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# Investigation of the retaining effect of a pectin-containing edible film upon the crumb ageing of dietetic sucrose-free sponge cake

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**Abstract**

The crumb ageing of dietetic sucrose-free sponge cake (DC) was assessed by scanning electron microscopy (SEM) observations carried out on the first and the sixth day of DC storage. The storage duration was selected according to the standard requirements for DC storage in Bulgaria. No visible changes in the microstructure had occurred on the sixth day of storage in the crumb of the DC covered with pectin film, in contrast to that without pectin film (control sample). The matrices of the partly gelatinized starch and coagulated proteins (light zones) in the DC covered with pectin film kept their fine structure and were not disposed in parallel to the air-pocket walls. Therefore, the extent of retrogradation of starch granules in the control sample was higher, and the ageing, too. This was the reason why the main factor of this process, i.e. the bound water states, was investigated. The quantitative changes in both bound water states (strongly and slightly bound water) were registered by combined dynamic analysis (differential thermal analysis (DTA) and thermogravimetry analysis (TGA)). A significantly bigger (1.5 times) amount of strongly bound water in the crumb of the DC covered with pectin film than in the control sample was proved on the sixth day of storage. The total amount of bound water in both cakes reduced during the storage process. This reduction was considerably more slightly expressed in the DC covered with pectin film as it had reached 4.75% towards 16% in the control sample.

It was proved that, simultaneously with the changes in the bound water states, the qualitative characteristics (structural and mechanical properties, and colour) of the crumb of DC had also changed. Higher values of shrinkage and springiness of the DC covered with pectin film were read on the fifth day. Smaller changes in the crumb colour of the DC covered with pectin film were ascertained by spectrophotometry.

The investigations demonstrated the prevention of crumb ageing of dietetic sucrose-free sponge cake when a pectin-containing edible film was used. This sponge cake had better preserved freshness, especially up to the fifth day of storage.


*Keywords:* Cake without sucrose staling; Edible coatings; Product dry shrinkage; Scanning electron microscopy; Water-retaining capacity

## 1. Introduction

The ageing of bread crumb and paste products is associated mainly with starch retrogradation (Hoseney, Lineback, & Seib, 1978). It has been established (Puchkova & Suogrobova, 1980; Sanina, Puchkova, & Avdeeva, 1987; Yorchack, Berzina, & Royter, 1988) that the water state in the crumb significantly influences this process. It is well known that the structural, mechanical and the colloidal properties of crumb change during storage and that this is due to the complicated water distribution among the high-molecular weight substances, especially starch and proteins. Thus water transforms from the strongly to slightly bound state as visible ageing is observed (Schiraldi, Piazza, & Riva, 1996).

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It is considered (Ivanov, Tanchev, & Obretenov, 1984) that pectin is widely applicable in foodstuffs because of its various properties. The hydrocolloidal and polyelectrolytic properties of pectin determine its unique abilities, such as: strong water retention in colloidal systems together with their stabilization; easy plasticization with glycerol; due to its hydrophobic groups, ability to adsorb organic lipoid substances; an expressive cation-exchange ability forming its curative action (Doudkin, Cherno, Kazanskaya, Vainshtein, & Masik, 1988; Gurr & Asp, 1994). The investigations of many authors (Coffin & Fishman, 1994; Fishman & Coffin, 1998; Miers, Swenson, Schultz, & Owens, 1953; Schultz, Owens, & Maclay, 1947; Swenson, Miers, Schultz, & Owens, 1953) present the structural and mechanical properties of edible films containing citric and apple pectin in the form of aqueous solutions with concentrations up to 1%. There are no data about the prevention of crumb ageing of paste products which is caused by pectin films.

The objective of this study was to investigate the retaining effect of a pectin-containing edible film upon the crumb ageing of dietetic sucrose-free sponge cake.

## 2. Materials and methods

Sugar free sponge cakes exhibit quicker ageing of the crumb and, respectively, a reduced consumption quality. That is why the sucrose-free sponge cake has a shorter storage time than the sucrose-sweetened one as proved in our recent investigations (Baeva & Terzieva, 2001a, 2001b). In order to make the storage time of the sucrose-free sponge cake longer, we have investigated the influence of a pectin-containing edible film upon the crumb ageing of cake.

Sucrose-free sponge cake batter was made according to a technological scheme described in a Patent Form No. 463/02.07.2001 (Baeva & Terzieva, 2001a, 2001b) and a double-bowl mixing procedure was used.

The sponge cakes were baked in a metallic pan containing 65 g of batter and placed in an electric oven (Rahovetz-02, Bulgaria) for 30 min at 180 °C.

The edible film contains vegetable polysaccharide – apple pectin, which is highly esterified with a 63% degree of esterification (62% purity, 125,000 molecular mass), produced by Higher Institute of Food and Flavour Industries, Department of Organic chemistry, Bulgaria. The pectin is used as a stabilizer of the edible film and is prepared as an emulsion.

The crumb ageing of the sucrose-free sponge cakes stored under standard conditions (temperature up to 18 °C and relative air moisture up to 75%) was investigated up to the sixth day from the production date according to the standard requirements (Bulgarian State Standard 4636-82, clause 6.4.2.3).

The scanning electron microscopy (SEM) observations were used to determine the cake crumb microstructure towards the degree of starch retrogradation (Cloke, Davis, & Gordon, 1984; Hoseney et al., 1978; Lineback & Wongsrikasem, 1980). The cake samples studied by scanning electron microscopy (SEM) were taken at 2.5 cm from its outside edge and equidistantly from its upper and lower crusts. Wedges were cut with a razor blade and mounted on a metal (molybdenum) stub. The samples were then double-coated in a vacuum evaporator (high-vacuum apparatus Edwards-306 COATER, United Kingdom) with aluminium, and viewed on a scanning electron microscope Tesla-BS 340, Czechoslovakia.

The amount of strongly and slightly bound water, as a percentage of the bound water in the cake crumb, was determined by differential thermal analysis (DTA) and thermogravimetry analysis (TGA) (Wendlant, 1978). These methods are based on the measurement of the sample mass change as a result of the moisture release on heating. The amounts of the strongly and slightly bound water were determined by the quantity change of the energy used for water evaporation on continuous heating. The analysis was done by means of a derivatograph OD-102 (MOM – Budapest, Hungary) under the following conditions: sample mass, $100 \pm 0.5$ mg; heating range, (20–150) °C; heating speed, 2.5 °C/min; sensitivity, 100 μV/°C; chart speed, 2 mm/min; sensitivity of the TGA-curve, 1/15; sensitivity of the DTA-curve, 1/3; gas environment, static air; pan, cermet and cone; thermocouple, Pt/Pt/Rh put in an inert environment ($Al_2O_3$). Each measurement of the cake crumb was repeated twice.

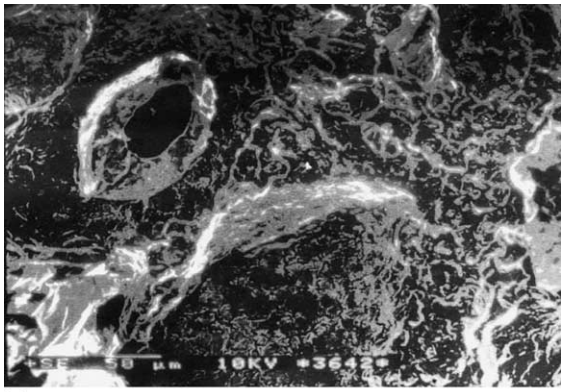
The physical characteristics of sponge cakes were measured 2 h after baking: moisture of sponge cake crumb according to Bulgarian State Standard (BSS) 3412-79, sponge cake shrinkage (at the 5th and 125th s) and springiness (relaxation at the 60th s). Each moisture value was the average of three results, obtained after drying in an oven at 105 °C to constant weight. The shrinkage and springiness (relaxation) of the sponge cake were measured with an automatic penetrometer (model AP 4/3, Dresden, Germany). A hemispherical body with a diameter 12.5 mm and total weight 700 g acted on the sectional surface of asponge cake sample, 30 mm thick, determining the shrinkage at the 5th and 125th s. Relaxation was checked by means of a hemispherical body with a diameter 20 mm and total weight 40 g acting upon a 30-mm thick sample after a preliminary manual pressing to 200 PU (Penetrometer Units) for 5 s and a following liberation for 60 s. This procedure was used to determine crumb springiness.

The spectrophotometer PU 8800 UV/VISIBLE, produced by Pye Unicam; Ltd., England, was used to determine the colours of cake crumbs. The method of Hunter was applied for cake colour determination according to

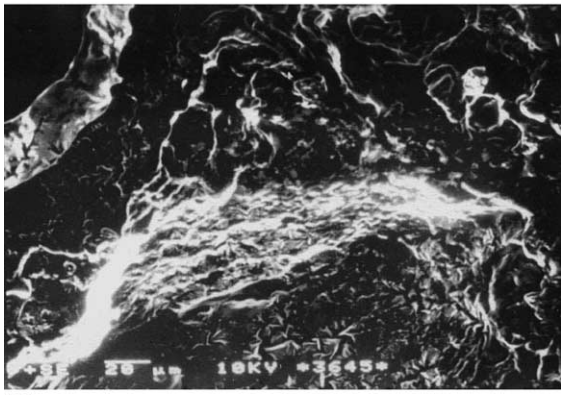
three indices. The *L*-values manifest quantitatively the brightness changing from 0 for black to 100 for white. The index "*a*" expresses quantitatively the red colour when it is positive and the green colour when it is negative. The index "*b*" expresses quantitatively the yellow colour when it is positive and the blue colour when it is negative.

## 3. Results and discussion

The SEM observations of the microstructure of both dietetic sucrose-free sponge cakes (DC) at high magnifications represent the starch retrogradation degree as an important index for their ageing. The SEM photographs were recorded on the first and the sixth day of DC storage. In both DC types, the forms of the matrices of gelatinized starch and coagulated proteins (light zones) were not changed due to the partial gelatinization of starch (Figs. 1–4). It was evident (Figs. 1 and 3) that, on the sixth day in the dietetic sucrose-free sponge cake without pectin film (control sample), the matrices of the gelatinized starch and the coagulated proteins were more compact and with more expressed layered structure than that on the first day. It was found that, in the crumb of DC



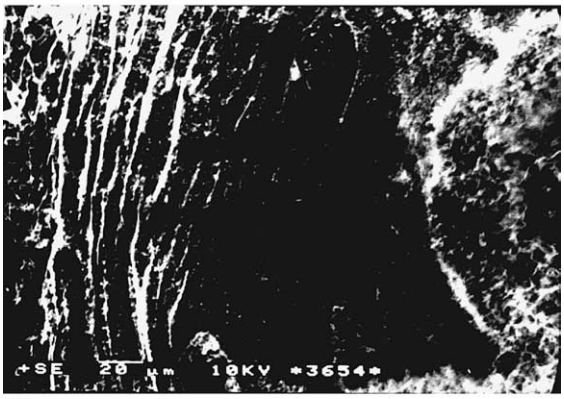

(a)




(b)

Fig. 1. SEM of control sample stored for 1 day: (a) medium magnification; (b) highest magnification.


(a)




(b)

Fig. 2. SEM of DC covered with pectin film stored for 1 day: (a) medium magnification; (b) highest magnification.

covered with pectin film no visible changes in the microstructure had occurred on the sixth day of storage (Figs. 2 and 4). The matrices of the partly gelatinized starch and coagulated proteins were not disposed in parallel to the air-pocket walls and kept their fine structure to a greater extent. They were more spread out and with a lower density toward the control sample. Thus, the extent of retrogradation of starch granules in the control sample was higher, and, therefore, the ageing, too.

The quantitative changes in both bound water states (slightly, $W_1$ and strongly, $W_2$) are represented in Table 1.

The amount of total bound water in both DC had reduced during the storage process. The reduction was significantly more slightly expressed in the DC covered with pectin film as on the sixth day its value was 4.75% compared to 16.00% in the control sample. Even on the first day of storage, the amount of total bound water in the crumb of DC with pectin film was 2% higher than that in the control sample. This tendency was kept up to the sixth day of storage as the difference had risen to 13.25%. Between the first and the fourth day of storage, in the crumb of DC covered with pectin film, a relatively constant level of total bound water and identical correlation of both states of total bound water in favour of $W_2$

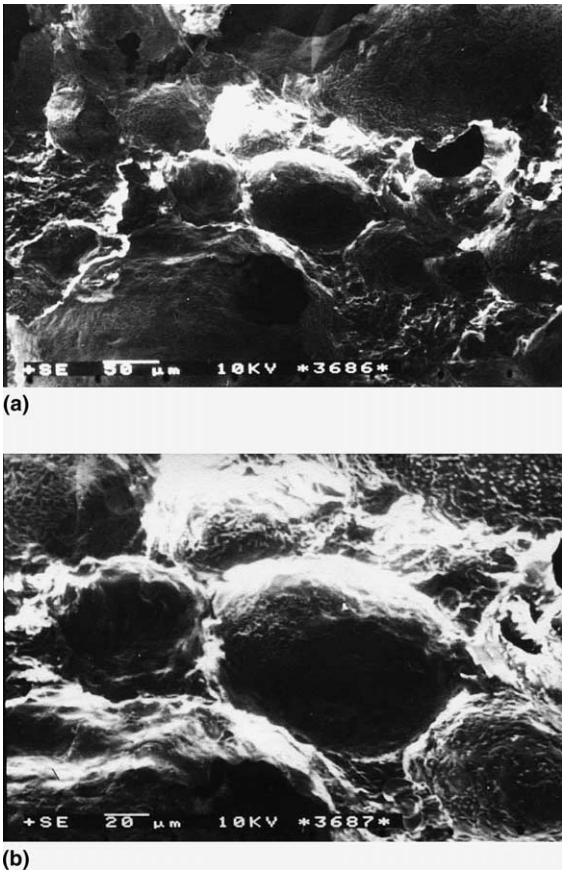



Fig. 3. SEM of control sample stored for 6 days: (a) medium magnification; (b) highest magnification.

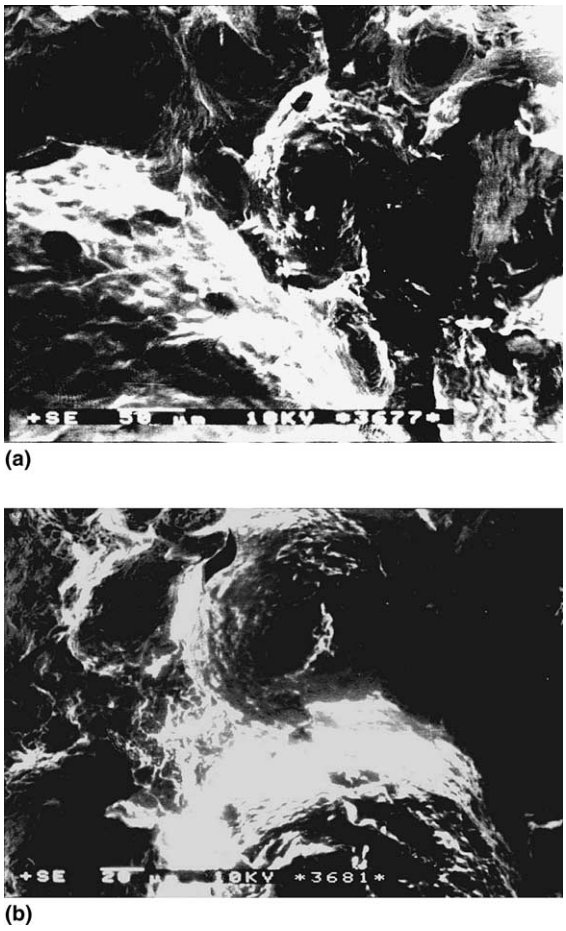



Fig. 4. SEM of DC covered with pectin film stored for 6 days: (a) medium magnification; (b) highest magnification.

Table 1
Amounts of two bound water states[a] in the crumb of the dietetic sucrose-free sponge cakes as a function of storage time

| Storage time (day) | Dietetic sucrose-free sponge cakes | | | | | |
|---|---|---|---|---|---|---|
| | Value of control sample, $n = 2$ (mean ± SD) | | | Value of DC covered with pectin film, $n = 2$ (mean ± SD) | | |
| | Water 1 (%) | Water 2 (%) | Total bound water (%) | Water 1 (%) | Water 2 (%) | Total bound water (%) |
| 1 | 23.0 ± 0.71 | 22.5 ± 0.71 | 45.5 ± 0.88 | 23.5 ± 0.71 | 24.0 ± 0.71 | 47.5 ± 0.35 |
| 2 | 22.5 ± 0.71 | 24.3 ± 1.15 | 46.8 ± 0.98 | 21.0 ± 0.53 | 25.8 ± 1.06 | 46.8 ± 1.06 |
| 3 | 21.5 ± 0.71 | 21.8 ± 0.35 | 43.3 ± 0.35 | 20.5 ± 0.71 | 26.5 ± 0.35 | 47.0 ± 0.71 |
| 4 | 20.0 ± 0.18 | 22.3 ± 0.35 | 42.3 ± 0.35 | 21.5 ± 0.88 | 24.5 ± 1.06 | 46.0 ± 0.71 |
| 5 | 19.5 ± 0.53 | 21.3 ± 0.80 | 40.8 ± 1.33 | 18.0 ± 0.18 | 21.3 ± 0.35 | 39.3 ± 0.35 |
| 6 | 13.5 ± 0.88 | 16.0 ± 0.53 | 29.5 ± 1.20 | 19.0 ± 0.31 | 23.8 ± 0.62 | 42.8 ± 0.62 |

[a] Two bound water states determined by thermogravimetry analysis: Water 1, slightly bound water; Water 2, strongly bound water.

were observed. That determined the same temperature (72.5 °C) of separation of both states of total bound water in this cake up to the fourth day of storage. For the control sample, a reduction of total bound water and its two states was read after the second day of storage, which was more significant on the sixth day. As a result of these changes, it was found that the amount of $W_2$ in the crumb of DC with pectin film was 1.5 times higher than that in the control sample on the sixth day.

The water condition in DC determined the moisture losses in the process of storage. The data obtained for the moisture quantity in the crumb of both investigated sponge cakes are represented in Fig. 5. A considerable difference of moisture losses in the crumbs of the two DC samples was observed between the fifth and the sixth day of their storage, as on the sixth day the moisture reduction in the control sample crumb was 4.80% while, in the DC covered with pectin film, it was 3.03%. The

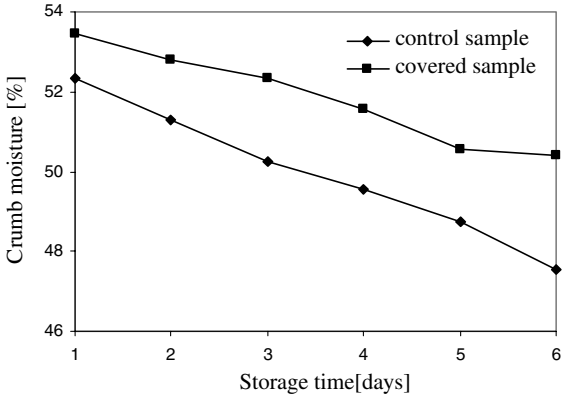



Fig. 5. Change of the sponge cake crumb moisture during storage for 6 days: control sample ($n = 3$, SD = ±0.36); covered sample ($n = 3$, SD = ±0.29).

ascertained lower moisture losses in the crumb of DC covered with pectin film were more considerable from the fourth to the fifth day of its storage. Taking into account the greater content of $W_2$ in the crumb of DC covered with pectin film, it was logical to observe a lower extent of moisture losses in it than in the control sample during the storage process.

During the storage of both DC samples, the changes in their crumbs were examined by standard physical methods. At the end of storage process (on the sixth day) some sealing in both DC crumbs was observed, expressed as decrease of shrinkage and springiness. The analysis of the determined structural and mechanical characteristics showed that the shrinkage measured at the 5th second was reduced to the greatest extent between the first and second day of sample control storage while, for the DC covered with pectin film, this characteristic was reduced smoothly during the whole period of storage (Fig. 6, Series 1 and 2). The shrinkage measured on the 125th second changed in analogy (Fig. 6, Series 3 and 4), as it decreased smoothly to the fifth day of storage of DC with pectin film. On the sixth day, the shrinkages of DC covered with pectin film measured at the 5th and the 125th second were, respectively, 1.27- and 1.35-times higher than that of the control sample. By analogy, the springiness of DC covered with pectin film was 1.13-times higher than that of the control sample on the sixth of storage (Fig. 6, Series 5 and 6). Considerable changes in the springiness changes in both DC samples were observed after the first day of their storage. The crumb of DC covered with pectin film not only kept its higher values of springiness, but was also characterized with a smoother reduction between the first and the fifth day of storage.

The investigations of colour, carried out by means of the spectrophotometer showed that the brightness "*L*" of the crumb had high and close values for both DC samples (Table 2). It had increased alike during the stor-

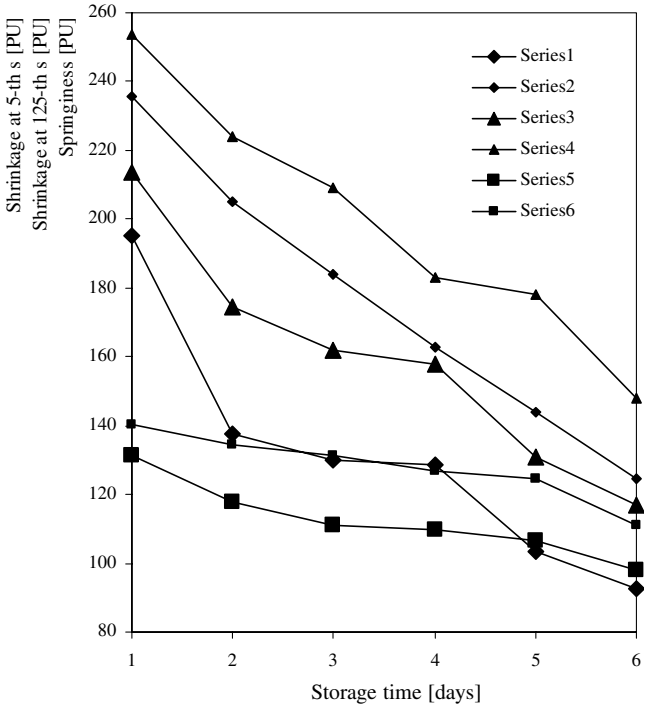



Fig. 6. Change of the shrinkage and springiness of dietetic sucrose-free sponge cakes (DC) during storage for 6 days: Series 1 – change of the control sample shrinkage at the 5th s ($n = 3$, SD = ±3.91); Series 2 – change of the DC covered with pectin film shrinkage at the 5th s ($n = 3$, SD = ±3.14); Series 3 – change of the control sample shrinkage at the 125th s ($n = 3$, SD = ±4.80); Series 4 – change of the DC covered with pectin film shrinkage at the 125th s ($n = 3$, SD = ±5.22); Series 5 – change of the control sample springiness ($n = 3$, SD = ±2.95); Series 6– change of the DC covered with pectin film springiness ($n = 3$, SD = ±2.10).

age and, as a result, the crumbs of the two DC were equally dark. Significant differences occurred in the indices "*a*" and "*b*" for the crumb colour. The greatest change was read for index "*a*", as during the storage the crumb of DC covered with pectin film had changed from red to green colour to a greater extent than did the control sample. The change of the yellow colour expressed by index "*b*" for DC covered with pectin film was lower towards the control sample.

Table 2
Indices for the crumb colour of dietetic sucrose-free sponge cakes

| Indices for colour | Dietetic sucrose-free sponge cakes | |
|---|---|---|
| | Control sample | DC covered with pectin film |
| Crumb on the first day | | |
| *L* | 69.6 | 71.8 |
| *a* | 0.42 | 0.12 |
| *b* | 24.3 | 23.0 |
| Crumb on the sixth day | | |
| *L* | 85.5 | 88.1 |
| *a* | −0.42 | −1.19 |
| *b* | 27.6 | 24.5 |

## 4. Conclusions

1. The SEM observations showed that, on the sixth day of storage in the crumb of DC covered with pectin film, the matrices of the partly gelatinized starch and coagulated proteins were not disposed in parallel to the air-pocket walls and kept their fine structure to a greater extent. Thus, the extent of retrogradation of starch granules in the control sample was higher, and, therefore, the ageing, too.
2. The reduction of the total bound water during the process of storage was significantly more slightly expressed in DC covered with pectin film as it had reached 4.75%, towards the 16.00% of the control sample. A considerably great content of strongly bound water in the crumb of DC covered with pectin film was proved, which was 1.5 times greater than that in the control sample on the sixth day of storage.
3. Between the fifth and the sixth day of cake storage, a considerable difference in moisture losses of the two DC crumbs was read, as the moisture reduction was 4.80% and 3.03% in the crumb of the control sample and DC covered with pectin film, respectively.
4. On the sixth day of storage, higher values of shrinkage and springiness for the DC covered with pectin film were read as follows: the shrinkages measured on the 5th and on the 125th second were 1.27 and 1.35, respectively, while the springiness was 1.13-times higher than those for the control sample. The DC covered with pectin film were characterized by higher shrinkage and springiness, reducing smoothly mainly up to the fifth day of storage.
5. The crumbs of the two DC samples were equally dark, and their brightness increased to identical extents during the storage. The crumb yellow colour of DC covered with pectin film was changed a little.
6. The investigations carried out proved that the pectin-containing edible film had a marked retaining effect upon the crumb ageing of dietetic sucrose-free sponge cake, as this cake had kept its freshness, especially up to the fifth day of storage.

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