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Shelf-life prediction of gluten-free rice-buckwheat cookies

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ABSTRACT

The objective of this work was to predict the shelf-life of unpacked and packed gluten-free rice-buckwheat cookies kept at ambient (23 ± 1 °C) and elevated (40 ± 1 °C) temperature during storage by measuring off-flavour volatile compounds (aldehydes), antioxidant capacity, total phenolic and rutin content and evaluating sensory properties. Analysis of variance and Tukey's HSD test at 95% confidence limit showed significant differences between the observed samples. Principal component analysis was used for assessing the effect of storage time, temperature and packaging condition on all investigated cookie parameters. Antioxidant capacity measured using DPPH test showed a decreasing tendency during storage in all investigated cookie samples. The obtained results correlated with a decrease in total phenolics and rutin content and an increase in total aldehydes content in cookies during storage. From the sensory evaluation, it could be concluded that the greatest loss of sensory quality resulted from hardness increase, fracturability decrease, and the raise of uncharacteristic odours and flavours. The end-point of cookie shelf-life obtained from sensory evaluation was lower compared to that obtained measuring total aldehydes content. Therefore, sensory properties might be the markers for gluten-free cookie shelf-life prediction rather than aldehydes content.

1. Introduction

Celiac disease is a permanent intolerance to gluten proteins of many common cereals such as wheat, rye, barley and oat. Therefore, celiac disease patients are recommended to be on a strict long-life gluten-free diet, which usually lacks in certain essential nutrients and contains lipids of low quality level from the nutritional point of view, as indicated by the high contents of triacylglycerol oligopolymers and oxidized triacylglycerols, as well as, in some cases, high levels of oleic acid trans isomers (Caponio et al., 2008). Due to the limitation of some nutrients, the fortification of gluten-free products is required to obtain a balanced diet for celiac patients. There are several papers about gluten-free added value products some of them focusing on sweet bakery products, such as cookies (Sakač et al., 2015), muffins (Matos et al., 2014) and biscuits (Schonlechner et al., 2006).

Shelf-life of foods is of great interest since it reflects their nutritional, functional, sensory and safety profile (Zieliński et al., 2012). The most remarkable changes in foods during processing, storage and handling result from lipid oxidation and microbiological spoilage leading to quality deterioration of foods, which, furthermore, could have harmful effects on health (Laguerre et al., 2007).

The lipid oxidation leads to the rancidity of high fat/oil containing products, which may affect their shelf-life. Rancidity is related to the development of unpleasant odours and flavours, which contribute to an unacceptable sensory profile of the product. The progress of lipid oxidation can be followed by measuring the content of marker compounds, among which some are volatile compounds, such as aldehydes. These secondary lipid oxidation products are generated from a wide range of hydroperoxides formed during the initiation stage of the reaction (Laguerre et al., 2007) and strongly contribute to the aroma at trace amounts due to their low odour threshold values (Sun et al., 2010).

Cookies are known for their long shelf-life because they are characterized by lower water activity (a_w) values than those that

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permit the growth of microorganisms (a_w > 0.6) (Chieh, 2006). However, they possess a high amount of vegetable fat (20–30% on flour weight basis), which makes them susceptible to oxidative changes (Zieliński et al., 2012). Hexanal, as the major volatile oxidation product of linoleic acid or further oxidation of 2,4-decadienal, was used as an indicator for oxidation of crackers (Berenzon and Saguy, 1998). The oxidative deterioration of cookies was also monitored in shortcake biscuits by measuring 2,4-decadienal and 2,4-heptadienal, which contributed to their rancidity (Yang et al., 2013). Viscidi et al. (2004) used heptanal as a marker of lipid deterioration, while Mandić et al. (2013) quantified five aldehydes for the same purpose.

Consumer tests are the most suitable tool for shelf-life determination of food products, but they are not easy to handle. Instead, the most widely used technique for shelf-life determination is based on a trained or expert panel, which is usually available at a food producer's facility. The panel performs descriptive sensory method based on measuring the intensity of sensory attribute correlated with the product deterioration.

In our previous work (Sakač et al., 2015), gluten-free cookies based on a mixture (80:20) of rice flour (RF) and light buckwheat flour (LBF), respectively were chosen as optimal regarding their enhanced mineral content, increased antioxidant capacity and the most acceptable sensory properties in comparison with the control cookies (rice cookies) and others based on rice-light buckwheat flour mixture (RF:LBF – 90:10 and 70:30). The enrichment of the mentioned cookies was achieved using buckwheat flour which is rich in minerals and rutin (Sedej et al., 2011). The increased antioxidant capacity of cookies resulted from the presence of rutin as a potent antioxidant, which suggests the potential of this compound to extend cookie shelf-life.

Having in mind the susceptibility of cookies to lipid oxidation, the objective of this work was to predict the shelf-life of unpacked and packed (polypropylene bags) gluten-free rice-buckwheat cookies (RF/LBF – 80:20) kept at ambient (23 ± 1 °C) and elevated (40 ± 1 °C) temperature during storage, measuring off-flavour volatile compounds (aldehydes), antioxidant capacity (1,1-diphenyl-2-picrylhydrazyl radicals (DPPH•) scavenging activity), total phenolic content (TPC), rutin content, and evaluating their sensory properties.

2. Material and methods

2.1. Materials

Rice flour – RF (moisture 10.9%, protein (N × 5.7) 7.52%, fat 0.29%, ash 0.27%, reducing sugars 1.50%, and starch 87.2%) and light buckwheat flour – LBF (moisture 10.1%, protein (N × 5.7) 8.96%, fat 1.39%, ash 1.11%, reducing sugars 1.91%, and starch 84.9%) were obtained from Hemija Komerc, Novi Sad, Serbia. Vegetable fat originating from refined palm and sunflower oil (fatty acid composition: C16:0 – 43.2%; C18:1n9c – 42.5%; C18:2n6c – 9.5%; C18:0 – 4.7%; C14:0 – 0.96%; C20:0 – 0.42%) was obtained from Puratos NV, Groot-Bijgaarden, Belgium. Sodium hydrogen carbonate (≥ 99.5%, p.a.) was purchased from Carl Roth GmbH, Karlsruhe, Germany, carboxymethyl cellulose sodium salt (CMC) from Alfa Aesar GmbH, Karlsruhe, Germany, diacetyl tartaric acid esters of monoglycerides (DATEM) from InCoPa GmbH, Munich, Germany, while the other ingredients (salt, sugar and honey) were purchased at the local market.

2.2. Preparation of cookies

The formulation of gluten-free rice-buckwheat cookies (RF/LBF – 80:20) was made according to Sakač et al. (2015). Dough mixing, processing and baking were performed on a laboratory-scale equipment as described by the mentioned authors. The ingredients were weighed as follows: flour mixture (240.0 g of RF + 60.0 g of LBF), deionized water 75.0 g, vegetable fat 85.0 g, granulated sugar 70.0 g, honey 45.0 g, $NaHCO_3$ 9.0 g, DATEM 9.0 g, CMC 4.5 g, and salt 2.1 g. Rice/buckwheat flour mixture was transferred into Farinograph mixing bowl (Brabender GmbH, Duisburg, Germany), which was previously tempered at 30 °C. Afterwards, the rest of the dry ingredients and vegetable fat were added and mixed for 2 min. Finally, 45 g of honey which was previously dissolved in water was poured into the mixer bowl and the dough mass was mixed for 25 min at 30 °C. The obtained cookie dough was let to rest at 8 °C for 24 h in order to allow the hydration of the added CMC. After the resting period, the dough was tempered at ambient temperature for 30 min and then sheeted to a thickness of 4 mm using a pilot scale dough sheeter (Mignon, Mestrino, Italy). The dough was cut using a stainless mould (60 mm × 55 mm) and finally baked at 170 °C for 12 min in a laboratory oven (MIWE gustoR, MIWE Michael Wenz GmbH, Arnstein, Germany).

2.3. Packaging and storage of cookies

The gluten-free rice-buckwheat cookies were packed into 40 μm polypropylene/polypropylene (OPP/OPP) bags, which gas permeability was 3858.9 mL/m^2 24 h, 1 bar for CO_2, 1236.3 mL/m^2 24 h, 1 bar for N_2, and 418.9 mL/m^2 24 h, 1 bar for air. Cookies were packed under atmospheric conditions using a laboratory vacuum sealer (AudionElektro, Swissvac (GB) Ltd, Slough, Great Britain) with teflonized heating areas (vacuum pump was not used). Each cookie was packed separately. Packed cookies were investigated in comparison with those in a bulk form (unpacked cookies).

Both packed and unpacked cookies were stored in a climate chamber (Binder, Tuttlingen, Germany) at ambient and elevated temperature (23 ± 1 °C and 40 ± 1 °C). The relative humidity was set at a constant value of 40%. The storage period was 9 months for cookies kept at elevated temperature, while those kept at ambient temperature were stored during 16 months. The cookies were analysed monthly for all examined parameters, except sensory parameters, which were evaluated every 15 days during storage.

2.4. Proximate composition

Proximate composition of cookies including protein (Official Method No. 950.36), fat (Official Method No. 935.38), reducing sugar (Official Method No. 975.14), total dietary fiber (Official Method No. 958.29), ash (Official Method No. 930.22) and water contents (Official Method No. 926.5) were determined by standard methods of analysis (AOAC, 2000). Starch content was determined by hydrochloric acid dissolution according to the ICC Standard (1994, No. 123/1). Fatty acid composition of vegetable fat was determined by the method described by Milovanović et al. (2012).

2.5. Preparation of ethanolic extracts

Cookie powder (5 g) was mixed with 50 mL of ethanol/water (80/20, v/v). Extraction was carried out by shaking the mixture at room temperature (23 ± 1 °C) for 1 h. After 1-h shaking, the suspension was left overnight at room temperature. The procedure was repeated twice with 50 mL of solvent, and combined extracts were dried using a vacuum-evaporator. The dried extract was dissolved in ethanol/water (80/20, v/v) to 10 mL volume and used for further investigation of antioxidant activity.