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Microbial quality and physicochemical property changes of Anggun sweet potato breakfast cereal during storage

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Abstract

Studies on quality changes of Anggun sweet potato breakfast cereal had been conducted for a 6-month storage period. Freshly prepared breakfast cereal samples were packed in Ony/Al/PE pouches (28 cm × 21.5 cm with 0.10 mm thickness) and stored at 27±3°C with relative humidity (RH) of 70-75%. Results showed that the lightness (L*) and red colour (a*) values were not significantly different, yellow colour (b*) values decreased, while the moisture content was in the range for the cereal products category during the storage period. The mesophilic bacteria, yeast and mould counts were within the acceptable limits for direct consumption. There was less than 1.0 log CFU/g for coliform bacterium and *Bacillus cereus* counts in the samples throughout the storage period. The anthocyanin content of the sample was 12.04±0.04 mg/100g at the end of storage. Anggun sweet potato cereal packed in Ony/Al/PE was found to be of an acceptable quality for up to 6 months when stored at 27±3°C (70-75% RH) and has the potential to be used as an alternative healthy breakfast cereal.

1. Introduction

The role of breakfast cereals in a balanced diet has been recognized for many years (Toma and Curtis, 1989; McKevith, 2004; McKevith and Jarzebowska, 2010). Breakfast provides a critical input of calories and nutrients for most of us at the start of the working day. Dietary guidelines note that the high nutrient density of breakfast cereals (especially those that are whole grain or high in cereal fiber) makes them an important source of key nutrients (National Health and Medical Research Council, 2013). In addition to providing an important source of vitamins and minerals, breakfast cereals are also important sources of antioxidants (Miller *et al.*, 2000; Baublis *et al.*, 2000; Ryan *et al.*, 2011) and phytoestrogens (Kuhnle *et al.*, 2009). As a result, the cereal industry has become a key provider of breakfast meals, offering a wide variety of products employing a wide range of cereal grains, either alone or in combination.

Breakfast intake has also been associated with reduced weight gain and chronic disease risk in longitudinal analyses (Cahill *et al.*, 2013; Bi *et al.*, 2015). Children who eat breakfast cereal, compared to other breakfasts or breakfast-skippers generally have healthier micronutrient profiles, including higher daily intakes of vitamins A and D, the B vitamins (thiamin, riboflavin, niacin, pyridoxine, folate) and the minerals such as iron, magnesium and zinc (Williams, 2014; Fayet -Moore *et al.*, 2016; Michels *et al.*, 2015; Barr *et al.*, 2014). Breakfast cereal is the main contributor of dietary fibre in the Australian diet (Australian Bureau of Statistics, 2014) and studies find that breakfast cereal consumers have higher daily intakes of whole grains. Breakfast cereal consumption is also an important driver of milk consumption, which facilitates higher calcium intakes (Williams, 2014).

This study uses purple sweet potatoes (Anggun variety) as the main ingredient in the production of breakfast cereals. Purple sweet potato is a functional food rich in anthocyanin that has been reported to possess unique colour, nutrition and disease-preventive properties (Hwang *et al.*, 2011). The intense colour of purple sweet potato is contributed by phenolic pigment known as anthocyanin. Anthocyanin is a member of the flavonoid group of phytochemicals, which have the outstanding antioxidant activity as well as anti-inflammatory properties, particularly when passing through our digestive tract (Teow, 2007; Mohanraj and Sivasankar, 2014). It has been reported that the concentration of anthocyanin in purple sweet potato is similar to the highest anthocyanin production crops, such as blueberries, blackberries, cranberries or grapes

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(Bridgers *et al.*, 2010).

Raw material characteristics and processing parameters are the major variables in the processes of agricultural products, such as thermal temperature, storage time, oxygen content, pH value, light, metal ion and enzyme activity (Martynenko and Chen, 2016). According Sui (2017) and Weber *et al.* (2017), thermal temperature, continuous illumination and storage time are equally important factors in affecting the degradation and colour change of anthocyanin. The studies by Kim *et al.* (2012) showed that the total content of anthocyanin in Korean purple sweet potatoes decreased by nearly half after steaming and the content of all monomer anthocyanins declined to various degrees. As this study involves the processing of using thermal temperatures to produce breakfast cereal products from purple sweet potatoes, it is necessary to monitor the stability of product quality. Therefore, the objective of this study was to determine the microbial quality and physicochemical property of Anggun sweet potato breakfast cereal during storage.

2. Materials and methods

2.1 Preparation of breakfast cereal sample

All the ingredients such as Anggun sweet potato flour (145 g), corn flour (100 g), sugar (24 g), roselle powder (5 g) and salt (1 g) were mixed thoroughly in a dough mixer. The well-mixed dough was extruded into a laboratory single screw extruder machine (Barabender, Germany). The temperature of the compression and the die section were adjusted at 85°C and 105°C respectively. The screw speed was kept around 60 rpm and 30 rpm for the feeding screw speed. The finished product was kept sealed in a plastic container prior to use.

2.2 Packaging and storage

Approximately 300 g of freshly processed Anggun sweet potato breakfast cereal was packed into oriented nylon/aluminium/polyethylene (Ony/Al/PE) sizes of 28 cm × 21.5 cm with 0.10 mm thickness. After that, these pouches were arranged in a storage cabinet and kept in the laboratory at 27±3°C with a relative humidity of 70-80% for 6 months. The sample was withdrawn monthly for analysis.

2.3 Microbiological analysis

Microbiological examination (total mesophilic aerobic counts, yeast and mould, coliform and *B. cereus*) was carried out on stored samples. About 10 g of samples were taken and transferred aseptically into a stomacher bag (Seward Medical, UK) containing 90 mL Ringer's solution (Oxoid, Hampshire, England) to give 10^{-1} dilution. The mixture was homogenized using a stomacher (Seward Lab Blender Model 400, London, UK) at room temperature. From the homogenate, serial dilutions were prepared in Ringer's solution and each dilution was poured into duplicate plates. Total mesophilic aerobic and yeast and mould counts were determined by poured plate methods using standard Plate Count Agar and Potato Dextrose Agar, respectively (ICMSF, 1978). Total coliform and *E. coli* in the homogenate were estimated by a poured plate method using Violet Red Bile Agar (AOAC, 1990). All plates were incubated at 37°C for 48 hrs. Microbiological data were transformed into logarithms of the number of colony-forming units (CFU) per g sample. Standard microbiological procedures were used for the detection of *B. cereus* in the samples (ICMSF, 1978).

$$TAC\ (mg/100\ g) = A/eL \times MW \times D \times V/M$$

Where, A = absorbance, e = molar absorbance for cyanidin-3-glucoside (26900), L = cell path length (1 cm), MW = molecular weight of cyanidin-3-glucoside (449.2 Da), D = dilution factor, V = final volume (mL) and M = the dry weight of powder sample (mg).

2.5 Colour measurement

The colour changes of breakfast cereal throughout the storage period were determined with a chromameter (CR 400 Minolta) by measuring the L*, a* and b* parameters. These values of a* and b* were used to compute the hue angle [$\tan^{-1}(b^*/a^*)$] and chroma values, $C^* = (a^{*2} + b^{*2})^{½}$ (Schanda, 2007). Five measurements on different areas of the sample surface were performed.

2.6 Moisture content

The moisture content of the cereal product was analysed by using the oven method (Pearson, 1976). Approximately 10 g of samples were put into an aluminium dish and dried in the oven overnight (12 Hrs) at 105°C. Then the dishes were removed and allowed to cool in a desiccator for 15 Mins before being weighed. Moisture content is given with the relation as below:

$$\text{Moisture content (\%)} = \frac{(\text{wet weight} - \text{dry weight})}{\text{wet weight}} \times 100$$

Where, moisture content is expressed on wet basis.

2.7 Statistical analysis

The data reported in the table is subjected to one-way analysis of variance (ANOVA). The mean values were compared using the Duncan Multiple Range Test throughout the storage period (Gomez and Gomez, 1984). Analyses were done in duplicate.

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3. Results and discussion

3.1 Microbial count

Mesophilic bacterial counts were not detected during the first 4 months of storage (Table 1). According to Forsido *et al.* (2021), thermal food processing techniques such as extrusion and roasting improve keeping qualities by reducing microbial load, enzyme activity and destruction of insects. However, the bacterial population was observable after 5 months of storage and increased by the sixth month with a log population density of 1.77 CFU/g. It might be due to the processing temperature (85 -105°C) used for the production of extruded cereals in this study was not sufficient to destroy all microorganisms in the product. Therefore, for a certain storage period, microorganisms can still reproduce under suitable conditions. Several conditions like water activity, the right temperature, nutrients and time are needed for microbial proliferation in foods (Fontana, 2008). Rampersad *et al.* (2003) reported that the high-temperature range of 120-125°C used for extrusion cooking was helpful in killing or reducing the number of microorganisms. However, the number of bacterial contents for 6 months of storage of cereals in this study is still below acceptable limits according to Ireland's Guidelines for the Microbiological Quality of Some Ready-to-Eat Foods at the Point of Sale.

The results also indicated that the populations of Coliform, *B. cereus* and yeast as well as mould were less than 1.0 log CFU/g throughout the study as shown in Table 1. It seems that the processing and handling activities of breakfast cereal samples were done in good hygiene condition. According to Gordon and Robertson (1993), extensive studies on metal foils have shown that microorganisms (including moulds, yeasts and bacteria) cannot penetrate into these materials in the absence of pinholes. Therefore, the use of appropriate packaging materials also can help in maintaining the quality of food products during storage.

3.2 Anthocyanin content

The anthocyanin content for freshly prepared breakfast cereal was 12.05 mg/100 g and this value slightly decreased to 12.04 mg/100 g at the end of storage (Figure 1). According to Chin-Chia *et al.* (2019), the light and temperature in the storage room are often the key factors for the shelf life of the product. Even if the food is not spoiled, the degradation of the bioactive ingredients and the colour appearance changes of the products still directly affect the consumer perception.

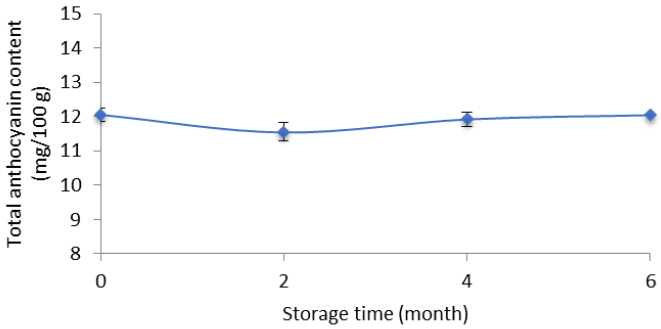

Figure 1. Total anthocyanin content changes of breakfast cereal during storage

It has been reported that anthocyanin converts to chalcones via an intermediate product in which C4 hydroxyl group ring is cleaved during illumination, and further oxidized to some lysate with time elapsing, such as 2,4,6-trihydroxybenzaldehyde, which causes anthocyanin degradation as well as discolouration (Furtado *et al.*, 1993; Zhao *et al.*, 2013). In addition, Weber *et al.* (2017) have also reported that thermal temperature, continuous illumination and storage time are equally important factors in affecting the degradation and colour change of anthocyanin. Nevertheless, the result showed that the anthocyanin content of breakfast cereal samples remained stable for a period of 6 months of storage. This might be due to the use of opaque packaging material (aluminium laminate) that protects the product from light, thereby slowing down the degradation process.

3.3 Colour measurement

Colour is an important parameter when comes to food products as it has an influence on the purchasing and preference of the product. L*-values beyond 50 indicate relatively lighter or brighter colours while

Table 1. Microbiological changes of breakfast cereal during storage

Storage time (month)	Microbial parameters			
	Mesophilic bacteria (log CFU/g)	Yeast and mould (log CFU/g)	Coliform (log CFU/g)	*Bacillus* sp. (log CFU/g)
0	< 1.0	< 1.0	< 1.0	< 1.0
1	< 1.0	< 1.0	< 1.0	< 1.0
2	< 1.0	< 1.0	< 1.0	< 1.0
3	< 1.0	< 1.0	< 1.0	< 1.0
4	< 1.0	< 1.0	< 1.0	< 1.0
5	1.71	< 1.0	< 1.0	< 1.0
6	1.77	< 1.0	< 1.0	< 1.0

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values below 50 represent darker colours (Falade and Oyeyinka, 2010). The initial L* value of freshly prepared breakfast was 57.57±0.85. This means that the breakfast cereal product used in this study was a brightly coloured category. There was no significant difference ($p>0.05$) in L*value at the first 4 months of storage (Table 2). However, the L* value was found significantly increase ($p<0.05$) after 5 months of storage, showing that the breakfast cereal became brighter for a longer storage period. Damian *et al.* (2017) also reported a similar trend in products that had been produced from orange-fleshed sweet potatoes.

Generally, the a* values parameter of the sample was found significantly ($p<0.05$) decreased after a month of storage. However, the rate of depreciation of a* value was relatively slow within 6 months of storage. The reduction of a* value may be given an interpretation that the red colour has decreased in the sample. The sample was found to be relatively more in the red region (Table 2) and this could be attributed to the breakfast cereal composition content. At the same time, there was a significantly ($p<0.05$) decrease in positive b*values which represents the yellow region throughout the storage period. On the other hand, colourimetry of breakfast cereal also could be evaluated by hue angle and chroma value. Overall, the hue angle values did not show significant differences ($p>0.05$) over the period of the storage study conducted (Table 2).

3.4 Moisture content

The moisture content of breakfast cereal stored at 27±3°C with a relative humidity of 70-80% for 6 months was shown in Figure 2. Nevertheless, the moisture content in the sample shows an inconsistent trend throughout of storage period. This phenomenon was believed due to the moisture content equilibration factor of extruded cereal products was not carried out before starting the packaging process. The headspace of the package was quite difficult to monitor because the packaging process was done manually, and the air content was uneven for each product package. The water vapour that was absorbed into the samples was most likely from the headspace of the package since no permeation from outside of the package was possible. The packaging material used in this study was Ony/Al/PE, which has a layer of aluminium in the material. According to Wiley (1986), theoretically, the laminated aluminium film has zero water vapour permeability. Therefore, this type of packaging material is able to prevent water vapour permeation into the packaged product. The moisture content of samples was 5.01±0.06% after 6 months of storage. This value was in agreement with that reported by Mbaeyi-Nwaoha and Odo (2018) who also obtained the moisture content in the range of 6.6 to 11.20% for breakfast cereal blended from orange flesh sweet potato.

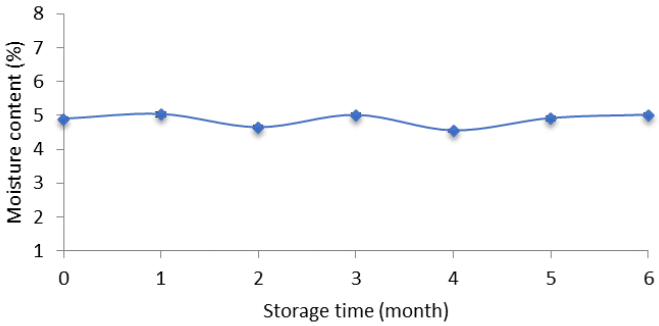

Figure 2. Moisture content changes of breakfast cereal during storage

4. Conclusion

The microbial results of breakfast cereal produced from purple sweet potato were within the range limits for the ready-to-eat foods category according to Ireland's Guidelines. The anthocyanin content in the cereal sample was relatively stable for a period of 6 months of storage. This feature made purple sweet potato (Anggun variety) worth being developed as an anthocyanin-rich health breakfast cereal. The breakfast cereal packed in laminated films of Ony/Al/PE with 0.10 mm thickness were stable in physical and microbiological qualities up to 6 months of storage at 27±3°C (70-80% RH).

Conflicts of interest

The authors declare no conflicts of interest.

Table 2. Colour parameters changes of breakfast cereal during storage

Storage time (month)	Colour parameters				
	L*	a*	b*	C*	Hue angle
0	57.57±0.85^{c}	19.54±0.27^{a}	1.86±0.05^{a}	19.63±0.26^{a}	5.44±0.19^{b}
1	57.14±0.59^{c}	17.55±0.67^{bc}	1.80±0.05^{ab}	17.64±0.67^{bc}	5.86±0.23^{a}
2	57.80±0.49^{c}	18.24±0.20^{b}	1.72±0.03^{bc}	18.32±0.20^{b}	5.39±0.04^{b}
3	57.46±0.46^{c}	17.88±0.59^{b}	1.70±0.07^{c}	17.96±0.59^{b}	5.44±0.10^{b}
4	57.46±0.46^{c}	17.91±0.55^{b}	1.66±0.11^{cd}	17.99±0.56^{b}	5.30±0.22^{b}
5	58.94±0.54^{a}	17.76±0.27^{bc}	1.65±0.07^{cd}	17.83±0.27^{bc}	5.29±0.22^{b}
6	58.49±0.39^{ab}	17.06±0.53^{c}	1.56±0.11^{d}	17.13±0.53^{c}	5.22±0.26^{b}

Values are presented as mean±SD. Values with different superscript within the same column are significantly different ($p<0.05$)

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