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The Study of the Influence of the Froude Criterion and of the Thermal Regime upon the Quality of the Granular Frozen Products by the Process of Fluidization

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Abstract: In the first part of the research, it was shown that the main factors that are responsible for the quality of the granular food products frozen using the fluidization method, are the size and the shape of the product that is exposed to the freezing by fluidization process, the heat transfer coefficients, the temperature, and the speed of the fluidization agent. All these factors are responsible for the size and the distribution of the ice crystals that are formed during the freezing process. The qualitative characteristic that is modified after the freezing by fluidization process is the structural-textural stiffness.

Key words: Quality, granular products, fluidization, thermal regime.

1. Introduction

The frozen food products industry is in a great measure based on the modern science and technology [1]. Starting with the first historical development concerning the frozen preservation of food products, nowadays, a combination of factors influences the commercialization and the utilization of the frozen technology process. The future growth of the frozen food products spreading is going to be mostly affected by economic and scientific factors. The population growth, the personal incomes, the relative cost of other forms of food products , the changes in tastes and preferences as well as the technological development of the frozen methods are some of the factors that are connected to the future of the frozen technology [2].

Nowadays, the fluidized layer freezing is the only method at a large scale that unifies the seasons as well as the supply variations and the demands of raw materials such as meat, fish, fruits and vegetables. In addition, it is very much possible the move of some big amounts of food products on big geographic distances. It is very important for the freezing process to be controlled, by including the preparation before the freezing process and the storage after the freezing of the product, in order to obtain the best quality in products. Therefore, the theory of the freezing process and the parameters implied should be understood very well.

In other words, the problems from the field of freezing technology through fluidization are not at all completely resolved, but only limited by our imagination.

The freezing process in fluidized layer consists mainly of thermo-dynamical and kinetic factors that can dominate each other in a certain stage of the freezing process. The major thermo-dynamical events are accompanied by the reduction of the heat content of the material during the freezing process [3, 4]. The product that must be frozen is firstly refrigerated/cooled until the temperature at which the nucleation begins. Before the ice is able to form itself, a nucleus is necessary on which the ice can develop; the process of the nucleus production is called and

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defined nucleation. Once the first ice nucleus appears in the solution, a transformation phase takes place from the liquid state to the solid one with the further development of the crystals. Therefore, the nucleation serves as initial freezing process and can be considered as the critical step that has been a result of a complete change of phase [5].

The freezing through fluidization is applied to the food products of small dimensions (granular ones), especially to the fruits and vegetables, and is accomplished by the insufflations of the cold air currents under the product layer and the obtaining of the fluidization state (pseudo-liquefying or boiling). In this way each particle comes into contact with the cold air on the whole exterior surface, thus resulting in a very quick freezing individual process. Taking this into account, the freezing through fluidization is also called individual or isolated freezing.

2. Material and Method

In order to begin the research, the preliminary studies were made using the laboratory installation presented in Fig. 1.

For the first step, the working regime of the installation is established.

The dynamic and the static pressures for the different positions of the hinged valve are determined with the help of the inclined arm manometer and the Pitot tube. The obtained results are graphically presented in Fig. 2 [5].

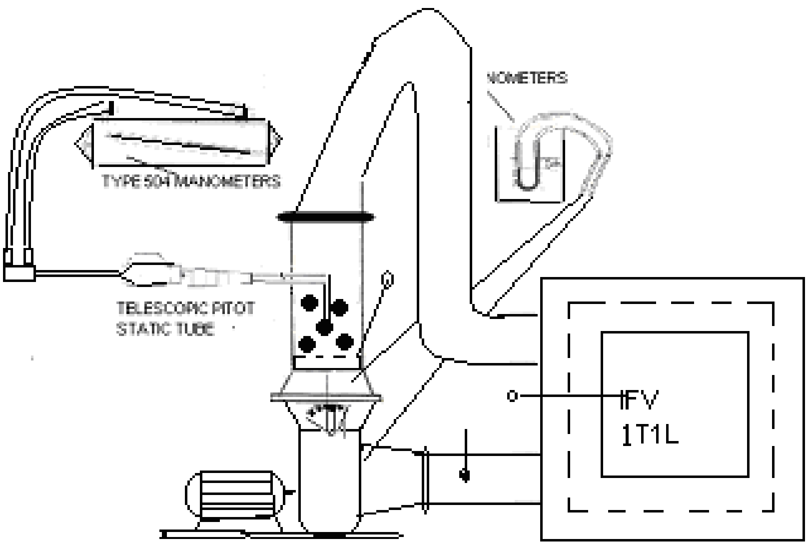

Fig. 1 Laboratory installation for the study of the fluidization state [10].

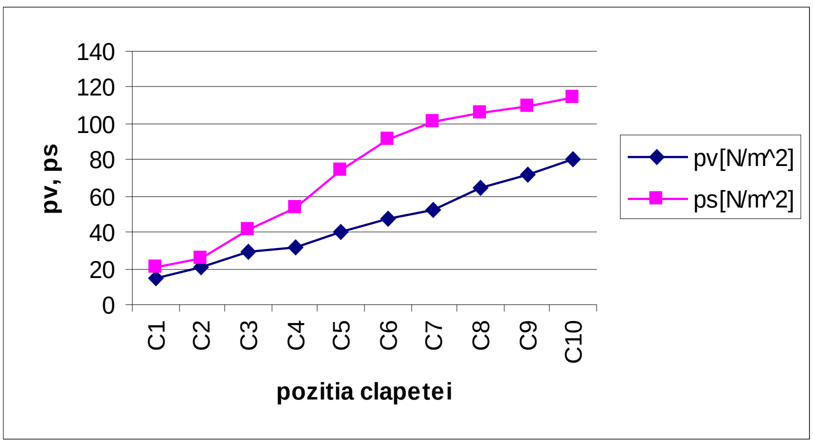

Fig. 2 The variation of the pressure according to the position of the hinged valve.

In Fig. 2, it can be noticed that the variation of the static and dynamic pressure depends upon the position of the hinged valve.

Fluidization depends upon the speed of the fluidization agent, w_0 [m/s], the difference in pressure ΔP [N/m^2] when the ascending air flow passes through the layer of products and the size of the product.

3. Results

It is known from the speciality literature that the fluidised layer freezing process is a complex heat and mass transfer process in a non-stationary regime [6, 7].

The optimisation is made up from finding a correlation between the speed of the fluidization agent and the temperature regime in a manner in which the final quality of the frozen granular products must meet an optimal quality [8].

In order to accomplish this objective at the industrial level, the hypothesis is admitted that the fluidized layer freezing installation is operating according to the technical conditions. In this case the values of the Froude criteria are within the limits prescribed by the speciality literature ($Fr = \mu = 100 - 120$).

For the accomplishing of this research it is taken into consideration a risk factor α = 0.05, and for the testing of the hypothesis the following steps will be followed [1, 4]:

(1) The following hypothesis is formulated:

$$H_0 : \mu = 110$$
$$H_1 : \mu \neq 110$$

(2) The testing statistics is chosen: z-test.

For the checking of the hypothesis data are used that are collected during the operation of the fluidised layer freezing installation FlowFreezer manufactured by S.C. Frigorifer S.A. Tulcea presented in Fig. 3.

The necessary temperature for ensuring the temperature regime in the FlowFreezer is obtained using the installation presented in Fig. 4 [9].

The operation parameters of the freezing installation and FlowFreezer freezer are presented in my thesis [9].

Knowing the parameters of the freezing agent it can easily be deducted the temperature of the cold air used for accomplishing the fluidization state in FlowFreezer.

For the determination of the humidity of the air, the hygro-thermo-anemometer is used.

With the help of these data they are determined using the h-x diagram, the other parameters of the fluidization agent, are presented in my thesis [9].

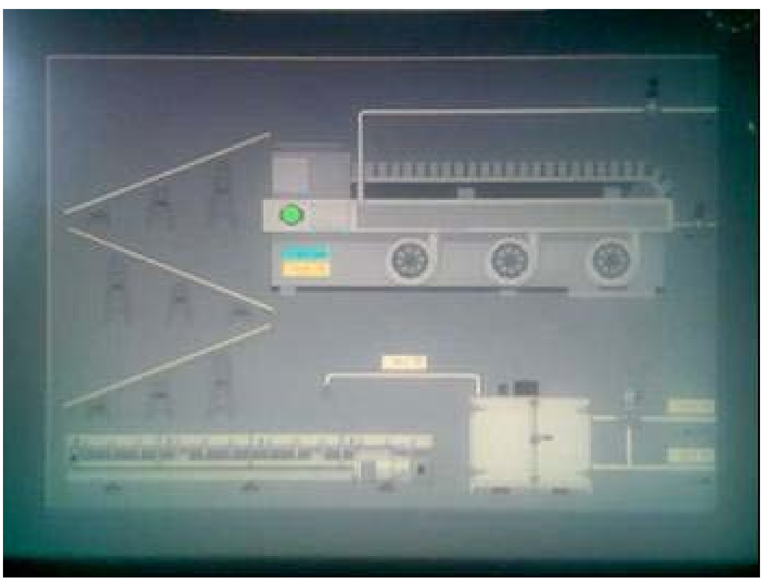

Fig. 3 The layout of the FlowFreezer freezing installation, S.C. Frigorifer S.A. Tulcea [10].

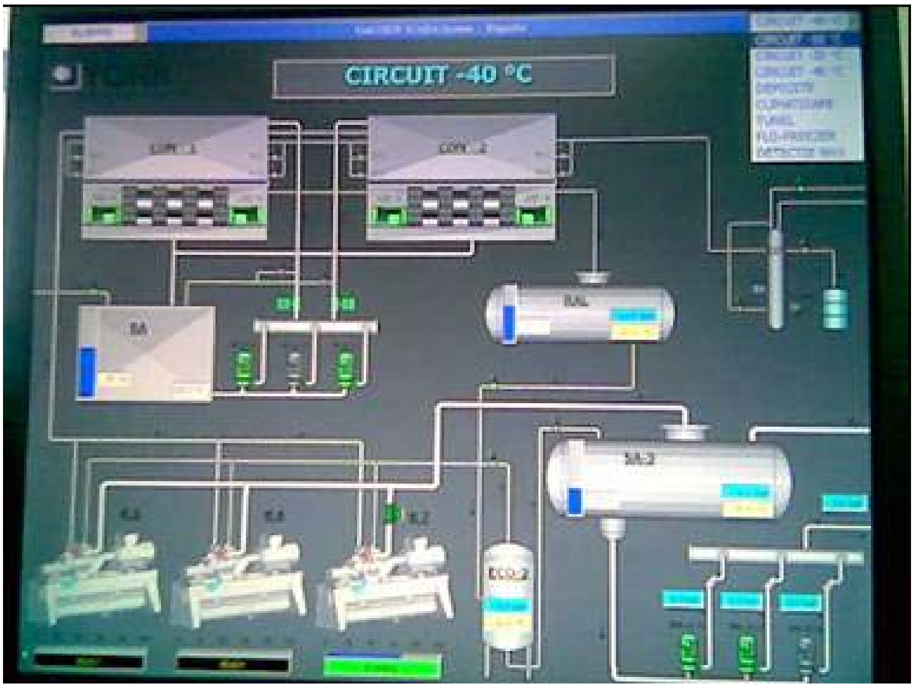

Fig. 4 The -40 °C circuit used for the cooling of the fluidization agent, S.C. Frigorifer S.A. Tulcea [10].

In order to visualize the eventual incongruities in the fluidization freezing process for the three product groups the histograms for the Froude criteria are drawn.

From the presentation of the histograms the fact can be noticed that in the case of the peas the Froude criteria has a uniform distribution, while in the case of the carrots the operation regime does not have any variation in the distribution. Therefore, there is the possibility that this regime is not the optimum one for the carrots. In the case of the strawberries the distribution seems to be very close to the one of the Gauss bells.

The results obtained for the Froude criteria are introduced in the Statistica software and the z test for the validation of the hypothesis is applied.

The result of the test is presented in Fig. 8.

After the testing of the hypothesis it is established that the alternative is true and in this case it is assumed the α risks making a type I error, which means to reject the unjustified zero hypothesis, H_0, according to which the values of the Froude criteria correspond to the ones in the speciality literature. Thus, according to the results of the sampling, it can be stated that, with a risk factor of 5%, the values of the Froude criteria do not correspond with the data from the speciality literature.

In this case, the values of the Froude criteria are calculated again starting from the factors that influence the fluidization freezing process.

For the beginning, the checking of the distribution normality is made using the numerical procedure “the χ^2 test”.

The procedure consists of making the frequencies curve for the observed distribution and the pattern comparison of this with the theoretical model “the Gauss-Laplace curve or bell”.

The variables taken into account by the analysis are referring to:

(1) The fluidization speed that influences the quality of the fluidization;

(2) The thermal regime (t = -20 °C ... -30 °C) applied to the granular products that are frozen by means of fluidization, that influences the heat and mass transfer; respectively the formation and the

distribution of the ice crystals, with effect upon the structural-textural quality of the frozen products.

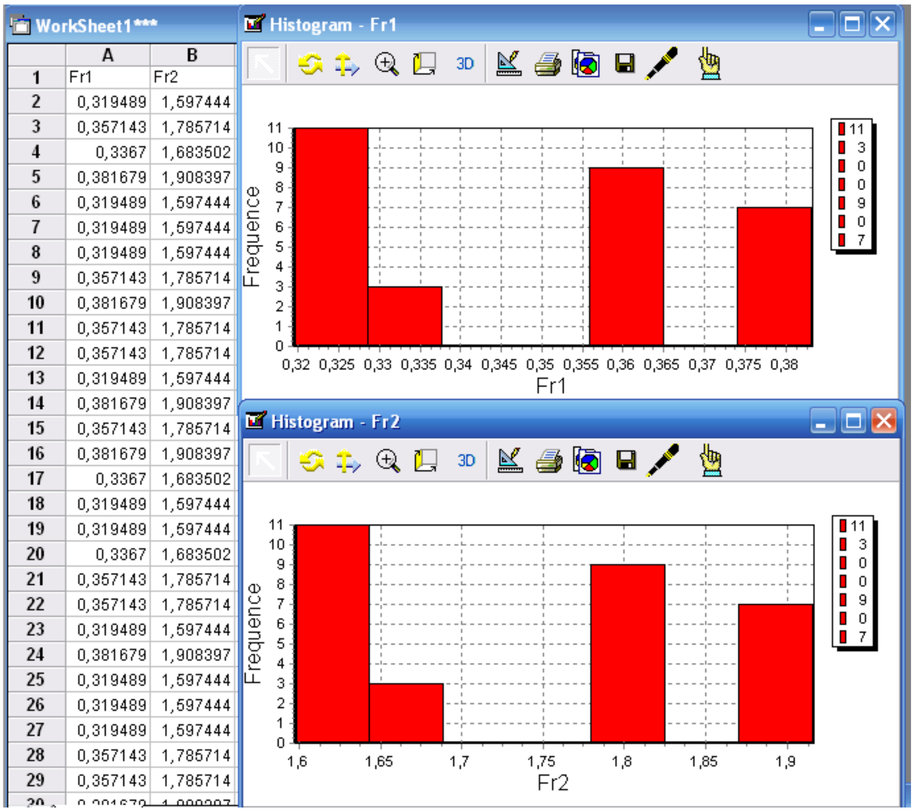

Fig. 5 The distribution frequency of the Froude criteria values for peas [10].

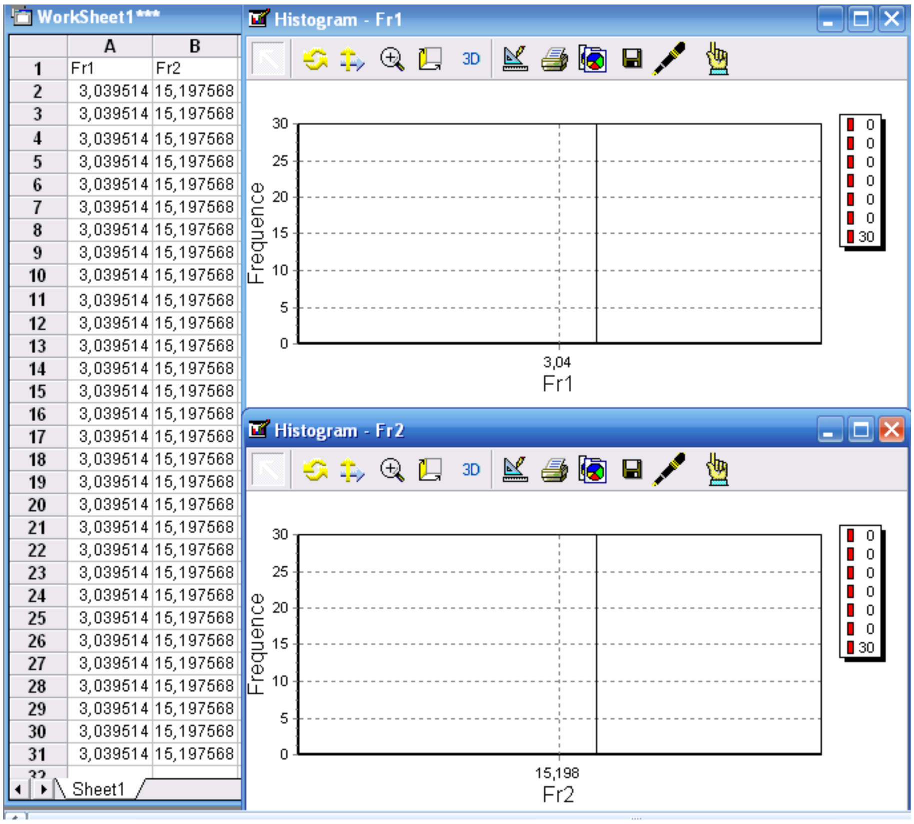

Fig. 6 The distribution frequency of the Froude criteria values for the carrot pieces [10].

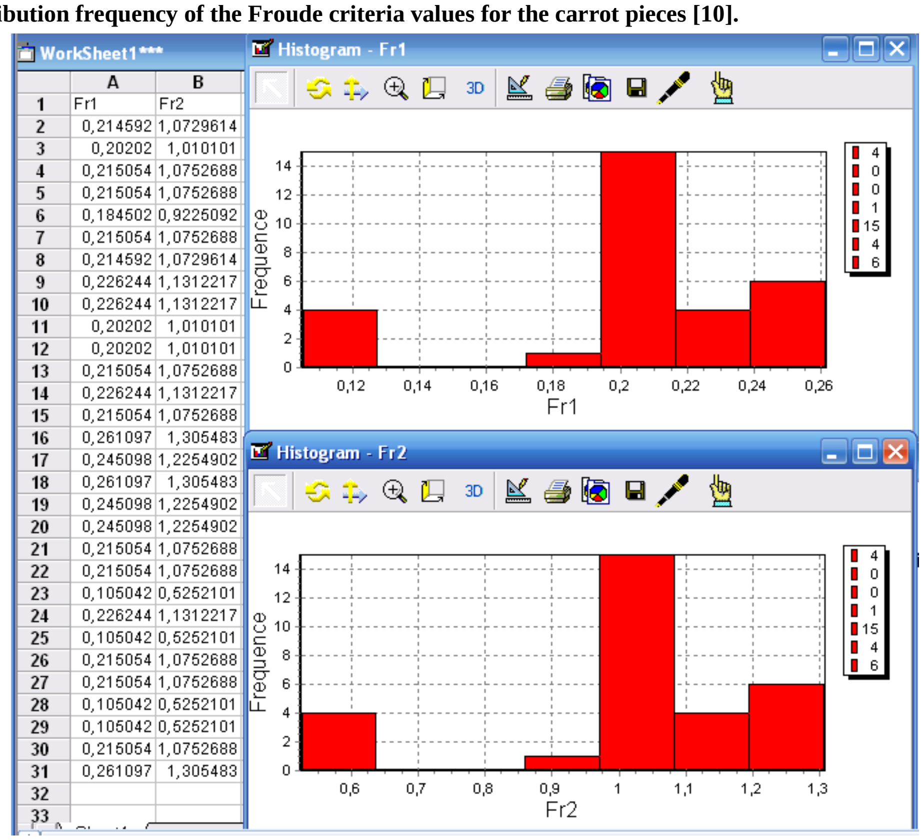

Fig. 7 The distribution frequency of the Froude criteria values for strawberries [10].

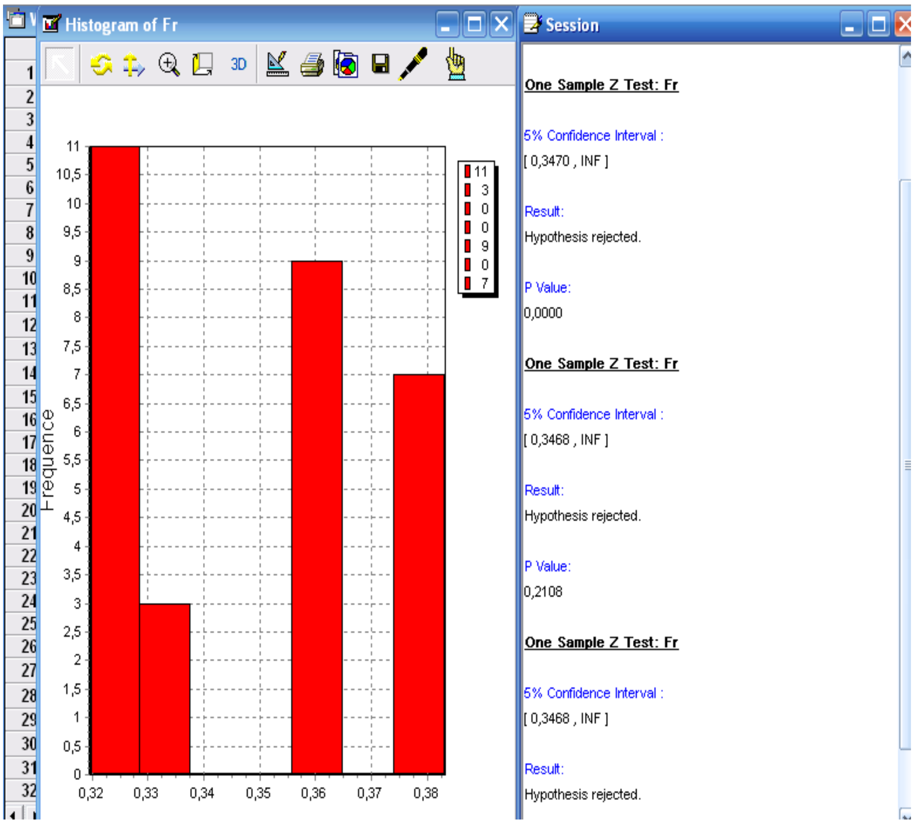

Fig. 8 The result of the test [10].

4. Conclusions

The experimental part presented in this thesis was made in the company S.C. Frigorifer S.A. from Tulcea, The laboratory for cold technique and climatisation in the food industry, the Physics laboratory—“Dunărea de Jos” University from Galați and USAMV-TPA Timişoara.

In the first part of the research, we studied the fluidization process and we compared the results obtained experimentally with the ones from the speciality literature. On the basis of this study, we established the mathematical model for the individual freezing and we made up computer software for monitoring the evolution of the movement of the ice front.

With this information, I went to S.C. Frigorifer S.A. where I worked on the FlowFreezer freezing installation. We traced the evolution of the freezing agent with the help of the York software from the York and Johnson Controls Company during the process of freezing by fluidization.

In order to optimize the process we used the statistical analysis SPSS 6.1 Guide for data analysis.

In the first stage we established the scientific hypothesis and we chose the statistical hypothesis in order to validate this one. In the next stage we established the variables that influence the process of freezing by fluidization.

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