1.24	0.46	2.28	2.20	3.12	0.85	3.42	1.82	0.08	0.92
20%	1.39	0.45	2.21	2.05	2.86	0.80	1.55	1.76	0.16	0.81
50%	2.10	0.47	1.96	1.81	2.47	0.70	1.17	1.49	0.15	0.66





Chopin+ protocol	
Mixing speed	80 rpm
Constant / adapted hydration	53.3% b14 / 1.1 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Blends in the same proportions (cassava/common wheat) were also analyzed at adapted hydration (1.1 Nm) to better study the rheological properties of the flour.

	WA (%b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Dev. time (min)	Stability (min)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Common wheat	53.3	0.41	2.25	2.17	3.45	1.10	7.27	1.84	0.08	1.28
5%	53.3	0.43	2.26	2.18	3.25	0.75	7.17	1.83	0.08	1.07
10%	54.9	0.47	2.29	2.23	3.55	1.07	9.90	1.82	0.06	1.32
20%	57.0	0.25	1.96	1.76	2.29	0.55	1.62	1.71	0.20	0.53
50%	67.5	0.18	1.38	0.98	1.41	0.50	0.53	1.20	0.40	0.43

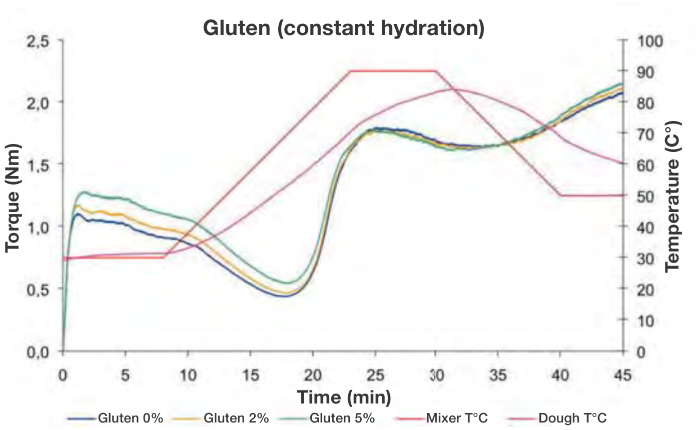
Incorporating cassava impacts the protein part (hydration and stability) and the starch part (low gelatinization and retrogradation capacity) when the incorporation is greater than 20%.

10 ❖ EFFECT OF ADDITIVES AND ENZYMES

10.1 ▶ Gluten

10.1.1 At constant hydration

It is generally accepted that adding gluten influences dough rheological properties and as a consequence finished product quality. The Mixolab® can be used to highlight these differences in rheological properties.



Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration (C1)	56.4% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	Gluten 0%	Gluten 1%	Gluten 2%	Gluten 3%	Gluten 4%	Gluten 5%
C1 (Nm)	1.1	1.13	1.17	1.18	1.24	1.28
C2 (Nm)	0.44	0.46	0.46	0.49	0.51	0.55
C3 (Nm)	1.8	1.81	1.78	1.76	1.78	1.78
C4 (Nm)	1.64	1.66	1.62	1.61	1.6	1.61
C5 (Nm)	2.08	2.14	2.11	2.12	2.12	2.16
Stability (min)	5.7	6.3	6.0	6.9	6.7	7.0

At constant hydration, the effect of gluten is seen as:

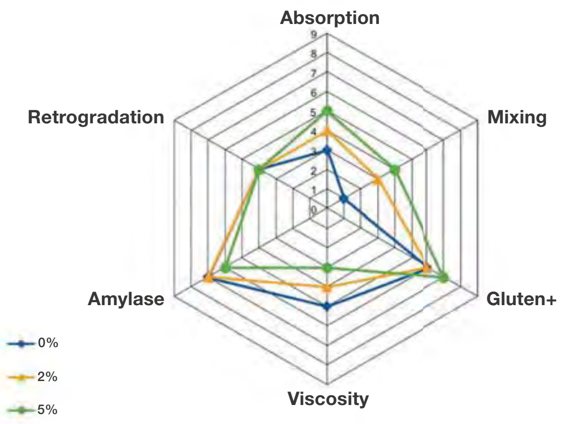
- An increase in C1 and, consequently, in the water absorption capacity.
- An increase in minimum consistency (C2), showing reduced weakening as temperature rises.
- Similar C3, C4 and C5 values. No modification in the “starch” phase of the curve.
- Improved stability.

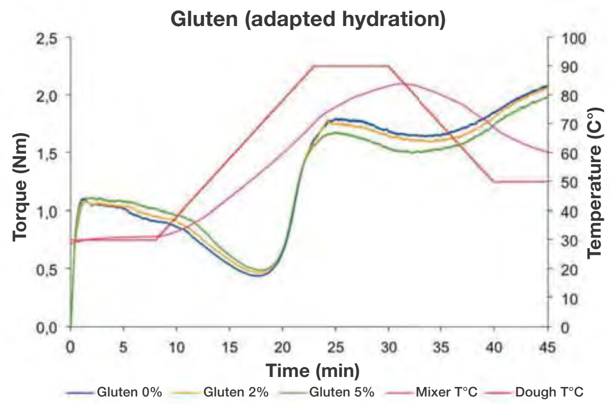
10.1.2 At adapted hydration

At adapted hydration, the effect of gluten is seen as:

- An increase in water absorption capacity.
- An increase in minimum consistency (C2), showing reduced weakening as temperature rises.
- Improved stability.
- A decrease in parameters C3, C4 and C5, showing a slight decrease in hot viscosity when gluten is added. There are 2 possible causes for this observation:
  - Gluten/starch interactions, reducing starch gel viscosity.
  - Larger volume of water modifying behavior during gelatinization (and possibly water getting out of proteins during heating).

Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min





	Gluten 0%	Gluten 1%	Gluten 2%	Gluten 3%	Gluten 4%	Gluten 5%
Hydration % (14% base)	56.40	56.80	57.20	57.40	58	58.50
C2 (Nm)	0.44	0.45	0.46	0.46	0.46	0.49
C3 (Nm)	1.8	1.79	1.79	1.73	1.69	1.68
C4 (Nm)	1.64	1.64	1.59	1.54	1.51	1.49
C5 (Nm)	2.08	2.13	2.07	2.02	1.99	1.98
Stability (min)	5.7	7.6	8.1	8.2	8.3	9.2

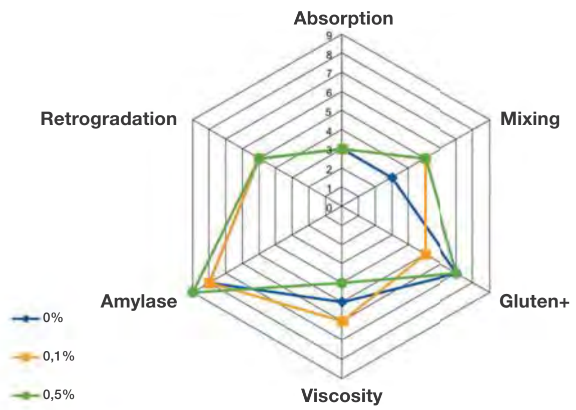
	Gluten 0%	Gluten 1%	Gluten 2%	Gluten 3%	Gluten 4%	Gluten 5%
Absorption	3	3	4	4	5	5
Mixing	1	3	3	3	3	4
Gluten+	6	7	6	6	6	7
Viscosity	5	5	4	4	4	3
Amylase	7	7	7	6	7	6
Retrogradation	4	4	4	4	4	4

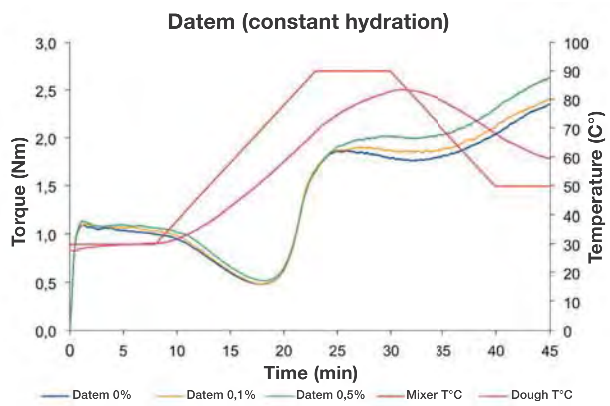
When gluten addition is combined to hydration correction (common during bread-making), it frequently modifies the behavior of the protein and starch fractions (modification of starch fraction behavior is not observed under constant hydration conditions).

10.2 ▶ Emulsifiers (Datem)

DATEM (DiAcetylTartric Esters of Monoglycerides) are mixture of fatty acids. They are synthetic emulsifiers used as enhancers in bread-making. Their use gives more soft doughs, able to support more vigorous mixing and ensuring better gas retention. They are also used to increase bread volume. The Mixolab® can be used to highlight behavior differences induced by DATEM addition.

Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	56.4% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min





	Datem 0%	Datem 0.1%	Datem 0.2%	Datem 0.3%	Datem 0.4%	Datem 0.5%
C1 (Nm)	1.11	1.11	1.1	1.1	1.16	1.14
C2 (Nm)	0.48	0.48	0.49	0.5	0.51	0.52
C3 (Nm)	1.87	1.91	1.93	1.7	1.59	1.65
C4 (Nm)	1.76	1.85	1.85	1.96	1.98	2.02
C5 (Nm)	2.36	2.41	2.44	2.55	2.53	2.63
C3-C4 (Nm)	0.11	0.06	0.08	-0.26	-0.39	-0.37
Stability (min)	9.4	9.9	10.2	10.2	10.3	10.4

	Datem 0%	Datem 0.1%	Datem 0.2%	Datem 0.3%	Datem 0.4%	Datem 0.5%
Absorption	3	3	3	3	3	3
Mixing	3	5	5	5	5	5
Gluten+	7	5	6	6	6	7
Viscosity	5	6	6	4	2	4
Amylase	8	8	8	8	9	9
Retrogradation	5	5	5	5	5	5

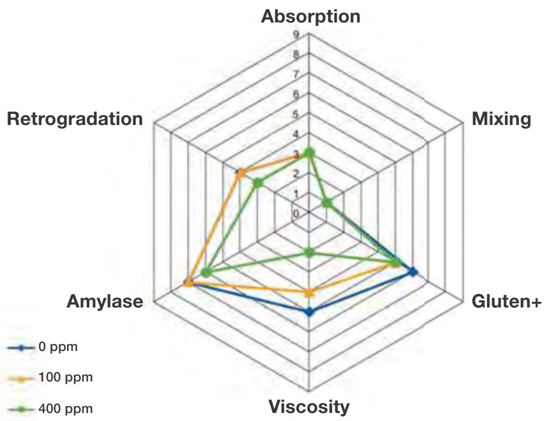
In the Mixolab®, DATEM action is characterized by:

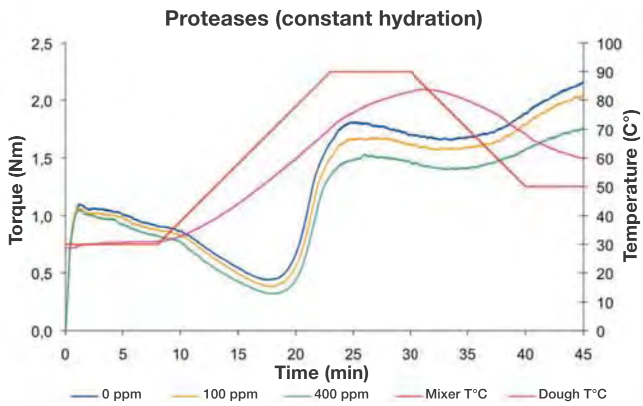
- A slight increase in C2, showing a strengthening of the gluten network.
- A decrease in the C3-C4 difference, showing starch paste stabilization and higher hot resistance.
- A progressive increase in dough stability, confirming the protein network improvement suggested by C2 value.

10.3 ▶ Proteases

Proteases are enzymes that break down proteins by breaking peptide bonds (weakening the gluten network). Proteases are used in biscuit making to reduce dough tenacity. They are also used to correct, in a more or less controlled way dough machinability, extensibility, viscosity and development time. The Mixolab® can be used to highlight behavior differences induced by protease addition.

Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	56.6% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min



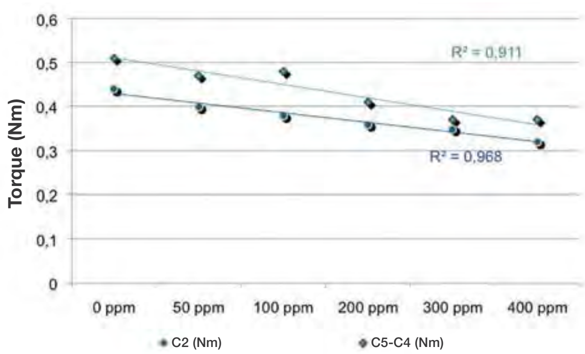


	0 ppm	50 ppm	100 ppm	200 ppm	300 ppm	400 ppm
C1 (Nm)	1.1	1.09	1.07	1.07	1.12	1.05
C2 (Nm)	0.44	0.4	0.38	0.36	0.35	0.32
C3 (Nm)	1.81	1.74	1.68	1.62	1.58	1.53
C4 (Nm)	1.65	1.61	1.56	1.51	1.45	1.4
C5 (Nm)	2.16	2.08	2.04	1.92	1.82	1.77
C3-C4 (Nm)	0.16	0.13	0.12	0.11	0.13	0.13
C5-C4 (Nm)	0.51	0.47	0.48	0.41	0.37	0.37
Stability (min)	5.7	5.4	5.5	4.9	4.3	4.8

	0 ppm	50 ppm	100 ppm	200 ppm	300 ppm	400 ppm
Absorption	3	3	3	3	3	3
Mixing	1	1	1	1	1	1
Gluten+	6	6	5	5	4	5
Viscosity	5	4	4	3	2	2
Amylase	7	7	7	7	6	6
Retrogradation	4	4	4	3	3	3

In the Mixolab®, protease action is characterized by:

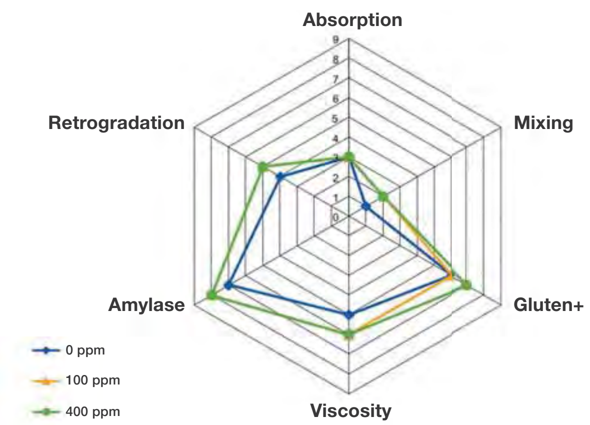
- A progressive decrease in C2 and stability, revealing a deterioration of the protein network.
- A decrease in hot viscosity (C3), that may be linked to altered water distribution.
- A constant C3-C4 difference, indicating unchanged diastasic activity.
- A decrease in the C5-C4 difference, indicating weaker starch gelling (retrogradation).

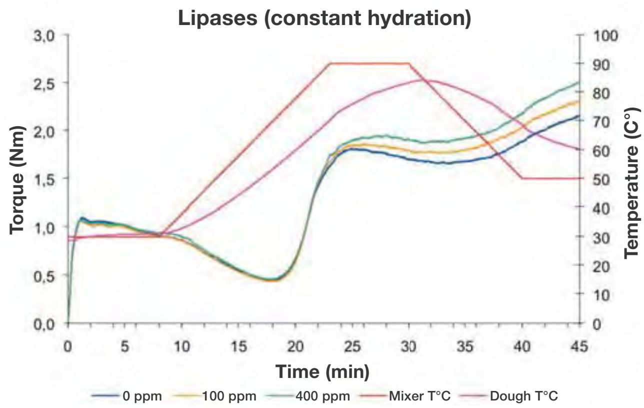


10.4 ▶ Lipases

Lipases hydrolyze lipids. Flour triglyceride hydrolysis leads to the formation of mono or diglycerides that are then oxidized by lipoxygenase. Creating hydroperoxides can then oxidize the thiol groups on proteins, creating disulfide bridges and reinforcing the gluten network. Lipase can be used in bread-making to improve bread volume, cell regularity and crumb whitening. The Mixolab® can be used to highlight behavior differences induced by lipase addition.

Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	56.6% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min





	0 ppm	50 ppm	100 ppm	200 ppm	300 ppm	400 ppm
C1 (Nm)	1.1	1.11	1.07	1.11	1.09	1.08
C2 (Nm)	0.44	0.43	0.44	0.45	0.44	0.45
C3 (Nm)	1.81	1.84	1.87	1.89	1.93	1.95
C4 (Nm)	1.65	1.71	1.76	1.81	1.84	1.87
C5 (Nm)	2.16	2.21	2.32	2.41	2.46	2.52
C3-C2 (Nm)	1.37	1.41	1.43	1.44	1.49	1.5
C3-C4 (Nm)	0.16	0.13	0.11	0.08	0.09	0.08
Stability (min)	5.7	5.7	6.1	6.1	6.3	7.8

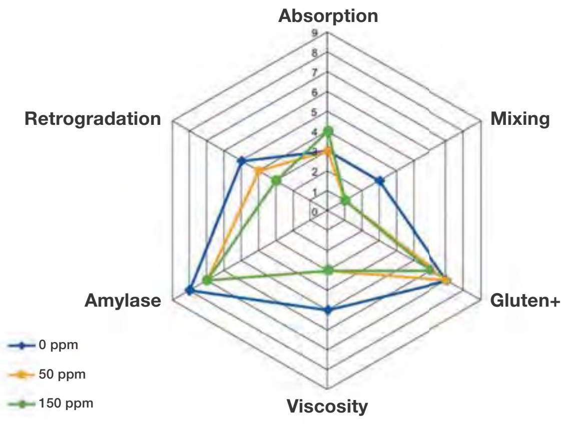
	0 ppm	50 ppm	100 ppm	200 ppm	300 ppm	400 ppm
Absorption	3	3	3	3	3	3
Mixing	1	1	2	1	2	2
Gluten+	6	6	6	7	6	7
Viscosity	5	5	6	6	6	6
Amylase	7	8	8	8	8	8
Retrogradation	4	4	5	5	5	5

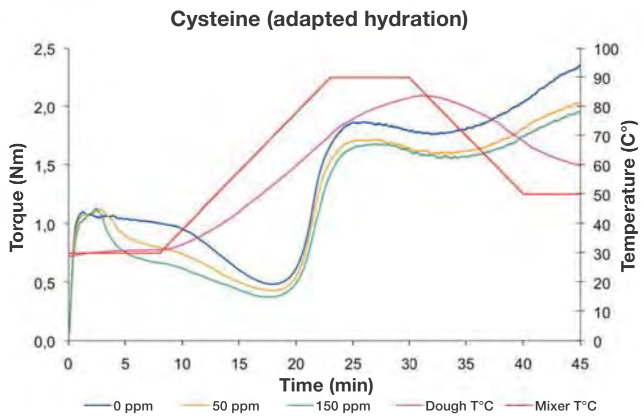
In the Mixolab®, lipase action is characterized by:

- Improved stability, for a constant C2 (formation of disulfide bridges).
- An increase in C3, combined with a decrease in the C3-C4 difference, showing starch paste stabilization and higher hot resistance. The effect of lipase on the C3, C4 and C5 parameters is similar to Datem due to the formation of mono or diglycerides.

10.5 ▶ Cysteine

Cysteine is an amino acid with a thiol (-SH) group. It is used as a reduction agent (reduction of disulfide bridges binding the gluten proteins). It accelerates dough development. It is commonly used in biscuit making, where extensible and non-elastic doughs are expected. The Mixolab® can be used to highlight behavior differences induced by cysteine addition.





Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	0 ppm	50 ppm	75 ppm	100 ppm	125 ppm	150 ppm
Hydration % (14% base)	56.4	57.0	57.1	57.2	57.8	57.4
C2 (Nm)	0.48	0.43	0.44	0.42	0.38	0.37
C3 (Nm)	1.87	1.72	1.74	1.71	1.69	1.68
C4 (Nm)	1.76	1.6	1.63	1.59	1.53	1.56
C5 (Nm)	2.36	2.04	2.12	2.07	1.96	1.97
C3-C2 (Nm)	1.39	1.29	1.3	1.29	1.31	1.31
C3-C4 (Nm)	0.11	0.12	0.11	0.12	0.16	0.12
C5-C4 (Nm)	0.6	0.44	0.49	0.48	0.43	0.41
Stability (min)	9.4	3.5	3.5	2.8	2.5	2.3

	0 ppm	50 ppm	75 ppm	100 ppm	125 ppm	150 ppm
Absorption	3	3	3	4	4	4
Mixing	3	1	1	1	1	1
Gluten+	7	7	7	6	6	6
Viscosity	5	3	4	3	3	3
Amylase	8	7	7	7	7	7
Retrogradation	5	4	4	4	3	3

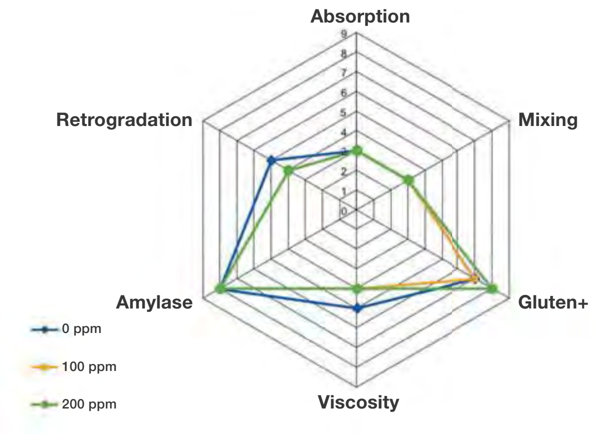
In the Mixolab®, cysteine action is characterized by:

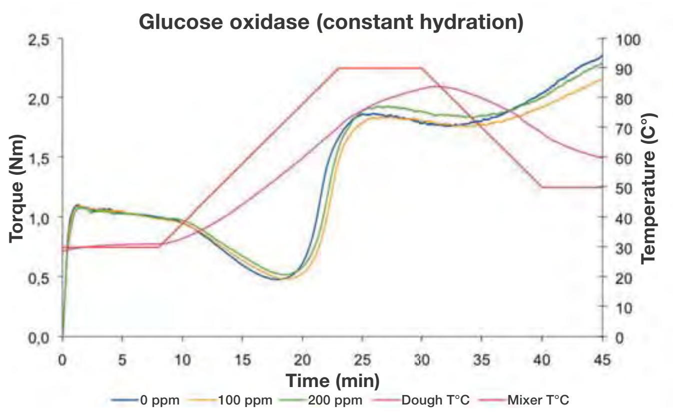
- A clear drop (from a dose of 50 ppm) in stability and C2, reflecting the reduced strength of the protein network.
- A decrease in C3 and the C3-C2 difference between the doses of 0 and 50 ppm, then becoming constant. Cysteine appears to slightly modify the hot viscosity potential.
- A constant C3-C4 difference; there is no action on diastatic activity.
- A decrease in the C5-C4 difference between the doses of 0 and 50 ppm, then remaining constant.

10.6 ▶ Glucose oxidase

Glucose oxidase catalyzes the oxidation of glucose to gluconic acid. This oxidation process induces a series of reactions leading to protein oxidation. The disulfide bridges formed reinforce the gluten network, increasing the mixing dough resistance.
The addition of glucose oxidase improves dough workability (increased elasticity and resistance during mixing, decreased tack during working, increased tolerance when placing in oven, etc.).

Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	56.6% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min





	0 ppm	25 ppm	50 ppm	100 ppm	150 ppm	200 ppm
C1 (Nm)	1.1	1.1	1.08	1.1	1.11	1.09
C2 (Nm)	0.44	0.48	0.48	0.49	0.52	0.52
C3 (Nm)	1.81	1.79	1.82	1.84	1.88	1.93
C4 (Nm)	1.65	1.74	1.73	1.76	1.8	1.83
C5 (Nm)	2.16	2.09	2.12	2.16	2.21	2.3
C3-C2 (Nm)	1.37	1.31	1.34	1.35	1.36	1.41
C3-C4 (Nm)	0.16	0.05	0.09	0.08	0.08	0.1
C5-C4 (Nm)	0.51	0.35	0.39	0.4	0.41	0.47
Stability (min)	5.7	9.4	9.4	9.2	9.9	10.2

	0 ppm	25 ppm	50 ppm	100 ppm	150 ppm	200 ppm
Absorption	3	3	3	3	3	3
Mixing	3	4	3	3	4	3
Gluten+	7	7	7	7	7	8
Viscosity	5	3	4	4	4	4
Amylase	8	8	8	8	8	8
Retrogradation	5	4	4	4	4	4

In the Mixolab®, Glucose Oxidase action is characterized by:

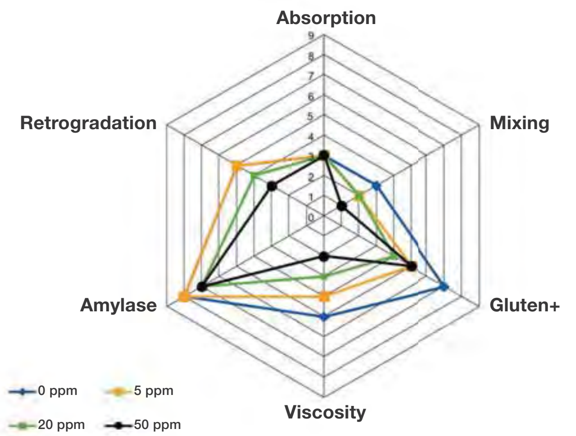
➲ A slight increase in C2 and stability, evidence of the strengthening of the protein network.

➲ Unchanged C3-C2, C3-C4, C5-C4 differences, showing that glucose oxidase has little effect on the starch phase.

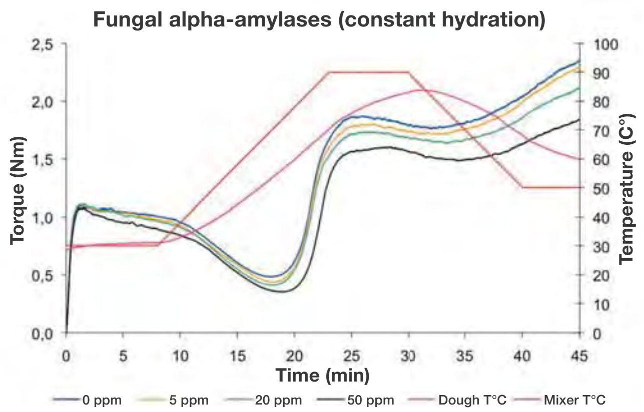
10.7 ▶ Amylases

10.7.1 Fungal amylases

α-amylases are endo-enzymes that hydrolyze starch by randomly breaking the α-(1,4) glycoside bonds on the amylose and amylopectin chains. When the endogenous α-amylase activity is too low (insufficient production of fermentable sugars), then fungal α-amylases, with an optimum activity temperature around 50°C, can be added. The Mixolab® can be used to highlight behavior differences induced by fungal α-amylase addition.



Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	56.4% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min



	0 ppm	5 ppm	10 ppm	20 ppm	30 ppm	50 ppm
C1 (Nm)	1.11	1.11	1.14	1.11	1.13	1.08
C2 (Nm)	0.48	0.44	0.46	0.41	0.38	0.35
C3 (Nm)	1.87	1.8	1.79	1.73	1.69	1.6
C4 (Nm)	1.76	1.71	1.68	1.63	1.58	1.48
C5 (Nm)	2.36	2.3	2.26	2.11	2.03	1.84
C3-C2 (Nm)	1.39	1.36	1.33	1.32	1.31	1.25
C5-C4 (Nm)	0.6	0.59	0.58	0.48	0.45	0.36
Stability (min)	9.4	8.5	8.3	7.4	5.9	5.4

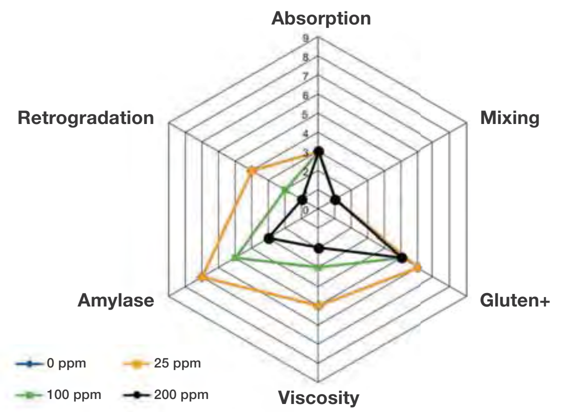
	0 ppm	5 ppm	10 ppm	20 ppm	30 ppm	50 ppm
Absorption	3	3	3	3	3	3
Mixing	3	2	2	2	1	1
Gluten+	7	5	5	4	3	5
Viscosity	5	4	5	3	3	2
Amylase	8	8	8	7	7	7
Retrogradation	5	5	5	4	4	3

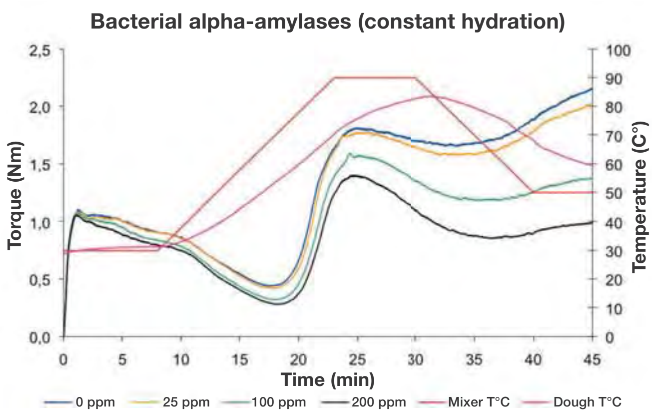
In the Mixolab®, fungal α-amylase action is characterized by:

- A drop in C2 and stability, showing a rapid action by release of water molecules in the dough (softening effect). Secondary activities could also be the source of these changes (e.g.: proteolytic activity).
- A clear drop in C3, showing the effect of starch hydrolysis up to 50°C.
- A decrease in retrogradation (C5-C4) that can be attributed to the presence of larger amounts of dextrins (produced by partial starch hydrolysis) in the dough.

10.7.2 Bacterial amylases

When flour diastasic activity is too weak (insufficient production of fermentable sugars), exogenous α-amylases may be added. Due to their high optimum activity temperature (between 50°C and 80°C), bacterial α-amylases are considered as anti-staling enzymes. Indeed, by breaking down starch, α-amylases slow the retrogradation process and delay staling. The Mixolab® can be used to highlight behavior differences induced by bacterial α-amylase addition.





Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	56.6% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	0 ppm	25 ppm	50 ppm	100 ppm	150 ppm	200 ppm
C1 (Nm)	1.1	1.09	1.1	1.08	1.07	1.06
C2 (Nm)	0.44	0.42	0.36	0.32	0.29	0.28
C3 (Nm)	1.81	1.78	1.71	1.59	1.46	1.4
C4 (Nm)	1.65	1.57	1.38	1.18	0.96	0.86
C5 (Nm)	2.16	2.03	1.68	1.39	1.14	1
C3-C2 (Nm)	1.37	1.36	1.35	1.27	1.17	1.12
C3-C4 (Nm)	0.16	0.21	0.33	0.41	0.5	0.54
C5-C4 (Nm)	0.51	0.46	0.3	0.21	0.18	0.14
Stability (min)	5.7	6.2	5.3	4.6	3.9	4.1

	0 ppm	25 ppm	50 ppm	100 ppm	150 ppm	200 ppm
Absorption	3	3	3	3	3	3
Mixing	1	1	1	1	1	1
Gluten+	6	6	5	5	5	5
Viscosity	5	5	3	3	2	2
Amylase	7	7	5	5	4	3
Retrogradation	4	4	2	2	1	1

In the Mixolab®, bacterial α-amylase action is characterized by:

➲ A drop in C2 and in stability, that may be due to the release of water molecules into the dough, or to the presence of secondary activities.

➲ A clear drop in C3, showing the effect of starch hydrolysis.

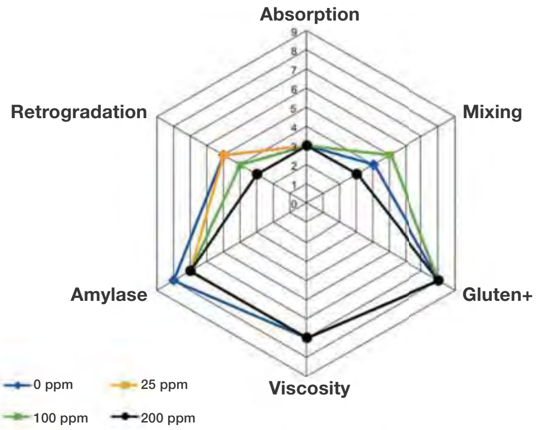
➲ An increase in the C3-C4 difference, showing that diastatic activity continues during the “hot” phase.

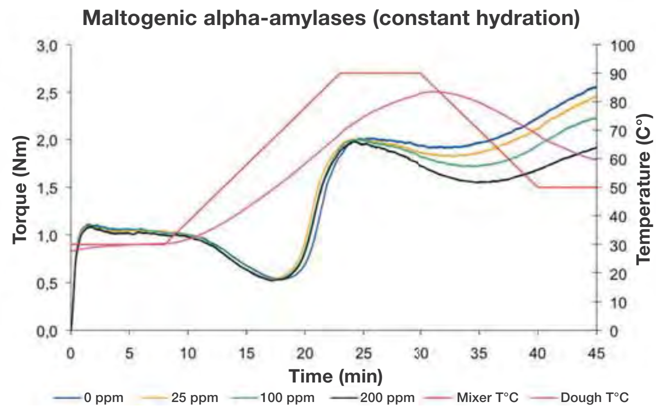
➲ A decrease in retrogradation (C5-C4) to be correlated with the anti-staling effects (decrease in C5).

10.7.3 Maltogenic amylases

When flour diastatic activity is too weak (insufficient production of fermentable sugars), exogenous α-amylases may be added. Maltogenic α-amylases are considered as anti-staling enzymes. Indeed, by breaking down starch, α-amylases slow the retrogradation process and delay staling. The Mixolab® can be used to highlight behavior differences induced by maltogenic α-amylase addition.

Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	56.6% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min





	0 ppm	25 ppm	50 ppm	100 ppm	150 ppm	200 ppm
C1 (Nm)	1.12	1.09	1.07	1.1	1.11	1.09
C2 (Nm)	0.54	0.54	0.52	0.54	0.52	0.52
C3 (Nm)	2.02	2.01	1.98	2	1.99	1.98
C4 (Nm)	1.91	1.83	1.7	1.72	1.53	1.55
C5 (Nm)	2.56	2.46	2.17	2.22	1.9	1.92
C3-C4 (Nm)	0.11	0.18	0.28	0.28	0.46	0.43
C5-C4 (Nm)	0.65	0.63	0.47	0.5	0.37	0.37
Stability (min)	10.6	10.8	10.8	10.8	10.5	10.38

	0 ppm	25 ppm	50 ppm	100 ppm	150 ppm	200 ppm
Absorption	3	3	3	3	3	3
Mixing	4	5	4	5	4	3
Gluten+	8	8	8	8	7	8
Viscosity	7	7	7	7	7	7
Amylase	8	7	7	7	5	7
Retrogradation	5	5	3	4	3	3

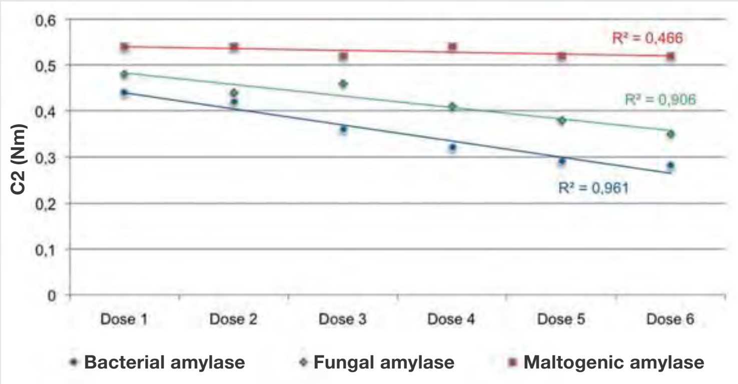
In the Mixolab®, maltogenic α-amylase action is characterized by:

- An increase in the C3-C4 difference, showing that diastatic activity continues during the “hot” phase.
- A decrease in retrogradation (C5-C4) to be correlated with the anti-staling effects (decrease in C5).

10.7.4 Comparison of Amylases

The effect of amylases on the rheological properties of the dough varies according to their type.

Hot protein stability

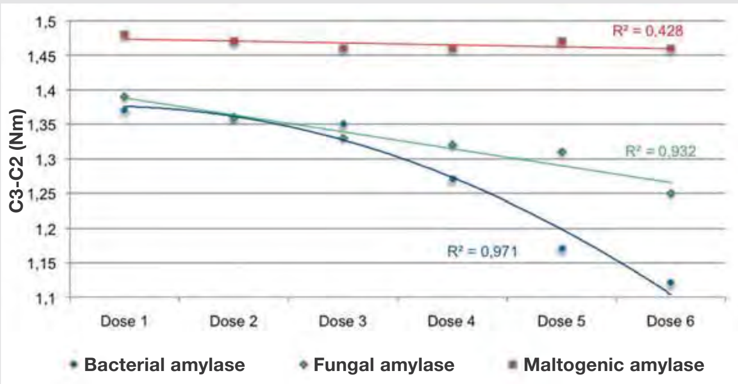


Bacterial amylase has a bigger effect on C2.

Fungal amylase also acts on C2, but to a lesser extent.

Maltogenic amylase does not appear to have any effect on C2.

Gelatinization

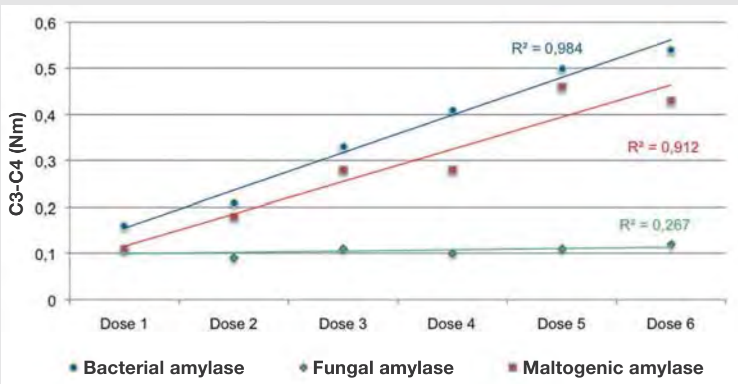


Bacterial amylase has a significant effect on gelatinization.

Fungal amylase also acts on starch gelatinization, but to a lesser degree.

Maltogenic amylase has a very low effect on gelatinization.

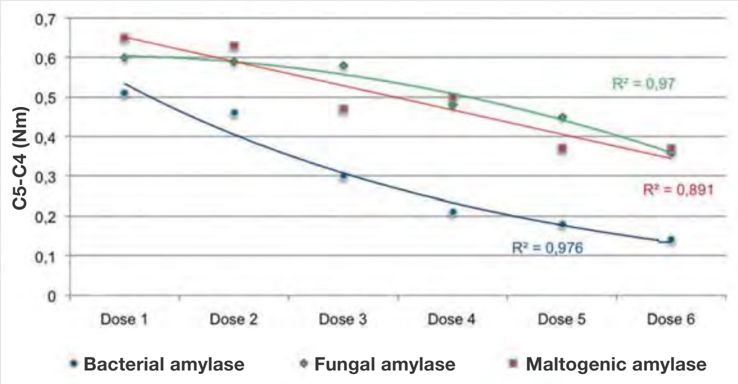
Liquefaction



Bacterial amylase and maltogenic amylase have a significant impact on the hot resistance of the dough. The liquefaction observed is proportional to the amount of amylase added in the dough.

Fungal amylase shows a different behavior. In the presence of fungal amylase, the dough keeps its hot properties.

Retrogradation



Bacterial amylase is the enzyme with the greatest effect on retrogradation, (and on the finish product shelf-life as well)

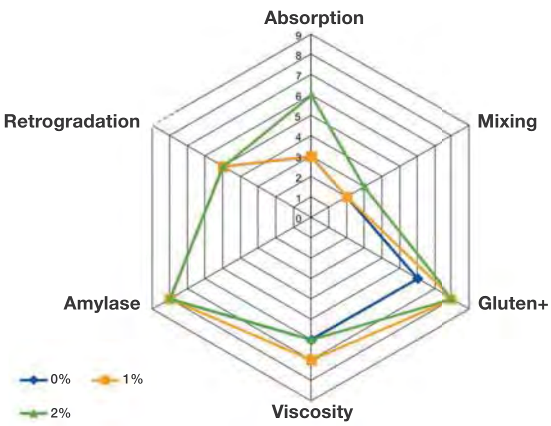
Maltogenic and fungal amylases show identical behavior.

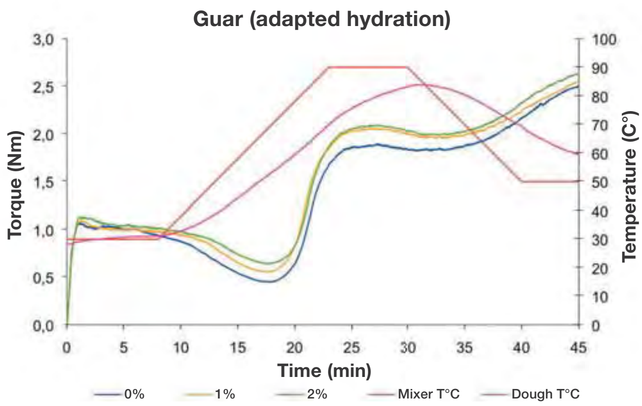
Thanks to the Mixolab®, it is possible to analyze and compare the impact of the various amylases on the dough rheological properties.

10.8 ▶ Guar

Hydrocolloids are water-soluble macromolecules. Used as texturizing agents, they are able to "bind" large amounts of water and modify its availability. When present in the aqueous phase, they modify the rheological properties of a food. The resulting products are viscous and thick (liquids) or gelled (solids).

Guar is used as a thickener in the food industry such as bread-making and cream making, but also in the chemical, pharmaceutical and cosmetic industries. The Mixolab® can be used to highlight behavior differences induced by guar addition.





Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	0%	1%	2%
Hydration % (14% base)	56.6	56.6	59.2
C2 (Nm)	0.45	0.56	0.64
C3 (Nm)	1.89	2.06	2.09
C4 (Nm)	1.82	1.95	1.99
C5 (Nm)	2.5	2.56	2.63
C3-C2 (Nm)	1.44	1.5	1.45
C4-C3 (Nm)	0.07	0.11	0.1
C5-C4 (Nm)	0.68	0.61	0.64
Stability (min)	7.7	9.6	9.7

	0%	1%	2%
Absorption	3	3	6
Mixing	2	2	3
Gluten+	6	8	8
Viscosity	6	7	6
Amylase	8	8	8
Retrogradation	5	5	5

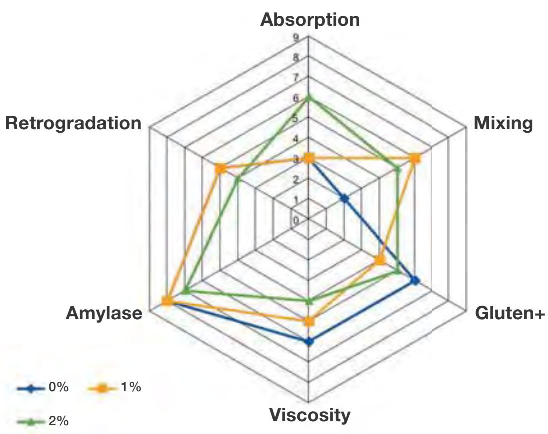
In the Mixolab®, guar action is characterized by:

- An increase in water absorption capacity (at 2% addition).
- An improvement in dough strength, seen as an increase in C2 and in stability (from 1% addition).
- No clear effect on the rest of the curve (viscosity peak, hot stability and retrogradation); the C3-C2, C4-C3 and C5-C4 differences are constant.

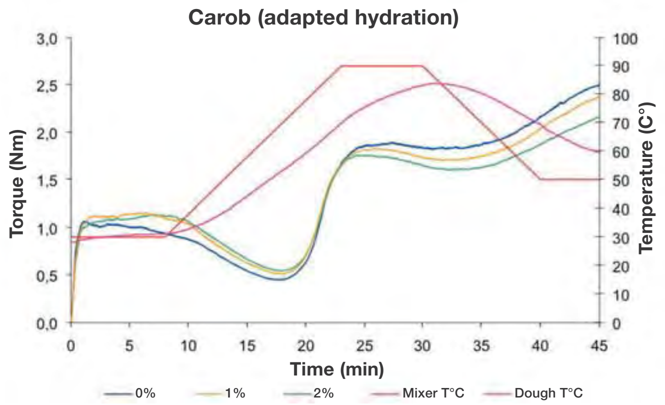
Guar has an effect on water absorption capacity, but also on the cold dough stability.

10.9 ▶ Carob

Carob is a thickener non-soluble in cold water. To fully dissolve, it requires heat treatment at 85°C. Indeed, energy is required for the water to separate the "smooth" areas. Carob is used in the food industry (mainly in combination) in creams, puddings and in bread-making. Carob is also used for its gelling properties in non-food applications.



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min



	0%	1%	2%
Hydration % (14% base)	56.6	57	59.5
C2 (Nm)	0.45	0.51	0.55
C3 (Nm)	1.89	1.83	1.76
C4 (Nm)	1.82	1.7	1.6
C5 (Nm)	2.5	2.38	2.18
C3-C4 (Nm)	0.07	0.13	0.16
C5-C4 (Nm)	0.68	0.68	0.58
Stability (min)	7.7	9.5	9.9

	0%	1%	2%
Absorption	3	3	6
Mixing	2	6	5
Gluten+	6	4	5
Viscosity	6	5	4
Amylase	8	8	7
Retrogradation	5	5	4

In the Mixolab®, carob action is characterized by:

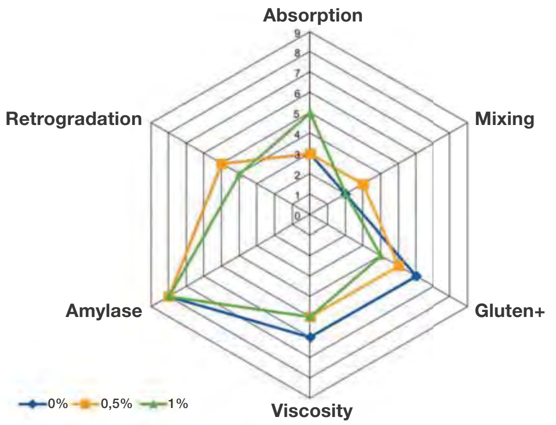
- An increase in water absorption capacity (particularly at 2%).
- A clear increase in stability and C2, indicating a reinforcement of dough structure.
- A drop in hot viscosity (competition for water between carob and starch).
- An increase in the C3-C4 difference, while remaining at a low level (0.07-0.16 Nm).
- A slight drop in starch retrogradation (C5-C4).

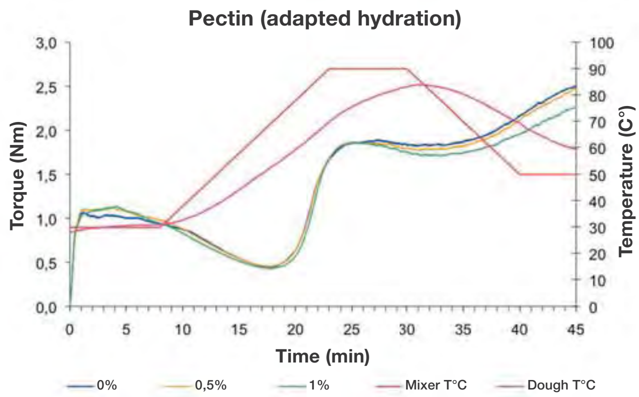
Carob affects the water absorption capacity of the dough, but also cold and hot stability.

10.10 ▶ Pectin

HM pectins are heat-soluble texturizing agents. During cooling in an acidic (2.5 < pH < 4) and sweet solution (dry extract > 60%), they form gels with a short and cohesive texture.

These gels are thermo-stable. The Mixolab® can be used to highlight behavior differences induced by HM pectin addition.





Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	0%	0.5%	1%
Hydration % (14% base)	56.6	56.6	58.5
C2 (Nm)	0.45	0.46	0.43
C3 (Nm)	1.89	1.87	1.86
C4 (Nm)	1.82	1.77	1.71
C5 (Nm)	2.5	2.48	2.25
C3-C4 (Nm)	0.07	0.1	0.15
C5-C4 (Nm)	0.68	0.71	0.54
Stability (min)	7.7	6.8	6.2

	0%	0.5%	1%
Absorption	3	3	5
Mixing	2	3	2
Gluten+	6	5	4
Viscosity	6	5	5
Amylase	8	8	8
Retrogradation	5	5	4

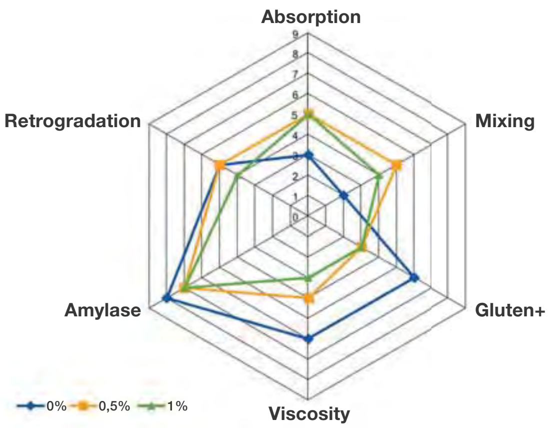
In the Mixolab®, HM pectin action is characterized by:

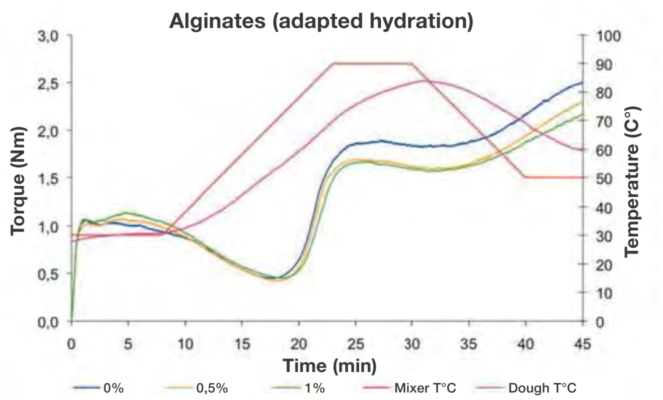
- An increase in water absorption capacity (from 1%).
- Very little effect on C2, with a slight decrease in stability.
- An increase in the C3-C4 difference, while remaining small (0.07-0.15 Nm).
- A slight drop in starch retrogradation (C5-C4).

HM pectins affect the water absorption capacity of the dough, but also cold and hot stability.

10.11 ▶ Alginates

Alginic acid can be combined with several cations, creating different types of alginate. Alginates are texturizing agents used as thickeners and gelling agents in the food industry such as the preparation of fruit, creams, toppings, but also in the chemical, pharmaceutical and cosmetic industries. The Mixolab® can be used to highlight behavior differences induced by alginate addition.





Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	0%	0.5%	1%
Hydration % (14% base)	56.6	58.1	58.6
C2 (Nm)	0.45	0.42	0.45
C3 (Nm)	1.89	1.69	1.67
C4 (Nm)	1.82	1.59	1.57
C5 (Nm)	2.5	2.3	2.16
Stability (min)	7.7	8.7	8.4

	0%	0.5%	1%
Absorption	3	5	5
Mixing	2	5	4
Gluten+	6	3	3
Viscosity	6	4	3
Amylase	8	7	7
Retrogradation	5	5	4

In the Mixolab®, alginate action is characterized by:

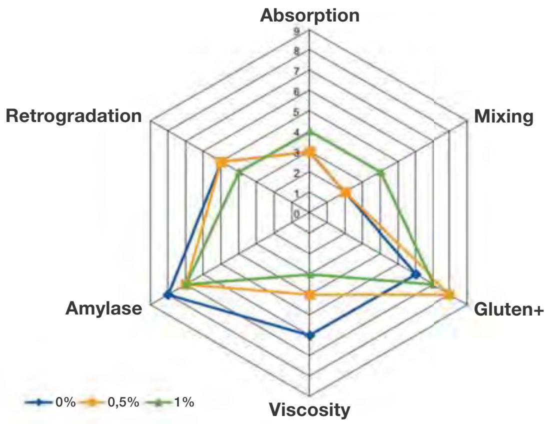
- A rapid increase in water absorption capacity.
- A slight improvement in stability (with no C2 modification).
- A clear decrease in hot viscosity (C3).
  (competition for water between alginates and starch?)
- No effects on the rest of the curve.

Alginates affect the water absorption capacity of the dough, but also cold stability and the gelatinization intensity.

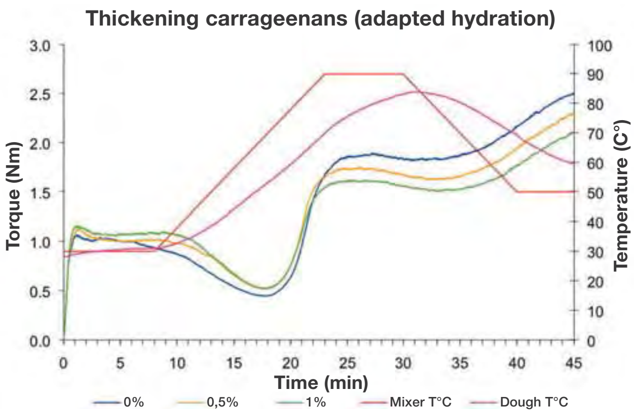
10. 12 ▶ Carrageenans

Carrageenans are texturizing agents used for their thickening and gelling properties. They play an important role in dairy applications, but are also used in non-food industries to stabilize emulsions and creams. The Mixolab® can be used to highlight behavior differences induced by carrageenan addition.

10. 12. 1 Thickening carrageenans



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min



	0%	0.5%	1%
Hydration % (14% base)	56.6	56.6	57.7
C2 (Nm)	0.45	0.53	0.53
C3 (Nm)	1.89	1.75	1.62
C4 (Nm)	1.82	1.62	1.51
C5 (Nm)	2.5	2.31	2.12
Stability (min)	7.7	9.2	11

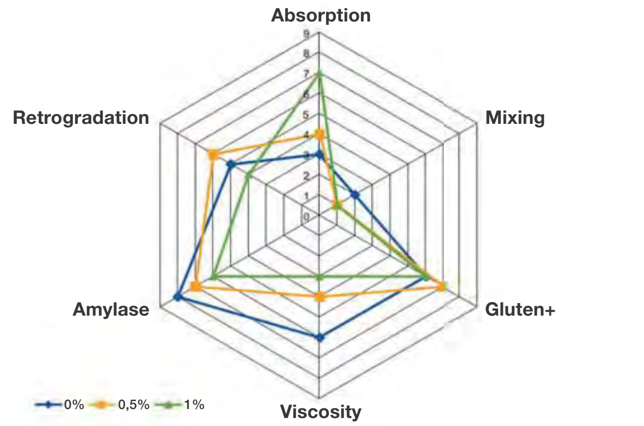
	0%	0.5%	1%
Absorption	3	3	4
Mixing	2	2	4
Gluten+	6	8	7
Viscosity	6	4	3
Amylase	8	7	7
Retrogradation	5	5	4

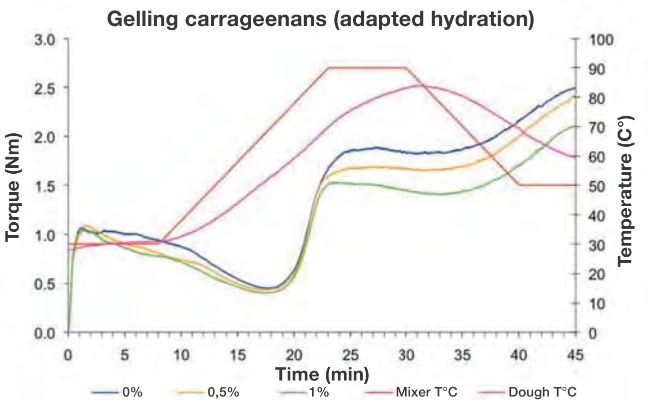
In the Mixolab®, thickening carrageenan action is characterized by:

- An increase in water absorption capacity.
- An improvement in the plastic qualities of the dough, measured by improved stability and increased C2.
- A drop in C3 (competition for water between carrageenans and starch).
- No notable modifications to the rest of the curve (the differences on C4 and C5 are linked to changes on C3).

Thickening carrageenans affect the water absorption capacity of the dough, but also cold stability and hot viscosity.

10. 12. 2 Gelling carrageenans





Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	0%	0.5%	1%
Hydration % (14% base)	56.6	57.7	60
C2 (Nm)	0.45	0.44	0.40
C3 (Nm)	1.89	1.7	1.53
C4 (Nm)	1.82	1.65	1.41
C5 (Nm)	2.5	2.43	2.12
Stability (min)	7.7	3.7	3.7

	0%	0.5%	1%
Absorption	3	4	7
Mixing	2	1	1
Gluten+	6	7	6
Viscosity	6	4	3
Amylase	8	7	6
Retrogradation	5	6	4

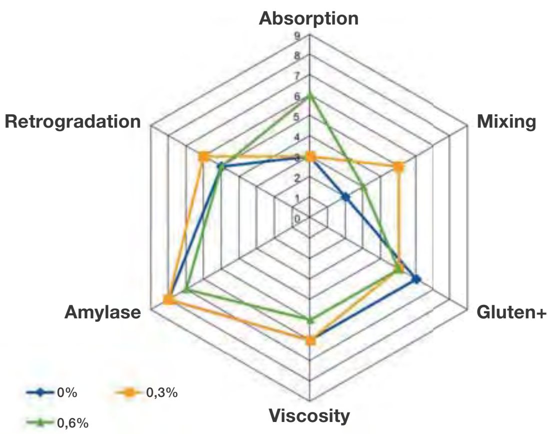
In the Mixolab®, gelling carrageenan action is characterized by:

- An increase in water absorption capacity.
- A decrease in the plastic qualities of the dough, measured by a significant drop in stability and a slight decrease in C2.
- A decrease in hot viscosity (C3).
- The rest of the curve does not show any modifications other than those resulting from the reduced hot viscosity.

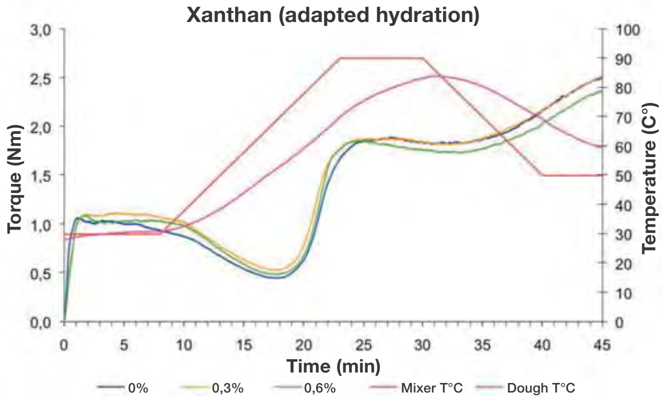
Gelling carrageenans affect the water absorption capacity of the dough, but also cold stability and hot viscosity.

10.13 ▶ Xanthan

Xanthan gum is a polysaccharide of microbial origin. Xanthan is soluble at cold temperature because of anionic side-chains. Xanthan gum is used as a texturizing agent in the food industry. The Mixolab® can be used to highlight behavior differences induced by xanthan gum addition.



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min



	0%	0.3%	0.6%
Hydration % (14% base)	56.6	56.6	58.8
C2 (Nm)	0.45	0.52	0.48
C3 (Nm)	1.89	1.88	1.85
C4 (Nm)	1.82	1.81	1.73
C5 (Nm)	2.5	2.53	2.37
Stability (min)	7.7	9.82	9.8

	0%	0.3%	0.6%
Absorption	3	3	6
Mixing	2	5	3
Gluten+	6	5	5
Viscosity	6	6	5
Amylase	8	8	7
Retrogradation	5	6	5

In the Mixolab®, xanthan gum action is characterized by:

- An increase in water absorption capacity (from 0.6%).
- An increase in stability, with a C2 remaining constant.
- No clear changes to the rest of the curve, with the exception of a decrease in C5 when adding 0.6% xanthan.

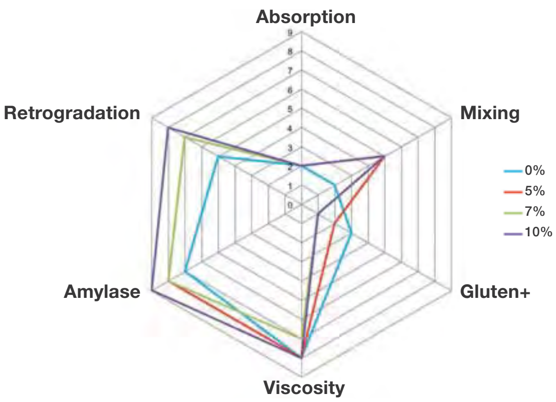
Xanthan has an effect on water absorption capacity, but also on the cold stability of the dough.

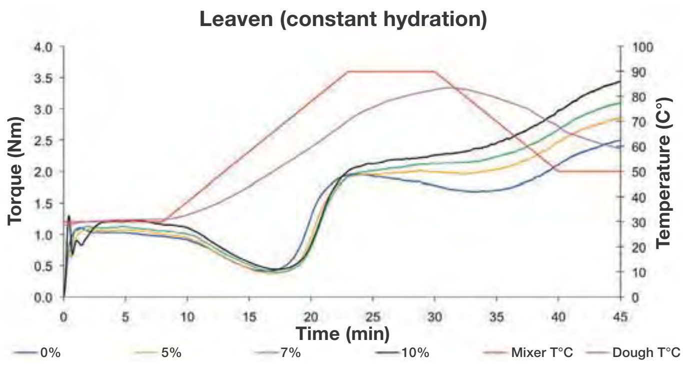
10.14 ▶ Leaven

Leaven consists of a culture of yeast and lactic acid bacteria growing in a mixture of flour and water. It is used to produce sourdough bread. It gives specific taste compared to a yeast-risen bread. Indeed, the particular acidity of sourdough bread is due to lactic acid and acetic acid produced by the lactic acid bacteria.

The Mixolab® can be used to highlight behavior differences induced by leaven addition to a dough.

Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	55% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min





	0%	5%	7%	10%
C1 (Nm)	1.11	1.09	1.13	1.23
C2 (Nm)	0.41	0.39	0.39	0.34
C3 (Nm)	1.97	2.02	1.91	2.02
C4 (Nm)	1.68	1.97	2.13	2.27
C5 (Nm)	2.51	2.90	3.11	3.45
Stability (min)	7.9	9.4	9.7	10.1

	0%	5%	7%	10%
Absorption	2	2	2	2
Mixing	2	5	5	5
Gluten+	3	2	1	1
Viscosity	8	8	7	8
Amylase	7	8	8	9
Retrogradation	5	7	7	8

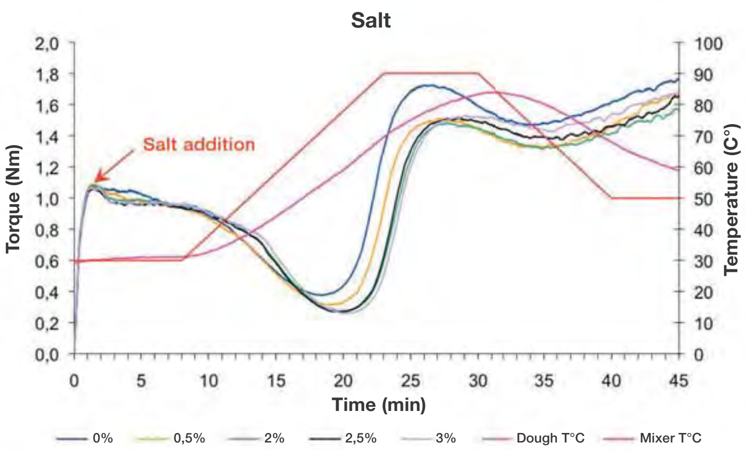
In the Mixolab®, leaven action is characterized by:

- A slight increase in water absorption capacity (C1).
- A decrease in amylase activity and, consequently, an increase in hot stability (C4, C3-C4).
- An increase in retrogradation (C5).

Leaven has a pronounced effect on dough behavior during heating and cooling phases.

11.1 ▶ Salt

The food industry puts too much salt in the products. This is the conclusion drawn by health studies conducted in the past ten years. Tests were conducted using the Mixolab® to measure the effect of salt on dough rheological behavior and to evaluate the impact of a moderate reduction of added salt doses.



Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	55% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	0%	0.5%	2%	2.5%	3%
C1 (Nm)	1.08	1.09	1.08	1.06	1.07
C2 (Nm)	0.38	0.32	0.27	0.27	0.26
C3 (Nm)	1.72	1.51	1.48	1.52	1.53
C4 (Nm)	1.47	1.32	1.32	1.38	1.43
C5 (Nm)	1.77	1.66	1.56	1.66	1.67
C3-C2 (Nm)	1.34	1.19	1.21	1.25	1.27
C3-C4 (Nm)	0.25	0.19	0.16	0.14	0.1
C5-C4 (Nm)	0.30	0.34	0.24	0.28	0.24

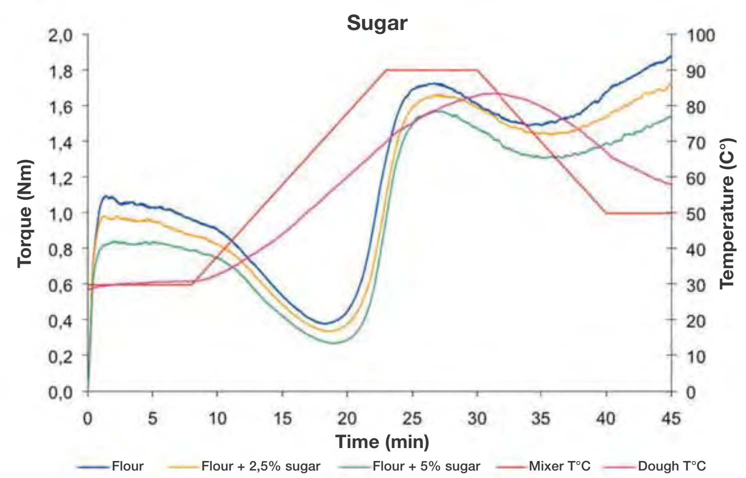
In the Mixolab®, salt (NaCl) action is characterized by:

- A progressive decrease in C2.
- Heating-induced weakening is delayed. The drop is then more rapid than the test without salt.
- Gelatinization temperature is delayed: the more salt added, the higher the temperature.
- Hot stability, on the other hand, increases (lower amylase activity). This may be due to a shorter amylase effect linked to delayed gelatinization.

Salt (NaCl) affects the plastic properties of dough. The effect is significant at doses between 0% and 0.5%. Over 2%, however, adding more salt has little effect. It should be possible to reduce the salt dose in bread products without significantly altering their technological qualities.

11.2 ▶ Sugar

Sugar is used as an ingredient in many bread, pastry or cookie recipes.
The Mixolab® was used to evaluate the influence of sugar on the rheological properties of dough.



Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	55% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Two sugar doses were tested using a constant hydration test protocol. The sugar was mixed with base flour and a sample was placed in the mixer.

In the Mixolab®, sugar action is characterized by:

- A clear decrease in C1, characteristic of dough over-hydration.
- A smaller drop in C1-C2 when sugar is incorporated.
- A constant C3-C2 difference, indicating unchanged gelatinization capacity.
- A constant hot stability (C3-C4) along with an identical diastatic activity.
- A decrease in C5-C4 suggesting improved finished product shelf-life.
- An increase in gelatinization temperature (Dough Temp. C2); the sugar would appear to have a delaying effect.

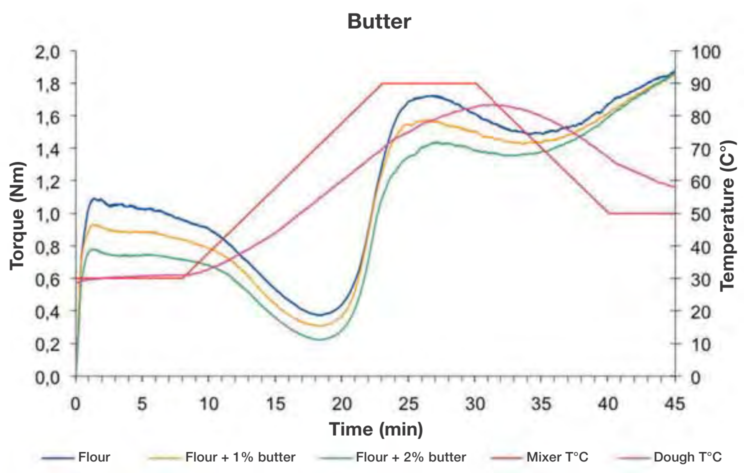
	0%	2.5%	5%
C1 (Nm)	1.1	0.98	0.84
C2 (Nm)	0.38	0.34	0.27
C3 (Nm)	1.73	1.67	1.57
C4 (Nm)	1.49	1.44	1.31
C5 (Nm)	1.88	1.73	1.55
C1-C2 (Nm)	0.72	0.64	0.37
C3-C2 (Nm)	1.35	1.33	1.3
C3-C4 (Nm)	0.24	0.23	0.24
C5-C4 (Nm)	0.39	0.29	0.24
Stability (min : s)	07:40	08:40	09:50
Dough Temp. C2 (°C)	54.2	54.7	56.6

It is important to reduce the amount of hydration water when sugar is incorporated into a dough. The gelatinization and diastatic activity for sweet dough remain unchanged, with the exception of the gelatinization temperature and weaker retrogradation, suggesting improved product shelf-life.

11.3 ▶ Fat

11.3.1 Butter test

Butter is used as an ingredient in many bread, pastry or cookie recipes.
The Mixolab® was used to determine the influence of butter on the rheological properties of dough.



Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	55% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Two butter doses were tested using a constant hydration test protocol. The butter was added to the flour during the Mixolab® auto-calibration step.

In the Mixolab®, butter action is characterized by:

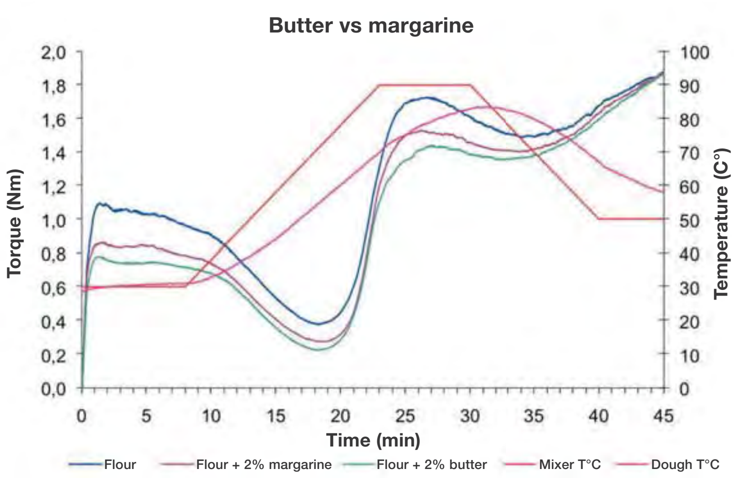
- A clear decrease in the C1 value.
- A smaller drop in C1-C2.
- A decrease in max viscosity (C3-C2) with butter addition (plasticizing effect hydrophobic barrier).
- Improved hot stability (C3-C4).
- Stronger retrogradation (C5-C4). It is interesting to note that the C5 value is identical for the 3 tests, despite the significantly different C1 to C4 torques.

	0%	1%	2%
C1 (Nm)	1.1	0.93	0.78
C2 (Nm)	0.38	0.31	0.23
C3 (Nm)	1.73	1.58	1.44
C4 (Nm)	1.49	1.43	1.36
C5 (Nm)	1.88	1.86	1.87
Stability (min :s)	07:48	09:05	09:31
C1-C2 (Nm)	0.72	0.62	0.55
C3-C2 (Nm)	1.35	1.27	1.21
C3-C4 (Nm)	0.24	0.15	0.08
C5-C4 (Nm)	0.39	0.43	0.51

Less water should be added when butter is incorporated into dough. Butter affects dough plasticity, but also the starch phase during heating and cooling. It modifies the maximum hot consistency (melting), hot stability and retrogradation.

11.3.2 Butter / margarine comparison

Fat is used as an ingredient in many bread, pastry or cookie recipes. The influence of two different fats was evaluated with the Mixolab®.



Chopin+ protocol	
Mixing speed	80 rpm
Constant hydration	55% b14
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

	Flour	Flour + 2% margarine	Flour + 2% butter
C1 (Nm)	1.1	0.86	0.78
C2 (Nm)	0.38	0.28	0.23
C3 (Nm)	1.73	1.53	1.44
C4 (Nm)	1.49	1.4	1.36
C5 (Nm)	1.88	1.87	1.87
Stability (min:s)	07:48	09:20	09:31
C1-C2 (Nm)	0.72	0.58	0.55
C3-C2 (Nm)	1.35	1.25	1.21
C3-C4 (Nm)	0.24	0.13	0.08
C5-C4 (Nm)	0.39	0.47	0.51

We tested the effect of adding 2% butter (animal fat) and 2% margarine (vegetable fat) on the same flour.

In the Mixolab®, the effects of butter and margarine are identical overall (see note on butter). Several differences can, however, be identified between these two raw materials:

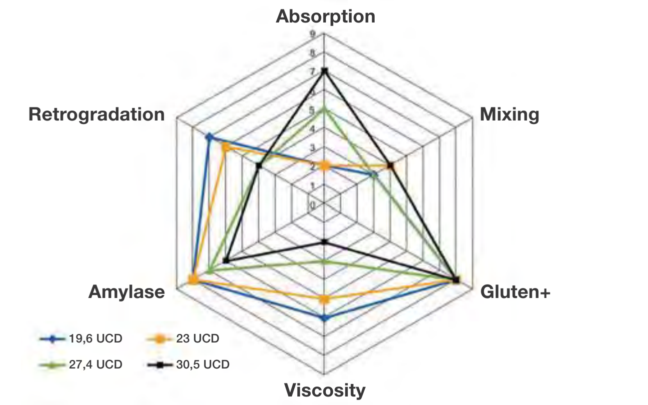
- A higher C1 value for margarine (the dough requires more water).
- Hot stability (C3-C4) is slightly better when butter is used.
- Retrogradation (C5-C4) is equivalent for both.

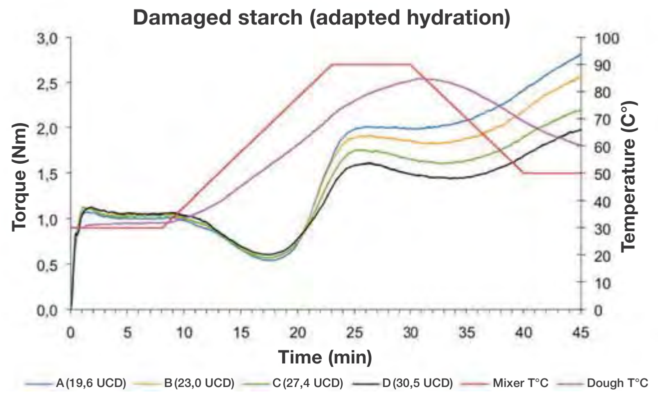
Butter and margarine show clear differences on water absorption capacity. The rest of the curve does not reveal any significant differences.
The Mixolab® can be used to study fats in a flour + water + fat mixture.

12 ❖ EFFECT OF DAMAGED STARCH

12.1 ▶ Damaged starch content

The extent of starch damage has a significant effect on flour quality and must be adapted according to the finished product to be manufactured. The Mixolab® can be used to highlight differences in rheological properties caused by variations in damaged starch content.

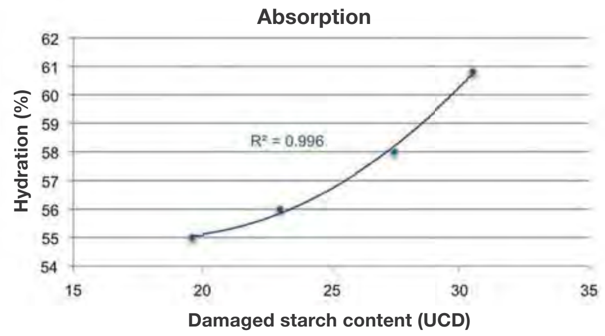


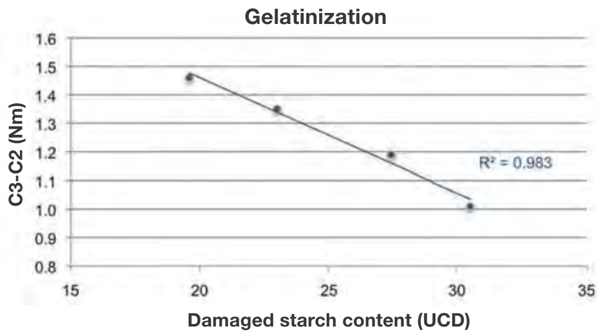


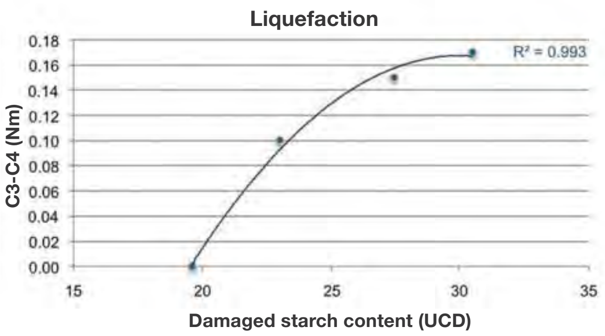
Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

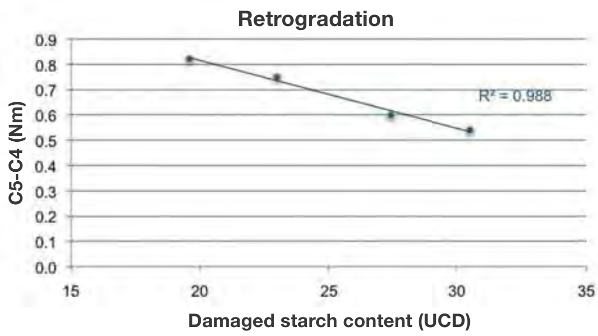
	19.6 UCD	23.0 UCD	27.4 UCD	30.5 UCD
Hydration (%) (base 14%)	55.0	56.0	58.0	60.8
C2 (Nm)	0.54	0.57	0.57	0.6
C3 (Nm)	2.0	1.92	1.76	1.61
C4 (Nm)	2.0	1.82	1.61	1.44
C5 (Nm)	2.82	2.57	2.21	1.98
C3-C2 (Nm)	1.46	1.35	1.19	1.01
C3-C4 (Nm)	0	0.1	0.15	0.17
C5-C4 (Nm)	0.82	0.75	0.6	0.54
Absorption	2	2	5	7
Mixing	3	4	3	4
Gluten+	8	8	8	8
Viscosity	6	5	3	2
Amylase	8	8	7	6
Retrogradation	7	6	4	4

We gradually damaged the starch in flour produced on a Chopin CD1 mill (multiple reduction steps). The resulting flour was tested in the Mixolab®.









In the Mixolab®, starch damage is characterized by:

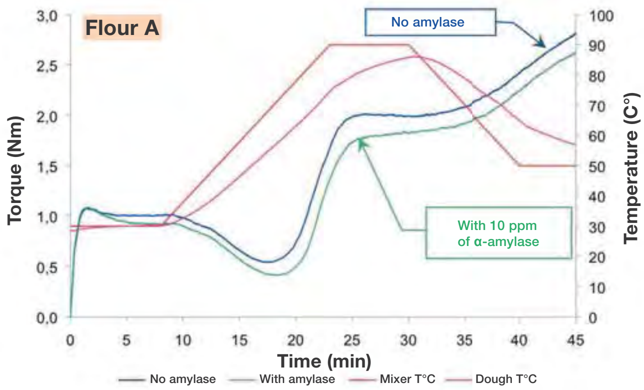
- A gradual increase in flour water absorption capacity (known effect of starch damage).
- A slight increase in C2.
- A clear and gradual decrease in the C3 value.
- A decrease in hot stability (increase in C3-C4).
- A decrease in retrogradation (C5-C4).

In a single test, the Mixolab® is able to measure different effects of damaged starch: improved water absorption capacity, intensification of amylase activity (C3, C3-C4), improved product shelf-life due to slower retrogradation (C5-C4).

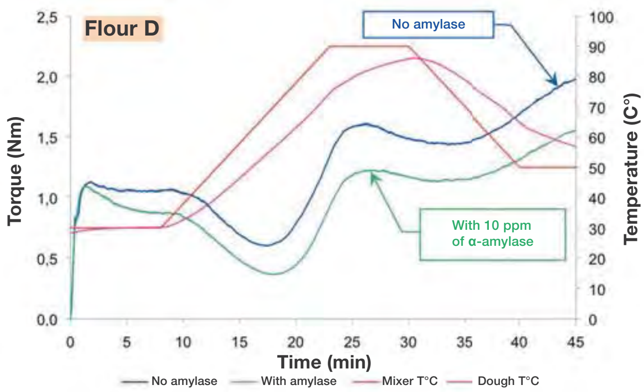
12.2 ▶ Influence of damaged starch on α-amylase activity

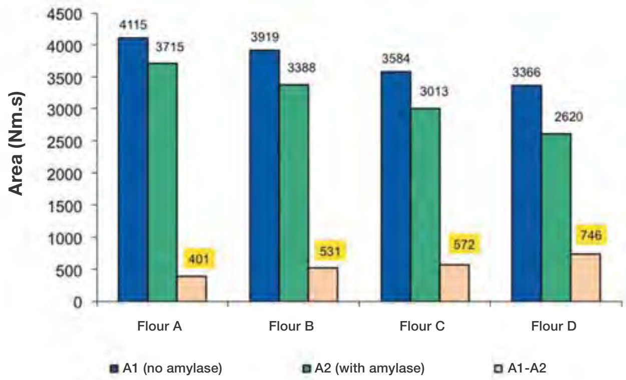
Exogenous α-amylases are frequently used to correct flour diastatic activity, thus improving the fermentative properties of cereal-based doughs. The aim of this study was to evaluate the impact of damaged tarch on α-amylase activity.

Four flours (A, B,C and D), with damaged starch contents from 19.6 to 30.5 UCD, were analyzed twice on the Mixolab®: the first test was conducted on the flour alone, while the second was conducted on flour with 10 ppm of fungal α-amylase added. The area between the two curves (with and without α-amylase) was then evaluated by calculating the S% index. It should also be noted that all 4 flours were produced on a CD1 mill from the same wheat: multiple reduction steps were done to gradually increase the damaged starch content.



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1.10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

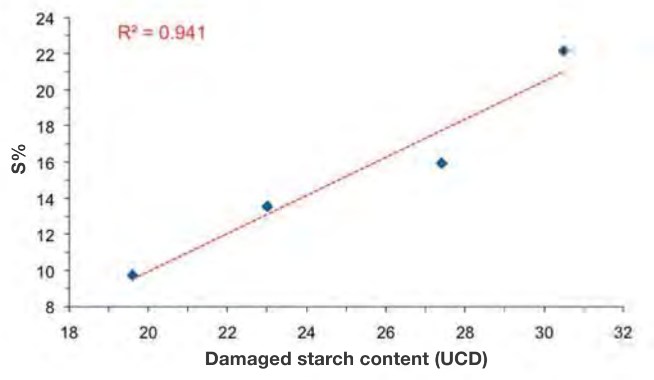




A1 = "no amylase" area under curve

A2 = "with amylase" area under curve

S% = (A1-A2) / A1 * 100

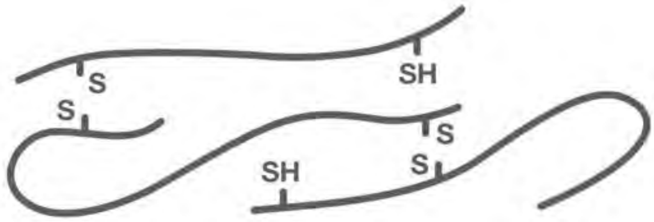


Flour	Grinding	Conversion	DS (UCD)
A	1	2	19.6
B	1	3	23.0
C	1	4	27.4
D	1	6	30.5

These tests confirm the respective effects of damaged starch and adding α-amylase (mainly, lower gelatinization peak and lower consistency of the gel formed when cooling).
Furthermore, these tests show there is a significant degree of synergistic action between α-amylase and damaged starch. Indeed, it is clear that a given dose of α-amylase has even more effect (increased S% index) if the damaged starch content is high. This synergistic action is probably beacause damaged starch granules are more accessible to enzymes than native starch granules.

It is consequently essential to be able to adapt the amount of α-amylases added according to the damage starch content. The SDmatic/Mixolab® duo provides a perfect solution for this.

13 ❖ VITAL GLUTEN ANALYSIS

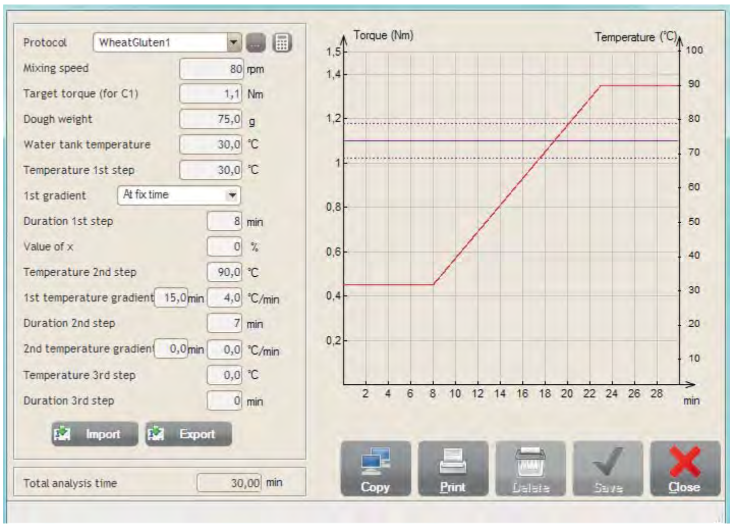


Vital wheat gluten is one of the most important improvers used in the bread-making industry. Despite this industrial benefit, few analytical methods are available to rapidly analyse the rheological properties of this product. The studies presented in this section show how the Mixolab® can meet this requirement.

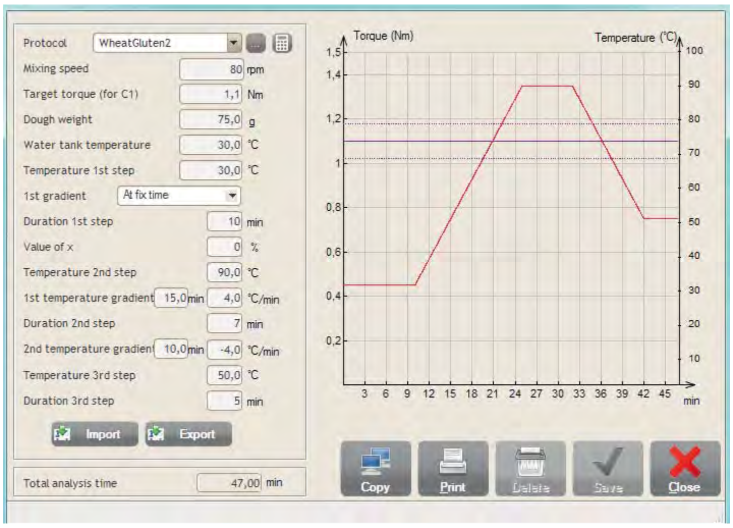
The Mixolab® offers 3 different protocols for analyzing vital gluten quality.

Besides the conventional CHOPIN+ protocol, 2 other specific protocols are available on the Mixolab® to test vital wheat gluten.

WheatGluten 1 protocol: used on pure gluten

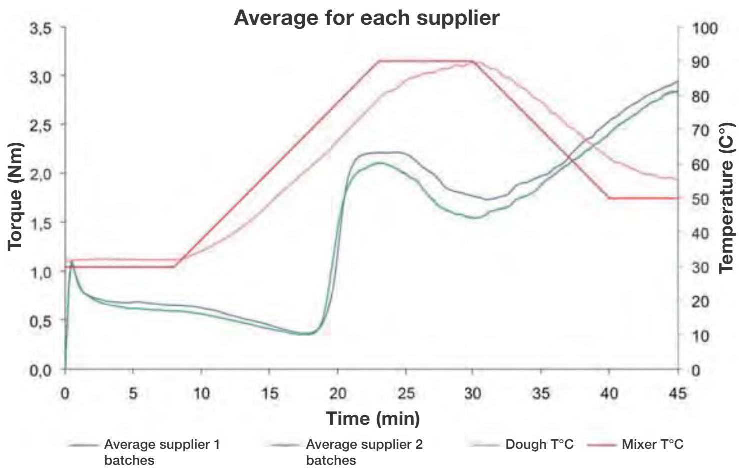


WheatGluten 2 protocol:
used on blends of gluten (40%) and starch (60%)

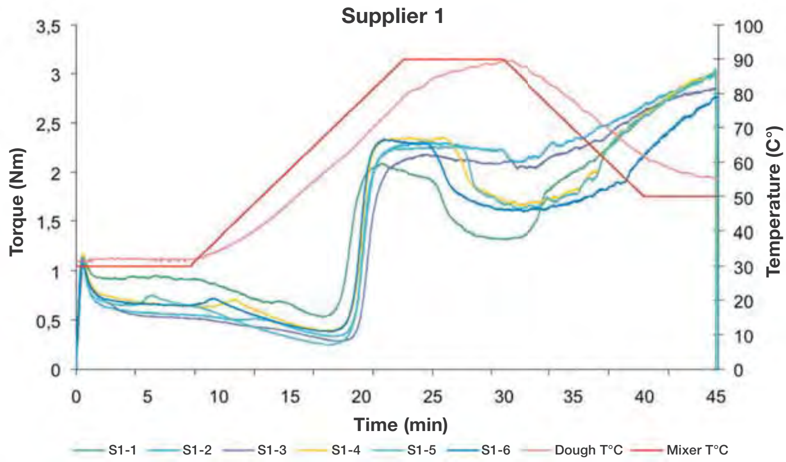


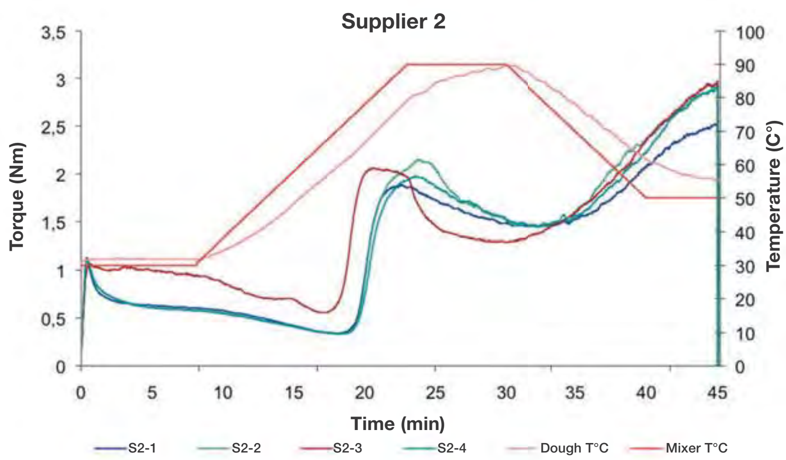
13.1 ▶ Standard protocol

For this study, conducted in partnership with an industrial miller, the vital glutens from 2 different suppliers were analyzed with the Mixolab®. All glutens tested were mixed with the same starch (40% - 60% gluten-starch ratio) prior to analysis.



Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min





Suppliers	Batch no.	Hydration (%)	Stability (min)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Supplier 1	1	56.8	0.6	0.53	2.09	1.32	3	1.56	0.77	1.68
	2	57.8	0.3	0.34	2.32	2.1	3.01	1.98	0.22	0.91
	3	60.2	0.5	0.29	2.18	2.04	2.86	1.89	0.14	0.82
	4	56	0.5	0.4	2.36	1.66	3.03	1.96	0.7	1.37
	5	56.5	0.3	0.25	2.27	1.63	3.05	2.02	0.64	1.42
	6	56.3	0.4	0.38	2.34	1.59	2.76	1.96	0.75	1.17
	Average	57.3	0.4	0.4	2.3	1.7	3.0	1.9	0.5	1.2
Supplier 2	1	58.5	0.4	0.34	1.89	1.44	2.53	1.55	0.45	1.09
	2	58	0.5	0.33	2.16	1.45	2.95	1.83	0.71	1.5
	3	56.0	8.7	0.56	2.07	1.29	2.97	1.51	0.78	1.68
	4	58.5	0.4	0.34	1.98	1.45	2.91	1.64	0.53	1.46
	Average	57.8	2.5	0.39	2.03	1.41	2.84	1.63	0.62	1.43

The batches from a single supplier are discriminated on their water absorption capacity. The results from the Mixolab® show that these glutens also display behavior differences when the dough is heated.

The Mixolab® can be used to show that interactions between gluten and starch differ according to the gluten used, thus allowing better raw material selection.

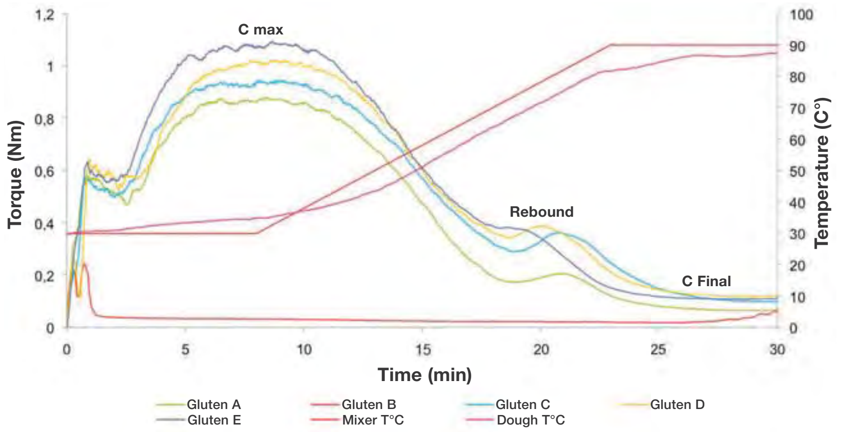
13.2 ▶ Specific protocols

Five samples of vital wheat gluten were analyzed using 3 different protocols.

	WheatGluten 1	Gluten 1	WheatGluten 2
Mixing speed (rpm)	80	200	80
Hydration (% b14)	120	120	Adapted for C1 at 1.1 Nm
Dough weight (g)	75	75	75
Tank temperature (°C)	30	30	30
Temperature 1st step (°C)	30	30	30
Duration 1st step (min)	8	8	10
Temperature 2nd step (°C)	90	90	90
1st temperature gradient (°C/min)	4	4	4
Duration 2nd step (min)	7	7	7
2nd temperature gradient (°C/min)			-4
Temperature 3rd step (°C)			50
Duration 3rd step (min)			5
Total analysis time (min)	30	30	47

The WheatGluten 1 and WheatGluten 2 protocols are the default protocols given on the Mixolab®. The Gluten1 protocol was created on the basis of the WheatGluten 1 protocol to maximize differences between various glutens (increase of mixing speed to 200 rpm).

13.2.1 WheatGluten 1 protocol



Sample	C Max (Nm)	Rebound	C Final (Nm)	C Max time (Min)
Gluten A	0.88	Yes	0.07	8.43
Gluten B	0.24	No	0.07	0.77
Gluten C	0.95	Yes	0.11	8.08
Gluten D	1.02	Yes	0.13	8.75
Gluten E	1.09	Yes	0.12	8.7

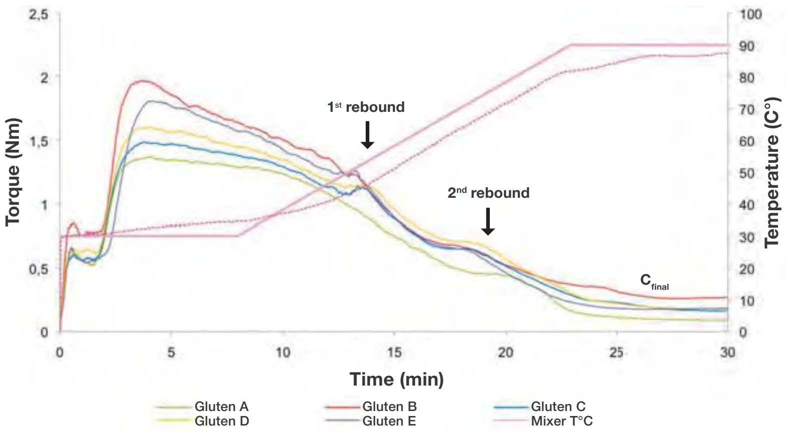
The results show significant differences between the different gluten qualities:

- The maximum torques. Gluten E has a greater water absorption capacity than glutens C and D. Sample A has the lowest water absorption capacity.
- The "rebound" amplitude when the dough temperature reaches 65°C. This "rebound" is particularly significant for samples C and D. It corresponds to the traces of starch in the gluten gelatinizing. It is then possible to determine how pure the gluten is.

Sample B has a lower water absorption than the other glutens. The dough formed in the Mixolab® mixer is under-hydrated. Because the mixing speed was too low to enable dough development, no torque was recorded during the test. The analysis of these samples with the Gluten1 protocol would address this.

The Mixolab®, combined with the protocol WheatGluten 1, can be used to discriminate different vital wheat gluten qualities.

13.2.2 Protocol Gluten 1



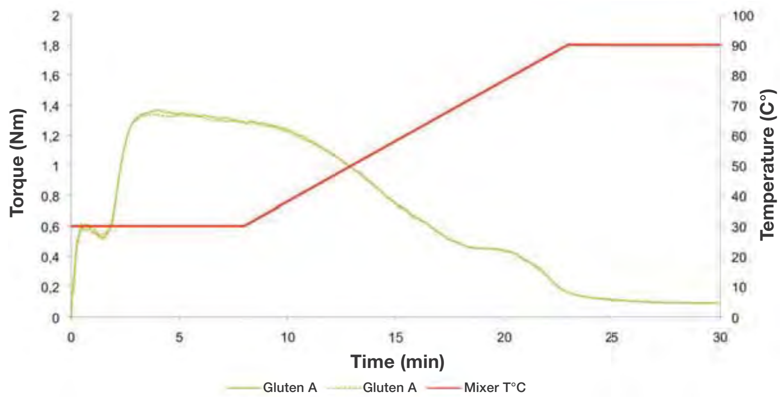
Sample	C_{max} (Nm)	C_{final} (Nm)
Gluten A	1.37	0.1
Gluten B	1.97	0.27
Gluten C	1.49	0.16
Gluten D	1.6	0.18
Gluten E	1.81	0.19

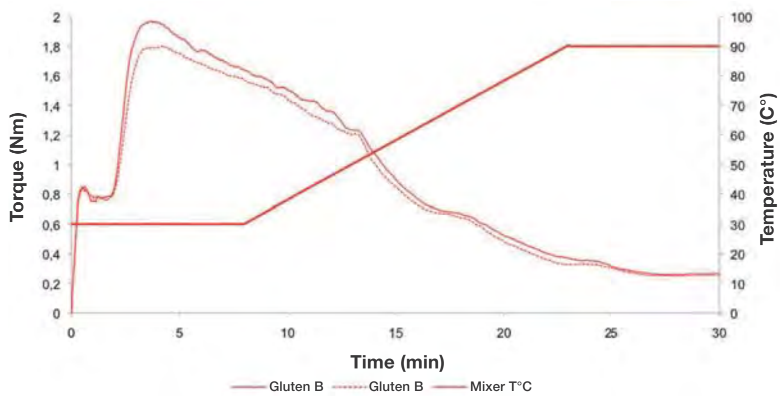
The results are perfectly consistent with the results from the WheatGluten 1 protocol.

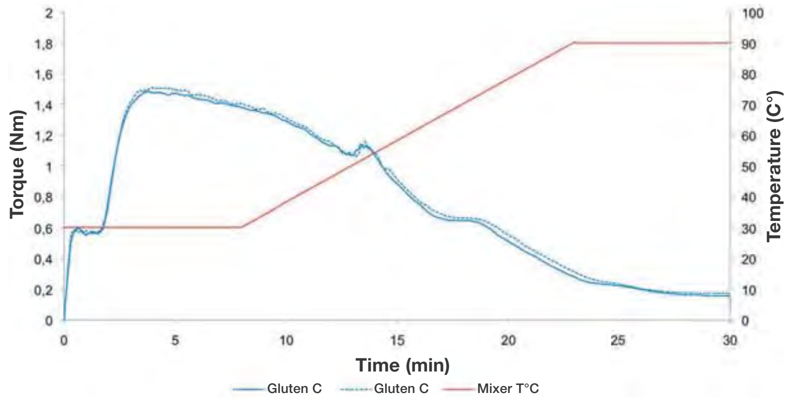
These results confirm that sample B has a higher water absorption capacity than sample E.

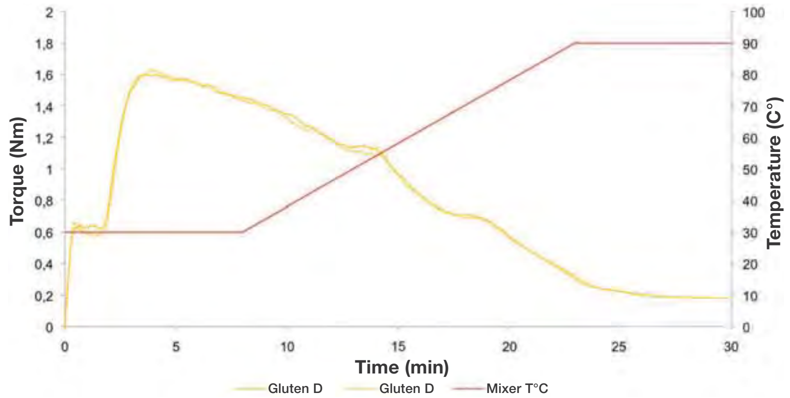
Using this protocol, another "rebound" is detected when dough temperature reaches 40°C. This rebound does not exist on all the samples. The rebound at 65°C varies according to the gluten tested.

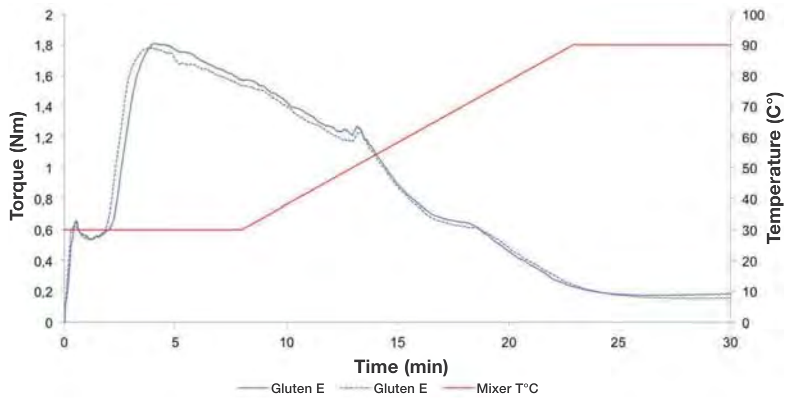
Each sample was analyzed twice to evaluate the repeatability of the method. The results show an excellent repeatability of the method (deviation less than 5% between 2 tests).







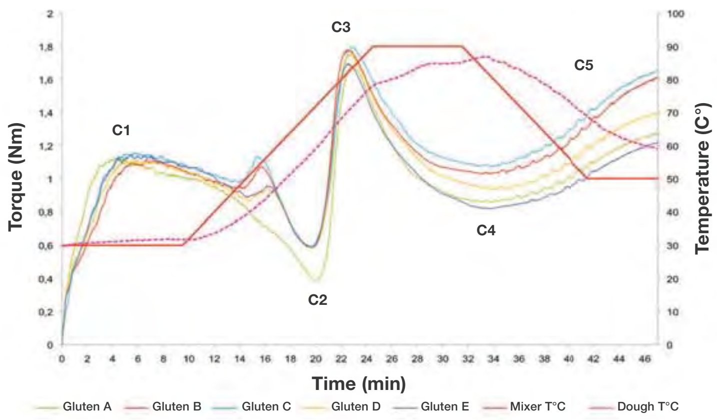




The Mixolab®, with the Gluten 1 protocol, provides a simple, effective and repeatable solution for evaluating vital wheat gluten properties.

13.2.3 WheatGluten 2 protocol

The tests described below were conducted by mixing 40% of gluten with 60% of starch.



Sample	Hydration (% b14)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	C3-C2 (Nm)	C3-C4 (Nm)	C5-C4 (Nm)
Gluten A	70.5	0.39	1.68	0.86	1.28	1.29	0.82	0.42
Gluten B	76	0.59	1.78	1.03	1.62	1.19	0.75	0.59
Gluten C	70.5	0.59	1.8	1.07	1.66	1.21	0.73	0.59
Gluten D	73.4	0.58	1.75	0.93	1.4	1.17	0.82	0.47
Gluten E	73.4	0.59	1.7	0.82	1.22	1.11	0.88	0.4

The results with the WheatGluten 2 protocol are consistent with those from the two other protocols.

The results show significant differences between the different gluten qualities:

- The water absorption capacities. Gluten B requires the most hydration in a blend with the starch.
- The level of the “rebound” when the dough temperature reaches 40°C. Only sample A does not show a rebound.

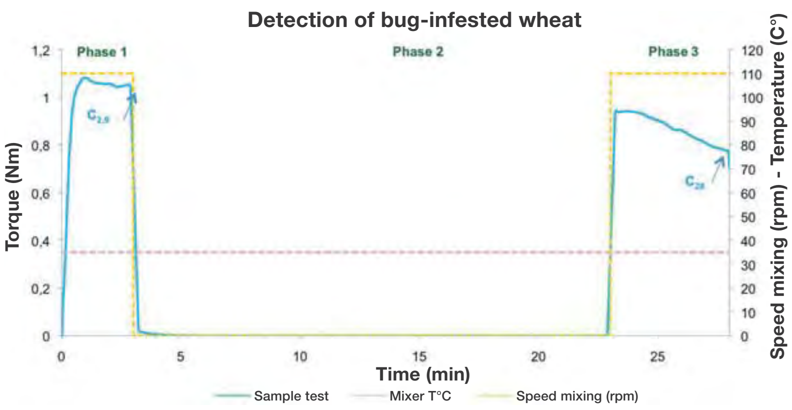
Given that WheatGluten 2 protocol is performed in the presence of starch in the dough, it provides additional information on the enzyme activity generated by vital glutens.

Gluten C has the highest C4 torque and the lowest hot variation (C3-C4). This gluten has the weakest amylase activity. On the other hand, gluten E shows a low C4 and a high hot variation (C3-C4). Gluten E has the strongest amylase activity.

The WheatGluten 2 protocol provides comprehensive information on vital wheat gluten properties.

14.1 ▶ Bug wheat analysis

The Mixolab® can be used to detect bug wheat using the Wheatbug protocol. The mixer temperature is set to 35°C and the mixing speed is variable (phases 1 and 3 at 110 rpm and phase 2 at 0 rpm).



Wheatbug protocol	
Constant hydration	55% b14
Dough weight	75 g
Tank temperature	35°C
Temperature 1st step	35°C
1st step speed	110 rpm
Duration 1st step	3 min
2nd step speed	0 rpm
Duration 2nd step	20 min
3rd step speed	110 rpm
Duration 3rd step	5 min
Total analysis time	28 min

Two new parameters are used to identify if the wheat is bug-infested:

☑ **Change in Mixolab Consistency** (CMC) is the difference in dough consistency observed between the end of the test and the end of the first phase. This parameter is expressed as a percentage.

$$\mathbf{CMC} = \frac{C_{28} - C_{2,9}}{C_{2,9}} \times 100$$

The lower the CMC value, the greater the bug infestation.

☑ **Slope Index Value** (SIV) is the highest slope, measured on the smoothed torque between the 23rd and 28th minute of the test.

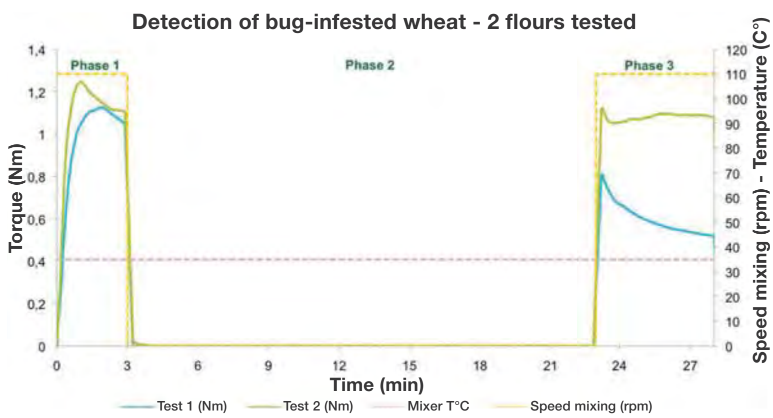
➲ An SIV value less than 0.1 indicates that wheat is not bug-infested.

➲ An SIV value between 0.1 and 0.15 indicate a strong presumption of contamination.

➲ An SIV value greater than 0.15 indicates that wheat is bug-infested.

The graph opposite shows the Mixolab® analysis of two flours with the Wheatbug protocol. The results demonstrate that test sample 2 is not bug-infested while test flour 1 is bug-infested.

NB: The proteolytic index (PI), measured with an Alveograph® degradation test on these samples, is 1.0% (test 2) and 48.3% (test 1), respectively.

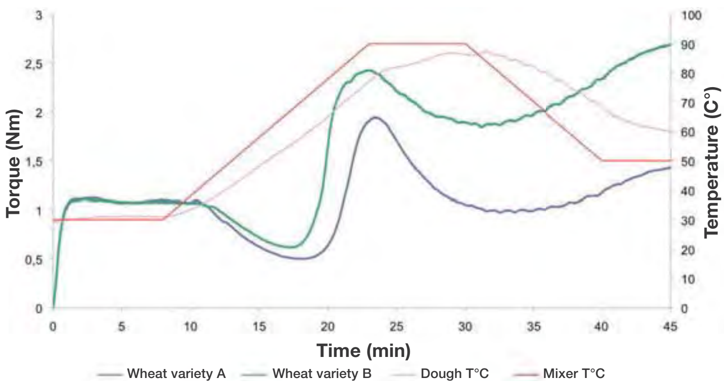


Bug-infested samples can be detected with Mixolab® using the Wheatbug protocol.

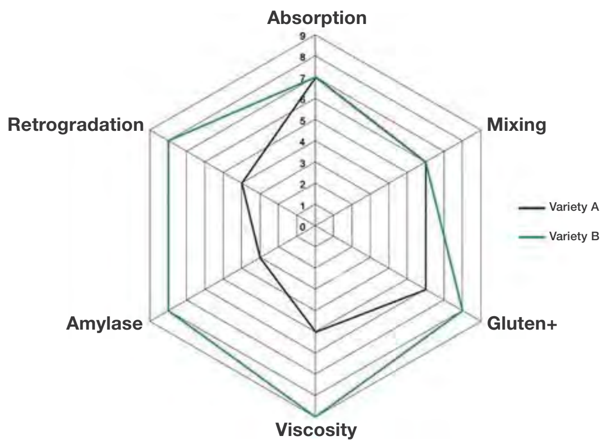
14.2 ▶ Animal feed application

14.2.1 Wheat digestibility

For this study conducted with a reference animal feed institute, two wheat samples of different varieties with different digestibility results were analyzed with the Mixolab®.



ChopinWheat+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min



	Wheat variety A	Wheat variety B
Absorption (%)	62.1	62
Stability (min)	10.9	11.6
C2 (Nm)	0.5	0.62
C3 (Nm)	1.95	2.43
C4 (Nm)	0.97	1.84
C5 (Nm)	1.43	2.69
C3-C2 (Nm)	1.45	1.81
C3-C4 (Nm)	0.98	0.59
C5-C4 (Nm)	0.46	0.85

The above graphs show that wheat variety B differs from wheat variety A by:

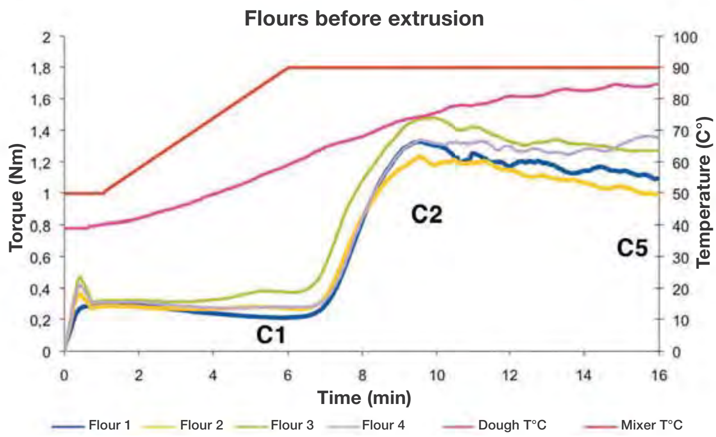
- A lower protein weakening (C2), meaning a greater protein resistance to temperature and mixing stress.
- A higher viscosity (Viscosity index of 9 for wheat variety B while wheat variety A has an index of 5). The gelatinization peak for wheat variety B is higher (C3 = 2.43 Nm versus C3 = 1.95 Nm for wheat variety A).
- A higher amylase index (wheat variety B has an index of 8, wheat variety A has an index of 3), indicating a low amylase activity.
- Greater gelling (C5).

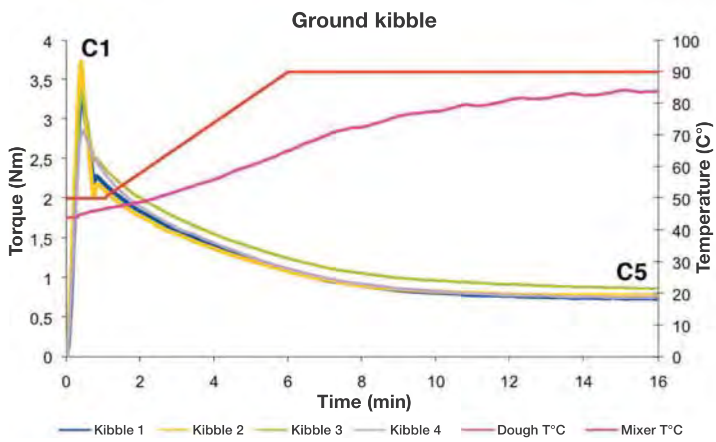
The Mixolab® can be used to analyze and discriminate two wheat samples with different digestibility results. The differences are seen during the Mixolab® heating phase.

14.2.2 Finished product gelatinization

In partnership with a pet food manufacturer, a Mixolab® study was conducted to determine the quality of flour used in the composition of dry pet food and to measure the starch gelatinization in the final product. Poor starch gelatinization can lead to digestive problems. It is therefore very important four our pets to have an analytical tool to measure this parameter.

Four flour samples (before extrusion) and the four corresponding dry pet food samples were analyzed using a protocol specifically developed for this application (Croquette protocol).





Cube protocol	
Mixing speed	200 rpm
Hydration	80% b14
Dough weight	90 g
Tank temperature	50°C
Temperature 1st step	50°C
Duration 1st step	1 min
Temperature 2nd step	90°C
1st temperature gradient	8°C/min
Duration 2nd step	10 min
Total analysis time	16 min

The 4 samples can be classified according to their viscosity at the 6th minute (before the start of gelatinization). Flour 1 had the lowest viscosity, followed by flours 2 and 4. Flour 3 displayed the highest viscosity. Gelatinization started between the 6th and 7th minutes. At the gelatinization peak, the average dough temperature was 75.1°C. Starch quality is characterized by the gelatinization peak (C2-C1 torques) and by gel hot stability (C5-C2 torques). The gelatinization peaks were similar.

	Flour					Kibble	
	C1 (Nm)	C2 (Nm)	C5 (Nm)	C2-C1 (Nm)	C5-C2 (Nm)	C1 (Nm)	C5 (Nm)
1	0.21	1.33	1.1	1.12	-0.23	3.36	0.74
2	0.27	1.23	0.99	0.96	-0.24	3.73	0.75
3	0.38	1.48	1.27	1.1	-0.21	3.35	0.87
4	0.28	1.34	1.36	1.06	0.02	2.86	0.75

The tests conducted on grinded products show that gelatinization was complete during the manufacturing process (no gelatinization peaks). Sample 3, in which pre-extrusion viscosity was the highest, also showed the highest post-extrusion viscosity (C5 = 0.87 Nm).

It is possible to analyze flours used in pet food, and final pet food products, using a simple and rapid (16 minutes) Mixolab® protocol.

14.3 ▶ Analysis of gluten-free products

Celiac disease is an autoimmune disease affecting 0.5 to 2% of the population depending on the country. The only treatment available for persons suffering from this disease is a special diet without gluten. The food industry is permanently looking for new solutions to create gluten-free products using blends of starch from various sources (corn, rice), sugar, fibre and plant protein.

In partnership with a manufacturer of gluten-free bread, two gluten-free formulas with different process properties, were analyzed with the Mixolab®.

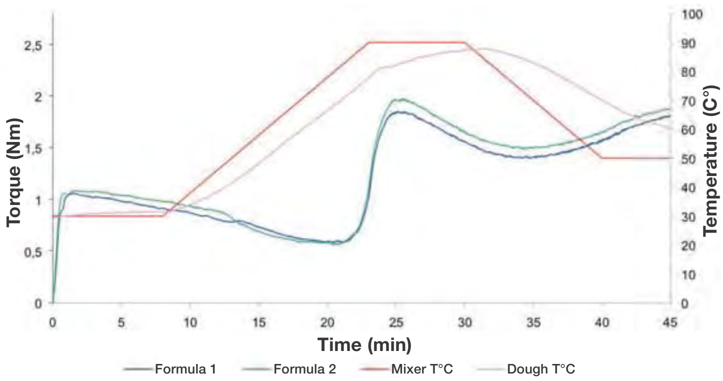
Formula 2 gave bigger bread volumes than formula 1. This is because formula 2 has a greater gas retention capacity than formula 1 (confirmed by analysis in the CHOPIN Rheofermentometer).

	Formula 1	Formula 2
Hydration (% b14)	84.8	81.0
Stability (min)	7.27	9.52
C2 (Nm)	0.58	0.56
C3 (Nm)	1.85	1.98
C4 (Nm)	1.4	1.49
C5 (Nm)	1.8	1.88
C3-C2 (Nm)	1.27	1.42
C3-C4 (Nm)	0.45	0.49
C5-C4 (Nm)	0.4	0.39

Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

The most significant quality differences between these two samples involved:

- Their water absorption capacity. Formula 1 had a higher water absorption capacity than formula 2. It is also worth noting that both formulas showed much higher water absorption capacities than the wheat flours conventionally used in bread-making (approximately 60%).
- Their stability. Formula 2 showed better mixing stability than formula 1.



- The gelatinization peak. Formula 2 showed a higher C3 value than formula 1. Its gelatinization potential (C2-C3) was superior.

The Mixolab® is perfectly suited for analyzing gluten-free formulas.

14.4 ▶ Protocol sequencing

During the bread-making process, a resting phase is frequently added during mixing.

With the Mixolab®, a resting phase can be added during mixing, before the CHOPIN+ protocol heating phase, by sequencing two successive protocols.

Two flour samples were analyzed with a 5-minute resting phase between 2 sequenced protocols.

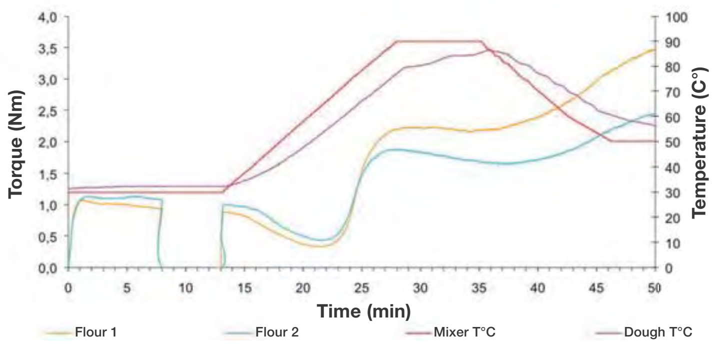
For this, protocol 1 is first started.

After leaving the dough formed in the mixer to rest for 5 minutes, lid opening and lever operation (right-left) have to be simulated.

Protocol 2 is then started. In this case, the auto reset option has to be disabled and the no calibration test selected. A value of “1” should also be entered in the hydration box. It is important to ensure that the nozzle is placed over the container during the first minutes of the test, then put on the mixer (to avoid any water loss by evaporation during the heating phase).

	Protocol 1	Protocol 2
Mixing speed	80 rpm	80 rpm
Target torque (for C1)	1.1 Nm	
Dough weight	75g	75g
Tank temperature	30°C	30°C
Temperature 1st step	30°C	30°C
Duration 1st step	8 min	0 min
Temperature 2nd step		90°C
1st temperature gradient		4°C/min
Duration 2nd step		7min
2nd temperature gradient		-4°C/min
Temperature 3rd step		50°C
Duration 3rd step		5min
Total analysis time	8 min	37 min

The curves obtained with these two protocols can then be processed with Excel.



		Flour 1		Flour 2	
		Protocol 1	Protocol 2	Protocol 1	Protocol 2
	Hydration b14	54.1%		58.8%	
Torque (Nm)	C2		0.31		0.42
	C3		2.20		1.87
	C4		2.09		1.62
	C5		3.46		2.4

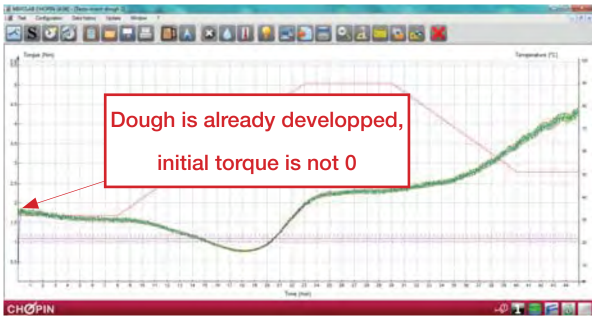
A resting phase can be added to the Mixolab® protocol, during the mixing phase.

15 ❖ TEST ON DOUGH SAMPLED FROM PRODUCTION LINE

15.1 ▶ Standard protocol analysis

The Mixolab® can be used not only to analyze any type of flour, but also to study previously mixed dough. This option may be of particular interest in the baking industry (in-process dough quality control).

A dough kit is available and can be used for this application on all Mixolab® units. This kit contains the dough feeder and a specific nozzle for this application.



✦ Test preparation

Tests on dough are prepared using the standard procedure with the “test preparation” window. It is important not to perform any operation during the calibration phase.

NB: In order to be able to start a test, it is necessary to complete the hydration and water content parameter fields. However, the values entered are not important, since they are not used during the test (since the dough introduced is from an industrial mixer, the flour and water quantities given by the application are not important).

✦ Introduction of dough in the mixer

Before starting the test:

➲ Weigh dough sample to analyse (75 g in the case of the CHOPIN+ protocol shown above).

➲ When the “measurement” window is displayed, introduce the dough into the mixer via the feeder such that the dough does not get out of the mixer.

➲ After 1 minute of test, place the water injection nozzle on the mixer.

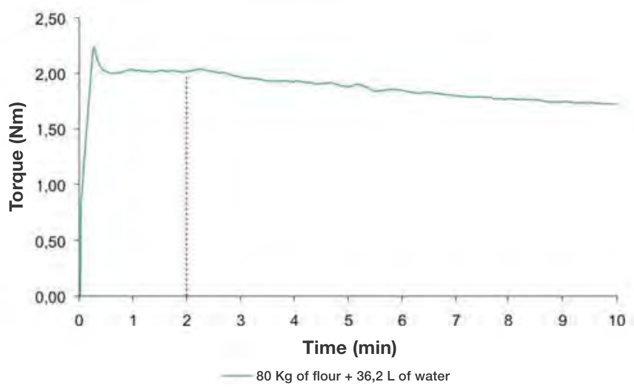
15.2 ▶ Application to control industrial mixing

Controlling the consistency of dough getting out of the mixer is a key step in the production of a lot of cereal products (rusks, bread loaves, etc.). This consistency is governed to a great extent by the amount of water added, which should be optimized according to the flour characteristics (moisture, protein content, damaged starch content, etc.) and to antagonistic technical and economic constraints: water addition must be as high as possible in order to maximize outputs and as low as possible to minimize production line problems (tack problems, dough machinability defects, etc.).

Our partner, a rusk manufacturer, works on batches of 80 kg of flour. At the end of each mixing operation, a person manually evaluates the consistency of the dough. Depending on the perceived consistency, the person decides whether or not to add water for subsequent mixing operations.

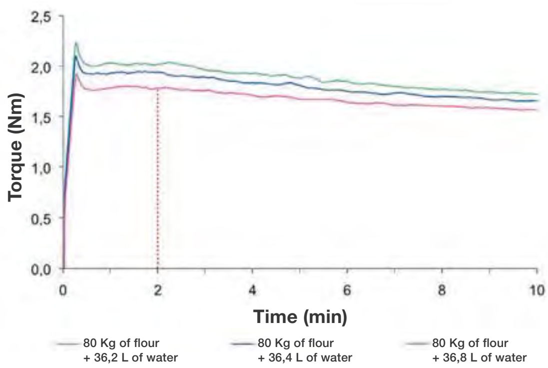
In order to remove any sensory subjectivity, our partner wanted to design a method to instrumentalize both consistency control and hydration correction.
A study was initiated to assess the ability of the Mixolab® to meet this need.

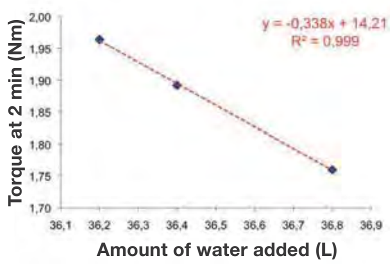
The first step was to determine the target consistency. An industrial mixing operation was launched, using a known flour and hydration, to obtain the desired final consistency. At the end of mixing, 100 g of dough was sampled and analyzed on the Mixolab®. The torque measured after 2 minutes was the target consistency.



Consistency protocol	
Mixing speed	100 rpm
Target torque (for C1)	-
Dough weight	100 g
Tank temperature	-
Temperature 1st step	26°C
Duration 1st step	10 min
Temperature 2nd step	-
1st temperature gradient	-
Duration 2nd step	-
2nd temperature gradient	-
Temperature 3rd step	-
Duration 3rd step	-
Total analysis time	10 min

The second step of the study was to change consistency according to the amount of water added to the mixer. Three industrial mixing operations (same flour, but 3 different hydration levels) were performed. At the end of each mixing operation, 100 g of dough was sampled and analyzed on the Mixolab®. Torques at 2 min were analysed. It showed that a 0.150 litre increase in water leads to a 0.05 Nm drop in consistency.





y1 = -0,3386 x1 + 14,219
y2 = -0,3386 x2 + 14,219
y1 - y2 = -0,3386 (x1 - x2)

Si on fixe :
y1 - y2 = 0,05 Nm

Alors :
x1 - x2 = (y2 - y1)/0,338 Nm = -0,147

Based on these two elements - target consistency and hydration correction -, it is possible to have a more rational control of the industrial mixing phase.

16 ❖ CORRELATION WITH TECHNOLOGICAL TESTS

For a large number of people in the cereal industry (millers, industrial bakers, etc.), technological tests such as bread-making tests or cookie-making tests are the primary method for evaluating flour quality. However, the duration of the tests and the need for expert operators (e.g. test bakers) limit the productivity of this type of analysis. Therefore, the development of quick and reliable instrumental methods for predicting technological flour quality would offer an undeniable benefit.

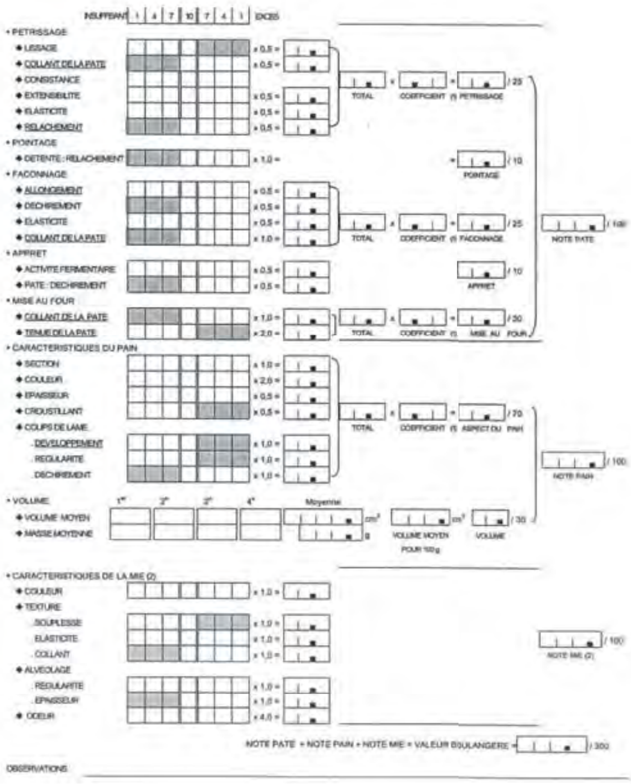
However, the development of such prediction methods faces different obstacles.

- The very wide diversity of existing technological tests. For bread-making alone, there are loaf breads and hearth breads, long and short fermentations, simple recipes and complex formulations, etc.
- Multiple and varied quality assessment parameters.
  In the case of bread, they include:
  - Unitary parameters (volume) and summary parameters (bread score).
  - Instrumentally quantifiable parameters (volume) and manually quantifiable parameters (dough tack).
  - Continuous value parameters (water absorption) and discrete value parameters (dough smoothing).
- Low result repeatability and reproducibility.

Parameter	Repeatability limit	Reproducibility limit
Volume (cm³)	158	315
Absorption (%)	1.4	3.5
Total score (/300)	25	43
Dough score (/100)	10	18
Crumb score (/100)	7	10
Bread score (/100)	17	28

Scoring grid for standard French bread type bread-making tests (NF V03-716)

On the basis of these various factors, it can be seen that the definition of a universal relationship between an instrumental analysis and a technological test is an illusion. Although the methodology applied may be common, it is necessary to adapt the prediction models to each type of test. Parameters to predict (volume, specific volume, etc.) need to be identified. The performances of these prediction models will always be closely dependent on the performances (repeatability / reproducibility) of the reference method.



Scoring grid for standard French bread type bread-making tests (NF V03-716)

16.1 ▶ Classification tests

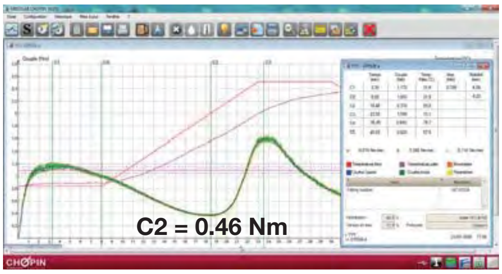
16.1.1 Bread making in a Belgian loaf tin

The Belgian bread-making test is similar to the English test due to the use of bread loaf tins. Tests were conducted by the Walloon Region Agronomic Research Center (CRA-W) in Gembloux. The goal was to assess the ability of the Mixolab® to estimate wheat baking quality (for Belgian bread-making).

A first comparative study conducted on two flour samples (A and N) obtained from pure varieties, illustrates the correlation between protein quality, bread volume and Mixolab® C2. Sample N has a resistant protein network (high C2), preventing the dough from developing correctly, producing a smaller bread.

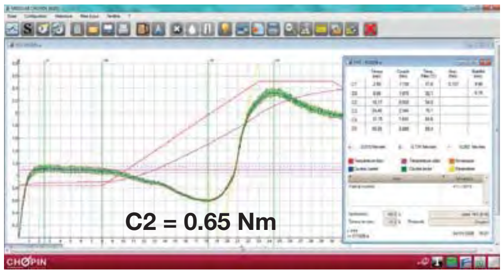
Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Variety A : volume 5252 cm^3 / flour



Variety A

Variety N : volume 4036 cm^3 / flour



Variety N

Moreover, a second study demonstrates that wheat varieties can be classified according to the suitability for Belgian bread-making on the basis of Mixolab® criteria (development time, stability and C2).

Wheat category	Development time	Stability	Min. torque (C2)
Strong wheat	> 8 min	> 11 min	> 0.60 Nm
BPS (superior)	> 3 min	Between 8 and 10 min	< 0.50 Nm
BPC (Common)	> 2 min	> 8 min	< 0.55 Nm
BAU (other uses)	< 2 min	< 8 min	--

The Mixolab® can be used to classify wheat varieties according to their suitability for Belgian bread-making.

Acknowledgments: CRA Gembloux (Belgium)

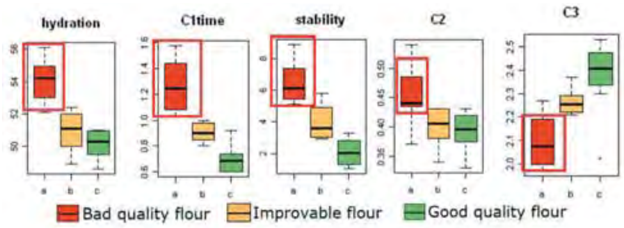
16.1.2 Cookie-making test

Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

Flour quality depends on the product to be manufactured and the manufacturing process used. Various studies were conducted, in collaboration with cookie manufacturers, to assess the ability of the Mixolab® to determinate and select flours according to their end use.

An initial study was conducted on biscuit flour. Various flours, referenced with technological methods (good quality biscuit flours, improvable quality biscuit flours, poor quality biscuit flours), were tested on the Mixolab®. The analysis of the main parameters (absorption, development time, stability, C2 and C3) primarily shows that poor quality biscuit flours are clearly identifiable (high absorption, high stability, long development time, high C2, low C3). Moreover, it is also possible to discriminate good quality biscuit flours and of improvable quality flour on development time, stability and C3.

Biscuits results



The same type of study was conducted on “Sponge cakes” and “American-style cookies”. The main Mixolab® properties required for each of these finished products were identified.

Mixolab®*	Biscuit	Sponge	Cookies
Stab (Min)	1:00 – 3:00	7:00 – 10:00	< 7:00
C2 (Nm)	0.35 – 0.45	0.35 – 0.45	0.45 – 0.55
C3 (Nm)	> 2.5	< 1.5	> 2.3
C4 (Nm)	n.d.	< 1.4	> 2.3
C5 (Nm)	n.d	< 2	> 3

** Values are indicative. They can vary according to receipe and the process.*

These studies confirm the benefits offered by the Mixolab® in the selection and control of biscuit flours. These studies also show that the quality of these flours is not only linked to protein. Starch also plays an important role.

16.2 ▶ Prediction tests

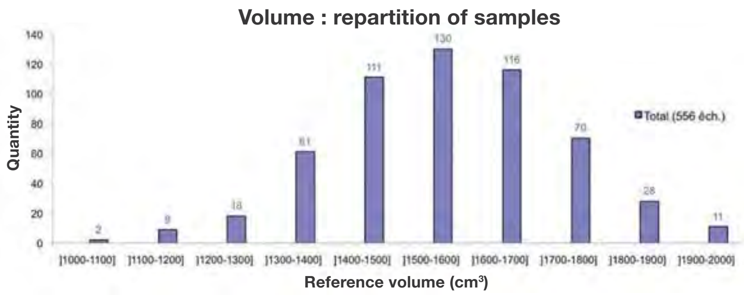
16.2.1 French hearth bread-making

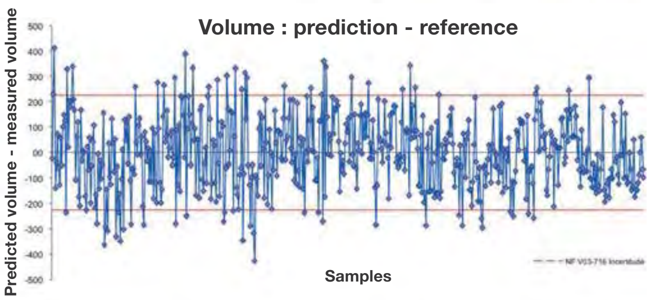
556 French flour samples, obtained from 4 different years, were successively tested for French bread-making (NF V03-716) and on the Mixolab® (Chopin+ protocol). Mathematical prediction models adapted to each bread making parameter have been created thanks to the spectral analysis of the curves, combined with the use of appropriate statistical tools (multiple linear regression).

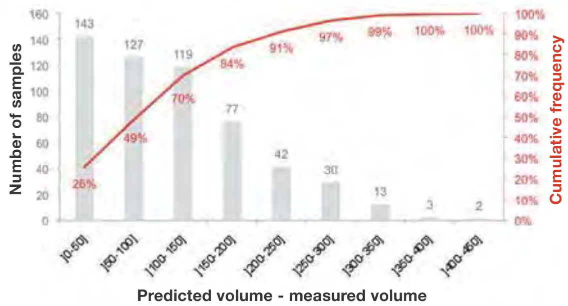
Performance of the models developed			
	Range	Tolerances (NF V03-716)	Spl. "in"* tolerances (NF V03-716)
Volume (cm^3)	1071-1999	225	88%
Absorption (%)	55.5-65.3	2.5	99%
Total score (/300)	104-286	31	77%
Dough score (/100)	17-100	13	76%
Crumb score (/100)	76-100	7	92%
Bread score (/100)	5-92	20	81%

** % of samples predicted within the tolerances (NF V03-716)*

Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min







More than 75% of predictions (even over 85% in the case of volume, absorption and crumb score) are within the tolerances. The developed models have very good performance.

It is possible to estimate the main parameters of the French bread-making test. It is important to note that the methodology implemented for these tests can be applied to all types of bread-making.

16.2.2 Sponge & dough type bread-making

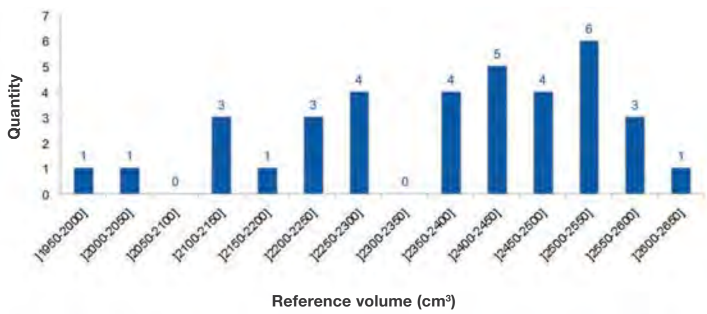
The Sponge & dough method is a 2-step bread-making method. First, a dough is formed by mixing a fraction of the total flour with water and yeast. Then, the dough ferment for 4 hours. Finally, the remaining flour and ingredients are incorporated.

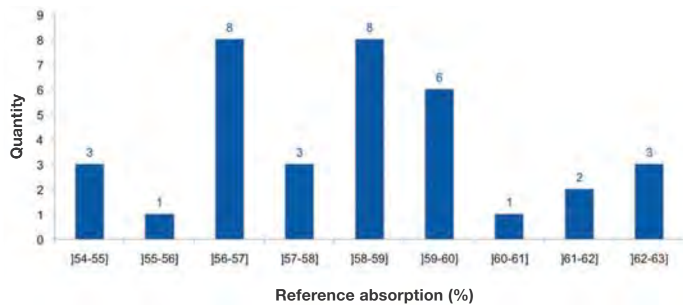
36 flour samples were successively tested in bread making according to the Sponge & dough method (AACC 10-11.01) and on the Mixolab® (Chopin+ protocol). Mathematical prediction models adapted to each bread making parameter have been created thanks to the spectral analysis of the curves, combined with the use of appropriate statistical tools (multiple linear regression).

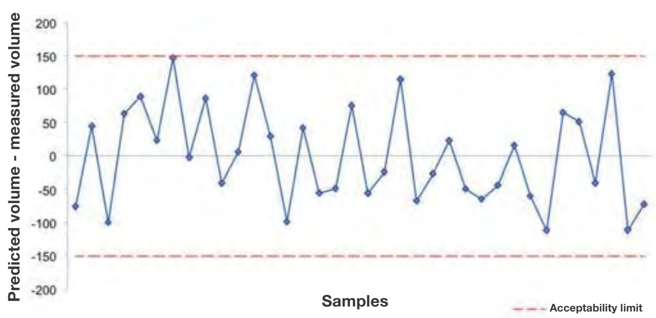
Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min

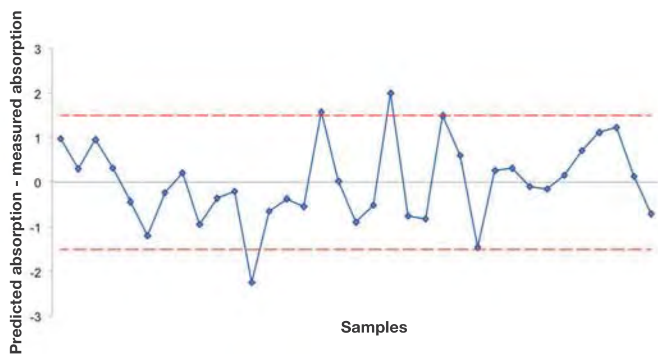
Performance of the models developed			
	Range	Tolerances	Spl. "in"* tolerances
Volume (cm^3)	1963-2650	150	100%
Absorption (%)	55-63	1.5	91%

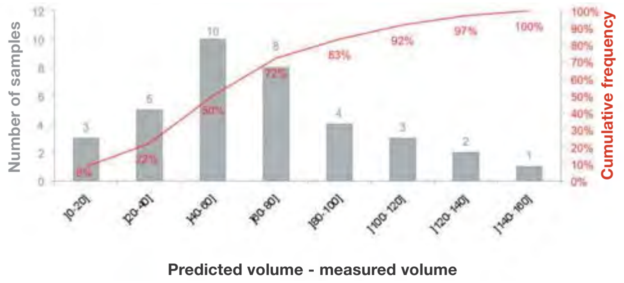
** % of samples predicted within the tolerances (set by our business partner)*

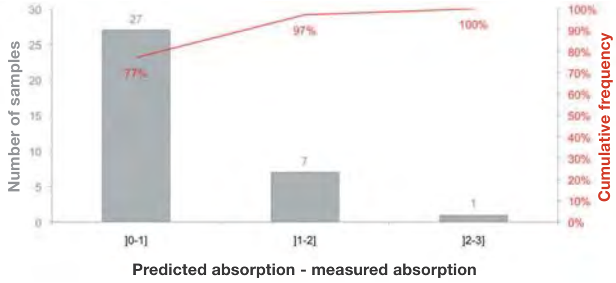












More than 90% of predictions are within the acceptability limits. The models developed have good performances.

These results, which need to be completed by incorporating additional samples, are more than encouraging and tend to show that it is possible to predict the main parameters of the Sponge & dough test.

It is important to note that the methodology implemented during these tests can be applied to all types of bread-making.

16.2.3 Marraqueta type bread-making

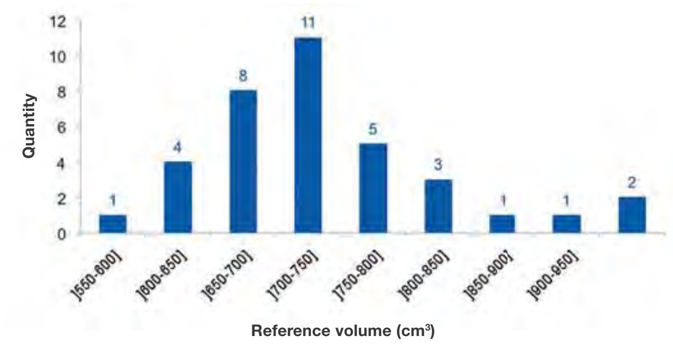
Marraqueta (also known as pan batido in Valparaiso, or pan francés in other parts of Chile) is a type of bread made from white wheat flour, water, yeast and salt. It requires longer fermentation times than other breads. This type of bread is eaten in Bolivia, Chile, Peru and in the Argentinean province of Mendoza.

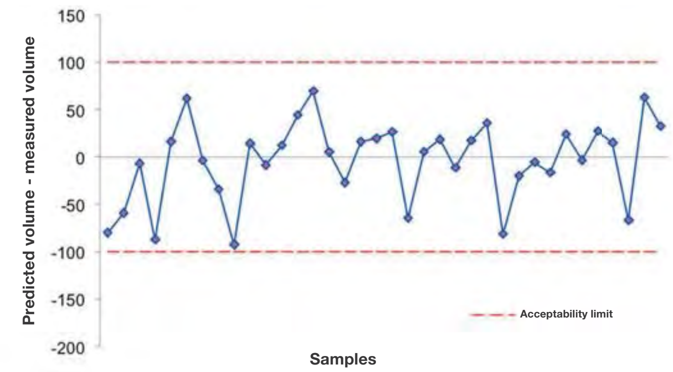
36 samples from Chile were successively tested in bread making using the Marraqueta method and on the Mixolab® (Chopin+ protocol). Mathematical prediction models adapted to each bread making parameter have been created thanks to the spectral analysis of the curves, combined with the use of appropriate statistical tools (multiple linear regression).

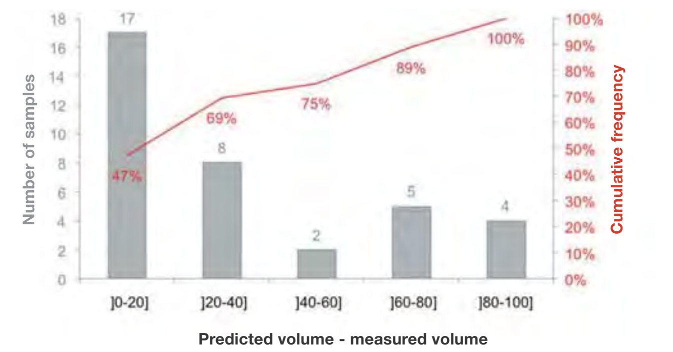
Performance of the developed model			
	Range	Tolerances	Spl. “in”* tolerances
Volume (cm^3)	583-1000	100	100%

** % of samples predicted within the tolerances (set by our business partner)*

Chopin+ protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min







100% of predictions are within the acceptability limits. The model developed to estimate volume is excellent. These results, which need to be completed by incorporating additional samples, are more than encouraging and tend to show that it is possible to estimate marraqueta bread volume.

It is important to note that the methodology implemented during these tests can be applied to all types of bread-making.

17 ❖ PROFILER ADAPTATION

17.1 ▶ Principle

The Mixolab® Profiler translates the standard curve (generated by the Chopin+ or Chopinwheat+ protocols) into a sequence of 6 indexes graduated from 0 to 9. Common wheat samples (flour or ground meal) are characterized according to 6 fundamental criteria.

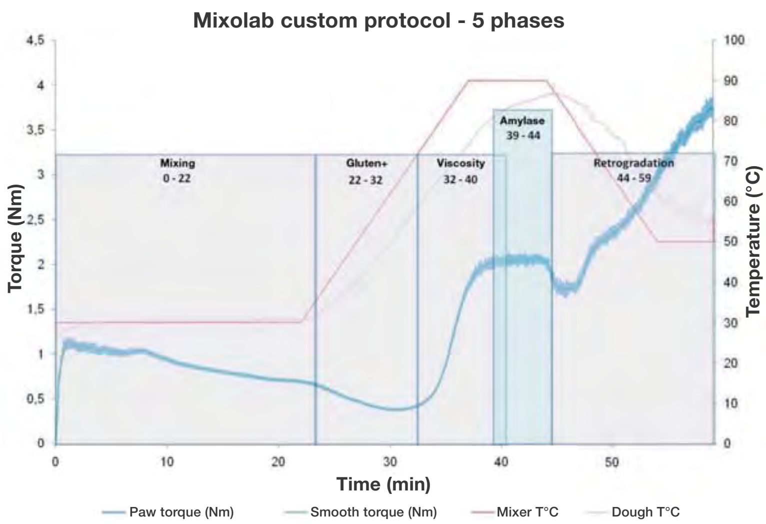
It may be useful to adapt the Profiler:

- If the protocol used routinely is not Chopin+ or Chopinwheat+.
- If the quality of samples tested are within a narrow range on each axis of the existing Profiler (a single type of flour for example).
- If the product under analysis was not obtained from common wheat.

An adapted Profiler may be developed by the Applications department, in conjunction with the Mixolab® user. For this development, at least 50 samples, covering the range of results routinely obtained with the special protocol or for the selected sample range, should be tested on the Mixolab®. An adapted hydration protocol must be used. The protocol used must not already be associated with a Profiler. If this is the case, the protocol name must be changed (it is possible to create a protocol with the same characteristics, but a different name). The results are analyzed to define new more relevant indexes since they are adapted to a specific product or custom protocol.

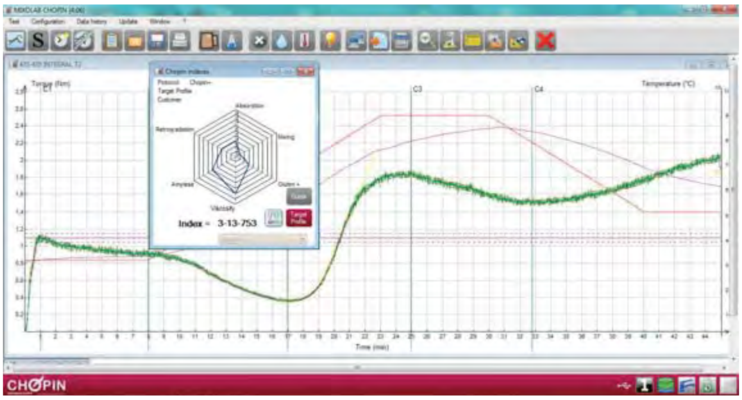
17.2 ▶ Profiler adapted to a custom protocol

Various adapted Profiles have already been implemented for custom protocols. The example presented below is a Profiler developed for a protocol with an extended mixing time at 30°C. This protocol was developed for flours with a long dough development time and/or very high stability.
Index calculation is performed over 5 defined phases of the Mixolab® curve. Each index takes into consideration specific parameters measured during the corresponding phase, such as specific torques, torque differences between two specific times, or the area under the curve.



Custom protocol: long mixing time at 30°C	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	22 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	59 min

This protocol can be used to analyze flours with high stabilities. Combined with the new Profiler, it is possible to create target Profiles to characterize samples analyzed daily.



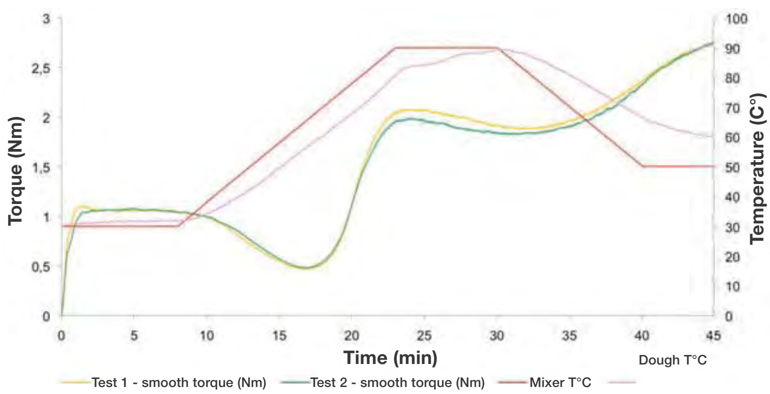
17.3 ▶ Profiler adapted to a flour type: Super-Profiler

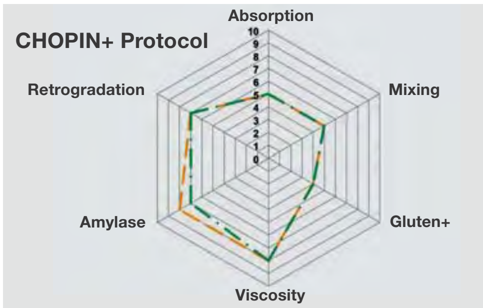
The example presented below is a Super-Profiler adapted to a specific type of flour for which the Chopin+ Profiler does not show a perfect discrimination. More than 100 flours were analyzed with the Mixolab®, using the "T55" protocol, that has the same characteristics as the Chopin+ protocol.

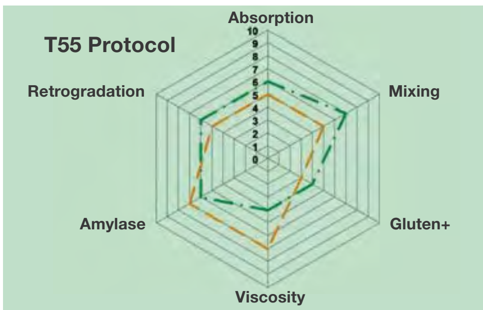
The study of the curves obtained for all samples to calculate 6 indexes from characteristic points on the curve (specific torques, areas under the curve, consistency differences, specific times), and distribute over the index scale from 0 to 9, only the range of results for this type of flour. This adaptation focuses on the usable zones of the Profiler covered by this type of product.

The graph below presents, for two flours, the indexes calculated using the Chopin+ profile (grey box) that are non-discriminatory. The green box shows the new indexes associated with the T55 protocol, used to discriminate the test samples more accurately.

T55 custom protocol	
Mixing speed	80 rpm
Target torque (for C1)	1,10 Nm
Dough weight	75 g
Tank temperature	30°C
Temperature 1st step	30°C
Duration 1st step	8 min
Temperature 2nd step	90°C
1st temperature gradient	4°C/min
Duration 2nd step	7 min
2nd temperature gradient	- 4°C/min
Temperature 3rd step	50°C
Duration 3rd step	5 min
Total analysis time	45 min







The Super-Profiler brings a more detailed discrimination within a given type of flour (T55 flour in this example).

18 ❖ MAIN PUBLICATIONS

Below is a list of the main publications using the Mixolab®. This list is not exhaustive.

Year	Title	Authors	Periodical / conference
2005	*Innovative evaluation of the rheological behaviour of bread dough controlling mixing energy and temperature*	Bollain C. Collar C.	Proceedings Intradfood vol II p 37-40
2006	*Formation of homopolymers and heteropolymers between wheat flour and several protein sources by transglutaminase catalyzed crosslinking*	Bonet A. Blaszcsak W. Rosell C.M.	Cereal chemistry N° 83 p 655-662
2006	*Novel approaches to dough rheology using the Chopin Mixolab*	Bollain C	Campden & Chorleywood
2006	*Rheological behaviour of whole wheat flour*	Haros M. Ferrer A. Rosell C.M.	IUFosT Nantes
2007	*Rheological behaviour of formulated bread doughs during mixing and heating*	Colllar C. Bollain C. Rosell C.M.	Food science and Technology International; 13; 99
2007	*Utilisation of the Mixolab to predict the suitability of flours in terms of cake quality*	Kahraman K. et al.	Eur Food Res Technol 227:565-570
2007	*Niveau de performance de la mesure du taux d'adsorption d'eau des farines et des caractéristiques rhéologiques de la pâte pendant le pétrissage avec le Mixolab Chopin*	Le Brun J. Geoffroy S. Dubat A. Sinnaeve G.	Industries des céréales 154, 20-27
2007	*Gluten composition, gluten quality and dough mixing properties (National Mixograph; CHOPIN Mixolab) of high Yielding wheats derived from crosses between common (T. aestivum) and synthétic (Triticum Dicoccon x Aegilops tauschii) wheats*	Pena R.J et al.	Eucarpia symposium.
2007	*Nuovo metodiche per lo studio delle proprieta viscoelsatiche in sfarinati di frumento duro*	Moscaritolo S. et al.	
2007	*Effets du procédé Oxygreen® sur la rhéologie de pâtes : études de farines de sarrasin par le Mixolab*	Piguel P. et al.	Industries des céréales, 152 p 22-24
2008	*Assessment of hydrocolloid effect on the thermo-mechanical properties of wheat using the Mixolab*	Rosell C.M. Collar C. Haros M.	Food Hydrocolloids 21 (2007) 452-462
2008	*Rice in "gluten free cereal products and beverages"*	Rosell C.M. Marcos C.	gluten free cereal products and beverages
2008	*Nuovo aproccio per la valutazione delle caratteristiche reologiche di impasti di frumento duro*	Moscaritolo S. Amoriello T. D'Egidio M.G.	Tecnica molitoria

Year	Title	Authors	Periodical/conference
2008	*Predicting the cookie quality of flours by using Mixolab*	Ozturk S. et al.	Eur Food Res Technol 227:1549-1554
2008	*Different strategies for optimizing rice based bread : ingredients, structuring agents and breadmakin process*	Rossel C.M. Marco C.	RACI conference
2008	*Measurement of water absorption rate in flours and rheological characteristics of dough during kneading*	Le Brun J. Geoffroy S. Dubat A. Sinnaeve G.	Tecnica molitoria
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2010	*Effects of transglutaminase on the rheological and mixolab thermomechanical characteristics of oat dough*	Huang W. et al.	Food chemistry 121 (934-939)
2010	*Contribution of lipids to physicochemical properties and mantu-making quality of wheat flour*	Sun H. et al.	Food chemistry 121 (332/337)
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2010	*The use of the Mixolab in predicting rice quality*	Xie L. et al.	Cereal chemistry In Press
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