TeRiFiQ

Project no. 289397

Combining Technologies to achieve significant binary Reductions in Sodium, Fat and Sugar content in everyday foods whilst optimizing their nutritional Quality

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Deliverable D6.3
Report on the industrial implementation of the reformulated bakery products and recommendations

Abstract: *This report presents results from reformulated bakery products at industrial scale. It outlines the conclusions of the demonstration phase including constraints the reformulation brings about for future industrial application.*

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Dissemination level	
PU Public (must be available on the website)	X
PP Restricted to other programme participants (including the Commission Services)	
RE Restricted to a group specified by the consortium (including the Commission Services)	
CO Confidential, only for members of the consortium (including the Commission Services)	

Glossary

Aw: water activity

Xw: water content

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1. Section1 - Purpose

The objective of the work package 6.3 is to transfer and demonstrate at industrial scale the applicability of the technologies dedicated to bakery products developed in WP3. The performances at industrial scale production as well as the acceptance by consumer of the reformulated products have been worked in WP6.
The TeRiFiQ's goal is a binary reduction of fat and sugar up to 25%.

The sub objectives are:
- Selection of reformulated recipes able to be studied at industrial scale,
- Technical adaptation to processing existing lines,
- Comparison of outcomes in terms of quality, production volume,
- Transferability of results to new products.

Two types of bakery products were studied in WP3: muffins and madeleine.

In order to reduce both fat and sugar, chosen formulations strategies were to work with inulins, polydextrose, starch and aroma.

2. Section 2 – Results

2.1 Selected products

2.1.1 Muffins

All baking trials were based on a plain muffin with no flavouring added.
Millba decided to upscale a Milk Chocolate Muffin for online tests. Milk Chocolate Muffin is Millba's biggest volume product, and a well-known taste for consumers. This is a moist American type of muffin baked with milk chocolate grains inside and milk chocolate chunks on top. Products are frozen and thawed before selling. Shelf life frozen is 12 months, shelf life thawed is 28 days. The products are single wrapped.

We have succeeded in removing the amount of fat and sugar targeted in the project: reduced sugar with 25 % and Fat (rape seed oil) with 25 %.
We have adjusted the recipe to this, both technically and organoleptic.
In order to achieve this we have used inulin (Frutalose SFP) as sugar replacement.

Technical adjustment in production - adjusted baking time and temperature to find the right color of the product. The nutritionally improved muffins had a slightly darker colour due to the inulin.

We have had three large-scale tests using our large baking oven, packaging and freezing equipment.

1. 25 % reduction of sugar and fat, no replacements, and reference
   Product was too compact, too dry and had less volume compared with reference muffins
2. 25 % reduction of sugar and 25 % reduction of fat + Frutalose SFP
   Went well, but found out that we had to adjust the baking time and temperature
3. 25 % reduction of sugar and 25 % reduction of fat + Frutalose SFP
   Adjusted baking time and temperature to find the right color of the product

2.1.2 Madeleine

Madeleine is a traditional sponge cake with a long shelf-life at room temperature.

Three recipes were worked at larger scale: the standard Madeleine, the TeRiFiQ madeleines developed in WP3 with inulin and polydextrose, and a Madeleine reduced in fat and sugar with no replacers.

- Technical adaptation

Adjustments were needed to apply the recipes from lab-scale at larger scale.
The amount of flour was slightly diminished to reduce the dough viscosity and to allow the proportioning pump to function properly and a good rising of the dough during baking. The baking time was adjusted to 7 minutes in all.
The control of relative humidity in the larger oven was impossible as done at labscale, and thus a compromising was found. An injection (10s) of hot water vapor is made at the beginning of the baking, with the vapor release trap closed during the 6 $^{1/2}$ minutes of cooking, and opened the last 30s to improve the surface coloration.

Productions were made in may 2015 for the 3 types of Madeleine.

The yield during baking has been followed by weighing the differences between the mass of dough put in the oven and the mass of madeleines produced, after resting. Three baking have been done for each recipe. The average results are presented on the graph below. The water losses are of the same order for the 3 recipes, even if the TeRiFiQ product seems to lose slightly more water during baking than the two others.

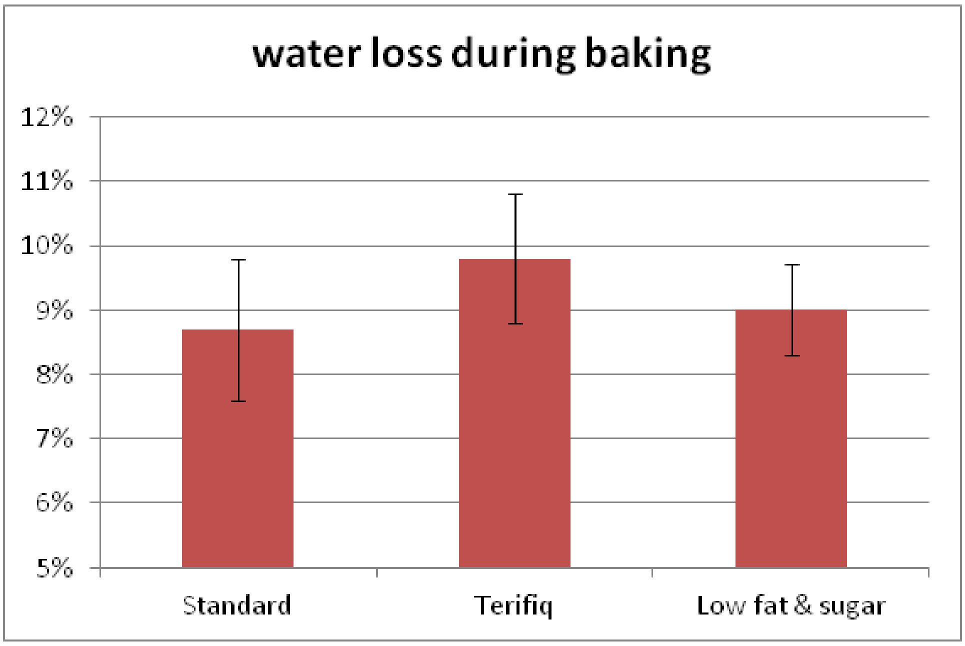

Figure 1. Water loss during Madeleine's baking (% of initial dough mass)

2.2 Characterization of the product made at larger scale

2.2.1 Muffins

2.2.1.1 Appearance

The volumetric appearance of the reference and the nutritionally improved muffins were measured by a Tex.Vol. instrument. No differences in volume, height or density were observed between the reference and the nutritionally improved muffins. The nutritionally improved muffins had a slightly darker colour due to the inulin.

2.2.1.2 Texture

The textural properties of the muffins were analysed using a standard Texture *Profile Analysis* protocol, where hardness, springiness, cohesiveness, gumminess and chewiness were measured. The textural properties are measured, and calculated, from two consecutives compression of 20% of the products height. No differences in these textural properties were seen between the reference and the nutritionally improved muffins.

2.2.1.3 Aw or Xw

(Safety predictive indicator)
Water activity (a_w) was measured using an AquaLab instrument, and again, no differences were seen between the reference and the nutritionally improved muffins. Adria has performed shelf life testing on both reference and the nutritionally improved muffins. Conclusions were that shelf life was similar on both reference and the nutritionally improved muffins.

2.2.1.4 Weight

No differences were seen in the weight of the final products between the reference and the nutritionally improved muffins.

2.2.1.5 Nutritional values

Table 1. Nutritional values of reference muffin and nutritionally improved muffin

	Reference muffin	Nutritionally improved muffin
Dry matter (g)	100	100
Energy (kJ – kcal)	1589 kJ, 380 kcal	1443 kJ, 345 kcal
Total fat (g)	21,1	17,5
Saturated (g)	3,8	3,5
Carbohydrate (g)	41,7	43,5
Sugars (g)	24,7	21,3
Protein (g)	5,5	5,5
Salt (g)	0,9	1
Fiber (g)	3,0	7,4

The nutritional values did not improve as much as we had hoped.
Nutritional value of inulin pr. 100g:
Carbohydrate 97 g
- Digestible (sugars) 15 g
- Non-digestible (oligo fructose) 82 g

According to EU directive 2008/100/EC the caloric value of oligo-fructose is 2 Kcal / gram

2.2.1.6 Sensory QDA (quality descriptive analysis)

The sensory evaluation was carried out by a panel of 10 well trained sensory assessors at Nofima AS, Norway. The panellists were selected and trained according to recommendations in *ISO 8586:2012 General guidelines for the selection, training and monitoring of selected assessors and expert sensory assessors*, and *ISO 13299:2003 General Guidance for establishing a sensory profile*. The aim was to investigate the sensory profile of five different muffins.
A list of 23 descriptive attributes for the muffins were agreed by the assessors and used in the study. Each muffin was divided into 4 equal sized parts before serving to the assessors on coded plates. The samples were analysed in duplicate at room temperature in a randomized order according to sample, replicate and assessor. For neutralization of the taste organ, the panellists were required to rinse the mouth with lukewarm water and unsalted crackers between samples. The panellist recorded their results at individual speed on a 15 cm non-structured continuous scale where the left side represented low intensity, and the right side high intensity. A computer transformed the responses into numbers between 1 (low intensity) and 9 (high intensity).

The test was conducted on five different muffin samples:
1 Plain Muffin, reference
2 Plain Muffin, 25 % reduction in sugar and fat + inulin
3 Plain Muffin, 25 % reduction in fat, with water replacement
4 Milk Chocolate Muffin, reference
5 Milk Chocolate Muffin, 25 % reduction in sugar and fat + inulin

There was no significant difference between the attributes for the samples baked as plain muffins (Fig.2). For the muffins with milk chocolate, small differences were found for juiciness, vanilla odour and sour flavour (Fig.3).

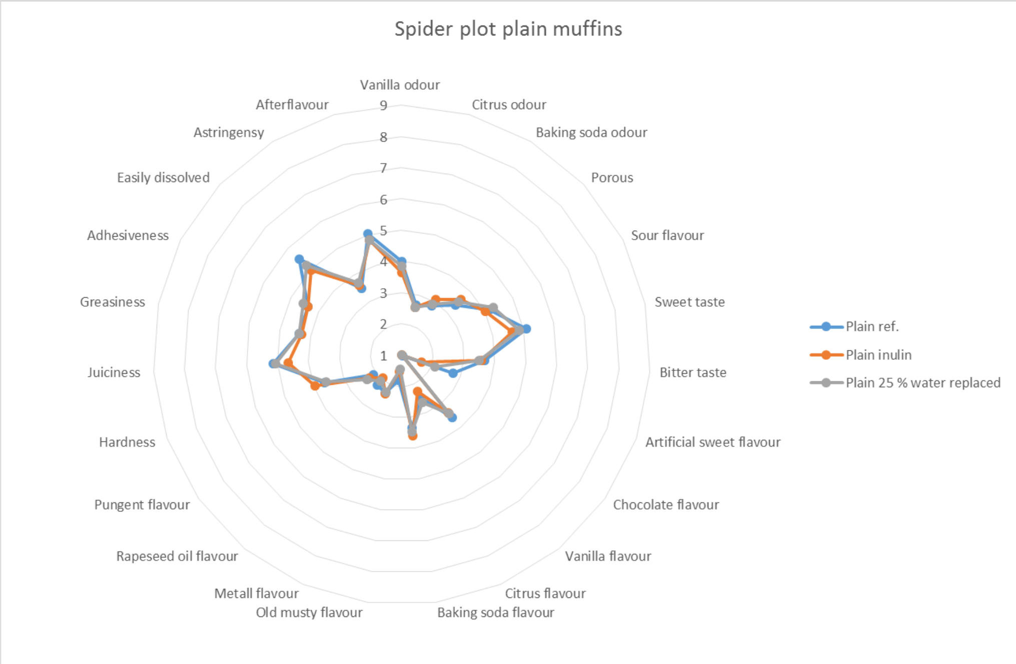

Figure 2. Spider web diagrams of sensory results for the 3 plain muffins.

The Milk Chocolate reference muffin had a more intense sour flavour, a higher score for juiciness and less intense odour of vanilla than the new formulated product. However, the differences were considered so small that consumers probably would not detect the change in recipe.

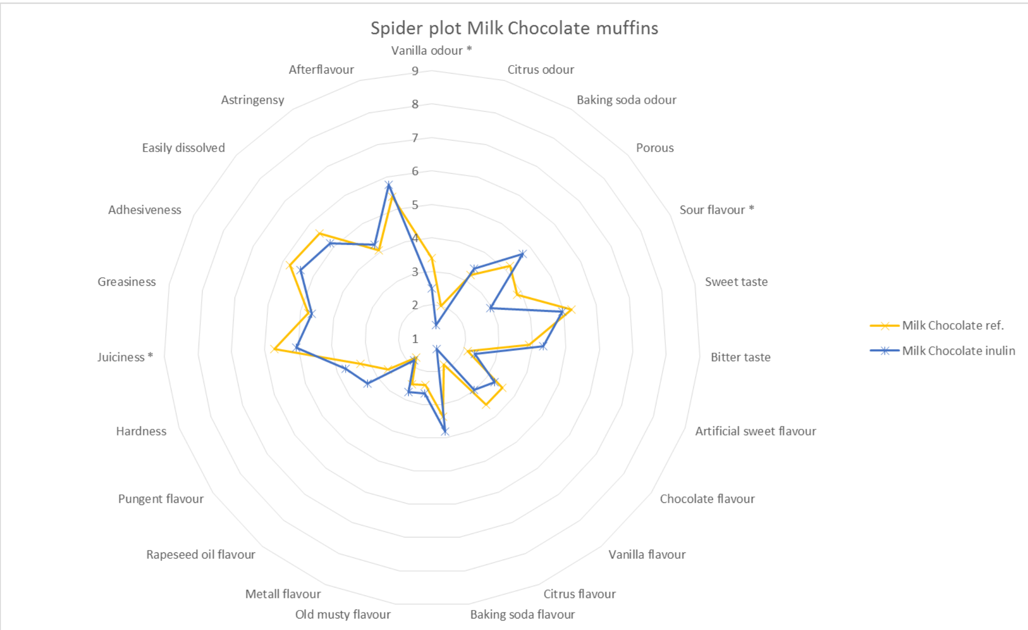

Figure 3. Spider web diagrams of sensory results for the Milk Chocolate muffins.
** Indicate significant difference (*=p<0,05)*

2.2.1.7 Consumer panel

Four triangle tests were conducted at Millba. Test of two samples: Reference muffin and the nutritionally improved muffins.

1. Reference muffin, 25 % reduction of sugar and 25 % reduction of fat + Frutalose SFP (Products had been thawed for 24 hours)

2. Reference muffin, 25 % reduction of sugar and 25 % reduction of fat + Frutalose SFP (Products had been thawed for 24 hours) as repetition at larger scale (for test number 1 the products where baked on the test kitchen, and for test number 2, the products where baked in the production at large scale).

3. Reference muffin, 25 % reduction of sugar and 25 % reduction of fat (Products had been thawed for 24 hours)

4. Reference muffin, 25 % reduction of sugar and 25 % reduction of fat + Frutalose SFP (Products had been stored at room temperature for 28 days)

We used an untrained panel consisting of 20 people for each triangle test. In total, 80 people tasted the products. They could not distinguish between the two products in any of the tests.

2.2.1.8 Cost impact

Milk Chocolate Muffins reduced with 25% fat and 25% sugar + added inulin is more expensive to produce than the reference. In this estimate, the prices of raw materials and the number of products per batch are taken into account.

2.2.2 Madeleine

The three types of madeleines (Standard, Reduced & TeRiFiQ) were characterized after baking and along self-life. The impact of the fat & sugar substitution was analyzed along 5 months.

2.2.2.1 Aspect: Color and development after baking

For both Standard and TeRiFiQ madeleines, a good development was observed after baking, better than the one obtained for the low fat & sugar.
Chimneys (elongated holes in the crumb) were obtained in the three recipes, illustrating a good viscosity of dough sufficient to:

- allow a rising of the dough under the gas dilatation,
- keep enclosed gas released during baking for the standard and the TeRiFiQ madeleines.

The reduced Madeleine dough didn't develop well during baking, certainly due to a too high viscosity.

Low fat & sugar madeleines, with no replacers, show a crumb more pale and dull than the TeRiFiQ and Standard Madeleine's crumb, brighter and yellower.

2.2.2.2 Rheology

2.2.2.2.1 Viscosity raw dough

The viscosity of the dough was obtained with a Brookfield DVRII viscosimeter, equipped with a spindle n°7. The viscosity of 400g of dough was measured at 50 rpm, after 30 and 60s to illustrate a slight rheofluidifiant behavior in triplicates.

Table 2. Viscosity's measurement of the dough (Cp)

	Standard		TERIFIQ		Low fat and sugar	
	30s	60s	30s	60s	30s	60s
Viscosity (Cp)	41200	40400	28960	28320	53040	51280
50rpm	42000	41120	31680	30640	56000	54400
spindle 7	44640	43600	31840	X	57360	55280
Mean value	**42613,3**	**41706,7**	**30826,7**	**29480**	**55466,7**	**53653,3**
Standard deviation	**1800,1**	**1678,7**	**1618,6**	**1640.5**	**2208,8**	**2101,9**

These measurements reveal significant differences between the 3 doughs.
The lower viscosity measured for the TeRiFiQ could explain the longest chimneys observed in the crumb, from the bottom to the top for some products. The high value obtained for the reduced Madeleine could explain the lack of development during baking.

2.2.2.2.2 Textural properties

The main textural properties of the madeleines were measured with an universal Texturometer TA-XT2. The Texture Profil Analysis protocol (TPA) was used to determine the hardness, the springiness, the cohesiveness and the chewiness of the fresh products and along shelf life.
In order to increase the repeatability, the madeleines were trimmed to perform the measurements. The double compression was done with a 20mm diameter cylinder at speed of 0.5 mm/s on a 20% of height deformation.

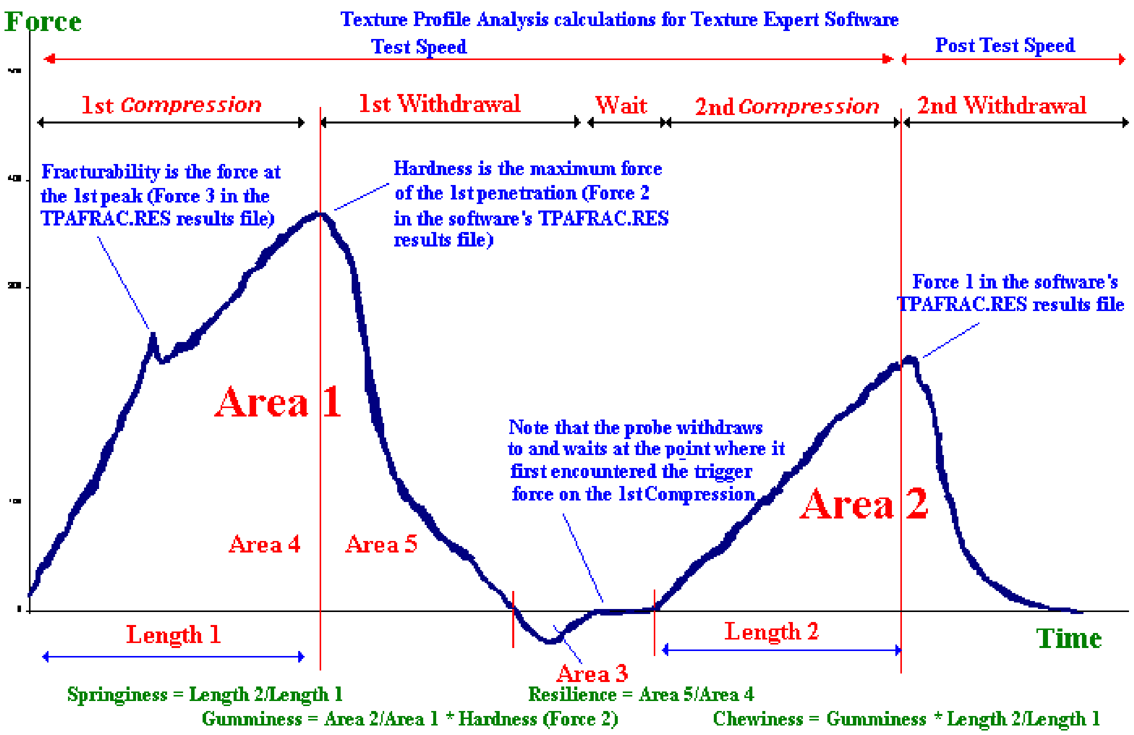

Figure 4. Textural Profile Analysis (TPA) diagram.

Hardness
This parameter represents the resistance to the first bite in the products.

The hardness of the three recipes has been measured one day after baking and during five months. The results are shown on the figure 5 below.
The low fat & sugar madeleine presents a hardness value significantly higher than the two other products. This high value is well correlated with the lack of development and the denser feel in mouth.
The Standard and the TeRiFiQ madeleines hardness values are similar on the 1st four months. The gap begins to increase from month 4 and is confirmed at month 5. It seems according to this parameter that the TeRiFiQ Madeleine could be perceived as harder as the standard after aging. The stalling impact may be higher on the TeRiFiQ products than on the Standard ones.

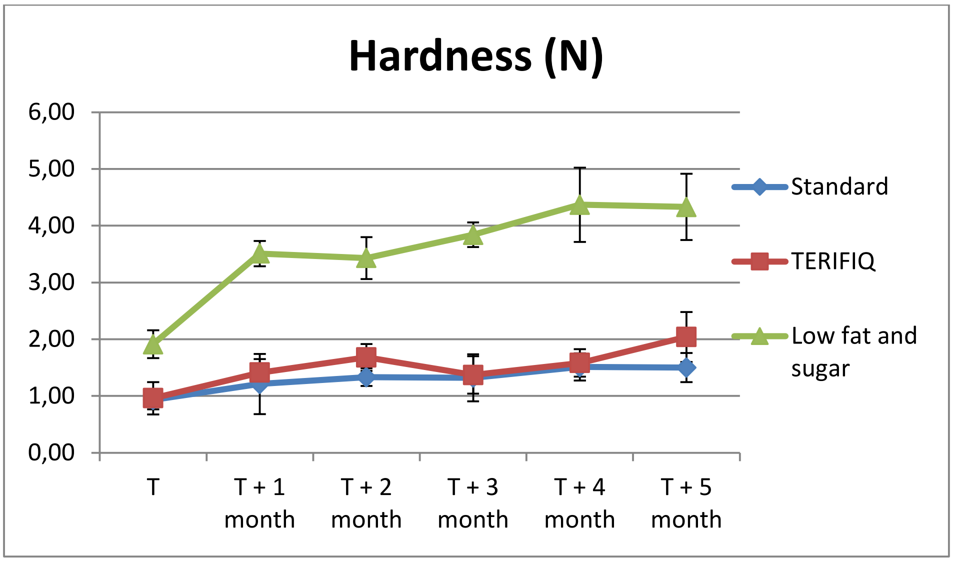

Figure 5. Evolution of Madeleines Hardness (in N) during storage.

Springiness

This parameter represents the loss of response between two consecutive compressions in the products, and thus an appreciation of the evolution of the crumb elasticity.

The crumb's springiness of the three recipes has been measured one day after baking and during five months. The results are shown on the table above and on the graph below.
As we can see on the graph below, the TeRiFiQ recipe seems to lose its springiness a little faster than the two other recipes. However the changes are small, and shouldn't be of high impact on the degustation in the first months.

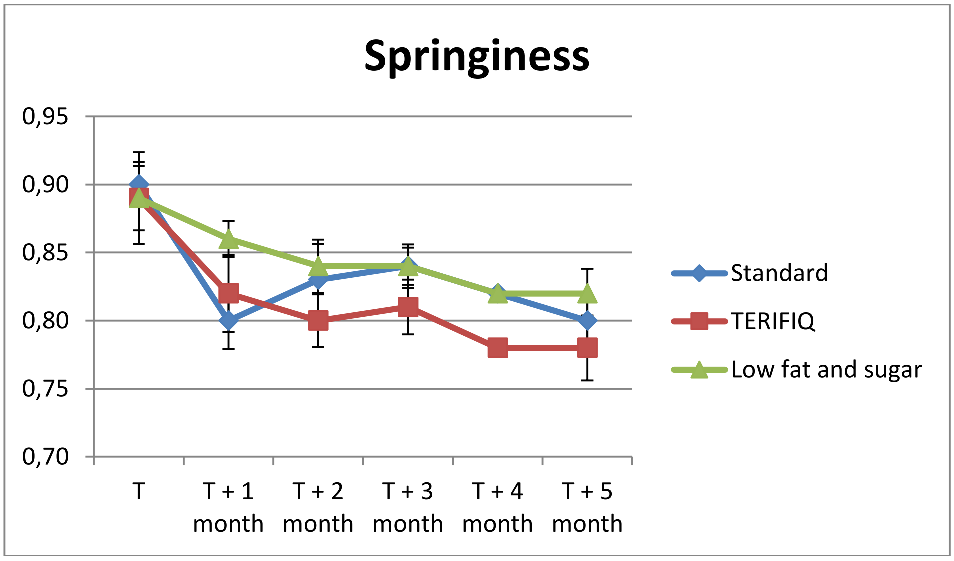

Figure 6. Evolution of Madeleines Springiness during storage.

Cohesiveness

This parameter represents the delay of time response between two consecutive maximum compressions in the products, and thus an appreciation of the stickiness of the crumb.

The cohesiveness of the three recipes has been measured one day after baking and during five months. The results are shown on the table above and on the graph below.
As we can see on the graph below, after a slight decrease between T and T+1 month, corresponding to the equilibration of water inside the product, no significant change is observed in and between the third products.
None of the three recipes present a sticky crumb, nor a crumb with a high friability after a few month of storage.

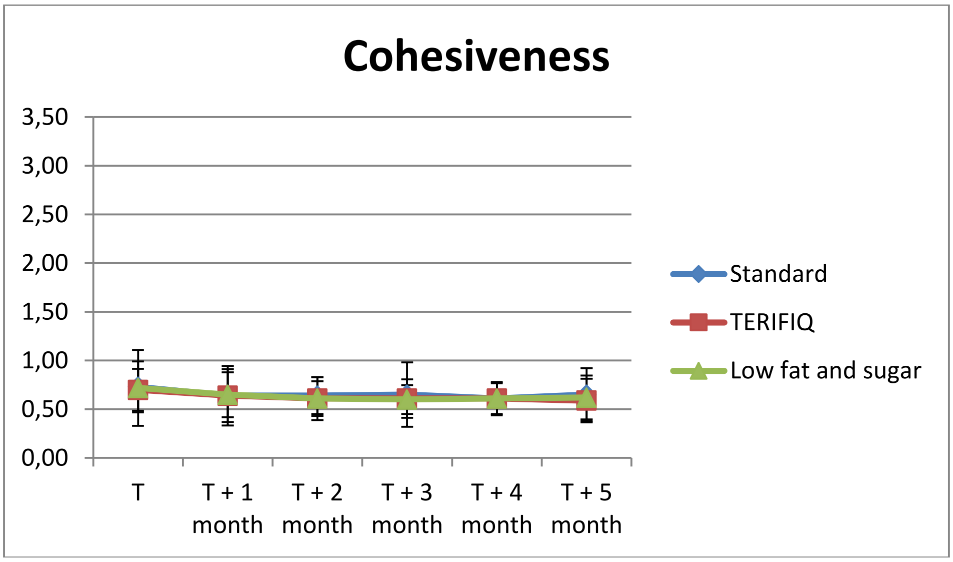

Figure 7. Evolution of Madeleines Cohesiveness during storage.

Chewiness

This parameter is a calculated value obtained from the three precedents. It somehow represents the changes of force to apply in order to chew the product.

The chewiness of the three recipes has been measured one day after baking and during five months. The results are shown on the table above and on the graph below.
The low fat & sugar madeleine presents a chewiness value significantly higher than the two other products, and increasing faster than the two others. This higher value is well correlated with the stalling impact and the feeling in mouth of a product denser and firmer.
The Standard and the TeRiFiQ madeleines chewiness values are similar on the 1st four months. The gap begins to increase at month 5 as observed for the hardness values.

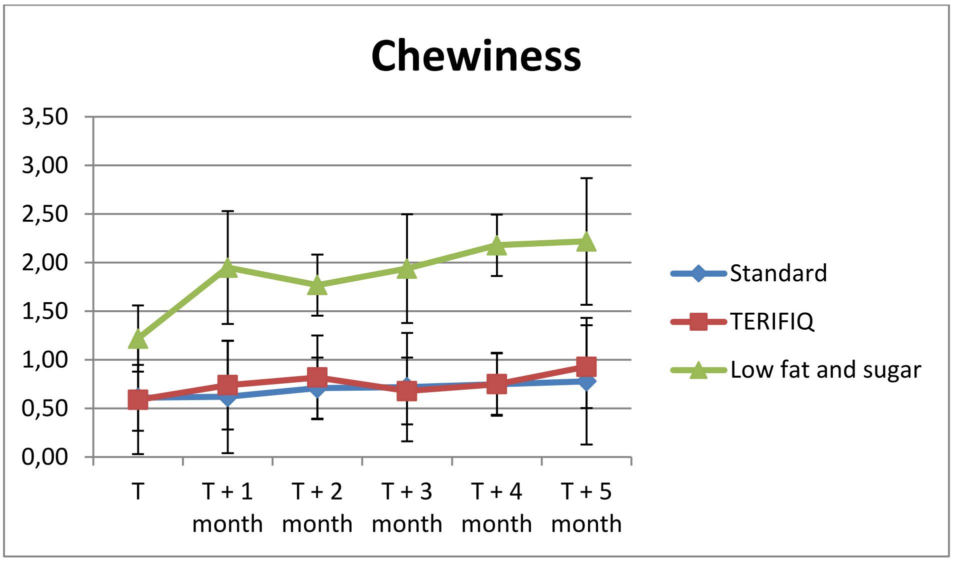

Figure 8. Evolution of Madeleines Chewiness during storage.

2.2.2.3 Aw or Xw

The water content and the water activity values of each 3 types of madeleines have been measured and followed as quality and safety predictive indicators.

The water content has been measured by desiccation in an oven at 103°C during 48H. The changes in water content during storage illustrate a progress of the stalling and drying of the products, losing their water by exchanges with the atmosphere.

Table 3. Evolution of Water content in Madeleine during shelf-life (%wet basis)

Xw						
	T	T + 1 month	T + 2 month	T + 3 month	T + 4 month	T + 5 month
Standard	16,54%	15,25%	16,32%	15,71%	15,90%	15,63%
TERIFIQ	18,43%	17,09%	17,87%	17,69%	17,80%	16,14%
Low fat and sugar	19,77%	19,24%	19,03%	20,03%	18,93%	18,51%

As seen in the table above, the three products lose the same amount of water on the first four month. The TeRiFiQ seems to have an increased loss between the month 4&5 than the two other recipes. The staling could be fast increasing after the 4th month of storage for the TeRiFiQ recipes, as observed for the hardness parameter. This observation has to be confirmed by further measurements.

Table 4. Evolution of Water activity in Madeleine during shelf-life

Aw						
	T	T + 1 month	T + 2 month	T + 3 month	T + 4 month	T + 5 month
Standard	0,711	0,685	0,717	0,706	0,711	0,702
TERIFIQ	0,755	0,702	0,734	0,746	0,735	0,704
Low fat and sugar	0,794	0,755	0,766	0,773	0,763	0,757

The measurements of the water activity values showed that the Standard and the TeRiFiQ products pose little risks for microbial spoilage due to their low Aw value (<<0.8). On the contrary, the low fat & sugar with no replacers presents an initial water activity value enabling the growth of moulds. During storage, due to water losses the water activity values decrease for the three products guiding them to a safety zone versus microbial spoilage.

2.2.2.4 Nutritional values

Preliminary, nutritional values have been calculated from recipe using CIQUAL (French food composition tables)

Table 5. Nutritional values of Madeleine

	Standard
Energy (kJ - kcal)	1854 - 443
Total fat (g)	22.6
Saturated (g)	2
Carbohydrate (g)	49.2
Sugars (g)	25.6
Protein (g)	7.1

Nutritional targets for TeRiFiQ Madeleine are 17g/100g for total fat and 19g/100g for sugars.
Nutritional analyses have been conducted by an independent laboratory.
Amount of nutrient in a product may vary due to factors such as source of values, variation in the raw materials, the effect of processing, storage conditions and time. The measured values are within the tolerances around the declared values (EC guidance document, 2012).

2.2.2.5 Consumer panel

The methodology chosen is a consumer panel joints with a comparative profile to:
- quantify the consumers' appreciation,
- identify the optimization trends.

This study has been subcontracting.
The consumers' panel included 123 adults (very robust), the multi trained product panel, 10 experts.

The TeRiFiQ Madeleine has been compared to the Standard Madeleine. It results that the two products are liked.

The main difference is on the textural aspect. TeRiFiQ Madeleine is firmer than the Standard. Consumers expected a product more aerated.

The expert panel (D3.3) gives information about difference between products. Relevant differences are shown by star.

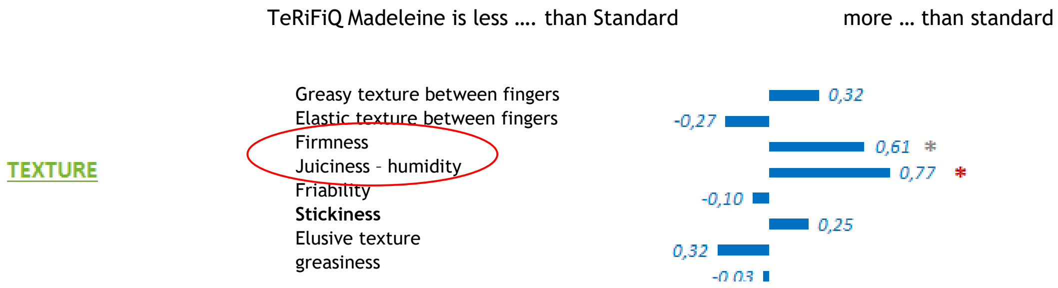

Figure 9. Comparative's profile between Standard and TeRiFiQ Madeleines (10 experts).

In the mouth, the TeRiFiQ madeleine is considered less dry than the Standard and tends to be firmer.
Experts also underline the enhancement of salted taste in TeRiFiQ Madeleine.
No significant differences were found on the fatness and sweetness feeling in mouth during degustation.

2.2.2.6 Cost impact

The reformulated products are more expensive to produce due to the cost of inulin and polydextrose.

2.3 Optimization

2.3.1 Madeleine

In order to improve texture without impairing nutritional value, optimization in process has been conducted:
- pre-hydration of fibers, in order to increase the freshness feeling in mouth, and prolonging the stability of the crumb versus the stalling,
- madeleine's aeration during baking, working on the dough viscosity, in order to reduce the feeling of a too compact crumb during degustation.

We also tested application of the cross-modal interaction in order to improve the sweetness perception.

8 types of aroma at different concentrations were tested:

- Cinnamon,
- almond,
- strawberry,
- vanilla,
- orange blossom,
- caramel,
- "sugar",
- peach.

Four aromas (A1, A2, A3 & A4) were selected by an internal panel on their positive impact on sweet perception. Thus, they have been incorporated in the TeRiFiQ madeleine before being testing by a naive panel of 30 people on the sugar intensity perception:

Best results on sugar perception improvement were observed for A4 and A2. Nevertheless, A4 gave a too marked taste for the madeleine typicality. So, the choice to mix A1 & A2 aromas to improve sugar intensity perception in the TeRiFiQ recipe was made.

3. Section 3 – Conclusion

At the starting point of TeRiFiQ project, cake industrials answered that the reduction of sugar while maintaining consumers' acceptance was a quite difficult aim.
Through this project we succeeded to reduce both fat and sugar without impairing the consumers' acceptance. This is particularly remarkable for long shelf-life products.

These improvements can be transfer to other Madeleine’s like product, which is a very large products category on the French market (size, form, flavor or inclusions).

Because of the regulatory status of ingredients and the technologies used, no restriction appears on the acceptability of the innovation.

The reformulated products are more expensive to produce due to inulin cost and number of products per batch.

Understanding interaction between structure and aroma release, odor-induced taste enhancement are applications that will be followed with interest in ADRIA Développement.

Understanding of consumer acceptance has given us a tool that will be used in future developments at Millba.

Recommendations: to achieve both reduction of sugar and fat in cake products inulin was used.
Technical adjustments in production are needed, i.e. baking time and temperature to find the right colour of the product.