PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
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E-mail: editorpjn@gmail.com

OPEN ACCESS

Pakistan Journal of Nutrition

ISSN 1680-5194
DOI: 10.3923/pjn.2017.659.665

Research Article

Development of Gluten-free Cookies Rich in Resistant Starch Type 3 from *Maranta arundinacea*

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Abstract

Background and Objective: Indonesia has potential as a gluten-free food source. Thus, efforts to utilize gluten-free flour in ready-to-eat products such as cookies are required. This research aims to determine the chemical, physical and sensory characteristics of gluten-free cookies made from sorghum flour, millet flour, corn flour, tapioca flour, *Maranta arundinacea* flour rich in resistant starch type 3 (RS3), *Maranta arundinacea* flour, *Coleus tuberosus* flour rich in RS3 and corn starch. **Materials and Methods:** Four types of cookies were made, namely, wheat flour cookies (as control) and three types of gluten-free cookies based on different proportions of *Maranta arundinacea* flour rich in RS3 [8% (FI), 10% (FII) and 12% (FIII)]. The cookies chemical, physical and sensory characteristics were analyzed. **Results:** Gluten-free cookies (FI, FII and FIII) had higher contents of fibre, RS3 and calories than wheat flour cookies (as control). The physical characteristics (weight, diameter, height and spread ratio) of gluten-free cookies differed significantly from those of wheat flour cookies but did not significantly differ with the amount of added RS3. Wheat flour cookies were harder than gluten-free cookies. Wheat flour cookies had higher sensory characteristic scores (colour, flavour, taste, crispiness and overall acceptability) than did gluten-free cookies. Among the gluten-free cookies, FI had better sensory characteristic scores. **Conclusion:** Based on the results of this research, gluten-free cookies low in calories, rich in RS3 and high in fibre have good physical and sensory characteristics and thus can be developed as functional food.

Key words: Chemical characteristics, physical characteristics, sensory characteristics, gluten-free cookies, *Maranta arundinacea*

Received: June 08, 2017 Accepted: August 01, 2017 Published: August 15, 2017

Citation: Mutiara Nugraheni, Sutopo, Sutriyati Purwanti and Titin Hera Widi Handayani, 2017. Development of gluten-free cookies rich in resistant starch type 3 from *Maranta arundinacea*. Pak. J. Nutr., 16: 659-665.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cookies are food much liked by the community. They are a type of biscuit made from soft dough, high in fat and relatively crispy when broken and have a solid texture. Cookies are representative baked goods containing three major ingredients: Flour, sugar and fat, which are mixed together with other ingredients to form cookie dough[1]. Cookies are characterized by a low moisture content and high levels of fat and sugar[2]. Cookies do not require ingredients (gluten) that cause them to expand while cooking, thus, gluten-free flour made from local crops can be used.

High-fibre gluten-free flour can be developed in Indonesia, which has an advantage as a source of local vegetable foods that can be used to make flour, namely, tubers, legumes and cereals. In order to take advantage of this potential, high-fibre gluten-free flour needs to be developed by combining locally grown foods to produce a composite flour that is gluten-free and rich in fibre.

Currently, customers have concerns over health and demand for healthy food has increased. One of the foods that is preferred by almost all age levels is cookies. Cookie products can be made as a functional food, because they can control the level of sugar in the blood and have a low glycemic index. This can be accomplished by changing the main ingredients, such as replacing wheat flour with starch that is modified to contain resistant starch type 3 (RS3) and ingredients that contain dietary fibre. Resistant starch cannot be digested in the small intestine but is fermented in the large intestine[3,4]. It can be obtained through physical modification, one of the methods used to produce RS3 is autoclaving-cooling. According to Sajilata *et al.*[4], resistant starch has physiological effects that are beneficial to health, such as colon cancer prevention, hypoglycaemic effects (decreased blood glucose after eating), reduced risk of the formation of bladder stones, hypocholesterolemic effects, inhibited accumulation of fat and increased mineral absorption.

Dietary fibre is the part of plants or carbohydrates that is resistant to digestion; it is absorbed through the wall of the small intestine and then fermented in the large intestine[5]. Dietary fibre includes a polysaccharide, oligosaccharides and lignin. It has beneficial physiological effects such as lowering blood cholesterol and blood glucose levels. Based on solubility in water, fibre is divided into two types, namely, soluble fibre and nonsoluble fibre[6]. Soluble fibre in the small intestine will form a solution that has high viscosity. Because of this characteristic, soluble fibre can affect the metabolism of lipids and carbohydrates and has some anticarcinogenic potential. Soluble fibre can maintain its structural matrix in water and forms a mixture that has low viscosity. This results in increased faeces mass and shortens the bowel transit time.

Some ingredients that are used for the manufacture of gluten-free flour are sorghum flour, millet flour, corn flour, tapioca flour and corn starch. *Maranta arundinacea* is an upright tuberous plant in kingdom *Plantae*, subkingdom *Tracheophyta*, division *Magnoliophyta*, class *Liliopsida*, subclass *Zingiberidae*, family *Marantaceae*[7]. *Maranta arundinacea* also has a fairly high starch content of approximately 20.96%. In addition, when compared with starch from various other sources, *Maranta arundinacea* starch has fairly high amylose content, making it possible to process *Maranta arundinacea* starch to produce RS3. *Maranta arundinacea* that is physically modified has low digestibility and contains quite high RS3 levels. Based on the speed of release of glucose and glucose absorption capability in the digestive tract, starches are classified into rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch[8].

Cookies developed from gluten-free *Maranta arundinacea* flour rich in fibre and RS3 can be used as functional food because they have a low glycemic index. According to Marangoni and Poli[9], the addition of dietary fibre in the manufacture of cookies will decrease the glycemic index by 41%. The purpose of this research is to develop cookies using composite gluten-free flour rich in fibre and RS3 and then evaluate their chemical composition and physical and sensory characteristics.

MATERIALS AND METHODS

Maranta arundinacea flour was obtained from a farmer-breeder of tubers in Clereng Kulon Progo, tapioca flour, corn starch, sorghum flour and millet flour were obtained from a Yogyakarta local market. *Maranta arundinacea* flour rich in RS3 and *Coleus tuberosus* flour rich in RS3 were obtained from processing with 3 cycles of modified autoclaving-cooling[10].

Cookie formulation: Cookies were prepared according to Gisslen[11] with slight modification. The gluten-free cookies FI (8%), FII (10%) and FIII (12%) differed in the proportion of *Maranta arundinacea* flour rich in RS3 against the total flour used. Based on the percentage of FI (8%), FII (10%) and FIII (12%), the amount of *Maranta arundinacea* flour rich in RS3 was 12 g (FI), 14 g (FII) and 16 g (FIII). The formula used is shown in Table 1.

Making cookies begins with making flaxseed gel by soaking 10 g of flaxseed in 45 mL of water, stirring and then

Table 1: Formulation of wheat flour cookies (as control) and three types of gluten-free cookies

	Types of cookies			
Ingredients	Wheat flour cookies as control (g)	Gluten-free cookies FI 8% (g)	Gluten-free cookies FII 10% (g)	Gluten-free cookies FIII 12% (g)
Wheat flour	150	-	-	-
Gluten-free flour ingredient	-			
Sorghum flour		52	52	52
Corn flour		28	28	28
Millet flour		26	26	26
Tapioca flour		13	9	7
Coleus tuberosus rich in RS3		1	1	1
Maranta arundinacea flour rich in RS3		12	16	18
Corn starch		9	9	9
Maranta arundinacea flour		9	9	9
Total gluten free flour		150	150	150
Other ingredients				
Flaxseed		10	10	10
Corn syrup		15	15	15
Salt		2	2	2
Cheddar cheese		75	75	75
Chocolate powder		5	5	5
Water		45	45	45

refrigerating for 15 min. Margarine and sugar were blended until creamy, then, the flaxseed gel was added and mixed well. Flour, cocoa powder and cheese were then added. The cookie dough was rolled to a 3 mm thickness and cut into round shapes using a cutter. The cookies were then baked at 120°C for 40 min. The cookies were cooled for 10 min, wrapped in aluminium foil and packed in a polyethylene bag.

Chemical analysis: The moisture, ash, fat, crude protein and dietary fibre contents of the samples were determined by the AOAC method[12]. The carbohydrate content was estimated by difference and caloric value was calculated. Analysis of resistant starch was performed[8].

Physical characteristics: Cookies were selected randomly and weighed using an analytical balance and the height and diameter were measured with a vernier calliper (Tricle Brand, Shanghai, China) before and after baking. To measure the diameter of cookies, three samples were placed next to one another and the total diameter was measured. The diameter of all cookies was measured. The average of the two measurements divided by three was taken as the final diameter of the cookie. Thickness was measured by stacking the cookies one above the other and restacking 4 times. The spread ratio was calculated using the following formula: Cookie diameter divided by height Zoulias *et al.*[13]. Physical characteristics (hardness) were measured using a Lloyd universal testing machine type 1000 S with in 24 h after baking.

Sensory evaluation: An 80 member semi-trained panel (30 males, 50 females) of students from the Culinary and Food Technology Department of Yogyakarta State University evaluated the samples using a 9-point hedonic scale method: 9 (extremely like) to 1 (extremely dislike). The cookies were evaluated 24 h after baking. Sensory testing was performed on all four types of cookies. Each panellist was presented with 4 coded randomized samples. Each sample was coded with a 3 digit random number and the positions of the samples were randomized. Panellists were seated in individual sensory booths.

Statistical analysis: Statistical data were analysed with SPSS version 11.0 (Illinois, USA) using one-way analysis of variance (ANOVA). Significance differences were tested using Duncan's Multiple Range Test. Three replications were used for chemical and physical analyses and sensory evaluation and Statistical significance was set at $p<0.05$.

RESULTS AND DISCUSSION

Cookies chemical characteristics: The cookie composition (Table 2) was significantly different ($p<0.05$) between the wheat flour cookies and gluten-free cookies in terms of water, ash, lipids, protein, carbohydrate, soluble fibre, nonsoluble fibre, total fibre, resistant starch and calorie contents. Table 2 shows that the gluten-free cookies had higher total fibre contents and resistant starch levels than did wheat flour

Table 2: Chemical characteristics of wheat flour cookies (as control) and three types of gluten- free cookies

	Types of Cookies			
Determination	Wheat flour cookies (control) (%)	Gluten-free cookies (FI) (%)	Gluten-free cookies (FII) (%)	Gluten-free cookies (FIII) (%)
Water content	3.38±0.07[a]	4.66±0.13[b]	4.48±0.07[b]	4.03±0.02[b]
Ash	3.45±0.07[a]	4.47±0.40[b]	4.52±0.16[b]	4.77±0.31[b]
Lipids	31.14±0.13[b]	31.75±0.21[c]	30.29±0.10[a]	30.10±0.02[a]
Protein	15.14±0.05[d]	13.40±0.40[c]	11.53±0.15[a]	12.16±0.09[b]
Carbohydrate	25.21±0.11[d]	19.41±0.78[a]	23.24±0.13[b]	24.01±0.06[c]
Soluble fibre	0.54±0.12[a]	1.34±0.17[b]	1.29±0.14[b]	1.29±0.20[b]
Nonsoluble fibre	20.56±0.16[a]	24.62±0.04[c]	24.07±0.11[d]	24.84±0.04[b]
Total fibre	21.09±0.13[a]	25.96±0.17[c]	25.36±0.22[b]	26.136±0.04[c]
Resistant starch	2.18±0.18[a]	4.84±1.13[b]	5.29±1.29[b]	6.76±0.19[b]

Values are the Mean±SD from triplicate determinations, different superscripts in the same row are significantly different (p<0.05)

Table 3: Physical characteristic of wheat flour cookies (as control) and three types of gluten-free cookies

	Types of Cookies			
Determination	Wheat flour cookies (control)	Gluten-free cookies (FI)	Gluten-free cookies (FII)	Gluten-free cookies (FIII)
Weight (g)	1.65±0.02[b]	1.32±0.02[a]	1.34±0.02[a]	1.33±0.03[a]
Diameter (mm)	31.59±0.13[b]	32.16±021[a]	31.84±0.41[a]	31.98±0.42[a]
Height (mm)	3.42±0.21[b]	3.23±0.31[a]	3.24±0.06[a]	3.24±0.05[a]
Spread ratio	9.24±0.09[a]	9.95±0.12[b]	9.84±0.23[ab]	9.87±0.21[ab]
Hardness (N)	12.24±0.25[b]	8.51±0.08[a]	8.44±0.06[a]	8.40±0.10[a]

Values are the Mean±SD from triplicate determinations; different superscripts in the same row are significantly different (p<0.05)

Table 4: Sensory characteristics of wheat flour cookies (as control) and three types of gluten-free cookies

	Types of Cookies			
Determination	Wheat flour cookies (control)	Gluten-free cookies (FI)	Gluten-free cookies (FII)	Gluten-free Cookies (FIII)
Colour	7.93±0.67[c]	7.63±0.60[b]	7.21±0.61[a]	7.04±0.66[a]
Aroma	8.01±0.58[c]	7.66±0.62[b]	7.23±0.69[a]	7.05±0.69[a]
Taste	7.89±0.50[c]	7.55±0.55[b]	7.24±0.66[a]	7.16±0.79[a]
Crispness	7.90±0.54[b]	7.69±0.61[b]	7.20±0.66[a]	7.08±0.71[a]
Overall acceptability	7.90±0.54[c]	7.69±0.61[b]	7.20±0.66[a]	7.08±0.71[a]

Values are the Mean±SD from triplicate determinations; different superscripts in the same row are significantly different (p<0.05)

cookies (p<0.05). The addition of a high amount of *Maranta arundinacea* flour rich in RS3 could increase the RS3 content of gluten-free cookies relative to that of wheat flour cookies. The protein content of wheat flour cookies was higher than that of the three types of gluten-free cookies. The three types of gluten-free cookies had lower energy contents than did wheat flour cookies (p<0.05).

Cookies physical characteristics: Table 3 shows the physical characteristics of the three types of gluten-free cookies (p<0.05) compared to those of wheat flour cookies as control.

Physical characteristics included weight (g), diameter (mm), height (mm), spread ratio and hardness (N). Wheat flour cookies (control) had a lower spread ratio than did the three types of gluten-free cookies (p<0.05). Table 3 shows that the decrease in the spread ratio was proportional to the increase in the proportion of *Maranta arundinacea* flour rich in RS3. Wheat flour cookies (control) were harder than the 3 types of gluten-free cookies.

Cookies sensory characteristics: Four types of cookies, wheat flour cookies (as control) and three types of gluten-free cookies (FI, FII and FIII), were made. The difference between cookies FI, FII and FIII was the proportion of *Maranta arundinacea* flour rich in RS3. Sensory analysis was performed on the cookies using 80 semi-trained panellists (30 males and 50 females), the sensory characteristics included colour, aroma, flavour, crispness and overall acceptability (Table 4). Table 4 shows that all of the cookies made could be categorized as favoured by panellists. However, wheat flour cookies had the highest value compared to the three types of gluten-free cookies, while the FIII cookies had the lowest values in terms of colour, aroma, flavour, texture and overall acceptability. The FI cookies had a higher overall acceptability than did the FIII and FII cookies. Table 4 shows that the addition of *Maranta arundinacea* rich in RS3 decreased the level of sensory acceptance by the panellists.

This research was conducted using 3 formulations distinguished based on the amount of *Maranta arundinacea* rich in RS3 (Table 1). Based on the chemical characteristics, it is observed that the levels of resistant starch were higher in gluten-free cookies than in wheat flour cookies (as control). This is because the constituent ingredient, gluten-free *Maranta arundinacea* flour, used for making the cookies is made rich in RS3 by 3 cycles of autoclaving-cooling[10]. The resistant starch content in the cookies increased with the increasing proportion of *Maranta arundinacea* rich in RS3 (Table 2). Another factor that increases the content of RS3 in cookies is the baking process. Replacing some of the flour with flour from novel genotypes with a high amylose content results in a higher content of RS in baked bread[14].

The total fibre content was higher in the FI, FII and FIII cookies than the wheat flour cookies (as control) due to some ingredients having a high fibre content, such as sorghum, millet and flaxseed. Dietary fibre levels of gluten-free flour are related to the composition of the ingredients sorghum flour and millet flour that include high fibre levels. Dietary fibre in sorghum flour is 4.7%[15] and in millet flour is 2.7%[16]. Use of millet flour can increase levels of dietary fibre in gluten-free cookies. This agrees with studies of Chappalwar *et al.*[17] showing that the chemical properties of oat and finger millet flour significantly improved the dietary fibre, protein and fat contents of cookies.

The use of flaxseed also plays a role in increasing levels of fibre in gluten-free cookies. Flaxseed (*Linum usitatissimum*) has functional components[18], including dietary fibre, α-linolenic acid (ALA) and lignans[19]. Flaxseed contains approximately 38-45% oil, 28% dietary fibre and 21% protein[20]. It is a very rich source of lignans (610-1330 mg 100 g^{-1})[21]. This agrees with research conducted by Ganokar and Jain[22], in which the replacement of some ingredients in cookies with flaxseed could increase the levels of dietary fibre relative to wheat flour cookies (as control).

The water content in the four types of cookies ranged from 3.38-4.66%. This trend can be accepted, as moisture content in freshly baked cookies is generally less than 5%[23,24]. Low water levels can affect the shelf life of cookies. Protein levels were higher in wheat flour cookies than gluten-free cookies, this is due to the protein content in wheat flour. Table 2 shows that the levels of ash are higher in the gluten-free cookies than in the wheat flour cookies (as control). This indicates that the gluten-free cookies contain higher mineral levels than the control wheat flour cookies.

Based on the results of the physical analysis of the cookies, the weight of wheat flour cookies was greater compared to the gluten-free cookies. However, the spread ratio of wheat flour cookies was lower than that of gluten-free cookies. The spread ratio serves as a parameter to evaluate the rising ability of cookies, a lower spread ratio implies better rising ability[25]. The low spread ratio of wheat flour cookies shows that wheat flour cookies have the ability to rise better than gluten-free cookies. According to Siddiqui *et al.*[26], cookies with a high protein content have a greater water binding ability, which eventually restricts their spread. This strengthens the results of this research because wheat flour cookies contain a higher protein content than the three types of gluten-free cookies, thus, the spread ratio of wheat flour cookies was the lowest of the four types of cookies. Protein affects the viscosity of cookie dough because the expansion of the protein gluten does not resume in the creation of cookies. An inverse correlation has been observed between diameter and protein content[27]. The protein gluten in the flour will form a web in the cookie dough through an apparent glass transition, thereby gaining mobility that allows the continuous web to increase the viscosity of gluten and stop the flow of cookie dough[28].

The main attributes that affect cookie quality are texture, flavour and appearance[29]. Another important aspect in designing cookies with improved nutritional status is the maintenance of the product's sensory characteristics because the consumer's acceptance of the product remains the key factor that determines the successful application of a newly developed product[30]. During baking, the undissolved sugar dissolves progressively and hence contributes to cookie spreading. Other cookie parameters that are influenced by the recipes sugar include hardness, crispness, colour and volume. Fat contributes to cookie spreading and to the general product appearance, it enhances aeration for leavening and volume and makes the cookies more easily breakable[31]. Hardness as measured by Lloyd shows that the addition of *Maranta arundinacea* flour rich in RS3 decreased the level of acceptability by the panellists. In contrast, the acceptability of wheat flour cookies (as control) was higher than that of the three types of gluten-free cookies. The presence of gluten resulted in the formation of elastic dough during handling, resulting in the wheat flour cookies having a harder texture after baking than gluten-free cookies. This difference may also be due to the high protein content due to the interaction of protein during dough development[32].

The results showed that FIII gluten-free cookies had the lowest values for all the sensory characteristics evaluated: colour, aroma, taste, crispness and overall acceptability. This result shows that enrichment with *Maranta arundinacea* flour rich in RS3 by more than 8% reduced the preference for the gluten-free cookies in terms of colour, aroma, taste, texture and overall acceptability.

CONCLUSION

Based on the chemical composition, physical characteristics and sensory evaluation of gluten-free cookies rich in RS3 from *Maranta arundinacea* flour, it can be concluded that gluten-free cookies have value and are a good source of functional components. The results of this study indicate that gluten-free cookies have characteristics of high fibre, high RS3 and low calories. Sensory evaluation showed that wheat flour cookies have higher values of colour, aroma, taste, crispness and overall acceptability than the three types of gluten-free cookies. Gluten-free cookies with 8% *Maranta arundinacea* flour rich in RS3 were characterized with higher values of colour, aroma, taste, crispness and overall acceptability than were gluten-free cookies with 10 and 12% of *Maranta arundinacea* rich in RS3.

SIGNIFICANCE STATEMENT

This research was conducted by making gluten-free cookies with added *Maranta arundinacea* flour rich in RS3. The results of this study indicate that gluten-free cookies have a chemical composition that is high in fibre, rich in RS3, low in calories and free of eggs. The gluten-free and egg-free cookies produced in this research have potential as a functional food for the management of glucose and lipid profiles, for celiac sufferers and for people who have gluten and egg sensitivities.

ACKNOWLEDGMENTS

The authors would like to thank the Directorate General of Higher Education of the Republic of Indonesia, with contract number: 04/Penel./P. Stranas/UN34.21/2017, 3 April 2017, which has funded this research.

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