The impact of packaging on the microbiological quality of breakfast cereals

Katarzyna Śliżewska*, Agata Nowakowska, Tomasz Piotr Olejnik, Elżbieta Sobiecka

Lodz University of Technology, Faculty of Biotechnology and Food Sciences, Lodz, Poland

Abstract

The aim of the paperwork was to study the microflora found in breakfast cereals available in stores, and to assess the effect of packaging on the microbiological product quality. The flakes tested were hermetically packed and sold by weight. The microbiological analysis included determination of the total number of mesophilic microorganisms, the total number of aerobic bacteria and mould, coagulase-positive bacteria of the *Enterobacteriaceae* family, including coliform bacteria, *Salmonella*, and *Shigella*. It was found that spore bacterial and moulds of the *Aspergillus* and *Penicillum* genus were the dominant microflora that contaminated flakes. There were no coagulase-positive staphylococci and *Salmonella* and *Shigella* bacteria. The most contaminated products were cocoa balls and wheat flakes with rice sold by weight. In general, lower contamination levels were found in hermetically packaged flakes than in those sold by weight.

Keywords: breakfast cereals, microbial contamination.

1. Introduction

The basis of human nutrition according to the food pyramid should be whole grain products, rich in health-promoting ingredients such as dietary fiber, minerals and vitamins. Numerous nutritional studies confirm that regular consumption of whole grain products has a beneficial effect on the human body, reducing the risk

* corresponding author e-mail: katarzyna.slizewska@p.lodz.pl
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of many lifestyle diseases, including obesity, cardiovascular diseases, diabetes and cancer [1].

Due to the increasing nutritional awareness of consumers and the search for products with high nutritional value, cereal flakes are still popular among consumers [2]. The products are aimed at a wide range of recipients, from preschool children to the elderly. A definite advantage of breakfast cereals is the variety of choices and the possibility of consuming them without additional heat treatment. The most popular breakfast cereals chosen by consumers are: oat flakes, corn flakes, flavored cereal flakes (chocolate, cinnamon, honey, etc.), muesli mixes, or granola [3].

Cereal grains, the product from which cereals are made, are an agricultural raw material particularly susceptible to contamination at every stage of production, from cultivation to processing. Microbiological contamination is one of the most serious threats associated with cereal grains and can occur at many stages of the food supply chain, such as cultivation, harvest, transport, storage, preparation and handling. These contaminants can reach cereal grains already in field conditions, transferred by various biotic (e.g. wild animals and insects) and abiotic (e.g. air, dust, water and equipment) factors present in the supply chain [4]. The number of microorganisms present in the grain and their species diversity depend on many factors, such as the location of cultivation, climatic conditions and the type of grain. Cereals growing in both cool and warm and humid climates are susceptible to contamination. In addition, grain is often subject to secondary infection during storage [5]. The microflora inhabiting cereal grains is divided into surface (epiphytic) and subsurface microflora. Surface microbiota includes bacteria, fungi and yeasts. Subsurface microflora develops mainly during grain storage, which leads to its spoilage [6].

The aim of the study was to assess the microbiological status of breakfast cereals available on the market and to determine the impact of packaging on the microbiological quality of these products.

2. Materials and methods

The study involved 8 breakfast cereals available for sale in hermetic packaging and by weight (tab. 1).

Tab. 1. Breakfast cereals tested (own study based on the data on the packaging).

Product	Packaging form	Composition
Cornflakes	foil packaging	Corn grits, sugar, salt, invert sugar syrup, molasses, enriching substances: vitamins (B3, B5, B2, B6, B9)
	by weight	Cornmeal 94%, sugar, salt, vitamin premix with iron: B vitamins, vitamin E, iron, salt
Cocoa balls	foil packaging	Whole grain wheat flour 53.1%, sugar, corn flour 17.2%, glucose syrup, low-fat cocoa 5.6%, enriching agent (mineral: calcium), contains sunflower and/or palm oil, salt, enriching agents (mineral: iron; vitamins: B3, B5, B2, B6, B1, B9, D)
	by weight	Flour 51% (whole wheat, rice, cornmeal), sugar, cocoa powder 4.9%, sunflower oil, salt, vitamin premix with iron: vitamin B1, vitamin B2, vitamin B6, vitamin B12, niacin (vitamin B3), folic acid (vitaminj B9), pantothenic acid (vitamin B5), vitamin E, iron
Muesli	foil packaging	Whole grain wheat 41.7%, rice 17%, raisins 15.9%, wholegrain oats 6.6%, sugar 5.1%, candied pineapple pieces 4.6% (pineapple, sugar, acidity regulator (citric acid), candied papaya pieces 1.9% (papaya, sugar), coconut chips pieces 1.8%, barley malt extract, sweetened dried cranberry pieces 1% (cranberries, sugar, rice flour, sunflower oil), glucose syrup, oat fiber, dried apple pieces 0.5%, salt, oligofructose, emulsifier, antioxidant
	paper tube	Cereal flakes 45% (wheat, oat), roasted peanuts 11%, walnuts 9%, dried dates 9% (dates 95%, rice flour), raisins (raisins, sunflower oil), dark chocolate 5.5% (cocoa mass, sugar, cocoa butter), spanish sage seeds /chia 5.5%, expanded wheat with honey (expanded wheat grains, honey)
Oat flakes	paper packaging by weight	Gluten-free whole grain oat flakes 100% Oat flakes 100%
Wheat flakes with rice	foil packaging	Whole grain wheat 50.9%, rice 37.3%, sugar, wholegrain oat flakes 7.1%, invert sugar syrup, barley malt extract (barley, malted barley), enriching agent (mineral: calcium), salt, glucose syrup, molasses, antioxidant (mixture of tocopherols), enriching agents (mineral: iron; vitamins: B3, B5, B2, B6, B9)
	by weight	Whole wheat flour 80%, sugar, rice 5%, salt, baking powder (raising agent: sodium carbonates, wheat flour, acidity regulator: diphosphates), wheat gluten, barley malt extract

Granola	paper tube	Granola 91.5% (oat flakes, wheat flakes, date syrup, chicory root fiber, rice flour, sunflower seeds, low-fat cocoa), dark chocolate 5% (cocoa mass, sugar, cocoa butter, emulsifier), freeze-dried raspberries 3.5%
Cocoa shells	foil packaging	Whole grain wheat flour 35.1%, chocolate powder 22.5% (sugar, cocoa 7.2%, wheat flour 17%, corn flour 15.3%, glucose syrup, sugar, barley malt extract, sunflower oil, enriching substance (mineral: calcium), emulsifier (lecithins), salt, enriching substances (mineral: iron; vitamins: B3, B5, B2, B6, B1, D
	by weight	Wheat flour 64.1%, sugar, low-fat cocoa 3.6%, cocoa 2.6%, glucose syrup, vegetable fat (palm), salt, emulsifier

The microbiological analysis of dried fruit included the definition of:

- the total number of mesophilic microorganisms (on PCA medium),
- the total number of oxygen sparing bacteria (on the PCA medium after subjecting the sample to the so-called thermal shock),
- microorganisms of the *Enterobacteriaceae* family (on the VRBG medium),
- coliforms and β-glucuronidase positive *Escherichia coli* (on the Chromocult®TBX medium),
- *Salmonella* and *Shigella* bacteria (on the SS medium),
- number of coagulase-positive staphylococci (on the Baird-Parker's medium),
- number of filamentous fungi (on the Sabouraud substrate).

10-fold dilutions of the analyzed samples were prepared and then cultured on Petri plates. Microbiological tests were conducted using the culture method in accordance with PN-EN ISO standards [7-10].

The identification of filamentous fungi was based on macroscopic observations of growth observations in plate cultures and based on microscopic observations.

3. Results and discussion

Based on the obtained results (tab. 2), a diverse number of bacteria, both mesophilic and sporulating were found in the analyzed breakfast cereals. Based on the obtained results (tab. 2), a diverse number of bacteria, both mesophilic and

sporulating were found in the analyzed breakfast cereals. The presence of mesophilic bacteria was not detected in packaged breakfast cereals (corn flakes, oat flakes, wheat flakes with rice), and if they did occur, they were in small quantities, around 2 Log_{10}CFU/g. In cereals sold by weight, the number of mesophilic bacteria was higher and ranged from 3 to 5 Log_{10}CFU/g.

Aerobic sporulating bacteria were not present in corn and oat flakes in either hermetic packages or sold by weight, and in cocoa balls and wheat flakes with rice in foil packages. In the remaining breakfast cereals, the number of aerobic sporulating bacteria was not high and ranged from 1 to 2 Log_{10}CFU/g.

Cereal grains are often contaminated with mesophilic microorganisms. The primary contamination of grain can easily multiply due to inadequate raw material storage and improper technological processing. Because the conditions of the drying process are unfavorable for microorganisms (high temperature maintained for a long time), most vegetative forms, especially during logarithmic growth, are lost. However, the process parameters can be withstood by microorganisms that have developed defense mechanisms that make them resistant to high temperatures. An example is bacterial spores, whose high heat resistivity results from their structure and chemical composition. While vegetative cells die after 10 minutes of heating at 80°C, endospores can withstand even hours of heating. In their structure they contain up to 15% water and dipicolinic acid the complexes with calcium ions of which allow them to survive the drying process [11].

The limits for the number of bacteria in breakfast cereals are set by national and EU regulations on microbiological criteria for food. In the European Union, including Poland, these regulations are included in Commission Regulation (EC) No. 2073/2005 on microbiological criteria for foodstuffs. Although this regulation does not specify specific limits for breakfast cereals, they can be classified as ready-to-eat products.

The total number of mesophilic bacteria can be used as an indicator of the overall hygienic quality of the product. However, the values may vary depending on the

specifications set by food manufacturers. The content of the total number of mesophilic bacteria in cereal products should be in the range of 10^3 to 10^6 CFU/g, according to the above Regulation. The obtained results of the number of bacteria were much lower, which means that they were within the norm.

Tab. 2. Total number of mesophilic and sporulating microorganisms.

Product		**Number of microorganisms [Log_{10}CFU/g]**	
		mesophilic	**sporulating**
Cornflakes	packaging	Ab	Ab
	by weight	3.15 ± 0.2	Ab
Cocoa balls	packaged	2.30 ± 0.1	Ab
	by weight	5.15 ± 0.4	1.08 ± 0.2
Muesli	packaged	2.91 ± 0.1	2.78 ± 0.1
	packaged	2.30 ± 0.3	1.76 ± 0.3
Oat flakes	packaged	Ab	Ab
	by weight	3.60 ± 0.3	Ab
Wheat flakes with rice	packaged	Ab	Ab
	by weight	5.04 ± 0.1	2.00 ± 0.2
Granola	packaged	2.08 ± 0.1	1.08 ± 0.1
Cocoa shells	packaged	2.06 ± 0.2	1.01 ± 0.1
	by weight	1.30 ± 0.1	1.12 ± 0.1

Ab – absent in 10 g; ± SD (Standard Deviation)

The presence of *Enterobacteriacea* bacteria was noted only in corn flakes by weight and oat flakes by weight. Their numbers were low and ranged from 0.4 to 0.7 Log_{10}CFU/g. In the remaining products, no *Enterobacteriacea* bacteria were found in 10 g. No coliform bacteria were found in any of the breakfast cereals analysed (tab. 3).

The main source of secondary pollution of dried fruits is man. We have a rich microflora on our skin and in the digestive tract. It was man who could be the reason for the presence of bacteria from the *Enterobacteriaceae* family in the analysed products.

Tab. 3. The number of microorganisms from the *Enterobacteriaceae* family and from the *coli* group

Product		**Number of microorganisms [Log_{10}CFU/g]**	
		mesophilic	**sporulating**
Cornflakes	packaging	Ab	Ab
	by weight	0.7 ± 0.1	Ab
Cocoa balls	packaged	Ab	Ab
	by weight	Ab	Ab
Muesli	packaged	Ab	Ab
	packaged	Ab	Ab
Oat flakes	packaged	Ab	Ab
	by weight	0.4 ± 0.1	Ab
Wheat flakes with rice	packaged	Ab	Ab
	by weight	Ab	Ab
Granola	packaged	Ab	Ab
Cocoa shells	packaged	Ab	Ab
	by weight	Ab	Ab

Ab – absent in 10 g; ± SD (Standard Deviation)

None of the tested products sold both in hermetically sealed containers and by weight, were contaminated with *Salmonella* and *Shigella* bacteria and coagulase-positive staphylococci.

The presence of filamentous fungi was found in the following flakes: corn flakes by weight, cocoa balls by weight, muesli in foil and paper packaging, oat flakes by weight, wheat flakes with rice by weight (tab. 4). The number of filamentous fungi in the flakes varied, ranging from 1.00 to 4.90 Log_{10}CFU/g. The highest content of filamentous fungi was found in the sample of muesli flakes in a foil package. The high content of mould fungi in this product could be caused by the presence of microbiologically contaminated dried fruit present in the muesli.

However, analyzing which filamentous fungi were on the breakfast cereals on macroscopic and microscopic observations, it was found they belong to the *Aspergillus* genus and the *Penicillum* genus (tab. 4, fig. 1).

Tab. 4. Number of filamentous fungi

Product		**Number of mould [Log_{10}CFU/g]**	**Morphological identification**
Cornflakes	packaging	Ab	-
	by weight	1.48 ± 0.2	*Penicillum*
Cocoa balls	packaged	Ab	-
	by weight	4.20 ± 0.1	*Aspergillus*
Muesli	packaged	4.90 ± 0.3	*Aspergillus*
	packaged	1.00 ± 0.1	*Aspergillus*
Oat flakes	packaged	Ab	-
	by weight	1.3 ± 0.2	*Aspergillus*
Wheat flakes with rice	packaged	Ab	-
	by weight	2.45 ± 0.2	*Penicillum*
Granola	packaged	Ab	-
Cocoa shells	packaged	Ab	-
	by weight	Ab	-

Ab – absent in 10 g; ± SD (Standard Deviation)

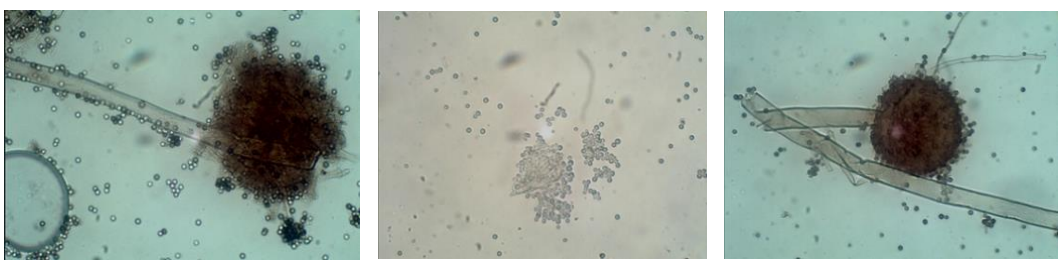

Fig. 1. Morphology of selected filamentous fungi (microscopic observations, x40).

4. Conclusion

Based on the microbiological analysis, it was found that bacterial spores and moulds of the *Aspergillus* and *Penicillum* genus were the dominant microflora that contaminated breakfast cereals. There were no coagulase-positive staphylococci and Salmonella and Shigella bacteria. The most contaminated product were cocoa balls and wheat flakes with rice sold by weight and muesli in foil packaging. In general, a low level of microbiological contamination of the studied cereals and a lower level of contamination of hermetically packaged cereals were found than in those sold by bulk.

References

[1] Sobota A., Rzedzicki Z., Sobieraj M.: *Badanie składu chemicznego płatków musli*. Bromatologia i Chemia Toksykologiczna, 45(2), 2012, pp. 131-137.
[2] Priya K.M., Sivakumar A.*: Analyzing consumer behaviour towards food and nutrition labeling: A comprehensive review*. Heliyon, 9(9), 2023, pp. 1-18.
[3] Williams P.G.: *The Benefits of Breakfast Cereal Consumption: A Systematic Review of the Evidence Base*. Advances in Nutrition, 5(5), 2014, pp. 636S-673S.
[4] Los A., Ziuzina D., Bourke P.: *Current and Future Technologies for Microbiological Decontamination of Cereal Grains*. Journal of Food Science, 83(6), 2018, pp. 1484-1493.
[5] Magan N., Aldred D. *Managing microbial spoilage in cereals and baking products*, [w:] *Food spoilage microorganisms*, C. Blackburn (red.), Woodhead Publishing Ltd, Cambridge, UK, 2006, pp. 194-212.
[6] Nierop S.V. *The impact of microorganisms on barley and malt quality - A review*. Journal of the American Society of Brewing Chemists, 64(2), 2006, pp. 69-78.
[7] PN-ISO 21527-2:2009. Food and feed microbiology. Horizontal method for the enumeration of yeasts and molds.
[8] PN-ISO 21528-2:2005. Food and feed microbiology. Horizontal method for the detection and enumeration of *Enterobacteriaceae*.
[9] PN-ISO 4833:2004. Food and feed microbiology. General rules for the determination of the number of microorganisms.
[10] PN-ISO 6888-1:2001/A1:2004. Food and feed microbiology. Horizontal method for the determination of the number of coagulase-positive staphylococci (*Staphylococcus aureus* and other species).
[11] Kołożyn-Krajewska D.: *Microorganisms in food - risks or benefits*. Żywności. Nauka. Technologia. Jakość, 3(4), 1995, pp. 21-31.