Rheology, baking and organoleptic characteristics of breads from different gluten-free flours with transglutaminase and protein supplements

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Written for presentation at the
2013 CIGR Section VII International Technical Symposium on

"Advanced food processing and quality management"

Guangzhou, China, 3-7 November, 2013

Abstract. *Celiacia is one of the most common forms of food intolerance. Today the only one possible form of treatment of celiacia is a complete exclusion of gluten containing products from the diet. Replacement of gluten in bread dough is a major problem of gluten-free bread production. In terms of the average consumer gluten-free products have lower quality, particularly fragile structure, unsightly appearance and sometimes - bad taste. Wheat protein (gluten) takes a variety of tasks in the bread production. Therefore a large number of ingredients is required to replace gluten. The majority of gluten-free products is produced from flour and starch (corn, potato, soy, buckwheat, rice) are available on the market today. We have proved and developed the technology of gluten-free bakery products based on gluten-free flour mixes. The protein-bearing soluble components can be used as the liquid phase of dough. Transglutaminase enzyme is recommended as additional structure regulator of dough and gluten-free bakery products.*

Keywords: gluten-free products, celiacia, transglutaminase, structure regulator.

1. Introduction

Consumption of gluten and related proteins can cause gluten enteropathy in people with a certain genetic predisposition. This disease is also known as celiac disease. Celiacia is one of the most common forms of food intolerance. If wheat proteins or other proteins related to them (such as barley's or rye's proteins) get into an organism of the patient with celiac disease, in the small intestine there is an immunologic reaction in which intestinal epithelial cells are destroyed. For this reason, patients with celiac disease must follow a strict diet and avoid eating all grain products that contain wheat, rye or barley (some authors recommend to abandon the oats). The mucosa is renewed as well as the function of suction if these crops are excluded from the diet. Simultaneously, organism of the patient is restored.

Today the only one possible form of celiacia's treatment is a complete exclusion of gluten containing products from the diet. People suffering from celiac disease must give up many familiar foods such as bread, pizza, cookies and beer. Therefore, scientists and specialists of food industry work on developing and improving gluten-free foods technologies.

Many kinds of gluten-free products that existed on the market earlier were produced from wheat starch. They could be threat for patients with celiac disease, as might contain a small amount of gluten. Hence now manufacturers prefer to work only with the types of flour and starch, which are really gluten-free. Mostly gluten-free products are produced from flour and starch (corn, potato, soy, buckwheat, rice) are available on the market today. All these measures are aimed at the interests of consumers. But replacement of gluten in bread dough is a major problem of gluten-free bread production for manufacturers.

In terms of the average consumer gluten-free products have lower quality, particularly fragile structure, unsightly appearance and sometimes - bad taste. Baked products from gluten-free ingredients are generally of poor quality due to the lack of the gluten network (Arendt et al., 2002). This is because gluten has unique technological properties besides dietary. Hydrated gluten proteins form the elastic-elastic properties of dough structure during its formation. As for starch, it contributes to the manifestation of the plasticity properties of the crumb during baking dough. Therefore, the regulation of the structural and mechanical properties of dough can be viewed primarily as a modification of the properties of gluten in particular and the native flour proteins in general.

The flour from gluten-free grains nevertheless contains proteins. In order to bring their technological properties and behavior in dough to the technological potential of gluten, it is necessary to apply certain food additives for structure control. For example, the known method of making bread from rice and corn flour, soy protein isolates in combination with correct rheological properties of dough and bread - xanthan or modifying starch in an amount of 1.0-3.0% by weight of flour (Барсукова Н.В., Красильников В.Н., 2010).

Transglutaminase is a relatively new way, which is used in the production of gluten-free baked goods. This enzyme catalyses an acyl-transfer reaction between the g-carboxyamide group of peptide-bound glutamine residues and a variety of primary amines (Motoki and Seguro, 1998). Transglutaminase (TGase) that is used in the bakery industry originates from microbial cultures. This enzyme has a positive effect on wheat proteins; its addition increases the volume of the dough. TGase application has shown positive effects on wheat-based baked goods: increased volume and improvement of baking quality of weak wheat flours (Basman et al., 2002). TGase is proposed to use for the production of gluten-free bread to improve the structural and mechanical properties of crumb (Stefano Renzetti, 2008). In this study, TGase was investigated for network formation potential on flours from six different gluten-free cereals (brown rice, buckwheat, corn, oat, sorghum and teff) used in breadmaking. TGase was added at 0, 1 or 10 U/g of proteins present in the recipe. However, it should be noted that the effectiveness of their action cannot be sufficiently high, as is evidenced by the images in the study (Fig. 1).

TGase is able to bind proteins of different origin: casein and albumin from milk, animal protein from eggs and meat, soy and wheat protein (Ando H. et al., 1989; Soeda T. et al., 1996).

The aim of the present study was to investigate the effectiveness of TGase application in improving the baking performances of gluten-free flours without addition of any hydrocolloids but with usage different types of gluten-free flour raw and several proteins (from milk or meat). Several cereal flours were investigated in order to assess the impact of TGase on different protein sources.

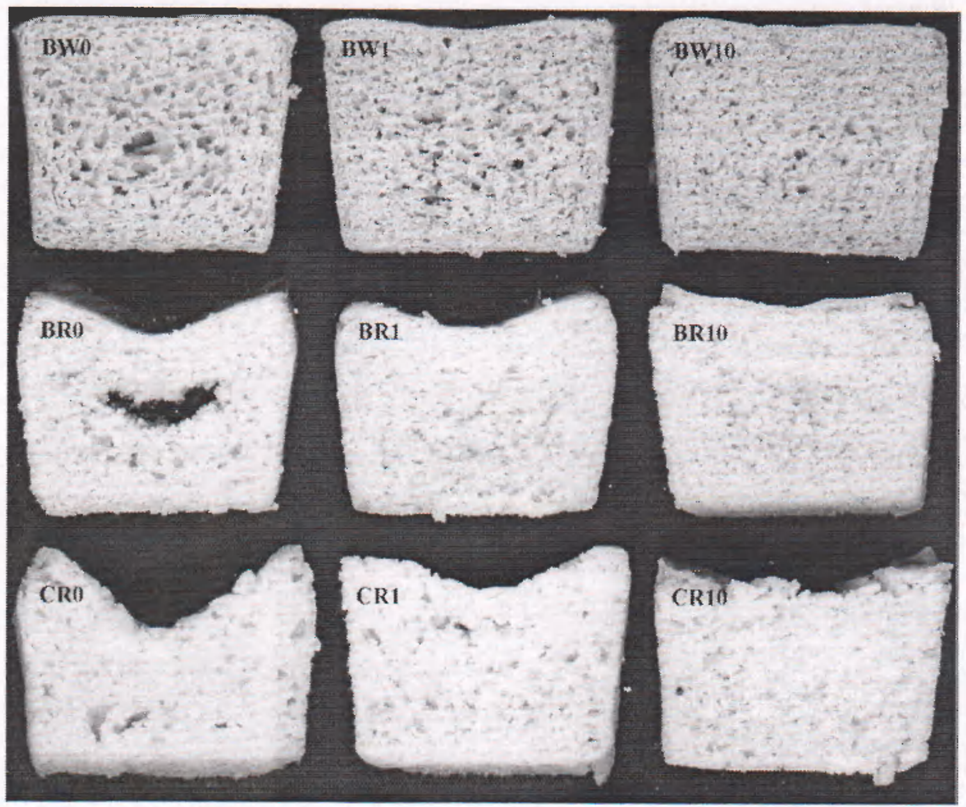

Fig. 1. Bread slices from buckwheat (BW), brown rice (BR) and corn flour (CR) formulations treated with different TGase levels (0, 1 and 10 U) (Stefano Renzetti, 2008)

We have proved and developed the technology of gluten-free bakery products based on gluten-free flour mixes. The protein-bearing soluble components can be used as the liquid phase of dough. TGase is recommended as additional structure regulator of dough and gluten-free bakery products.

2. Materials and methods

2.1. Materials

Rice flour ("Dobriansky fields", Ukraine), corn flour ("O-la-la", Ukraine), barley flour ("Dobriansky fields", Ukraine), oat flour ("Dobrodia-TD" Ukraine) were used in conjunction with instant dried yeast ("Saf-moment", France). Salt ("Artemsil", Ukraine), sugar ("Takida", Ukraine), cow's milk ("Prostokvashino", Ukraine), animal protein Геліос 11 ("TOMIG", Ukraine), instant gelatin ("Mriya", Ukraine) and tap water were also incorporated into the batters.

2.2. Methods

2.2.1. Flour analysis

Flour moisture was determined using the air-oven method (reference)

2.2.2. Transglutaminase application

The enzyme Revada TGase was added to the ingredients prior to mixing. The enzyme was dissolved in half of the amount of water required in the recipe. The addition of the enzyme was calculated on the basis of the amount of flour in a recipe. A formulation without any addition of enzyme was used as control.

2.2.3. Breadmaking

The same basic formulation was used for the breadmaking experiments with the following flours: corn (CR), rice (RC), oat (OT) and barley (BR). The formulation consisted of 100 parts flour (relative mass), 130 parts of water, 2 parts of salt, 1 parts of sugar and 2.5 parts of dried yeast. The amount of flour was interpreted as flour weight basis. Dried yeast, sugar and TGase were dissolved in liquid phase (milk or aqueous gelatin solution) at 30-35 ^{0}C and pre-fermented for 10 min. All dry ingredients were placed in the bowl of a Bosch MUM 86 R1 mixer (Bosch, Slovenia).

The pre-fermented yeast with the enzyme solution were added to the remaining ingredients prior to mixing. Mixing was performed for 2 min. with a paddle tool at slow/medium speed. After mixing, dough was left for its maturation at 30 ^{0}C for 30 minutes. Then dough was formed and baked in a deck oven (PYRAMIDA, Germany). After baking, the loaves were cooled for 90 min. on cooling racks at room temperature.

2.2.4. Bread evaluation

Standard baking tests were conducted on three loaves from each bread type: control breads (from rice, corn, oat and barley flour without protein supplements), also with TGase, milk and functional animal proteins (gelatin, Гелioc 11). Loaves were weighed and loaf volume was measured by rapeseed displacement. Loaf specific volume (ml/g) and bake loss (%) were then calculated. All measurements obtained with the three loaves from one batch were averaged into one value (one replicate). Experimental and control samples were prepared from the same batch of raw material. Organoleptic, physical and chemical properties of bread were evaluated by the standard method. For visual images of samples the camera NICON COOLPIX P7100 was used.

3. Results and discussion

3.1. Baking tests

At the first stage of research a raw flour role in the formation of organoleptic properties of bread was analyzed. The results are shown in Fig.2. As it can be seen, the composition of the flour mixture significantly affects the quality of products. Crumb color was different - yellow (if the corn flour was used as the main component of flour mix), light yellow (rice) and greyish (oat).

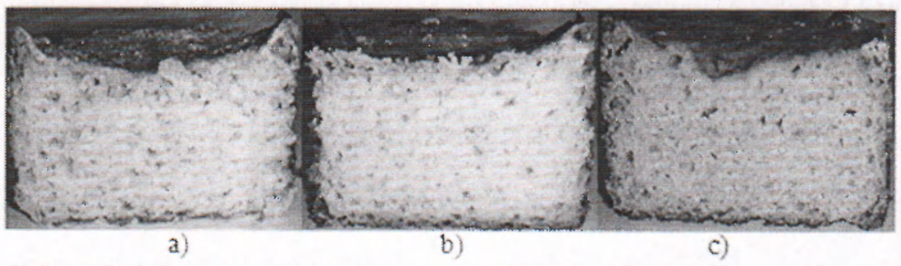

Fig.2. Bread slices from different flour mixtures: a – 50% CR, 25% RC, 25% OT; b – 50% RC, 25% CR, 25% OT; c – 50% OT, 25% CR, 25% RC

Crumb porosity and bread shape were different for various samples; surface condition was the best if the bread made from rice flour, the worst - from oat flour. Thus, we can assume that as the basis of the flour mixture rice flour can be recommended in an amount of at least 50% and with the addition of other gluten-free flour.

The objective of the next stage of the study was determination of the effect of the liquid phase on the quality of bakery and food products from gluten-free flour material. Samples were prepared with using the following components as liquid phase: water, milk, water solutions gelatin and Гелioc 11. The appearance of loaves (cross section) is shown in Fig.3 (a1, b1, c1, d1).

It was found that in the case of milk crumb structure slightly improved - porosity became more uniform and small. In addition, crust color changed to brighter. Bread crust acquired a nice bright golden color. However, the crumb was not essentially changed in color. In case of using water and milk in 1:1 ratio quality indicators occupied an intermediate position between the results of the use of water or milk separately.

We also investigated the influence of protein additives on quality of bread from gluten-free raw materials. As improving additives we used 3% aqueous solution of gelatin and Гелioc 11 - as 1% aqueous solution; these bread samples were compared with the control sample without additives (a basic recipe was applied to all flours used in this study). These supplements quite effectively influenced on the quality of gluten-free loaves - bread volume significantly increased; shape, appearance and porosity improved. However, Гелioc 11 functioned most effectively, although porosity was a bit uneven.

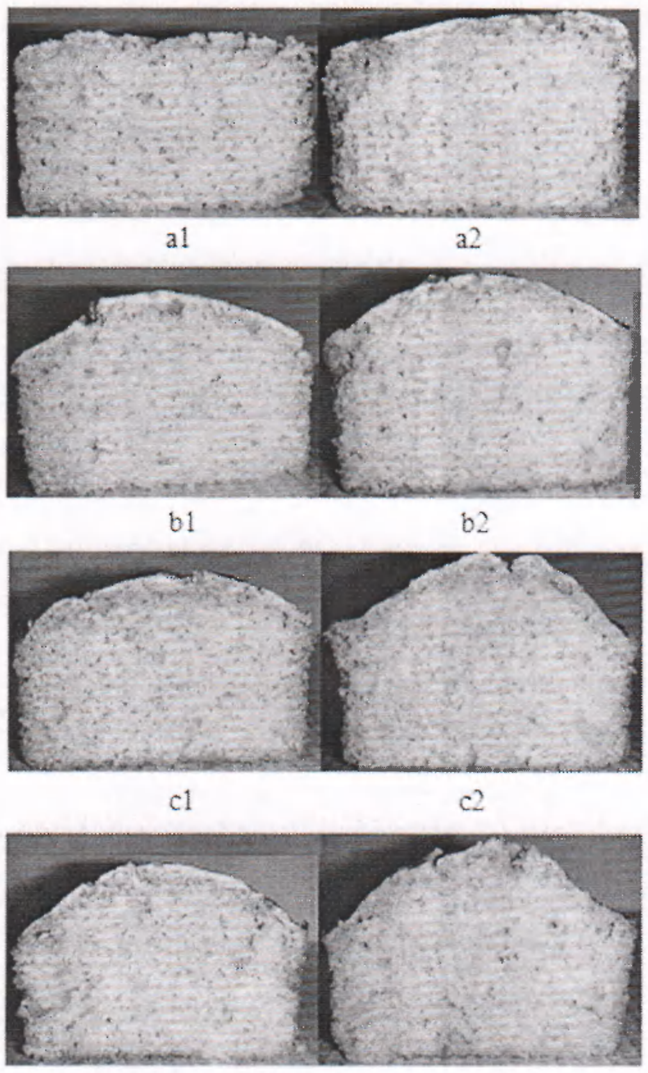

Fig.3. Slices of bread with TGase (2) and without TGase (1). It was used different liquid faze: a – water; b – milk; c - gelatin water solution; d - water solution of «Геnioc 11»

It was necessary to investigate the effect of TGase on the quality of gluten-free products with different prescription composition. The main purpose of the application of TGase was improving the bread structure. Standard baking tests were conducted on three breads for each sample. For each kind of protein supplement one level of enzyme were examined (0,05 g TGase/100 g of flour in recipe).

Overall, transglutaminase has a different reactivity with different proteins: very good - with casein and Na-caseinate of milk with 115 globulin and 75 soybean globulin, gelatin, meat, well - from egg yolk protein, collagen, wheat gliadin or glutenin; depending on conditions - with α-lactalbumin and β-lactoglobulin, ovoalbumin, myoglobin. Taking this aspect into consideration, we selected for the study proteins belonging to the first group with the highest reactivity towards TGase. The appearance of loaves is shown in Fig.3 (a2, b2, c2, d2). A remarkable effect of TGase could be seen on BR1 as a proper crumb appeared. In case of TGase treatment crumb structure improved, shape stability of products and their total volume increased. But TGase caused a various increasing in bread volume for all samples as Figure 3 shows. If in bread recipe certain protein sources (gelatin, milk, Геnioc 11) were used in addition TG enzyme acted significantly more efficient. The best results were obtained with the use of animal protein concentrates - Геnioc 11 and gelatin.

The results of “bread with Геnioc 11 and TGase” analysis are displayed in Table 1.

Bead had a smooth surface without undermining and cracks, good elastic crumb with a nice light yellow color, uniform porosity.

Table 1. Indicators of bread quality

Indicator	Characteristic
	Organoleptic
Visual appearance	Smooth, no cracks
Taste and smell	Nice, without off-aroma or off-taste
Crumb	Elastic, thin-walled, small, uniform porosity
	Physical and chemical
Bread acidity, deg.	1.3
Specific volume, cm^3 / g	2.4-2.6

Conclusions

The results of the present study show that the functionality of gluten-free flours in terms of breadmaking performances can be successfully improved by the action of TGase, the greatest degree - in the composition with animal proteins (milk, gelatin, Геnioc 11) and various types of flour. The TGase treatment of bread was reflected in significant improvement in the textural and structural characteristics of the resulting breads, improving the structural, mechanical and organoleptic characteristics of gluten-free products.