

Enhancing the Nutritional Value of Gluten-Free Cookies with Inulin

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Abstract: Gluten-free products are usually not fortified and are regularly prepared from refined flour and starch. Moreover, gluten-free products with high nutritional values are lacking in the market. The main objective of this study was to enhance the nutritional value of gluten-free cookies with inulin as a source of both prebiotics and fibre. Inulin was added at four levels (3.0, 3.5%, 4.0 and 4.5%) to the gluten-free cookie control formula (corn flour, corn starch, rice flour and lupine flour). Chemical, physical and sensory characteristics were determined. The results indicated that the addition of 3.0% inulin resulted in the highest protein, fat and ash content, while 4.0% inulin gave the highest moisture content. The total dietary fibre content increased with the inulin level, but the spread factor decreased with increasing inulin level. The sensory evaluation demonstrated that the addition of dietary fibre (inulin) at different concentrations did not compromise the sensory characteristics and incorporation of 4.0% inulin had satisfactory consumer acceptance. It was concluded that enhancing gluten-free cookies with a new fibrous prebiotic substance met the nutritional demands in relation to practical demand.

Keywords: Coeliac disease, gluten-free cookie, inulin, dietary fibres, prebiotic

INTRODUCTION

The World Health Organization and food-industry companies place rather high expectations on food products that meet consumer demand for a healthy lifestyle, with the aim of reducing the risk of chronic illnesses. In this context, functional foods play a special role since they are intended not only to satisfy hunger and provide humans with the necessary nutrients, but also to prevent nutrition-related diseases as they contain ingredients with an additional health value that produce beneficial physiological and metabolic effects (Brasil *et al.*, 2011). Inulin, a dietary fibre, is found mainly in endive roots (*Cichoriumintybus* L.) and several edible fruits and vegetables such as tomatoes, bananas, chicory, garlic, asparagus and onions. The inulin commonly used in the food industry is derived from chicory and composed of fructose units connected by β -(2, 1) links; therefore, inulin resists hydrolysis by human digestive enzymes and reaches the large intestines virtually intact, where they are fermented by the intestinal microflora (Roberfroid, 2007). In addition, inulin is among the most studied and well-established prebiotics. This attribute makes it ideal for fermentation in the colon, thus stimulating the growth of health-promoting bacteria, mainly *Lactobacilli* and

bifidobacteria. The increased presence of beneficial bacteria has been shown to reduce the presence of pathogenic or potentially pathogenic bacteria (such as *Clostridium perfringens* and *salmonella*) and may be useful in preventing and treating various diseases or conditions such as diarrhoea (Tuohy *et al.*, 2007). Moreover, the main metabolites upon fermentation of inulin are lactate, acetic and short-chain fatty acids, such as butyric and propionic acids. Some effects of these short-chain fatty acids include increased water and sodium absorption in the colon, mucosal cell proliferation, provision of energy and acidification of the luminal environment, which may protect against colon cancer (Neven, 2001). Coeliac Disease (CD), a gluten-sensitive enteropathy, is an immunological disease in genetically susceptible people, resulting from an inappropriate T-cell-mediated immune response caused by intolerance to gluten, which is a protein found in wheat, rye and barley (Beers and Berkow, 2004). Coeliac disease causes many problems, such as malabsorption of macro- and micronutrients and failure to thrive. The effective treatment of CD includes a lifelong gluten-free diet. Therefore, it is important to provide CD patients with a variety of nutritious and healthy products. However, the available array of products suitable for CD patients is limited and scarce

because it is a challenge to manufacture bakery products without wheat since gluten is responsible for the *Viscoelastic* properties and the formation of cohesive dough (Kulp and Ponte, 2002). Cookies are important baked products that are considered the most desirable products for all ages due to their low manufacturing cost, convenience, long shelf-life and good eating quality. Moreover, cookies can be used as a vehicle to deliver essential nutrients to CD patients. However, the most common types of cookie are empty of prebiotic content. CD patients require an increase in their daily recommendation of calories, protein, fibre, vitamins and minerals due to intestinal damage, which leads to malabsorption of macro- and micronutrients, abdominal distension, diarrhoea and severe constipation (Beers and Berkow, 2004). A deficit of fibre intake in the diet of an average consumer raised the issue of the development and production of dietary fibre-enriched cookies as the point of interest for both producers and researchers (Popov-Raljić *et al.*, 2013) Due to the above-mentioned health benefits of prebiotics and the scarcity of healthy products that are available for CD patients, gluten-free cookies were fortified with inulin (a prebiotic source) to enhance nutritional value, which is the main objective of this study.

MATERIALS AND METHODS

Gluten-free flour (20% lupine flour (*Lupinus albus*), 30% rice flour (*Oryza sativa*), 20% corn flour (*Zea mays*) and 30% corn starch) was obtained from Modern Flour Mills and Macaroni Factories (Amman, Jordan). The other cookie ingredients were used to improve the overall quality of the product, including vegetable hydrogenated shortening (36%), sugar (40%), milk (10%), sodium bicarbonate (0.5%), salt (1%) and two commercial food-grade gum samples: Arabic gum (1.5) and Guar gum (2%) from Foodchem International Corporation (China). Inulin was obtained from (Azienda Chimica E Farmaceutica (Italy). Five samples were prepared; the first sample was control (without inulin). Samples A, B, C and D contained 3, 3.5, 4 and 4.5% of added inulin, respectively. Physical, chemical and sensory analyses were conducted. All gluten-free samples were pre-baked, refrigerated and baked.

Chemical analysis: Proximate chemical analysis (moisture, protein, lipid, crude fibre and ash) was determined in duplicate for all gluten-free samples according to the AACC procedure (AACC, 2000). Total carbohydrates were calculated by difference as $100 - (\text{protein} + \text{fat} + \text{moisture} + \text{ash} + \text{fibre})$.

Physical analysis: Spread Factor. The AACC (2000) was used to evaluate the cookies width, thickness and spread factor. Cookies width (W) was measured by placing six cookies edge to edge to get an average

width in millimetres. The cookies' Thickness (T) was measured by stacking six cookies on top of one another, then restacking in a different order and measuring them to get the average in millimetres. Spread Factor (SF) was determined by the following equation: $SF = W/T$

Colour measurement: The colour of all gluten-free samples was measured using a Minolab colorimeter CR-300 (Ramsey, N.J., U.S.A) and recorded in the $L^*a^*b^*$ colour system. The $L^*a^*b^*$ colour system consists of a luminance or lightness component (L^*) and two chromatic components: the (a^*) component for green (-a) to red (+a) and the (b^*) component from blue (-b) to yellow (+b). The colorimeter was calibrated using a standard white plate. Values of white standard were $L = 97.1$, $a = +0.13$, $b = +1.88$. Colour was measured at two positions on both sides. Duplicate samples were used for each blend and then the measurements were averaged.

Sensory analysis: A selected panel of ten was trained by the researcher using standard product evaluation criteria developed by Hussain *et al.* (2006) and Rababah *et al.* (2006) six training sessions of two hours each was conducted in which the panellists were trained to evaluate sensory attributes of the gluten-free cookie. The panellists used the orientation session to improve their reproducibility and accuracy. Randomly coded samples were served to the panellists individually. Panellists were supplied with distilled water for cleansing the palate between samples. The attributes were analysed based on their respective factors of importance regarding the quality of a cookie according to (Dutcosky, 2007): their overall impression, overall flavour, overall texture, overall colour, crust colour, crumb colour, hardness and aftertaste of the sample. The Hedonic scale test was used for overall impression, flavour, texture and crust colour of the sample as follows: 1 = dislike extremely to 9 = like extremely. This descriptive scale was used for all other parameters.

Statistical analysis: The data was analysed by using the Statistical Package for Social Sciences (SPSS, version 15.0, 2007, Chicago, IL). One-way analysis of variance (ANOVA) test was performed to test differences between blends followed by mean separation using Duncan's Analysis. Findings with a p-value of ≤ 0.05 were considered to be statistically significant.

RESULTS AND DISCUSSION

Table 1 illustrates the chemical composition of gluten free cookies; the data obtained suggested that the moisture content of a food is of great significance for many scientific, technical and economic reasons (i.e., the lower the moisture content of the cookies, the better

Table 1: The Chemical composition of gluten-free cookies

Chemical parameters	Control	A	B	C	D
Moisture	2.12± 0.04 ^a	2.50±0.4 ^a	2.78±0.4 ^a	2.85±0.1 ^a	2.94±0.3 ^a
Protein	13.97± 0.1 ^a	13.95±0.2 ^a	13.93±0.3 ^a	13.92±0.3 ^a	13.91±0.2 ^a
Fat	12.42± 0.2 ^a	12.87±0.3 ^a	12.67±0.2 ^a	12.65±0.3 ^a	12.61±0.3 ^a
Ash	1.88± 0.01 ^a	1.94±0.2 ^a	1.89±0.3 ^a	1.76±0.2 ^a	1.69±0.2 ^a
Total carbohydrate	69.61±0.2 ^a	68.74±0.3 ^a	68.75±0.4 ^a	68.81±0.3 ^b	68.85±0.3 ^a
Total dietary fibre	3.86±0.3 ^c	11.77±0.3 ^b	12.89±0.3 ^{ab}	13.11±0.3 ^{ab}	14.96±0.3 ^a

Values are the average of two replicates ± the standard deviation; row values with the same letters are not significantly different (p≤0.05); Sample A contain (3%) Inulin; Sample B contain (3.5%) inulin; Sample C contain (4%) inulin; Sample D contain (4.5%) Inulin

Table 2: Physical parameters of gluten-free cookies

Physical parameters	Control	A	B	C	D
Width (mm)	17.2±1.05 ^a	17.5±1.05 ^a	17.5±1.02 ^a	17.6±1.03 ^a	17.8±1.08 ^a
Thickness (mm)	3.98±1.09 ^a	3.8±1.09 ^a	3.8±1.03 ^a	3.8±1.01 ^a	3.6±1.07 ^a
Spread factor	4.3±1.07 ^a	4.6±1.01 ^a	4.6±1.02 ^a	4.63±1.01 ^a	4.9±1.01 ^a

Values are the average of two replicates ± the standard deviation; row values with the same letters are not significantly different (p≤0.05); Sample A contain (3%) Inulin; Sample B contain (3.5%) inulin; Sample C contain (4%) inulin; Sample D contain (4.5%) Inulin

the storage stability). The mean values for moisture content (Table 1) showed statistically non-significant (p>0.05) variations among all sample cookies and ranged from 2.12±0.04 to 2.94±0.3%.

Means for protein content of all sample cookies illustrated a non-significant (p>0.05) effect of the addition of inulin; the crude protein content ranged from 13.91±0.2 to 13.97±0.1 in all cookies (Table 1). The means for fat content of cookie samples (Table 1) showed non-significant differences with ranges from 12.42±0.2 to 12.87±0.3%.

Ash content in a food substance indicates inorganic remains after the organic matter has been burnt away. The mean ash content values of all types of cookies are given in Table 1. Ash content varied (non-significantly) from 1.69±0.2 to 1.94±0.2% in all cookies.

The means for total carbohydrate content of all types of cookies in Table 1 show that total carbohydrate content in different cookies ranged from 68.74±0.3 to 69.61±0.2%.

The means for crude fibre of all types of cookies (Table 1) showed that fibre content ranged from 3.86±0.3 to 14.96±0.3%. In relation to dietary fibre content, as expected, it was noticed that as the addition of inulin increased, so did the fibre content. Moreover, there was a significant difference (p≤ 0.05) among the samples, where sample D (4.5% inulin) showed a significant increase in this component while the control exhibited the lowest fibre content. It has been shown that fibre deficiency is common in gluten-free diets because gluten-free products are generally not enriched or fortified and are frequently made from refined flour or starch. The recommended daily intake for total fibre for adults aged 50 years and younger is 38 g for men and 25 g for women, while for men and women over 50 years, it is 30 and 21 g of fibre per day, respectively (Stojceska *et al.*, 2010). The typical diet of the coeliac does not always deliver the recommended 20 to 30 g of dietary fibre per day. Adults diagnosed with CD have a lower intake of fibre when compared to a control group of individuals on a normal diet (Grehn *et al.*, 2001) and

this increases the risk of a variety of diseases. The serving size of this product is two pieces (each is 17g) since the Reference Amount Customarily Consumed (RACC) for cookies is 30 g. Therefore, each serving size of this product would provide approximately 6 g of fibre with a 4.5% inulin addition level. Accordingly, this product is considered rich in fibre for CD patients.

Table 2 shows the physical parameters of gluten-free cookies. The data obtained suggest that the mean values for the width (diameter) of all types of cookies, which ranged from 17.2±1.05 to 17.8±1.08 mm had a non-significant impact on this trait. Mean values for thickness of all types of cookies are shown in Table 2.

The thickness of cookies ranged from 3.6±1.07 to 3.98±1.09mm. Spread factor indicates the ratio, which depends upon the values of width and thickness. Means for spread factor revealed (Table 2) non-significant (p > 0.05) differences among all types of cookies. The spread factor of cookies ranged from 4.3±1.07 to 4.9±1.01; these values are in agreement with the acceptable range reported in the literature. Having no significant difference between samples indicated that the addition of inulin had minimal effects. Moreover, no changes in these physical parameters were desirable because otherwise, the chewing and final shape of the cookies would have been changed and thus, not appealing to CD patients. Spread factor and size of the cookies depends on particle size and moisture content of flour (Gaines and Donelson, 1985). The present study revealed that the addition of inulin had no adverse effects on the physical parameters of cookies.

The effects of gluten free cookie formulation on colour measurements were performed and presented in Table 3. Namely, the top and bottom surface colour of baked cookies are very important parameters in the initial acceptability of products tested by consumers (Zucco *et al.*, 2011). According, to Chevallier *et al.* (2000) cookie colour surfaces occur as a result of non-enzymatic browning (Maillard reactions) between reducing sugars and amino acids as well as from starch

Table 3: Colour characteristics of gluten free cookies

Colour parameters	Control	A	B	C	D
L*	72.20 ^a	72.02 ^a	71.00 ^a	71.00 ^a	70.10 ^a
a*	-2.98 ^a	-2.94 ^a	-2.90 ^a	-2.89 ^a	-2.87 ^a
B*	35.80 ^a	35.83 ^a	35.85 ^a	35.87 ^a	35.90 ^a

Row values with the same letters are not significantly different ($p \leq 0.05$); Sample A contain (3%) Inulin; Sample B contain (3.5%) inulin Sample C contain (4%) inulin; Sample D contain (4.5%) Inulin

Table 4: Sensory evaluation of gluten-free cookies

Attributes	Control	A	B	C	D
Texture	5.10±1.16 ^a	5.25±1.16 ^a	5.63±1.21 ^a	5.74±1.12 ^a	5.80±1.17 ^a
Aroma	5.54±1.3 ^a	5.01±1.28 ^a	5.45±1.14 ^a	5.22±1.15 ^a	5.78±1.16 ^a
Flavour	5.62±1.5 ^a	5.14±1.09 ^a	5.44±1.14 ^a	5.56±1.04 ^a	5.88±1.02 ^a
Softness	5.41±1.4 ^a	5.54±1.4 ^a	5.21±1.4 ^a	5.10±1.4 ^a	5.32±1.4 ^a
Overall impression	5.840±1.07 ^a	5.80±1.09 ^a	5.78±1.21 ^a	5.71±1.16 ^a	5.98±1.04 ^a

Average of 50 judgments. Hedonic Scale: (7) Like extremely; (6) Like very much; (5) Like moderately; (4) Neither like nor dislike; (3) Dislike moderately; (2) Dislike very much; (1) Dislike extremely; The samples (mean±standard deviation) followed by the same letter (same row), not significantly different ($p \leq 0.05$); Sample A contain (3%) Inulin; Sample B contain (3.5%) inulin; Sample C contain (4%) inulin; Sample D contain (4.5%) Inulin

dextrinisation and sugar caramelisation. The lightness (L*), redness (a*) and yellowness (b*) values of gluten-free and control cookies suggest the following ranges of cookie colour: L* = 70.1 to 72.2, a* = -2.87 to -2.98 and b* = 35.8 to 35.9. There was no significant ($p > 0.05$) difference between all of the cookie samples; these results agreed with those obtained by Mandala *et al.* (2009), who reported that no significant difference in crust colour was observed for inulin addition at 3% in freshly baked breads. From the results it can be seen that the increased addition of inulin reduced the lightness, which confirmed that reported by Morris and Morris (2012), who indicated a darker crust colour for all levels of addition (2.5, 5 and 7.5%) and 2 types of inulin. An enhancement of bread crust coloration was also reported for breads prepared with as little as 3% and up to 10% inulin. These darker colours have been explained by a greater number of reducing ends involved in a Maillard reaction. Shorter chain inulin results in even darker colour, as it possesses a higher proportion of low molecular weight fructans (Peressini and Sensidoni, 2009). A slight change in colour was favourable to maintaining the original, colour of the cookies that is deemed acceptable for consumers.

Sensory evaluation results of gluten-free cookies are presented in Table 4. These results showed that the most influential descriptors concerning gluten-free cookie evaluation were: texture, aroma flavour and overall impression, in which all attributes score between 5 and 6 from like moderately to like very much. This indicated that no adverse effects of the addition of inulin exist and that the addition might actually improve the sensory attributes; sample D (4% inulin) yielded the highest score. The addition of these fructans (inulin) is promising as they do not alter the appearance or flavour of foods, which agrees with the results of Brasil *et al.* (2011). Moreover, the substance adds softness and moisture, allowing its use as a substitute for fat in starch-rich products such as cakes and cookies, as well as in pasta for soups and spaghetti (Franck, 2002). A similar conclusion has been reported by many studies, suggesting that the addition of 5.7%

inulin to white bread as a substitute for fat does not affect its sensory characteristics (Lajolo and Menezes, 2006). In summary, different concentrations of inulin do not compromise the sensory characteristics of the product nor its acceptance by consumers.

CONCLUSION

The results obtained in this study demonstrated that the addition of dietary soluble fibre (inulin) at different concentrations did not compromise the sensory characteristics of the product nor its acceptance by the consumers. This product is considered a rich source of fibre due to the two main ingredients: lupine and added inulin. Therefore, it helps to meet consumer requirements for fibre (38 g for adult men and 25g for adult women). Enhancing the fibre value of gluten-free cookies provides health benefits, including a reduction in the bowel transit time, prevention of constipation, reduction of the risk of colorectal cancer and lowering of blood cholesterol. Similarly, the health benefits of inulin include an increase in mineral absorption (Ca and Mg), a decrease in triglyceridaemia, production of short-chain fatty acids, a lowering of the risk of colon cancer and irritable bowel syndrome and promotion of the growth of beneficial gut microflora. Finally, considering the prebiotic action, the use of inulin represents an important technological alternative. Therefore, the developed product attends to the demand of practicality expected by the consumers. Developing these high nutritional gluten-free cookies helps to create a major opportunity for food producers to provide more healthy dietary fibre-enriched products, which are currently lacking in the gluten-free market.

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