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The effect of packaging type on quality of cereal muesli during storage

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Abstract. Cereal-derived breakfast products (cereal flakes, bread, and muesli) are increasingly consumed because they are an important source of energy for adults and children. Shelf-life of foods is highly dependent on the permeability characteristics of the packaging materials, which emphasize the importance of packaging design. The aim of this study was to evaluate changes of physically-chemical, microbiological and sensory parametrs of cereal muesli with chocolate and apricots during storage. Samples of muesli with chocolate and apricots were packaged in 3 different types of packaging–paper bag, paper tubes and *Doypack* (stand-up pouches) and stored for 9 months (at 20 ± 2°C temperature and relative air humidity – 55 ± 3%). During the storage moisture content, water activity, total plate count of mesophilic aerobic and facultative anaerobic microorganisms (MAFAm), mould and yeast, volatile compounds and sensory quality were evaluated in analysed muesli samples. The lowest moisture content after 9 months storage was determined for muesli samples stored in paper bag. Total number of mesophilic aerobic facultative anaerobic microorganisms (MAFAm, mould and yeast) of muesli in all samples during storage slightly increased. After 9 months storage muesli with chocolate and apricots in the *Doypack* had the best sensory properties. In muesli with chocolate and apricots there were identified 18 volatile compounds. The results indicated that paper bags were the least suitable for packaging of cereal muesli with chocolate and apricot, because of essential quality changes of samples during their storage. The shelf-life of 9 months can be recommended for cereal muesli with chocolate and apricots packaged in paper tube or *Doypack*.

Key words: cereals, muesli, packaging, storage time.

INTRODUCTION

Cereals are crop plants from the grass family (*Poaceae*) and produce seeds (fruits) with high starch contents which are used for human consumption, animal feed production and industrial purposes. Among the many cultivated species of cereals, an increasingly important role is played by barley, rye and oats (Perkowski et al., 2012). Cereals provide a very substantial proportion of the needs of the world's population for dietary energy, protein, and micronutrients. The major cereal crops are wheat, rice, and maize, but sorghum, millets, barley, oats, and rye are important only in some regions. Unprocessed cereals are low in fat, and a good source of fibre and phytochemicals. Cereal grains are made into a very wide range of cereal-based foods using traditional and technologically more advanced processes, which can result in changes in nutritional value (Price & Welch, 2013).

Muesli is a mixture of grain flakes and dried fruits, where can be also added seeds and nuts. It is traditionally consumed for breakfast together with milk, yogurt or hot water.

Albertson et al. (2008) showed that ‘cereal itself contains high level of healthful micronutrients and macronutrients, compared to foods consumed during non-cereal breakfasts; cereal tends to facilitate consumption of other healthful foods at breakfast and replace consumption of less healthful foods; and cereal consumption may be a marker for a pattern of behaviour that includes healthful eating and high levels of physical activity throughout the day’.

Oats, maize, rye or wheat can be primarily used for the preparation of breakfast cereal and muesli. However, there are relatively few studies where the muesli cereals are triticale, barley and other cereals (Senhofa et al., 2014). Triticale, oats and barley belong to the group of crops with high energy and nutritional value arising from a high content of biologically valuable proteins, high portion of lipids compared to other cereals, favourable saccharide composition as well as from significant levels of dietary fibre, vitamins and mineral substances (Demirbas, 2005; Gajdosova et al., 2007).

Extra additives with elevated nutritive value as dried fruits, nuts and others contain more moisture than flakes thus creating additional microbiological hazard during muesli storage. Some of the microorganisms present in cereals constitute a potential hazard since their development may alter the properties of the grains, and the mycotoxins produced by some moulds could potentially pose a health risk. It has been reported, that these microorganisms are located close to the surface of the grain, but the real thickness affected by microbial contamination has not been determined (Laca et al., 2006). Contamination of the grains during storage, transportation and processing further affects the microflora of developed new product as, for example, muesli.

Muesli and breakfast cereal shelf-life is limited by chemical and physical changes and the rate of deteriorative reactions depends on its composition as well as environmental factors. Moisture content is identified as the critical quality parameter and relative air humidity as the most influential environmental factor (Macedo et al., 2009; Macedo et al., 2013).

The use of packaging in the food supply chain is very important and is an essential part of food processing. Cereal products are usually packaged in paper/polyethylene packaging. Packaging materials for flakes can be combined using 2 different material types–the first is foreseen for product protection and the other for consumer for ease use (Robertson, 2006). Significant developments in food packaging materials have provided the means to suppress microbial growth as well as protect foods from external microbial contamination (Cutter, 2002). Packaging materials have been developed specifically to prevent the deterioration of foods resulting from exposure to air, moisture, or pH changes, retaining sensory properties.

The aim of this study was to evaluate physically-chemical, microbiological and sensory parameters changes of cereal muesli with chocolate and apricots during storage.

MATERIALS AND METHODS

Experiments were carried out at the Latvia University of Agriculture, Faculty of Food Technology. During storage (0, 2, 4, 6 and 9 months) the moisture content, water activity (a_w), microbiological parameters, sensory properties and volatile compounds were determined for muesli with chocolate and apricots.

Characterisation of muesli with chocolate and apricots

Muesli with chocolate and apricots contains:
45% roasted (200 ± 10°C for 10 min) whole grain triticale flakes; 22% roasted (200 ± 10°C for 10 min) whole grain oat flakes; 15% dried apricots; 10% dark chocolate pieces; 8% roasted linseeds.

Characterisation of packaging materials

Samples of muesli with chocolate and apricots were packaged in three different multi-layered packaging materials, which provide light and moisture impermeability:

Paper tubes with lid (Fig. 1, a) – cardboard paper tubes with aluminium layer inside and low density polyethylene (LDPE) black cover (Visican Ltd., Netherlands);

Paper bag (Fig. 1, b) – brown kraft paper 90–100 g m^{-2} with polypropylene (PP) window (UAB Eltaka, Lithuania);

Sealable *Doypack* (stand-up pouches,) (Fig. 1, c) – Pap50g/Alu7/Pe60 material (Cor Rijken Verpakkingen B.V., Netherlands).

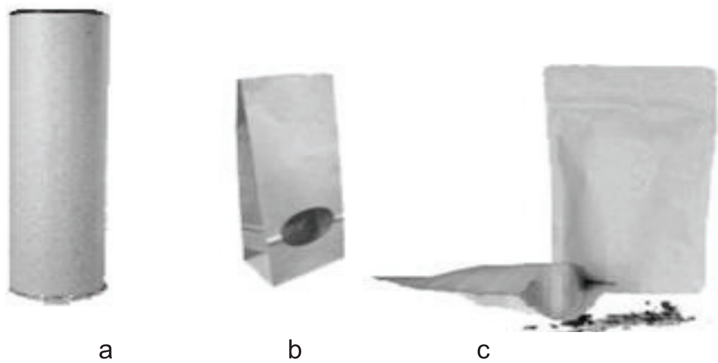

Figure 1. The packaging used in the research (a – paper tube with lid, b – paper bag with transparent window, c – sealable *Doypack*).

The amount of muesli in each package was 250 ± 10 g, the muesli was stored for 9 months at 20 ± 2°C temperature and relative air humidity – 55 ± 3%.

For determination of moisture content, water activity, and volatile compounds in muesli with chocolate and apricots, approximately 100 g of sample was ground in laboratory mill Knifectec Mill 1095 (AB Foss Analytical, Sweden) and immediately used for analysis.

Moisture content

Moisture content of muesli with chocolate and apricots was determined by drying 5.00 ± 0.03 g of sample in the oven (GmbH Memmert, Germany) for 1 hour at 110 ± 1°C (LVS EN ISO 712:2010A). The analyses of moisture content were done in triplicate.

Water activity (a_w)

Water activity (a_w) was determined using LabSwift-aw (AG Novasina, Switzerland) equipment. Ground muesli sample was filled in the sample dish and placed in the measurement chamber according to producer's recommendations. The analyses of water activity were done in triplicate.

Microbiological parameters

Total plate count of mesophilic aerobic and facultative anaerobic microorganisms (MAFAm) were determined in conformity with the standard LVS EN 4833:2003 ($n = 6$); yeasts and moulds– the standard ISO 21527-2:2008 ($n = 6$).

Sensory evaluation

The experts were selected and trained according to the recommendations described in ISO 8586-1 (1993). Training was completed at the Latvia University of Agriculture. It was done in two sessions–training and selection of panellists, and specific training for evaluation of muesli sensory properties (8 selected assessors).

Descriptive test was used for detection and description of sensory quality of muesli. Descriptors for evaluation of muesli sensory properties (overall appearance, texture, aroma, and taste) were determined by consensus of all selected assessors. . Each sensory property was evaluated in the range from 5 (very good quality) to 1 (unsatisfactory quality, serious defects). There was used quality number (QN) for sensory properties evaluation of muesli with chocolate and apricots. The quality number was calculated according to the following equation (Straumite et al., 2012):

$$QN = \frac{Ap + Te + Ar + Ta}{4}, \quad (1)$$

where: Ap – muesli overall appearance; Te – muesli texture; Ar – muesli aroma; Ta – muesli taste.

Based on QN muesli with chocolate and apricots quality was classified as follows: 5.00–4.80 – very good quality (performance of quality parameters); 4.79–4.00 – good quality (inessential deviations); 3.99–3.50 – average quality (pronounced deviations, insignificants defects); 3.49–2.50 – satisfactory quality (significant defects); 2.49–1.00 – unsatisfactory quality (serious defects).

Overall appearance was evaluated for dry muesli samples. Muesli samples (15 g) for texture, aroma and taste assessment were poured with hot water (t = 95 ± 2°C), stirred and assessed after 5 min.

Volatile compounds

Volatile compounds were extracted using solid-phase microextration (SPME) in the combination with gas chromatography/mass spectrometry. SPME fibre was coated with a thin polymer film – Carboxen/Polydimethylsiloxane (CAR/PDMS). The film thickness is 85 µm with bipolar polarity (Supelco, Inc., USA). Five grams of sample were placed in a 20 ml vial. Volatile compounds were detected according to methods described by Sabovics et al. (2014). Compounds were identified by comparing their mass spectra with mass spectral library Nist98.

Statistical analysis

The results (mean, standard deviation, *P* value) were processed by mathematical and statistical methods useing Microsoft Office Excel 2007 software; significance was defined at $P < 0.05$.

RESULTS AND DISCUSSION

Moisture content

The moisture content of freshly prepared muesli is 14.42 ± 0.18% (Fig. 2). It is relatively high comparing with cereal flakes because muesli contains various ingredients with different moisture content, such as dried apricots, chocolate pieces, and seeds. As a result the moisture content of several compounds is not equal; however, all compounds can interact each to other until moisture balance in the package is achieved. Experimental results revealed that moisture content of muesli with chocolate and apricots is significantly ($P = 0.0004$) affected by packaging material type during its storage.

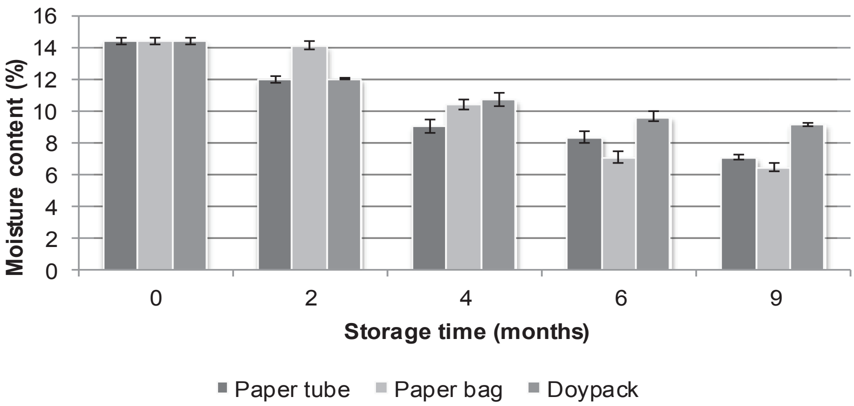

Figure 2. The moisture content changes of muesli with chocolate and apricots during storage.

The results of present experiment demonstrate, that the highest water loss after 9 months storage was observed for muesli samples packed in paper bag (56% water loss) and paper tube (51% water loss). There was no significant difference between moisture content of muesli with chocolate and apricots stored in paper bag or paper tube ($P > 0.05$).

After 9 month storage muesli moisture content was 6.48–9.20%, what coincides with results of Aigster et al. (2011), who found that granola muesli moisture content is in the range of 5.7–7.1%. It can be concluded that the muesli sample moisture content during storage is adequate, compared to other authors findings on flakes moisture content. The smallest moisture loss was observed in the sample of muesli with chocolate and apricots packaged in *Doypack*. Wherewith, it can be concluded that the most suitable packaging among studied for long-term storage is the *Doypack.*

Water activity

Reduced water activity (a_w) does not provide a complete inactivation of microorganisms, but partially restrict their activity in the product, which helps to ensure a longer shelf-life. In all types of studied packages water activity of the samples decreased during storage (Fig. 3), thus demonstrating significant (P < 0.05) effect of packaging material on water activity of the product.

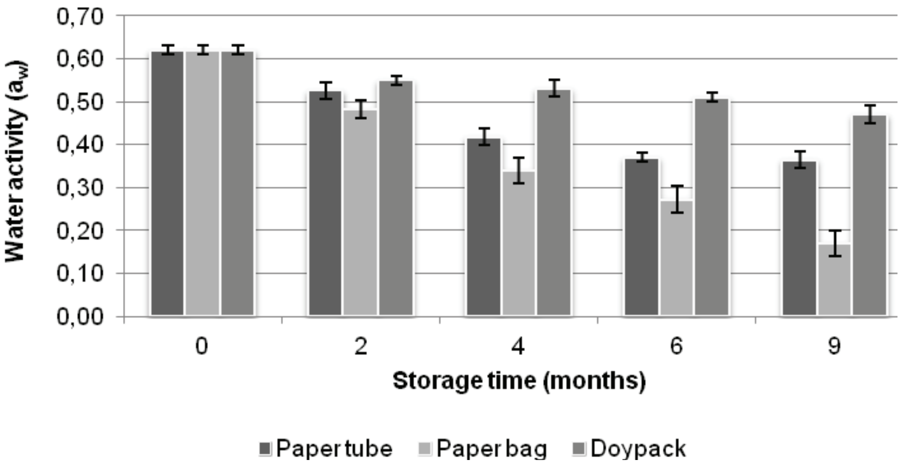

Figure 3. Changes in water activity *(a_w)* of muesli with chocolate and apricots during storage.

In Latvia does not exist regulation on water activity of muesli and cereal products, but it is important parameter determining the product shelf life. *Beuchat* (1981) has carried out a study which found that dry food products like flakes have water activity below 0.6. This indicates that the product is microbiologically safe and it slows the development of various microorganisms. After 9 months storage in different packages water activity of muesli samples was below 0.6. During muesli storage for 9 months water activity (a_w) of muesli with chocolate and apricots packaged in paper bag decreased 3.6 times from 0.62 to 0.17. The water activity of muesli in paper bag decreased most rapidly, what could be explained with the packing material and its moisture permeability. Paper bag is recommended for muesli storage up to 2 months, but in case of longer storage time (up to 9 months) – *Doypack* packaging, in which a_w decreased only 1.2 times.

Microbiological parameters

Microorganisms in food are a serious problem that can lead to product spoilage and deterioration in the quality (Celiktas et al., 2007). Traditionally grain microflora is composed of bacteria, yeasts and moulds; however, flakes and grains containing grain husks have increased risk of microbial contamination.

During muesli storage experiment it was detected, that the total count of mesophilic aerobic and facultative anaerobic microorganisms (MAFAm) increases in all three types of packaging materials (Table 1). The highest total colony count after 9 months of storage was observed in the samples packed in paper bags – $2.5\times10^5 \pm 3.4\times10^2$ CFU g^{-1}.

Table 1. Changes of muesli microbiological parameters during storage

Parameters /	Storage time, months				
Samples	0	2		6	9
MAFAm CFU×g-¹					
Paper tube	$1.4\times10^3 \pm 2.1\times10^1$	$1.2\times10^4 \pm 2.8\times10^1$	$2.2\times10^4 \pm 2.0\times10^1$	$2.4\times10^4 \pm 3.4\times10^2$	$3.7\times10^4 \pm 3.1\times10^2$
paper bag	$1.4\times10^3 \pm 2.7\times10^1$	$2.1\times10^4 \pm 3.6\times10^1$	$2.7\times10^4 \pm 2.1\times10^1$	$1.6\times10^5 \pm 2.6\times10^2$	$2.5\times10^5 \pm 3.4\times10^2$
Doypack	$1.4\times10^3 \pm 1.6\times10^1$	$1.5\times10^4 \pm 2.4\times10^1$	$1.9\times10^4 \pm 2.1\times10^1$	$2.3\times10^4 \pm 3.1\times10^2$	$3.2\times10^4 \pm 1.9\times10^2$
Yeasts CFU×g⁻¹					
paper tube	$1.3\times10^2 \pm 1.0\times10^1$	$2.1\times10^3 \pm 1.7\times10^1$	$2.6\times10^3 \pm 1.4\times10^1$	$3.2\times10^3 \pm 2.1\times10^1$	$3.4\times10^3 \pm 1.2\times10^1$
paper bag	$1.3\times10^2 \pm 2.4\times10^1$	$2.8\times10^3 \pm 2.5\times10^1$	$4.3\times10^3 \pm 3.2\times10^1$	$5.2\times10^3 \pm 1.8\times10^2$	$5.8\times10^3 \pm 3.0\times10^2$
Doypack	$1.3\times10^2 \pm 2.8\times10^1$	$1.9\times10^3 \pm 2.4\times10^1$	$2.7\times10^3 \pm 2.0\times10^1$	$3.4\times10^3 \pm 3.2\times10^1$	$3.6\times10^3 \pm 1.8\times10^1$
Moulds CFU× g⁻¹					
paper tube	$1.0\times10^2 \pm 0.8\times10^1$	$1.2\times10^3 \pm 1.0\times10^1$	$2.4\times10^3 \pm 0.7\times10^1$	$3.6\times10^3 \pm 1.0\times10^2$	$3.8\times10^3 \pm 1.2\times10^2$
paper bag	$1.0\times10^2 \pm 1.5\times10^1$	$2.4\times10^3 \pm 1.1\times10^1$	$3.2\times10^3 \pm 1.3\times10^2$	$4.9\times10^3 \pm 2.7\times10^1$	$5.5\times10^3 \pm 1.8\times10^2$
Doypack	$1.0\times10^2 \pm 0.9\times10^1$	$2.1\times10^3 \pm 1.3\times10^1$	$2.6\times10^3 \pm 1.1\times10^1$	$3.5\times10^3 \pm 1.1\times10^1$	$3.7\times10^3 \pm 1.6\times10^2$

Increase of yeast cell count occurs in the first 4 months of storage. The smallest yeast cell growth was detected after 9 months of storage in muesli with chocolate and apricots packaged in *Doypack* ($3.6\times10^3 \pm 1.8\times10^1$ CFU g^{-1}).

FS (International Commission for the microbiological specific actions for food products) has indicated that the limit for the number of moulds in dry products such as cereals could vary from 10^2 to 10^4 CFU g^{-1} (ICMFS, 2005). Freshly prepared samples of muesli with chocolate and apricots contain $1.0\times10^2 \pm 0.8\times10^1$ CFU g^{-1}, however after 9 months of storage the amount of microorganisms increased up to $5.5\times10^3 \pm 1.8\times10^2$ CFU g^{-1} in paper bag.

Mesophilic aerobic and facultative anaerobic microorganisms (MAFAm), yeast and moulds growth dynamics in muesli samples during storage is influenced by the presence of air and its diffusion through packaging material, contributing to development of microorganisms. Paper bags are the most permeable packaging material among studied materials, therefore microflora development in a package can be observed.

Sensory evaluation

Sensory evaluation of muesli samples was realised for muesli with chocolate and apricots after 9 months of storage. Obtained results demonstrate that the highest evaluation received muesli packaged in *Doypack* (QN = 5.00) and paper tubes (QN = 5.00) (Table 2).

Table 2. Sensory evaluation results of muesli with chocolate and apricots

Package	Overall appearance	Texture	Aroma	Taste	QN
Paper tube	5.00	5.00	5.00	5.00	5.00
Paper bag	5.00	5.00	4.00	3.00	4.25
Doypack	5.00	5.00	5.00	5.00	5.00

Sensory evaluation of stored muesli samples with chocolate and apricots in paper tubes and *Doypack* revealed that product along with cereal taste and aroma has typical chocolate aroma and taste. However, in the same muesli sample stored in paper bags, chocolate and apricots taste and aroma became less pronounced and it was dominated by cereal taste and aroma.

Volatile compounds

Changes of qualitative and quantitative composition of volatile compounds in the end product, may affect not only the packaging material but also the storage temperature and the interaction between volatile compounds of the various ingredients (Figiel et al., 2010).

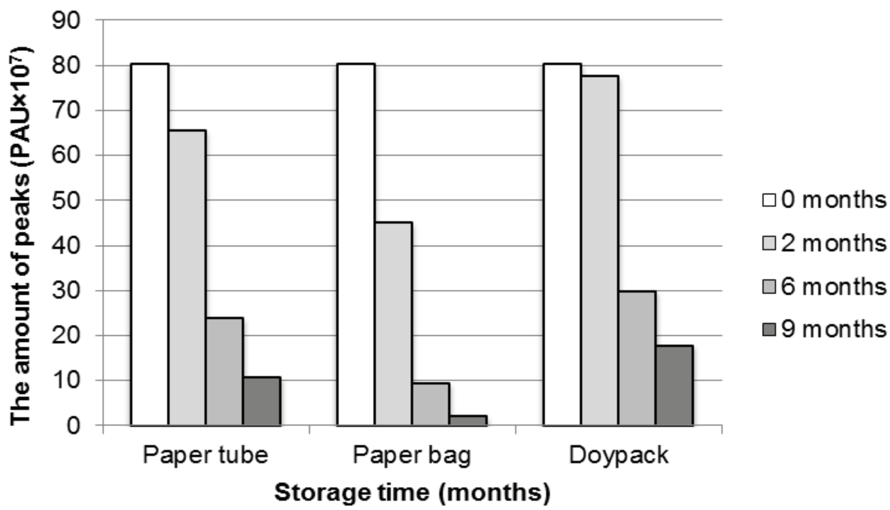

Figure 4. Changes of total amount of volatile compounds during storage.

In the first 2 months of storage there was observed small decrease in volatile compounds peak areas, but the rapid decline of volatile substances was observed from 2 to 9 months of storage (Fig. 4). It should be noted that the most rapid reduction of volatile compounds was found in samples packaged in paper tubes, quantitative composition of the volatile compounds after 9 months storage has decreased 38.3 times. However, the least decrease of volatile compounds peak areas in products stored for 9 months in *Doypack*.

In chocolate and apricot muesli there were totally identified 18 volatile compounds, of which 7 compounds were identified in all samples irrespective of packaging materials. The identified volatile compounds in muesli with chocolate and apricots from the aroma profile, where dominant aromas are malty, whiskey (3-methyl-butanal), green (hexanal), almond, bread (furfural), citrus (D-limonene), grape (ethyl caprate), fruit (4-penten-2-ol) and acid (acetic acid). The other identified 12 compounds were less than 2%.

In a study of chocolate and apricot muesli samples there were identified volatile compounds belonging to different classes: alcohols, aldehydes, ketones, terpenes, esters, and carboxylic acids. The most dominating volatile compounds class in muesli with chocolate and apricots was carboxylic acids (28%), but the least have been identified alcohols and terpenes.

CONCLUSIONS

The results indicated that paper bags were the least suitable for packaging of cereal muesli with chocolate and apricots, because of essential quality changes of samples during their storage. The shelf-life for cereal muesli with chocolate and apricots packaged in paper tube or *Doypack* for 9 months could be recommendable.

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