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SIMULATION STUDY OF THE HUMIDITY AND TEMPERATURE INFLUENCE ON ACRYLAMIDE FORMING

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Abstract: *This paper presents a study by computer simulation of the technological parameters influence for fried potatoes slices obtaining on Acrylamide forming. Frying process simulation allows highlighting issues that cannot be determined experimentally in such technological process, such as temperature evolution within the potato slices points, the temperature distribution inside the potato slices, the influence of size and technological parameters on these factors. The results obtained by computer simulation refer to frying oil temperature influence on potato slices, duration and roasting potato slice thickness influence in the formation of Acrylamide in the finished product.*

Key words: *Acrylamide, humidity, temperature, potatoes.*

1. Introduction

Thermal processing of potato slices involves two aspects: the moisture content of the slices of French fries and their Acrylamide content. In terms of interest moisture content is that it be as small to large shelf life of the product. In terms of content Acrylamide interest is it to be as low as possible because the Acrylamide is a potentially carcinogenic substance. These two aspects are contradictory finding optimal parameters desired processing which ensured the acceptable values of the two parameters.

2. Objectives

The objective of the roasting process simulation is to find the optimum parameters of the technological process for obtaining fried potato slices so that the Acrylamide content to be small and the finished product to not be affected.

3. Material and Methods

Thermal processes in the food industry are physical processes - chemical complex, it is accompanied by a variety of other processes as follows: heat transfer, phase changes, diffusion process, changes in volume, flow process, processes local power supply voltages internal mechanical deformations, etc. These processes influence the micro and macrostructure products, their compactness, strength, etc. Following are ultimately influenced product quality, material consumption in the production process and energy consumption and environmental impact.

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In the technological process of fried potatoes primarily interested the product quality (residual moisture uniformity roasting, degree of combustion, energy, manufacturing cost). They are influenced by factors of semi dimensional (size slices), their characteristics (initial moisture content, starch content) factors constructs ovens (geometry and dimensions of the work, the position of the transport, heating), technological factors (oil temperature, the temperature of the heating elements, thermo physical characteristics of materials of all installations, power mode and circuit materials processing plants) [2].

Systematic research of thermal processes chips production facility by experimental methods in industrial or laboratory conditions is particularly difficult due to the complexity and installations due to the difficulty of measuring some parameters within the potato slices during processing (temperature, humidity). For this reason a method that allows a systematic and detailed study of this process is the computer simulation.

Mathematical modelling of frying potato slices is to transpose into mathematical equations and thermal processes of phase transition (evaporation) inside the potato slices and inside the roaster.

At present it is not known specialized software to perform simulation of chips frying process. Implementation of such software requires first developing a mathematical model of the process. Making a first program of its kind, even with a higher degree of approximation, further improvements will been to pick which ultimately is more faithful to all aspects and peculiarities of the process.

The ultimate objective of achieving such an advanced software optimization process consists technologic. Also such a program can be a starting point for the development of software for similar processes in the food industry, and other industries.

Models and software for 2D simulation of thermal processes are applicable to cases in which heat transfer takes place predominantly in two directions. This corresponds to systems that have translational symmetry. 2D simulation has the following advantages: simple structure of the programs, their use easier, much less time to perform simulations [1].

Due to the development of computer technology in the last two decades, worldwide, research on the modelling and simulation of industrial thermal processes have experienced a great development. We have developed special software to simulate such metallurgical processes. Because in this industry manufacturing costs, materials and energy consumption and environmental impact are very high. Such a soft, high performance was achieved and the Transilvania University of Brasov [1].

Based on experience in this area is likely to achieve mathematical models and simulation software for thermal processes in the food industry.

Simulation of thermal processing of food processes has a special importance to optimize the quality of these products. If chips frying process simulation allows to highlight issues that cannot be determined experimentally in such technological process, such as temperature evolution within the potato slices points, the temperature distribution inside the potato slices, the influence of size and technological parameters on these factors.

Considering these aspects of modelling and simulation stage thermal processes in the food industry, the research was aimed to achieve a first thermal process simulation software for frying the potatoes slices.

3.1. The principle of mathematical modelling 2D frying chips

Because until now has not developed a software (computer program) to simulate the thermal processes in frying chips, initially was considered necessary to create a mathematical model and a software for 2D simulation of this process.

This is possible and given the translational symmetry geometry processing chip manufacturing facilities. Subsequently, based on experience it will be possible to achieve a soft stage more complex 3D simulation. As noted above, the 2D simulation roasting process is applicable to the study of thermal processes taking place in systems with translational symmetry. Can be considered continuously operating frying tunnel, the chips are processed fulfil this condition.

2D models to simulate frying the chips take into account the heat transfer in only two directions (in a system of Cartesian axes xOy) by deep fryer assembly section (tank-potato-oil). This mode of heat transmission is close to reality and the cross section for systems with large length in the other two dimensions. Mathematical modelling of frying chips starts from model developed to simulate the solidification of liquid metal alloy castings. Relations that shape the process was modified and adapted to the roasting potatoes, given the presence of moisture and evaporation potato slices and Acrylamide formation process at temperatures above 120 ° C. The mathematical model developed using finite difference method. Fryer whole cross section through tunnel with continuous operation (section perpendicular to the direction of travel chips) is divided into elements square with Δ side. The sides of the elements are parallel to the axes of a Cartesian system xOy, as shown in Figure1.

The mathematical model is based on the differential equation of heat transfer between items. The equation is explained by finite difference method. It is recommended that side of elements (Δ) be chosen so that the elements resulting from the division to be homogeneous in terms of material (that consist of a single material, oil, metal, potato). The time of implementation process of roasting is also divided into very small finite intervals τ.

The accuracy of the calculation is even greater as space and time is fine. But as the mesh is finer increase the time it takes simulations. At some point, every element of the system resulted from the split section is characterized by the values of the thermo physical material from which it is established [1].

3.2. Mathematical model assumptions

In developing 2D mathematical model for chips manufacturing frying were considered the following assumptions:

- Initially at ambient temperature potato slices are of solid consistency, is made of a cellular material - the fibre with a complex chemical composition which comprises water, starch, protein, minerals and vitamins;
- Heating the slices of potato solids chemically bound water releasing chemical decomposition;
- At a temperature of constant 100 °C, water evaporates absorbing latent heat of vaporization;
- After removing water from potato slices instead of cooking oil is taken;
- Heat transfer processes within the system elements to be performed only by thermal conductivity;
- The transmission of heat within the system is carried out in the directions Ox, Oy perpendicular to the cross-sectional area in the system;

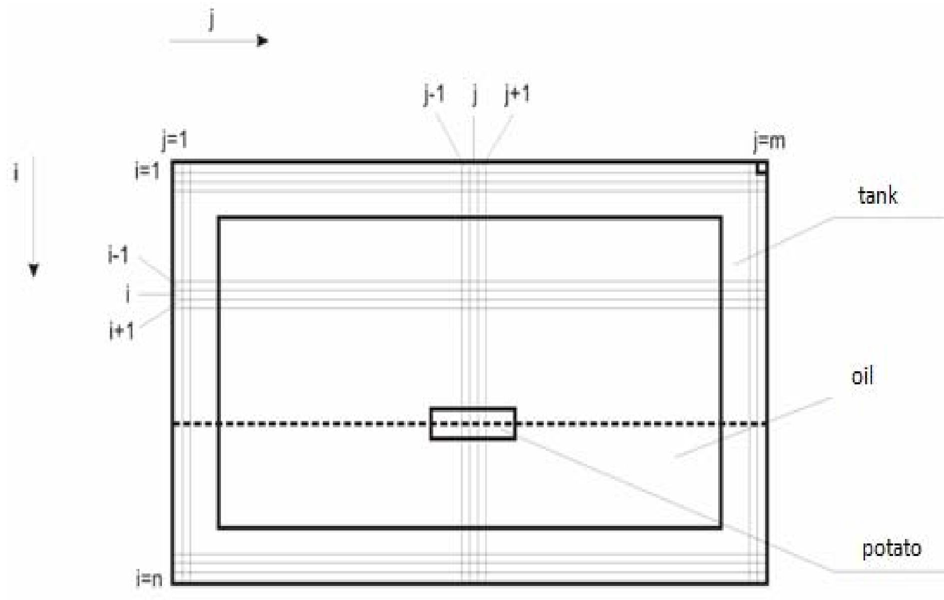

Fig. 1. *Scheme split shaft assembly - oil - potato slice for finite elements for modelling in 2D Cartesian coordinates*

- Heat transfer by forced convection, which occurs inside the heating agent (cooking oil), oil-driven process shaking caused by the moving of the system (pallets, conveyor belt) is taken into account by a coefficient equal transmission heat through thermal conductivity;
- Contact between the model elements is perfect throughout the process;
- Heat exchange between the furnace and the environment is taken into account by the heat transfer coefficient equivalent;
- Take into account average values of specific heat and thermal conductivity equivalent;
- The relative content of bound water in the slices is u0 = 0.9 (90%=u0=initial moisture);
- Potato remaining solid fraction at the point (the evaporating temperature) after vaporization of the water is made up of remaining moisture (s) and the solid residue (r) - which is considered to be constant;
- Remaining solid residue from potato slice (finished good) is r=0.1 (10%);
- During roasting, solid fraction changes due to evaporation of water from 1 to 0.1 (that is between 100% and 10%);
- Acrylamide begins to form at temperature T=120C;
- The tendency of Acrylamide forming is proportional to cell volume where the temperature is higher than 120C;
- Roasting whole system can comprise four elements (potato, cooking oil, oil heat);
- Assembly is constituted of four types of material, its form - called, alloy liquid coolants, insulating materials.

Finite difference modelling requires constant maintenance of the network step is divided form. In this situation cannot be considered the variation of density with temperature, as this would lead to changes in mass elements and therefore a departure from the principle of conservation of mass.

4. Results and discussions

During the simulation study of the thickness influence, the thick of potato slices ("h") was changed. It was intended that the thickness of potato slices commonly used in the food industry is between 1.6 - 1,9mm. In the study conducted by simulation, the potato slice thickness = 1.5mm changed between h= 1,5mm and h = 3 mm (from 0.3 mm to 0.3 mm). It was considered that cooking oil is the same in all cases.

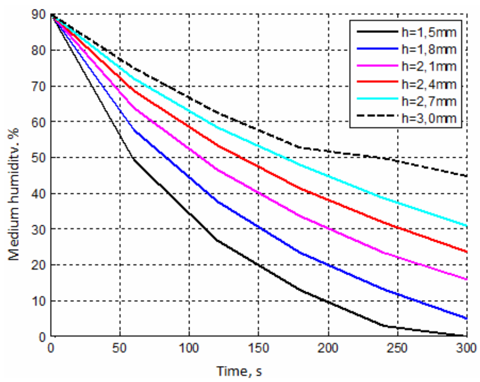

Fig. 2. *Evolution versus time and the average residual moisture of chips for various thickness "h" of the potato slices (frying oil temperature, u = 180˚C)*

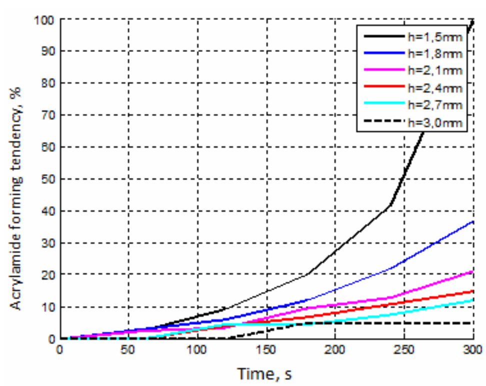

Fig. 3. *Evolution versus time and trend of Acrylamide formation (TA) in the chips for various thickness "h" of the potato slices (oil temperature Tu = 180˚C)*

The frying conditions in chips food processing was considered that oil temperature is T = 180˚C. The influence of slice thickness and potato roasting time on the evolution of temperature, humidity and the trend of Acrylamide formation are showed in Fig.2 and Fig.3.

The effects of the thickness of the roasting time between t = 1 minute and t = 5 minutes were analyzed. Results on the formation of Acrylamide trend in chips section are showed in Table 1.

From Fig. 2 and Fig. 3 following it can be seen followings:

- The temperature of the potato slices in the section analyzed very quickly reaches 100C, the heating time at this temperature is less than one minute;
- Average humidity potato slices begin to decline significantly immediately after the introduction of potatoes in heated oil;
- Thick potato slices also influences considerably removing water from potato slices;
- When the slices with a thickness of 3 mm, the average moisture remaining after 5min is still high, about 30% due to the fact that in the central section of the water does not evaporate completely;
- The corners and the sides of the slices reach very quickly at temperatures higher than 100C and lose moisture rapidly, shortly after entry into the hot oil;
- For a given temperature, cooking time should be related to the thickness of the chip manufacturing potatoes;
- In the case of potato slices having a thickness of 1.8 mm optimal duration of the roasting are approx. 3 minutes, the average remaining time in which the humidity is approx. 23% and the area prone to the formation of Acrylamide is about. 12%.
- All four oil temperature values for which the study was conducted, the temperature in the centre of the potato slice is practically the same, namely equal 100°C;

Results on the formation of Acrylamide trend in chips section Table 1

Crt. No.	The thickness of the slice	Tendency to form Acrylamide, TA, depending on time					
		t1 = 0s	t2 = 60s	t3 = 120s	t4 = 180s	t5 = 240s	t6 = 300s
Symbol	h	TA	TA	TA	TA	TA	TA
Unit measure	mm	%	%	%	%	%	%
1	1.5	0	2,5	9,17	20,0	41,57	100
2	1,8	0	2,98	5,97	11,94	21,89	36,81
3	2,1	0	2,34	3,5	9,36	12,86	21,05
4	2,4	0	0	4,0	6,67	10,67	14,67
5	2,7	0	0	4,54	4,54	7,57	12,12
6	3,0	0	0	0	5,0	5,0	5,0

5. Conclusions

The tendency of Acrylamide forming appears visible after approx. 1.5 to 2 minutes into the roasting. In the case of very thin slices with thickness of 1.5 - 1.8mm tendency to form Acrylamide increases considerably over four minutes duration. If the temperature of the oil to 140°C, the average residual moisture of chips (thickness h = 1.8 mm) is maintained at a high level (over 40%) even 5 minutes of roasting, which affects their quality.

For potato slice thickness h = 1.8 mm and u = 200 °C temperature cooking oil, Acrylamide is formed on the entire section. If the oil temperature is u = 140°C, the tendency of Acrylamide forming of in potato slice section is zero, but the potato remains very high humidity (over 40%), which affects the taste and quality of the finished good.

6. Acknowledgements

Based on the study it can be said that the optimum temperature for frying chips is in the range 160˚C - 180˚C.All observations lead to the conclusion that the optimal thickness of the slices of potato chips production 180˚C oil temperature is h - 1.8 mm.

References

1. Ciobanu I., Munteanu I.S., Crisan A., Monescu V., Bedo T., 2007. Modelling, Simulation and Optimization of Casting Solidification. Transilvania University Press, Braşov.
2. Durán M., Pedreschi F., Moyano P., 2007. Oil partition in pre-treated potato slices during frying and cooling, Journal of Food Engineering, Volume 81, Issue 1, July 2007, p. 257–265.