VOLUME 2, 2018
DOI: 10.31058/j.as.2018.24016

# Investigation of Kinetics Drying Pasta with Added Corn Flour

**Jelena Markovic[1*], Jasmina Stojiljkovic[2]**

[1]Department of Food Technology and Environment, College of Applied Studies, Vranje, Republic of Serbia
[2]Chief of Department of Food Technology, College of Applied Studies, Vranje, Republic of Serbia

## Email Address
jelena.markovic@visokaskola.edu.rs (J. Markovic), jasmina_vranje@yahoo.com (J. Stojiljkovic)
*Correspondence: jasmina_vranje@yahoo.com

**Received:** 23 June 2018**; Accepted:** 23 July 2018**; Published:** 4 September 2018

## Abstract:
In this study was investigated dry pasta from dedicated wheat flour with the addition of corn flour. Drying is comprised of four kinds of pastas: noodles for soup, wide noodles, narrow noodles and spaghetti. Three series were made at different drying temperatures, 55 ℃, 70 ℃ and 80 ℃. Measured by the change in mass of pasta and water loss during drying, the greatest weight loss occurred in with wide noodles, spaghetti, and lowest in the narrow noodles. The moisture content after drying, the pasta with the addition of corn flour was 12.7 % for all four type of pasta.

## Keywords:
Corn Flour, Pasta, Drying

## 1. Introduction

One of the important treatment of some farm products is drying process. Blowing the hot air to the object is the most common method of this process thus water contained is evaporated, [1]. Drying process is one of the most ancient method of food preservation [2]. Drying is a complex process of exchanging mass and heat, both between the material being dried and within the material itself. Drying is the removal of solid-phase liquid from heat, up to the content of dry matter characteristic of the dry product. The definition is based on the fact that evaporation of the liquid is associated with the corresponding heat transfer. At the same time, heat transfer was followed by the transfer of mass in the form of water vapor from the surface of the material to its surroundings. The purpose of drying process is to reduce the water content in the producst so that the environment is not suitable for micro-organisms reproduction [3,4,5].

Drying of pasta is based on the principle of convection - the exchange of heat and moisture between the pasta and the heated air flowing around the pasta. During the drying process the first evaporating moisture from the surface of the dough, and then there is a migration of the moisture from inside the test. As a result of this process leads to the formation of a gradient of moisture content in the center of the pasta and on its surface, and the time required to balance depends on the thickness of the pasta

and the speed of diffusion of moisture. The basic parameters of the air that determine the drying speed of the pasta are: temperature, humidity and air flow velocity [6].

One of the fundamental and critical control points in the dried pasta production is the drying process in air flow [7]. Depending on the dry bulb temperature of the hot air used, three modes of drying are generally used: low temperature drying (LT): temperatures of 50-55 ℃ for 14-20 hours; hight temperature drying (HT): temperatures of approximately 75 ℃ for 7-10 hours and ultra hight temperature drying (UHT): temperatures of 80-120 ℃ for a few hours, [8].

The preferred flour for pasta is that obtained from hard wheat with high protein content and solid glue resistant to stretching [9]. Pasta of this kind of flour has yellowish color, stubble, tear resistance, does not lose shape, do not cling and do not split. With the addition of corn flour, during pasta mixing, it was shown that pasta had good characteristics, and even better than the use of wheat flour during the drying process. Among the quality properties of spaghetti, texture is one of the most important factors affecting pasta quality and consumer acceptance [10].

The temperature dependence of the water sorption behavior, particularly the effects of starch gelatinization on this behavior, has not fully been assessed. We reported that the expression of a hyperbolic type, in which the cooking time was divided by the square of the initial diameter of spaghetti, was useful for describing the water sorption processes of spaghetti having different initial diameters and estimating the equilibrium moisture content and the initial rate of water sorption [11].

To dry the pasta, in addition to knowing air conditioning, it is necessary to emphasize the transmission of mass and energy in detail. Drying of pasta represents the final phase of a technological process that requires a lot of skill, attention and responsibility. The most important is the setting of drying speed. In the event of a quick drying of the pasta, it can shoot, so it has significant fractures, and other defects such as cracks, white spots and inequalities in the color of the pasta itself are created. If, however, drying of pasta takes place in too slow drying, the pasta can be so degraded that it can not match the purpose. The higher air temperature and velocity increase the evaporation rate. However, the gradient of evaporation rate by temperature tends to decrease from 0.46 gram/$^{o}$C to 0.2 gram/$^{o}$C. Contrarily, the gradient is increased by velocity from 5 gram/(m/s) to 9 gram/(m/s), [1]. Based on this fact, it can be concluded that the effect of temperature is less significant at high air velocity. The basic principle of drying process is to transport water vapor from wet object to the air. Velocity of air is proportional to the mass flow rate of air. At higher mass flow rate, the capacity increase since a lot of amount of air.

The aim of the paper is to examine the kinetics of pasta drying and the problems that arise during the drying process. The paper presents the influence of adding corn flour at the time of drying pasta. This work shows that the addition of corn flour in the stains gives good results in terms of drying at the appropriate temperatures.

## 2. Materials and Methods

### *2.1. Procedure for pasta production*

As a material in this work, pasta was used (noodles for soup, wide noodles, narrow noodles and spaghetti). Pasta products are obtained by mixing and forming wheat grieze or dedicated flour with water. The basic raw materials for making pasta are

flour, water, and eggs. Corn flour and sodium glutamate were used as additional raw materials.

The used flour for making pasta is T-400, which is produced and packed by a mill in Drazevac, a moisture content of 13.5%, a degree of acidity 2.2 and an ash content of 0.45%, a pH of 5.9.

All trials were done in the laboratory of the Faculty of Technology in Leskovac and the chemical laboratory of the Public Health Institute from Leskovac. The dough is mixed with continuous (direct) seeds, all the raw materials are added directly to the flesh. The water temperature for the test stocks was 28 ℃, with a humidity of 30%

Pasta with the addition of corn flour was made so that the ratio of wheat and corn flour is 70:30. Maize flour contains considerably higher amounts of fat than wheat, and the protein entering into its composition does not create glue, so that the dough can not be formed and tied.

### *2.2. Drying Process*

The drying process begins immediately after the matrix test has passed. Drying takes place under the influence of convection - hot air flow and is based on the exchange of heat and moisture between the pasta and the heated air flowing into the oven around the pasta. As the air temperature is higher, evaporation of the water from the pasta surface is more intense. By increasing the air flow rate around the pasta, evaporated water is removed more quickly. The pasta was dried in three phases depending on the air temperature:

- Phase I- drying at low temperatures at 55 ℃ for 1.5 hours;

- Phase II - drying with medium high temperatures at 70 ℃ (pre-drying) for 10-20 hours;

- Phase III - drying with medium high temperatures over 80 ℃.

For the drying of the pasta were used the convective type experimental dryers, which were made by hand. Dryer is a rectangular shape made of galvanized sheet metal, with five wood. The working medium is warm air obtained from a calorifier located in the bottom of the dryer.

The drying process was carried out by the fact that at the beginning of the drying the temperature in the dryer was 55 ℃, in order to increase the temperature to 70 ℃ after one drying cycle, and at the end of the drying temperature, the temperature was 80 ℃. The temperature was increased because the pasta at 55 ℃ showed an insufficient dryness, at 70 ℃ it was partially dried, while at 80 ℃ the pasta showed the real effect of dried pasta.

Pasta samples with corn flour were dried for a period of 270 minutes. The weight and moisture content were read after 15, 30, 45, 60, 75, 90, 120, 150, 210 and 270 minutes.

### *2.3. Statistical Analysis*

Statistical analysis of data is represented by the model of exponential dependence. The model of exponential dependence (exponential curve) served as a model for obtaining the results of drying the pasta with the addition of corn flour. Exponential dependence is the curve:

$$y = y_0 + A_1 e^{-(x/t_1)} \quad (1)$$

using the program Origin Version 4.0.

Amplitude A and values x are associated parameters. When the command for this dependence is selected, the Origin program will make the necessary initiative for the parameters and set the corresponding fixed number, which is close to the minimum value of the parameter x. It also sets the corresponding fixed number that is close to the asymptotic value of the variable y for the large values of the parameter x.

This section should contain sufficient details so that methods can be appropriately cited and readers can assess whether the materials and methods justify the conclusions or not. It can be divided into subsections if several other methods need to be described. You need explain how you studied the topic, identify the procedures you followed, and structure this information as logically as possible.

## 3. Results and Discussion

Table 1 shows the results of drying of pasta containing corn flour and dried at 55 ℃.

***Table 1.*** *Change in mass and change in moisture content during drying pasta with corn flour at 55 ℃.*

| Time min | Change in mass, g | | | | Change in moisture content, % | | | |
|---|---|---|---|---|---|---|---|---|
| | Noodles for soup | Wide noodles | Narrow noodles | Spaghetti | Noodles for soup | Wide noodles | Narrow noodles | Spaghetti |
| 0 | 220 | 220 | 220 | 220 | 93.13 | 93.13 | 93.13 | 93,13 |
| 15 | 211 | 215.7 | 217.6 | 216.8 | 90.03 | 90.45 | 88.9 | 89.54 |
| 30 | 196 | 202.5 | 213.6 | 210 | 85.34 | 87.9 | 72.64 | 80.07 |
| 45 | 190 | 197 | 208.1 | 201.7 | 78.96 | 77.76 | 68.56 | 73.27 |
| 60 | 184 | 185.2 | 204.2 | 196.5 | 70.1 | 71.04 | 60.08 | 69.32 |
| 75 | 180.6 | 176.3 | 200.9 | 186.5 | 59.79 | 62.5 | 54.23 | 61.76 |
| 90 | 173 | 161.7 | 197 | 178.3 | 41.14 | 47.5 | 47.16 | 56.34 |
| 120 | 170.7 | 158.4 | 192.7 | 173 | 34.6 | 37.21 | 36.07 | 45.6 |
| 150 | 165 | 150.1 | 198.3 | 169.5 | 25.69 | 22.76 | 29.43 | 34.14 |
| 210 | 160 | 150.6 | 180.9 | 165.1 | 17.08 | 17.11 | 17.24 | 18.06 |
| 270 | 158 | 151.8 | 180.6 | 161 | 17.21 | 17.27 | 17.19 | 17.20 |

Based on the results in Table 1, it can be concluded that the weight of pasta has decreased steadily after all time intervals. The largest reduction in weight was observed in wide noodles (62 g), and at least in narrow noodles (39.4 g).

It can also be concluded that pasta with the addition of corn flour, after drying of 270 min, still have a large mass, which means that the dough could not be well fermented and remained unchanged. As a consequence, there is an inadequate drying temperature of 55 ℃.

The experimental results from Table 1 are shown graphically in Figures 1 and 2.

Drying of pasta at 55 ℃ for 1.5 hours represents a pre-drying phase where half of the total amount of water is removed, which should be removed by drying. The moisture content in the pasta with corn flour gradually decreased during all measurement intervals. The flow mode is such that during 270 minutes the pasta is dried to a humidity ranging from 17.19 to 17.27%. The strongest moisture was recorded at wide, and the smallest in narrow noodles. The pasta is then in a plastic state and therefore a sharper drying regime is applied, that is, the drying temperature is increased to 70 ℃.

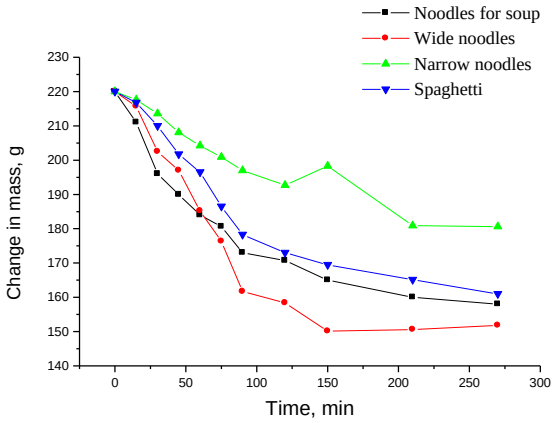


***Figure 1.*** *Changing the weight of pasta on 55 ℃.*

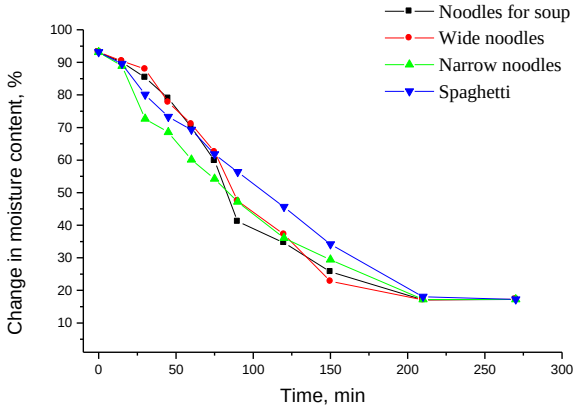


***Figure 2.*** *Changing the moisture content of pasta on 55 ℃.*

The second stage of the pasta drying is more demanding and represents the main drying at a temperature of 70 ℃. The drying time of the pasta at this temperature is from 10 to 20 hours. The results of measuring the change in mass and the change in the moisture content of various forms of pasta are given in Table 2.

***Table 2.*** *Change in mass and change in moisture content during drying pasta with corn flour at 70 ℃.*

| Time, min | Change in mass, g | | | | Change in moisture content, % | | | |
|---|---|---|---|---|---|---|---|---|
| | Noodles for soup | Wide noodles | Narrow noodles | Spaghetti | Noodles for soup | Wide noodles | Narrow noodles | Spaghetti |
| 0 | 220 | 220 | 220 | 220 | 88.57 | 88.57 | 88.57 | 88.57 |
| 15 | 208.65 | 211.34 | 217.54 | 217.36 | 85.75 | 85.04 | 81.4 | 82.87 |
| 30 | 195.31 | 203.5 | 214.78 | 214.09 | 75 | 64.7 | 67.9 | 69.6 |
| 45 | 190.8 | 192.1 | 213.21 | 207.7 | 59.14 | 55.8 | 58.06 | 52.3 |
| 60 | 187 | 181.6 | 213 | 192.5 | 45.41 | 44.08 | 47.32 | 45 |
| 75 | 181.07 | 170.33 | 212.9 | 184.6 | 33.07 | 32.7 | 33.6 | 33.7 |
| 90 | 175 | 163.7 | 208.76 | 177.32 | 26 | 29 | 24.5 | 28.1 |
| 120 | 168.92 | 159.48 | 199.7 | 171 | 20.06 | 19.1 | 19 | 20 |
| 150 | 164.46 | 155.19 | 197.3 | 166.48 | 17.97 | 18.06 | 16.54 | 16.86 |
| 210 | 159.06 | 150.6 | 181.06 | 159.05 | 13.02 | 13 | 12.88 | 12.73 |
| 270 | 154.2 | 149.89 | 180 | 156.76 | 12.9 | 12.9 | 12.97 | 12.86 |

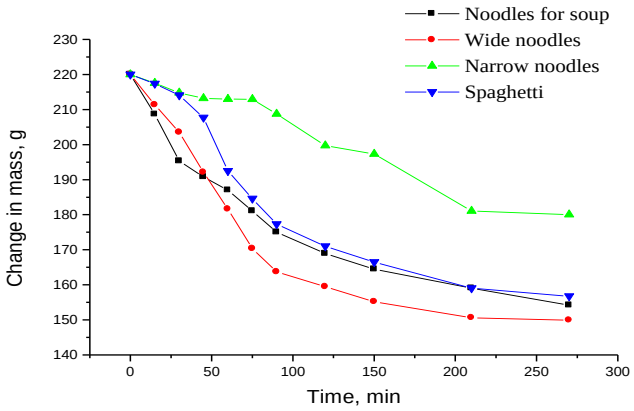


***Figure 3.*** *Changing the weight of pasta on 70 ℃.*

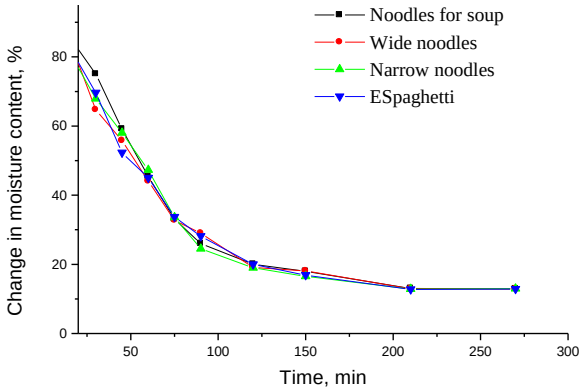


***Figure 4.*** *Changing the moisture content of pasta on 70 ℃.*

Figure 3 gives a graphical view of changing the paste drying mass to 70 ℃. During the drying of the pasta at 70 ℃ it is observed that the weight of the pasta is reduced, which means the pasta is transferred from plastic to solid state. The largest mass loss was recorded in wide noodles, noodles for soup, spaghetti, and the smallest in narrow noodles. By comparing the results from Table 2 related to moisture content, it can be concluded that drying at 70 ℃ of pasta gradually loses water, water evaporates a considerable percentage, suffers significant changes in structure and mechanical properties. The highest moisture was recorded in soup noodles and wide noodles, accounting for 12.9%.

Drying pasta at 80 ℃ represents the final phase, and the results of the measurements are shown in Table 3. Higher temperature of air has larger capacity of water vapor so that the evaporation rate from the product is increased.

Based on the results in Table 3 for weight change, a decrease in weight for all types of pasta was recorded in relation to the initial weight of 220 g pasta. The largest loss of mass in the case of wide noodles and spaghetti, and the smallest in narrow noodles.

From Table 3 it can be seen that the moisture content of the pasta has dropped to 12.7% in all four types of pasta, which is a pasta stabilization phase, which has already been determined and after 210 minutes of pasta drying at 80 ℃. The moisture was distributed appropriately throughout the whole of the pasta, equalizing the

moisture content of the pasta. This showed that pasta achieved a satisfactory level during drying at 80 ℃. In all four types of pasta, moisture content is 12.7%.

***Table 3.*** *Change in mass and change in moisture content during drying pasta with corn flour at 80 ℃.*

| Time, min | Change in mass, g | | | | Change in moisture content, % | | | |
|---|---|---|---|---|---|---|---|---|
| | Noodles for soup | Wide noodles | Narrow noodles | Spaghetti | Noodles for soup | Wide noodles | Narrow noodles | Spaghetti |
| 0 | 220 | 220 | 220 | 220 | 87.65 | 87.65 | 87.65 | 87.65 |
| 15 | 197 | 190 | 236 | 196 | 84 | 84.4 | 80.5 | 82.3 |
| 30 | 191 | 181 | 226 | 189 | 72 | 62.7 | 66.6 | 68.6 |
| 45 | 182 | 177 | 219 | 180 | 54 | 54.9 | 56.9 | 51 |
| 60 | 176 | 171 | 211 | 174.5 | 42 | 43.2 | 45.8 | 40.2 |
| 75 | 170 | 165 | 201 | 170.5 | 30 | 31.4 | 31.9 | 32.3 |
| 90 | 168.5 | 160 | 194 | 168 | 27 | 21.5 | 22.2 | 27.4 |
| 120 | 165 | 158 | 189 | 166 | 20 | 17.6 | 15.3 | 23.5 |
| 150 | 163.5 | 156 | 187.5 | 164 | 17 | 13.7 | 13.2 | 19.6 |
| 210 | 155 | 149 | 178 | 154 | 12.7 | 12.7 | 12.7 | 12.7 |
| 270 | 155 | 149 | 178 | 154 | 12.7 | 12.7 | 12.7 | 12.7 |

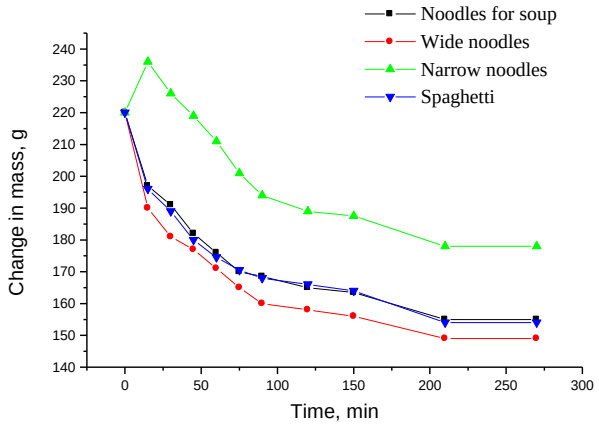


***Figure 5.*** *Changing the weight of pasta on 80 ℃.*

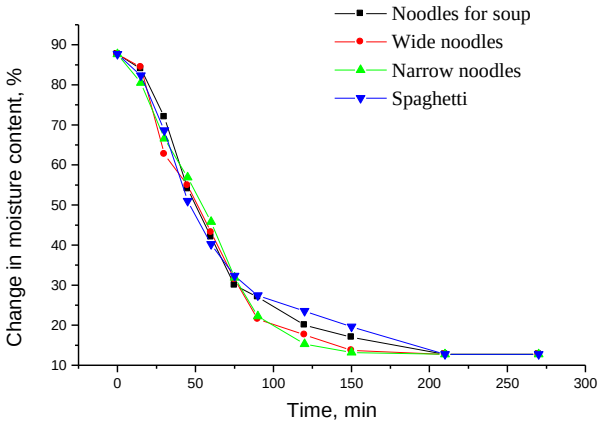


***Figure 6.*** *Changing the moisture content of pasta on 80 ℃.*

The experimental results for changing the mass and moisture content with time from Table 3 are shown in graphic dependence in Figures 5 and 6. The graph in Figure 5 shows a change in the weight of the pasta with the drying time in the final

drying phase. The largest loss of mass in the case of wide noodles and the smallest in narrow noodles. In Figure 6 shows that the pasta humidity dropped to 12.7%, which represents the phase of stabilization of pasta, bringing the pasta achieve a satisfactory level of humidity during the drying at a temperature of 80 ℃.

When drying pasta at low temperatures, the quality of pasta depends on the quality and quantity of the protein from the raw material, while only the quantity of protein is responsible for drying at high temperatures for the quality of the pasta, [12]. Also, a large number of studies indicate that high technological (60-85 ℃) and very high (85-110 ℃) temperatures achieved great technological progress, which is reflected in increasing productivity, reducing energy consumption, improving the sensory product quality and its microbiological correctness [13,14].

Spaghetti dried under high-temperature conditions had better quality after cooking than that dried under low-temperature conditions [12]. The dependence of the properties of cooked spaghetti on drying conditions is due to changes in the inner structure of spaghetti during drying [15,16].

However, drying pasta at very high temperatures can result in tanning of the pasta, i.e. the pasta takes on an intense orange color, which is a consequence of Maillard's reaction and formation of furosine, a harmful, toxic compound. The gluten-free mesh denaturates and becomes insensitive when the pasta is dried at high temperature, which makes the protein fraction less sensitive to changes during cooking, [17]. Also, the matrix interferes with the starch swelling, so the pasta dried at high temperatures absorbs a smaller amount of water.

The leakage of amylose from the spaghetti dried under low-, high- and veryhigh-temperature conditions during their cooking processes and showed that more amylose leaked from the spaghetti dried at lower temperature [18].

The samples from Table 3 showed that the temperature of 80 ℃ was the most adequate and that the quality of pasta did not change at this temperature, which should be shown.

The results of the curves obtained on the charts were compared with the exponential curve (on the basis of which the obtained results were compared). From the attached one it can be seen that the obtained results do not have too much deviation from the given exponential curve, which was the goal.

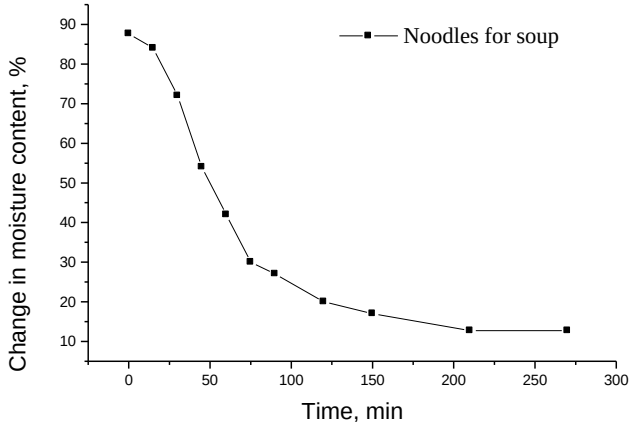


***Figure 7.*** *Exponential value of change of moisture content with time for noodles for soup.*

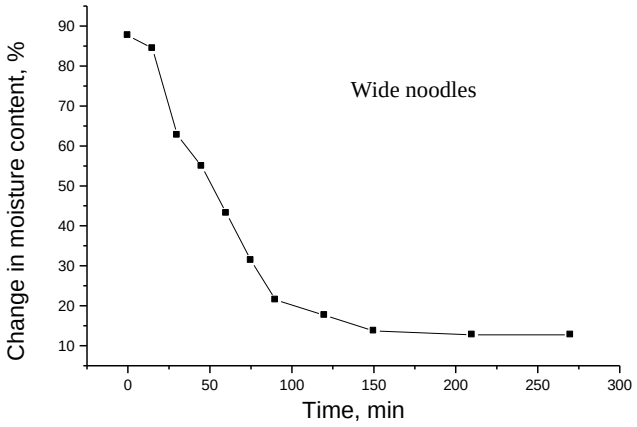


***Figure 8.*** *Exponential value of change of moisture content with time for wide noodles.*

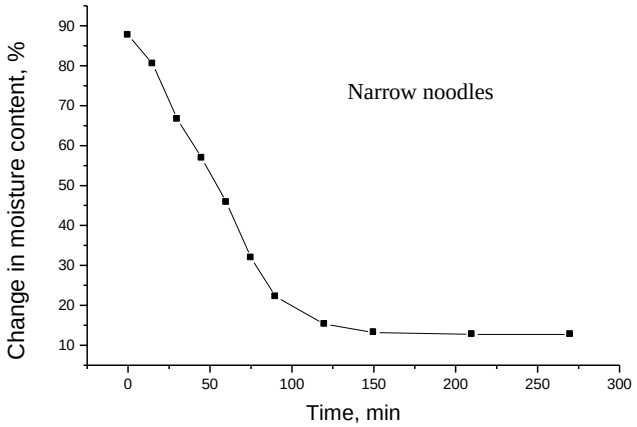


***Figure 9.*** *Exponential value of change of moisture content with time for narrow noodles.*

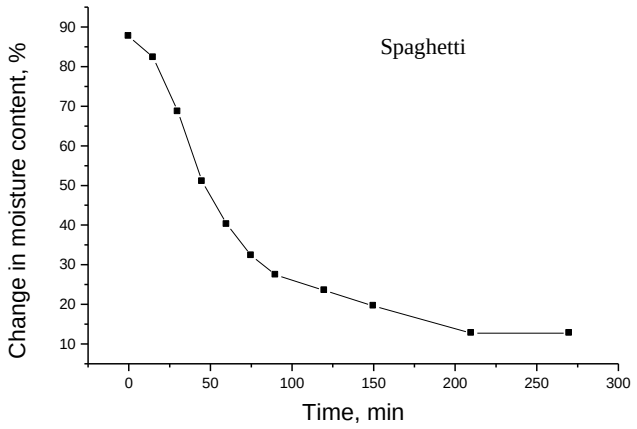


***Figure 10.*** *Exponential value of change of moisture content with time for spaghetti.*

In the initial drying period (for the first 60 min), the moisture content of the pasta (noodles for soup - Figure 7, wide noodles - Figure 8 and narrow noodles - Figure 9) was linearly decreasing with time, and in the continuation of drying the moisture gradient profile was hyperbolic. This could be expected because, during drying, there was an increase in the resistance of the diffusion of water from the interior of the

pasta to the surface, which means that the loss of moisture content of the pasta loses plastic-elastic properties and slowly passes into a solid form. The change in moisture content over time with spaghetti (Figure 10) had almost half-hippocellular shape throughout the drying period, which is explained by unchanged resistance to the diffusion of moisture from the interior to the surface of the pasta. It can be concluded that the loss of moisture in the pasta with the addition of corn flour was uniform.

Table 4 shows the values of the exponential model with Figures 7, 8, 9 and 10.

***Table 4.*** *Coefficients for the model of the exponential dependence of maize pasta on corn flour.*

| Coefficients | Noodles for soup | Wide noodles | Narrow noodles | Spaghetti |
|---|---|---|---|---|
| $Y_0$ | 9.01568 | 9.01568 | 7.9305 | 11.61416 |
| $A_1$ | 94.18912 | 94.18912 | 94.40911 | 90.57039 |
| $t_1$ | 54.99231 | 54.99231 | 58.39075 | 55.13538 |

## 4. Conclusions

During the drying process, the value of the paste weight gradually decreased, so that the maximum mass decrease was recorded after drying at 80 ℃. The largest mass loss was recorded in the case of wide noodles and spaghetti, and the smallest in narrow noodles.

The moisture content at the end of drying in the pasta with the addition of corn flour was gradually reduced and at the end of drying it was 12.7% in all four types of pasta.

The results of the curves obtained on the graphs that were compared with the exponential curve (on the basis of which the obtained results were compared) do not have too much deviation from the given exponential curve, which was the goal.

Accordingly, the study leaves the possibility of further testing of kinetics, in particular, the speed of drying pasta at different temperatures with the addition of other types of flour (soya flour).

## Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

## References

[1] Putra N. R.; Ajiwiguna AT. Influence of Air Temperature and Velocity for Drying Process. *Procedia Engineering*, 2017, 170, 516-519.

[2] Berk. Food Process Engineering and Technology, third ed. Oxford: Academic Press, 2009.

[3] Cengel Z. Heat and Mass Transfer an Engineering Approach, Second ed. McGraw-Hill, 2000.

[4] Wang J.; Xia S. Y. Drying characteristics and drying quality of carrot using a two-stage microwave process. *Journal of Food Engineering*, 2005, 505-511.

[5] Wannapakhe S.; Chaiwong T.; Dandee M.S.; Prompakdee S. Hot Air Dryer with Closed-Loop Oscillating Heat Pipa with Check for Reducing Energy in Drying Process I-SEEC, 2011, 77-82.

[6] Bejarovic G. Pasta production technology. Tiski cvet, Novi Sad, Republic of Serbia, 2001.

[7] Zanoni B. Tecnologia Alimentare. La classe delle operazioni unitarie di disidratazione per la conservazione dei prodotti alimentari, Vol. I, Firenze, Firenze University Press, 2006.

[8] Kill R. C.; Turnbull K. Pasta and Semolina Technology, Wiley, Hoboken, Blackwell Science, 2008.

[9] Zezelj M. Tehnologija žita i brašna, knjiga I, Tehnološki fakultet, Zavod za tehnologiju žita i brašna, Novi Sad, 1995, 295-297.

[10] Pestoric M. Definisanje i valorizacija eksternog profila industrijski proizvedene testenine. Magistarski rad, Tehnološki fakultet, Univerzitet u Novom Sadu, Novi Sad. 2007.

[11] Ogawa, T.; Kobayashi, T.; Adachi, S. Water sorption kinetics of spaghetti at different temperatures. *Food Bioprod. Process*, 2011, 89, 135-141.

[12] Petitot M.; Brossard C.; Barron C.; Larre C.; Morel M. H.; Micard V. Modification of pasta structure induced by high drying temperatures. Effect on the in vitro digestibility of protein and starch fractions and the potential allergenicity of protein hydrolysates. *Food Chemistry*, 2009, 116, 401-412.

[13] Cuq B.; Gonçalves F.; Mas J. F.; Vareille L.; Abecassis J. Effect of content and temperature of spaghetti on their mechanical properties. *Journal of Food Engineering*, 2003, 59, 51-60.

[14] Pestoric M.; Pojic M.; Filipcev B.; Simurina O.; Torbica A.; Janic Hajnal E. Sensory differentiation of commercially produced spaghetti. *Food and Feed Research*, 2015, 42, 109-117.

[15] Zweifel C.; Handschin S.; Escher F.; Conde-Petit B. Influence of high-temperature drying on structural and textural properties of durum wheat pasta. *Cereal Chemistry*, 2003, 80, 159-167.

[16] Cubadda R. E.; Carcea M.; Marconi E.; Trivisonno M.C. Influence of gluten proteins and drying temperature on the cooking quality of durum wheat pasta. *Cereal Chemistry*, 2007, 84, 48-55.

[17] Bonomi F.; D'Egidio M.G.; Iametti S.; Marengo M.; Marti A.; Pagani M.A.; Ragg E.M. (2012). Structure–quality relationship in commercial pasta: A molecular glimpse. *Food Chemistry*, 2012, 135, 348-355.

[18] Baiano A.; Conte A.; Nobile M.A.D. Influence of drying temperature on the spaghetti cooking quality. *J. Food Engineering*, 2006, 76, 341-347.