

## Impacts of air drying and DIC pretreatments on textural properties of frozen/thawed apple fruits.

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### **Abstract**

*This research work is about dehydrofreezing assisted by DIC treatment as an innovative conservation process of apple fruits. Samples previously dehydrated and DIC treated were frozen at -30 °C and at two different practical freezing rates. The effects of sample water content (W) and practical freezing rate (PFR) on freezing characteristics and apple texture were examined. Thaw exudate water (TEW) of 200% and 100% db samples was approximately 3 g/100 g water. Whereas, it was lower than 0.5 g/100 g water for samples with 30% db W during thawing at 4 °C. Moreover, the impact of PFR on TEW was significant and very important only for high W samples. For samples whose water content was lower than 100% db, firmness was as higher as the W was lower, without any significant impact of PFR.*

**Keywords:** *Dehydrofreezing; Instant controlled pressure drop; Water content; Practical freezing rate; Texture.*

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## 1. Introduction

Freezing is a common fruit and vegetable conservation process that preserves the sensorial quality and nutritional compounds [1]. However, in the case of high-water-content perishable fruits and vegetables, the treatment is usually accompanied by irreversible damage of cell structures and possible deterioration of textural quality of the frozen products after thawing due to large ice crystals formed in the tissue during freezing process [2]. Dehydrofreezing which is a preservation process that involves partial dehydration before freezing can be used in order to diminish tissue damage [3-5].

The reduction in the product water content before freezing improves both freezing performance and product quality in the case of *Golden delicious* apples [6]. Process performance is revealed through an improvement of freezing rate and a decrease of freezing time [7] as well as lower energy consumption, lower cost of packaging, distribution, and storage. Whereas, quality improvement includes better preservation of structural and textural characteristics and decrease of thaw exudate water rich on soluble nutrients.

In the other hand, since the partially dried products are not yet microbiologically stabilized, subsequent treatment is necessary, before freezing, for product decontamination.

Likewise, to remove the impact of possible shrinkage of partially dried products instant controlled pressure drop (DIC) process is also required [8].

However, no work has been reported in the literature about mechanical properties after the combined process ‘air drying + DIC + freezing’. Hence, the main objectives of this study were to (i) establish a new freezing method, namely, DIC-assisted dehydrofreezing, and to (iii) assess and compare the impacts of water content and practical freezing rate on thaw exudate water and textural characteristics of dehydrofrozen products previously DIC treated.

## 2. Materials and Methods

### 2.1. Process treatments

Initial water content (W) of apple fruits (var. *Golden delicious*) was determined according to AOAC official method 934.06 [9]. It was of  $700 \pm 10\%$  dry basis (db). Discs of  $10.0 \pm 0.2$  mm thick were prepared for process treatments and texture analysis.

### 2.2. Partial drying

Partially drying experiments were carried out in a airflow dryer under constant conditions: air temperature, air velocity, and air relative humidity of 45 °C, 2 m/s, and 12%, respectively. Drying experiment was stopped once desired water content (W) levels were attained (200, 100, and 30% db).



### 2.3. DIC treatment

Partially dried apple samples with different water contents (200, 100, and 30% db) were DIC treated by an adequate equipment (ABCAR-DIC Process, La Rochelle, France).

### 2.4. Freezing

Partially dried and DIC treated apple samples at different water content levels were frozen in a freezer (Whirlpool Model AFG 363/G, Italy) with air temperature of  $-30\text{ }^{\circ}\text{C}$  at two different practical freezing rates; high practical freezing rate (PFR+) and low practical freezing rate (PFR-) depending on the thermal resistance established between the freezing airflow and the sample surface [7].

### 2.5. Thawing process

Completely frozen apple samples previously DIC treated were thawed in a refrigerator (FAR Model RT 140, Romania) at  $4\text{ }^{\circ}\text{C}$  overnight just before starting the textural measurements [6].

### 2.6. Quality assessments

#### 2.6.1. Determination of thaw exudate water

Dehydrofrozen DIC treated-apple samples were used to measure thaw exudate water (TEW) expressed in g/100 g water, during the thawing phase [7,10].

#### 2.6.2. Texture measurement

Textural firmness of DIC treated-dehydrofrozen/thawed apple slices was evaluated by measuring the maximum puncture force through a puncture test with a cylindrical puncture probe of 2 mm in diameter at a constant speed of 5 mm/s using Instron Universal Testing machine (Model 5543, USA) [6].

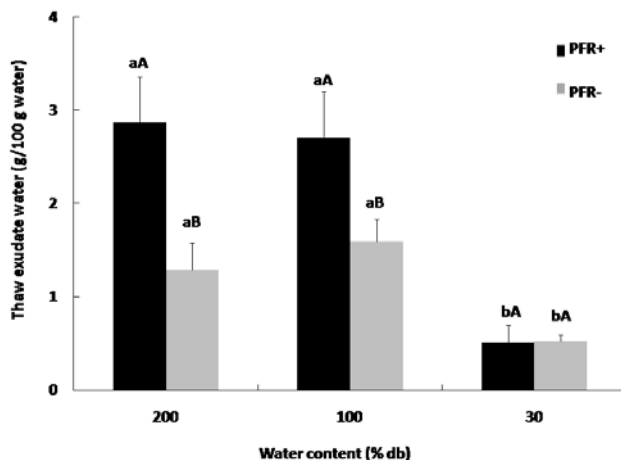
### 2.7. Statistical analysis

Bifactorial analysis of variance and SNK test were carried out using the Statistical Package for the Social Sciences (SPSS) version 20.

## 3. Results and discussions

### 3.1. Thaw exudate water

The impacts of water content (W) of apple samples and practical freezing rate (PFR) on thaw exudate water (TEW) during thawing of DIC treated-dehydrofrozen apple samples were investigated and experimental results are illustrated in Figure 1.



*Figure 1. Impacts of water content and practical freezing rate on thaw exudate water (TEW) of DIC treated-dehydrofrozen apples. (Data are expressed as the mean  $\pm$  standard deviation. Values for the same practical freezing rate having the same letter (a, b and c) for thaw exudate water (TEW) are not significantly different at a confidence level of 95%. Values for the same water content level having the same letter (A, B and C) for thaw exudate water (TEW) are not significantly different at a confidence level of 95%).*

Figure 1 shows the impact of the two different practical freezing rates on the thaw exudate water (TEW) of dehydrofrozen DIC treated-apple samples with different water contents (200, 100, and 30% db) during thawing process. Thaw exudate water (TEW) of 200% and 100% db apple samples frozen at -30 °C was approximately 3 g exudate water /100 g water in the product at high practical freezing rate (PFR<sup>+</sup>) after thawing at a temperature of 4 °C. Indeed, it was lower than 0.5 g/100 g water for apple samples with 30% db water content and frozen at the same practical freezing rate (PFR<sup>+</sup>).

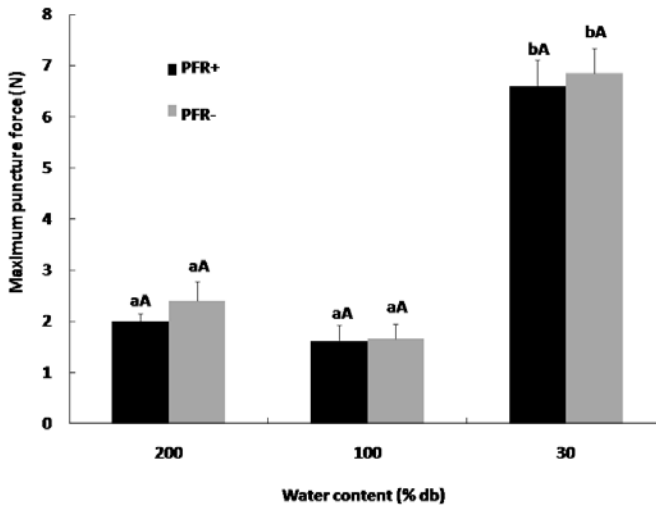
Previous researches have equally demonstrated that dehydration by hot air causes a diminution in drip loss during the thawing process in the case of dehydrofrozen strawberry and pineapple fruits [11,12]. These authors reported that air drying prior to freezing presents the advantage of decreasing the drip loss and the water exudate volume after thawing process as compared to osmotic dehydration [11,12].

As it is shown in Fig. 1, the higher the initial water content of dehydrofrozen apples, the higher the amount of TEW. Same results were obtained for several dehydrofrozen fruits such as strawberry, kiwi fruits, and pears [13,14]. The TEW decrease during thawing of DIC treated-dehydrofrozen samples may also be explained by a preservation of the structural and textural properties of apple samples as a consequence of the partial removal of water before freezing.

In the other hand, the impact of practical freezing rate on thaw exudate water (TEW) was significant and very important for high water content samples (200% and 100% db). It had less significantly detrimental effect on TEW for lower water content samples (30% db).

### 3.2. Texture variation

The maximum puncture forces (firmness) after thawing of DIC treated-dehydrofrozen apple samples, which were frozen at two different practical freezing rates (PFR<sup>+</sup> and PFR<sup>-</sup>) are shown in Figure 2.



*Figure 2. Impacts of water content and practical freezing rate on firmness of DIC treated-dehydrofrozen apples. (Data are expressed as the mean  $\pm$  standard deviation. Values for the same practical freezing rate having the same letter (a, b and c) for maximum puncture force are not significantly different at a confidence level of 95%. Values for the same water content level having the same letter (A, B and C) for maximum puncture force are not significantly different at a confidence level of 95%).*

As it is shown in Figure 2, firmness (maximum puncture force) of DIC treated-dehydrofrozen apple samples was constant (about 2 N) for high water content levels of 200% and 100% db, for both practical freezing rates. It increased for lower water content to reach 6.5 N for 30%-db samples, while no effect due to practical freezing rate was evidenced. ANOVA and LSD tests carried out for the firmness values statistically confirmed these differences. DIC-dehydrofreezing/thawing processes induced a significant ( $p < 0.05$ ) increase of firmness with the decrease of sample humidity. Moreover, according to the result of the simple range test (SNK test), two homogeneous groups were identified.

The first group includes 200% and 100%-db apples. The second group only included samples with water content of 30% db.

These results confirmed that the significant impacts of water content on firmness obtained in the case of dehydrofrozen apples without DIC pretreatment, with also an insignificant effect of practical freezing rate. Firmness values of dehydrofrozen/thawed and non DIC pretreated apples were about 2, 4.5, 7, and 12 N for samples with water contents of 700, 200, 100, and 30% db, respectively [7]. Firmness of dehydrofrozen apples was found to be higher for samples non-DIC treated. This difference on firmness is explained by textural modifications caused by DIC treatment applied before freezing as texturing process [6].

Similar results, concerning the impact of air drying performed as freezing pretreatment on textural properties, were obtained for dehydrofrozen/thawed strawberry and kiwi fruits [11]. Airflow drying as freezing pretreatment resulted in dehydrofrozen/thawed products with improved textural properties and higher firmness. Indeed, the low water content of dried samples prevents the cell wall damage and preserve the product structure during freezing and thawing processes [2,6].

#### **4. Conclusions**

Fruits and vegetables present a category of food products which is characterized by high water content generally higher than 500% db. This category of agriculture products can also be characterized by initial microbial contamination. Partial drying coupled to instant controlled pressure drop (DIC) as adequate pretreatment should present an intensification way for fruit and vegetable freezing process. The coupling of these operations presents several advantages concerning the product stability through a partial removal of water and a decontaminating pretreatment.

Thaw exudate water for DIC treated-dehydrofrozen apples during the thawing was approximately 3 g/100 g water for high water content samples (200 and 100% db). Whereas, it was lower than 0.5 g/100 g water for samples with 30% db water content. The impact of practical freezing rate on thaw exudate water was significant only for high water contents. For low water content level (30% db), practical freezing rate became a less important parameter for freezing process.

Water content had a significant effect on the textural properties of apple fruits after DIC-dehydrofreezing/thawing processes. In fact, fruit sample firmness increased when water content decreased for both practical freezing rates. Whereas, practical freezing rate had an insignificant impact on apple firmness.

In conclusion, partial removal of water constitutes a promising solution to reduce the negative impacts of freezing on textural quality. This process coupled with a texturizing pretreatment, showing perfect decontamination effects, can be suggested as an innovative fruit and vegetable conservation process. This new method allow obtaining dehydrofrozen

products with high textural quality after thawing and particularly without imposing a severe control of the partial drying step especially for the microbiological quality of products.

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