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Consumer preferences and physical evaluation of shortbread stored in different packaging

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Abstract

The work aimed to assess the quality of crackers and sponge, vanilla and butter biscuits stored for 28 days in an original packaging, plastic box (Polypropylene 0.2 mm), food film (HDPE 10 mm) and paper bag. Sensory tests did not prove influence of packaging on the product quality. The authors observed: water desorption for sponge biscuits (ca. 5%), water absorption of 0.06%–1.84% for other biscuits, hardness increase of 20% ÷ 40% for sponge biscuits, hardness decrease by 10% ÷ 23% for vanilla biscuits, hardness increase for crackers in original packaging (+46%) and paper bag (+20%), hardness decrease for samples in food film (- 8%) and plastic box (−26%), hardness change for butter biscuits (from +9% to −15%). Complex assessment proved that HDPE film and PP box most effectively protected the product against the environmental influence. Lengthening the biscuit lifetime requires introduction of innovations regarding the manufacturing technology and packaging design/structure. Presented tests indicate both the advantages and disadvantages of typical packaging, seen from the consumer perspective. It must be remembered that “manufacturer”—“consumer requirements” relation is one of the most important stages of product assessment and development. The authors believe that the obtained results are useful for packaging producers that are new on the market, but also for those which are experienced.

KEYWORDS

food product, packaging, quality, sensory assessment, storage time

1 | INTRODUCTION

The shelf life of a product is best determined as a part of the product development cycle. Packaging may be one of the means by which the shelf life limiting processes are controlled, or the packaging may limit the product shelf life (Brown, Williams, & Kirwan, 2011). In some instances, the packaging alone be effective in extending the shelf life, for example, by providing a complete light and oxygen barrier.

Chemical components of food react with oxygen affecting the colour, flavour, nutritional status and occasionally the physical characteristics of foods (Shim & Lee, 2013). The affects are deleterious and limit the shelf life; moreover, they are essential to achieve the desired product characteristics. Packaging is used to both exclude, control or contain oxygen at the level most suited for a particular product.

According to Aday and Yener (2014) packaging is one of the critical factors that influences the purchasing behaviour. Food products available for sale on the market are mostly packed into portion packs. Thus, crucial function of such packs is to provide a durable product of a good quality (Pal & Bhattacharjee, 2018; Pereira de Abreu, Cruz, & Paseiro-Losada, 2012). In addition the pack serves informative purposes, it also protects the product against damage, and influence of storage and transport conditions (Kruijf et al., 2002). Besides, findings from the study conducted by Venter, Merwe, Beer, Kempen, and Bosman (2011) indicated that consumer perception of food packaging are focused on the functional (purposive, recyclable and informative) and physical attributes (attractive, of high quality and hygienic).

It is claimed that crucial feature of traditional materials intended for contact with food is their inactivity, ability to stay neutral. This means that only insignificant interaction between the food and packaging is allowed (EU Commission Regulation, 2016/1416; Pawlicka, 2016; Restuccia et al., 2010). Various tests have proved influence of some substances coming from packaging (Bhunia, Sablani, Tang, & Rasco, 2013; Restuccia et al., 2010; Zhang, Kenion, Bankmann, Mezouari, & Hartman, 2018). All the above is especially important when it comes to product quality and consumer safety (Ali & Kapoor, 2009; Arvanitoyannis & Bosnea, 2004).

Innovative food packaging such as edible coatings present a new approach to optimizing the product quality. In this case, packaging is an integral part of the product (Aguirre-Joya et al., 2018). In addition to product quality, the packaging technology also takes into account environmental, material and legal aspects. The popularity of edible coatings is the result of an increasing awareness of consumers who are looking for safe, comfortable and stable food. However, it should be noted that the edible coating is not a universal packaging for all types of food, and this in turn poses a big challenge for the technologists (Pooja Saklani, Nath, Kishor Das, & Singh, 2019). Economic requirements and links with the supply chain (production, distribution, storage, sale) are also important.

Another critical component taken into account in food production are aspects ensuring additional protection of the packaging. Packaging of this kind is called active packaging. According to authors (Chen et al., 2018) "active packaging material" is one of the most promising alternatives to traditional packaging, in which the antimicrobials or antioxidants are incorporated into or coated onto the packaging material to extend the food shelf life and improve the consumer's safety. For moisture-sensitive and lipid-containing foods, the common quality loss is caused by the moisture absorption through packaging and lipid oxidation. According to the authors (Nosáľová, Loučanová, & Parobek, 2018), the attributes of active and intelligent packaging are mainly the extension of the product's protective function, that is, the transition from passive protection to active protection and as well the visibility of the information function. Active packaging on a large scale is used in the USA, Japan or Australia, on a slightly smaller scale in the European Union. According to Dobrucka (2013) in contrast to traditional packaging, active and intelligent packaging may change the composition and organoleptic characteristics of food, provided the changes to be consistent with the provisions for food.

Other authors have also indicated an innovative packaging form for shortcake biscuits (Romani et al., 2015). Their study demonstrates that modified multilayer polymeric materials, with negligible environmental impact, can be successfully applied for biscuit packaging, without no effect on the overall quality of the food product during the storage. Insignificant differences in the assessment of primary and secondary lipid oxidation were observed among differently packed biscuits during the whole storage.

Another modern solution in the storage of shortbread cakes indicated by Balestra et al. (2019), is a new ecofriendly packaging. Authors confirmed in their research the best performances in terms of physical-chemical quality of biscuits. According to those authors the obtained results remain useful information for the industrial application.

For foods sensitive to moisture changes and containing lipids, the loss of quality is due to the absorption of moisture by the packaging and the oxidation of lipids. Duta, Culetu, and Mohan (2019) studied the quality parameters of biscuits placed on trays wrapped with various types of foil (polyethylene terephthalate, polypropylene, polyvinyl chloride and polyethylene). These authors found an increase in moisture content, water activity, free fatty acids and peroxide value, and a decrease in hardness and in sensory quality.

Important packaging feature is its ability to be re-closed. Food manufacturers know how to deal with this problem, however, some product changes occurring after packaging opening cannot be undone. One of said changes, in case of biscuits, is change of water content. Two physical phenomena are related to it, water absorption and desorption. Change of product's water content is a factor that destabilizes the sensory qualities of the product (Ansari, Maftoon-Azad, Farahnaky, Hosseini, & Badii, 2014; Heiniö, 2014; Khaled & Malak, 2017; Singha, Guizani, Al-Alawi, Claereboudt, & Shafiur Rahmana, 2013). As a result of sensory qualities destabilization, change in flavour takes place which often means worsening of the biscuit quality. Another significant product parameter is hardness. This quality is differently approached by the consumers,therefore, in order to meet their requirements it is good to know what kind of changes occur or what kind of changes can be expected in case of improper packaging used. Hardness parameter is strictly connected to sensory quality of the product, therefore, it does affect the complex assessment of the product quality. As it has already been mentioned, it is a great challenge for the production engineers and food manufacturers to find such packaging which after opening and re-closing would preserve the unchanged quality features protecting the product uninterruptedly against loss of its inherent quality. In addition to the above-mentioned quality features and types of packaging according to Świda, Halagarda, and Popek (2018) it is also important to meet the consumer requirements, expectations and preferences, namely to propose functional, convenient and safe packaging that protects the product and the health of the consumer.

The purpose of the research was to propose to consumers safe forms of packaging, and indicate the packaging in which the stored biscuits retain their original characteristics as long as possible. Obtaining such information by means of conducted instrumental analysis and sensory evaluation allows meeting the requirements of consumers with the proposed quality given to producers. Direction of physical and sensory changes occurring in shortcrust biscuits stored in various most commonly applied packaging types were presented.

2 | MATERIALS AND METHODS

2.1 | Materials

Four popular types of biscuits available on retail sale were used for in the work (Table 1).

2.2 | Methods

2.2.1 | Sensory analysis

From each type of test biscuits, four samples of respective quantity were selected, the samples were placed in various packaging types (Table 2). Thus prepared samples were stored for 28 days in stable ambient conditions (humidity of 30%, temperature of 21°C). Sensory quality assessment was carried out by a trained, selected 10-person team, whose competences were monitored in accordance with ISO 8586:2014. The test consisted in periodical comparison of test biscuits and reference sample, carried out every 7th day. Reference sample was a biscuit of each type freshly taken out from an original packaging. This aimed to provide more precise sensory assessment. Values of sensory descriptors for a single panellist were calculated by the following interrelations

$$D_{1-7(REF)} - D_{1-71(TS)} = \Delta D_{1-7}$$

$$D_{2-7(REF)} - D_{2-7(TS)} = \Delta D_{2-7}$$

$$\ldots\ldots\ldots\ldots\ldots\ldots$$

$$D_{n-7(REF)} - D_{n-7(TS)} = \Delta D_{n-7}$$

where, $D_{1\text{-}7(REF)}$, value of descriptor no. 1 for reference sample in test Day 7; $D_{1\text{-}7(REF)}$, value of descriptor no. 1 for test sample in test Day 7; $D_{n\text{-}7(REF)}$, value of nth descriptor for reference sample in test Day 7; $D_{n\text{-}7(REF)}$, value of nth descriptor for test sample in test Day 7; $\Delta D_{1\text{-}7}$, descriptor's change rate in test Day 7.

Each descriptor's change was indicated as an average value of particular descriptor differences, provided by the assessing team. The value was calculated using the following equation:

$$\overset{\ominus}{X}_{D} = \frac{D_{1P1} + D_{1P2} + \ldots + D_{1Pn}}{n}$$

where, D_{1P1}, change of value of descriptor no. 1, indicated by the first panellist; D_{1P2}, change of value of descriptor no. 1, indicated by the second panellist; D_{1Pn}, change of value of descriptor no. 1, indicated by the nth panellist; n, number of panellists.

All sensory descriptors assessed during the test are presented in Table 3.

2.2.2 | Texture tests (hardness)

Biscuits hardness tests were carried out with use of CT 3-4500 texture meters manufactured by Ametek Brookfield Engineering Labs, Inc. It was assumed that with the passage of storage period, water sorption or desorption from test samples occurs, which as a result brings changes in the hardness. The test aimed to find packaging which protects the biscuits against the water content changes the best. The test cycle took 28 days. Within this period, samples' hardness was tested in constant time intervals (0, 7, 14, 21 and

TABLE 1 Characteristic of biscuits used in the research

Type of biscuits	Ingredients
Sponge biscuits (S1)	35% wheat flour, 25% pasteurized egg component, sugar, water, glucose-fructose syrup, potato starch, rape oil, rising agents E 503, salt, acidity regulator, citric acid, emulsifier E 471, carotene pigment
Vanilla biscuits (S2)	wheat flour, invert sugar, palm oil, water, rising agents, ammonium carbonates, sodium carbonates, vanilla flavour, corn-starch, lecithin emulsifier (from soy), salt, preservative: sodium pyrosulphite
Crackers (S3)	wheat flour, rape oil, rising agents: ammonium carbonates, sodium carbonates, barley malt extract, salt, glucose, powdered eggs, lecithin emulsifier
Butter biscuits (S4)	wheat flour, sugar, palm oil, milk butter (5%), invert sugar syrup, rising agents: sodium carbonates and diphosphates, dried whey (from milk), whole milk powder, salt, lecithin emulsifier, acidity regulator: citric acid

TABLE 2 Type of biscuits packaging used in the research

Type of packaging	Material	Water vapour permeability [g/cm^3/24 hr]	Volume [pieces]
Paper bag: (P1)	Grammage 80–120 g/m^2—open packaging	Not specified	21
HDPE food film: (P2)	High density polyethylene, 10-micrometre thick	5.9	
Plastic box: (P3)	0.2 mm thick polypropylene	10.7	
Original packaging: (P4)	Polyethylene, plus paper insert in case of butter biscuits—open packaging	17.7	

TABLE 3 Sensory descriptors

	Biscuits			
Descriptor	**S1**	**S2**	**S3**	**S4**
Sweet aroma	T	T		
Vanilla aroma		T		
Butter aroma				T
Sweet flavour	T			
Butter flavour				T
Salt flavour			T	
Hardness	T	T	T	T
Crustiness	T	T	T	T
General assessment	T	T	T	T

Note: "T" = assessed descriptor.

28 days). The determined values were accurate to 0.5% FSR (Full-Scale Range—specification of CT 3-4500). The following measurement parameters were adopted: sampler speed 2 mm/second, target value for the sampler from 10 mm to 4 mm (depending on test biscuit type), maximum sampler load from 5 g to 20 g (depending on test biscuit type). In the course of tests, TA 17 sampler of TA-P KIT 2 set manufactured by Ametek Brookfield Engineering Labs, Inc. was used. Hardness measurement was performed for each biscuits after a specified storage time in triplicate.

2.2.3 | Water content tests

For water content tests, MA 50.3Y moisture analyzer manufactured by Radwag Wagi Elektroniczne, Polska, was used. Sample mass measurement was accurate to 0.001 g, and water content to 0.001%. Test methodology consisted in single weighing and drying of biscuits in a constant temperature of 102°C with 0, 7, 14, 21 and 28 days interval. For water content tests, samples previously subjected to hardness test were used. Before drying, each sample was crushed mechanically, and each took a form of tiny bits. Sample (m_1) of ca. 2 g mass was spread over the whole weighing pan surface as a layer of a uniform thickness. Removal of the total amount of water from the test samples meant stable final mass (m_2). It was assumed that sample mass is stable if it does not change over 25-s long period of time. This corresponded to finish mode "Automatic 2" of the moisture analyzer menu (info of the manufacturer). Water content was calculated on the basis of the following equation:

$$\%WC = 100 \cdot \left(m_1 - m_2\right) / m_1$$

where m_1, start mass of the sample (prior drying); m_2, end mass of the sample (after drying).

Water content measurement was performed for each biscuits after a specified storage time in triplicate.

The authors inform that the proposed method of measuring the water content has been validated for cookies in terms of the following parameters: temperature, mass, humidity, thickness of the sample layer, as well as the method of drying the sample. The study carried out the measurement assuming the parameters specified in the validation process. The validation process itself was not included in the work. Detailed procedure regarding method validation was adopted from Kowalska, Janas, and Woźniak (2018).

2.3 | Statistical analysis

For development of statistics regarding the results obtained in the course of sensory analysis, Q-Dixon test was used. Each set of results obtained for given test descriptor was provided in an ascending order, next, using the following equation, *R* range between results of each data set were calculated:

$$R = x_n - x_1$$

where, x_n, maximum value of a given series of measurements; x_1, minimum value of a given series of measurements.

Then values Q_1 and Q_2 were calculated and compared to a critical value Q_{kr} for significance level $\alpha = .05$ and for respective quantity of degree of freedom $f = n$.

$$Q_1 = \frac{x_2 - x_1}{R}$$

$$Q_2 = \frac{x_n - x_{n-1}}{R}$$

One-component analysis of variance ANOVA was used in order to detect whether any statistically crucial differences between descriptors of test biscuits occur, packaging type in which the biscuits were stored was taken into account. The test was carried out for general assessment descriptor, the value was a complete sensory assessment of the product. Variance analysis aimed to show whether the packaging does influence product's sensory quality or not. With regard to this two test hypothesis were made, H_o and H_1.

$$H_o = \frac{s_p^2}{s_r^2} \leq 1.$$

$$H_1 = \frac{s_p^2}{s_r^2} > 1$$

where, H_o, null hypothesis, product packaging does not influence sensory quality; H_1, alternative hypothesis, product packaging influences sensory quality; s_p^2, intergroup variance regarding packaging type; s_r^2, variance inside group (residual).

After tests, the hypothesis were verified.

For water content and hardness measurements, a regression analysis was carried out to check whether the variability of the hardness of the cookies was correlated with changes in the water content resulting from the storage of products in different packaging.

A correlation coefficient was also determined to determine the strength and direction of the relationship between changes in the water content and changes in the hardness of biscuits.

3 | RESULTS AND DISCUSSION

3.1 | Sensory tests

Moisture migration can produce deleterious physical and chemical changes in multicomponent foods, potentially affecting safety, shelf life and also sensory quality (Heiniö, 2014; Lee & Van Hout, 2009; O'Connor, FavreauFarhadi, & Barrett, 2018). Assessment of selected sensory descriptors allows to implement crucial modifications regarding the manufacturing technology which in turn enables obtaining less costly product of improved quality. Percent values of sensory descriptors change for samples S1, S2, S3, S4 after 28-day long test are to be found in Table 4.

It has been concluded that regardless of packaging type in which biscuits (S1) were stored, the sweet aroma decreased by 20%–30%. The least significant change was observed for packaging P3 (plastic box), featuring closed lid. Despite changes of this descriptor, no significant changes of sweet flavour were noted, its value remained constant throughout the whole test. When it comes to hardness and crustiness of biscuits (S1) stored in packaging P1, it was observed that they were much harder and more crispy. Increase of hardness by 80%, and of crustiness by 27% was recorded. This type of packaging did not isolate the sample from the ambient conditions, free access of air to the test sample was ensured. During complex sensory assessment the greatest stability of the sample versus the reference sample was obtained for sample stored in packaging P3 (−4%), and for sample stored in packaging P2 (−5%). This result confirms that isolation of a sample from the environment is a good solution when it comes to production of packaging for biscuits, this kind of solution guarantees the product safety and quality. (Manley & Clark, 2011).

TABLE 4 Percent values of sensory descriptors change for biscuits stored in various packaging types for 28 days

	Packaging type			
Biscuit/Descriptor	**P1**	**P2**	**P3**	**P4**
S1				
Sweet aroma	−20	−31	−17	−28
Sweet flavour	1	0	1	3
Hardness	80	31	11	22
Crustiness	27	26	17	10
General assessment	−11	−5	−4	−16
S2				
Sweet aroma	−13	−11	−13	−13
Vanilla aroma	−13	−11	−16	−13
Sweet flavour	4	2	9	11
Hardness	11	13	20	20
Crustiness	13	15	15	22
General assessment	9	0	2	11
S3				
Salt flavour	11	2	15	6
Hardness	−2	4	2	11
Crustiness	9	7	−4	13
General assessment	9	0	2	4
S4				
Butter aroma	15	2	−2	−7
Butter flavour	−2	0	−7	2
Hardness	15	20	18	18
Crustiness	27	26	17	10
General assessment	6	14	9	5

During analysis of biscuits S2 it was noted that regardless of the packaging type, few dozen percent loss of sweet and vanilla flavours occurred. When analyzing the sweet flavour, hardness and crustiness, the authors observed, for all sample types stored in various conditions, that values of the descriptors increased by few or few dozen percent versus the reference product. It was stated that for general assessment the test sample versus the reference sample changed by 11% maximum (sample stored in packaging P4). No sample change was observed for test sample stored in packaging P2, that is, the sample when compared to the reference one was ideal. Slight changes occurred in case of sample from packaging P3 (only ca. 2%). The above observations let one conclude that for this type of biscuits (S2) both packaging types P3, P4 are the best solution allowing to isolate the product from the environment. Similar conclusions were obtained by (Peelman, Ragaert, Verguldt, Devlieghere, & De Meulenaer, 2016), who likewise proved interrelation between the environment and products quality.

Generally, characteristic feature of sample S3 was salt flavour, change of which versus the reference sample ranged between 2% (packaging P2) and 15% (packaging P3). Hardness of sample stored in packaging P1 decreased by 2% when related to the reference value. The crustiness of the sample stored in packaging P1, P2, P4 increased from 7% to 13%. In case of sample stored in packaging P3, crustiness slightly decreased. Despite change of test descriptors such as flavour, hardness and crustiness it was stated that when it comes to a general assessment of stored biscuits, no significant sensory changes were noticed regardless of the packaging type. Result close to reference sample was obtained for samples stored in packaging P2 and P3.

Sample S4 was characterized by two crucial features: butter aroma and flavour. The greatest change with regard to butter aroma was recorded for sample from packaging P1 (15%), and the smallest for sample form packaging P4 (−7%). The best butter flavour stability was obtained for sample form packaging P2, minor deviation of this descriptor was also observed for packaging P1 and P4 (±2%). According to panellists, hardness increased several percent for each sample regardless of the packaging. Greater values were noted for crustiness descriptor, particularly for samples stored in packaging P1 and P2 (increase of ca. 27% vs. the reference sample).

Quite insignificant increase (+10%) was registered for sample stored in packaging P4. Complex assessment of sample S4 in case of each packaging type showed 5%–14% increase in value. However it should be noted that the slightest deviation of test sample versus the reference sample was observed for biscuits stored in packaging P1 and P4. These were open packaging types, they did not provide isolation of the sample form the environment.

Determining whether packaging influenced the sensory quality within the storage period required the use of one-component analysis of variance. The test aimed to find confirmation or negation for above presented H_o hypothesis. Results of this test were presented in Table 5.

On the basis of results of one-component analysis of variance ANOVA it was concluded that for all test biscuits H_o hypothesis is true. This means that packaging types in which biscuits were stored do not influence change of sensory value when it comes to the general assessment.

3.2 | Water content tests

It is commonly known that water content is one of the most significant parameters affecting the biscuits quality and sensory assessment. According to authors (Zhou et al., 2018) moisture content decreasing and internal structure changes, can cause that the binding force between the water molecules and materials increase. With the above in mind, change in water content of a product may radically modify the product's sensory value (Mathlouthi, 2001).

All types of biscuits stored in various packaging types were subjected to water content tests. Obtained results for all the samples, along with standard deviation values, are presented in Table 6.

During tests two processes were observed, absorption of humidity from the environment, samples S2, S3, S4 and desorption of water from the sample to the environment, sample S1. The results are accordant with those of authors (Kowalska, Majewska, & Lenart, 2011) who stated that either gain or loss of weight being an effect of change of water content in sample depends on the biscuit type. Other authors (Guine, Barroca, Pereira, & Correia, 2014) concluded that both the humidity absorption and desorption are specific features of each product, conditioned by both the chemical composition and the internal structure. For most measurements of water content, precision ranged between 0.01% and 0.07%. The greatest deviations when it comes to precision were noticed for sample S1. In case of this sample, total loss of water in the course of the test was 5.04% regardless of packaging type. Decrease of water content in sample S1 as a result brought dried product of changed physical-chemical and sensory qualities. Similar conclusions were drawn up by authors (Błońska, Marzec, Kowalska, & Wróblewska, 2012), they stated that significant loss of water in a biscuit makes it less acceptable for a consumer and significantly changes its physical-chemical features. According to them and Pawlicka (2016), desorption of water from sample depends on applied, in the course of production, methods of dough raising and aeration. Other authors suggest that the structure when it comes to porosity mainly depends on duration and conditions of aeration of egg component, which in turn causes fast desorption of moisture to the environment (Żbikowska & Krygier, 2004).

When assessing water content for biscuit S1, a conclusion was made that the least significant dynamics of changes of water content (α_{S1}) within the first 7 days of the test was obtained for a biscuit stored in packaging P2 (Figure 1). This packaging type covered the sample tightly due to which "environment"—"sample" interaction

TABLE 5 Sensory analysis—statistical data

	SS	*df*	MS	*F*	Value - *p*	Test *F*
S1: (y)						
	103.084975	3	34.36166	0.164039	.919017	3.238872
	3,351.5642	16	209.4728			
In total	3,454.649175	19				
S2: (y)						
	106.275495	3	35.42517	0.181926	.907108	3.238872
	3,115.57488	16	194.7234			
In total	3,221.850375	19				
S3: (y)						
	94.31996	3	31.439987	0.2065227	.8903792	3.2388715
	2,435.76052	16	152.23503			
In total	2,530.08048	19				
S4: (y)						
	52.02748	3	17.342493	0.1631333	.9196134	3.2388715
	1,700.93984	16	106.30874			
In total	1,752.96732	19				

Note: (y) - Source of variance between groups, within groups.

TABLE 6 Changes in water content of biscuits stored in various packaging types for 28 days

Biscuit test period [days]	Packaging type			
	P1	P2	P3	P4
S1				
0	9.67 ± 0.05	9.67 ± 0.05	9.67 ± 0.05	9.67 ± 0.05
7	5.24 ± 0.07	7.15 ± 0.02	5.68 ± 0.04	5.57 ± 0.05
14	4.58 ± 0.07	5.40 ± 0.01	4.80 ± 0.11	4.72 ± 0.05
21	4.92 ± 0.07	4.84 ± 0.07	4.86 ± 0.11	4.83 ± 0.03
28	4.63 ± 0.06	4.61 ± 0.04	4.61 ± 0.05	4.63 ± 0.03
S2				
0	4.11 ± 0.10	4.11 ± 0.10	4.11 ± 0.10	4.11 ± 0.10
7	4.30 ± 0.01	4.24 ± 0.03	4.39 ± 0.05	4.41 ± 0.01
14	4.31 ± 0.01	4.26 ± 0.06	4.31 ± 0.05	4.36 ± 0.03
21	4.36 ± 0.04	4.31 ± 0.05	4.30 ± 0.02	4.45 ± 0.02
28	4.33 ± 0.02	4.17 ± 0.03	4.24 ± 0.02	4.28 ± 0.01
S3				
0	4.25 ± 0.16	4.25 ± 0.16	4.25 ± 0.16	4.25 ± 0.16
7	4.82 ± 0.05	4.55 ± 0.03	4.77 ± 0.01	4.59 ± 0.05
14	4.68 ± 0.04	4.59 ± 0.04	4.25 ± 0.04	4.20 ± 0.07
21	4.93 ± 0.03	4.53 ± 0.04	4.41 ± 0.01	4.89 ± 0.10
28	4.64 ± 0.08	4.41 ± 0.02	4.39 ± 0.06	4.24 ± 0.04
S4				
0	2.02 ± 0.05	2.02 ± 0.05	2.02 ± 0.05	2.02 ± 0.05
7	4.45 ± 0.01	3.15 ± 0.02	3.71 ± 0.02	3.73 ± 0.01
14	3.79 ± 0.02	3.21 ± 0.02	3.59 ± 0.13	3.17 ± 0.04
21	4.13 ± 0.04	3.51 ± 0.06	3.77 ± 0.02	3.46 ± 0.04
28	3.86 ± 0.05	3.45 ± 0.01	3.62 ± 0.04	3.36 ± 0.01

was highly reduced. When it comes to loss of water the greatest difference (Δwc) between sample stored in packaging P2 and samples stored in packaging P1, P3, P4 was observed between 7th and 14th day of the test. After 14 days water content changes stabilized for all biscuit types. The last test stage (21–28 days) resulted with product's water content value ranging from 4.61% (products stored in packaging P2, P3) to 4.63% (products stored in packaging P1, P4). During assessment of water content of sample S2, two processes were observed. In the first test stage (1–7 days) absorption of humidity from the environment was a dominant phenomenon, ca. 0.35% for sample stored in packaging P3, P4 and ca. 0.25% for sample stored in packaging P1. The slightest dynamics of absorption of water (α_{S2}) from the environment was noted for sample stored in packaging P2. Sample stored in this packaging was quite hermetically isolated form the environment, therefore "product"—"environment" interaction was considerably reduced. For samples stored in packaging P3 and P4, water absorption and desorption processes were observed interchangeably between 7th and 14th day of the test; this indicated test product instability. For samples stored in packaging P1 and P2, absorption of water from the environment continued. In the last test stage, that is, between 21st and 28th day (grey column/s—Figure 1), regardless of packaging type only desorption of water from the biscuits to the environment was noticed. This process resulted with slightly higher total water content of test samples when compared to their initial state (Table 6). All in all, the greatest water content increase was registered for sample stored in packaging P4 (+0.22%), the smallest for sample stored in packaging P2 (+0.06%).

During stage one of sample S3 test, that is, within the first 7 days, great dynamics of water absorption process was observed (marking α_{-S3}). The dynamics was comparable for each sample regardless of the packaging type. Initially the greatest increase of water content (+0.57%) was registered for sample stored in packaging P1, the slightest (+0.3%) for sample stored in packaging P2. The most stable water content value during the whole test was the value of sample S3 stored in packaging P2 (Figure 1). Sample S3 stored in packaging P1 and P4 was not enough isolated from the environment (open packaging), the packaging P3 did not contact the sample tightly, this caused considerable change in water content of the sample during the test cycle. After test completion it was concluded that water content of sample S3, regardless of packaging type was slightly higher when compared to values obtained at the test start. The greatest change of water content (+0.39%) occurred for biscuit S3 stored in packaging P1, the slightest for biscuits stored in packaging P4 (+0.01%).

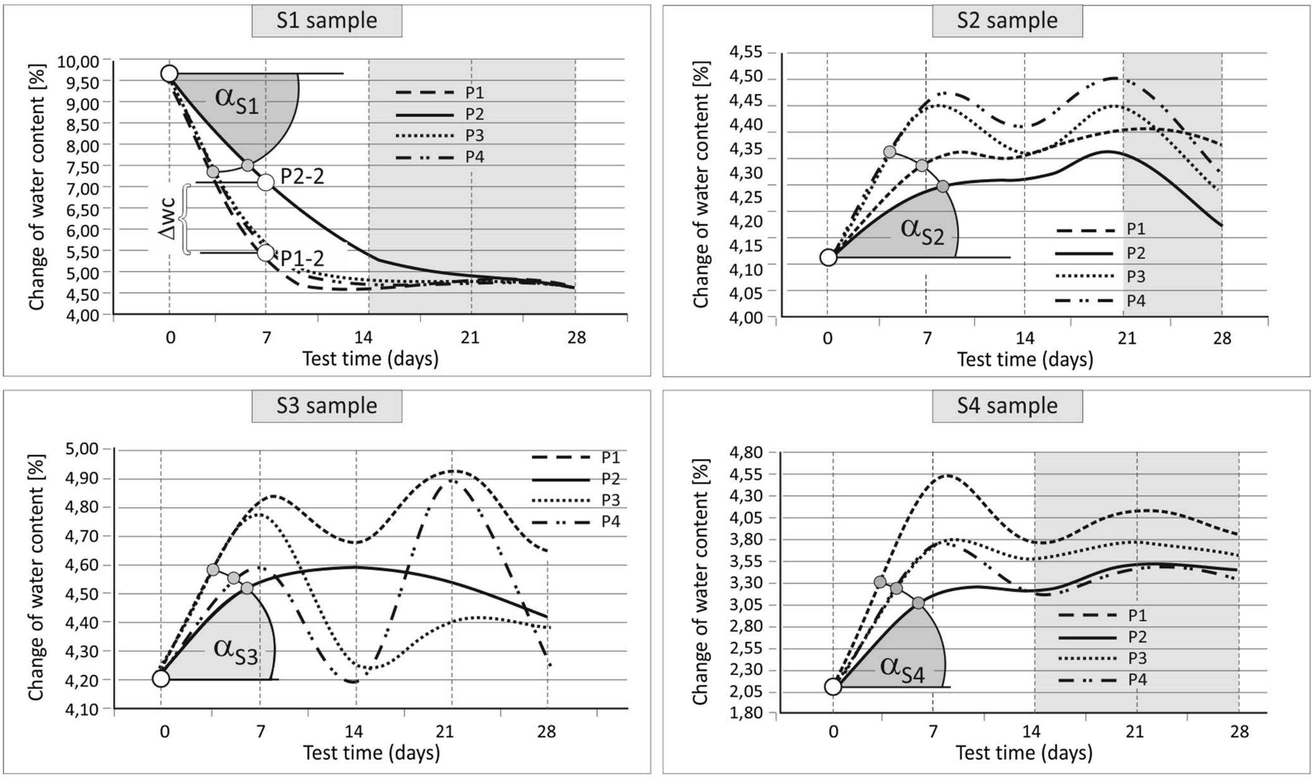

FIGURE 1 Water content in biscuits depending on the type of packaging were used

Regardless of the packaging, for all samples S4 throughout the whole test only absorption of water from the environment was observed. At the initial stage of the test (the first 7 days), the greatest dynamics (+2.43%) of the process was observed for sample stored in packaging P1 (Figure 1). After 7 days water content of sample stored in packaging P1 stabilized, the value was ca. 3.86%, and it was greater by 1.84% versus the initial value. In case of samples stored in packaging P2, P3, P4, the water content increase was comprised within 1.34%–1.60% range. Between 14th a 28th day, stabilization of water content value for all the samples was observed (grey column—Figure 1). After 28 days water content for samples S4 ranged between 3.86% (for packaging P1) and 3.36% (for packaging P4) and it was on average greater by 1.52% versus the initial water content value. After tests completion it was concluded that absorption of water was the greatest in case of sample stored in packaging P1, in case of packaging P4 it was the least significant. Maximum difference when it comes to increase of water content in samples S4 placed in packaging P1, P2, P3, P4 was 0.5%, which is about 30% of the total absorption. This shows that the samples differ even though their water content level is comparable, which is due to packaging type used for storing. The effects are accordant with work of (Giannou, Lebesi, & Tzia, 2014) where it is said that packaging type influences shelf-life of bakery products. In the course of analysis of all water absorption and desorption curves for samples S1, S2, S3, S4, it was noticed that the least significant water content changes were obtained for samples stored in packaging P2. Packaging P2 reduced interaction between the product and the environment to the greatest extend. The most considerable changes when it comes to water content, were recorded for samples S3, S4 stored in packaging P1 and for sample S2 placed in packaging P4. Packaging P1 (paper bag) and P4 (original packaging) were open type of packaging due to which the samples were exposed to a direct contact with the environment.

3.3 | Texture tests (hardness)

Most consumers perceive the quality of biscuits through sensory features such as flavour or aroma (Żbikowska, Kowalska, & Pieniowska, 2018). Authors (Wilkinson, Dijkstehuis, & Minekus, 2000) state that when it comes to assessment of biscuit's quality, it is the product structure that matters. Complex assessment of the structure is possible only via human senses, for this purpose human reaction to physical and chemical qualities is rated. Measurement performed using devices, for example, measurement of hardness, allows to express the tested feature, for example, hardness, via numeric values. Determining precise hardness value helps to design and introduce technological improvements aiming to provide better quality, without affecting the acceptable sensory qualities. Hardness test was performed for all previously specified sample variants. Detailed results obtained during the hardness test, along with standard deviation values, are presented in Table 7.

Between the 1st and 7th day of the test, increase of hardness was recorded for sample S1 regardless of the packaging. Dynamics of the process is presented in Figure 2, it is marked by $\alpha_{h\text{-}S1}$ symbol. The slightest increase of hardness versus initial value (ca. 10%) was

TABLE 7 Changes in the hardness of biscuits stored in various packaging types for a period of 28 days

Biscuit test period [days]	Packaging type P1	P2	P3	P4
S1				
0	3,002.8 g ± 249	3,002.8 g ± 249	3,002.8 g ± 249	3,002.8 g ± 249
7	3,354.5 g ± 681	4,210.5 g ± 353	3,816.7 g ± 747	4,318.0 g ± 765
14	3,966.3 g ± 436	3,962.1 g ± 512	4,154.5 g ± 654	4,272.0 g ± 436
21	4,288.6 g ± 654	3,620.7 g ± 657	3,840.2 g ± 204	4,015.0 g ± 287
28	4,298.3 g ± 972	3,609.0 g ± 154	4,180.2 g ± 248	4,367.6 ± 493
S2				
0	787.2 g ± 62	787.2 g ± 62	787.2 g ± 62	787.2 g ± 62
7	728.0 g ± 37	772.5 g ± 29	745.0 g ± 81	708.0 g ± 109
14	641.8 g ± 82	654.5 g ± 70	622.6 g ± 22	725.6 g ± 68
21	663.3 g ± 58	653.8 g ± 75	680.2 g ± 95	673.8 g ± 28
28	671.8 g ± 112	629.6 g ± 76	703.0 g ± 54	607.8 g ± 24
S3				
0	437.5 g ± 71	437.5 g ± 71	437.5 g ± 71	437.5 g ± 71
7	393.3 g ± 67	595.1 g ± 104	479 g ± 103	582.8 g ± 292
14	377.0 g ± 65	507.1 g ± 181	407.3 g ± 39	460.8 g ± 91
21	402.5 g ± 136	358.8 g ± 124	443.0 g ± 46	489.0 g ± 157
28	520.3 g ± 36	403.3 g ± 38	319.5 g ± 29	643.0 g ± 31
S4				
0	660.5 g ± 44	660.5 g ± 44	660.5 g ± 44	660.5 g ± 44
7	652.1 g ± 74	680.8 g ± 54	676.1 g ± 53	694.6 g ± 84
14	636.0 g ± 118	739.6 g ± 76	749.1 g ± 64	728.8 g ± 94
21	630.0 g ± 105	741.3 g ± 84	655.6 g ± 101	796.5 g ± 48
28	568.3 g ± 42	719.0 g ± 141	617.8 g ± 52	700.1 g ± 73

registered for sample stored in packaging P1, whereas the greatest (ca. 45%) for sample stored in packaging P4. Between 14th and 28th day, hardness instability was observed (ca. 10%) for samples stored in packaging P3, P4. Only in case of sample stored in packaging P1, hardness increase was uninterruptedly observed until test Day 21. After Day 21, constant hardness value was obtained for sample stored in packaging P1, the value was by ca. 43% greater versus the initial value. Constant hardness value between the 21st and the 28th day was obtained also for sample in packaging P2. Total increase of hardness for this sample was the slightest and it was ca. 20% versus the initial value. At the last test stage for sample S1 stored in packaging P3, P4, great dynamics of change of hardness parameter was registered, (β_{S1}). The greatest increase of hardness was observed for samples stored in "open" packaging, that is, in such packaging that did not reduce environment—product interaction, P1 (43%), P4 (45%). In case of sample S1 the observed hardness increase was an effect of desorption of water from sample structure, amounting to ca. 5.06% (Figure 1).

Within the whole test cycle for samples S2, regardless of the packaging, hardness decrease by ca. 10% ÷ 23%, when compared to the initial value, was noted. At the first stage of the test, Days 1 to 7, dynamics of changes of hardness ($\alpha_{h\text{-}S2}$) for all the samples was the same. For sample in packaging P4, temporary hardness stabilization was observed between Days 7 and 14, however later, constant increase was recorded with dynamics (β_{S2}) comparable to dynamics noted at the initial stage (Figure 2). After 14 days, decrease of hardness was registered for samples stored in packaging P1 (from ca. −16% to ca. 14%), and in packaging P3 (from ca. −20% to −11%). The slightest change in hardness was recorded for sample stored in packaging P3. This packaging type featured closed space where the samples were placed. The greatest change in hardness value (ca. 23% vs. the initial value) was obtained for biscuits stored in an original packaging. Generally it may be concluded that decrease in hardness of samples S2, was connected with the process of adsorption of humidity to structure of sample stored in all types of packaging within the whole storage period. According to authors (Mandala, Ioannou, & Kostaropoulos, 2006) increase of water adsorption influences biscuit structure and causes greater porosity.

During the hardness test in case of sample S3, great variation of values was observed (Figure 2). It has been stated that the said variation corresponded with changes in water content of this sample (Figure 1). For the first 7 days of hardness test, the same dynamics of change ($\alpha_{h\text{-}S3}$) was observed for samples stored in packaging P2, P4. Much less significant changes were observed for sample placed in packaging P3, this sample, in later cycle stages,

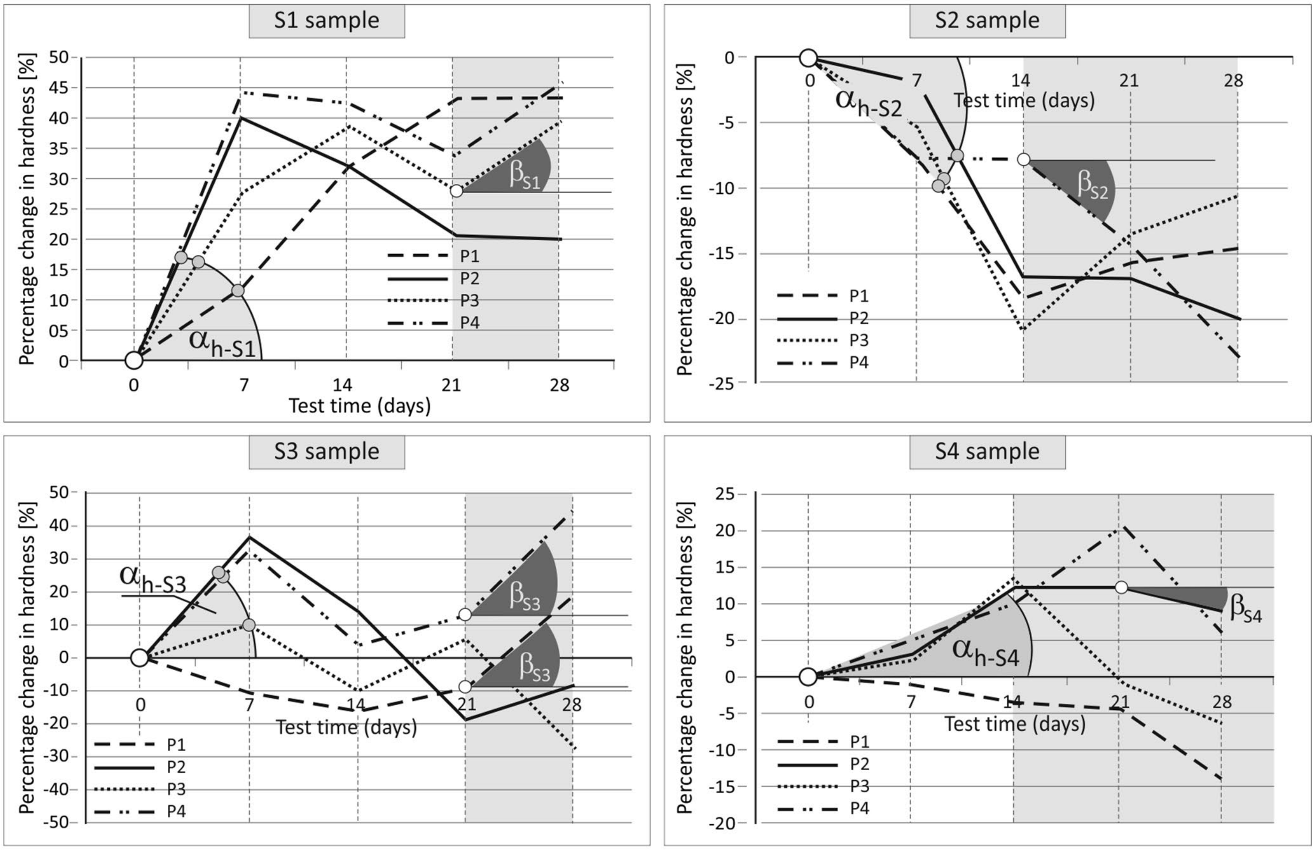

FIGURE 2 Hardness of biscuits depending on the type of packaging were used

showed slight change in hardness, from +10% to −10% versus the initial value. Between test Days 21 and 28, it was registered that this sample hardness decreased by −26% versus the initial value. For sample stored in packaging P1 the hardness increased in total by 20%, and for sample stored in packaging P4 by 46%. In case of these samples great dynamics of change (β_{S3}) could be observed between Days 21 and 28 (Figure 2). Neither of the packaging types reduced interaction between the environment and the product. For sample in packaging P2 after completion of test, change of sample hardness by −8% versus the initial value was registered. It was concluded that packaging P2, P3 prevented influence of the environment on the test product. For samples stored in these packaging types, decrease of hardness was proved, whereas for samples placed in packaging P1, P4 (open packaging), hardness increase was observed.

Hardness test resulted with no significant changes in case of sample S4. Between Day 1 and 14, dynamics of hardness changes ($\alpha_{h\text{-}S4}$) (Figure 2) for samples in packaging P2, P3, P4 was the same —increase by about 10% versus the initial value was noted. After 14th day, constant value of ca. 12% was registered for sample stored in packaging P2, however, during the last test cycle, between Days 21 and 28, the hardness decreased slightly (β_{S4}), to 9% versus the initial value.

Throughout the whole test cycle performed for sample S4 stored in packaging P1, one-direction hardness change was observed, the obtained value versus the initial one was −14%. After test completion for sample stored in packaging P3 hardness decrease by ca. −6% was registered, and for sample stored in packaging P4, the final hardness value was +6% versus the initial value. Analysis of results obtained for samples S4 showed that the obtained standard deviation values were the lowest when speaking of all performed measurement series.

Value of correlation coefficient for biscuits S1 stored in packaging marked with symbols P1–P4 indicated negative dependence between water content changes and hardness changes, that is, decrease of water in product S1 resulted with increase of its hardness (Table 8). The strongest correlation (−.97, −.95) was observed for product S1 stored in packaging P3, P4, the weakest for product stored in packaging P2. For product S1 stored in packaging P2 only in case of 24% the changes in water content caused hardness change.

For product S2, the best correlation (.76) of water content changes and hardness changes was obtained for packaging P1. The packaging structure (paper) was not enough strong barrier for sorption of water which resulted with decreased product hardness. For product stored in remaining packaging types, water content change was only in about 21% related to observed changes of product S2 hardness. Regardless of used packaging, negative value of Pearson coefficient was obtained, in other words, the increase of water content in product S2 caused hardness decrease.

The weakest dependence of water content changes in relation to hardness changes was observed for product S3. Maximum value of R square regress coefficient was only 19%, and it concerned the product that was stored in packaging P3, whereas no dependence was noted when the product was placed in a factory packaging. Positive value

TABLE 8 Dependence between water content and hardness—statistical data (n = 5)

Biscuit	Packaging type P1	P2	P3	P4
S1				
Regres. coeff.: R square	0.64	0.24	0.93	0.90
R Square Standard error	1.50	2.13	0.63	0.77
Correlation coeff.	−0.8	−0.49	−0.97	−0.95
S2				
Regres. coeff.: R square	0.76	0.21	0.22	0.21
R Square Standard error	0.06	0.08	0.11	0.14
Correlation coeff.	−0.87	−0.45	−0.47	−0.46
S3				
Regres. coeff.: R square	0.11	0.13	0.19	0.00
R Square Standard error	0.28	0.15	0.22	0.35
Correlation coeff.	−0.32	0.37	0.44	0.01
S4				
Regres. coeff.: R square	0.10	0.65	0.01	0.28
R Square Standard error	1.04	0.41	0.85	0.65
Correlation coeff.	−0.32	0.81	0.10	−0.53

of correlation coefficient was obtained for products stored in packaging P2, P3, P4, this means that increase in absorption of moisture by the product results also with increase of its hardness. Contrary dependence was proved for product stored in packaging P1. It should be, however, said that error of regression coefficient determination was greater than the coefficient value, which implies nonlinear dependence of hardness changes in relation to water content changes.

The greatest value of regression coefficient (.65) was obtained for product S4 stored in packaging P2, which means that hardness change was in 65% related to water content change. For product S4 stored in other packaging this dependence was 28% maximum (packaging P4). No dependence was observed between the water content and hardness changes when the product was stored in packaging P1 (0.10) and P3 (0.01). Water content increase was correlated positively for product S4 stored in packaging P2, P3, and negatively when packaging P1, P4 was used.

Low values of correlation coefficients show that there is a need to conduct more thorough analysis and tests, where the biscuit hardness must depend on a greater number of variables.

4 | CONCLUSIONS

During assessment of sensory quality of sample S1, a conclusion was made that its state did deteriorate. For remaining samples, that is, S2, S3 and S4, the general assessment value was slightly higher than the one obtained at the test start. Based on that, it can be said that the sensory quality of these biscuits did not undergo statistically significant changes which would be noticeable during sensory tests. Referring to carried out statistical analysis of variance (ANOVA), it was found that the used packaging types did not influence sensory quality of test sample. It must be, however, noticed that values of samples' descriptors such as sweet flavour, vanilla aroma and hardness did decrease. This implies that in time, unfavourable changes occurred in the test samples as a result of environment—product interaction. While carrying out test of water content change, water desorption process (sample S1) and both water absorption and desorption processes (samples S2, S3, S4) were observed. These processes did influence samples' hardness, especially the hardness of sample S1. While assessing packaging type as protection of biscuits against influence of the environment it was stated that none of the packaging types was of the ability to protect the product's quality during storage. This leads to an unequivocal conclusion that product unpacking is the very moment when the changes start to occur and they happen regardless of packaging type. Dynamics of this process depends on the biscuit's structure type, number of pieces, the size, biscuit type and of course on storage time plus packaging material. Changes occurrence can be partially limited by either separation of the biscuit from the environment, or by sealing of the packaging, however, these attempts will only delay processes influencing the final assessment of the product, it is obvious that once started process of product modification cannot be prevented or stopped.

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