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Effects of Package Damage on Quality of Fried Potato Snacks during Storage

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ABSTRACT

The aim of this investigation was to assess the effect of the degree of package damage on the shelf life of classic potato chips and chips made of dough (fabricated). The degree of package damage significantly affected the quality of fried potato snacks during storage. The higher the degree of package damage, the more intensively the products absorbed water from the environment. The changes in moisture directly affected chip texture, making it harder. A high, positive correlation ($r = 0.89$) was observed between the hardness of products and the degree of package damage, as well as with the storage period. Fabricated chips had a significantly harder texture and more profound changes regarding shelf life than traditional potato chips. The degree of package damage also influenced the pace of alterations in the fat fraction of the products stored. The pace of hydrolytic and oxidation changes increased as the degree of package damage and storage time increased. Regardless of the length of storage and the kind of package damage, more advanced changes in the fat fraction were recorded for chips made of dough than for traditional chips. Chips stored in packages with less damage (fewer holes), when subjected to sensory assessment, were granted less than 4 points after 2 months of storage, while those stored in open packages obtained the same number of points after just 1 month.

Keywords: fabricated potato chips, potato chips

INTRODUCTION

Potato chips are one of the most popular snack products obtained from potatoes. Traditional chips are made of thin potato slices (1–1.8 mm thick) fried in hot oil, and differ slightly in shape and size depending on the quality of the initial material. This natural diversity produces a ready product requiring packaging in relatively large packages to protect the delicate and crispy chips from breakage. Subsequently, some years ago, an alternative version of potato chips was introduced, made of dough prepared from dry raw potato materials (starch, flakes, granules, flour and dried ground potatoes). Snacks formed from such a dough enabled the even size and shape of the ready product, as well as much easier packaging (Hix 2002).

Both traditional chips and those made of dough are characterized by similar properties – low moisture (below 2%), high content of fat (30-39%), gold–yellow color, potato and oil taste and flavor, and also crisp and delicate texture (Hix 2002; Kita *at al.* 2009). These properties are directly related to the quality of the initial raw materials, i.e., potato and frying oil, while their shape is formed in the course of the technological process. Yet this kind of product, before it finally reaches the consumer, is usually stored for several or some dozens of weeks. Thus, the effect of storage conditions should be included in the factors determining the quality of this group of products.

Regarding the specific composition of potato chips, shelf life is dependent, first of all, on the changes in moisture and on the stability of fat fractions. Increased moisture, connected with water absorption from the surroundings, directly influences the texture of the stored products, which results in the loss of their characteristic crispiness, to finally become harder (Annapure *et al.* 1998; Kita 2002). The alterations in fat, connected mainly with oxidation, lead to changes in chip taste and flavor. Taking these facts into account, special attention has been paid to the conditions chips are stored in and, first of all, the kind of material used for packaging, namely, its high tightness regarding water and oxygen (Park *et al.* 1996). Another factor improving the quality of chips during storage was the application of a modified atmosphere, which efficiently delays oxidation alterations in fat (del Nobile 2001). A number of studies were also undertaken to examine the effect of the kind and quality of frying oil on the durability of snack products in the course of their storage (Pangloli *et al.* 2002; Houhoula and Oreopoulou 2004; Kita 2006). Chips fried in palm oil or its fractions (du Plessis and Meredith 1999; Mathäus 2007) featured higher stability than those fried in traditionally used oils. Stability of products during storage was significantly effected by the degree of degradation of frying medium – the higher the degree, the more rapid and more intensive the changes. Further examination involved the use of antioxidants introduced directly into the frying oil, as well as those components of spice mixtures placed directly on the surface of ready products (Che Man and Tan 1999; Lalas and Dourtoglu 2003; Houhoula *at al.* 2004; Chiou *at al.* 2009; Farhoosh *at al.* 2009; Fatihanim *at al*. 2009). Although antioxidant activity and efficiency was diverse, their addition advantageously affected the shelf life of ready products.

Investigations conducted so far have taken into account chips and other fried snacks made of potato packed in original water- and oxygen-tight packages. There is however, no available data regarding the quality of this group of products in the case of storage in damaged packages. Therefore, the aim of this investigation was to assess the effect of the degree of package damage on the shelf life of traditional and fabricated potato chips.

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Table 1 Characteristics of potato chips (TPCs – traditional potato chips, FPCs – fabricated potato chips) before storage.

	TPCs with red pepper	TPCs with cheese	FPCs with red pepper	FPCs with cheese
Moisture (%) (± SEM)	1.93 ± 0.08	1.71 ± 0.07	1.47 ± 0.11	1.38 ± 0.08
Texture (N) (± SEM)	19.54 ± 2.35	17.51 ± 2.18	55.07 ± 4.61	52.91 ± 3.97
Fat content (%) (± SEM)	35.87 ± 0.19	35.38 ± 0.13	29.10 ± 0.17	29.63 ± 0.15
Fatty acid composition (%)				
C 16:0	41.74	42.06	40.24	39.67
C 18:0	4.42	4.39	4.54	4.51
C 18:1	39.55	39.44	39.94	40.13
C 18:2	10.29	10.13	10.63	10.64
Peroxide value (meq O_2/kg) (± SEM)	1.4 ± 0.11	0.8 ± 0.09	1.8 ± 0.10	1.7 ± 0.09
FFA (% oleic acid) (± SEM)	0.29 ± 0.05	0.44 ± 0.07	0.54 ± 0.04	0.43 ± 0.03

MATERIALS AND METHODS

Materials

The material used in this study consisted of two kinds of potato snacks: potato chips (Top-chips) – made of var. 'Saturna' potatoes and fabricated potato chips (Chipsletten) (both with red pepper and cheese flavours). These potato snacks were produced in a production plant in Lower Silesia (Poland). The traditional potato chips and fabricated potato snacks resulted from the same technological conditions, and were originally packed into 100-g packages made of thermoweldable aluminium foil. The products were divided into three groups: original closed packages, damaged packages (with 5 holes with a diameter of 1 mm each) and in opened packages; packages were stored under standard conditions for 4 months (temperature 20°C, 40-50% RH). Analyses were performed on fresh products and after 1, 2 and 4 months of storage. 3 packages of each sort of snack served as test material. Their content (in total 300 g for every type of analysed potato chip) was mixed in order to obtain unified material. All experiments were performed in triplicate.

Chemical analyses

Potato snack moisture content was determined using a gravimetric method. Fat content of snacks was measured according to Soxhlet's method (AOAC 1995). Fat was extracted using a Büchi B-811 Universal Extraction System (Büchi Labortechnic AG, Flawil, Switzerland). Samples (2 g) were extracted for 180 min using diethyl ether as a solvent (AOAC 1995). The peroxide value (PV) and free fatty acids (FFA) content were determined in fat fractions of the snacks according to AOAC standards. The fatty acid methyl esters were prepared with BF_3 in methanol as the methylating agent. Determination of fatty acid composition was achieved by gas chromatography (GC) using an RTX-2330 capillary column, 105 m in length, ID diameter = 0.25 mm; film thickness = 0.20 µm; detector (FID) temperature = 260°C; injection temperature = 260°C; column temperature was held at 160°C for 30 min and the temperature was programmed to increase to 180°C at 3C/min, held for 17 min, increase to 210°C at 5°C/min and held for 45 min. Helium was used as the carrier gas. Changes in the content of fatty acids in the samples, defined as the degree of unsaturation, were calculated as (Kita 2006):

(C 18:2 + C 18:3)/ (C 16:0 + C 18:0).

Texture analyses

The texture of potato snacks was determined using an Instron 5544 connected to a computer, equipped with a rectangular attachment for cutting. The velocity of the head with the attachment was 250 mm/min with a 2 kN load cell. Measurements were made for determining maximum shear force (Fg_{max}) necessary to cut the potato snack. Each measurement was conducted on 30 potato chips.

Organoleptic evaluation

Sensory attributes – color, flavor, odor and texture – were assessed according to a 5-point scale (5 points – best, 1 point –worst). 10 panelists aged 23-25 years (all students of the Faculty of Food Science) with sensory evaluation experience were trained in the descriptive evaluation of potato chips.

Statistical analysis

Data was analysed statistically using Statistica v. 6 software (2001). For comparison, the results obtained were subjected to one-way analysis of variance by application of Duncan's multiple range test ($p \leq 0.05$). To assess rank variables (sensory evaluation of snacks with a 1-5 scale), a non-parametric Kruskal-Wallis test was used. Homogenous groups were identified on the basis of the determined ranks. Correlation coefficients (ANOVA) were determined in order to find a relationship between texture and fat fraction quality (PV) versus storage conditions and other quality parameters of the potato snacks. Differences at $p \leq 0.05$ were considered significant.

RESULTS AND DISCUSSION

Table 1 shows characteristics of snack products before storage. Both the traditional potato chips (TPCs) and fabricated potato chips (FPCs) featured an appropriate moisture level (below 2%) and typical organoleptic properties. The chips made of dough were of a significantly harder texture compared to the traditional chips, which was related with the different production technology used for this type of snack. The content of fat in both kinds of snacks was similar and ranged from 35% in the traditional potato chips to 29% in the fabricated potato chips. Fat fractions in all products were characterized by fatty acid content typical for palm oil, as well as a low content of peroxides and free fatty acids.

Damaged and open packages affected the moisture of the stored chips (**Fig. 1**). When stored in damaged packages, both the traditional and the fabricated potato chips increased their moisture content in subsequent months. The most considerable changes in chip moisture were observed in chips stored in open packages, whose moisture after 4 months exceeded 4%. In the case of damaged package chips, moisture also showed an increased value (>2%) as early as after 2 months. The changes in stored snack product moisture were also recorded in previously conducted research, when different products in original packages (not damaged) were stored (Kita 2002). As storage time increased, product moisture increased and the pace of water absorption mainly depended on the kind of package and storage environment. When potato chips were stored in critical conditions in a climatic chamber, moisture increased an average 2.5 times faster than when standard conditions were used (Kita *at al.* 2003).

Changes in chip moisture were directly connected with changes in product texture (**Fig. 2**). As the time of storage increased, both the traditional chips and the fabricated chips gradually lost their characteristic crispness and became harder. Especially, intensive changes in texture were recorded for the chips stored in open packages – after 4 months of such storage the hardness of the fabricated chips increased from 50 to 82N. Disadvantageous changes in product texture were also observed for the chips stored in

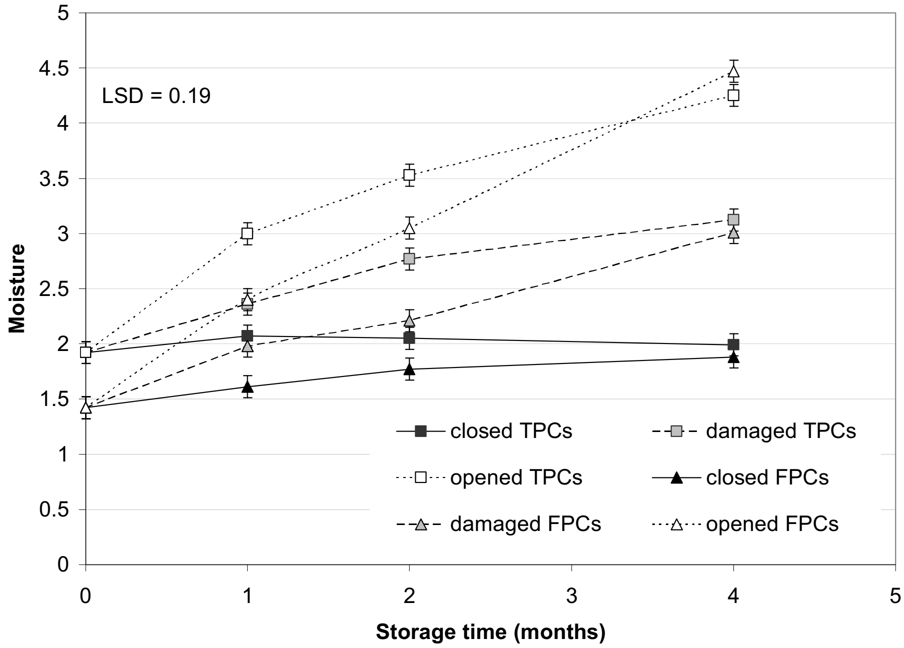

Fig. 1 Moisture content (%) of traditional potato chips (TPCs) and fabricated potato chips (FPCs) during storage in packages with different degrees of damage (averages for type). Values represent mean ± standard error (SE).

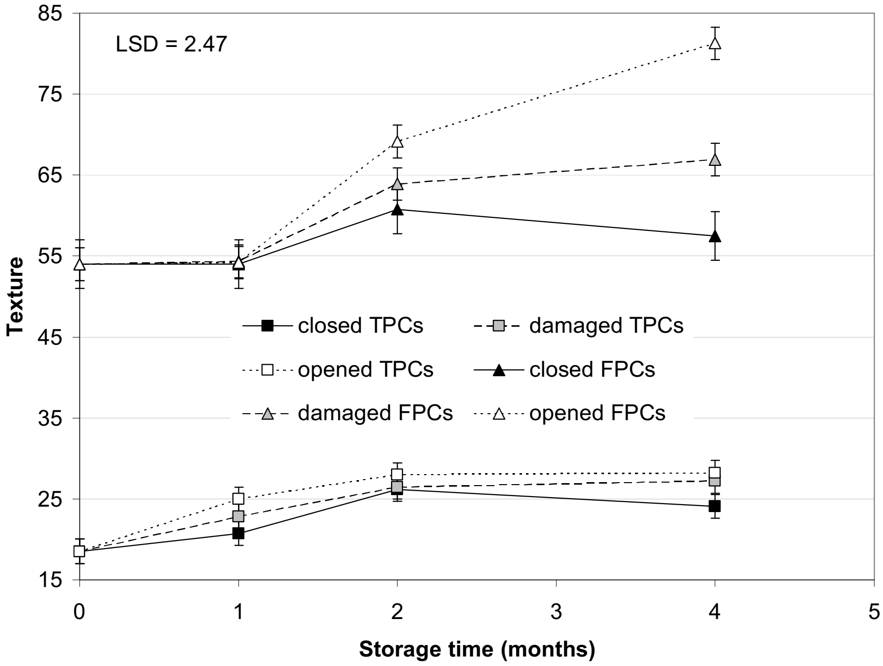

Fig. 2 Texture (N) of traditional potato chips (TPCs) and fabricated potato chips (FPCs) during storage in packages with different degrees of damage (averages for type). Values represent mean ± standard error (SE).

damaged packages, although their hardness increased by 10N (FPCs) and 6N (TPCs). Other examinations confirmed similar alterations in stored snack products texture. The phenomenon of becoming harder is directly connected with the process of water absorption, although the mentioned process is, to a high degree, limited by the actual water content. In a previous investigation involving chips stored for 9 months in a climatic chamber, a final decrease was observed in chip hardness at the end of their storage, which proves the existence of a certain critical moisture level (Kita and Lisińska 2004). Above that value, other structural changes begin to take place leading to a decreased hardness and to the beginning of softening, which worsens the texture of the chips even more.

Although the direction of changes in both types of snack products was similar, the chips lost their crispiness and got harder, more profound changes were recorded for fabricated chips compared to traditional chips. This is probably connected with their differing composition and texture, allowing for the absorption of higher amounts of water, as well as with alterations in starch (amongst others retrogradation), directly resulting in a stiffer structure in the product (Salvador *et al.* 2009).

The quality as well as durability of fried snack products is highly dependent on the oxidation stability of the fat they contain. The alterations in peroxides and free fatty acids are shown in **Fig. 3-4**. Damaged packages, either by making holes in them or by opening them, accelerated the pace of both hydrolytic and oxidative alterations in both product types. As could be expected, a higher pace of alterations was recorded for products stored in most damaged packages. The highest intensity was observed in oxidation processes, expressed by the quantity of peroxides formed, for the fabricated chips (made of dough) compared to the traditional

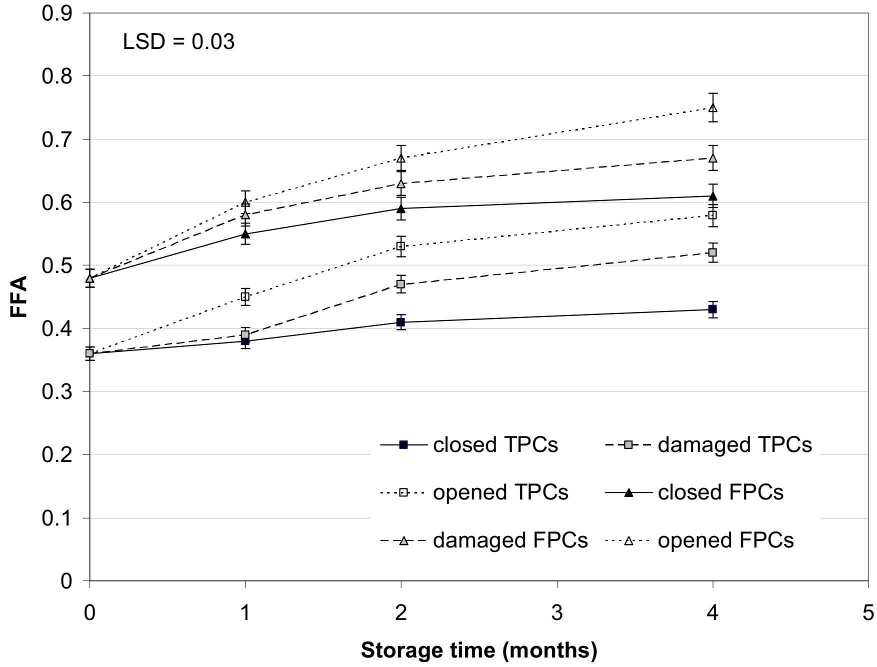

Fig. 3 Free fatty acid (FFA) content (% oleic acid) of fat extracted from traditional potato chips (TPCs) and fabricated potato chips (FPCs) during storage in packages with different degrees of damage (averages for type). Values represent mean ± standard error (SE).

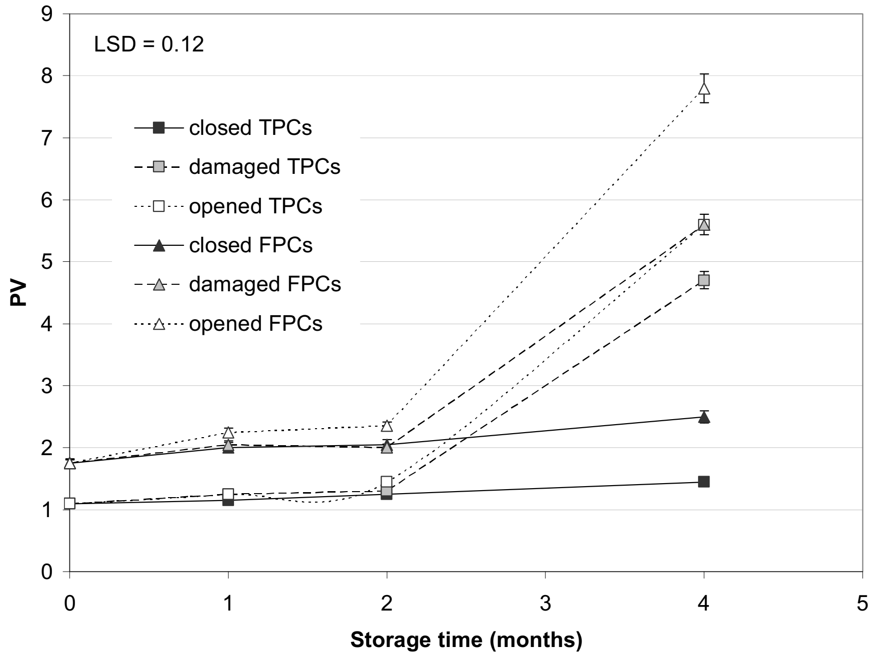

Fig. 4 Peroxide value (PV; meq O_2/kg) of fat extracted from traditional potato chips (TPCs) and fabricated potato chips (FPCs) during storage in packages with different degrees of damage (averages for type). Values represent mean ± standard error (SE).

chips. This phenomenon was also true for both the chips stored in packages with holes and for the opened packages. Higher oxidation product formation was connected with the higher initial content of peroxides in those products before storage began. In other research, involving a comparison of alterations in peroxides contained in snack products fried in oils featuring different degrees of degradation, stored product oxidation processes were much more intensive in fat fractions of products fried in used oils than those fried in fresh oils (Kita 2006). Different chemical compositions of non-fat fractions might also have affected the pace of stored product oxidation. Jonnalagada *et al.* (2001), comparing product oxidation content in three kinds of snacks fried in cottonseed oil, reported that more peroxides formed on the subsequent days of storage in snacks made of dough than in potato chips.

The higher pace of alterations in fat fractions of fabricated chips was confirmed by the analysis of fatty acids composition, whose changes are shown in **Fig. 5** as an unsaturation degree. After 4 months of storage, the degree of unsaturation decreased in the fat fractions of all products stored and the greater the damage to the package, the more profound the alterations that took place. Comparing to data in the literature, the alterations observed were not as great, yet all the products subjected to analysis were fried in palm oil – the kind of fat featuring high thermo–oxidative stability. Considerably more profound alterations were observed by other authors who analyzed products fried in rapeseed, sunflower, soybean and other oils. When potato chips (var. 'Norchip') were fried in different canola oils better oxidative stability was exhibited when chips were fried in modified oils in comparison with traditional oil. Chips fried in hydrogenated oil had lower rates of accumulation of peroxides, but a higher level of volatiles during storage than

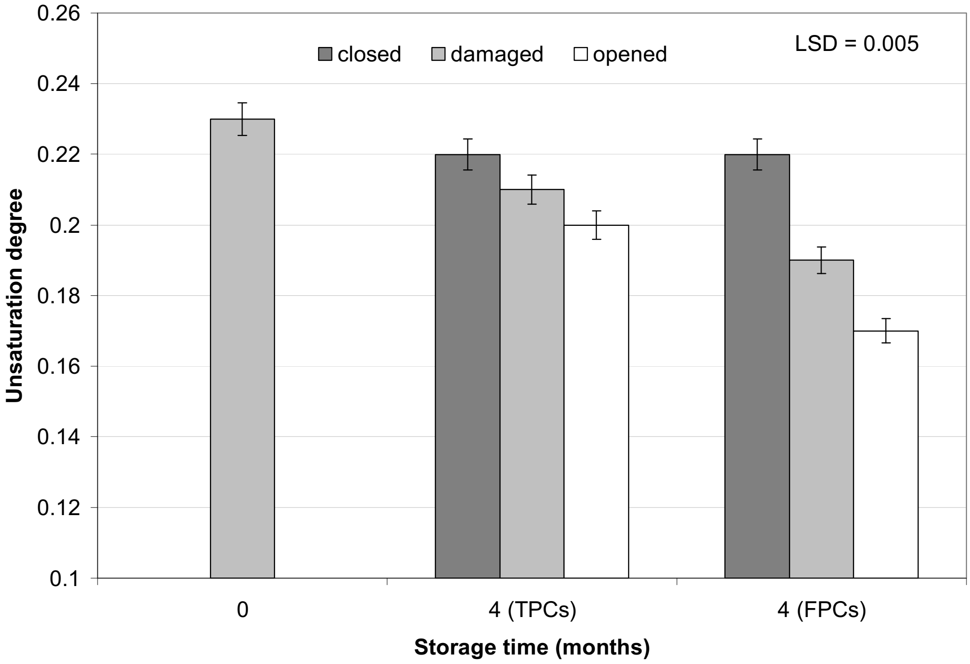

Fig. 5 Degree of unsaturation of fat extracted from traditional potato chips (TPCs) and fabricated potato chips (FPCs) during storage in packages with different degrees of damage (averages for type). Values represent mean ± standard error (SE).

chips fried in low-linolenic and high-oleic canola oils (Petukhov *et al.* 1999). In another experiment, when potato chips (var. 'Atlantic') were fried in cottonseed, sunflower and palm olein oils and their blends the best properties during storage were exhibited by chips fried in blends with palm olein (Pangloli *et al.* 2002). Khan *et al*. (2008) showed that coconut oil blends could be used as frying oil in the preparation of potato chips. Warner and Fehr (2008) compared different kinds of soybean oils. They observed that mid-oleic/ultra-low linolenic acid soybean oil used as frying medium produced oxidative stable fried food.

The results of general organoleptic analysis are shown in **Table 2**. All the assortments of the chips analyzed characterized an appropriate quality (assessed by granting maximum number of points) before storage. The time of storage, and, first of all, the degree of package damage, affected the worsening of chips' sensory properties. The most advanced quality worsening was recorded for the products stored in the most damaged packages, while the least worsened quality was detected in the products stored in undamaged packages. Among the products stored in packages showing different degrees of damage, the fabricated chips featured significantly worse quality compared to the traditional chips, which was directly connected with more advanced changes in chip texture, as well as more intensive oxidation processes, affecting product taste and flavor. However, no effect of the kind of spices used on the quality of the analyzed products was reported. This dependence was observed in another experiment involving chips stored for 7 months. Then, the chips flavored with cheese–onion featured more satisfactory sensory properties compared to those flavored with bacon–red pepper (Kita 2002).

The correlation coefficients (**Table 3**) confirm the relationships between the parameters under investigation. Both the degree of damage to packages and the length of storage time significantly influenced the texture of the snacks as well as peroxide content in fat fractions of the stored products. The texture is also correlated with the type of potato snack (traditional chips or fabricated chips) and moisture content. However there is no correlation between the kind of spices and the examined parameters.

Table 2 Total organoleptic assessment (points 1-5) of potato chips (TPCs – traditional potato chips, FPCs – fabricated potato chips) during storage in packages with different degree of damage.

Type of snacks	Storage time (months)	Total organoleptic assessment (points 1-5)		
		Closed	Damaged	Opened
TPCs	0	5.00 cA	5.00 cA	5.00 dA
with red	1	5.00 cC	4.73 cB	4.30 cA
pepper	2	4.60 bC	4.10 bB	3.72 bA
	4	4.25 aC	3.42 aB	2.54 aA
TPCs	0	5.00 cA	5.00 dA	5.00 dA
with	1	5.00 cC	4.66 cB	4.21 cA
cheese	2	4.70 bC	4.07 bB	3.64 bA
	4	4.44 aC	3.51 aB	2.81 aA
FPCs	0	5.00 cA	5.00 dA	5.00 dA
with red	1	5.00 cB	4.18 cA	4.04 cA
pepper	2	4.65 abB	3.84 bA	3.61 bA
	4	4.32 aC	3.19 aB	2.41 aA
FPCs	0	5.00 cA	5.00 dA	5.00 dA
with	1	5.00 cB	4.37 cA	4.11 cA
cheese	2	4.58 bC	3.89 bB	3.22 bA
	4	4.29 aC	3.21 aB	2.18 aA

Lower-case letters indicate significant differences between columns (for every kind of potato chips), $p \leq 0.05$
Capital letters indicate significant differences in columns, $p \leq 0.05$

Table 3 Correlation coefficients between texture (N) and PV (peroxide value) of fat fraction of potato chips (traditional potato chips and fabricated potato chips) and characteristic parameters of stored products.

Parameters	Texture (N)	PV of fat fraction
	Correlation coefficient (r)	
Kind of potato snack	0.78*	0.37
Kind of spices	0.26	0.03
Degree of damage of packages	0.89*	0.69*
Storage time	0.67*	0.51*
Moisture	0.78*	0.32

* significant correlation, $p \leq 0.05$

CONCLUDING REMARKS

The degree of package damage did significantly affect the quality of fried potato snacks during storage. The higher the degree of package damage, the more intensive the absorption of water from the environment. Changes in stored product moisture also directly affected chip texture, making it harder. A high correlation was observed between the hardness of products and the degree of package damage, as well as the length of storage. Significantly harder texture and more profound changes regarding shelf life characterized the fabricated chips, but not the traditional chips. The degree of package damage also influenced the pace of alterations in fat fractions of the products stored. The pace of hydrolytic and oxidation changes increased as the degree of package damage and storage time increased. Regardless of the length of storage and the kind of damage to packages, more advanced changes in the fat fraction were recorded for the fabricated chips compared to the traditional chips. The chips stored in packages with less damage (holes), when subjected to sensory assessment, were granted fewer than 4 points after 2 months of storage, while those stored in open packages obtained the same drop in points after just 1 month.

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