Agronomy Research **16**(S2), 1388–1395, 2018
https://doi.org/10.15159/AR.18.139

Effects of processing conditions on physical parameters of triticale flakes

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Abstract. Consumer interest in breakfast cereal flakes has increased during the last few years. Various technologies, used to produce flakes, significantly influence their quality parameters and shelf-life stability. The main purpose of the present research was to investigate how different processing methods affect the physical parameters of triticale flakes. For obtaining the flakes, cleaned whole triticale grains were treated using the following technologies: dry processing (hot air), steam processing and soaking with subsequent steaming. For preparing the flakes different kilning methods and traditional flaking rolls were used. Traditionally made rolled and dried whole grain triticale flakes were analysed as a control sample. Using standard methods, the flakes' moisture content, water activity, microstructure, swelling capacity and colour changes were analysed. The gap settings of flake rollers do not influence significantly ($P < 0.05$) changes of starch during processing. However, the starch granules were fully transformed into sugars in the flake samples with greater thickness. Non-significant ($P < 0.05$) steaming and hot air drying (toasting) conditions' effects were observed on the changes of the starch granules during processing. Strong correlation was determined during the analysis of water activity and moisture content. The moisture content of the ready- to-eat flakes varied from 2.54% to 10.66%, and the water activity value was from 0.108 to 0.494. Compared with traditionally processed flakes (control sample) the colour of the flakes prepared using other technologies changed significantly, the ΔE values varied from 9.587 to 18.554. The colour of the soaked-steamed-rolled-hot air dried samples was similar but those significantly differed from the colour of soaked-dried-rolled-hot air dried flake samples. The soaked-dried-rolled-hot air dried flakes were darker compared with other analysed flake samples.

Key words: triticale flakes, technology, quality.

INTRODUCTION

Nowadays, breakfast cereals are one of the basic elements in the human diet (Mathebula et al., 2017). In general, breakfast cereals are processed grains for human consumption, typically ready-to-eat. However, ready-to-eat cereals are produced by a variation of several technological operations such as cooking, shape forming, finish drying, flavouring, sweetening, enrichment with vitamins and minerals (Caldwell et al., 2016). Breakfast cereal products historically have been used as milled grains of wheat and oats, that required further cooking at home prior to consumption. Nowadays, due to the efforts to reduce in-home preparation time, breakfast cereal technology has evolved from a simple procedure to the manufacturing of ready-to-eat products that are convenient and quickly prepared (Mbaeyi-Nwaoha, 2016). Most ready-to-eat cereals may be grouped into several general categories regarding their manufacturing processes: flaked cereals (corn flakes, wheat flakes, and rice flakes), including extruded flakes, gun-puffed whole grains, extruded gun-puffed cereals, shredded whole grains, extruded and other shredded cereals, oven-puffed cereals, granola cereals, extruded expanded cereals, baked cereals, compressed flake biscuits, muesli-type products, and filled bite-size shredded wheat (Fast, 2000). The basic flake making process includes the following main processing stages: starch gelatinisation, browning reaction, interrupting the enzymatic process, sugars dextrinization, caramelisation and moisture reduction (Matz, 1991).

Traditionally, in the world flaked, puffed, shredded, and cooked ready-to-eat cereals are made from whole grains or parts of grains of corn, wheat, rice, or oat (Caldwell et al., 2016). Nowadays, the manufacturers are paying more and more attention to use untraditional cereals in flake production like triticale. For example, triticale flakes should be used as one of the compounds in flake mixtures obtaining a ready-to-consume product with elevated nutritive value, good sensory properties and appropriate shelf-life (Kince et al., 2017).

In general, triticale (× *Triticosecale* Wittmack) was developed by crossing rye and wheat (McGoverin et al., 2011). The results presented in a review by Zhu (2018) conclude, that world production of triticale has been increased during the last few years because triticale has higher starch, arabinoxylans, β-glucans, fructans, lignins, proteins (including α-amylase), alkylresorcinols, vitamins, and polyphenols contents. However, Fraś et al. (2016) indicate, that triticale varieties with a favourable chemical composition from a nutritional and technological perspective can be a good material for flour and bread production. Arendt & Zannini (2013) indicate, that triticale offers a better amino acid balance, mainly due to the high lysine content, resulting a greater biological value than wheat protein.

The main purpose of the present research was to investigate how different processing methods affect the physical parameters of triticale flakes.

MATERIALS AND METHODS

Flake sample preparation

In the present experiment three different technologies for flake production were used: commercially processed flakes (control sample) - purchased ready-made triticale whole grain flakes (mixture of several cultivars) from JSC Dobeles dzirnavnieks (Latvia). The processing technology includes cleaned triticale grain steaming, rolling and drying.

Samples with the first code 1 (cooking technology 1) - cooked triticale flakes were obtained by 1 min steaming, and applying pressure 0.5 ± 0.1 bar for 10 min and at different flaking roll gap settings (respectively, sample 1/3/1 - 0.06 ± 0.01 mm and sample 1/4/1 - 0.04 ± 0.01 mm). Processed triticale flakes were transferred for drying into Mitchell Bach Dryer (GmbH Baker Perkins, UK) for 35 ± 5 min at 80 ± 1 °C. Samples with the first code 2 (cooking technology 2) - triticale grains were transferred into Rotary Cereal Cooker (GmbH Baker Perkins, UK) with adding of extra water 20 ± 3% from grains total amount, after that samples were 5 min steamed and cooked 30 ± 5 min at pressure 1.2 bar. Samples 2/1/2/1, 2/1/3/1, 2/1/4/1 differed by flaking roll gap settings, respectively, 0.10 ± 0.01, 0.06 ± 0.01 and 0.04 ± 0.01 mm gap. Processed triticale flakes were transferred for drying into Mitchell Bach Dryer (GmbH Baker Perkins, UK) at 80 ± 1 °C for 30 ± 5 min.

Toasting procedure was performed in decreasing temperatures under 200 ± 10 °C for less than one minute in the toaster New Thermoglide Toaster Rig (GmbH Baker Perkins, UK).

Moisture content

Moisture content of triticale flakes was determined using air-oven method (AACC Method 44-15.02) by drying of 5.00 ± 0.05 g sample in the oven Memmert (GmbH Memmert, Germany) - for 1 hour at 110 ± 5 °C temperature. The analyses of moisture content were done in triplicate.

Water activity (aw)

Water activity (aw) was determined using LabSwift-aw (AG Novasina, Switzerland) equipment. Ground flakes were used for the determination of water activity. The analyses of water activity were done in triplicate.

Colour

The colour of triticale flakes was determined using ColorTec-PCM/PSM (Accuracy Inc., USA) in the colour system CIEL*a*b* (L*0 = black, 100 = white, a* + value = red, a* - value = green, b* + value = yellow, b* - value = blue). Ground flakes were used for the determination of colour. Ten readings for each sample determined the colour, and the total colour difference (ΔE) was calculated using Minolta equations (Chakrborty et al., 2011).

Starch microstructure

Starch microstructure was determined using the method described by Rakcejeva et al. (2016) using triocular microscope 'Leica DM 2500 LED HD' (Leica Microsystems, Germany); via 10 × 20 magnification of the microscope.

Statistical analysis

Microsoft Excel 2013 software was used for mathematical data processing. The hypothesis of the thesis was verified with *P*-value method, and factors were evaluated as significant if $P < \alpha_{0.05}$. For the interpretation of the results it was accepted, that $\alpha = 0.05$ with 95% confidence. Tukey's test was used to determine differences among the samples.

RESULTS AND DISCUSSION

Moisture content and water activity. Moisture content influences not only the shelf-life of foodstuffs but also their taste, texture, weight and appearance. Usually, a slight deviation from a defined necessary value has significant impact on the physical properties of a food product. On the other hand, water activity (a_w) of the food product represents the energy status of water molecules, which influences various biochemical reaction and microbial growth in food products (Labuza, 1975).

Moisture content 10–12% is sufficient to provide appropriate quality for dry cereal product during their storage. In the present research we found a significant technologies' impact (*P < 0.05)* on the moisture content of flakes and water activity changes in triticale flakes. The moisture content of control flake samples was relatively high 10.665% compared with other flake samples (Table 1), that can mainly indicate their comparatively lower quality stability during storage. However, a strong correlation (R = 0.98604) was established between moisture content and water activity changes of the analysed whole-grain triticale flake samples. Significant impact of the different technologies on moisture content and a_w was also observed (Table 1). Compared with control flake sample, it is possible to reduce significantly ($P < 0.05$) the moisture content in the product by using different technological ways maximally by 4.2 times (sample 1/4/1). On the other hand, higher moisture content was obtained in samples 2/1/2/1 (6.23%), 2/1/3/1 (4.68%) and 2/1/4/1 (4.42%) that could be explained with extra water addition during flake processing (cooking technology 2). At the same time, the moisture content of ready-to-consume products should be lower, if the density of flakes is lower.

Table 1. Changes of flake moisture and water activity (a_w)

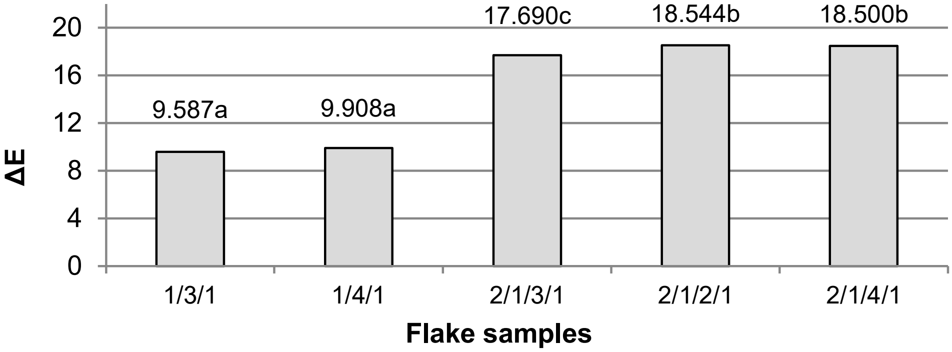
Flake samples	Moisture content, %	a_w
Control	10.67 ± 0.16^a	0.494 ± 0.040^a
1/3/1	3.62 ± 0.01^d	0.155 ± 0.010^d
1/4/1	2.55 ± 0.01^d	0.108 ± 0.006^d
2/1/2/1	6.23 ± 0.05^b	0.339 ± 0.004^b
2/1/3/1	4.68 ± 0.05^c	0.231 ± 0.001^c
2/1/4/1	4.42 ± 0.02^c	0.225 ± 0.001^c

Different letters represent significant differences between values ($P < 0.05$).

Katz & Labuza (1981) indicated in their study, that critical water activities, where the crispy products became sensory unacceptable, generally are in the 0.35–0.50 a_w range. However, Waichungo et al. (2000) indicated, that the critical water activity, the water activity at which the textural characteristics of the extruded puffed corn starch samples significantly changed, was determined to be between 0.36–0.58, which mainly confirms the results obtained from this particular study.

Colour changes. Traditionally, consumers accept food because of their visual aspects before tasting and purchase. Therefore, colour is the most decisive element for food choice (Lee et al., 2013). In this case, ΔE colour value can help evince colour differences of the analysed products, through calculation of values, which correlates with the human visual attitude to differences between two presented colours (McGrath et al., 2017).

In the present research a significantly different ($P < 0.05$) colour was obtained for all flakes with different processing method compared to control flake samples (Fig. 1). After processing, the flakes become two times darker colour than the control sample, especially samples 2/1/2/1 and 2/1/4/1 (ΔE = 18.500–18.544). The darker colour of the obtained samples mainly could be explained with the additional drying during flake production and higher (1.2 bar) cooking pressure (cooking technology 2). However, the samples produced using technology 1 were slightly lighter in colour, but they were darker compared with the control flake sample (ΔE = 9.908–9.587). Ilo & Berghofer (1999) in their research concluded that the kinetic rate constants for the colour for the extruded products depend on the product temperature and feed moisture content. Therefore, lower processing temperatures, time and moisture content of raw material could provide lighter colour of triticale flakes in the future.



Different letters represent significant differences between values (P < 0.05)

Figure 1. Colour differences of analysed flake samples.

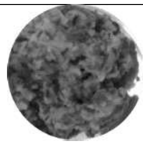
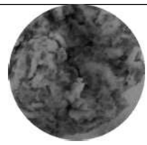
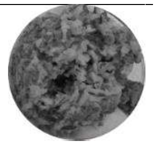
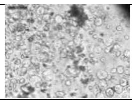
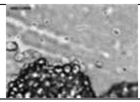
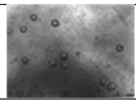
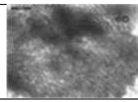
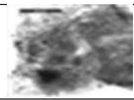
Flake swelling. The main changes with starch granules occur in the product during its thermal processing. Food porosity and relative density, as well as granule diameter, granule size distribution play an important role in mastication, bolus formation, and transportation of the bolus in the human gastrointestinal tract and in starch hydrolysis (Alam et al., 2017). For example, rolled oats usually are partially cooked during processing and softened because of the steam treatment. Porridge made from rolled oats requires only a brief domestic cooking time to complete the process of starch gelatinisation (Kent & Evers, 1994). The retrogradation of starch also occurs during the thermal processing of breakfast cereals, resulting textural changes such as increased hardness and reduced stickiness (Kong & Singh, 2011).

In the present experiments a significant technology influence ($P < 0.05$) was observed in the starch granules of the analysed flake samples. Mainly, starch granules were distinctly visible in the control flake samples (Table 2). However, after making flakes by using different technological parameters, the size of starch granules changed significantly (P < 0.05). Use cooking technology 1, the main influence was observed on triticale flake thickness, in the thin samples starch was practically gelatinised (Table 2). Similar results were obtained when using cooking technology 2. However, during flake manufacturing process using both technologies, the size of starch granules changed significantly (approximately by 18%) compared with control flake samples. Starch gelatinisation processes occur more quickly in thin samples processed under pressure and for longer time.

Gelatinisation and retrogradation are the key functional properties of starch that indicate the quality and nutritional value of starchy foods such as breakfast cereals. However, starch retrogradation is advantageous in some technologies, such as in the production of breakfast cereals, due to modification of the structural, mechanical, and sensory properties of ready-to-eat products (Wang et al., 2015). For example, beans that had been pressure cooked have significantly increased rapidly digestible starch and slowly digestible starch, and decreased resistant starch. But the increased digestibility of rice starch is associated with lower amylose content (Toutounji, 2015).

In the present research for visual appearance of cereal flakes the water absorption capacity of breakfast cereals was determined using method described by Kince et al. (2017) with modifications. Starch granule degradation observed with microscope (Table 2) had strong visual correlation with unacceptable appearance of flakes, soaked in water. The samples with malted starch granules were similar to porridge. However, flake samples with visible starch granules (18.19 µm and 18.32 µm) had better consistency and apperance (samples 1/3/1 and 2/1/2/1). However, it should be noted, that the control flakes practically had not changed their appearance after soaking, which mainly could indicate their inconvenient mastication during their future use in human diet.

Table 2. Microstructure and appearance of cereal flakes

Flake sample	Control	1/3/1	1/4/1	2/1/2/1	2/1/3/1	2/1/4/1
Appearance of cereal flakes						
Overview of starch granules						
Equivalent diameter of starch granules, µm	22.04 ± 8.03	18.19 ± 4.38	gelatinised starch*	18.32 ± 2.65	gelatinised starch	gelatinised starch

*gelatinised starch – starch granules were completely dissolved.

The changes in pressure and temperature during flake processing increase the content of damaged starch up to 80% and induce deep structural modifications of the starch granules which become no longer identifiable - starch is gelatinised. These physical changes may affect starch digestibility too, because the damaged starch is more exposed to amylolytic enzymes than native starch (Cattaneo et al., 2015).

CONCLUSIONS

1. The results of the present research demonstrate significant influence of technology ($P < 0.05$) on the physical properties (moisture content, water activity, colour and swelling capacity) of ready-to-eat flakes.

2. As a result, it is possible to achieve better ready-to-eat product quality by variation of flake thickness and extra water addition during processing - the physical parameters of thicker (0.10 ± 0.01 mm gap) sample changed less than those of the thinner ones.

3. It is possible to significantly influence the starch gelatinisation process resulting increased digestibility.

ACKNOWLEDGEMENTS. The present research leading to these results in accordance with the contract No. 1.2.1.1/16/A/004 between 'Latvian Food Competence Centre' Ltd. and the Central Finance and Contracting Agency (11.11.2016), has been conducted by 'Felici' Ltd. with the support from the European Regional Development Fund (ERDF) within the framework of the project 'Latvian Food Industry Competence Centre'.

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