

Physicochemical, Textural, and Sensory Evaluation of Reduced Fat Gluten- Free Biscuit Prepared with Inulin and Resistant Dextrin Prebiotic

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ABSTRACT

The aim of this study was to evaluate the effects of inulin (IN) and resistant dextrin (RD) as fat replacer and prebiotic on gluten-free biscuit and its dough. To make the gluten-free biscuits, we used rice flour, corn flour and corn starch in the proportion of 3:1:1, respectively. The influence of prebiotics on the dough properties was studied via texture profile analysis including firmness, cohesiveness, adhesiveness, gumminess and springiness. Biscuit quality was assessed by spreading behavior, texture and surface characteristics, chemical properties, and sensory evaluation. Compared to the control, a significant increase in firmness (17.04 N to 52.85 N), cohesiveness (0.49 to 0.65) and gumminess (8.45 N to 32.71 N) of dough (except RD25) was observed when substitution percent of fibers increased. Adhesiveness and springiness did not have significant changes. Enhancing of fat replacement percentage caused significant changes compared to the control in hardness (9.60 to 24.52 N) and L* (58.79 to 56.94), a* (8.99 to 9.71), water activity (0.225 to 0.096), moisture (4.97% to 4.12%), total fat (12.65% to 3.90%), peroxide index (1.89 to 0.90 meq/kg), fiber (2.02% to 9.51%), carbohydrate (76.49% to 84.63%), and calorie (443.38 to 396.52 Kcal). The consumers did not find significant differences in acceptability between the control biscuits and the biscuits with 25% of fat replaced by RD and IN except color and flavor that were better than the control. Gluten-free biscuits containing IN25 and RD25 were similar to the control biscuits, and they could have additional health benefits derived from IN and RD presence.

Keywords: Baking quality, Celiac, Prebiotic, Low fat Biscuit, Texture analyzer,

INTRODUCTION

Celiac disease (CD) is a chronic immune-mediated enteropathy triggered by exposure to gluten, the water-insoluble protein fraction in wheat, rye, and barley, in the genetically predisposed individuals. Adhering to a gluten-free (GF) diet was recommended as the only treatment for CD

(Spijkerman et al., 2016). According to FDA guidelines, a GF product may contain no more than 20 ppm prolamin (Food and Drug Administration 2013). Formulations of GF products are made from flours such as rice, corn, and other ingredients such as starches, egg, dairy proteins and hydrocolloids that could mimic the viscoelastic properties of gluten and result in improved structure,

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mouthfeel, and acceptability of these products. Rice flour is a suitable substitute for wheat flour due to its bland taste, white color, digestibility, and hypoallergenic properties. Other substitute for wheat flour is corn flour. Corn flour contains high levels of many important vitamins and minerals, including potassium, phosphorus, zinc, calcium, iron, B₁, B₃, B₆ and folate (Bourekoua et al., 2016). The storage proteins of corn and rice do not contain the toxic cereal prolamins. Furthermore, patients with CD require an increase in fiber, vitamins, and minerals of their daily diet due to malabsorption, abdominal distension, diarrhea and severe constipation (Thompson et al., 2005). Recently, alterations in the gut microbiota toward *Firmicutes*, *Bacteroides*, *E.coli*, *Clostridium* and decreases in anti-inflammatory bacteria such as *Bifidobacterium*, *Lactobacillus* spp. have been reported in CD that is related to aspects of gluten-induced inflammation and their symptoms in CD (Marasco, 2016). Modulation of the gut microbiota to improve ongoing symptoms, despite adhering to GF diet, has been considered for the management of CD (Hobden et al., 2013). Prebiotics contain indigestible and fermentable carbohydrates that modulate gut microbiota and provide the fiber needed for patients (Gargari et al., 2015; Dehghan et al., 2016; Karimi et al., 2016). So, formulation of GF with prebiotics such as resistant dextrin and inulin may decrease adverse effects of CD.

NUTRIOSE[®] FM06 is a purified resistant dextrin, a glucose polymer (rich in α -1, 4 and α -1, 6 linkages) derived from maize. It has been shown that NUTRIOSE[®] FM06 can modulate the gut microflora towards *Lactobacillus* spp., and *bacteroides* and butyrogenic genera such as *Clostridium* cluster XIVa and *Roseburia* genus (Hobden et al., 2013). In addition, recent evidence shows that NUTRIOSE[®] can contribute to reduce blood glucose response, improve gut health and immune system, weight management, and reduce the incidence of

obesity (Aliasgharzadeh et al., 2015a). Inulin-type fructans are indigestible carbohydrates, containing fructose monomers linked by β (1, 2) bonds whose degree of polymerization is 2 to 60. The long-chain inulin (DP: 10-60; average DP=25) is produced by eliminating all oligomers with a degree of polymerization <10 (Niness, 1999). Inulin increase mineral absorption (Farhangi et al., 2016) and improve cardiovascular disease risk factors (Aliasgharzadeh et al., 2015b; Dehghan et al., 2013) via changing composition of the gut microbiota. So, enrichment of food products with these prebiotics may improve nutritional status and adverse effects of CD. Among food products, bakery products are the most favored candidates for enrichment and fat replacement due to having a preferential place in the food pyramid. Biscuits are the most desirable baked products due to their affordable cost, availability in different tastes, longer shelf life, and good eating quality (Schober et al., 2003). In addition to health-promoting properties of prebiotics, they can be suitable replacement for fat without major changes in the technological process. Review of the literature, did not show a study on evaluating the effects of inulin (IN) and resistant dextrin (RD) as prebiotic and fat replacer on GF biscuit properties and their dough. Therefore, the present study aimed to test the effects of inulin and resistant dextrin as fat replacer and prebiotic on the quality parameters and nutritional content of GF biscuit.

MATERIALS AND METHODS

Raw Materials

Corn starch, rice flour, corn flour, milk powder, semisolid fat, gluten-free baking powder, sucrose, salt, carboxymethyl cellulose (CMC) (Henzak chemie; Iran) and eggs were purchased from the local market.

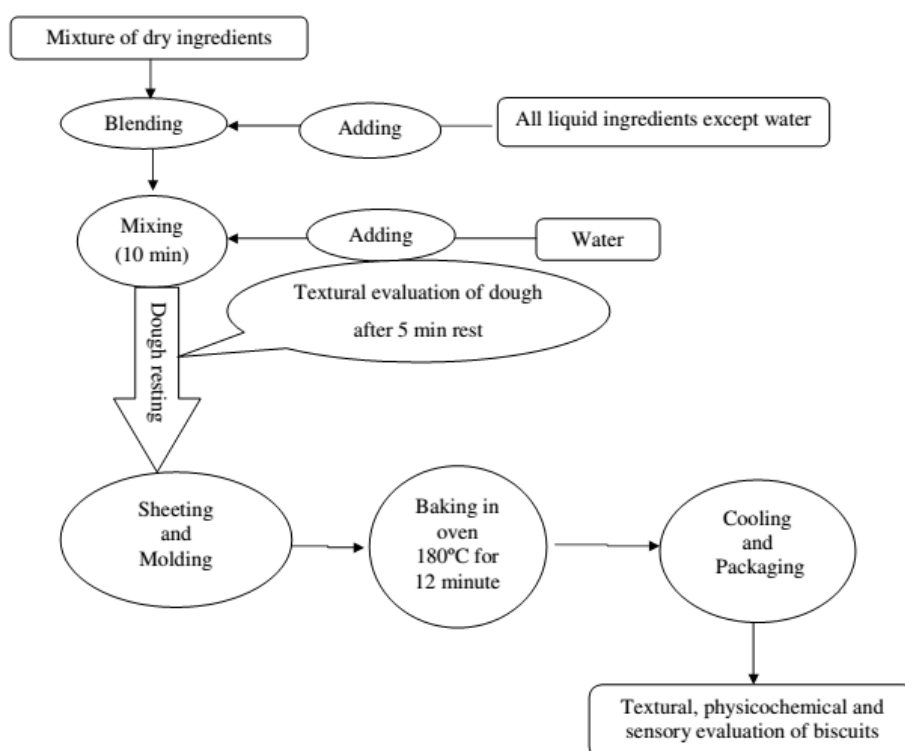


Figure 1. Flow chart of reduced fat gluten-free biscuit preparation with inulin and resistant dextrin.

Inulin (Sensus, Borchwef, the Netherlands) and resistant dextrin (NUTRIOSE® FM06; Roquette) were used as prebiotic and fat replacer in this study. Flow chart of study is presented in Figure 1.

Dough and Biscuit Preparation

The formulation used to develop the biscuits was proposed by Schober (2003), with some modifications (Schober et al., 2003). Seven formulations were prepared using the same quantity of all the ingredients, except the fat, IN, and RD. Fat was substituted by IN and RD as shown in the Table 1. The biscuits contained 25, 50 and 75 (g/100 g flour basis) of IN and RD as IN25, IN50, IN75 and RD25, RD50, RD75, and were prepared in the same way as the full-fat product (the control sample). For making biscuits: the ingredients were weighted according to the recipes, all dry ingredients were mixed together in a dough

mixer (Kenwood Chef A901, Kenwood Manufacturing Co Ltd, New Lane, Hampshire, UK) for 3 minutes. Then, all liquid ingredients, except water, were added to the dry mixture and combined at low speed for 3 minutes. At the end, water was added and mixed for 10 min. The dough was left to rest for 5 minutes. Then, the dough was sheeted with a rolling pin to a thickness of about 6 mm. Circle pieces cut of dough were formed by using templates with an outer diameter of 50 mm. The biscuits were baked at 180 °C for 12 minutes. After baking, biscuits were cooled to room temperature and were packaged in polyethylene bags for further examination one day after baking.

Textural Evaluation of Dough and Biscuits

The texture characterization of dough and biscuits was performed using a Texture Analyzer TA-XT plus (Stable Micro-Systems,

**Table 1:** Formulation of dough used for preparation of gluten-free biscuits.

| Ingredients (g/100 g flour basis) | Control | IN25 ^a | IN50 | IN75 | RD25 ^b | RD50 | RD75 |
|-----------------------------------------------------|-----------|-------------------|-----------|-----------|-------------------|-----------|-----------|
| Mixed flour (rice & corn flour +corn starch(3:1:1)) | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Sugar | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Semisolid fat | 20 | 15 | 10 | 5 | 15 | 10 | 5 |
| Egg | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Skimmed milk powder | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Invert syrup | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| CMC ^c | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Salt | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Lecithin | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Baking powder | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Inulin | 0 | 5 | 10 | 15 | - | - | - |
| Resistant dextrin | 0 | - | - | - | 5 | 10 | 15 |
| Water | 4 | 6 | 10 | 15 | 6 | 10 | 15 |

^a inulin, ^b resistant dextrin, ^c Carboxymethyl cellulose. The bold numbers are changed in formulation.

UK). The texture evaluation of the dough was assessed using a texture profile analysis (TPA) in compression mode. The dough was molded in a plastic container (45 mm diameter and 8 mm height), and rested for 15 min before the test. Analysis was carried out according to Raymundo *et al.* (2014) with slight modification (Raymundo *et al.*, 2014). The biscuit dough was compressed 75% of the original height. The test speed was 5 mm.s⁻¹ and there was a 5 seconds interval between the two compression cycles. Each sample of dough was compressed twice in succession to mimic biting using a 6 mm stainless steel probe. Based on the above force–time curve, firmness (1st bite), cohesiveness, adhesiveness, gumminess, and springiness of the biscuit dough were measured. Data on forces (F) and areas under curve (A) of the force-time curves were used to calculate the following TPA parameters:

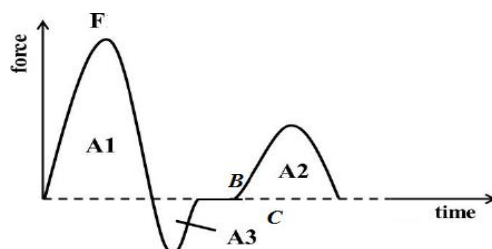


Figure 2. Typical texture curve for dough properties (control sample).

Firmness=Maximum peak force during the first compression cycle (F)

Adhesiveness=Negative force area for the first bite (A₃)

Cohesiveness= Ratio of positive force area during the second compression to that during the first compression (A₂/A₁).

Gumminess=Cohesiveness × firmness.
Springiness=The distance that the food recovered its height during the time that elapsed between the end of the first bite and the start of the second bite (BC) (Friedman *et al.*,1963).

Typical texture curve (textural characteristics of dough) is presented in Figure 2.

To determine fracture profiles, each biscuit was placed on a heavy duty platform table with a holed plate, and the penetration test was performed using P/2 element moving at 0.5 mm/s. The probe penetrated through the biscuits (10% strain). The maximum force of penetration was reported as the hardness of biscuits (Sudha *et al.*, 2007). It can be considered as the average force necessary to bite the biscuit during the respective period of time. Measurements were replicated three times for each formulation.

Chemical Properties

Before the following chemical analyses, biscuits were crushed and sieved to

homogenized samples. The Chemical parameters of biscuit including total fat, peroxide, pH, protein, ash, moisture content, water activity (aw), and total dietary fiber were determined according to the AOAC (2000) methods (Horwitz, 2000). Water activity was determined using a chilled-mirror dew point technique at 22 °C (Aqua Lab Series 3, Decagon Devices, Pullman Wash., U.S.A.). Carbohydrate content was calculated by difference to 100% of main constituents (moisture (%), ash (%), protein (%) and fat (%)) (Raymundo et al., 2014). Calorie ratios were calculated according to the Atwater system (Maclean et al., 2003; Krystyjan et al., 2015). The results of the experiments were presented as the average of three replicates.

Baking Quality and Color of Biscuits

The physical parameters include dimensions (thickness, diameter), spread ratio, and color. The digital caliper (INGCO Digital Caliper Hdcd01200, China) was used to measure biscuits dimensions. The biscuit thickness and diameter were measured by placing 6 biscuits edge-to-edge (both vertically and horizontally). Dimensions of biscuits were presented in cm as the reported values were the mean of three replicates mean value/6 of three different experiments. Spread ratio was estimated by calculating the ratio diameter/thickness values (Sonone et al., 2015). The upper surface color of all GF samples was accessed using a digital Hunter Lab Mini Scan EZ Colorimeter (Konica Minolta, Inc., Tokyo, Japan). Measurements were calculated with CIE (L*, a*, b*) system. L* shows the lightness (L* = 0 black, L* = 100 white). Chromatic components were determined: a* share of the green color (a* < 0) or red (a* > 0) and b* share of blue (b* < 0) or yellow (b* > 0). Analyses were carried out in triplicate and expressed as the mean value with standard deviation.

Sensory Evaluation

Sensory evaluation is one of the main factors that reveal the customer's demands and perception about the quality of the product. Sensory test was carried out by methods of consumer test according to the method described by Krystyjan *et al.* (2015) with some modifications (Krystyjan et al., 2015). Sensory evaluation was performed by a total of 100 untrained taste panelists of 50 males and 50 females aged 18- 65 years, who were selected among employers in the Aysuda Company. The biscuits were coded randomly with three-digit numbers and the sample presentation followed a balanced complete block experimental design. Consumer acceptance was evaluated on five-point hedonic scales (1=dislike extremely and 5=like extremely). For each sample, the consumers scored the attributes acceptability in the following order, appearance, color, flavor, texture, and overall acceptability.

Statistical Analysis

The data was analyzed by using the Statistical Package for Social Sciences SPSS (Version 19.0 software, Chicago, IL). One-way analysis of variance (ANOVA) test was performed to test differences between trails followed by mean separation using LSD's Analysis. Differences were presented by alphabetic letters. Results with a $P \leq 0.05$ were considered to be statistically significant.

RESULTS AND DISCUSSION

Effect of Fat Replacement on the Texture Parameter of Dough

The textural properties of biscuit dough are important, as they affect the quality of the biscuits. Table 2 shows the effect of different proportions of fat, IN, and RD on the biscuit dough properties. Enhancing fat

**Table 2:** Effect of inulin and resistant dextrin as a fat replacement on textural characteristics of gluten-free biscuit and dough

| Samples | Firmness (N) ^c | Cohesiveness (Any unit) | Adhesiveness (N.mm) | Gumminess (N) | Springiness (mm) ^d | Max force (N) |
|--------------------|---------------------------|-------------------------|-------------------------|-------------------------|-------------------------------|--------------------------|
| Control | 17.04±0.22 ^f | 0.49±0.04 ^d | -0.34±0.11 ^a | 8.45±0.59 ^d | 1.71±0.01 ^a | 9.60±0.81 ^d |
| IN 25 ^a | 19.98±0.32 ^e | 0.65±0.05 ^a | -0.35±0.02 ^a | 13.10±1.09 ^c | 1.68±0.08 ^a | 11.15±0.61 ^{cd} |
| IN 50 | 47.70±0.16 ^b | 0.50±0.04 ^{cd} | -0.37±0.18 ^a | 24.08±1.87 ^b | 1.81±0.10 ^a | 17.03±0.28 ^b |
| IN 75 | 52.85±1.15 ^a | 0.61±0.05 ^{ab} | -0.29±0.63 ^a | 32.71±2.34 ^a | 1.84±0.11 ^a | 24.52±0.50 ^a |
| RD 25 ^b | 20.14±1.04 ^e | 0.51±0.02 ^{cd} | -0.36±0.08 ^a | 10.21±0.10 ^d | 1.72±0.16 ^a | 11.74±0.84 ^c |
| RD 50 | 25.81±1.50 ^d | 0.57±0.03 ^{bc} | -0.31±0.25 ^a | 14.83±0.85 ^c | 1.68±0.07 ^a | 16.40±0.94 ^b |
| RD 75 | 35.68±0.97 ^c | 0.65±0.05 ^a | -0.37±0.04 ^a | 23.24±1.34 ^b | 1.80±0.13 ^a | 24.02±0.42 ^a |

^a Resistant dextrin, ^b Inulin, ^c Newton, ^d millimeter, Values (mean ±SD) in particular column followed with different letters show significant differences ($P \leq 0.05$). Max force related to the hardness of biscuits

replacement percentage with IN and RD caused increased dough firmness. It could be seen that the IN75 sample recorded higher firmness (52.85 N) than the control (17.04 N) and other samples. These results are in accordance with Krystyjan *et al.* (2015), Sudha *et al.* (2007), and O'Brien (2008), who reported the biscuit dough hardness increased by decreasing fat content, as lubricating agent, in the formulation (Sudha *et al.*, 2007; O'Brien, 2008; Krystyjan *et al.*, 2015). Replacement of fat with prebiotic in the formulation results in decreased surrounding of starch and hydrophilic hydrocolloids particles by fat and increases their availability for hydration, which leads to harder and compact dough (Pareyt and Delcour, 2008). Pairwise comparison of samples containing the same percent prebiotics showed difference in firmness, except at 25% substitution. Inulin samples were harder than RD ones. The data showed that dough containing IN and RD (except RD25) had higher gumminess than the control (Table 2). These results are in agreement with Krystyjan *et al.* (2015) and Meyer (2011) findings (Meyer *et al.*, 2011; Krystyjan *et al.*, 2015). Increased gumminess is probably related to gel formation by these fibers (Martínez-Cervera, de la Hera *et al.* 2013, Mensink, Frijlink *et al.* 2015). Enhancing fat replacement percentage with IN and RD caused a significant increase in the dough cohesiveness. This result agrees with the

finding that reported increase in dough cohesiveness with reduction of fat (Sudha *et al.*, 2007; Filipčev *et al.*, 2014). These observations can be associated with a denser cell structure in fat-replaced biscuits. At higher levels of fat substitution, the number of cells decrease and the structure appears without cells (Mamat and Hill, 2014). No significant difference in adhesiveness and springiness of dough was observed between different percentages of IN or RD replacement and the control (Table 2). The springiness of the dough was independent of the measured firmness and was not affected by the addition of the fibers.

Effect of Fat Replacement on Texture of Biscuits

The textural results of biscuits containing different IN and RD percentages are shown in Figures 3a and 3b. Fat replacement caused a significant increase ($P \leq 0.05$) in the maximum force of penetrating test for biscuits, which correlates with hardness. The hardness of biscuits, as a result of fat reduction, was highly correlated to firmness of dough ($r = 0.999$). Biscuits with IN25 or IN50 did not show significant difference ($P > 0.05$) in hardness compared to the control. The hardness was significantly higher in IN75 and RD75 (24.52 N, 24.02 N, respectively). It can be due to a decrease in fat content, as hydration enhancement factor

Table 3. Effect of inulin and resistant dextrin as a fat replacement on baking quality of gluten- free biscuits samples.

| Samples | Width (cm) | Thickness (cm) | Spread factor (Any unit) | L* | a* | b* |
|-------------------|--------------------------|--------------------------|--------------------------|--------------------------|-------------------------|-------------------------|
| Control | 4.915±0.021 ^a | 0.635±0.002 ^a | 7.735±0.046 ^a | 58.79±0.13 ^a | 8.99±0.02 ^c | 28.74±0.13 ^a |
| IN25 ^a | 4.911±0.018 ^a | 0.633±0.003 ^a | 7.759±0.065 ^a | 57.79±0.02 ^b | 9.05±0.07 ^c | 28.77±0.16 ^a |
| IN50 | 4.904±0.008 ^a | 0.634±0.002 ^a | 7.732±0.039 ^a | 57.22±0.02 ^{bc} | 9.35±0.05 ^b | 28.90±0.07 ^a |
| IN75 | 4.886±0.016 ^a | 0.63±0.003 ^a | 7.755±0.022 ^a | 56.94±0.07 ^c | 9.68±0.03 ^a | 29.29±0.12 ^a |
| RD25 ^b | 4.911±0.017 ^a | 0.634±0.001 ^a | 7.742±0.037 ^a | 57.24±0.42 ^{bc} | 9.35±0.12 ^b | 28.86±0.11 ^a |
| RD50 | 4.908±0.007 ^a | 0.634±0.001 ^a | 7.745±0.028 ^a | 57.59±0.22 ^{bc} | 9.59±0.12 ^{ab} | 28.99±0.14 ^a |
| RD75 | 4.905±0.014 ^a | 0.631±0.003 ^a | 7.772±0.026 ^a | 57.05±0.14 ^c | 9.71±0.07 ^a | 29.51±0.16 ^a |

^a Inulin, ^b Resistant dextrin, Values (mean ±SD) in particular column followed with different letters show significant differences ($P \leq 0.05$).

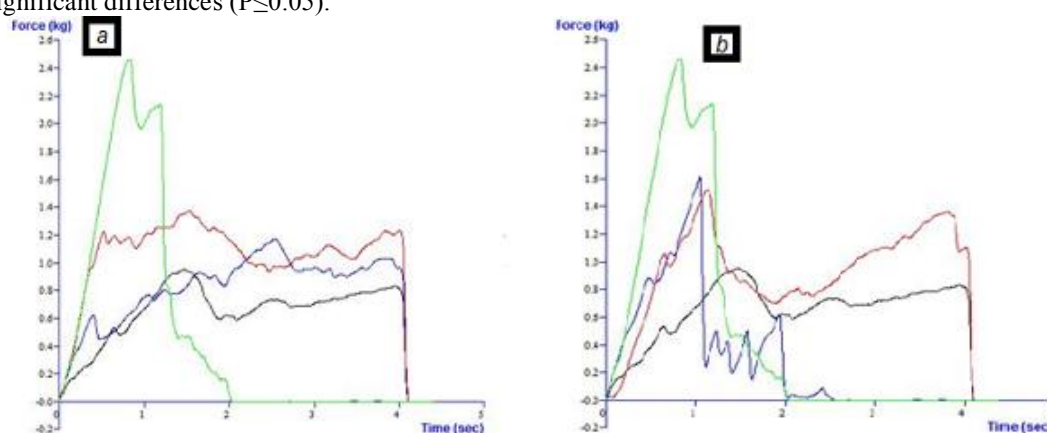


Figure 3. The graph of comparison biscuit hardness of different percentage of fat replacement by a:inulin; b:resistance dextrin. Black line: control; blue line: 25% substitution; red line: 50% substitution; green line: 75% substitution.

of other hydrophilic components. Our results are in agreement with observations of other researchers. (Rodríguez-García et al., 2013; Banerjee et al., 2014; Laguna et al., 2014).

Effect of Fat Replacement on the Baking Quality of Biscuit

In this study, baking quality of biscuits, such as dimension, was evaluated. Changes in the baking quality of biscuits on fat reduction are shown in Table 3. Fat replacement with different percentages of IN and RD did not show significant difference in dimensions of the Biscuits ($P > 0.05$). These findings about baking quality are favorable because changes in the mentioned physical parameter can affect the chewing

and final shape of the biscuits and decrease desirability of the product.

Effect of Fat Replacement on Color of Biscuits

Color is a main characteristic for bakery products because, together with texture and aroma, it contributes to consumer preference. The effect of fibers (IN and RD) addition on crust color of the biscuits is summarized in Table 3. In general, L* values of biscuits decreased significantly with the addition of IN and RD. IN75 and RD75 showed the greatest darkness. Pair wise comparison of samples lightness containing prebiotics with the same levels did not show significant differences. The different percent of IN (except IN25) and



RD replacement were characterized by a larger share of red ($a^* > 0$) than the control samples ($P \leq 0.05$). The IN and RD substitution for fat did not statistically affect the changes of b^* values of biscuits compared with the control. The browning of the crust biscuits due to the addition of fibers was pleasing in GF biscuits which generally tend to have a pale crust color compared with wheat biscuits. The IN75 and RD75 samples had the most toasted color. These results were in agreement with results of Rößle *et al.* (2011) that showed higher concentrations of IN led to a higher browning index (Rößle *et al.*, 2011). Color changes in crust could be attributed to a greater percent of reduced sugar (provided by the inulin and resistant dextrin), which would increase interaction between the reducing sugars and amino acid and result in Maillard-type reaction (Poinot *et al.*, 2010) and would form brown polymers or melanoidins. Decreased low moisture content of IN75 and RD75 biscuits may help to enhance the Maillard reaction.

Effect of Fat Replacement on Chemical Properties of Biscuit

The chemical properties of biscuits containing different percentages of IN and RD are summarized in Table 4. Enhancing fat replacement percentage showed a significant decrease in total fat and peroxide compared with the control. This reduction has been directly related to the percentage of fat substitute that can be desirable for the GF biscuit because it may provide oxidation stability of biscuits during storage and improve product quality (Poinot *et al.*, 2010). Comparing the protein and ash values showed that fat mimetic did not produce significant changes ($p > 0.05$). These findings are on the same lines as found by others (Sofyan Maghaydah *et al.*, 2013). Fat replacement with IN and RD significantly decreased moisture contents and water activity of the samples. The moisture and aw of the control biscuit were significantly

Table 4. Effect inulin and resistant dextrin as a fat replacement on chemical composition of gluten-free biscuits.^a

| Samples | Fat (g/100 g) | Peroxide value (meqO ₂ /Kg) | Ash (g/100 g) | Protein (g/100 g) | Water activity | Moisture (g/100 g) | Carbohydrate (g/100 g) | Fiber (g/100 g) | Calorie (Kcal/100g) |
|---------|-------------------------|----------------------------------------|-------------------------|-------------------------|--------------------------|--------------------------|-------------------------|------------------------|--------------------------|
| Control | 12.65±0.15 ^a | 1.89±0.12 ^a | 0.84±0.004 ^a | 5.90±0.09 ^a | 0.225±0.001 ^a | 4.97±0.04 ^a | 76.49±0.24 ^d | 2.02±0.19 ^d | 443.38±0.80 ^d |
| IN25 | 9.83±0.09 ^b | 1.57±0.04 ^b | 0.84±0.011 ^a | 5.84±0.02 ^a | 0.170±0.003 ^c | 4.54 ± 0.03 ^b | 79.27±0.10 ^e | 4.56±0.31 ^d | 428.36±0.63 ^c |
| IN50 | 6.67±0.46 ^c | 1.38±0.05 ^c | 0.85±0.016 ^a | 5.82±0.11 ^a | 0.124±0.002 ^e | 4.28 ± 0.02 ^c | 81.99±0.31 ^b | 5.78±0.15 ^c | 411.31±2.47 ^b |
| IN75 | 3.92±0.16 ^d | 0.94±0.14 ^c | 0.84±0.010 ^a | 5.86±0.04 ^a | 0.096±0.002 ^g | 4.12 ± 0.04 ^d | 84.44±0.20 ^a | 9.46±0.24 ^a | 396.52±0.86 ^a |
| RD25 | 9.74±0.17 ^b | 1.63±0.01 ^b | 0.85±0.005 ^a | 79.92±0.09 ^a | 0.179±0.002 ^b | 4.58 ± 0.03 ^b | 79.92±0.12 ^c | 5.23±0.78 ^c | 430.38±3.16 ^c |
| RD50 | 7.24±0.75 ^c | 1.14±0.09 ^d | 0.83±0.015 ^a | 5.78±0.06 ^a | 0.138±0.003 ^d | 4.30±0.02 ^c | 81.66±0.77 ^b | 6.83±0.19 ^b | 414.98±3.86 ^b |
| RD75 | 3.90±0.33 ^d | 0.90±0.10 ^e | 0.87±0.008 ^a | 5.83±0.15 ^a | 0.118±0.002 ^f | 4.26±0.01 ^c | 84.63±0.35 ^a | 9.51±0.31 ^a | 396.96±1.65 ^a |

^a Results are expressed as mean ± standard deviation of three replicates. Means with same letter within column are not significantly different ($P \leq 0.05$).

higher than the fat replacer formulations (4.97% vs 4.12% w/w and 0.225 vs 0.096, respectively). IN75 and RD75 showed the greatest reduction in moisture and aw. It could lead to a longer shelf life of biscuits containing fat replacers. The results are in general agreement with the data reported by Laguna *et al.* (2014), Raymundo *et al.* (2014), and Ajila *et al.* (2008) (Ajila *et al.*, 2008). The lower moisture and aw of samples containing prebiotic can be attributed to reduction of fat coating properties on other components of formulation (Rodríguez-García *et al.*, 2013). This effect could increase interaction between hydroxyl groups of polysaccharide macromolecules present in the prebiotic fibers and water, which in turn results in increased absorption of water. Other carbohydrate-based substitutes such as RD and IN absorb water and form a gel-like matrix which confers some of their functional properties (Glibowski and Bukowska, 2011). Carbohydrate content of GF biscuits containing IN and RD was higher than the control (from 3.60 to 10.60%). In spite of increased carbohydrate content, the caloric value of biscuits was low (Table 4). Krystyjan *et al.* (2015), by

replacing fat with IN in biscuit, and Aggarwal (2016), by using polydextrose as fat replacer, observed a significant reduction in the caloric value of the products compared with the control (Krystyjan *et al.*, 2015; Aggarwal *et al.*, 2016). Furthermore, replacement of fat with RD and IN significantly increased total dietary fiber content (from 56% to 78%). It was reported that addition of 5% inulin to extruded snacks increased total dietary fiber content without negative impact on product quality (Peressini *et al.*, 2015). As regards CD patients, who have a lower intake of fiber (Alvarez-Jubete *et al.*, 2010), fat replacement with IN and RD may help to provide the required dietary fiber of GF diets.

Effect of Fat Replacement on Sensory Parameters of Biscuit

Sensory evaluation is considered as a valuable tool in determining consumer acceptability of innovative products. Introducing a new product to the market makes sense only when it meets the consumers' acceptance. Otherwise, such

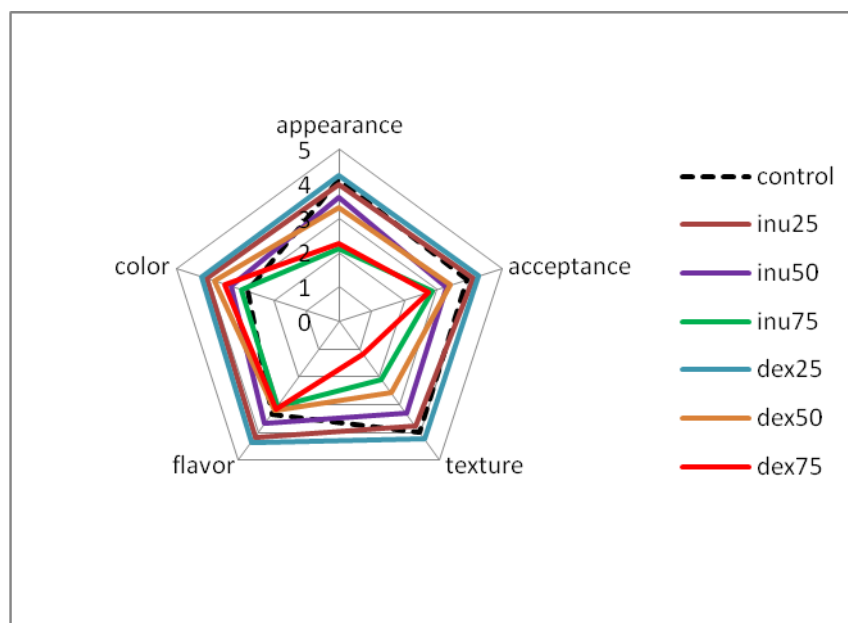


Figure 4. Spider-graph for the sensory profile of gluten-free biscuit samples.



product should be rejected. The mean sensory acceptance scores for the 'appearance', 'color', 'texture', 'flavor', and 'overall acceptance' of samples are presented in Figure 4. There was no significant difference in the appearance, texture, and overall acceptance between the control and RD25, IN25 biscuits, whereas difference in color and flavor were significant. The same results for color evaluation were obtained by the colorimeter. The IN75 biscuits had the lowest scores, especially in texture and appearance. The GF biscuits containing IN75 and RD75 had the least overall acceptance score. The panelists found that the RD25 and IN25 biscuits had the highest score for any of the sensory attributes. It could be concluded that the best replacement of IN and RD to obtain high overall acceptability score in GF biscuits was 25%. This result is in agreement with other authors who reported the acceptability ratings of sensory panels were relatively unaffected by a 25% reduction in fat (Drewnowski et al., 1998). Laguna *et al.* (2014) reported that among different amounts (15 and 30 g/100 g) of fat replacement with IN or hydroxypropyl methylcellulose, replacement with 15 g IN or hydroxypropyl methylcellulose provided the maximum acceptable value (Laguna *et al.*, 2014).

CONCLUSION

According to the obtained results, GF biscuits needed for patients with CD can be prepared using IN and RD as prebiotic and fat replacers up to 75%. However, the highest acceptance scores for sensory evaluation were obtained for IN25 and RD25 biscuits (25% replacement). So, it could be concluded that the best replacement of fat for preparation of a low-fat/low calorie GF biscuits with acceptable prebiotic properties is biscuits containing IN25 and RD25.

Practical Applications

Substituted gluten-free biscuits with prebiotics such as inulin and resistant

dextrin can be introduced to celiac disease patients as a suitable snack to change gut microbiota and balance the nutritional profile while keeping their sensory properties. In addition to the potential nutritional benefit, different prebiotic fibers improve color and flavor, which is additional advantage.

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ارزیابی خواص فیزیکی شیمیایی، بافتی وحسی بیسکویت بدون گلوتن کم چرب حاوی پری بیوتیک اینولین و دکسترین مقاوم

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چکیده

این مطالعه با هدف بررسی اثرات استفاده از اینولین (IN) و دکسترین مقاوم (RD) به عنوان جایگزین چربی و پری بیوتیک در خمیر و بیسکویت فاقد گلوتن طراحی شد. برای تهیه بیسکویت-های فاقد گلوتن از آرد برنج، آرد ذرت و نشاسته ذرت به نسبت 1:1:3 استفاده شد. به منظور ارزیابی تاثیر پری بیوتیک ها بر ویژگی های بافتی خمیر، پروفایل بافتی خمیر شامل سفتی، پیوستگی، چسبندگی، صمغیت و ارتجاعیت ارزیابی شد. کیفیت بیسکویت با ارزیابی رفتار پخش پذیری، ویژگی های سطح، بافت، آنالیزهای شیمیایی و حسی مورد بررسی قرار گرفت. با افزایش درصد جایگزینی چربی با فیبرها، افزایش معنی داری در ویژگی سفتی (85/52-04/17 نیوتن)، پیوستگی (0/49-0/65) و صمغیت (32/71-8/44 نیوتن (خمیر در تیمارهای جایگزین نسبت به نمونه شاهد مشاهده شد در حالیکه چسبندگی و ارتجاعیت خمیر تغییر معنی داری نشان نداد. افزایش جایگزینی با فیبرها منجر به تغییرات معنی دار در ویژگی های بیسکویت شامل سفتی (N 52/24-60/9)، (79/58-94/56) L^* ، (71/9-99/8) فعالیت آبی (0/225-0/096)، رطوبت (12/4-97/4%)، درصد چربی کل (3/90-12/65)، عدد پراکسید (89/1-89/0 meq/Kg90/0)، مقدار فیبر (2/02-9/51%)، کربوهیدرات (84/63-76/49) و (52/396-38/443) kcal در تیمارهای جایگزین نسبت به نمونه شاهد گردید. مصرف کنندگان تفاوت چشمگیری در مقبولیت نمونه های با 25٪ جایگزینی چربی با اینولین و دکسترین مقاوم در مقایسه با نمونه شاهد مشاهده نکردند جز در ویژگی رنگ و طعم که امتیاز بهتری نسبت به نمونه شاهد داشتند. این مطالعه نشان می دهد بیسکویت فاقد گلوتن حاوی 25٪ جایگزینی چربی با IN و RD مشابه نمونه شاهد بوده و می تواند ویژگی سلامت بخشی محصول را ارتقا دهد.