Effect of fibers and whole grain content on quality attributes of extruded cereals

Sophie Chassagne-Berces[a], Michael Leitner[b], Angela Melado[c], Pilar Barreiro[c], Eva Cristina Correa[c], Imre Blank[a], Jean-Claude Gumy[a], Hélène Chanvrier[a]

[a] *NESTEC SA, Nestle PTC Orbe, 1350 Orbe, Switzerland (sophie.chassagne@rdor.nestle.com, helene.chanvrier@rdor.nestle.com)*
[b] *RECENDT – Research Center for Non Destructive Testing GmbH, Hafenstrasse 47-51 4020 Linz, Austria (michael.leitner@recendt.at)*
[c] *UPM, 28040 Madrid, Spain (angela.melado@upm.es, pilar.barreiro@upm.es)*

ABSTRACT

Incorporation of fiber in cereals may lead to quality issues, thus decreasing consumer acceptance. This is partially due to deterioration of the microstructure, one of the primary quality attributes of cereals. The objective of this study was to better understand the mechanisms by which dietary fibers affect the quality of cereal products during extrusion-cooking. The study quantified the effect of amount and type of fiber and whole grain on (i) texture, (ii) structure, and (iii) rehydration properties of extruded cereals. New innovative methods were applied and combined with traditional techniques to characterize both the structure and the rehydration properties.

Extruded cereals were produced using a starch-based recipe (whole and wheat flours) and two sources of fibers (oat bran concentrate and wheat bran). The oat and wheat bran levels used in this study were 0, 10, and 20%. The different mixtures were extruded in a pilot twin-screw extruder BC21 (Clextral) and then sugar coated after drying. Mechanical properties of extruded cereals were investigated by compression test. The cellular structure was observed by X-ray tomography. The quality of coating (thickness, homogeneity) was analyzed by optical coherence tomography. The rehydration properties of such cereals in milk were evaluated by magnetic resonance imaging and optical coherence tomography.

This work revealed that structure assessment of extruded cereals may lead to a better understanding of the effect of fiber addition on texture and rehydration properties. The application of innovative methods, such as optical coherence tomography and magnetic resonance imaging, was found to be useful to quantify the structural properties.

Keywords: extruded cereal; fibers; structure; texture; rehydration properties; innovative techniques

INTRODUCTION

Health and nutritional policies are currently promoting the increase of dietary fiber content in food, especially in cereal-based products. However, incorporation of fiber in cereals may lead to quality issues [1-2], thus decreasing consumer acceptance. This is partially due to deterioration of the microstructure, one of the primary quality attributes of extruded cereals [3-5]. Consequently, the production of fiber-enriched extruded cereals remains a challenge, in particular when maintaining functional and quality properties. The objective of this study was to better understand how dietary fibers affect the quality of cereal products during extrusion-cooking. The studies quantified the effect of source and amount of fiber and whole grain on (i) texture, (ii) structure, and (iii) rehydration properties of extruded cereals. New innovative methods were applied and combined with traditional techniques to characterize both the structure and the rehydration properties.

MATERIALS & METHODS

Studies were carried out on starch-based (wheat, whole wheat) recipes. Two sources of fibers were added: oat bran concentrate (OBC) and wheat bran (WB) for their high soluble (β-glucans) and insoluble (arabinoxylans) fiber levels, respectively. The oat and wheat bran levels used in this study were 0, 10, and 20%. The different recipes (Table 1) were extruded in a pilot twin-screw extruder BC21 (Clextral), dried to 3% water (w/w) using a force-air convection oven. The following extrusion parameters were kept constant: die design, screw speed (400 rpm), product temperature (135°C) and water addition (20%).

Table 1. Cereal composition (% dry matter) of different samples

Samples	Whole Grain	Fiber rich ingredients		Filler		
	Whole Wheat	OBC	Wheat Bran	Wheat flour	Corn	Sugar
F0 WG40	40	0	0	40	18	2
F0 WG60	60	0	0	20	18	2
F0 WG80	80	0	0	0	18	2
F10 WG40 OBC	40	10	0	30	18	2
F10 WG60 OBC	60	10	0	10	18	2
F10 WG80 OBC	80	10	0	0	8	2
F10 WG40 WB	40	0	10	30	18	2
F10 WG60 WB	60	0	10	10	18	2
F10 WG80 WB	80	0	10	0	8	2
F20 WG40 OBC	40	20	0	20	18	2
F20 WG60 OBC	60	20	0	0	18	2
F18 WG80 OBC	80	18	0	0	0	2
F20 WG40 WB	40	0	20	20	18	2
F20 WG60 WB	60	0	20	0	18	2
F18 WG80 WB	80	0	18	0	0	2

Each sample was coated with 30% (w/w) of syrup composed of sucrose (67%), dextrose (5%) and water (28%) and dried again to 3% water (w/w).

Mechanical properties of extruded cereals were investigated by compression test using a Kramer shear cell equipped with a 500 kg load cell cell moving at 1mm/s through a 1.7cm thick cereal bed. The cellular structure was scanned by X-ray tomography (SkyScan 1172, Belgium) at 40kV over 180°. Information on porosity, cell size, and cell wall thickness distributions were extracted from 3D image analysis. The quality of coating (thickness, homogeneity) was analyzed by optical coherence tomography. The rehydration properties of such cereals in milk were evaluated by magnetic resonance imaging (MRI) and optical coherence tomography. Several kinds of milk (considering increasing fat level) were tested with 200 MHz MRI and further image processing by means of texture analysis based on histogram studies.

RESULTS & DISCUSSION

Whatever the type of fiber (oat bran concentrate or wheat bran), the modifications of mechanical properties after addition of fiber rich ingredients or whole grains show similar trends (Figure 1):

- Without addition of fibers (0%), the maximum force and the number of peaks do not change much when increasing the whole grain content.
- Conversely, adding fibers significantly increases the maximum force (F_{max}), whereas the number of peaks (N_{peak}) decreases, thus showing an increase of hardness and a decrease of "crispness" when the fibers are added.
- Interestingly, the higher the addition of fibers, the more the addition of whole grain has an impact on texture properties (ie. F_{max} and N_{peak}).

The modifications of texture parameters (F_{max} and N_{peak}) are more important with oat bran concentrate than with wheat bran.

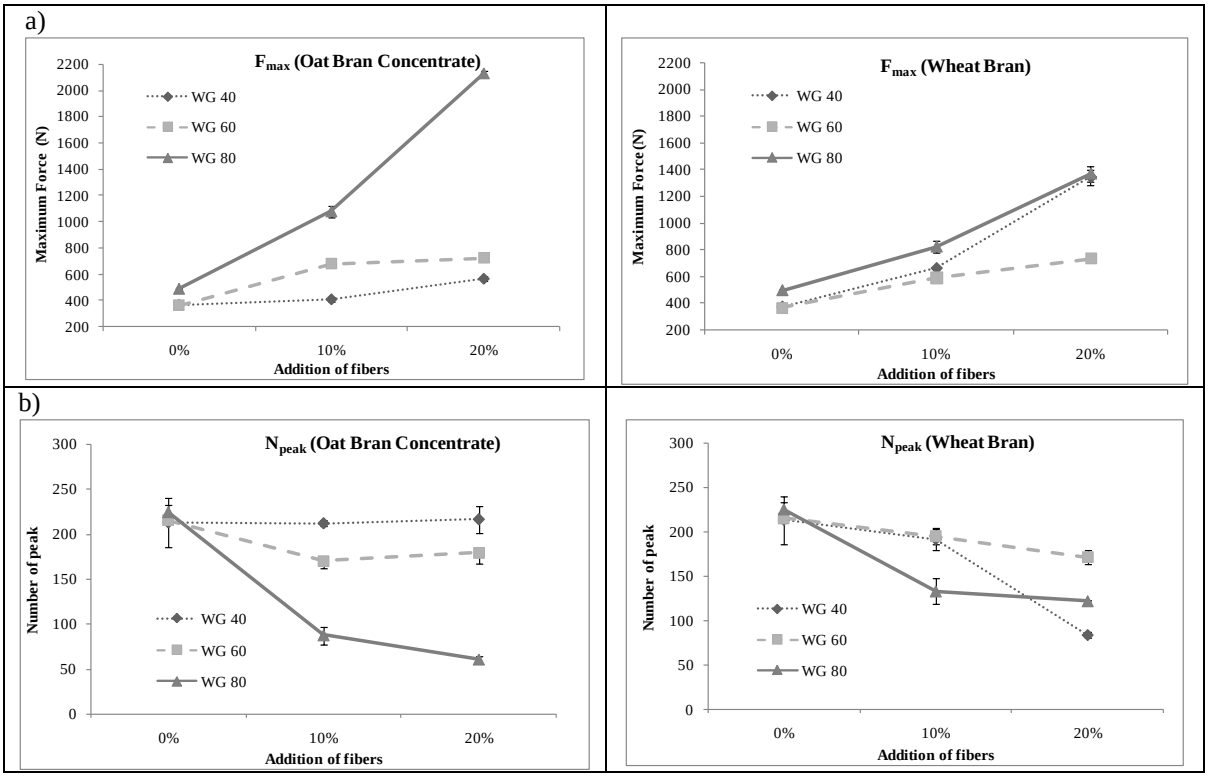

Figure 1. Effect of fibers and whole grain (WG) content on two parameters of texture (a- Maximum force and b- Number of peaks) for two sources of fibers: Oat Bran Concentrate and Wheat Bran.

Modifications of mechanical properties were linked with variations of cell size and cell wall structure (Figure 2).

- Without addition of fibers (F0-), only minor modifications of porosity and cell size are observed when the whole grain content increases while the cell wall thickness increases significantly between 40% and 60% WG content.
- Conversely, adding fibers decreases the expansion of extruded cereals and thus the cell size and the porosity decreases while the thickness of cell wall globally increases, in agreement with the increase of maximum force observed.

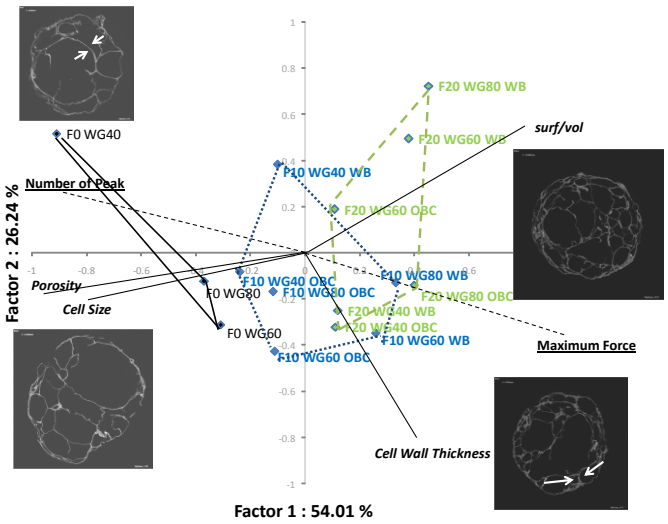

Figure 2. Cellular Structure. Principal component analysis of structure data: similarity map of component 1 and 2. Convex hulls were drawn for 0% (F0-), 10% (F10-) and 20% (F20-) of fiber contents. Main structure and texture attributes are plotted.

Rehydration in Milk:
A loss of hardness and crispness is observed after immersion in milk. The hardness of dry products is well correlated with those of the soaked products (Figure 3). A low amount of fiber addition seems to result in a maintaining of hardness when poured in milk. . This is confirmed by MRI measurements showing a slower penetration of milk into the pellets containing fibers (Figure 5).

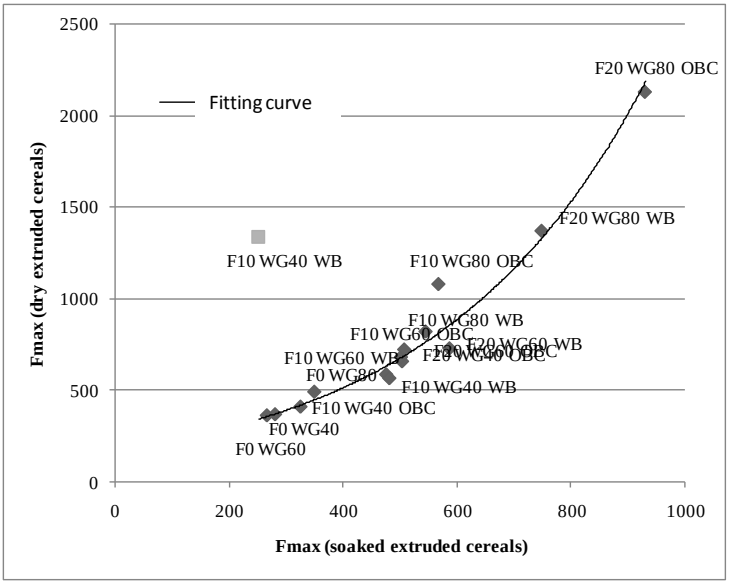

Figure 3. Correlations between the maximum forces measured for dry and soaked extruded cereals

Figure 4 shows an OCT image sequence for one experiment of rehydration. The cereal pellets are fixed in a cylinder and semi-skimmed milk at room temperature is poured up to 80% of the pellets height. The images are ordered from a-h) according to the rehydration progress during the experiment. At the beginning, no milk is visible along the upper surface of the cereals (Figure 4.a). Then some milk is appearing in the image at the spot indicated by the black arrow (Figure 4.b). From figure 4c to 4h, more and more milk becomes apparent along the upper surface of the cereal pellet, concomitantly to the collapse of the height of the cereal.

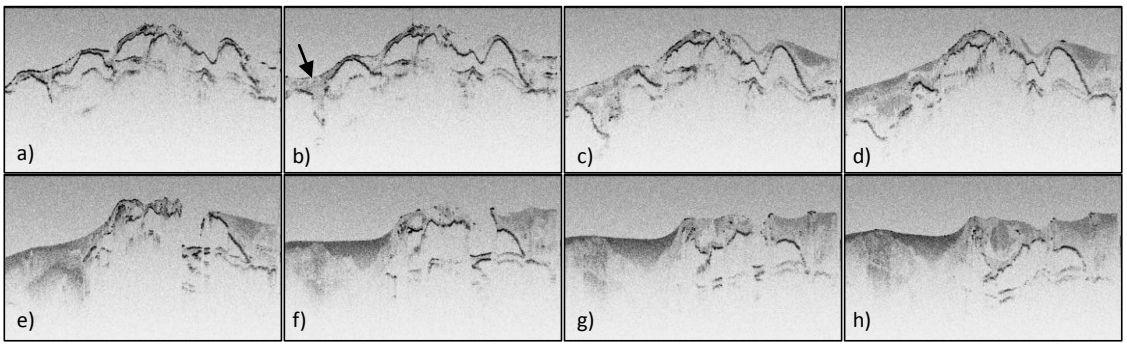

Figure 4. Sequence of OCT images showing the rehydration process of extruded cereals in semi-skimmed milk. The images are ordered from a)-h) according to the progress in time. Image size: 4 x 1.5 mm^2.

OCT made it possible to visualize the quality of coating (when observing dry pellets) and to follow the rehydration process of extruded cereals in milk: the collapse of the structure that is immerged in milk can be followed and quantified.

Figure 5 represents the normalized variances against the variation coefficient for three extruded cereals both coated and non-coated. Differences in the behavior of the different samples are observed through their

trajectory that could be related to the hydration level. The higher the addition of fiber is, the shorter the trajectory is, corresponding to a lower hydration. The two samples (F20 WG60 OBC and F10 WG60 WB) having 20% of oat bran concentrate and 10% of wheat bran, respectively, show lower trajectories than the sample F0 WG60 without addition of fiber.
Furthermore, MRI highlights that the differences in the rehydration properties between coated and non coated extruded cereals seem to be dependent on content and composition of the cereal base.

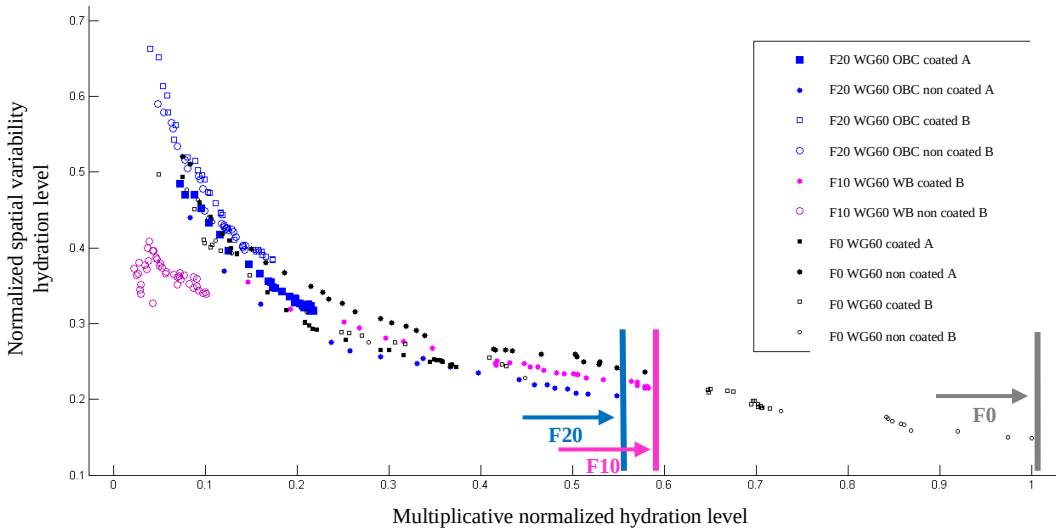

Figure 5. MRI features on cereal hydration

CONCLUSION

This work showed that structure assessment of extruded cereals may lead to a better understanding of the effect of fiber addition on texture and rehydration properties. The application of innovative methods, such as optical coherence tomography and magnetic resonance imaging, was found to be useful to quantify the structural properties. In the future, the relationship between a quantitative analysis of expanded structure changes in extruded cereals with high fiber content and the final texture properties will be used to define optimized process conditions and recipes for an improved consumer satisfaction.

AKNOWLEDGEMENTS

This work has been carried out with financial support from InsideFood – Integrated sensing and imaging devices for designing, monitoring and controlling microstructure of foods (FP7-226783).
The authors wish also to thank Fabrice Desbois and Damien Testori for their excellent technical assistance in microscopic and texture measurements. We would also like to thank all pilot plant operators for their technical support.

REFERENCES

[1] Yanniotis S., Petraki A., Soumpasi E. (2007). Effect of pectin and wheat fibers on quality attributes of extruded cornstarch. Journal of Food Engineering, 80(2), 594-599.
[2] Brennan M. A., Merts I., Monro J., Woolnough J. & Brennan C.S. (2008). Impact of Guar and Wheat Bran on the Physical and Nutritional Quality of Extruded Breakfast Cereals. Starch – Stärke, 60(5), 248-256.
[3] Jin Z., Hsieh F. & Huff H.E. (1995). Effects of soy fiber, salt, sugar and screw speed on physical properties and microstructure of corn meal extrudate. Journal of Cereal Science, 22(2), 185-194.
[4] Yao N., Jannink J.L., Alavi S. & White P.J. (2006). Physical and sensory characteristics of extruded products made from two oat lines with different β-glucan concentrations. Cereal Chemistry, 83(6), 692-699.
[5] Rzedzicki Z. & Blaszczak W. (2005). Impact of microstructure in modelling physical properties of cereal extrudates. International Agrophysics, 19(2), 175-186.