sciendo

RURAL SUSTAINABILITY RESEARCH
49(344), 2023
ISSN – 2256-0939



Received: 20 April 2023 Revised: 12 May 2023 Accepted: 14 June 2023

Effect of Storage Period on Acid Value and Sensory Attributes of Puffed Wheat Grains 'Badyrak Vanilla' and 'Badyrak with Whey'

***Nurzat Konkubaeva[1,3], Asylbek Kulmyrzaev[2], Anarseit Deydiev[2], Vitalijs Radenkovs[3], Ruta Galoburda[3]**

[1]Institute of Technology, Kyrgyz State Technical University named after I. Razzakov, 66 Chyngyz Aitmatova prospect, Bishkek, Kyrgyzstan

[2]Kyrgyz-Turkish Manas University, Chyngyz Aitmatov Campus (Djal), Bishkek, Kyrgyzstan

[3]Latvia University of Life Sciences and Technologies, 2 Liela street, Jelgava, Latvia

Abstract. Puffed grains made from whole wheat, corn or rice grains are ready-to-eat breakfast cereals that do not require additional preparation. Two recipes for puffed grain coatings were developed in the previous studies. Sunflower oil was used in the coating, which may affect storage stability. Due to lipid hydrolysis, free fatty acids may be released, causing rancid off-flavour. The aim of this study was to determine the changes in the acid value of lipids and sensory attributes of sweet-coated puffed wheat grains 'Badyrak vanilla' (BV) and 'Badyrak with whey' (MC) depending on temperature during their eight-month storage. The products were packaged in metallised polypropylene pouches, 30 g each. The acid value was studied monthly at different storage temperatures (20 ± 2 °C and 4 ± 2 °C). In puffed wheat grain products, 65% of fatty acids are polyunsaturated, 25% monounsaturated, and 10% saturated. The high proportion of unsaturated fatty acids over saturated makes oil more susceptible to oxidation. Literature studies and sensory evaluation of puffed wheat grains allowed setting a limiting acid value at 4.0 mg KOH g^{-1} lipids. The increase in acid value was storage temperature dependent. Thus, the acid value exceeded the established limit in the fifth month for MC and the sixth month for BV when stored at 20 ± 2 °C. At the same time, noticeable changes in puffed wheat grain flavour were observed. The temperature coefficient (Q_{10}) for MC was 2.0, whereas for BV it was 1.5, indicating that the acid value increase in MC was more affected by temperature than that in BV.

Key words: puffed wheat grain, acid value, whey, fatty acids.

Introduction

The employment of the population in the modern world requires the creation of enriched products that are safe to eat and do not require additional time for cooking. Such products include breakfast cereals (Fast, Perdon, & Schonauer, 2020). Puffed grains are made from whole grains of wheat, corn and rice in a ready-to-eat form without additional preparation. Wheat is one of the staple products used to secure food stocks due to its shelf-stable nature and being rich in proteins, minerals, vitamins, and fibre. Sweet-coated puffed wheat grain is a ready-to-eat breakfast cereal that is very popular among consumers. Two recipes for puffed wheat grains, 'Badyrak vanilla' (BV) and 'Badyrak with whey' (MC) were developed by Konkubaeva (2016). The addition of whey improved sensory characteristics and enriched the product with vitamins B1, B2 and B6, as well as amino acids (Konkubaeva, Usubalieva, & Kojobekova, 2019). In the coating of these products, oil was used, which may be a limiting factor for the shelf-life of products due to the oil degradation. Technological processes and storage of food products are accompanied by various chemical changes, which depend on the product's composition and environmental factors. The most sensitive components of food products are lipids. Because of lipid oxidation, oxidative rancidity appears. In such cases, the food product becomes unfit for consumption (Rosentrater, 2022). The degree of unsaturation of fatty acids in the lipids affects the formation of rancidity.

The researchers analysed the change in acidity, moisture content, and other indicators during

* Corresponding Author's email: nkonkubaeva@gmail.com

DOI: 10.2478/plua-2023-0006

© 2023 N.Konkubaeva et al. This is an open access article licensed under the Creative Commons Attribution-NonCommercial-NoDerivs License (http://creativecommons.org/licenses/by-nc-nd/3.0/).

wheat flour storage and showed that the chemical characteristics changed during storage (Ohtsubo, 1995). Several studies have confirmed the decomposition of triglycerides during storage. Such changes include lipid hydrolysis forming free fatty acids (Atungulu Griffiths *et al.*, 2008; Park *et al*., 2012)respectively. Studies have shown that during long-term storage, wheat flour acidity increases (Hrušková & Machová, 2002; Jiang, Liu, & Chen, 2020b). Ageing during storage leads to numerous changes in cereals' chemical and physical properties, including an increase in the amount of free fatty acids (Ohtsubo, 1995). In the process of puffed wheat grain production, wheat grains are cleaned of impurities and the outer layer of the grains is removed. At the same time, wheat loses its protective layer and becomes more susceptible to chemical changes during storage (Obadi *et al.*, 2018). First lipid oxidation occurs, which is accompanied by the formation of peroxides and hydroperoxides. Also, with the attack of lipase, hydrolysis of neutral fats occurs with the formation of free fatty acids and glycerol (Obadi *et al*., 2018). Wu *et al*. (2016) confirmed that cereal storage time affects the accumulation of free fatty acids. The accumulation of free fatty acids leads to deterioration of sensory properties and deterioration of food suitability for consumption.

The acid value is commonly used to indicate quality deterioration during grain storage, as lipid degradation is faster than that of protein and starch degradation (Genkawa *et al*., 2008). Jiang, Liu & Chen (2020a) also reported that analysis of the change in free fatty acid content is a good method to assess the storage quality of wheat flour. The attractive sensory characteristics of foods are also important, as appearance influences the quality and enjoyment of food (Manzoor *et al*., 2021; Sebastião *et al.*, 2023).

Therefore, the aim of this study was to determine the changes in the acid value of lipids and sensory attributes of sweet-coated puffed wheat grains 'Badyrak vanilla' and 'Badyrak with whey' depending on temperature during their eight-month storage.

Materials and Methods

Materials. Durum wheat grains (*Triticum turgidum)*, sunflower oil, powdered sugar, vanillin, and whey powder were purchased from the Kyrgyz market. Reagent grade chemicals were purchased from Sigma Aldrich Cheli Ltd. (St. Louis, USA).

Puffing and coating of wheat grains. Coated puffed wheat grain was manufactured in the private enterprise Maky Dan LLC (Bishkek, Kyrgyz Republic). First, durum wheat grain was cleaned of impurities, moistened with warm water (35–40 °C) to a moisture content of 14.0–14.5%, and kept at this temperature for 14–16 h. Then, the grains were loaded into a preheated puffing gun B-35M (China), and the lid was closed hermetically, and heated for 15 min, raising the pressure in the apparatus to 1.0–1.2 MPa. The temperature in the device reached 220–240 °C. When the lid was opened, grains expanded due to pressure differences inside the grain and surrounding atmosphere. Puffed wheat grains without coating served as the raw material for the production of breakfast cereals – puffed wheat grains with sugar and vanillin 'Badyrak vanilla' (BV) and puffed wheat grains with sugar and whey powder 'Badyrak with whey' (MC). To obtain BV, powdered sugar, sunflower oil, and vanillin were added; for MC, powdered sugar, sunflower oil, and whey powder were added and mixed in a tumbler according to the procedure described by Konkubaeva (2016). The resulting products were packaged in hermetically sealed metallised polypropylene pouches (metPP), 30 g each and stored at 20 ± 2 ºC or 4 ± 2 ºC.

Proximate chemical composition. Moisture content of puffed wheat grains with coating was determined immediately after sample grinding, following the standard method 44-15A (AACC 44-15A, 2000). Total nitrogen and crude protein content (conversion factor 5.7) was determined according to the Kjeldhal method (AOAC 992.23, 2019) Fat content was analysed applying AOAC 2003.05 & 2003.06 (2006) methods. Ash content was determined gravimetrically after sample burning AOAC 923.03-1923 (2019). Total carbohydrates were calculated by subtracting individually determined constituents from total mass according to the equation (1):

$$\text{Carbohydrates} = 100 - (\text{Fat} + \text{Protein} + \text{Ash} + \text{Water}) \quad (1)$$

The temperature coefficient (Q_{10}) was calculated form the equation (2):

$$Q_{10} = \left(\frac{R_2}{R_1}\right)^{\frac{10}{T_2 - T_1}}, \quad (2)$$

where R_1, R_2 – reaction rate at temperature T_1 and T_2, respectively.

Acid value (AV; n = 3) of the puffed grains was determined immediately after sample grinding, following the standard method GOST 52466-2005. The method is based on the lipids extraction by n-hexane with subsequent solvent evaporation, drying, weighing the fat and titration of free fatty acids with a 0.1 M solution of potassium hydroxide (KOH).

The content of fatty acids was determined according to the procedure described by Radenkovs *et al.* (2022). Briefly, fatty acids were prepared for

Table 1

Sensory characteristics of puffed wheat grains

Sensory attribute	Description
Appearance	Products in the form of puffed grains
Colour	Typical for the respective type of product and the additives used. Dot-like spots of dark colour, characteristic of raw materials, are allowed
Flavour	Typical for the respective type of product, with the taste and aroma of the additives used, without foreign taste and aroma
Texture	Crispy, porous, airy

Table 2

The numerical unipolar scale applied in the sensory evaluation of puffed wheat grains

Sensory attribute	Points	Description
Appearance	0	Does not meet the requirements
	1	Puffed grains are deformed
	2	Most of the grains stuck to each other
	3	Sticking of grains to each other is noticeable
	4	Meets the requirements
	5	Perfectly meets the requirements
Colour	0	Does not meet requirements
	1	Deep darkening of the grains is noticeable
	2	Significant darkening of the grains is noticeable
	3	Slight darkening of individual grains is noticeable
	4	Meets the requirements
	5	Perfectly meets the requirements
Flavour	0	Does not meet requirements
	1	Pronounced bitterness and foreign rancid odour
	2	Noticeable bitterness and foreign rancid odour
	3	There is a bitterness and an inconspicuous foreign odour
	4	Meets the requirements
	5	The pronounced taste and aroma are characteristic of the product
Texture	0	Does not meet requirements
	1	Soft and sticky
	2	Feels slightly sticky
	3	Airy, less crispy
	4	Airy, crispy
	5	Perfectly meets the requirements

gas chromatography – mass spectrometry (GC-MS) analysis using 0.5 M trimethylphenylammonium hydroxide (TMPAH) solution in methanol reagent for methylation. The analysis of obtained fatty acid methyl esters (FAME) was completed on a Clarus 600 system equipped with a quadrupole analyser Clarus 600 C mass selective detector (Perkin Elmer, Ltd., Waltham, MA, USA). The GS-MS conditions were set according to the protocol provided by Radenkovs *et al.* (2022).

Sensory analysis. Panellists for sensory evaluation were selected and trained according to the guidelines for the selection, training and monitoring of assessors

laid down in the standard ISO 8586. In training, 45 participants (8 men and 37 women) – master degree students and teaching staff of the Institute of Technology, Kyrgyz State Technical University named after I. Razzakov were involved. The training of panellists consisted of several stages. First, a selection test was conducted. Training was then given on how to conduct assessments correctly and how to examine appearance, colour, flavour, and texture. Panellists were familiarised with the requirements for puffed wheat grains described in Table 1. Since the test samples are new products, and the additives used have a significant effect on flavour, the panellists were additionally familiarised with the requirements. Sample BV should have the flavour of a vanilla flavoured wafer, whereas sample MC should resemble the flavour of a milk ice cream flavoured wafer. As a result, 12 panellists (2 men and 10 women) were selected for sensory evaluation.

Before the sensory evaluation, all the samples under study were tempered to room temperature (20 ± 2 °C) since one of the samples was stored at a temperature of 4 ± 2 °C. Approximately 15 grams of samples were placed on the plate and coded with random three-digit numbers. The data was collected in pre-prepared forms. The panellists sequentially determined the appearance, colour, flavour and texture using a five-point scale, as shown in Table 2. During the evaluation, water was provided to clear the palate to prevent interference of flavour between samples.

Sensory evaluation was performed monthly during the eight-month storage; average scores are reported.

Statistical analysis. The results obtained are reported as the mean values ± standard deviation. The t-test was applied using Microsoft Excel 2016 software; if $p \leq 0.05$, differences among the variables were considered significant.

Results and Discussion

The proximate composition of puffed wheat grains BV and MC shows that moisture content in two types of products did not differ significantly (Table 3). The content of proteins in the BV sample was higher than in the MC because the addition of whey powder decreased the puffed wheat grain percentage in the product. Thus, a smaller proportion of protein was introduced in the puffed product from a protein-rich durum wheat (Yuksel & Kayacier, 2022breads were wasted by consumers due to staling and the aim of the study is to develop a new snack food by fortification of wheat chips with stale bread flour (SBF; Rincón-Aguirre *et al.*, 2022). The fat content also was higher in the BV compared to MC sample. The use of sunflower oil as an additive, along with other components, led to an increase in fats. The addition of whey powder reduced the percentage of oil in the product; hence, this reduced fat in the MC sample. The carbohydrate content was higher in the MC sample, possibly due to the lactose provided by whey. The ash content was also higher in the MC sample.

A high proportion of both monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids (Table 4) in developed puffed and coated wheat grains (24.88 and 64.59%, respectively) makes product more susceptible to lipid oxidation and hydrolysis. According to Mohammadi & Ostovar (2023), polyunsaturated fatty acids are more susceptible to decomposition due to enzymatic and non-enzymatic reactions.

The study results (Figure 1) show that acid value increased over time. According to the *Codex Alimentarius* (CODEX STAN 19-1981, 1981), the maximum acid value of fats and oils should not exceed 4.0 mg KOH g^{-1} lipids. The acid value of the BV sample (20 ± 2 °C) reached 3.8 ± 0.03 mg KOH g^{-1} lipids in the sixth month of storage and 4.1 ± 0.02 mg KOH g^{-1} lipids in the seventh month. The acid value remained within the acceptable range under storage conditions at 4 ± 2 °C. The acid value of the MC sample (20 ± 2 °C) reached 3.8 ± 0.03 mg KOH g^{-1} lipids in the fifth month of storage and 4.4 ± 0.02 mg KOH g^{-1} lipids in the sixth month. At low storage temperatures of this

Table 3

Proximate chemical composition of sweet-coated puffed wheat grains

Variables	Content in puffed wheat grains, g 100 g^{-1}	
	BV	MC
Moisture	3.21 ± 0.14a	3.14 ± 0.007b
Protein	7.62 ± 0.17a	6.16 ± 0.03b
Fat	16.05 ± 0.09a	14.41 ± 0.04b
Carbohydrates	72.37 ± 0.39b	75.12 ± 0.07a
Ash	0.75 ± 0.03b	1.17 ± 0.04a

Different letters in rows indicate significant differences between samples ($p \leq 0.05$).

Table 4

Fatty acid profile in puffed grain products before storage

Fatty acid group	Fatty acid profile in puffed wheat grains, % from fatty acids	
	BV	MC
Saturated fatty acids (SFA)	10.22	10.53
Monounsaturated fatty acids (MUFA)	24.77	24.88
Polyunsaturated fatty acids (PUFA)	65.01	64.59

sample, the acid value was within the acceptable range also after eighth-months of storage. Salman & Copeland (2007) used the amount of free fatty acids value as a measure of the storage quality of wheat flour. It has been confirmed that the higher the storage temperature, the faster the fat decomposition occurs, resulting in increased free fatty acid content. The accumulation of free fatty acids may lead to the formation of bitterness (Nikolić *et al.,* 2008). Controlling the formation of free fatty acids is essential since it allows eliminating the development of off-flavour in stored produce and ensures long-term storage.

Faster degradation of lipids led to an acid value increase in MC compared to BV, which may be due to higher ash content in MC (Table 4), when iron and other minerals present in the product may act as pro-oxidants (Noon, Mills, & Norton, 2020). The slower acid value increase in BV may also be due to the ability of vanillin to act as an antioxidant (Tai, Sawano, & Yazama, 2011). Analysis of data (Figure 1) allowed calculating the temperature coefficient Q_{10}, which shows the factor by which the rate of reaction increases for every 10 degrees. The obtained Q_{10} values were 1.5 and 2.0 for BV and MC, respectively. It is consistent with the findings of Zhou *et al*. (2002), who reported the effect of temperature and light on the rate of hydrolysis and oxidation.

The sensory evaluation revealed that during the first three months, the sensory attributes of the samples did not change. Therefore, data for the first, second, and third months were not included in Figure 2. However, changes in flavour, texture and appearance were observed during subsequent storage.

When stored at 20 ± 2 °C, the first changes in flavour were noticeable in the MC sample in the fifth month of storage (3.8 points). In contrast, in the BV sample,

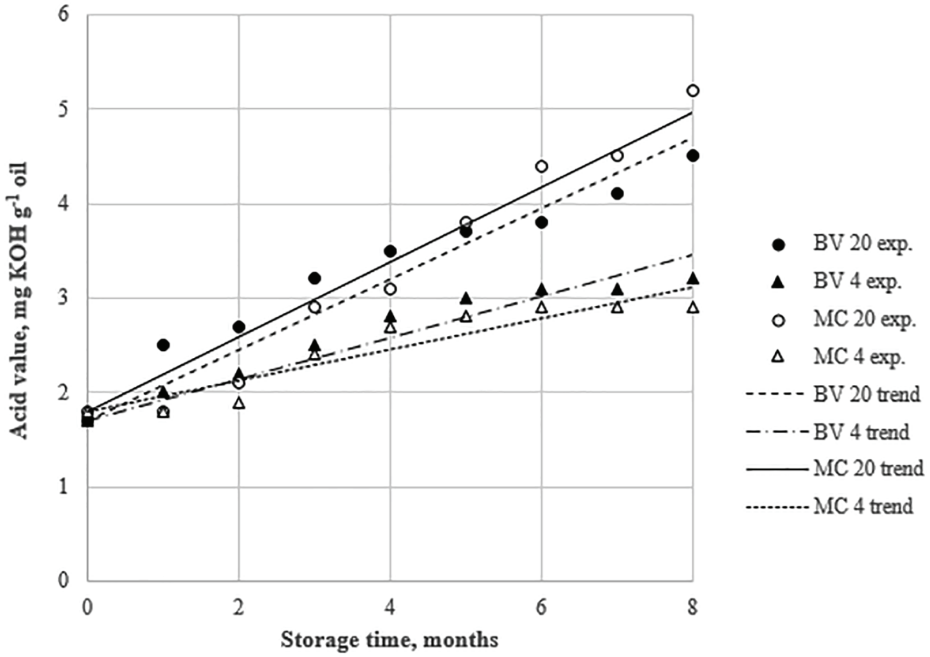


Figure 1. Changes in the acid value of puffed wheat grains 'Badyrak vanilla' (BV) and puffed wheat grains 'Badyrak with whey' (MC) during eight-months of storage depending on temperature (20 ± 2 °C and 4 ± 2°C). Numbers along the sample abbreviations indicate storage temperature; exp. – experimental values; trend – the trend line fitted to experimental data.

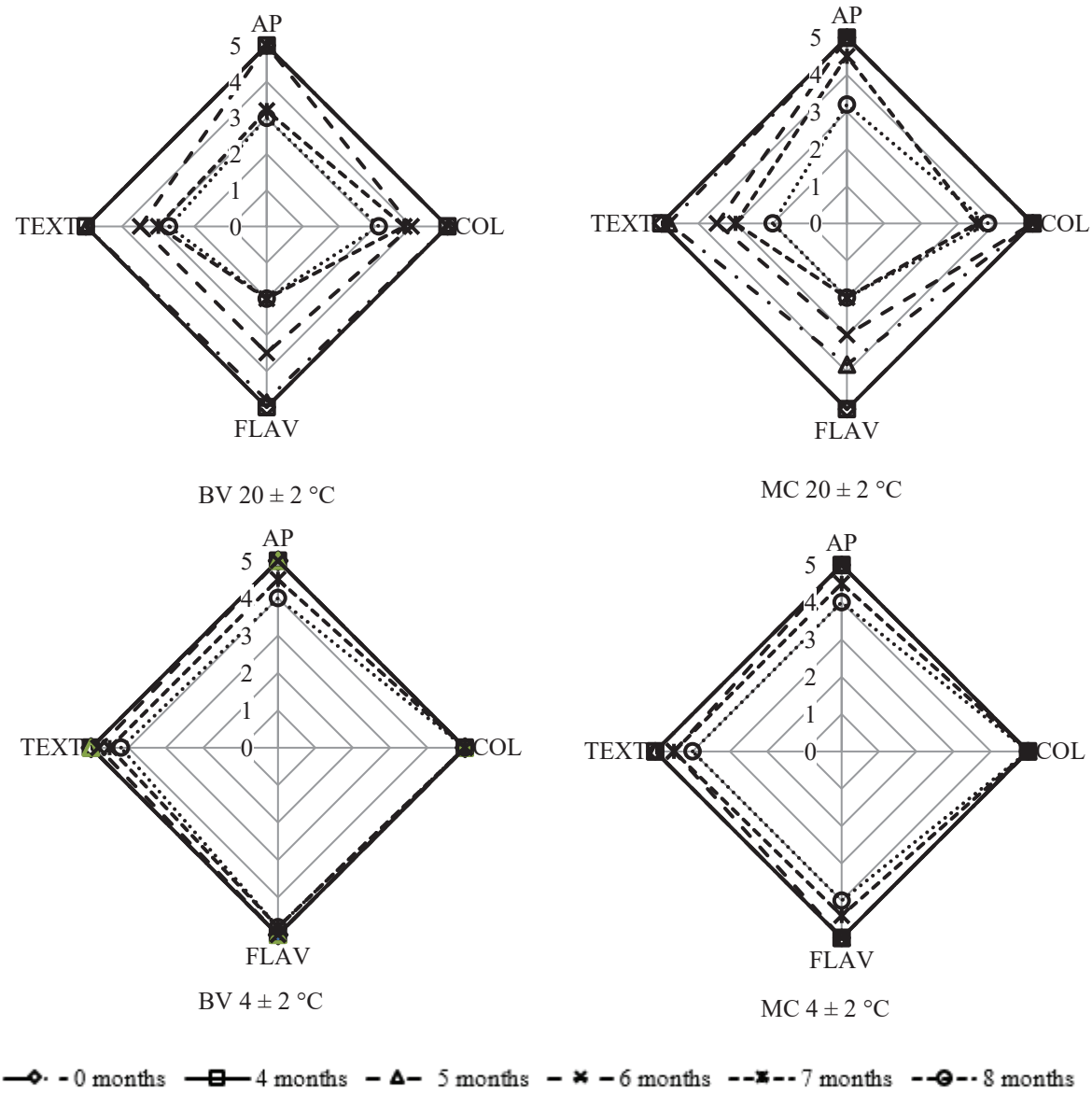


Figure 2. Sensory attributes of puffed wheat grains with vanilla flavour (BV) and whey (MC) during their 8-month storage at 20 ± 2 °C and 4 ± 2 °C. AP – appearance; COL – colour; FLAV – flavour; TEXT – texture.

the first changes in flavour were observed in the sixth month of storage, corresponding to 3.5 points. Panellists highlighted that the sample BV had bitter notes and off-flavour. Then, changes in the texture were evident, the grains became less crispy in the sixth month of storage, and the values corresponded to 3.5 points (BV 20 ± 2 °C) and 3.5 points (MC 20 ± 2 °C). In the remaining samples, which were stored at temperature of 4 ± 2 °C, changes in flavour were less pronounced, but in the seventh month of storage, the grains became less crispy, which also is an important quality parameter of puffed wheat grains and should be further studied.

Acid value correlated with sensory scores. When the acid value exceeded the limit in the fifth or sixth month of storage, the overall sensory quality received lower scores, primarily due to the changes in flavour and the appearance of an unpleasant aftertaste.

Conclusions

This study evaluated the acid value and sensory attributes of puffed wheat grains 'Badyrak vanilla' (BV) and 'Badyrak with whey' (MC) at various storage conditions. The changes in the flavour of the MC sample were observed in the fifth month of storage at 20 ± 2 °C, when the acid value reached 3.8 ± 0.03 mg KOH g^{-1} lipids being close to the critical limit. The BV sample at the same storage temperature after six months of storage also exhibited noticeable changes

in flavour. In the following months of storage, the acid value reached 4.4 ± 0.02 mg KOH g^{-1} lipids in MC and 4.1 ± 0.02 mg KOH g^{-1} lipids in the BV sample. The acid values were within the acceptable range at low storage temperatures until the eighth month of storage. The calculated temperature coefficients (Q_{10}) indicated that the acid value increase in MC was more affected by temperature than that in BV.

References

AACC 44-15A. (2000). Moisture – air – oven methods. Approved methods of the American Association of Cereal Chemists. St.Paul.

AOAC 2003.05. (2006). Crude fat in feeds, cereal grains, and forages. Official Methods of Analysis of AOAC International. Arlington.

AOAC 923.03-1923. (2019). Ash of flour. Direct method. Official Methods of Analysis of AOAC International. Arlington.

AOAC 992.23. (2019). Crude protein in cereal grains and oil seeds. Official Methods of Analysis of AOAC International. Arlington.

Atungulu Griffiths, G., Toshitaka, U., Fumihiko, T., & Daisuke, H. (2008). Effect of vapors from fractionated samples of propolis on microbial and oxidation damage of rice during storage. *J. Food Eng.* 88(3), 341–352. https://doi.org/10.1016/j.jfoodeng.2008.02.019

Fast, R. B., Perdon, A. A., & Schonauer, S. L. (2020). Breakfast—Forms, ingredients, and process flow. In A. A. Perdon, K. S. Poutanen, & S. L. Schonauer (Eds.), *Breakfast Cereals and How They Are Made: Raw Materials, Processing, and Production* (pp. 5–35). AACC International Press. https://doi.org/10.1016/B978-0-12-812043-9.00002-3

Genkawa, T., Uchino, T., Inoue, A., Tanaka, F., & Hamanaka, D. (2008). Development of a low-moisture-content storage system for brown rice: Storability at decreased moisture contents. *Biosys. Eng.* 99(4), 515–522. https://doi.org/10.1016/j.biosystemseng.2007.12.011

GOST 52466-2005. (2005). Grain and grain products. Method for determination of acid number of fat. Moscow.

Hrušková, M., & Machová, D. (2002). Changes of wheat flour properties during short term storage. *Czech J. Food Sci.* 20(4), 125–130. https://doi.org/10.17221/3522-cjfs

ISO 8586:2023. (2023). Sensory analysis – General guidance for the selection, training and monitoring of assessors. Geneva.

Jiang, H., Liu, T., & Chen, Q. (2020a). Dynamic monitoring of fatty acid value in rice storage based on a portable near-infrared spectroscopy system. *Spectrochim. Acta - Part A: Mol. Biomol. Spectrosc.* 240, 118620. https://doi.org/10.1016/j.saa.2020.118620

Jiang, H., Liu, T., & Chen, Q. (2020b). Quantitative detection of fatty acid value during storage of wheat flour based on a portable near-infrared (NIR) spectroscopy system. *Infrared Phys. Technol.* 109, 103423. https://doi.org/10.1016/j.infrared.2020.103423

Konkubaeva, N. (2016). Opportunities to improve the nutritional value of breakfast cereals. *News of KSTU Named after I. Razzakov*, 3(39), 153–158.

Konkubaeva, N., Usubalieva, A., & Kojobekova, K. (2019). Analysis of the content of vitamins and minerals in puffed wheat "Badyrak vanilla" and "Badyrak with whey." In *The collection includes scientific-materials of the International conference participants on the theme of "Food safety, resources, energy-efficiency and innovative technologies"* (pp. 376–378). Namangan.

Manzoor, M., Singh, J., Gani, A., & Noor, N. (2021). Valorization of natural colors as health-promoting bioactive compounds: Phytochemical profile, extraction techniques, and pharmacological perspectives. *Food Chem.* 362, 130141. https://doi.org/10.1016/j.foodchem.2021.130141

Mohammadi, N., & Ostovar, N. (2023). Chemical composition, fatty acid composition, and volatile compounds of a traditional Kurdish fermented cereal food: Tarkhineh. *Food Chem. Adv. 2*, 100187. https://doi.org/10.1016/j.focha.2023.100187

Nikolić, N., Radulović, N., Momcilović, B., Nikolić, G., Lazić, M., & Todorovic, Z. (2008). Fatty acids composition and rheology properties of wheat and wheat and white or brown rice flour mixture. *Eur. Food Res. Technol.* 227, 1543–1548. https://doi.org/10.1007/s00217-008-0877-z

Noon, J., Mills, T. B., & Norton, I. T. (2020). The use of natural antioxidants to combat lipid oxidation in O/W emulsions. *J. Food Eng.* 281, 110006. https://doi.org/10.1016/j.jfoodeng.2020.110006

Obadi, M., Zhu, K. X., Peng, W., Sulieman, A. A., Mahdi, A. A., Mohammed, K., & Zhou, H. M. (2018). Shelf life characteristics of bread produced from ozonated wheat flour. *J. Texture Stud.* 49(5), 492–502. https://doi.org/10.1111/jtxs.12309

Ohtsubo, K. (1995). Quality control: Chemical components and analysis thereof. In S. Chikubu (Ed.), *Rice post-harvest technology* (pp. 450–469). Tokyo: The AEC Corporation.

Park, C. E., Kim, Y. S., Park, K. J., & Kim, B. K. (2012). Changes in physicochemical characteristics of

rice during storage at different temperatures. *J. Stored Prod. Res.* 48, 25–29. https://doi.org/10.1016/j.jspr.2011.08.005

Radenkovs, V., Juhnevica-Radenkova, K., Kviesis, J., & Valdovska, A. (2022). An environmentally friendly approach for the release of essential fatty acids from cereal by-products using cellulose-degrading enzymes. *Biology* 11, 721. https://doi.org/doi.org/10.3390/biology11050721

Rincón-Aguirre, A., Figueroa-Cárdenas, J. de D., Ramírez-Wong, B., Ibba, M. I., & Martínez Cruz, E. (2022). Nixtamalization of durum wheat and the effect on protein secondary structure, gliadins, dough, and breadmaking quality. *J. Cereal Sci.* 107, 103539. https://doi.org/10.1016/j.jcs.2022.103539

Rosentrater, K. A. (2022). Biochemical, functional, and nutritive changes during storage. In K. A. Rosentrater (Ed.), *Storage of cereal grains and their products* (pp. 443–501). Duxford, Cambridge, Kidlington: Woodhead Publishing. https://doi.org/https://doi.org/10.1016/B978-0-12-812758-2.00010-6

Salman, H., & Copeland, L. (2007). Effect of storage on fat acidity and pasting characteristics of wheat flour. *Cereal Chem.* 84 (6), 600–606. https://doi.org/10.1094/CCHEM-84-6-0600

Sebastião, V. G., Batista, D., Rebellato, A. P., Alves Macedo, J., & Steel, C. J. (2023). Sustainable production of naturally colored extruded breakfast cereals from blends of broken rice and vegetable flours. *Food Res. Int.* 172, 113078. https://doi.org/10.1016/j.foodres.2023.113078

Tai, A., Sawano, T., & Yazama, F. (2011). Antioxidant properties of ethyl vanillin in vitro and in vivo. *Biosc. Biotechnol. Biochem.* 75(12), 2346–2350. https://doi.org/10.1271/bbb.110524

Wu, J., McClements, D. J., Chen, J., Liu, W., Luo, S., & Liu, C. (2016). Improvement in storage stability of lightly milled rice using superheated steam processing. *J. Cereal Sci.* 71, 130–137. https://doi.org/10.1016/j.jcs.2016.08.006

Yuksel, F., & Kayacier, A. (2022). Effects of addition of stale bread flour on the acrylamide, fatty acid composition, resistant starch content, and in vitro glycemic index in wheat chips production using response surface methodology. *LWT - Food Sci. Technol.* 161, 113354. https://doi.org/10.1016/j.lwt.2022.113354

Zhou, Z., Robards, K., Helliwell, S., & Blanchard, C. (2002). Ageing of stored rice: Changes in chemical and physical attributes. *J. Cereal Sci.* 35(1), 65–78. https://doi.org/10.1006/jcrs.2001.0418

Acknowledgement

This study was supported by Latvian State scholarship (Agreement No. 2.5.-18/6).