Importance and Testing of Damaged Starch in Flour Milling

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Introduction

"Since the classic work of Jones on the mechanical damage incurred by starch during flour milling (1960), more attention has been paid to this aspect of cereal chemistry.

"The damaged-starch content of flours has been shown to exert both adverse and beneficial effects on the flour. For example, a series of studies initiated by Bird indicated that the presence of excessive amounts of damaged starch could lead to erroneous interpretations of results from the wheat-meal fermentation time test, the sedimentation test, and many physical dough parameters (1957, 1961)."

(Williams, 1967
Board of Grain Commissioners for Canada)

Introduction

Function of Flour in Breadmaking: Structure

1. **Protein** (gliadin and glutenin) and water form viscoelastic material, called gluten. Gluten retains gas formed by sugar fermentation and contributes to structure of dough and bread.

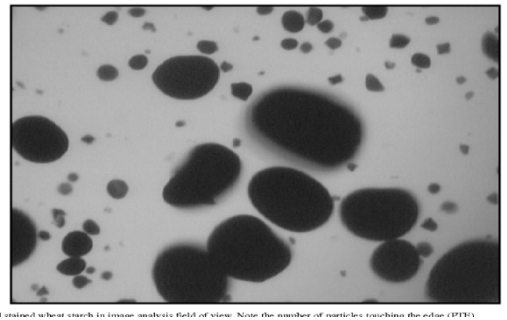
2. **Starch** + water + heat forms a viscous paste that sets to a gel after baking. During bread storage the starch crystallizes (retrograde) and contributes to firming (major part of staling) of breads. Starch is the main component of flour; from 68 to 72%.

What is damaged starch?

<u>Structurally disruption/modification of starch granules in wheat and flour!</u>

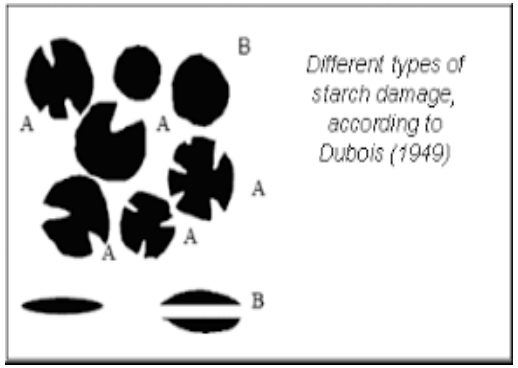
Starch damage, **damaged starch**, mechanically activated starch, mechanical starch modification

Small, Round (B-starch)

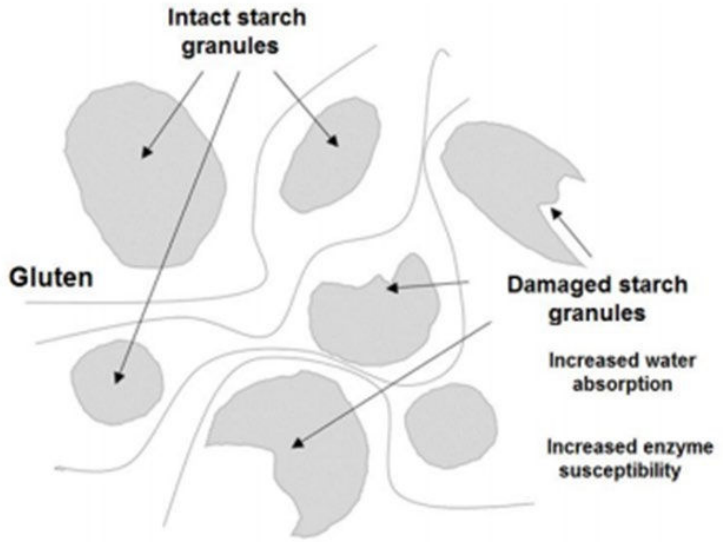


(Wilson, et al., 2006)

Large, lenticular (A-starch)



Different types of starch damage, according to Dubois (1949)



Where does it come from ?

There are two types of starch damage:

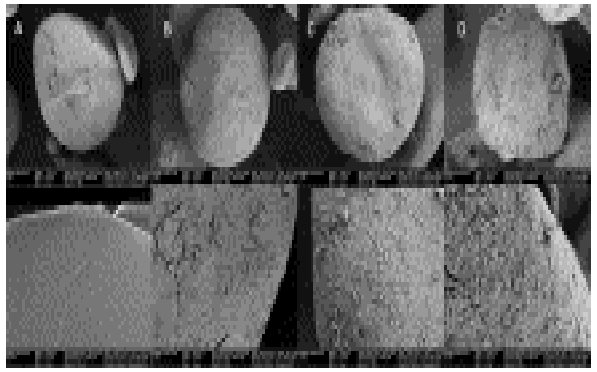
- ***Damaged starch comes from the wheat itself (as a function of hardness) - genetic criteria –***

The first is that which results in the starch granule being broken in two. Although the granule is clearly damaged, this type of damage results in starch that is not susceptible to attack by fungal α-amylase.

Where does it come from ?

- ***Damaged starch also comes from the milling process - mechanical criteria -***

The second more classic starch damage produced during milling results in granules that have partially or completely lost their crystallinity and are susceptible to fungal α-amylase.



Barrera, et al., 2013

Starch damage during milling

- **Roller milling damages a small but significant number of the starch granules in the flour.**

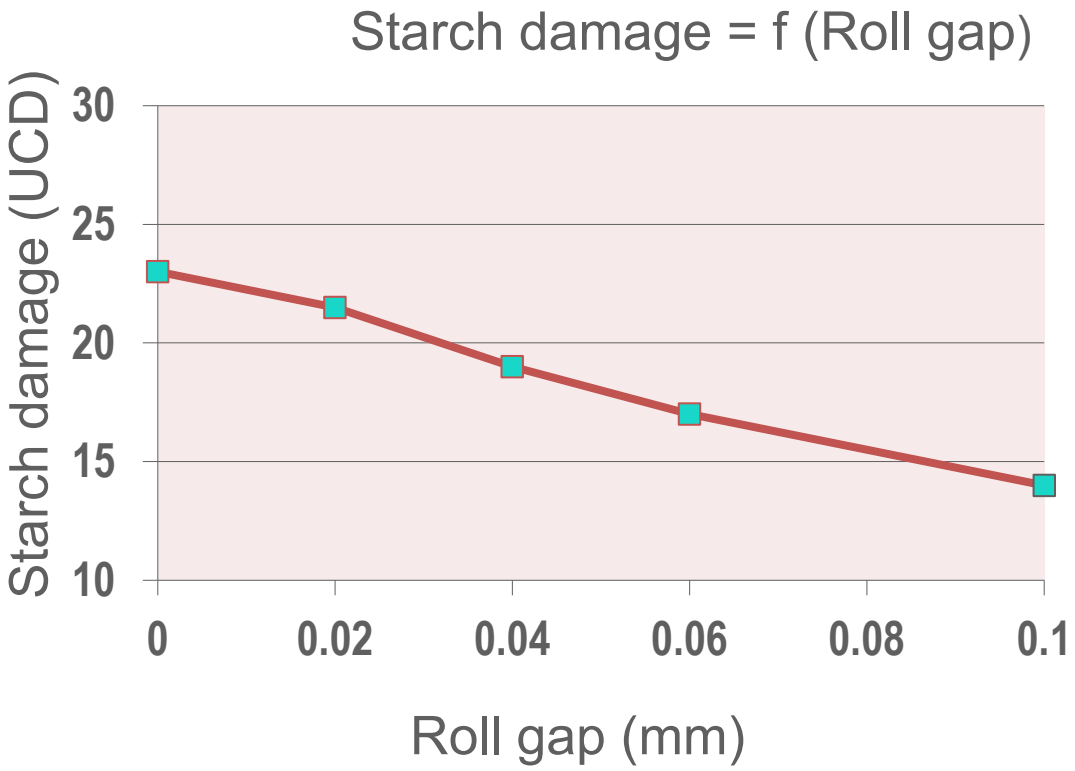
In general, the level of damage depends not only on the hardness of the wheat used but also on the settings of the milling rolls. Indeed, given a constant wheat supply, flour with increasing water-absorption characteristics can be produced by adjusting the roll settings such that increasing levels of starch damage are produced.

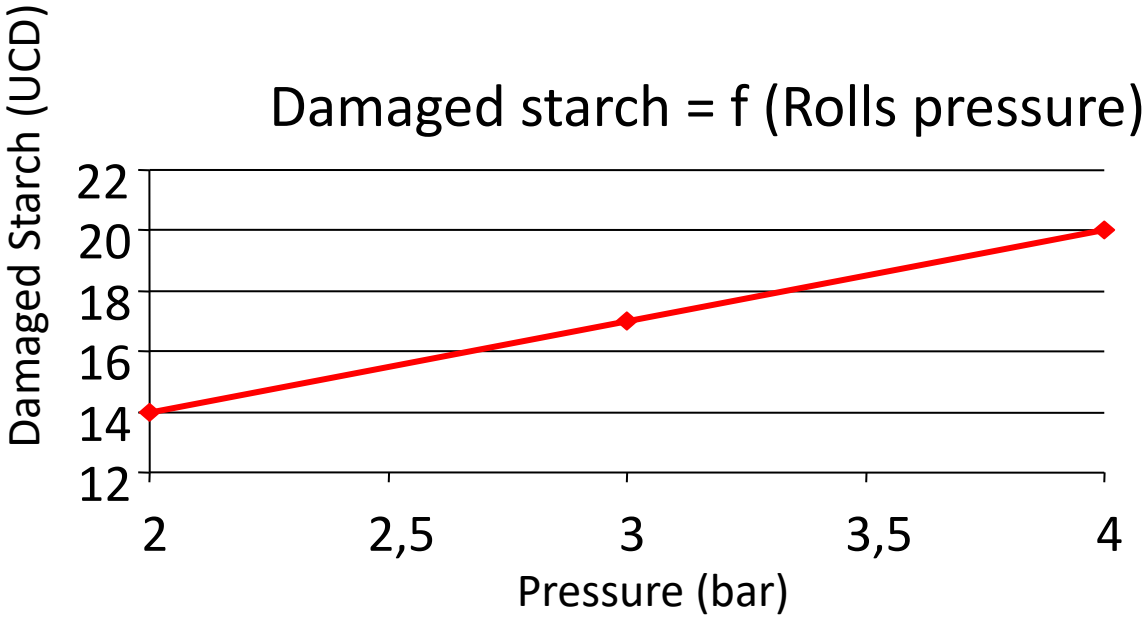
Hard

Soft

Starch damage during milling

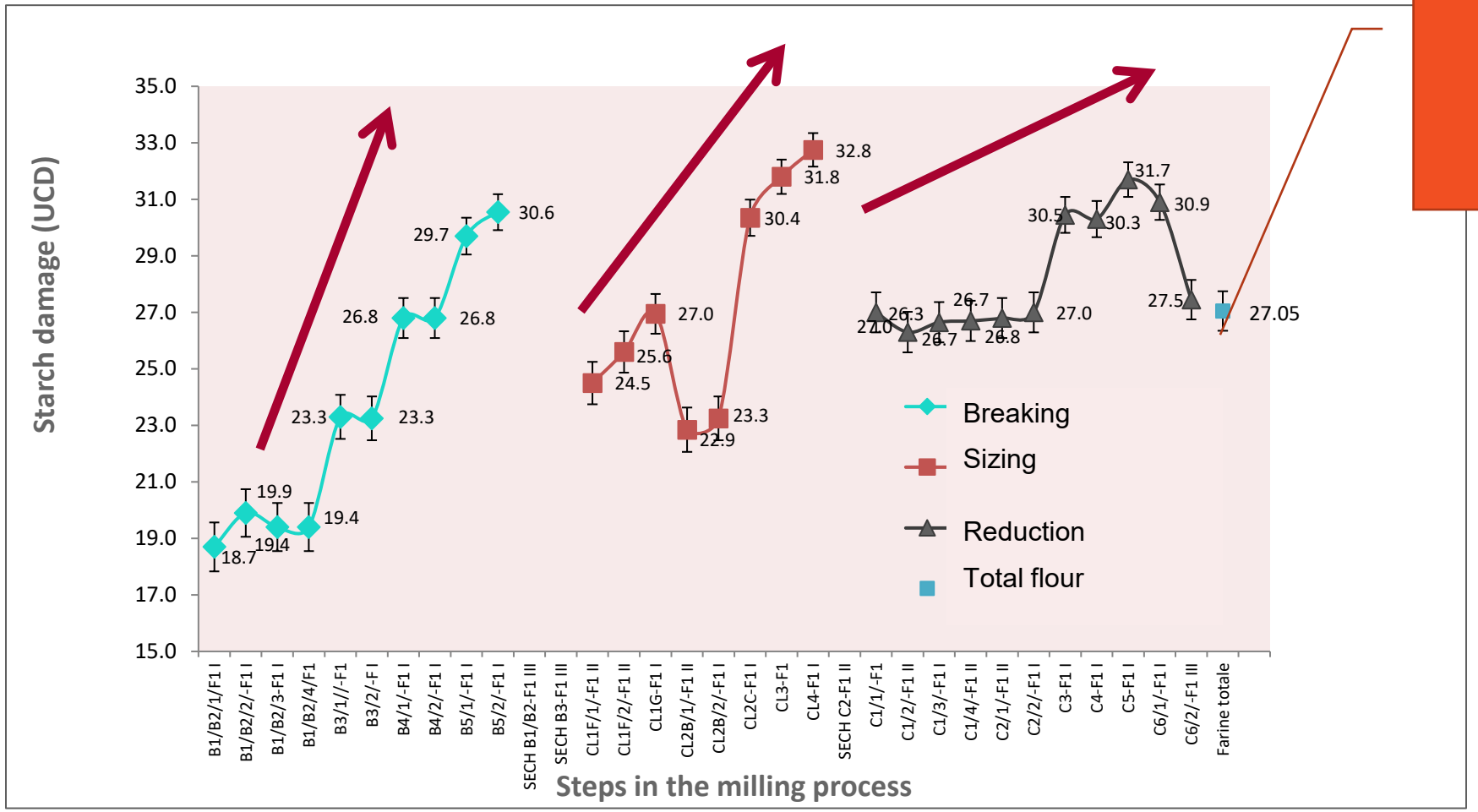
Impact of roll adjustments





Starch damage during milling

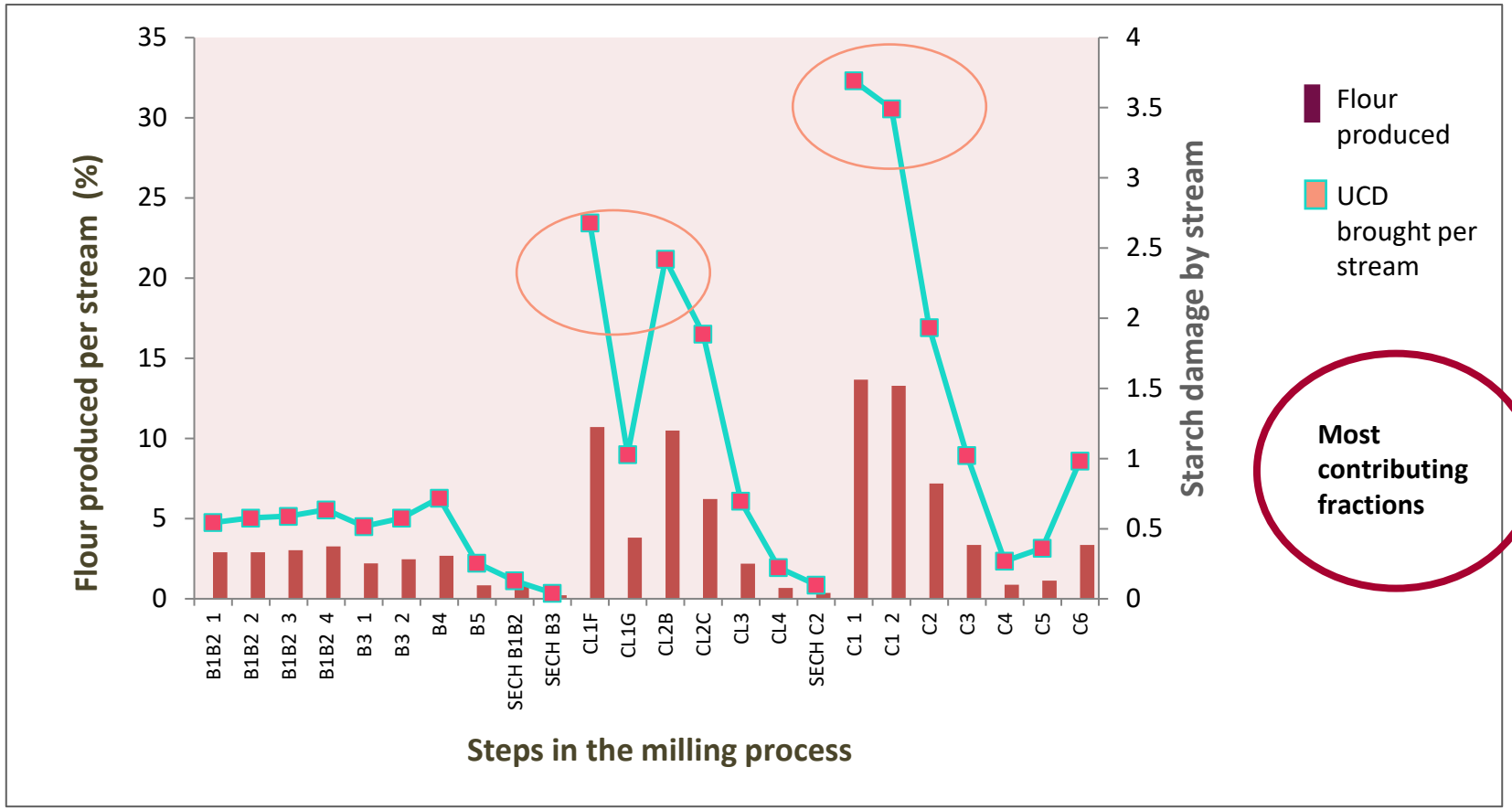
Analysis of flour streams: Starch damage increases throughout the process…



Final flour
SD ≤ 25 UCD

Starch damage during milling

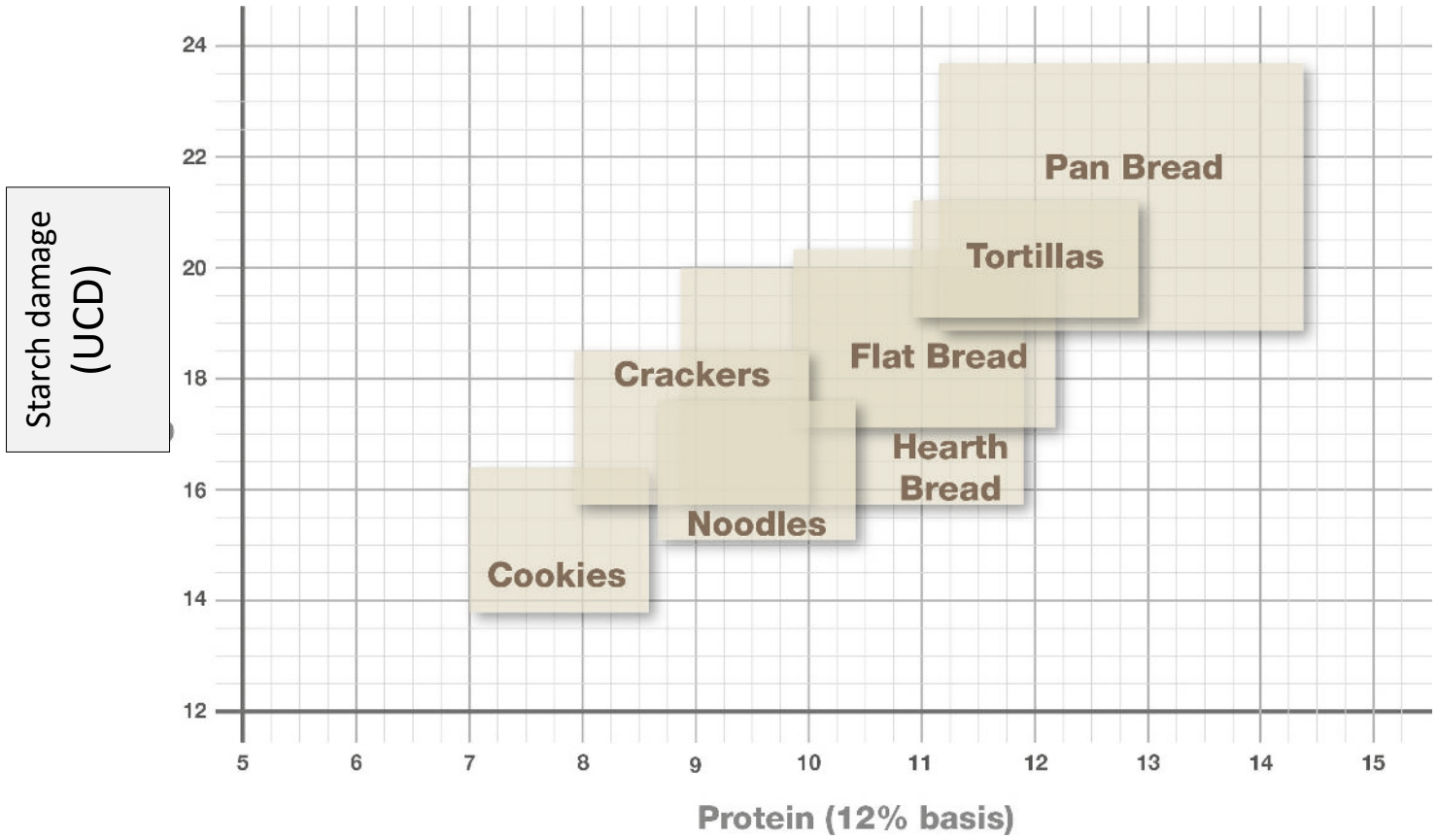
Sizing and reduction heads streams have a strong impact on the final starch damage. They **must be controlled in priority**!



Why measure starch damage?

Why measure starch damage?

For any product, there is an optimum/moderate level of starch damage!



Why measure starch damage?

- When starch damage occurs at low levels (or at optimum/moderate levels for the desired product) of the total wheat starch, they are considered to be beneficial to flour performance;

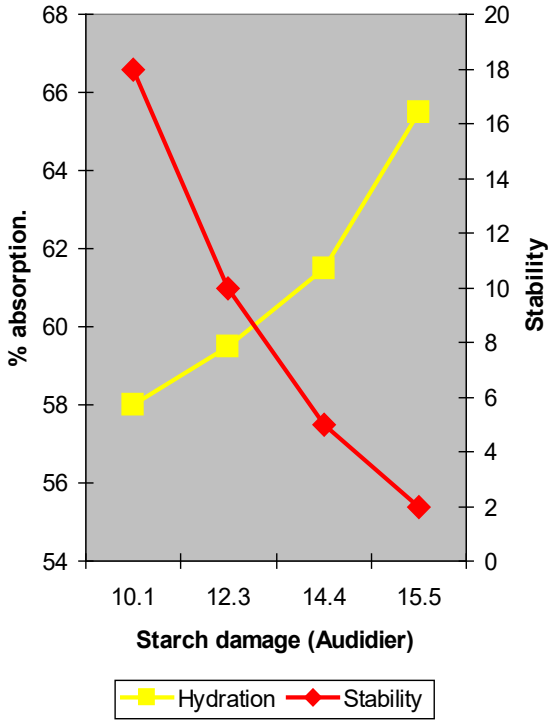
  because they are readily accessible to water and enzyme penetration and serve the dual function of increasing flour absorption and providing fermentable maltose for the yeast.

Why measure starch damage?

EFFECTS ON WATER ABSORPTION

- Protein absorbs 1.8 times its weight of water,
- Pentosans: 10 times,
- Native starch: 0.4 times,

Damaged starch: 3 to 4 times!



MILLERS' OBJECTIVE

- Produce the largest amount of flour from a lot of wheat (economic profitability)
- Produce flours according to the specifications of their customers (high hydration capacity flours for example for bread making flours)

BAKERS' INTEREST

- Add max content of water (better yield and better profit)

Why measure starch damage?

EFFECTS ON DOUGH PROCESSING

- “Doughs produced with high mechanical starch modification levels may not be fully developed at Peak time (optimum mixing time) and display a second peak” – Modify mixing time?
- “Possibility of having a sticky dough probably because of weakened protein–filler interfacial interactions and larger voids within the protein network?”

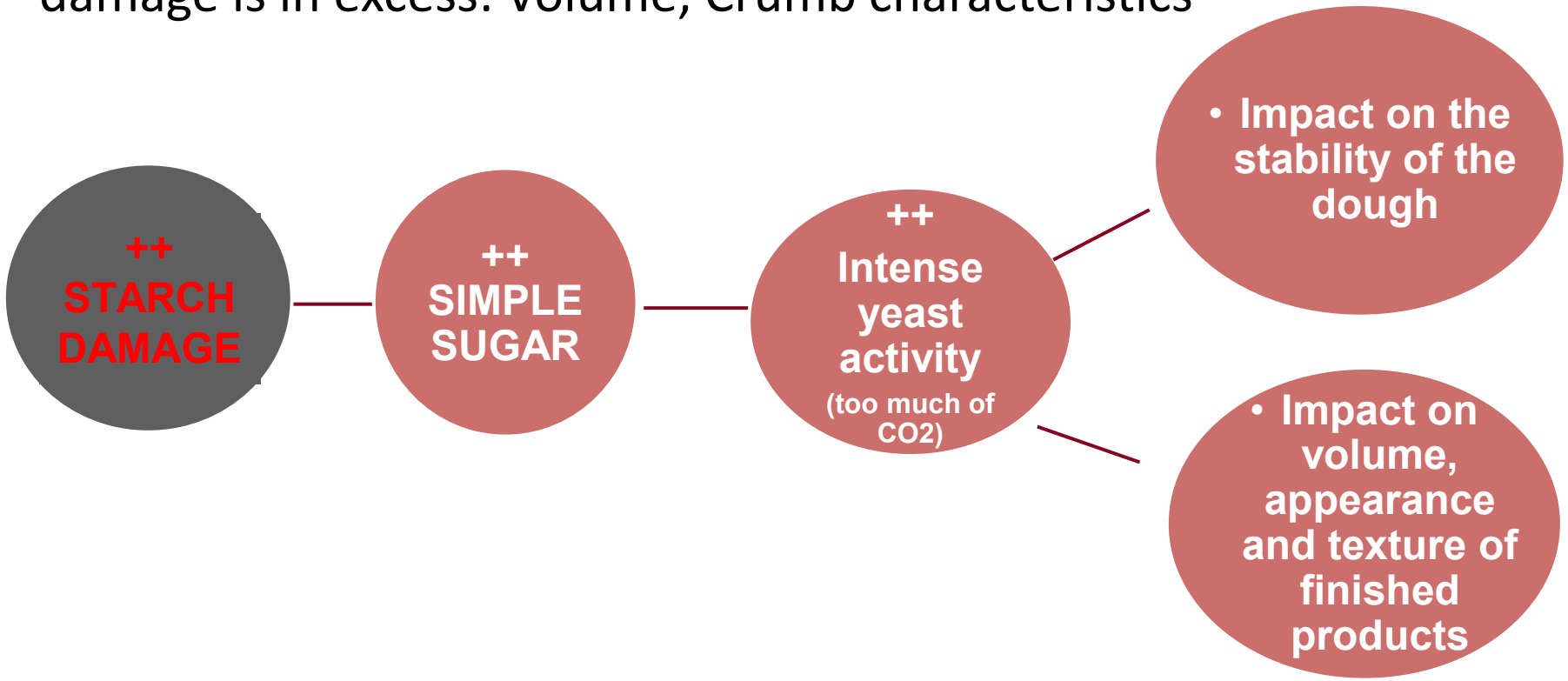
Hackenberg, et al., 2019

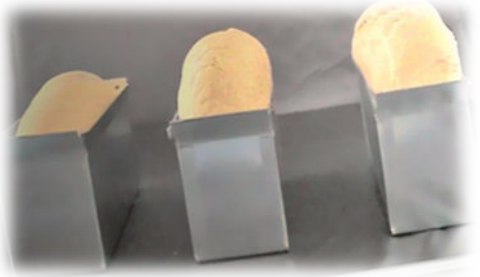
Damaged starch increases initial water absorption and prevents optimum gluten formation during mixing!!!

Why measure damages?

EFFECTS ON FERMENTATION CHARACTERISTICS

Amylases preferentially attack damaged starch, not native starch. If starch damage is in excess: Volume, Crumb characteristics



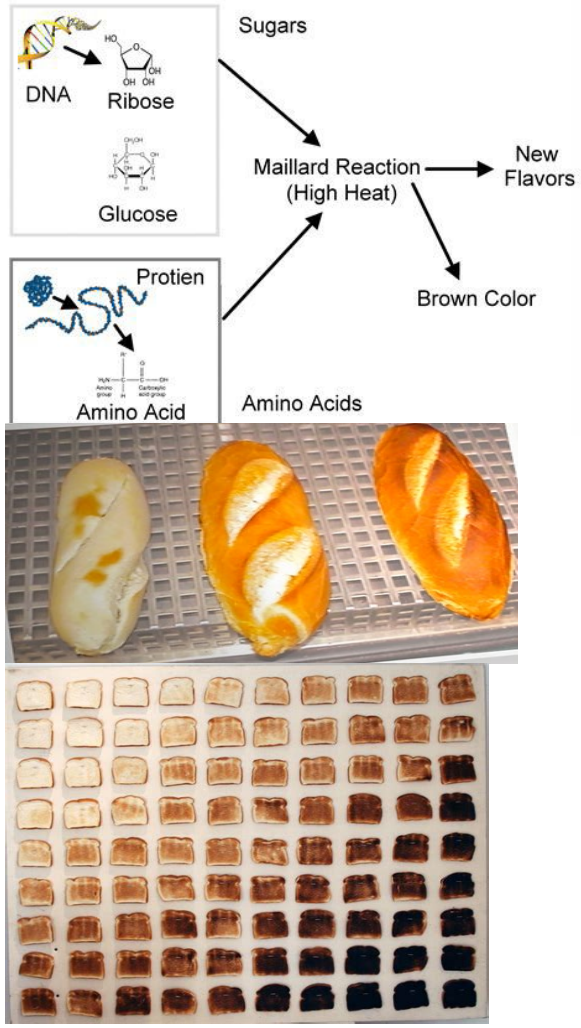


Why measure damages?

EFFECTS ON FERMENTATION CHARACTERISTICS

Amylases preferentially attack damaged starch, not native starch.
If starch damage is in excess: Crust color

++ STARCH DAMAGE — ++ SIMPLE SUGAR — ++ Coloration possibly higher (Maillard reaction) and caramelization



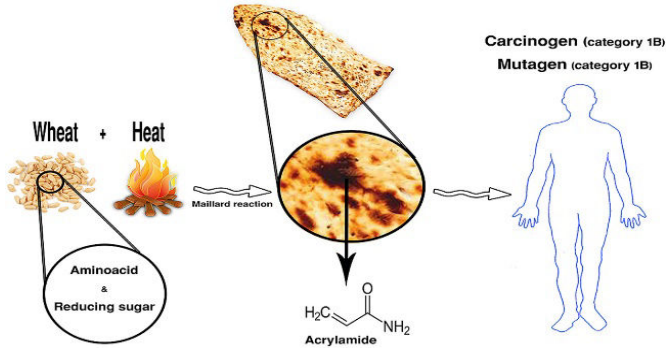
Why measure starch damage?

EFFECTS ON ACRYLAMIDE FORMATION IN BREAD

“Damaged starch content in wheat flour from the same cultivar showed **a strong positive correlation with acrylamide formation in bread** since reducing sugar contents increased with increasing damaged starch content in flour.”

“The mitigation of acrylamide formation in bread can be achieved by reducing damaged starch in flour and by **fermentation** of the dough.”

Wang, et al., 2017



Eslamizad, et al., 2019

Why measure starch damage?

EFFECTS ON STALING/SHELF LIFE OF THE BREAD

"Bread specific volumes decreased as the damaged starch content increased. Therefore, bread crumb firmness increment could be related with higher level of amylopectin retrogradation and with lower crumb density."

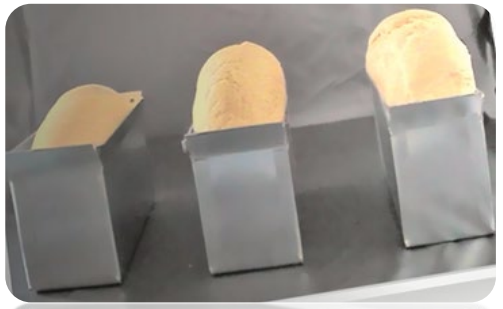
"The **content of damaged starch** also influences the bread staling through **increasing the retrogradation of the amylopectin and crumb firmness**, and therefore affects negatively the quality of the resulting fresh products and their shelf life."

Le´on, et al., 2006

Why measure starch damage?

If the level of **damaged starch** becomes too **high**, the **dough rheology and baking performance are negatively affected**.

Stickiness



Fermentation

Texture

Color

Cracks

Why measure starch damage?

EFFECTS ON COOKIES, CAKES, BISCUITS

In soft wheat products, especially in cookies and cakes, high levels of damaged starch are detrimental to quality:

In cookie production, flour with high level of damaged starch requires longer baking time for evaporating the water surplus.

Why measure starch damage?

EFFECTS ON COOKIES, CAKES, BISCUITS

- **An excess of starch damage causes:**
  - Broken cookies when packaging is opened!
  - Cookie with too much/low color
  - Non-standard/uniform size

"An inverse correlation between cookies spread ratio and damaged starch level in wheat flour, and higher damaged starch content tended to cause lower diameter of cookies."

Wang, et al., 2020

Why measure starch damage?

EFFECTS ON NOODLES

- **An excess of starch damage causes:**
  - For Chinese noodle making, the flour with excessive damaged starch can absorb more water and reduce noodle cooking and eating quality!

Why measure starch damage?

EFFECTS ON EFFECTS ON WHEAT FLOUR TORTILLA TEXTURE

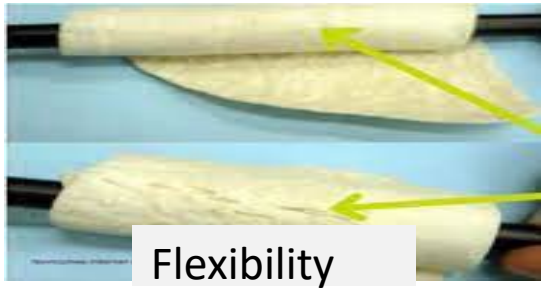
- **An excess of starch damage causes:**

  As damaged starch increases, the flour tortillas become less stretchable, and firmness and rollability increase.

“To make a tortilla with acceptable rollability, starch damage should not be too high!”

Mao and Flores, 2001

Wikipedia



Why measure starch damage?

Starch damage could not be increased indefinitely for at least two reasons:

- **First**, as water absorption increased with the increase in starch damage, the air-dough interface in gas cells became proportionally less stable during baking, leading to a loss of volume and a coarse texture.

- **Second**, with too high a level of starch granule fragmentation, the available gluten can be insufficient to coat the surface of the starch, resulting in a loss of gas retention capacity, a lower loaf volume and a breakdown of cell structure.

Why measure starch damage?

All concerned!

"Proofed" Bread

Flat breads

Biscuits

Noodles, fideos (wheat flour)

"Durum" Wheat

- *For breadmaking*
- *For pasta*

Tortillas !!...

Why measure starch damage?

AS A MILL OPTIMIZATION TECHNIQUE

Conclusions

No significant gain in flour production from baseline to hard grind, just increased amount of starch damage.

- ✓ The possibility to optimize midds rolls using a combination of flour release and **starch damage** does exist.
- ✓ **Starch damage** and ash results were correlated, especially towards the tail end of the mill, however, they don't have a direct effect on one another.
- ✓ Measuring **starch damage** on reduction rolls could ensure a more consistent grind between shifts and help monitor excess grinding pressure.
- ✓ Next steps would be to measure energy usage compared to flour released and **starch damage** to determine savings.

Thiele, 2016

Why measure starch damage?

TO ACT ACCORDINGLY!

If I do not have enough starch damage?

I can:

- ✓ Set the mill differently
- ✓ Choose a harder type of wheat...
- ✓ Both of them...

If I have too much starch damage?

I can:

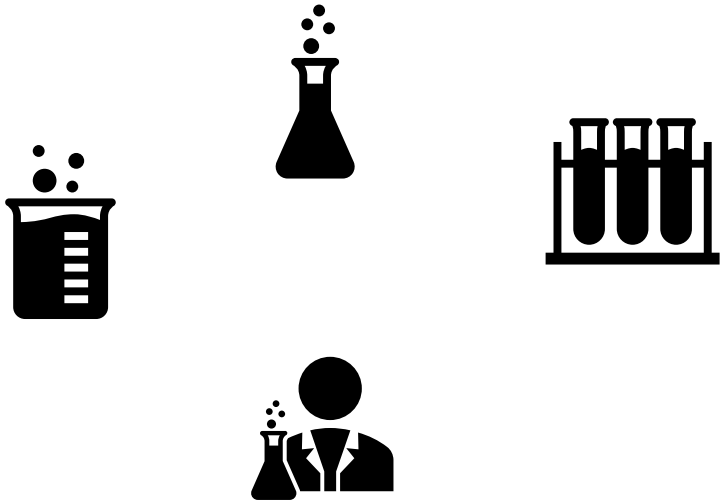
- ✓ Take care of amylases content
- ✓ Add gluten to increase rheological properties
- ✓ Set the mill differently
- ✓ Change wheat for a softer one…

In every case, we see the necessity for measuring the damaged starch in the flour !!!

Why measure starch damage?

In view of the importance of damaged starch to the flour and baking industries, many methods have been developed to quantify its presence:

Colorimetric
Polarimetric
Spectrophotometric
Enzymatic
Amperometric



Damaged starch determination methods

Damaged starch determination methods

AACC Approved Methods of Analysis, 11th Edition

Starch

AACC Method 76-30.02
Determination of Damaged Starch

Objective

This method determines the percentage of starch granules in flour or starch preparations that is susceptible to hydrolysis by fungal alpha-amylase. Percent starch damage is defined as g starch subject to enzymatic hydrolysis per 100 g sample on a 14% moisture basis.

Damaged starch determination methods

AACC Approved Methods of Analysis, 11th Edition

Starch

AACC Method 76-31.01
Determination of Damaged Starch -- Spectrophotometric Method

Objective

In this method, damaged starch granules are hydrated; this is followed by hydrolysis to monosaccharides and limit dextrins by fungal alpha-amylase. Amyloglucosidase is then used to convert dextrins to glucose, which is specifically determined spectrophotometrically after glucose oxidase/peroxidase treatment. Damaged starch is calculated as a percentage of flour weight on an "as is" basis. *This method is applicable to wheat flour and starch.*

Damaged starch determination methods

AACC Approved Methods of Analysis, 11th Edition

Starch

AACC Method 76-33.01
Damaged Starch -- Amperometric Method by SDmatic

Objective

This method measures the kinetics of iodine absorption in a liquid suspension, using an amperometric probe. Results are given in an iodine absorption index percentage (A_I%). An indication of the speed of iodine absorption in seconds is also reported as "V_{abs}". *The method is specific to white flour obtained from Triticum aestivum coming from either laboratory or industrial milling, but it can also be used on wholemeal flour.*

CHOPIN SDmatic

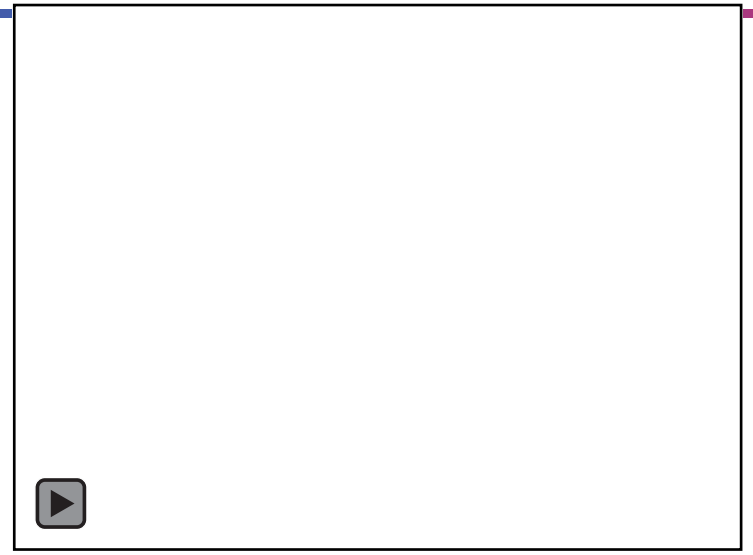
The SDmatic by CHOPIN Technologies

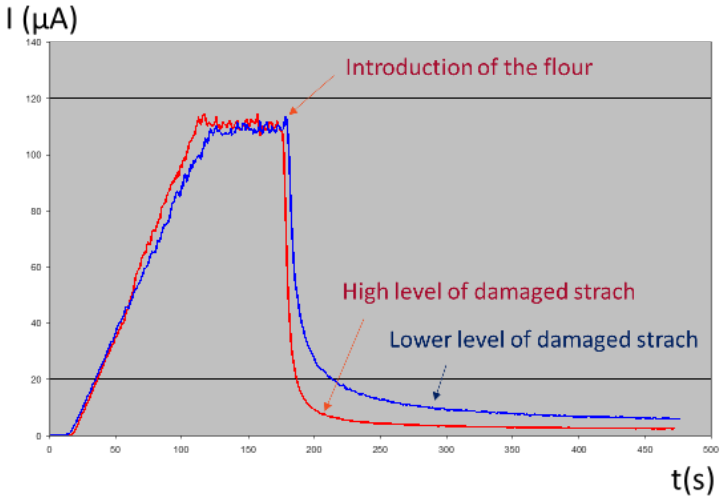
The SDmatic CHOPIN provides a simple, precise, and fast (less than 10 min) measurement of starch damage in flour!

Compliant with
NF V03-731; AACC 76-33.01; ICC 172/1; FTWG N°24; ISO 17715 : 2013

CHOPIN SDmatic

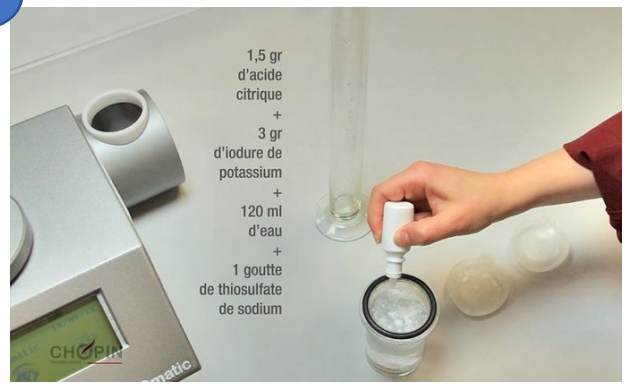
- The CHOPIN SDmatic method (AACC 76-33.01) is a standalone amperometric method to quantify starch damage.
- The SDmatic is based on the principle of ***Medcalf & Gilles, 1965*** method.
- The CHOPIN SDmatic test is based on starch's affinity to iodine. At the end of the test, the SDmatic measures the residual current/iodine absorption in a diluted flour suspension!
- The higher the damaged starch, the more iodine is bound and the smaller is the residual current.





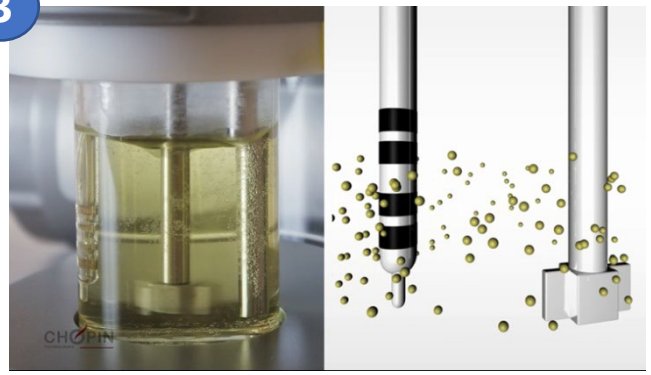
CHOPIN SDmatic

1 Prepare the solution.

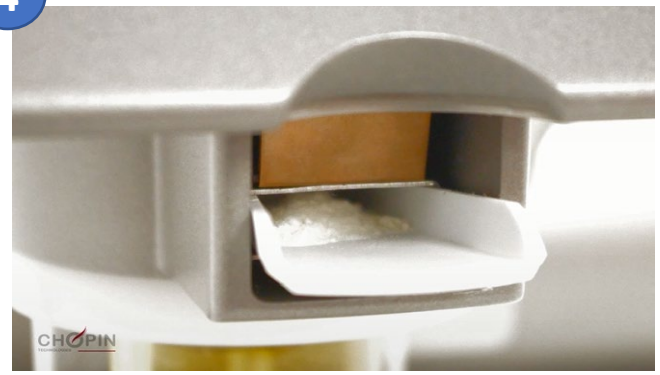


2 Place the reaction bowl in the SDmatic and put the flour (1g) in the spoon.

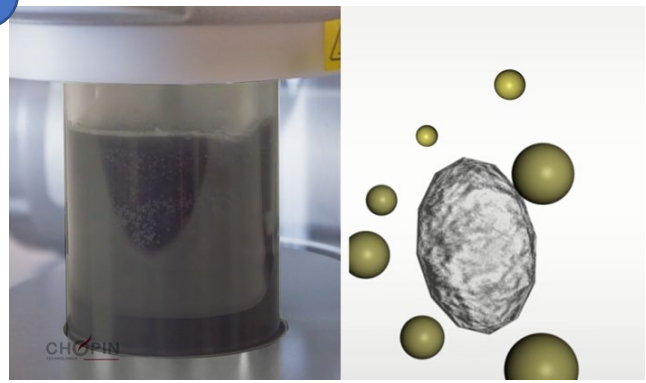
3 Press start and the element brings the solution to 35°C and produces iodine



4 The flour is introduced and the iodine binds to it



5 The probe measures the residual current



6 Results are displayed

CONCLUSION

Conclusion

Case study : Check in the regularity of starch damage of entering flour?

- French bakery since 1970.
- In 2018, the company launched their first range of organic bread.
- Facing fluctuations in the quality of finished bread (bread collapse during baking process, poor volume associated with reddish color).
- Quality control
  - Miller provides alveograph and farinograph specifications
  - Bakery controls the protein (NIR) up on reception





Conclusion

Case study : Check in the regularity of starch damage of entering flour?

- 10 flours were analyzed for **starch damage**, protein levels and quality of finished products
  - Protein levels ranged between 13 and 13.5% (within specifications)
  - Based on bakery observations the breads were ranked in 2 types
    - **Good (5 flours)** → going through the line smoothly and giving good product: **Accepted**
    - **Bad (5 flours)** → Not passing well during production, showing sticky dough and poor quality of bread: **Rejected**

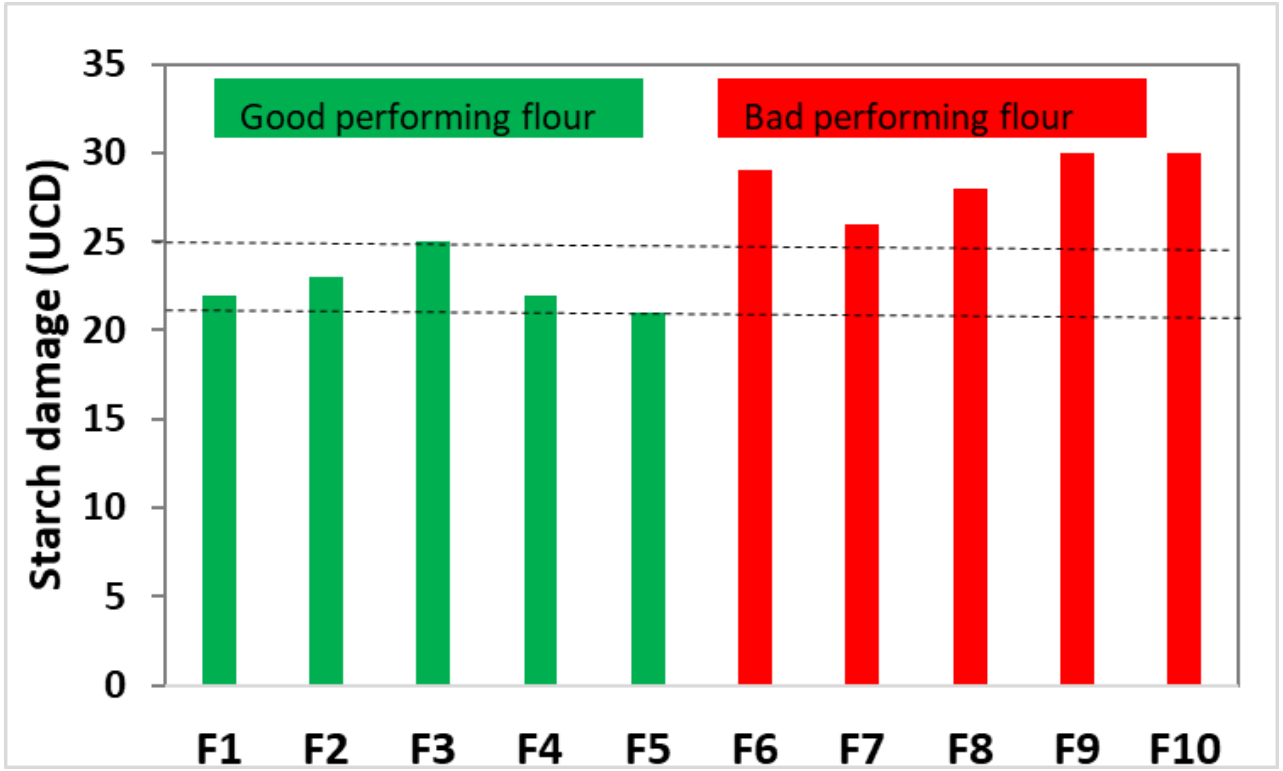
Accepted

Rejected

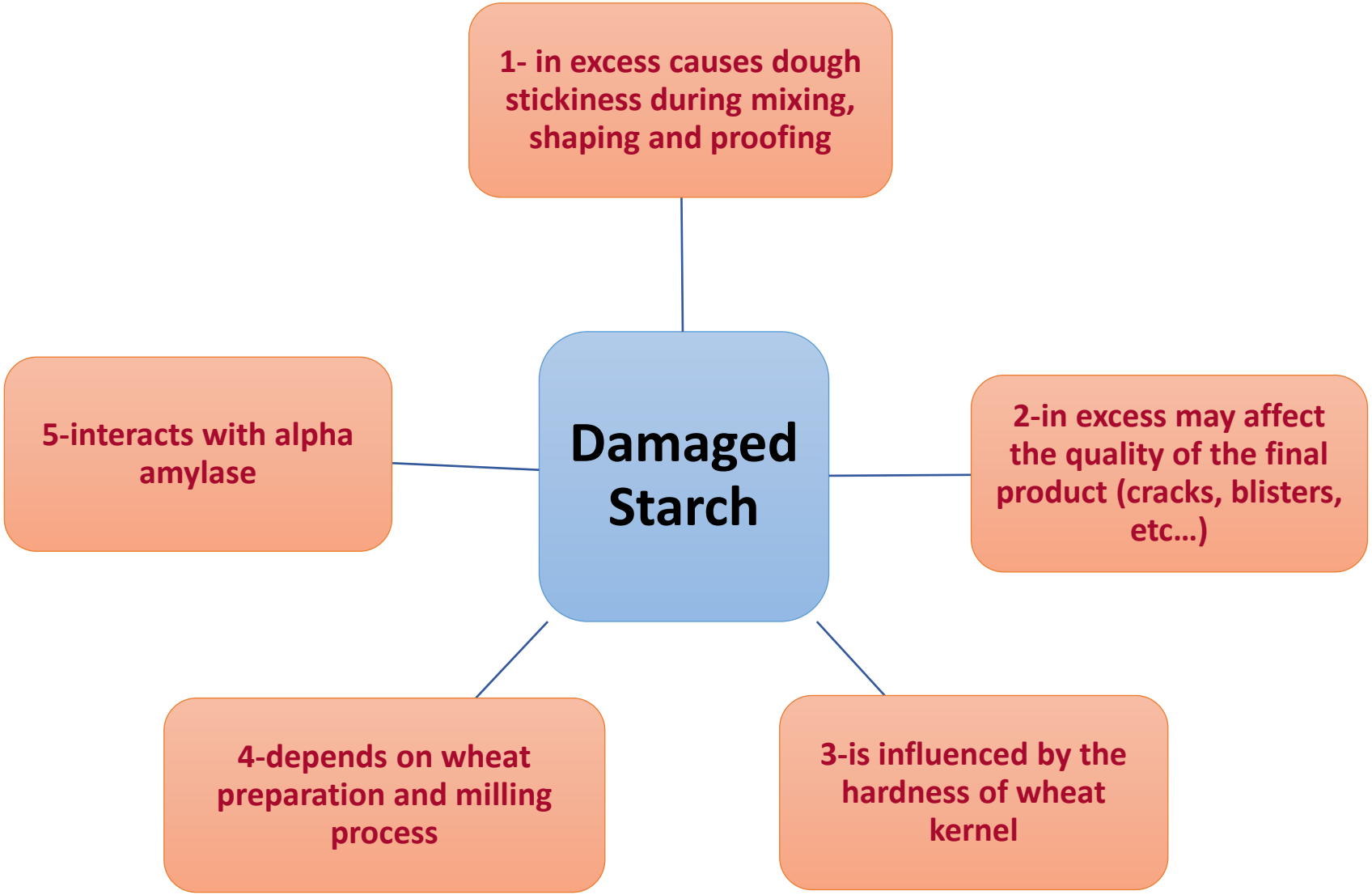
Conclusion

Case study : Check in the regularity of starch damage of entering flour?

- ❑ We analyzed the same flours with the SDmatic.
- ❑ And showed we could segregate easily the “Good ones” and the “Bad ones”
- ❑ Good flours showed UCD values between 21 and 25 UCD
- ❑ Bad flours higher than 26 UCD
- ❑ **SDmatic specifications**
  - ❑ **Good flour – 21 – 25 UCD**
  - ❑ **Bad flour : > 26 UCD**



Conclusion


1- in excess causes dough stickiness during mixing, shaping and proofing
5-interacts with alpha amylase
Damaged Starch
2-in excess may affect the quality of the final product (cracks, blisters, etc…)
4-depends on wheat preparation and milling process
3-is influenced by the hardness of wheat kernel

Conclusion

- Blending flours
- Anticipate overload
- Optimize rolls life
- Avoid lower yield

= Cost reduction

Conclusion

“Damaged starch content should be a parameter of relevance to optimize the process of cookie and bread manufacture.”

(Barrera, et al., 2007)

“Therefore, attention should be paid to the content of damaged starch in the cereal flours since it affects negatively the quality of the resulting fresh products and their shelf life.”

Le´on, et al., 2006

KPM Analytics
Company Overview

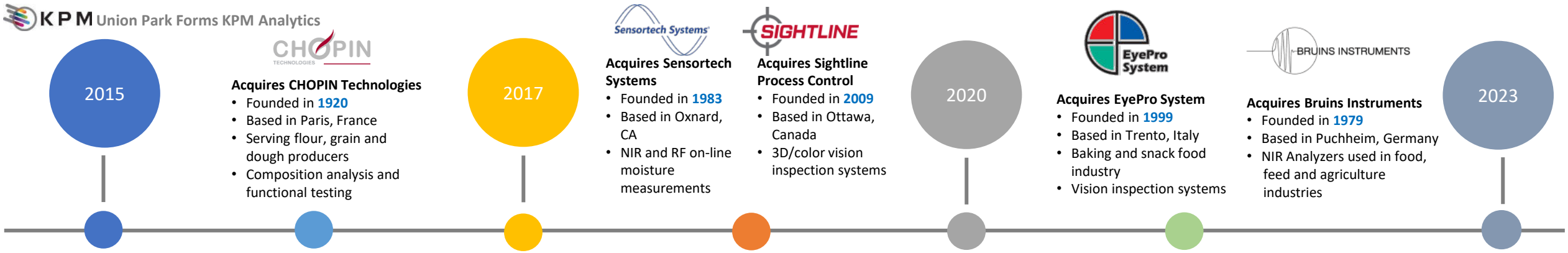
Our Mission

We craft assurance.

For our partners. For their customers.

Timeline and Progression of KPM Analytics

KPM Analytics brands have long and successful histories servicing customers worldwide



KPM

Industries We Serve

KPM's main focus is serving food producers, helping them ensure quality and protect their brand.

KPM is leading the industry for quality solutions at all stages of production.

Food Production Agriculture Feed & Forage Environmental Industrial

Our product lines are also widely used in agriculture and feed and forage to measure critical quality parameters.

Environmental, chemistry and industrial industries benefit from our accurate lab and sensing technologies.

KPM

A Global Team

KPM customers are supported by our global sales, service and authorized distribution network.

9
8 product brands based in 5 countries and growing.

200 +
Over 200 distributors worldwide.

15,000 +
Over 15,000 installations around the world.

U.S.A. (Boston)
+1 (774) 462-6700

Canada (Ottawa)
+1 (800) 768-6821

U.K. (London)
+44 1536 408066

France (Paris)
+33 01 41 47 71 38

Poland (Warsaw)
+48 22 6739526

Germany (Frankfurt)
+49 (6721) 988 6720

Italy (Rome)
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+86 (10) 63345789

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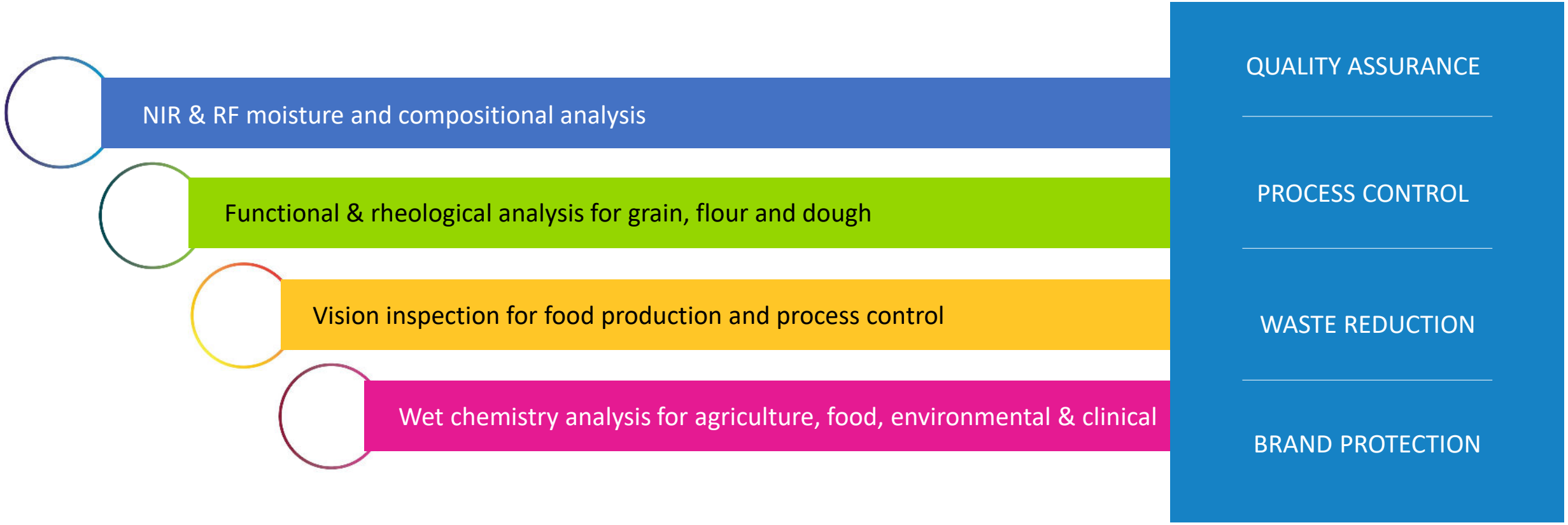
KPM

Solutions for Every Stage of Production



Grain, Flour & Dough Analysis

- The CHOPIN product brand is a pioneer and a reference in the analysis of cereals and their derivatives
- Instruments provide precise, repeatable methods and results
- Ensures operational specifications, regulatory compliance, and quality standards for millers, bakers and research institutes

Grain Analysis

- Weight, moisture, impurity and falling number measurement of grains
- EM10

Flour Analysis

- Measure flour characteristics including falling number, starch damage etc.
- SRC-CHOPIN 2, SDMatic

Dough Analysis

- Industry standard for measuring dough characteristics
- Alveolab®, AlveoPC, Mixolab 2, Rheo F4

Sample Preparation Devices

- Grinder, mill, & homogenizers
- Grinder-CHOPIN, LabMill, CD1-Mill, MR2L-MR10-L

CHOPIN is recognized by, and in collaboration with, numerous international standards including ISO, EN, AFNOR, AACC, and ICC.

KPM

Thank you!

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