EFFECT OF TQ PROCESSING ON CELL WALL IN RELATION TO FIRMNESS OF CARROT TISSUE – PART I. THE TISSUE MODEL

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Abstract *The cell being the basic element of the products of vegetal origin, in this paper there is studied the influence of the heat transfer on the relationship between the cellular wall and the structural-textural firmness of the carrot tissue. By applying the 3 temperature regimes, water begins to eliminate itself by exoosmosis causing the detachment of the plasmalene from the cellular wall determining the decrease of the relative dimension of the cells, differentially, according to the freezing zone. As methods of determination there are used the tissue model (Voronoi-Delaunay theory) and the firmness test. The tissue model is based on the behavioral study of the cellular matrix, of the cells and of the intercellular space. The firmness test, the parameters are obtained during a puncture test is maximum force that can be correlated with firmness. Electron microscopy technique (SEM) have been used in exploring physical changes in carrots frozen matrix related to both modification of the thickness of cellular membrane and of the relative dimension of the cells. The theory Voronoi-Delaunay a study of the resultant microstructure of carrots frozen matrix based on firmness can provide useful information about the physical state of matrix. The firmness test is widely used in texture measurement of carrots frozen.*

Key words: *freezing by fluidization, heat transfer (TQ)*

Introduction

The structure and composition of the vegetal origin products are two factors which play an important role on their firmness. They are responsible for the different effects of the experimental results.
Thus, the structure influences the mechanical events, such as the penetrometric degrees, whereas, the composition influences the thermal event [1].
The thermo-dynamic events occurring during the freezing process in fluidized bed are accompanied by the decrease of the heat content of the product as shown in figure1.

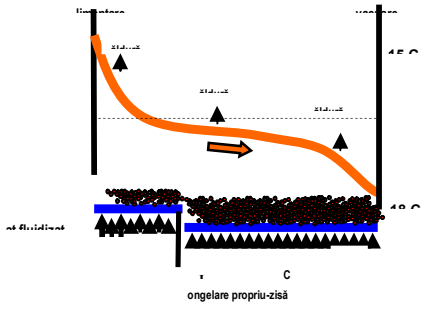


Figure 1 - The thermo-dynamic events occuring during the freezing process in fluidized (source: IQF Frost)

The heat transfer is done by convection combined with the conducted one. Convection is the most important mechanism for the heat exchange between a particle (carrot pieces) and the fluidization agent (cold air), between whom there is direct contact and relative movement.

The heat transfer is done as follows: the heat passes by thermal conduction from the surface of the product to the fluidization agent adjacent to this one, which has as an effect the increase in temperature and internal energy of the fluidization agent; this process takes place within the fluidization agent close to the product particles, named *limit layer*. Next, the agent with a higher temperature moves towards the agent zones with lower temperatures, where, coming in contact with these they transmit part of their heat.

The convection is thus a process of heat, mass and impulse transfer. The heat is stored in the agent particles and transported as a result of their movement. The mechanism of the process does not depend directly on the temperature difference, but the net effect is that of the heat transfer in the direction of the temperature lowering.

The intensity of the heat and mass transfer by convection depends greatly on the fluidization of the particles within the layer.

Despite all these, however, the size and placing of the ice crystals may deteriorate the physical structure. Consequently, the cause of the undesired physico-chemical alterations during the freezing is the water crystalization and the superficial dehydration of the product.

The transformation of water into ice(water crystalization) has the advantage that it settles the structure of the tissues and it separates the water quantity in the form of ice crystals so that this is not available either as solvent or as reactive component. As a result, the diffusion of other compounds in the tissue is very weak and, together with the diminishing of the temperature, it helps to the decrease of the reaction velocity. The minimizing of the phase change duration contributes to the obtaining of an optimum quality of the product [2].

The freezing by fluidization is the only preservation method which does not modify the structure of the product, but which can produce a certain dehydration or loss of water content that may lead to losses of quality and consequently to economic losses.

The granular product, which has a temperature superior to the heat transfer environment (that of the fluidization agent t = - 25... – 30 ^{0} C) begins to dehydrate. This process begins at the surface and immediately beneath it, followed by the water transport from the interior components of the product towards the surface. The longer the pre-cooling period is, the greater the loss by dehydration is During the air cooling of the solid food products, the water will be transfered from the product to the fluidization agent. This water transfer should be minimized in order to maintain the quality of the product [3].

The dehydration curve is affected by the nature of the product, the type of the freezing apparatus, the temperature of the fluidization agent and the functioning conditions. In conclusion, the water loss by evaporation is greater in the pre-cooling stage, because the mass transfer speed decreases in the freezing stage.

The temperature and speed of the fluidization agent influences the dehydration as well.

Consequently, the maintaining of adequate functioning conditions may reduce dehydration, a greater benefit being the result.

The importance of incorporating surface water dehydration is highlighted by others as well and acknowledged widely because

the loss of humidity from the surface of the product not only accelerates the freezing process but also modifies the structure of the product[4].
The cell being the basic element of the products of vegetal origin, in this paper there is studied the influence of the heat transfer on the relationship between the cellular wall and the structural-textural firmness of the carrot tissue, as well as that of the tissue pattern employing the Voronoi-Delaunay theory which refers to the cellular arrangement/organization and the resistence presented during the penetration test.

Materials and methods

As methods of determination there are used the *tissue model (Voronoi-Delaunay theory)* and *the firmness test.*
The tissue model is based on the behavioural study of the cellular matrix, of the cells and of the intercellular space. For such a study there is applied the *Voronoi-Delaunay theory.*
This offers us informations about the cell organisation, generally, and the shape, relative size of the cells in particular.
With this model we will demonstrate the correlation between the cell organization and the structural-textural firmness, obtained in the firmness test.

The firmness test is popular because of its simplicity since only the force required to push a puncture probe into or through the sample must be determined.
The parameters are obtained during a puncture test is maximum force that can be correlated with firmness.

Results and discussion

In the tissue of vegetal origin, water can be found in different forms, exercising a significant influence on the development of the properties of the cellular matrix and, in particular, on the value of the freezing point.

In the freezing process of the vegetal origin products, the cellular matrix presents the structure which can suffer modifications.
By freezing the water contained in the tissue there is created an osmotic force which causes the migration of the water from inside the cell in the immediate vicinity of the cellular wall with ice crystal formation. This phenomenon determines the contraction of the cell and the concentration of the substances contained in the cellular matrix in a new cellular matrix.
These changes lead, among others, to the increase of the cellular pH, of the concentration of mineral salts as well as that of the sugar and proteins.
So, the change of the composition of the cellular matrix, due to dehydration, most often leads to changes of the thermo-physical and structural properties.

The value of the freezing point is, as well, an essential characteristic conditioned by the cellular matrix, which is highlighted in figure 2.

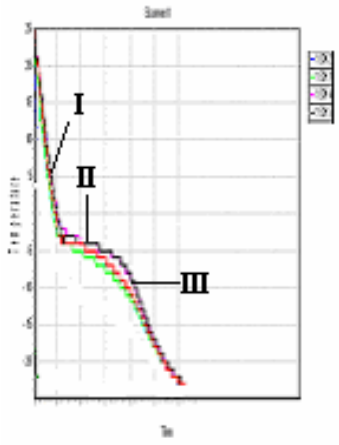


Figure 2 The value of the freezing point (R1. -25 ^{0}C ÷ -27 ^{0}C, green; R2. -27 ^{0}C ÷ -29 ^{0}C, red; R3. -29 ^{0}C ÷ -31 ^{0}C, black; I – zone I; II – zone II; III – zone III)

According to figure 1, when the product is introduced in the fluidized bed freezing installation, this comes into contact with the cold air characterized by a certain pressure, temperature and humidity.

In *the first freezing zone* (figure 2) the cold air exercises a higher pressure than that of the vacuolar content, phenomenon that determines water to migrate from the vacuole, whose volume shrinks, making a withdrawal movement in which is involved the cytoplasm that detaches itself from the cellular wall, remaining fixed to the skeleton-like membrane through very fine cytoplasm cords.

As a consequence of the crossing of the water through the cell wall favors the increase of the crystals already formed.

In the second zone, the cellular matrix goes through the stage of the change of phase, the ice is formed outside the cells and the fraction of extracellular solution which is not frozen becomes concentrated in the solution.

The modification of the relative dimension which takes place during this process and the water quantity that remains in the cells plays a significant part in the resistance of the cellular wall during the preservation by freezing.

When the sub-cooling stage begins, in *the third zone*, the extracellular space becomes a mixture of solid crystals of ice from pure water and liquid solution.

The process continues as long as intracellular water remains in liquid state, and the steam pressure is maintained higher than that of the outer ice.

Consequently, the extensibility of the matrix is based upon the plasticity of the primary wall, capable to expand as a result of the osmotic changes from the cells.

The extensibility of the matrix is done differentially according to the thermal regime, by the relative removal of the cellulosic micro fibrils (table.1).

In this case the structural changes in table 1 are analyzed with the help of the tissue model based on the Voronoi-Delaunay theory, which refers to the resistance opposed to the penetration test and cellular arranging (table 2). In table 2 there can be noticed that the tissue matrix is well defined by the cell walls which have as its basis the cellulose associated with the hemicelluloses and pectin.

Although the structure of the matrix and the spatial organization is similar, there can be noticed a slight modification of the thickness of cellular membrane and of the relative dimension of the cells within the layer. This phenomenon has influence upon the structural-textural firmness of the product (figure 3).

The increase of the thickness of the cellular membrane is owed to the successive settling of new cellulosic layers along the cellular wall as a result of the osmotic exchanges.

As can be noticed from table 2 the changes of the relative dimension take place uniformly, on the entire surface of the cellular wall, according to the theory of increase by extensibility.

By applying the 3 temperature regimes, water begins to eliminate itself by exoosmosis causing the detachment of the plasmalene from the cellular wall determining the decrease of the relative dimension of the cells, differentially, according to the freezing zone.

These modifications influence in their turn the structural-textural firmness of the product.

Physically, the the structural-textural firmness can be determined with the help of the Penefel DFT 14 penetrometre and the results are highlighted in figure 3

Table 1

SEM

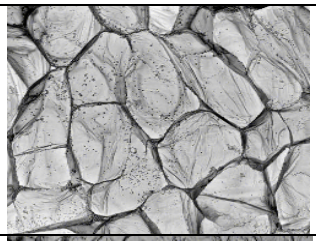
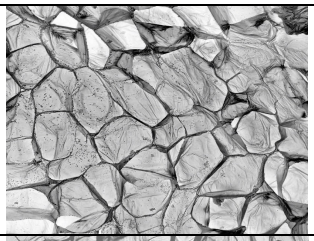
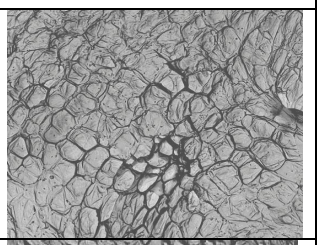
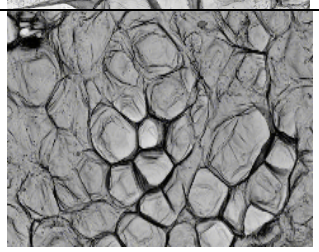
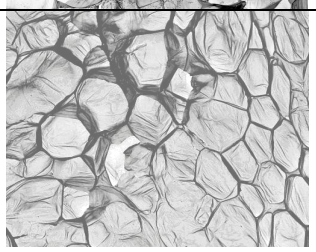
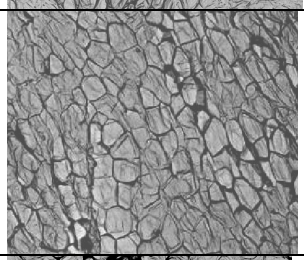
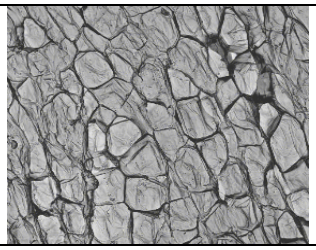
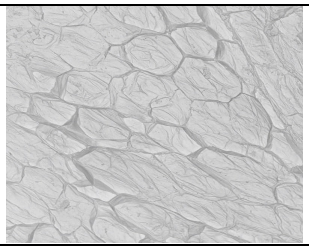
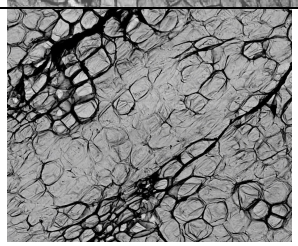
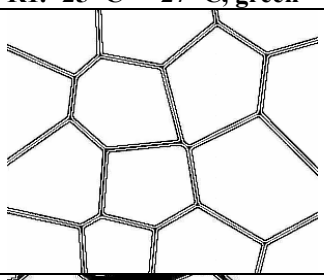
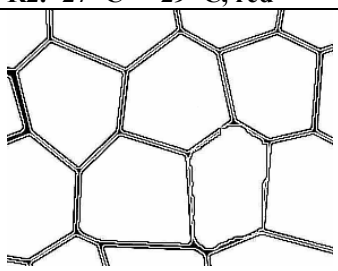
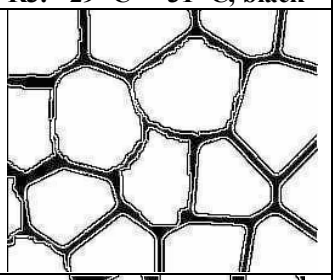
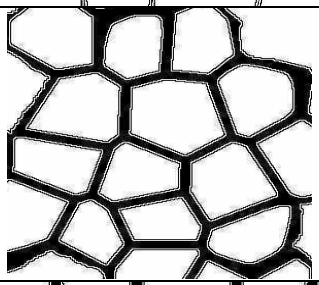
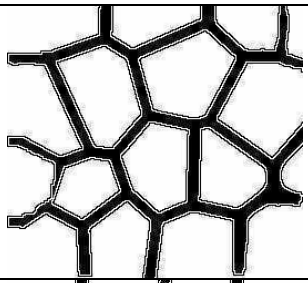
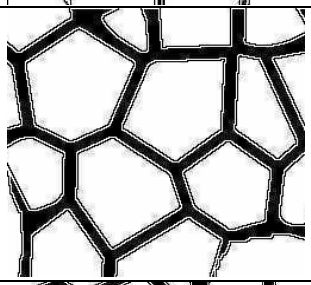
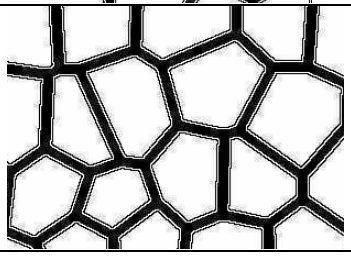
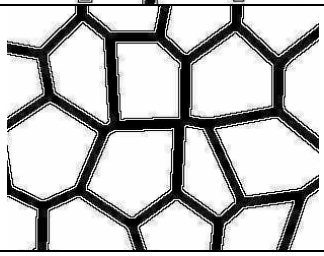
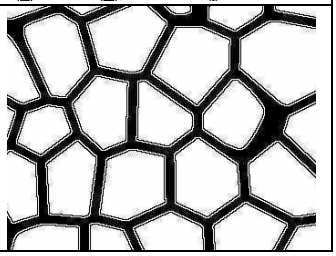
	R1. -25 ^{0}C ÷ -27 ^{0}C, green	**R2. -27 ^{0}C ÷ -29 ^{0}C, red**	**R3. -29 ^{0}C ÷ -31 ^{0}C, black**
Zone 1			
Zone II			
Zone III			

Table 2

Cellular arranging by Voronoi-Delaunay theory

	R1. -25 ^{0}C ÷ -27 ^{0}C, green	**R2. -27 ^{0}C ÷ -29 ^{0}C, red**	**R3. -29 ^{0}C ÷ -31 ^{0}C, black**
Zone 1			
Zone II			
Zone III			

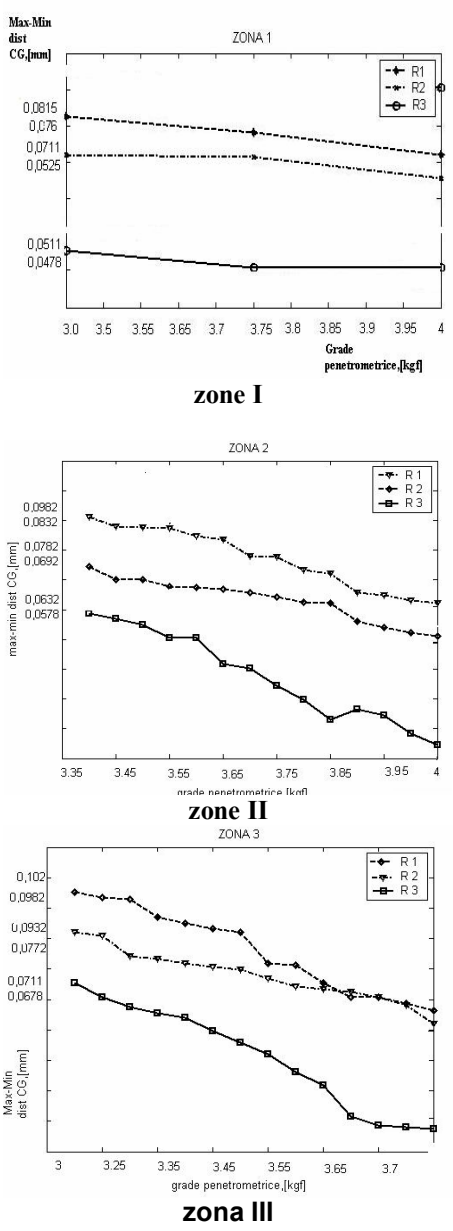


Figure 3 – Influence TQ(R1, R2, R3) of the cell wall

As it can be noticed from figure 3 the incline of the lines is respected/observed for all 3 zones.

The only differences come up for the thermal regime that was employed.

There can be noticed that the shorter the applied thermal regime is, the smaller is the distance between the axes of the geometrical centres, established with the Voronoi-Delaunay theory.

This phenomenon is due to the osmotic changes that take place at cellular level during the heat transfer.

Correlating these modifications with the structural-textural firmness test there can be seen that the better results are obtained when applying the R3 temperature regime.

Conclusion

Electron microscopy technique (SEM) have been used in exploring physical changes in carrots frozen matrix related to both modification of the thickness of cellular membrane and of the relative dimension of the cells. The theory Voronoi-Delaunay a study of the resultant microstructure of carrots frozen matrix based on firmness can provide useful information about the physical state of matrix. This provides a good example of the use of SEM for a study of the cellular arrangement/organization because it illustrated the changes in microstructure (in this case ice-crystal size distribution) and the effects of carrots frozen firmness.

The firmness test is widely used in texture measurement of carrots frozen.

In this paper studied the effects on TQ (thermal treatment) during freezing by fluidization on firmness of carrots slices.

As a result of a study the following have been noticed:

- the tissue matrix is well defined by the cell walls;
- can be noticed a slight modification of the thickness of cellular membrane and of the relative dimension of the cells within the layer;
- the better results are obtained when applying the R3 temperature regime.

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