Creation of a Milling Performance Index (MPi) based on the behavior of wheat during laboratory milling

Stéphane Cochet
Export Director

October 31, 2018

INTRODUCTION

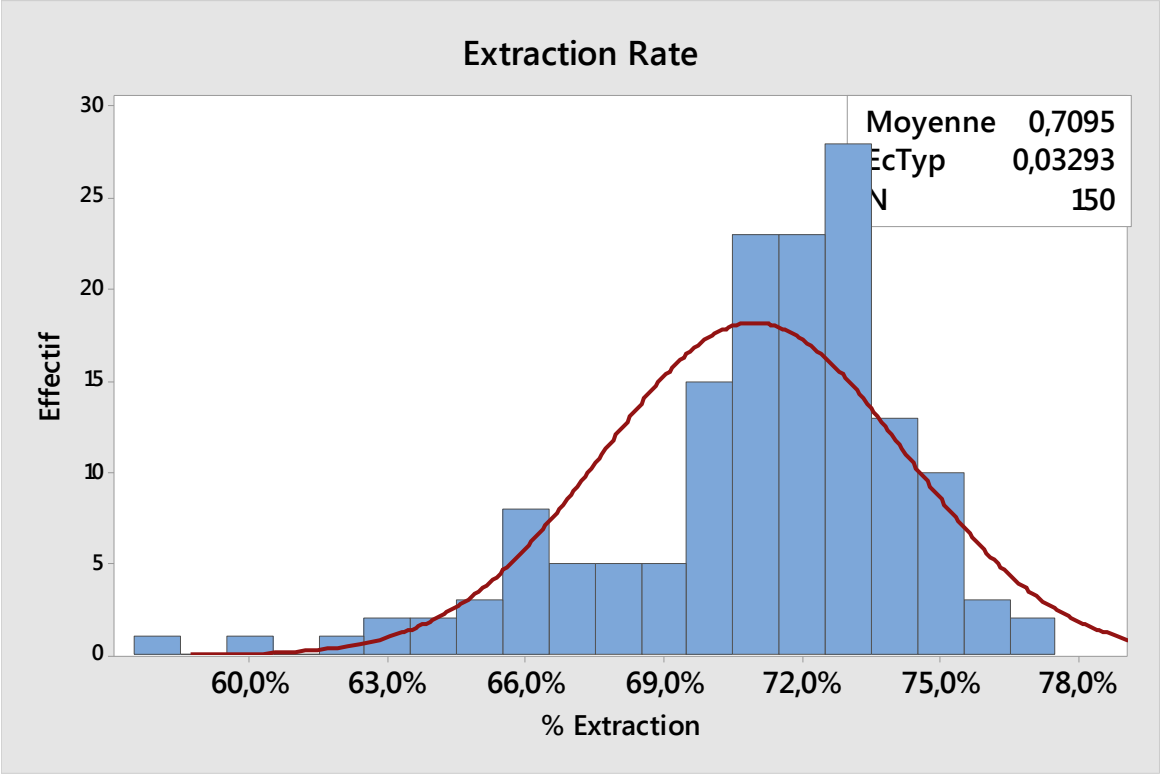
- In the milling industry, wheat is characterized by its milling behavior (resistance to crushing and extraction rate) and by the quality of the flour produced

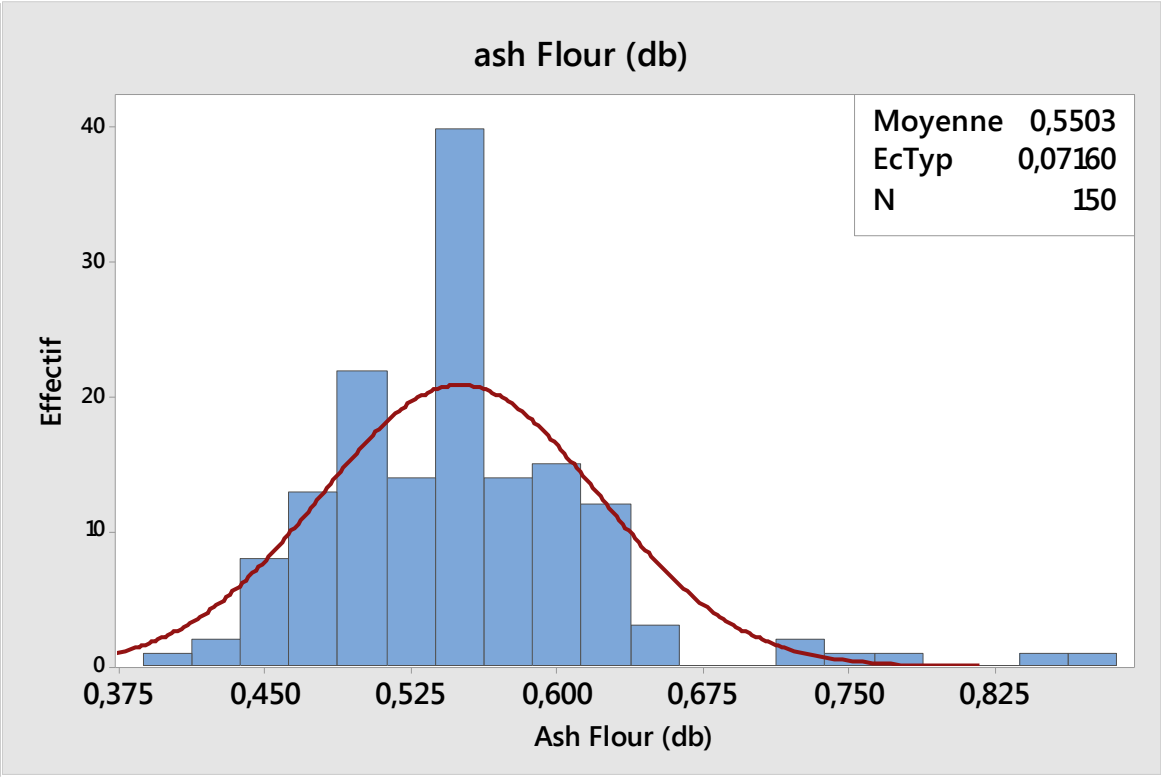
- Laboratory mill is used to anticipate, in the laboratory, the behavior of wheat in the industrial mill, and to evaluate its extraction potential and the quality of the flour produced

CHOPIN TECHNOLOGIES

The way we currenly look at milling…

The higest possible extraction… **…for a certain ash content**

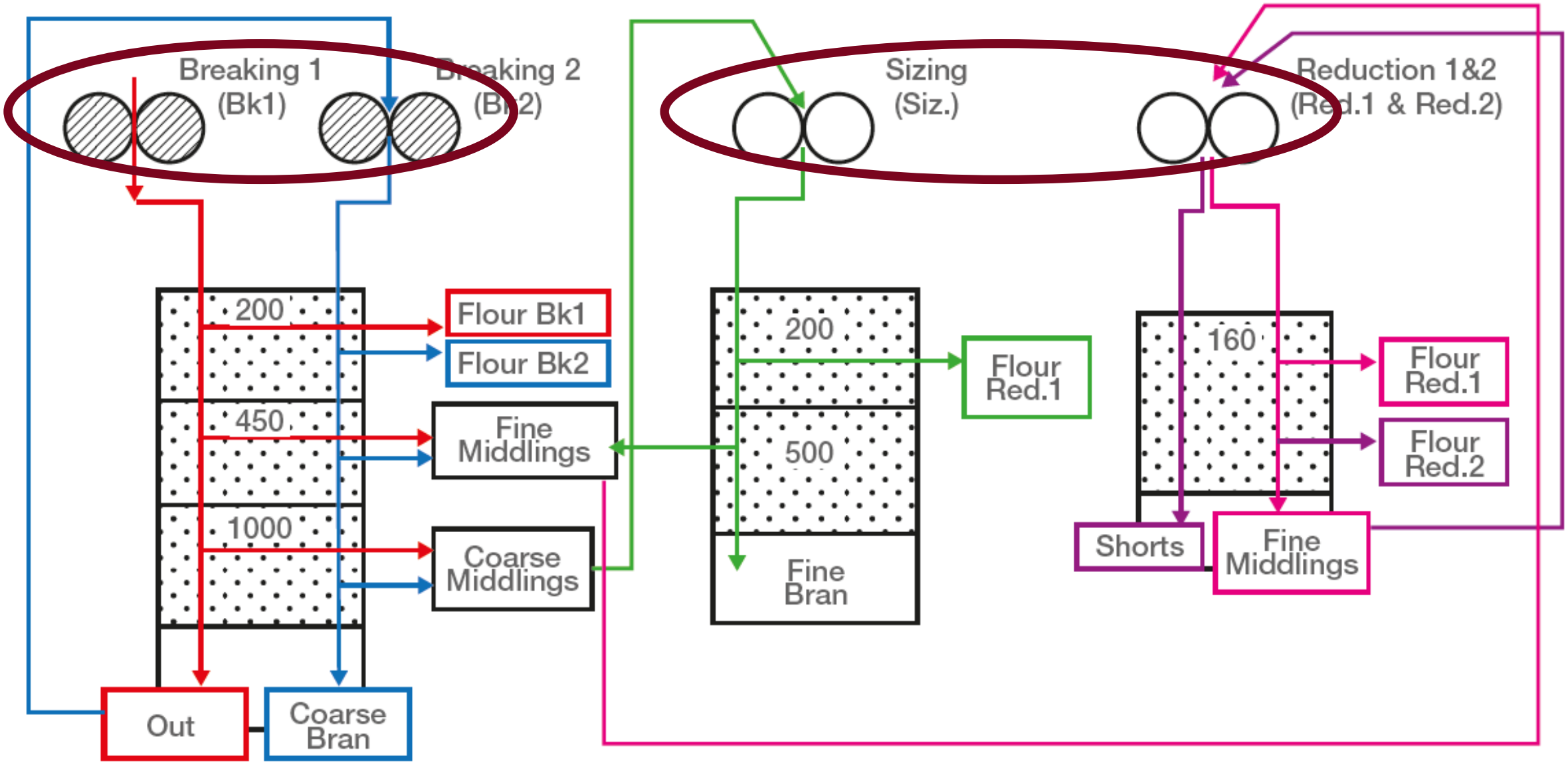




Laboratory mill : today situation

- No official method/standard with mill settings
- No official tool : no way to compare wheat behavior
- No rules or guidelines
- No indexes or (easy to understand) parameters excepted extraction rate
- No real use of a lab mill to study and understand the wheat and its behavior in the milling industry

CHOPIN TECHNOLOGIES



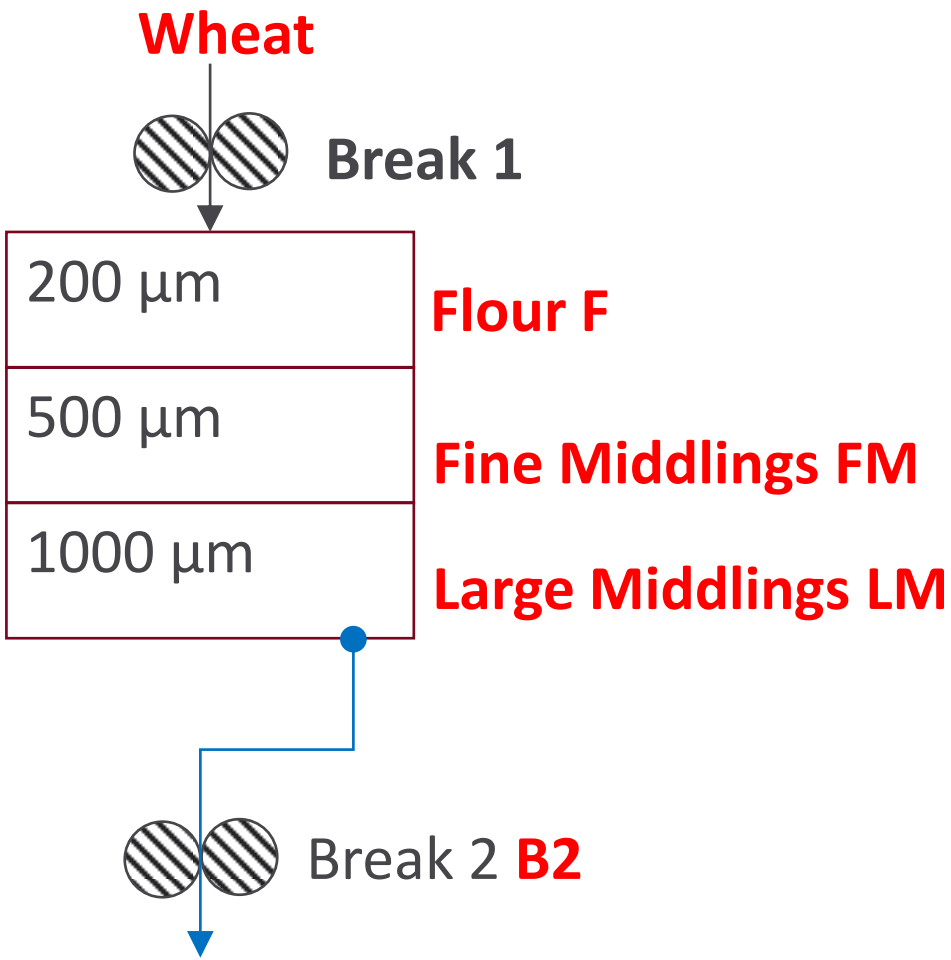
MILLING DIAGRAM

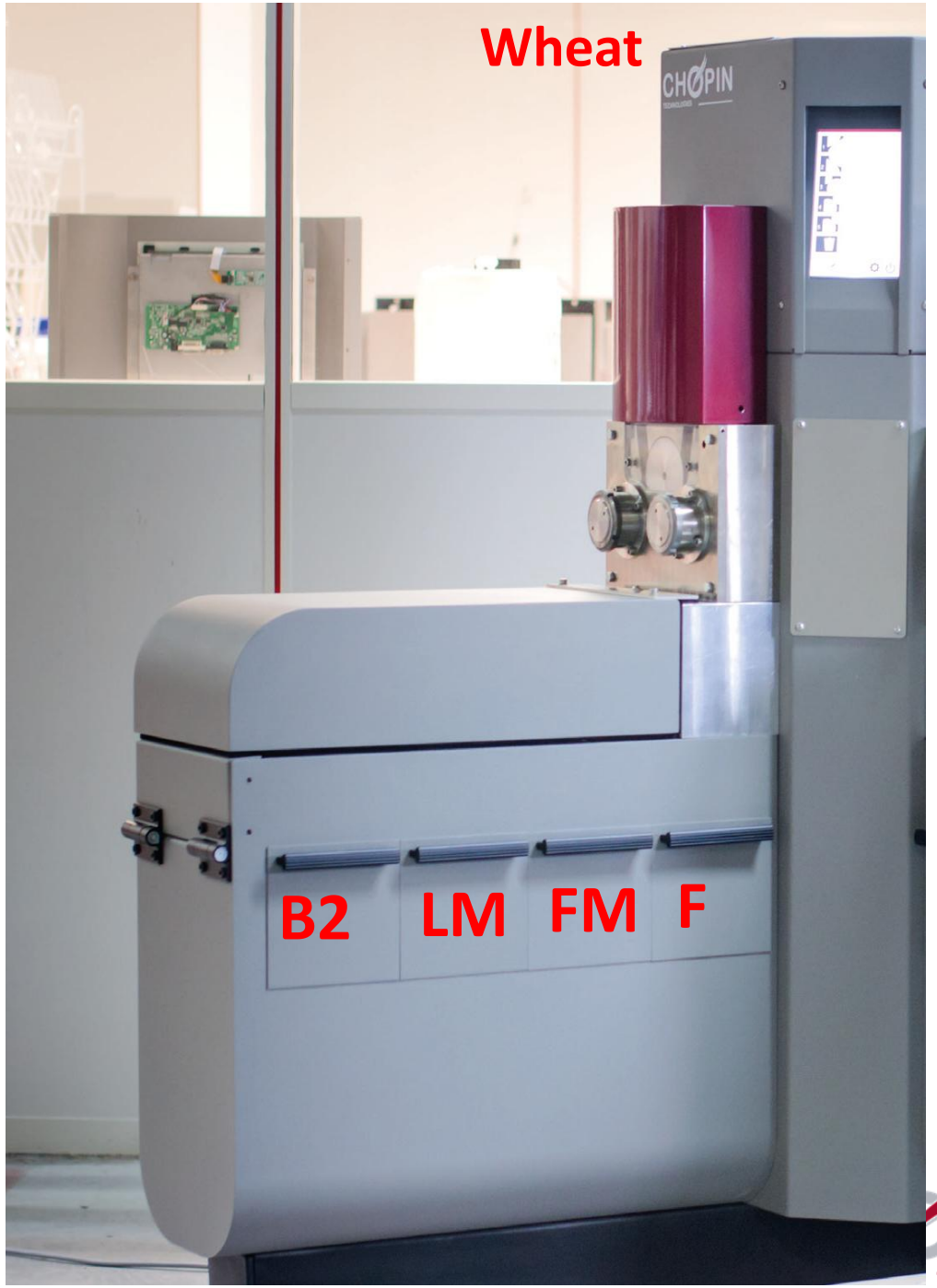
CHOPIN TECHNOLOGIES

Breaking 1

Wheat

B1 corrugated rolls


Wheat
Break 1
200 µm
500 µm
1000 µm
Flour F
Fine Middlings FM
Large Middlings LM
Break 2 B2

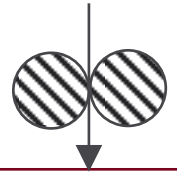

Wheat
CHOPIN
B2
LM
FM
F

Breaking 2

From B1

B2 corrugated rolls

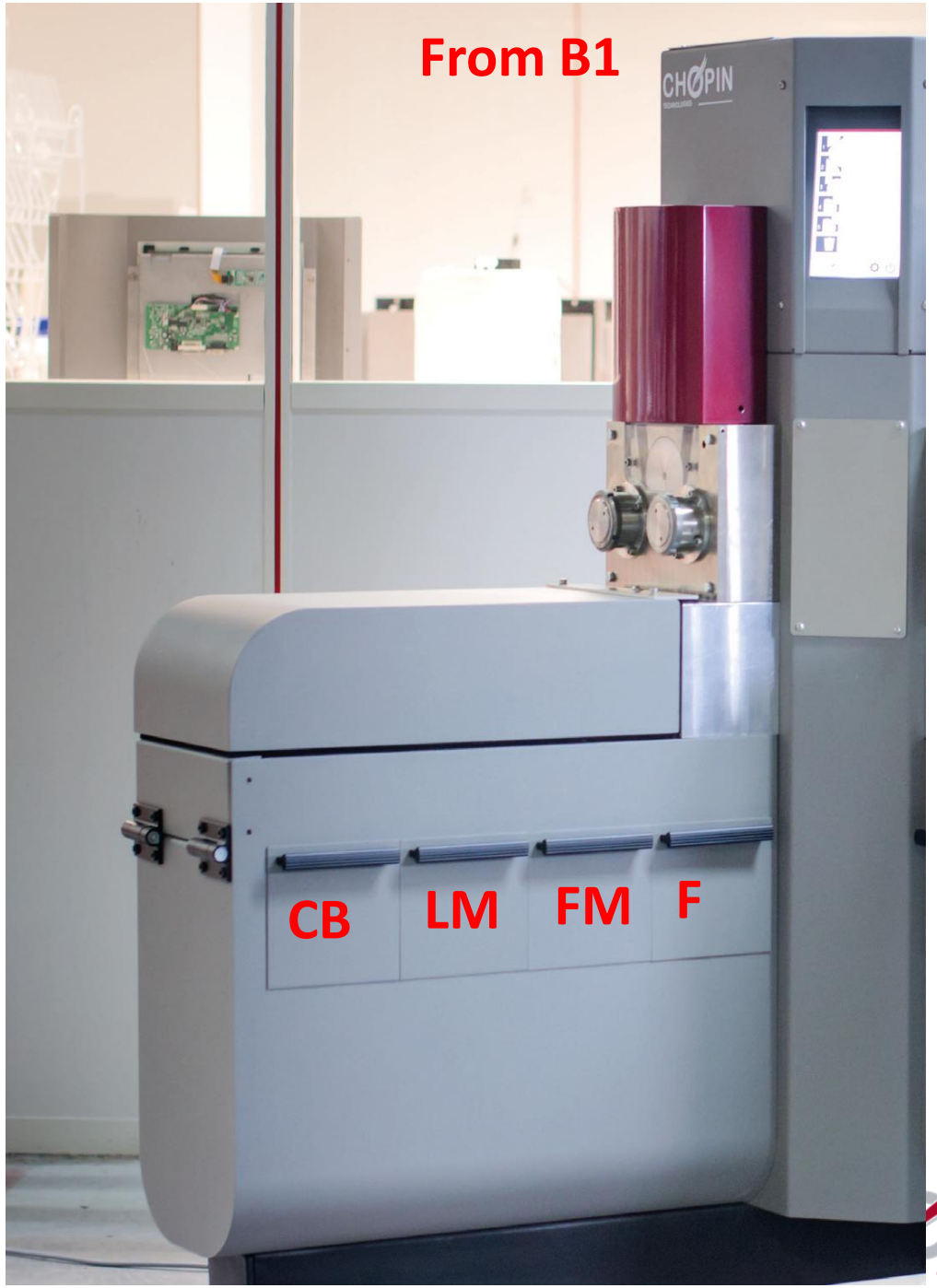
From B1



Break 2

200 µm	Flour F
500 µm	Fine Middlings FM
1000 µm	Large Middlings LM

Coarse Bran CB



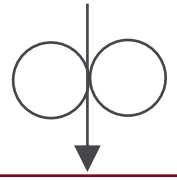
Sizing

Large Middlings

Sizing smooth rolls

CHOPIN TECHNOLOGIES

Large Middlings



Sizing

200 µm	Flour F
500 µm	Fine Middlings FM

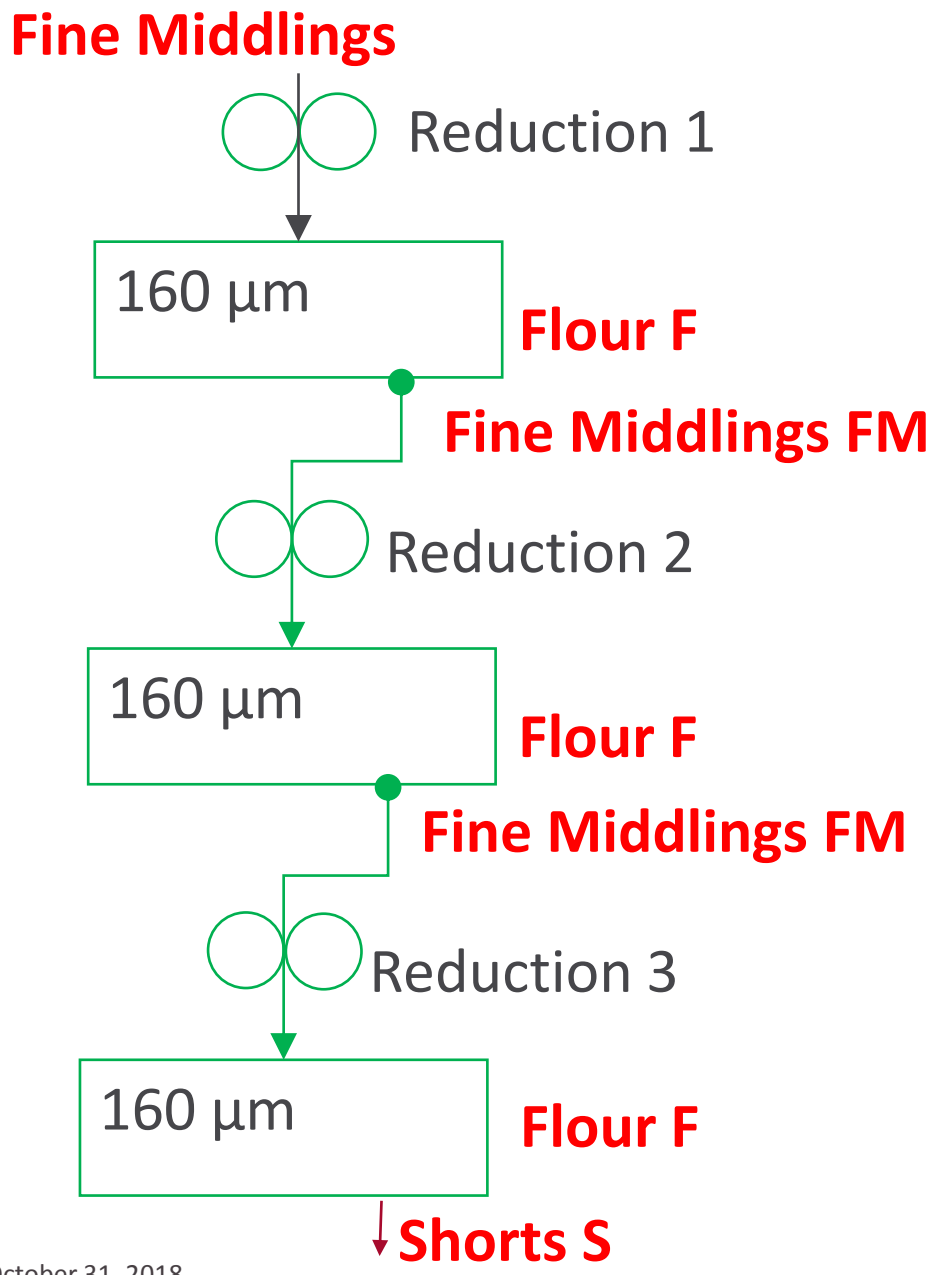
Fine Bran FB

Reduction 1, 2 and 3

Fine Middlings

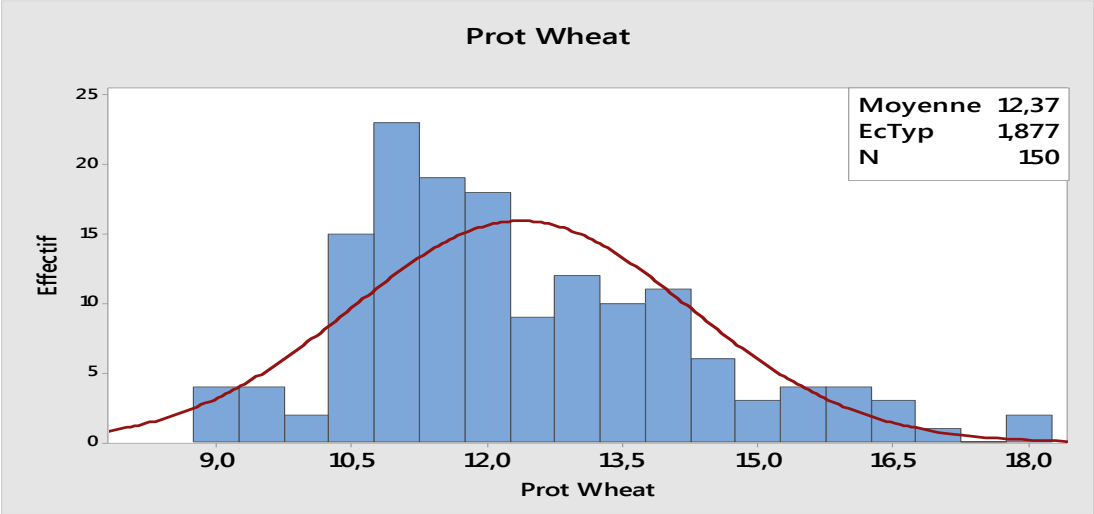
Reduction 1, 2 and 3 smooth rolls

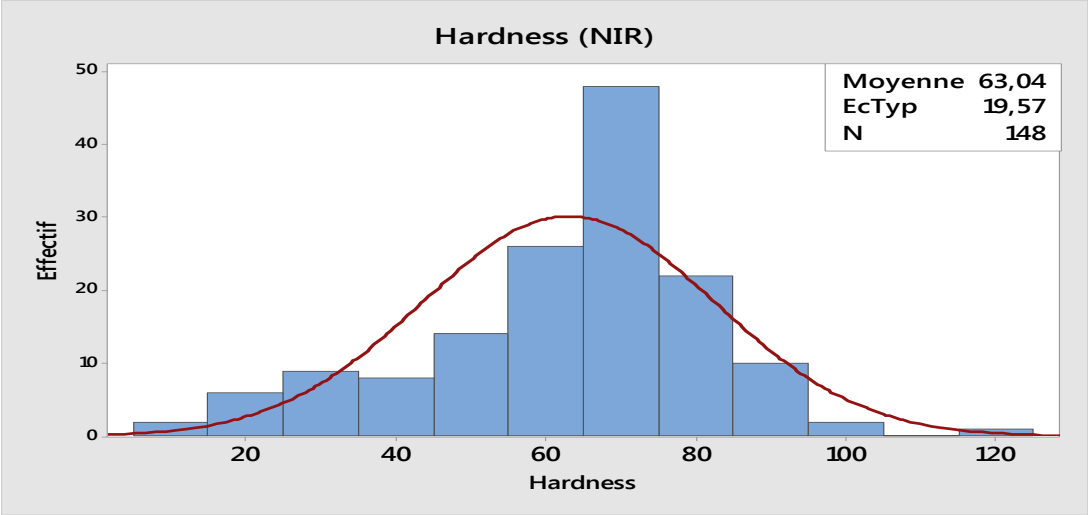
CHOPIN TECHNOLOGIES


Fine Middlings
Reduction 1
160 µm
Flour F
Fine Middlings FM
Reduction 2
160 µm
Flour F
Fine Middlings FM
Reduction 3
160 µm
Flour F
Shorts S

Fine Middlings
LabMill
F
FM

Study material :
150 Wheat samples coming from 15 countries





Protein range: from 9 to 18%

Hardness range: from 10 to 120

Test Conditions

- Sample Size 1700 g
- Wheat Moisture determination : NIR (Infraneo)
- Add Water to reach 16% H2O.
- Shake during 15 minutes (MR10L)
- Resting Time : 24h
- Humid wheat moisture determination : NIR (Infraneo)
- Milling with LabMill using standard (Factory) settings : no influence of the settings between the simples tested

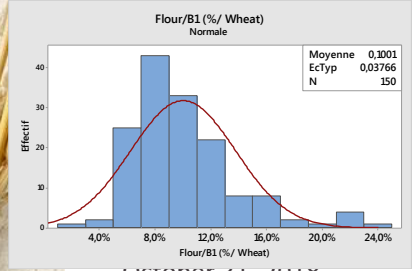
CHOPIN TECHNOLOGIES

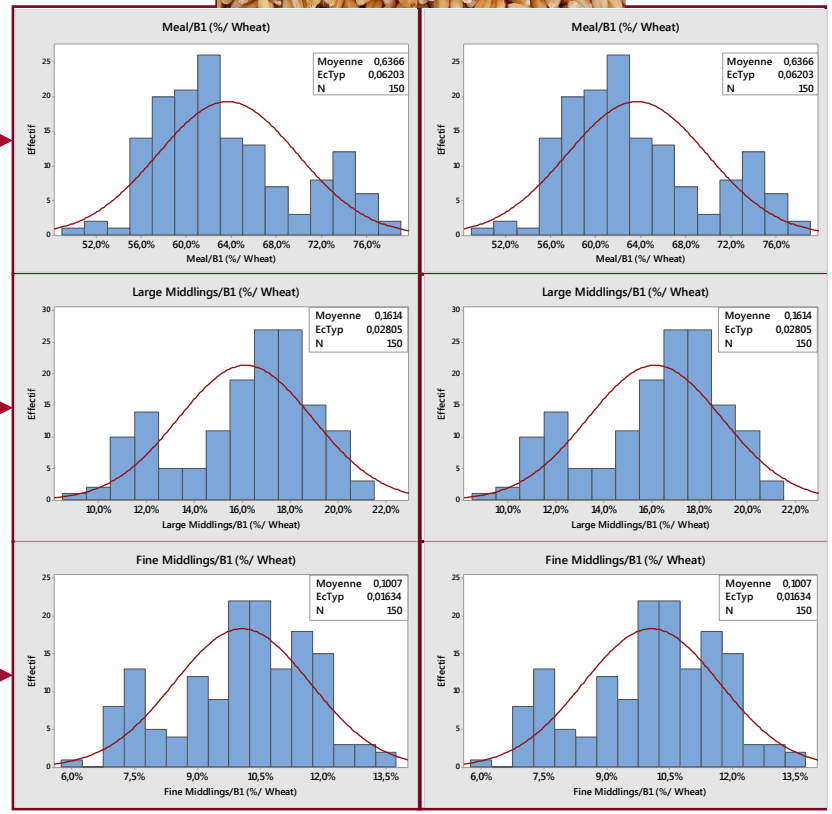
Analyzing wheat behavior at 1st Break

Wheat

Break 1

1000 µm
500 µm
200 µm





	%/Wheat	
	Average	Range
Meal B1	63,7	51,1 - 78,0
Large Middlings	16,1	9,5 - 20,8
Fine Middlings	10,1	6,3 - 13,8
Flour	10,1	2,9 - 23,1

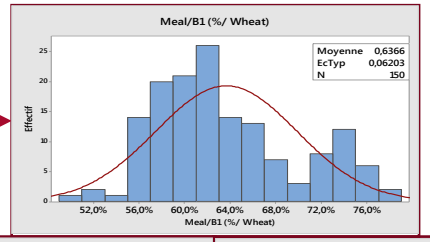
Big differences in milling = diverse behaviors!

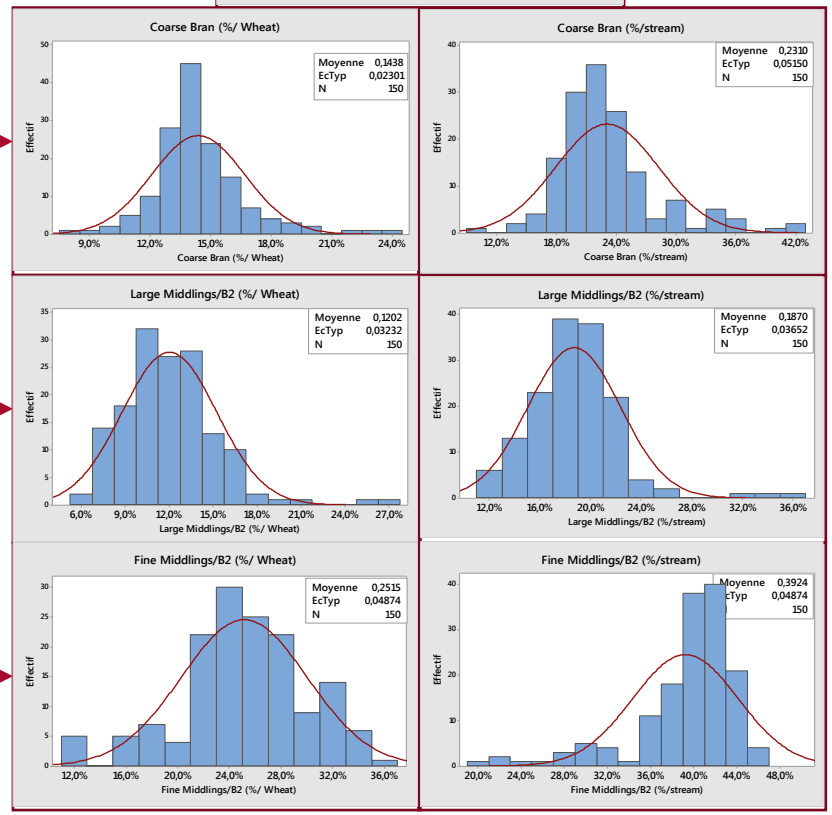
Analyzing wheat behavior at 2nd Break

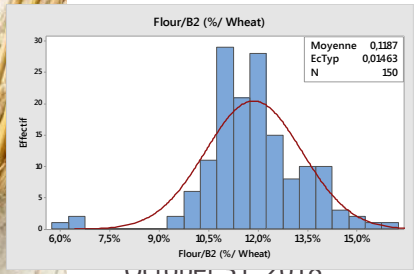
Meal B1

Break 2

1000 µm
500 µm
200 µm







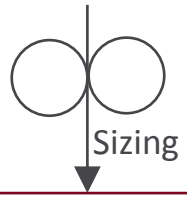
	%/Wheat	
	Average	Range
Coarse Bran	14,4	7,9 - 24,3
Large Middlings	12,0	6,4 - 26,6
Fine Middlings	25,2	11,4 - 35,2
Flour	11,9	6,1 - 15,8

Big differences in milling = diverse behaviors!

CHOPIN TECHNOLOGIES

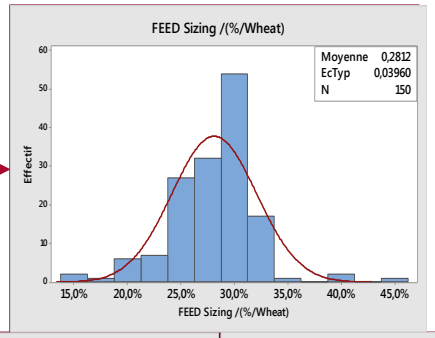
Analyzing wheat behavior at Sizing

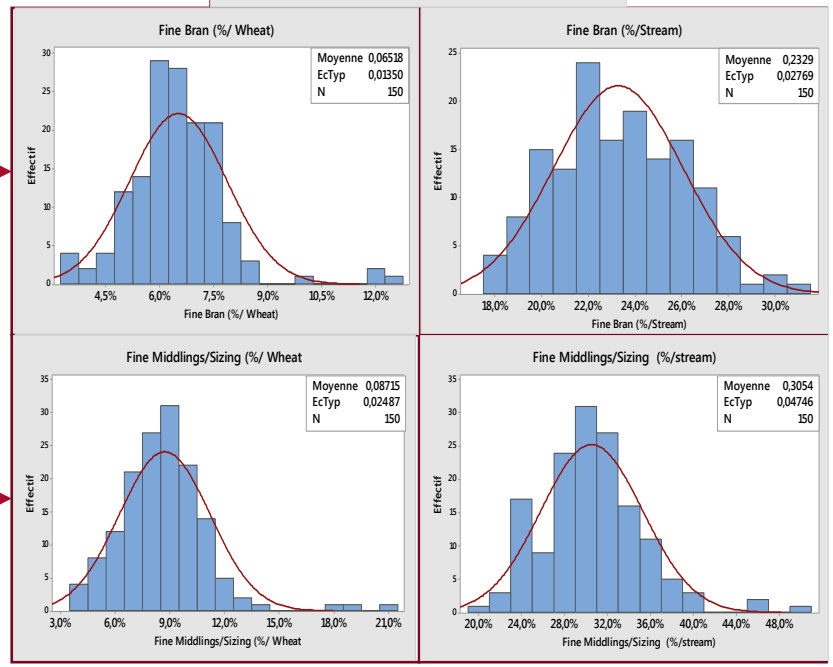
Large Middlings from B1 & B2

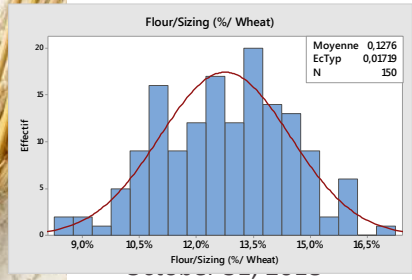


500 µm

200 µm







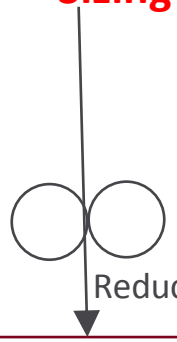
	%/Wheat	
	Average	Range
Fine Bran	6,5	3,3 - 12,6
Fine Middlings	8,7	3,6 - 21,3
Flour	12,8	8,3 - 17,1

Big differences in milling = diverse behaviors!

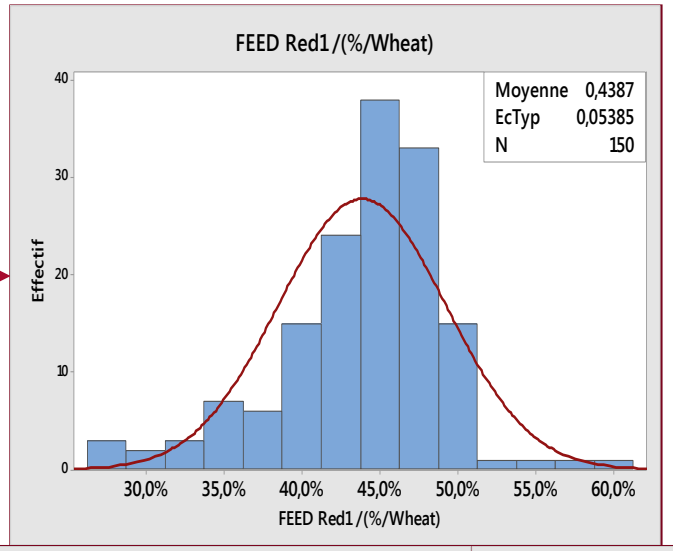
CHOPIN TECHNOLOGIES

Analyzing wheat behavior at 1st Reduction

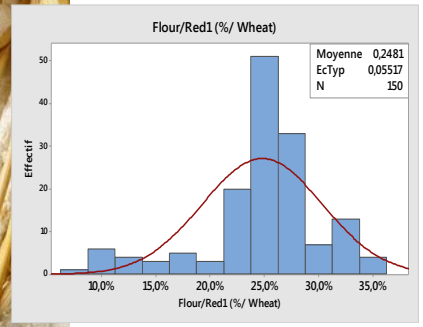
Fine Middlings from B1, B2 & Sizing

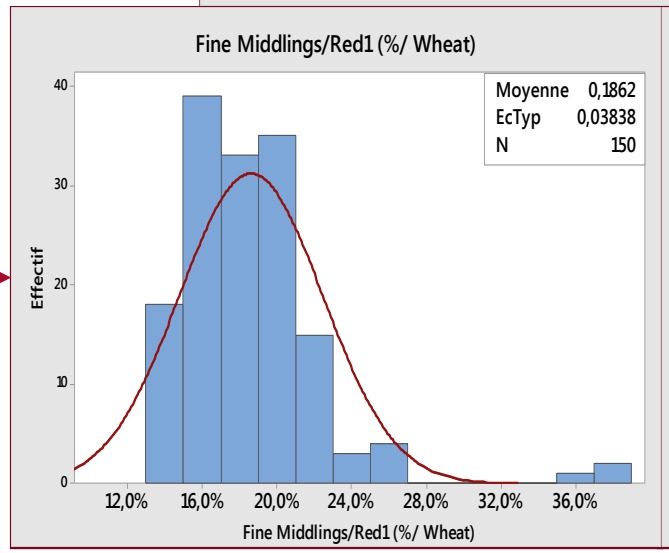


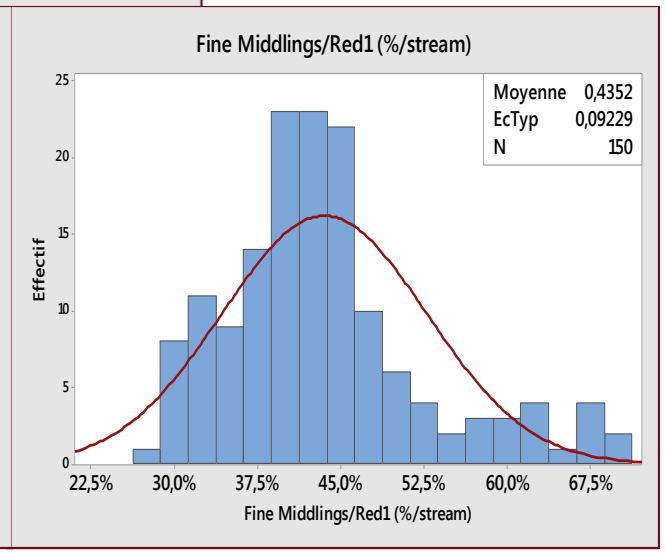
160 µm



	%/Wheat	
	Average	Range
Fine Middlings	18,6	13,8 - 37,5
Flour	24,8	8,4 - 34,9





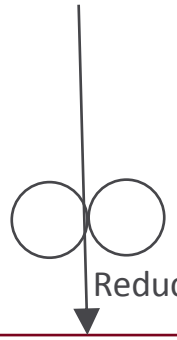


Big differences in milling = diverse behaviors!

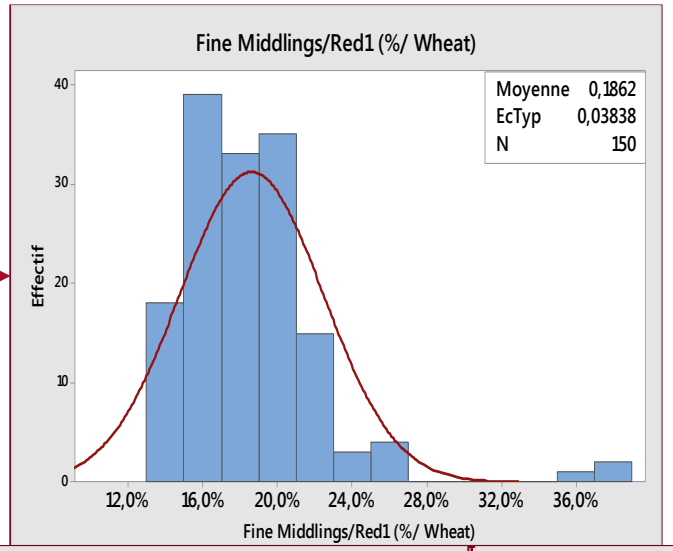
CHOPIN TECHNOLOGIES

Analyzing wheat behavior at 2nd Reduction

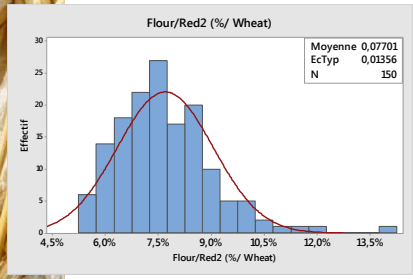
Fine Middlings Red1

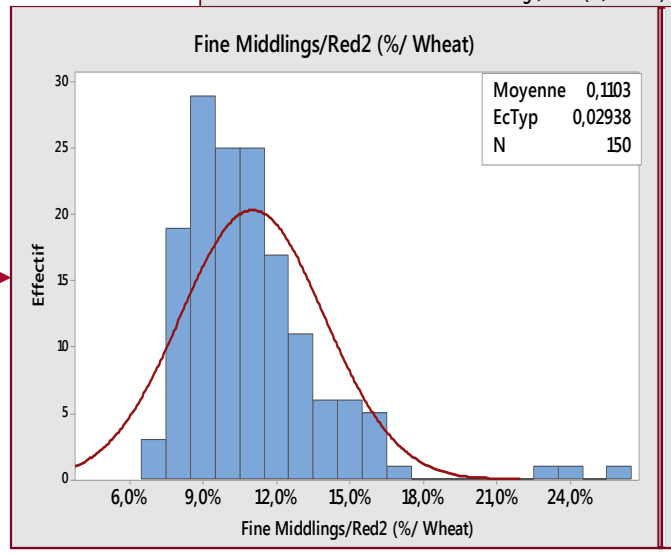


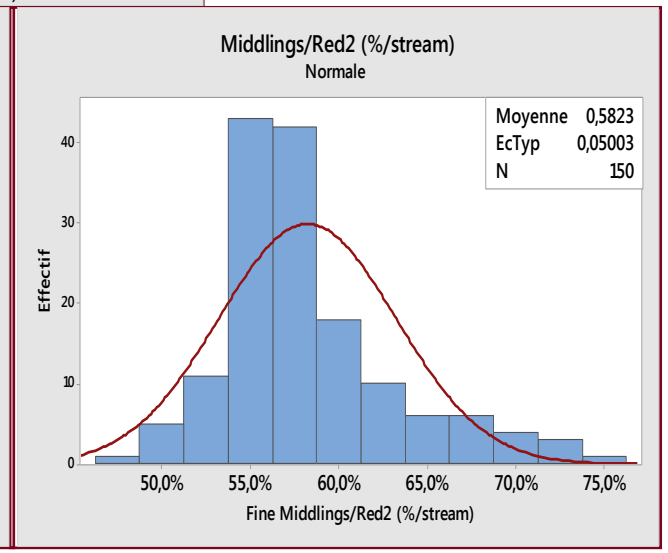
160 µm



	%/Wheat	
	Average	Range
Fine Middlings	11,0	6,9 - 25,6
Flour	7,7	5,3 - 14,0



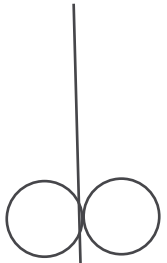




Big differences in milling = diverse behaviors!

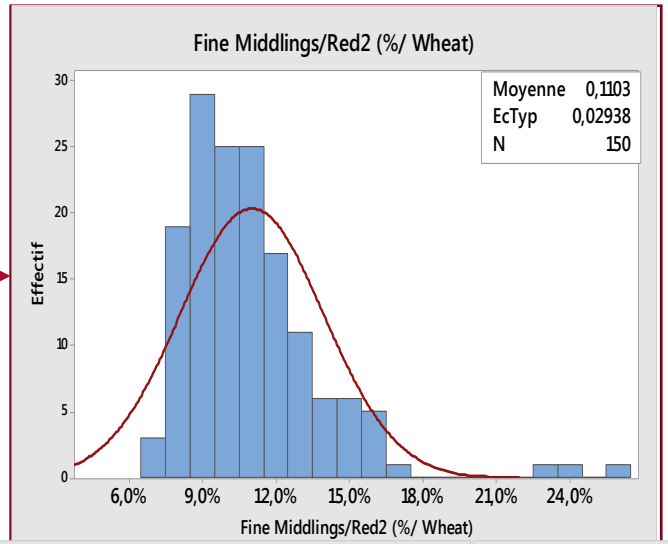
Analyzing wheat behavior at 3rd Reduction

Fine Middlings Red2

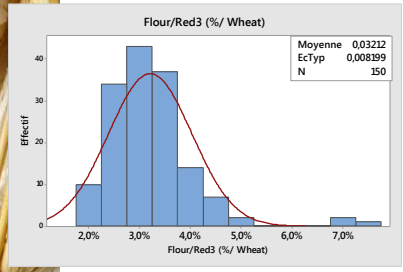


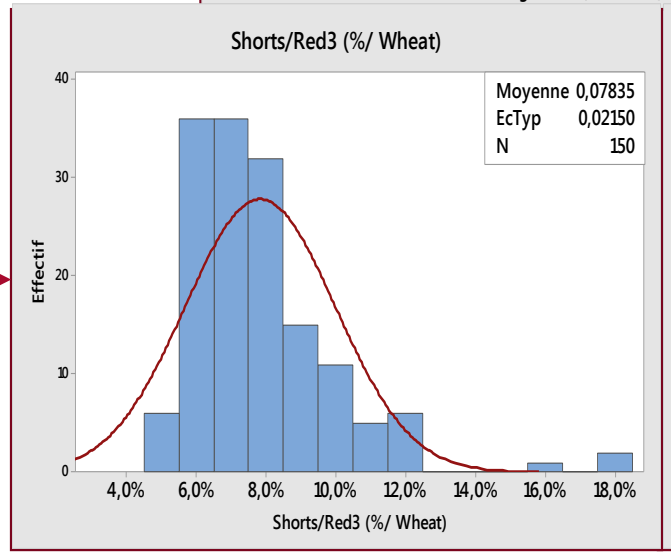
Reduction 3

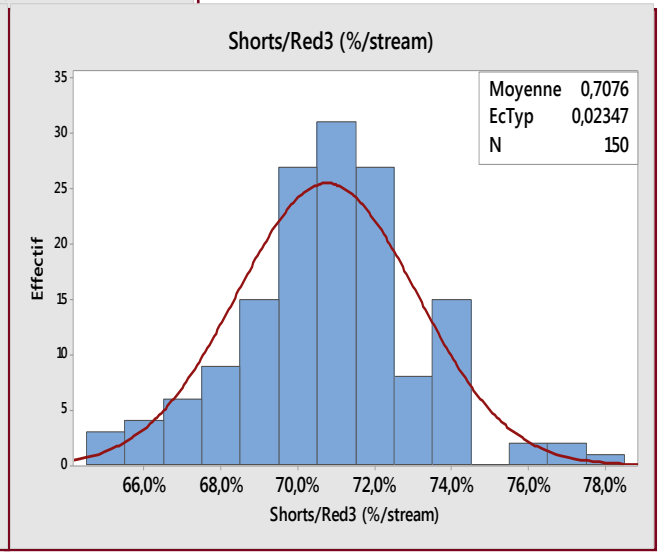
160 µm



	%/Wheat	
	Average	Range
Shorts	7,8	4,8 - 18,1
Flour	3,2	1,8 - 7,3







Big differences in milling = diverse behaviors!

CHOPIN TECHNOLOGIES

Half time conclusions and questions

- 150 wheat, submitted to the same milling, have shown extremely diverse behaviors.
- Based on these observations, could we develop a way to easily characterize wheat behavior during milling?
- What could be the benefit of such measurement?

Developping a new parameter, Milling Preformance Index (MPi), to characterise wheat behaviour during milling

October 31, 2018

Resistance and dissociation Indexes

- Based on these observations we can characterize wheat behaviour during milling with a simple Resistance to Crushing and Dissociation Indexes

Resistant To Crushing

$$\frac{W_{Fine\ MiddlingsB1} + W_{FlourB1}}{W_{Coarse\ MiddlingsB1} + W_{MealB1}}$$

B1 Index	B1 RCi
<16%	7
16,1-21%	6
21,1-26%	5
26,1-31%	4
31,1-36%	3
36,1-41%	2
>41%	1

Easy To Crush

From B1 | From B1+B2

4 5

Resistance Index

Dissociation index

$$\frac{\sum Break\ Fine\ Middlings}{\sum Break\ Coarse\ Middlings}$$

B2 RCi	B2 Index
7	<106%
6	106,1-113%
5	113,1-122%
4	122,1-131%
3	131,1-148%
2	148,1-157%
1	>157%

Hard to dissociate

Easy To Dissociate

CHOPIN TECHNOLOGIES

The Reduction index

$$\sum \text{Reduction flour}$$
$$\sum \text{Reduction Middlings}$$

Hard to dissociate

From Red1+Red2+Red3

5

Reduction index

Red RCi	Red Index
7	<70%
6	70,1-75%
5	75,1-79%
4	79,1-86%
3	86,1-92%
2	92,1-97%
1	>97,1%

Easy To Dissociate

CHOPIN TECHNOLOGIES

Milling Performance Index (MPi), describes the wheat behavior during milling.

4	5	5

Resistance Index
(easiness to open the kernel)

Dissociation index
(easiness to produce fine middlings)

Reduction index
(easiness to extract flour from fine middlings)

CHOPIN TECHNOLOGIES

Completing the Milling Performance Index (MPi), For a complete information.

Add
EXTRATION RATE

Add
FLOUR ASH CONTENT

70 - 455 055

Information on potential yield
How much?

Information on how this yield is obtained
How?

Information on quality
How good?

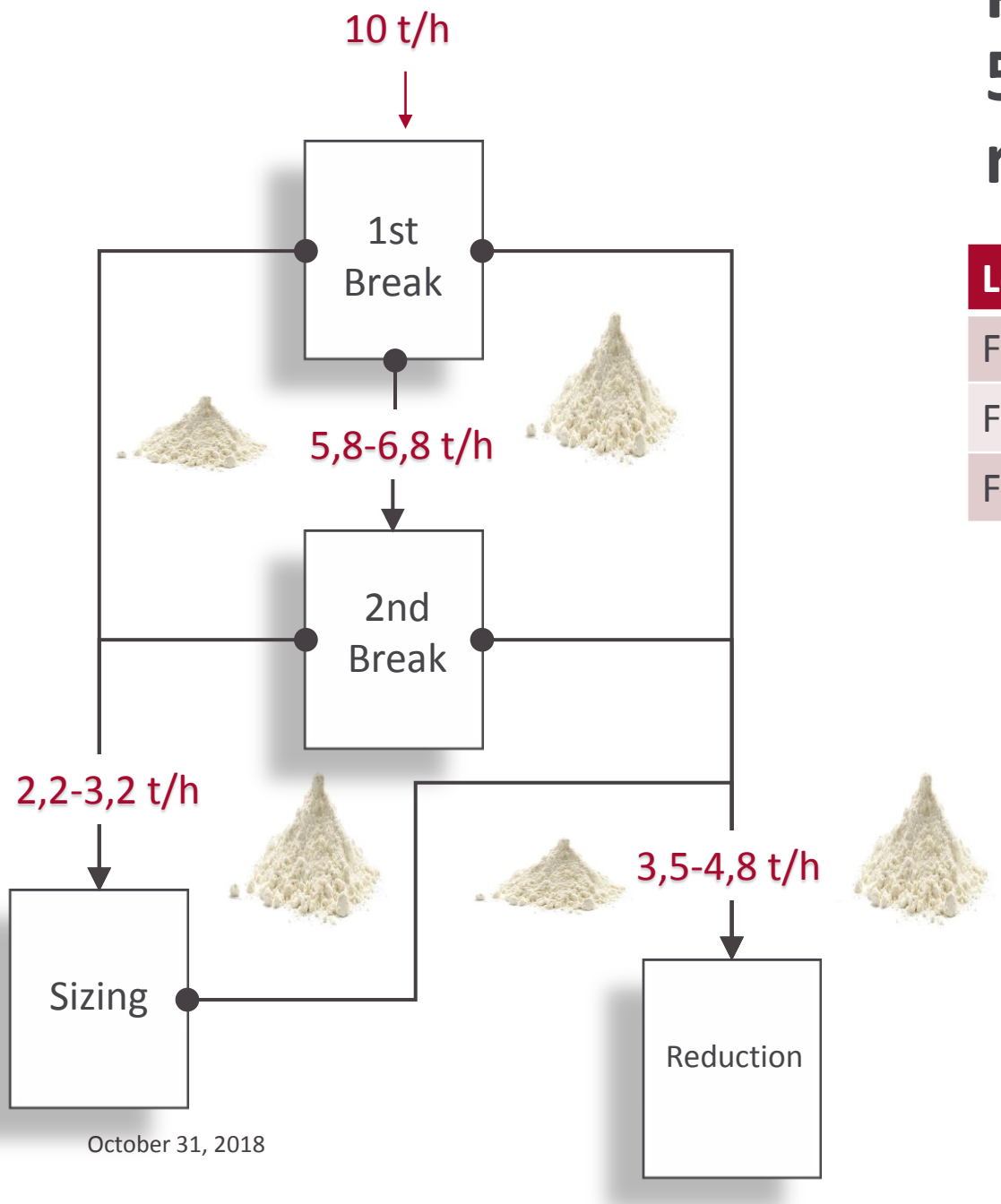
CHOPIN TECHNOLOGIES

Practical example 1
5 samples with same Extraction rate and different MPi

MPi	Extraction rate (%)	Meal/B1 (%)	Large Middlings B1 (%)	Fine Middlings B1 (%)	Flour B1 (%)	Coarse Bran (%)	Large Middlings/B2 (%)	Fine Middlings/B2 (%)	Flour B2 (%)	Fine Bran (%)	Fine Middlings/Sizing (%)	Flour Sizing (%)	Fine Middlings/Red1 (%)	Flour/Red1 (%)	Fine Middlings/Red2 (%)	Flour/Red2 (%)	Fine Middlings/Red3 (%)	Flour/Red3 (%)	Feed material → Sizing (%)	Feed Material → Reduction (%)
233	70,0	57,6	14,3	12,1	15,9	17,1	7,9	17,9	14,5	5,2	5,3	11,4	16,7	18,1	10,1	6,7	7,4	2,8	22,1	35,3
333	70,0	58,6	16,0	11,8	13,5	15,4	9,1	21,3	12,6	5,7	6,8	12,4	19,0	20,5	12,0	6,9	8,7	3,4	25,0	39,8
444	69,8	61,5	15,4	10,9	12,0	16,5	10,1	22,6	12,0	5,6	7,9	11,9	18,9	22,0	11,2	7,7	7,9	3,4	25,5	41,3
555	70,4	64,5	18,1	9,5	7,9	13,1	13,9	26,8	10,4	7,2	11,8	12,8	23,6	24,2	13,4	10,2	9,1	4,4	32,0	48,2
644	70,4	66,0	16,9	9,6	7,4	12,7	13,9	28,2	11,0	7,4	10,2	13,1	21,7	25,9	13,3	8,4	9,6	3,7	30,8	48

All % are given as a % of entering wheat

Practical example 1
5 Samples with same Extraction rate and different MPi



Looking at	Average	Range	Variation
Feeding 2nd Break	6 t/h	1t/h	+/- 17 %
Feeding Sizing	2,5t/h	1t/h	+/- 40 %
Feeding Reduction	4,2 t/h	1,3 t/h	+/- 31 %

- Same flour extraction can be obtained with samples responding very differently to the milling process.
- In the industry this can generate difficulties at different stages (grinding, sifting…)

Feed numbers in t/h are hypothetical, helping comparison –not example of existing situation-

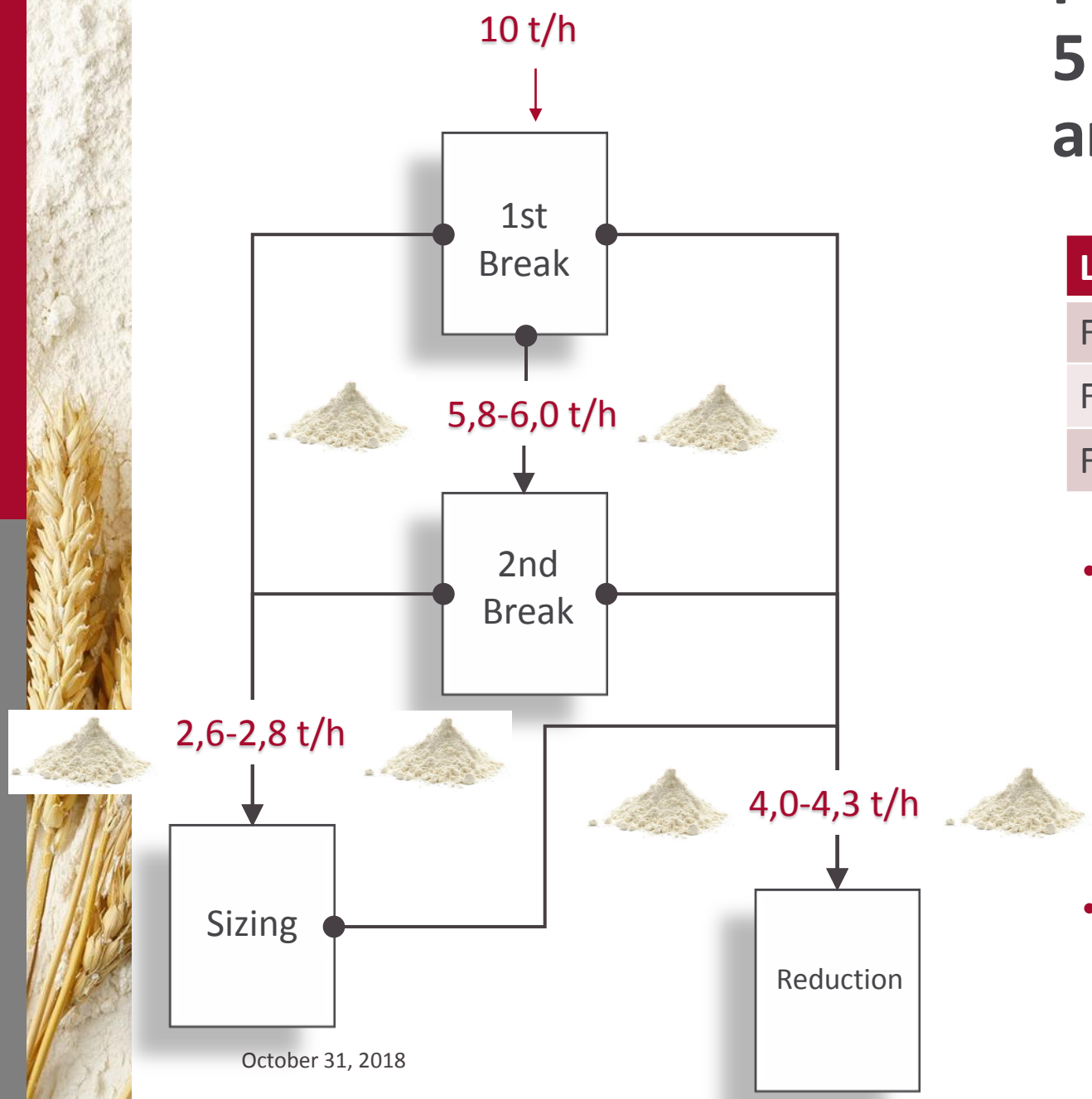
CHOPIN TECHNOLOGIES

Practical example 2
5 samples with same MPi and different Extraction rate

MPi	Extraction rate (%)	Meal/B1 (%)	Large Middlings B1 (%)	Fine Middlings B1 (%)	Flour B1 (%)	Coarse Bran (%)	Large Middlings/B2 (%)	Fine Middlings/B2 (%)	Flour B2 (%)	Fine Bran (%)	Fine Middlings/Sizing (%)	Flour Sizing (%)	Fine Middlings/Red1 (%)	Flour/Red1 (%)	Fine Middlings/Red2 (%)	Flour/Red2 (%)	Fine Middlings/Red3 (%)	Flour/Red3 (%)	Feed material → Sizing (%)	Feed Material → Reduction (%)
344	70,4	59,9	16,1	11,4	12,4	15,7	9,8	22,2	11,9	5,8	7,7	12,3	19,5	21,3	11,5	8,0	8,2	3,4	25,9	41,3
344	71,7	58,4	16,4	11,8	13,4	14,5	9,4	21,8	12,3	5,9	6,9	12,9	18,5	21,6	10,7	7,8	7,7	3,0	25,8	40,5
344	72,9	59,6	16,2	11,0	12,8	15,4	9,9	21,8	12,2	5,1	7,2	13,5	16,0	23,8	9,0	7,0	6,3	2,7	26,0	40,1
344	73,8	57,3	17,4	12,0	13,2	14,2	8,9	21,5	12,5	5,8	6,8	13,6	15,7	24,2	8,5	7,2	5,9	2,6	26,3	40,2
344	74,8	58,8	17,4	11,3	12,4	13,0	10,2	23,6	11,8	5,6	8,4	13,3	16,3	26,5	8,9	7,4	6,3	2,6	27,5	43,3

All % are given as a % of entering wheat

Practical example 2
5 Samples with same MPi and different Extraction rate



Looking at	Average	Range	Variation
Feeding 2nd Break	5,9 t/h	0,2 t/h	+/- 3 %
Feeding Sizing	2,7 t/h	0,2 t/h	+/- 7 %
Feeding Reduction	4,15 t/h	0,3 t/h	+/- 7 %

- Because it is based on the observation of wheat behavior during crushing MPi classifies wheat according to their response to milling stress.
- This allows a new and useful way to look at Laboratory milling results.

Feed numbers in t/h are hypothetical, helping comparison –not example of existing situation-

CHOPIN TECHNOLOGIES

Practical example 2
5 samples with same MPi and different Extraction rate

MPi	Extraction rate (%)	Meal/B1 (%)	Large Middlings B1 (%)	Fine Middlings B1 (%)	Flour B1 (%)	Coarse Bran (%)	Large Middlings/B2 (%)	Fine Middlings/B2 (%)	Flour B2 (%)	Fine Bran (%)	Fine Middlings/Sizing (%)	Flour Sizing (%)	Fine Middlings/Red1 (%)	Flour/Red1 (%)	Fine Middlings/Red2 (%)	Flour/Red2 (%)	Fine Middlings/Red3 (%)	Flour/Red3 (%)	Feed material → Sizing (%)	Feed Material → Reduction (%)
344	70,4	59,9	16,1	11,4	12,4	15,7	9,8	22,2	11,9	5,8	7,7	12,3	19,5	21,3	11,5	8,0	8,2	3,4	25,9	41,3
344	71,7	58,4	16,4	11,8	13,4	14,5	9,4	21,8	12,3	5,9	6,9	12,9	18,5	21,6	10,7	7,8	7,7	3,0	25,8	40,5
344	72,9	59,6	16,2	11,0	12,8	15,4	9,9	21,8	12,2	5,1	7,2	13,5	16,0	23,8	9,0	7,0	6,3	2,7	26,0	40,1
344	73,8	57,3	17,4	12,0	13,2	14,2	8,9	21,5	12,5	5,8	6,8	13,6	15,7	24,2	8,5	7,2	5,9	2,6	26,3	40,2
344	74,8	58,8	17,4	11,3	12,4	13,0	10,2	23,6	11,8	5,6	8,4	13,3	16,3	26,5	8,9	7,4	6,3	2,6	27,5	43,3

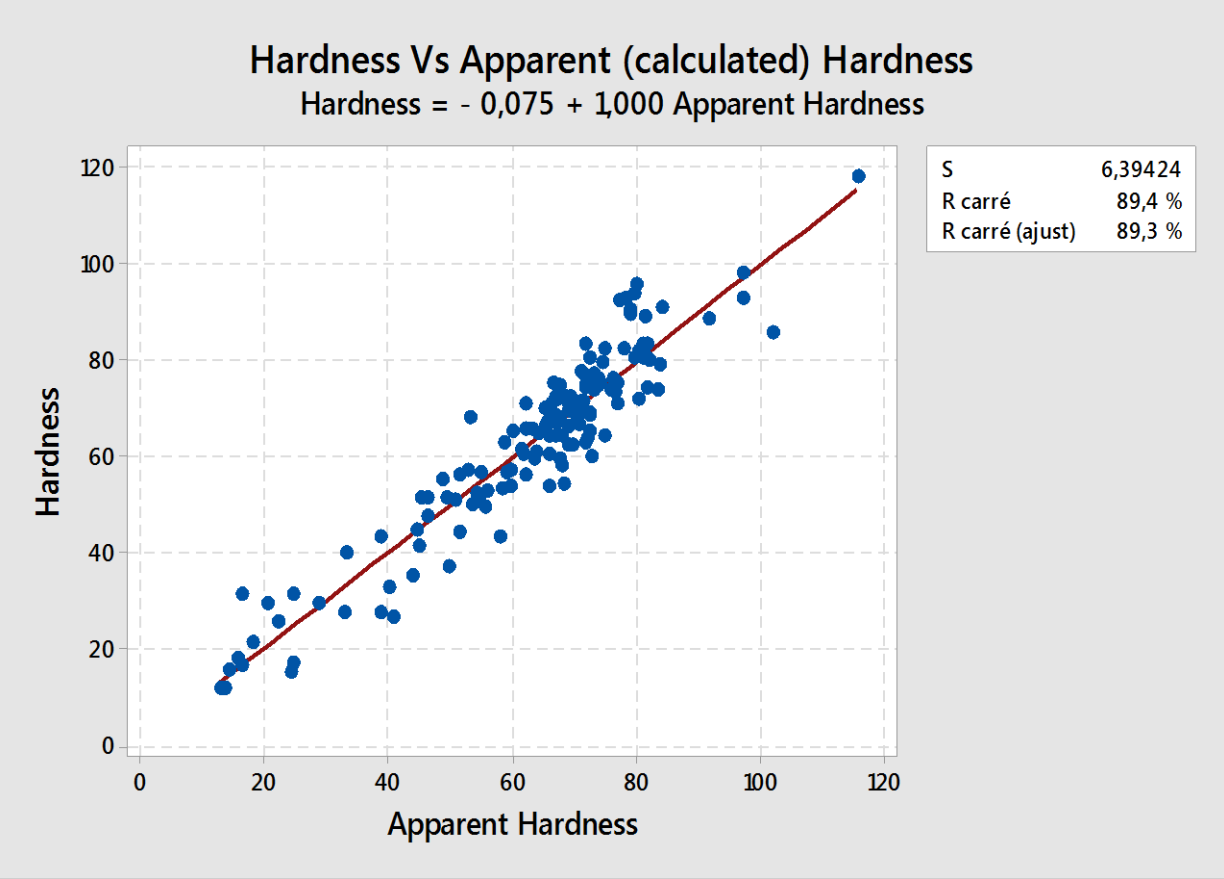
All % are given as a % of entering wheat

Apparent Hardness

- Apparent hardness can be calculated by analyzing product production based on % of products released by stream

- By the formula

Apparent Hardness = 324,5 - 176,5 Meal/B1 + 135,1 Large Middlings/B1 - 787 Fine Middlings/B1 - 117,1 Coarse Bran + 109,4 Fine Middlings/Sizing - 55,1 Flour/Sizing - 33,1 Fine Middlings/Red1 - 81,8 Shorts/Red3



Putting theory into action : LabMill Analytical Spreadsheet

October 31, 2018

Wheat milling behavior at a glance :

a comprehensive sumarizing spreadsheet

1/ Indicate the test conditions

2/Enter the weight of the different fractions

3/you can add flour ash content

All fractions are automatically calculated, based on wheat weight and on the fraction of product entering the stream

Milling Performance Index automatically calculated

Apparent Hardness automatically calculated

Extraction Rate automatically calculated

/03/2018				Operator	A. Dubat		
Sample identification		58-ARG-BL-INT					
Wheat input (g)		1700		Comments			
Wheat initial moisture (%)							
Wheat moisture for milling (%)		15,9					
Tempering time (h)		24					
		Weight (g)	%/Wheat	%Stream Feed	Resistance index	Dissociation index	Conversion index
1st Break	Meal/B1	1040,4	61,2%	6[illegible]%	0,26	1,26	0,85
	Large Middlings	301,9	17,8%	17,8%			
	Fine Middlings	186,4	11,0%	11,0%			
	Flour	168,4	9,9%	9,9%			
2nd Break feed material		1040,4	61,2%	100,0%			
2nd Break	Coarse Bran	272,9	16,1%	26,2%			
	Large Middlings	165,0	9,7%	15,9%			
	Fine Middlings	402,3	23,7%	38,7%			
	Flour	196,3	11,5%	18,9%			
Sizing feed material		466,9	27,5%	100,0%			
Sizing	Fine Bran	89,0	5,2%	19,1%			
	Fine Middlings	131,4	7,7%	28,1%			
	Flour	243,9	14,3%	52,2%			
1st reduction feed material		720,1	42,4%	100,0%			
1st reduction	Fine Middlings	269,9	15,9%	37,5%			
	Flour	443,4	26,1%	61,6%			
2nd Reduction	Fine Middlings	146,9	8,6%	54,4%			
	Flour	124,3	7,3%	46,1%			
3rd Reduction	Shorts	101,3	6,0%	69,0%			
	Flour	44,9	2,6%	30,6%			
Total product recovered		1684,4	99,1%				
Total Flour		1221,2					
Extraction rate		**72,5%**					
Flour Ash Content							

Milling Performance Index (MPi)

4	**4**	**4**
Higher index (7) indicates more resistance to crushing	Higher index (7) indicates more resistance to create fine particles	Higher index (7) indicates more resistance to flour production from fine middlings

Apparent Hardness Index

57

Scale ranges from 0 (soft) to 100 (Hard)

Actual sample | Graphical analysis | Tables for comparison

CHOPIN TECHNOLOGIES

Wheat milling behavior at a glance :

a possibility to compare with reference values

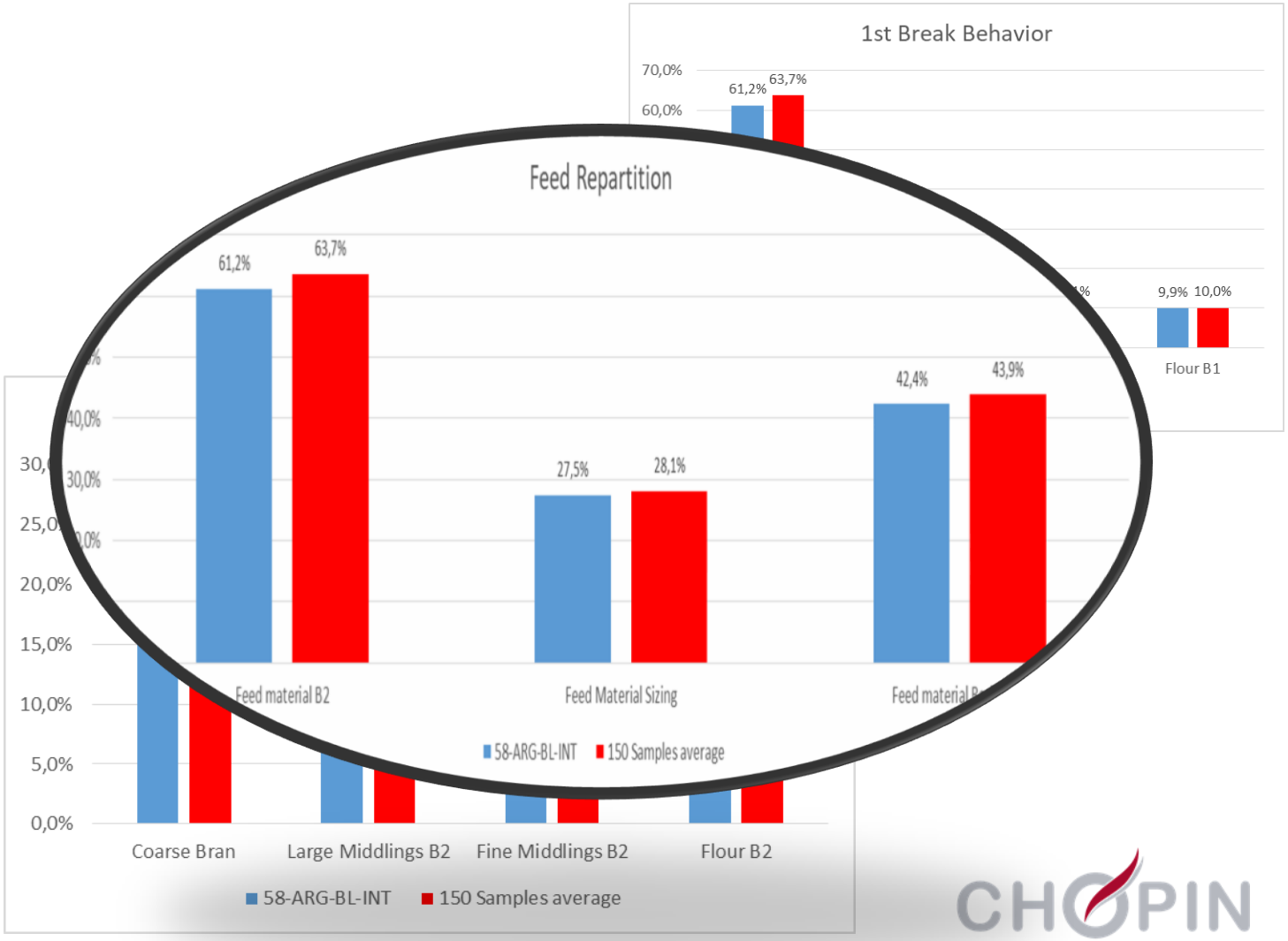
	B	C	D	E	F
	Date		Operator		
3	Comparison with Internal reference				
4					
5					
6				Admitted tolerance +/-	1%
7	Id	58-ARG-BL-INT	150 Samples average	Accepted lower	Accepted higher
8	Meal B1	61,2%	63,7%	62,7%	64,7%
9	Large Middlings B1	17,8%	16,1%	15,1%	17,1%
10	Fine Middlings B1	11,0%	10,1%	9,1%	11,1%
11	Flour B1	9,9%	10,0%	9,0%	11,0%
12	Id	58-ARG-BL-INT	150 Samples average	Accepted lower	Accepted higher
13	Coarse Bran	16,1%	14,4%	13,4%	15,4%
14	Large Middlings B2	9,7%	12,0%	11,0%	13,0%
15	Fine Middlings B2	23,7%	25,2%	24,2%	26,2%
16	Flour B2	11,5%	11,9%	10,9%	12,9%
17	Id	58-ARG-BL-INT	150 Samples average	Accepted lower	Accepted higher
18	Fine Bran	5,2%	6,5%	5,5%	7,5%
19	Fine Middlings Sizing	7,7%	8,7%	7,7%	9,7%
20	Flour Sizing	14,3%	12,8%	11,8%	13,8%
21	Id	58-ARG-BL-INT	150 Samples average	Accepted lower	Accepted higher
22	Fine Middlings Red1	15,9%	18,6%	17,6%	19,6%
23	Flour Red1	26,1%	24,8%	23,8%	25,8%
24	Fine Middlings Red 2	8,6%	11,0%	10,0%	12,0%
25	Flour Red2	7,3%	7,7%	6,7%	8,7%
26	Shorts	6,0%	7,8%	6,8%	8,8%
27	Flour Red 3	2,6%	3,2%	2,2%	4,2%
28	Id	58-ARG-BL-INT	150 Samples average	Accepted lower	Accepted higher
29	Feed material B2	61,2%	63,7%	62,7%	64,7%
30	Feed Material Sizing	27,5%	28,1%	27,1%	29,1%
31	Feed material Reduction	42,4%	43,9%	42,9%	44,9%
32	Id	58-ARG-BL-INT	150 Samples average	Accepted lower	Accepted higher
33	Coarse Bran	16,1%	14,4%	13,4%	15,4%
34	Fine Bran	5,2%	6,5%	5,5%	7,5%
35	Shorts	6,0%	7,8%	6,8%	8,8%

Actual sample | Graphical analysis | **Tables for comparison**

CHOPIN TECHNOLOGIES

Wheat milling behavior at a glance :

and a graphical visualization of the results



CHOPIN TECHNOLOGIES

Conclusion

Let’s start REALLY analyzing wheat milling

- The Milling Performance index is a new parameter that helps understanding wheat behavior during milling.
- Certain wheat can have high extraction potential but grinding characteristics not suitable for certain mil diagrams.
- Selecting wheat according to their potential extraction AND behavior during milling makes sense to ensure that incoming wheat is adapted to millers needs.

CHOPIN TECHNOLOGIES

Repeatability and reproducibility of the Labmill

Experimental setup

Summary

Parameter	Range (%)	Average	Repeatability CV% Calculated on the mass of product (in g)	Reproduciblity CV% Calculated on the mass of product (in g)
Extraction rate	56-76	70,3%	1,2%	1,7%
1st Break Flour	3-25	10,1%	1,9%	4,2%
2nd Break Flour	6-16	11,2%	1,4%	4,0%
Sizing Flour	8,5-18,5	12,8%	2,3%	4,2%
1st Reduction flour	8-35	24,5%	4,7%	6,6%
2nd Reduction flour	5-14	7,8%	7,8%	10,7%
3rd Reduction flour	3-7	3,2%	10,8%	13,4%
Coarse Bran	8-24	14,4%	3,3%	6,1%
Fine Bran	4-12	6,5%	2,7%	8,2%
Shorts	3-18	7,8%	6,3%	12,2%

CHOPIN TECHNOLOGIES

Conclusion

Conclusions

- This first approach shows
  - A very good repeatability, higher CVs are related to streams with relatively little amount of product, then a minimum difference in wheight has higher impact on CVs.
  - Reproduciblity is also good taking into account the large variability of test conditions.
  - Last but not least the Labmill shows to perform exactly the same on all kind of wheat making it a mill suitable whatever the wheat hardness is.

Let’s start REALLY analyzing wheat milling

- The Milling Performance index is a new parameter that helps understanding wheat behavior during milling.
- Certain wheat can have high extraction potential but grinding characteristics not suitable for certain mil diagrams.
- Selecting wheat according to their potential extraction AND behavior during milling makes sense to ensure that incoming wheat is adapted to millers needs.

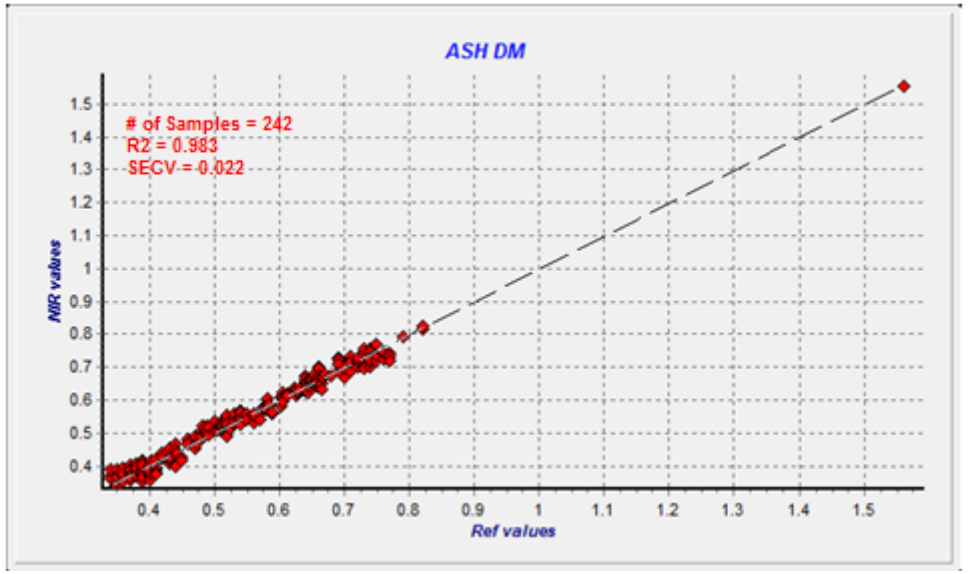
CHOPIN TECHNOLOGIES

NIR Spectralab

CHOPIN TECHNOLOGIES

Key advantage - Accuracy

Accuracy (SEP)		
Proteins	Moisture	Ash
0.200	0.129	0,017 to 0.030



- Accuracy similar to ash oven reference method – **in 30 seconds**

- Other manufacturers of NIR claim to obtain an equivalent accuracy for the ash content. This is often the case only at the cost of very frequent calibration adjustments (often once a week, sometimes every day!), Which is a nightmare for users.

CHOPIN TECHNOLOGIES

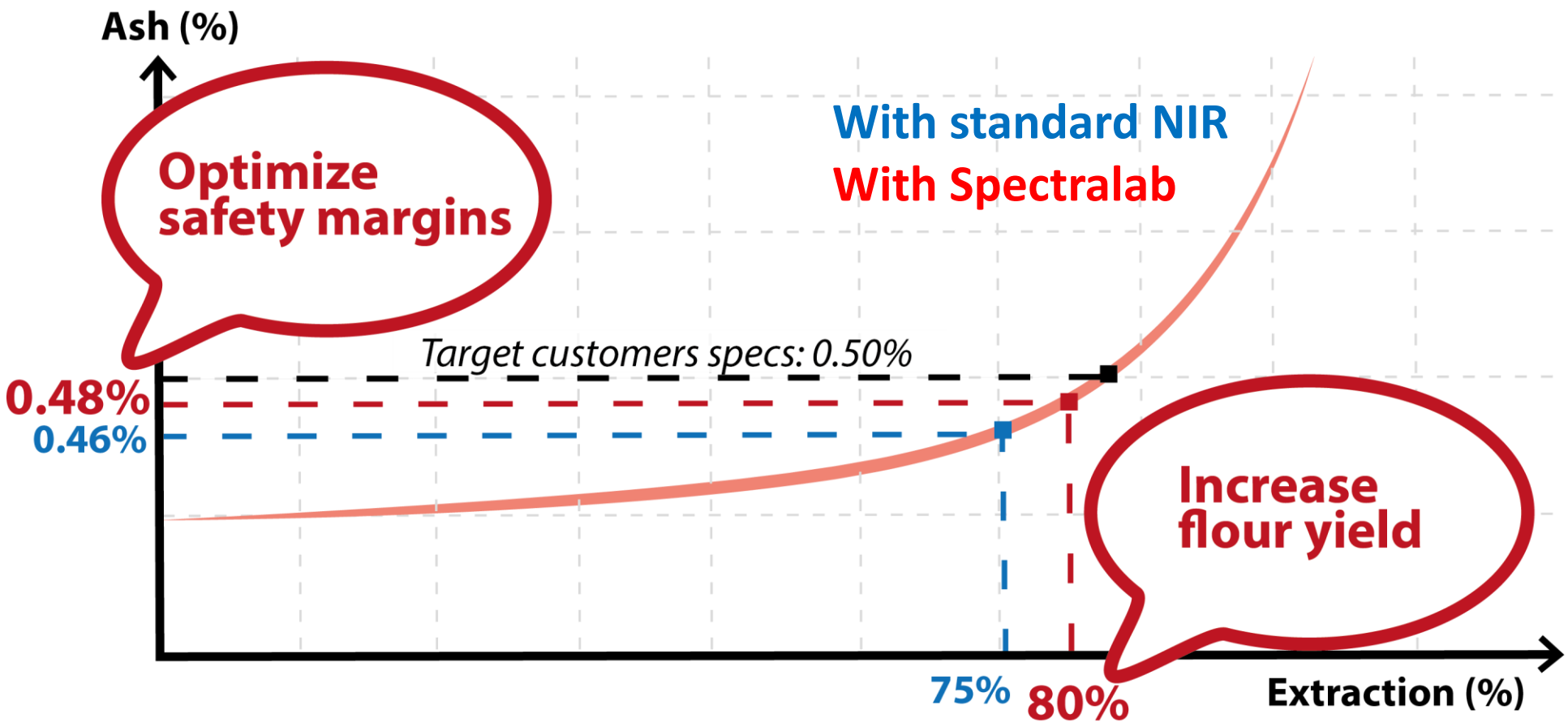
Accuracy – Spectralab vs ash oven

- **Spectralab**
- SEP = 0.017 to 0.030 (depending on range and number of samples)
- **SEP** = 0.024 (average)
- **Uncertainty** (reproducibility) :
  - 2 x SEP
  - 2 x 0.024 = **0.048**

- **Ash oven reference method NF ISO 2171** (1h at 900°C)
- **Uncertainty** (reproducibility) :
  - 2 x S_R
  - 2 x 0.023 = **0.046**

CHOPIN TECHNOLOGIES

Increase performance using a very rapid and precise measure of ash content



Values given as an example - results vary depending on the mill (1 to 5%)

Conclusion

Spectralab can be used at the milling process to optimize the ash content and to increase the extraction rate and so…

CHOPIN
TECHNOLOGIES