

STUDY OF THE EFFECT OF FREEZING ON THE VISCO-ELASTIC PROPERTIES OF STRAWBERRIES

*Fundo, J., Brandão, T.R.S., Quintas, M. and *Silva, C.L.M.*

Escola Superior de Biotecnologia, Universidade Católica Portuguesa

Rua Dr. António Bernardino de Almeida

4200-072 Porto, Portugal

tel: 225580058 fax: 225090351

*crislui@esb.ucp.pt

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ABSTRACT

The objective of this work was to study the influence of freezing on the visco-elastic properties of strawberries.

Food structure plays an important role in food quality and functionality. It is important for the consumers to find an identical sensation when they eat a fresh strawberry and when the strawberry is defrosted. The visco-elastic properties of a food product are an indirect measure of its structure. Experimental measurements of these properties may correlate to changes on the physical attributes of the product.

In this work, a dynamic mechanical analyser was used to assess changes on loss (E'') and storage (E') modulus, applying a compressive test with a $\varnothing 1.5$ cm parallel plate geometry.

Strawberries were acquired in a local market and frozen in a blast and fluidized bed freezer at -30 °C for 1 hour. Samples were stored at -30 °C in freezing chambers.

Analyses were performed on fresh strawberries, after freezing and during storage. The samples were cut in small cylinders (1.5cm x 1.5cm) and left to relax during 1 hour at room temperature.

Preliminary tests were performed in order to evaluate the linear visco-elastic region and the loss and storage modulus were determined. A dynamic frequency sweep test was also performed.

Results showed that the behaviour of fresh strawberry sample varies significantly when compared with a defrosted sample. The influence of the storage still cannot be evaluated and is currently under study.

Overall, it can be concluded that the freezing process greatly influenced the visco-elastic properties of the strawberries.

INTRODUCTION

In our days, consumers are demanding more attractive food products that look and taste excellent, are easy to prepare and are nutrition balanced. Freezing is a simple and common method of food preservation. This process delays food deterioration and growth of microorganisms, and extends the product shelf life while maintaining its original characteristics [1]. However, when a food product freezes, several changes occur: water is transformed into ice, there is a volume expansion and the ice crystals may incite the rupture of cellular walls. This process is responsible for structural changes, which directly affect texture. This is especially critical for high water content foods (fruits and vegetables are examples), and may result in extensive irreparable cell wall damages.

Texture is a very complex property to define, involving a great number of food characteristics somehow associated with fracture and particle size. It clearly plays a basic role in food appreciation and perceived characteristics. Food products' attributes are detected by mechanical, tactile, visual and auditory receptors by the consumer [2], and texture is dynamically evaluated throughout consumption [3].

Rheological measurements may help to explain some aspects related to food texture. Although it is not possible to quantify this perception, results from rheological experiments can be used to explain structure changes occurring when a food product is submitted to different processing conditions.

The knowledge of foods' rheological behaviour is also important in process design, since it allows the minimisation of the degree of damage by optimisation of the applied stress and/or strain [4]. A relation between structural mechanics of the food material and the observed mechanical behaviour plays also an important role in quality control [5].

Dynamic mechanical tests are indicated when analogies between food physical properties and human sensory is the objective to achieve [6]. Dynamic tests are usually applied in studies of visco-elastic properties of materials, such as foods in the linear visco-elastic region. The materials are subject to a deformation or stress varying harmonically with time, including direct stress or strain measurements. These tests can be carried out using either rotational or compression/elongation equipment, with controlled stress or strain.

In compression/elongation testing, the elastic properties of a material can be evaluated on the basis of the elastic or storage modulus (E'), which is the ratio of elastic stress to strain, meaning the ability of a material to store energy elastically. The viscous properties are measured by the viscous or loss modulus (E''), that is the ratio of viscous stress to strain, representing the ability of a material to dissipate energy. The sum of storage and loss modulus is called "Young's Modulus" or modulus of elasticity and is represented by E [6,7].

The tangent of the phase angle ($\tan \delta$) between the applied oscillatory strain and the oscillatory stress response is the ratio of the loss to the storage modulus and is a measure of the damping property of the material. [6,7].

The use of rheological measurements in foodstuffs, especially in fruits, is limited by one major difficulty, that is the assurance of material isotropy. This drawback can be minimised by the proper choice of fruit samples and/or by cutting samples within the pulp. The natural heterogeneity of the fruit pieces should not be forgotten when testing these products, and replicates must be carried out.

The objective of this work was to study the influence of freezing on the visco-elastic properties of strawberries, using a dynamic mechanical analyser.

MATERIALS AND METHODS

Sample preparation

Fragaria ananassa strawberries, acquired in a local market, were frozen in a blast and fluidized bed freezer (Armfield FT36) at -30°C for 1 hour and stored at -30°C in freezing chambers (Fitoterm, S550 BT), simulating industrial processing. This storage temperature was selected based on previous studies with strawberries, with the objective of assessing quality retention during frozen storage [8,9].

Before analysis, the samples were cut in small cylinders (1.5cm x 1.5cm) and left to relax for 1 hour at room temperature to eliminate any state of stress caused to the sample due to the pressures caused by cutting.

Rheological measurements

Rheological analyses were performed on fresh strawberries, after freezing (day 0) and during storage time (days 7, 14, 21, 29, 35 and 49).

A Dynamic Mechanical Analyser, DMA (Rheometrics® Solid Analyser II) was used to measure the visco-elastic properties of samples in compression, using parallel plates (ϕ 1.5 cm). The DMA used in this work was strain-controlled and an oscillatory strain was applied to the sample. Resulting sinusoidal stress of the sample was measured, and the viscous and elastic properties were analysed.

Tests were performed in order to evaluate the linear visco-elastic region, estimate both loss and storage modulus within the region and determine the strain to be applied in further testing. To achieve this goal, a dynamic strain sweep test was carried out, using 1 Hz frequency and at constant temperature (20°C).

A dynamic frequency sweep test, with constant strain (2.5×10^{-4}) and temperature (20°C) was also carried out.

Three replicates were analysed for each condition, and the values of loss and storage modulus were calculated from the average of the experimentally obtained results.

RESULTS AND DISCUSSION

Preliminary results of the dynamic strain sweep test (Figure 1) showed a similar interval of visco-elasticity both for fresh and defrosted strawberries. According to these results, the value of strain chosen for the frequency sweep test was the same for all tested samples and equal to 2.5×10^{-4} .

In Figure 2 it is shown a typical example of fresh and defrosted strawberries samples result of a frequency sweep test. It can be observed that storage and loss modulus are constant with time of observation (frequency). Although large differences in the loss and storage modulus occurred between fresh and defrosted samples, E' is higher than E'' in both cases. This is due to the fact that strawberries behave more like a solid than a liquid, and although the freezing process dramatically changes the structure of strawberries, this characteristic is maintained.

Results show evidence that the freezing process drastically affects the visco-elastic properties of strawberries. It is possible to observe the great reduction on the values of storage and loss modulus from the fresh to the defrosted samples. This can also be confirmed by visual inspection of strawberries, that became softer and without consistency after the freezing process.

Comparing a fresh sample with a defrosted one, it is possible to observe that the ratio E' to E'' was also modified, i.e. E'' suffered a greater reduction than E' . This may indicate that during the freezing process, the samples lost more "ability to store elastic energy than to dissipate it".

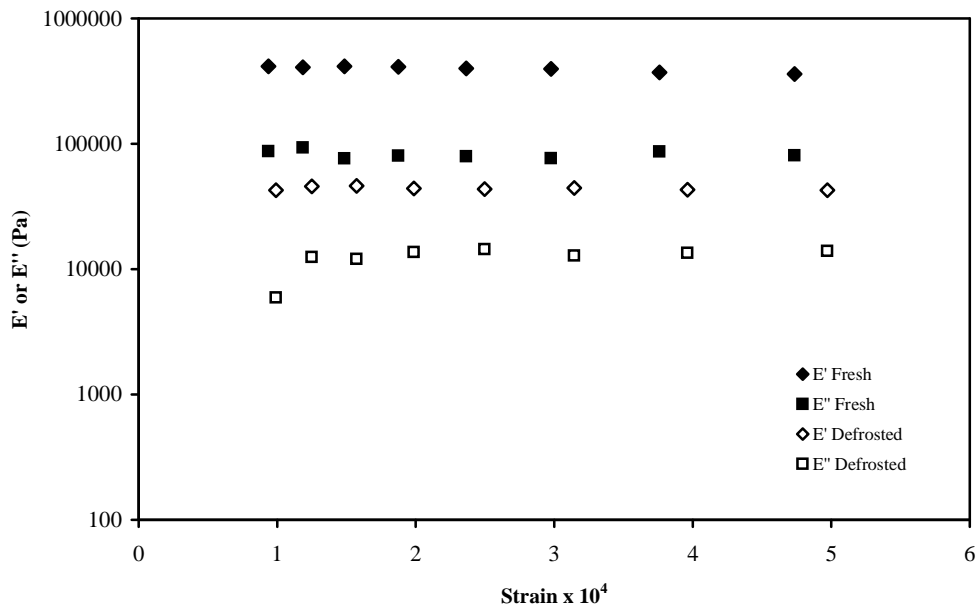


Figure 1. Results of a dynamic strain sweep test in both fresh and defrosted samples.

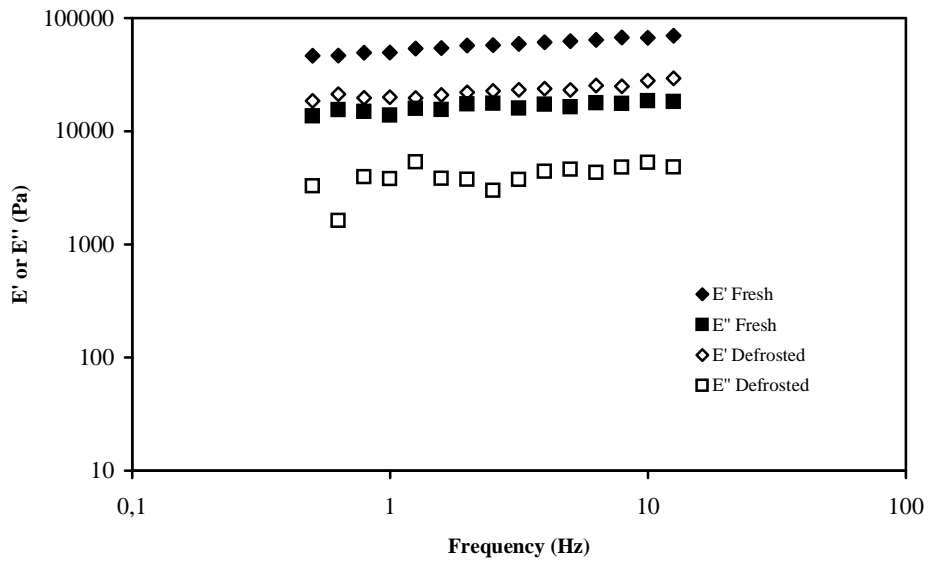


Figure 2. Typical result of a frequency sweep test for fresh and defrosted samples.

No significant changes occurred in the visco-elastic properties of the samples during storage at -30°C (Figure 3). This is probably due to the fact that this temperature has been selected based on previous studies, being the lowest storage temperature [8,9] for reducing quality loss. This could indicate that -30°C was below the glass transition temperature. However, a published work referred a value equal to -51.3°C for *Fragaria ananassa* strawberries [10]. This fact can lead to two major conclusions: i) the time of storage under study was not enough to perceive significant changes and/or ii) if the selected storage and freezing temperature was lower than -30°C , a greater quality retention could be observed.

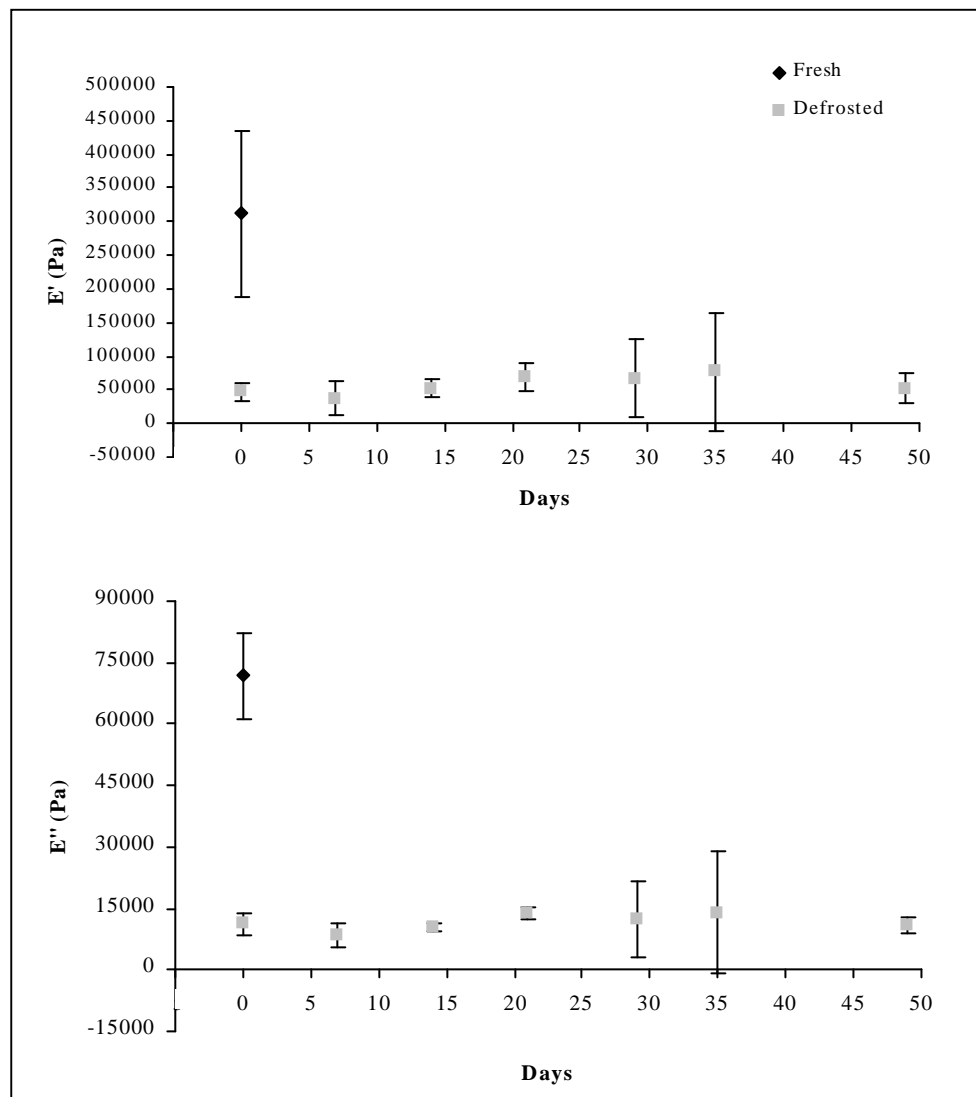


Figure 3. Storage and loss modulus as function of days of storage at -30°C (results were obtained using strain equal to 2.5×10^{-4}). The bars indicate the standard deviation of the experimental values.

CONCLUSIONS

From rheological measurements it was observed that strawberries' characteristics resemble behaviour closer to a solid material. Although the "solid like" characteristic is maintained, the freezing process greatly affects the visco-elastic properties of strawberries. After freezing, a decrease in E' and E'' was observed, which can be related with the visual observation of softening and lost of firmness.

During frozen storage at $-30\text{ }^{\circ}\text{C}$ no significant changes occurred in the samples visco-elastic behaviour.

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