

**Drying characteristics of Turkish ravioli, mantı**

**Mantıların kurutma karakteristiği**

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**Abstract**

Mantı, Türkiye'de yıllardır birçok insan tarafından tüketilen, özgün tada sahip bir hamur işidir. Bu çalışmadı, iki yaygın tipte mantı örneği (hamur tabakalarının kâğıt torbalar halinde sarmalmasıyla üretilen geleneksel Kayseri mantısı ve üçgen mantı) mikrobiyolojik olarak güvenli olmalarını sağlamak amacıyla su aktivitesi değerlerinin 0.8’den daha düşük seviyeye getirilmesi amaçlanmıştır. Kurutma işlemi konvektif bir kurutucuda 60, 70 ve 80 °C’de gerçekleştirildi. Drying rates were obtained for traditional Kayseri mantı and the desired water activity value for this mantı was reached at drying temperatures of 70 °C ve 80 °C, and only at 80 °C for the traditional Kayseri mantı. Drying rates increased by increasing temperature levels.

**Anahtar kelimeler:** Turkish ravioli, Drying kinetics, Water activity, Modelling, Drying rate.

1 **Introduction**

Bakery products are an important group of foods made by the addition of various components to dough and widely consumed in many countries. Mantı is one of the traditional Turkish dishes included in this group containing meat and dough, which are generally preferred constituents by a wide range of consumers [1]. Mantı is sold as packed, unpacked, chilled, frozen or baked, and the main materials of this traditional product are wheat flour, water and eggs. Some types of mantı may contain other materials such as mashed potatoes, cheese, minced meat and spices. Generally, mantı is prepared by filling these various materials into the rectangular or other kinds of shaped dough parts. Products similar to mantı include ravioli, tortellini and pelmeni, which are consumed in Italy and many countries around the world [2],[3].

Chemical, enzymatic and microbial deterioration in foods during storage depends on their water activity levels and the microbial growth is almost completely restricted at levels below 0.6 (Roos 2001). The moisture content of ravioli and tortellini, products similar to mantı, ranges from 26 to 34% while their water activity values varies from 0.92 to 0.95 [4]. Therefore, one of the most effective factors on the deterioration of mantı is its moisture content and nutritional value which are subjected to mostly lipid oxidation or microbial growth [5]. Although high-moisture foods such fresh pasta, pizza dough and mantı are dried at high temperature, pathogens like *Salmonella* spp. and *S.aureus* can survive in the final product. As drying continues, their water activity values fall below 0.8, which results in the inhibition of bacterial growth over time [6].

Technologically, drying is the process of making a food product more stable by lowering its water content under constant and safe conditions. The most common applications in the drying of agricultural products are tunnel and cabinet-type dryers included in hot air dryers. Because of their simplicity and low costs, these types of dryers are commonly used [7],[8].

Several studies on the drying processes of mantı like bakery products are available in the literature as pasta [9]-[12], noodles [13]-[15]. Also, Dağlıoğlu [2] investigated the quality attributes of mantı samples subjected to microwave drying. During drying processes, determining the drying characteristics of foods is highly critical to obtain final products with superior quality, which directly depends on drying conditions [16]. To the best of our knowledge, the drying characteristics of mantı samples with different shapes have not been studied yet. Therefore, this study was aimed to determine
the drying characteristics of traditional Kayseri and triangular manti samples at three different temperatures and to find out the best fit mathematical model for the experimental data.

2 Materials and methods
Frozen traditional Kayseri manti and triangular manti samples were obtained from a national market in Turkey. The average thickness values of triangular and traditional Kayseri manti samples were 10.0±3.1 and 12.0±2.2 mm respectively. Samples were thawed in a refrigerator until their central temperature reached 4±1 °C, which was monitored regularly by a thermometer with a stainless steel probe (Testo 720, Testo Inc., Lenzkirch, Germany). Then, samples were kept at room temperature for an hour to allow the moisture balance between outer dough sheet part and inner minced meat part of manti samples.

Drying operations were performed by natural convection in a preheated oven (FN 500, Nıve, Ankara, Turkey) at 60, 70 and 80°C with 3 replicates for each temperature. During drying, weight loss was monitored gravimetrically by a digital balance (Weightlab WL-3002L, Germany) and results were recorded. Drying procedure was carried out until the water activity value fell below 0.6. The initial moisture content of the manti samples were determined as about 0.350 g. water. g⁻¹ dry matter and the final value was about 0.059 g. water. g⁻¹ dry matter for Kayseri manti and 0.029 g. water. g⁻¹ dry matter for triangular manti samples. At the end of drying, manti samples were carefully wrapped in aluminum foil, placed in plastic containers, and kept under refrigerated conditions for 48 h (±4±1 °C). Then, water activities of the samples were determined using the water activity device (Testo 645, Testo Inc., Lenzkirch, Germany). Total dry matter contents of manti samples were determined by drying at 105±1°C for 8 h. Moisture contents of manti samples were calculated based on the Equation 1.

\[ M_t = \frac{m - DM}{DM} \]  

(1)

where \( M_t \) represents the moisture content value at any time (g. water. g⁻¹ dry matter), \( m \) is the sample weight (g) and \( DM \) is the dry matter content of manti (g).

Moisture ratio values were calculated according to Equation 2:

\[ MR = \frac{M_t - M_e}{M_0 - M_e} \]  

(2)

where \( MR \) and \( M_t \) are the moisture ratio and the moisture content at any t time (g. water. g⁻¹ dry matter); \( M_e \) and \( M_0 \) are the equilibrium moisture content and initial moisture content values (g. water. g⁻¹ dry matter), respectively. During the food drying processes, \( M_e \) may not be used in calculations because it is very small compared to \( M_t \) and \( M_e \) that does not influence the results [17]. The rate of drying is found by taking the derivate of drying time curves versus moisture content which is represented by the Equation 3.

\[ Drying \ Rate = \frac{M_{t+dt} - M_t}{dt} \]  

(3)

where \( M_{t+dt} \) represents the moisture content at \( t+dt \) time (g. water. g⁻¹ dry matter) and \( dt \) is the drying time (h).

Drying rates and \( MR \) values of manti samples were determined from experimental drying data. To determine the mathematical drying kinetics of the samples, semi-empirical models were used (Table 1).

Table 1. Thin layer drying models used for modelling experimental data.

| Models                  | Equation             | Reference |
|-------------------------|----------------------|-----------|
| Henderson and Pabis     | \( MR = xe^{(-kt)} \) | [18]      |
| Newton                  | \( MR = e^{(-kt)} \)  | [19]      |
| Page                    | \( MR = e^{(-kt^n)} \) | [20]      |
| Modified Page           | \( MR = ae^{(-kt)} + c \) | [21]      |

For the statistical evaluation the coefficient of determination \( (R^2) \), root mean square error \( (RMSE) \) and chi-square \( (x^2) \) parameters were used to obtain the correspondence between the experimental and theoretical \( MR \) values of kinetic models.

\[ RMSE = \left[ \frac{1}{N} \sum_{i=1}^{N} (MR_{prd,i} - MR_{exp,i})^2 \right]^{0.5} \]  

(4)

\[ x^2 = \frac{\sum_{i=1}^{N} (MR_{exp,i} - MR_{prd,i})^2}{N - n} \]  

(5)

where \( MR_{prd} \) is the estimated moisture content, \( MR_{exp} \) is the experimental moisture content, \( n \) and \( N \) are the number of coefficients in the tested model and number of the experimental data, respectively. \( RMSE \) values show the deviation between the estimated values obtained from the tested model and the experimental values. A decrease in chi-square \( (x^2) \) value represents an increase in conformance. The lower values of \( x^2 \) and \( RMSE \) with higher values of \( R^2 \) are desirable.

3 Results and discussion
Figures 1 and 2 show the graphical representation of drying rates versus moisture content \( (MC) \) values at three different temperatures for triangular and traditional Kayseri manti samples, respectively.
Conformance of experimental data for triangular mantı samples with theoretical models by nonlinear regression analysis.

| Model            | Temperature (°C) | Constant and Coefficients | $\chi^2$ ($x10^{-3}$) | RMSE ($x10^{-2}$) | $R^2$ |
|------------------|------------------|---------------------------|-----------------------|------------------|-------|
| Henderson        | 60               | k=0.0056 a=1.0359         | 0.533                 | 2.189            | 0.993 |
| and Pabis        | 70               | k=0.0060 a=1.0492         | 0.317                 | 1.683            | 0.995 |
|                  | 80               | k=0.0060 a=1.0116         | 0.149                 | 1.155            | 0.996 |
| Newton           | 60               | k=0.0055                  | 0.020                 | 0.423            | 0.993 |
|                  | 70               | k=0.0058                  | 0.111                 | 0.996            | 0.995 |
|                  | 80               | k=0.0059                  | 0.155                 | 1.179            | 0.996 |
| Page             | 60               | k=0.0089 n=0.9116         | 0.173                 | 1.247            | 0.995 |
|                  | 70               | k=0.0079 n=0.9436         | 0.151                 | 1.162            | 0.996 |
|                  | 80               | k=0.0096 n=0.9141         | 0.097                 | 0.930            | 0.997 |
| Modified Page    | 60               | k=0.0056 n=0.9116         | 0.173                 | 1.247            | 0.995 |
|                  | 70               | k=0.0058 n=0.9436         | 0.151                 | 1.162            | 0.996 |
|                  | 80               | k=0.0062 n=0.9141         | 0.097                 | 0.930            | 0.997 |
| Logarithmic      | 60               | k=0.0061 a=1.0330 c=0.0495 | 11.324                | 1.132            | 0.992 |
|                  | 70               | k=0.0070 a=1.0402 c=0.0468 | 1.272                 | 3.374            | 0.990 |
|                  | 80               | k=0.0071 a=1.0118 c=0.0463 | 1.003                 | 3.001            | 0.993 |

Conformance of experimental data for triangular mantı samples with theoretical models by nonlinear regression analysis.

| Model            | Temperature (°C) | Constant and Coefficients | $\chi^2$ ($x10^{-3}$) | RMSE ($x10^{-2}$) | $R^2$ |
|------------------|------------------|---------------------------|-----------------------|------------------|-------|
| Henderson        | 60               | k=0.0054 a=1.0624         | 21.593                | 13.975           | 0.991 |
| and Pabis        | 70               | k=0.0060 a=1.0142         | 0.272                 | 1.558            | 0.995 |
|                  | 80               | k=0.0057 a=1.0663         | 22.266                | 14.231           | 0.985 |
| Newton           | 60               | k=0.0056                  | 0.020                 | 1.835            | 4.073 |
|                  | 70               | k=0.0060                  | 0.111                 | 0.003            | 0.053 |
|                  | 80               | k=0.0059                  | 0.155                 | 2.089            | 4.359 |
| Page             | 60               | k=0.0126 n=0.8600         | 0.027                 | 0.496            | 0.999 |
|                  | 70               | k=0.0098 n=0.9100         | 0.117                 | 1.027            | 0.997 |
|                  | 80               | k=0.0171 n=0.8138         | 0.092                 | 0.916            | 0.989 |
| Modified Page    | 60               | k=0.0061 n=0.8600         | 0.027                 | 0.496            | 0.999 |
|                  | 70               | k=0.0062 n=0.9100         | 0.117                 | 1.027            | 0.997 |
|                  | 80               | k=0.0067 n=0.8138         | 0.092                 | 0.916            | 0.989 |
| Logarithmic      | 60               | k=0.0073 a=1.0148 c=0.0638 | 5.604                 | 0.991            | 0.992 |
|                  | 70               | k=0.0071 a=1.0147 c=0.0457 | 3.221                 | 0.995            | 0.990 |
|                  | 80               | k=0.0068 a=1.0790 c=0.0496 | 16.687                | 0.985            | 0.993 |
Pranyak [13] determined the drying characteristics of Asian noodles at three different superheated steam velocities and temperatures. Similar to the present study, Newton and Page models were the best models explaining the drying kinetics of noodles. The Modified Henderson equation was used to explain the drying data of pasta by Litchfield and Okos [26] and Japanese noodle by Inazu [14]. Investigating the drying properties of rice noodles in a hot air oven, Kongkiattisak and Songsermpong [24] reported that higher temperatures and air velocities decreased the moisture content of samples more efficiently while Two-Term and Logarithmic models were best semi-theoretical models explaining the drying characteristics of rice noodles.

Kaushal and Sharma [27] investigated the drying characteristics of noodles prepared with different flours and dried in a convective dryer for four different temperature levels. Rehydration reduced with an increase in drying temperature, and Verma model was the most suitable model for the compliance of experimental MR data. Studying the drying characteristics of sorghum crackers dried in a tray dryer, Susanti et al. [28] reported that Newton and Lewis models properly fit to estimate the moisture content of the samples at different air velocities.

Zhou et al. [29] conducted the drying process of instant noodles with convective air dryer at five different temperature and three different air velocities, and drying process occurred in a falling rate period, which was the best described with the logarithmic model. In a study of the thin layer baking-drying kinetics for crisp breads, Page, Wang & Singh and logarithmic models were observed to the best explain the baking-drying process [25].

Lertwatarasiriul [23] determined the drying kinetics of cassava crackers in a hot air drier for different temperature levels. Among the empirical models, Modified Page model was determined as the most suitable to explain drying process. Chen et al. [30] modelled the rehydration process of dumpling wrapper for three different temperatures in a freeze-drier. Rehydration characteristics of dumpling wrapper were directly influenced by drying temperature, and Peleg and Weibull models were well-fitted with rehydration process of dumpling wrapper. Results indicated that the water activity values of the triangular mantı samples reduced below to the desired value of 0.6 faster than those of the traditional Kayseri mantı samples due to the higher drying rates obtained in the former ones. Also, drying time and rate declined substantially with an increase in drying temperature. The Page, Modified Page and Newton models were the most suitable models at different temperature levels. Results indicated that triangle mantı samples should be dried at temperatures higher than 70 °C while temperatures higher than 80 °C are highly recommended for drying traditional Kayseri mantı samples.

4 Conclusions

In the current study, the drying kinetics of different types of mantı (Turkish ravioli) samples, which is one of the most consumed traditional foods of Turkish cuisine, were determined. Water activity values of the triangular mantı samples reduced below to the desired value of 0.6 faster than those of the traditional Kayseri mantı samples because of the higher drying rates obtained in the former ones. Moreover, the water activity of traditional Kayseri mantı samples fell below the desired value only after 8 h of drying at 80°C. Drying time and rate declined substantially with an increase in drying temperature. Only a falling rate period was observed for two types of mantı samples. The Page, Modified Page and Newton models were the most suitable models at different temperature levels. Results indicated that triangle mantı samples should be dried at temperatures higher than 70 °C while temperatures higher than 80 °C are highly recommended for drying traditional Kayseri mantı samples.
higher than 80°C are highly recommended for drying traditional Kayseri mantı samples.

5 Nomenclature

\( a_w \) : Water activity,
\( \text{DM} \) : Dry matter content of mantı (g),
\( m \) : Sample weight (g),
\( M_0 \) : Initial moisture content (g water g\(^{-1}\) dry matter),
\( \text{MC} \) : Moisture content,
\( M_e \) : Equilibrium moisture content (g water g\(^{-1}\) dry matter),
\( MR \) : Moisture ratio,
\( MR_{exp} \) : Experimental moisture content,
\( MR_{pred} \) : Estimated moisture content,
\( M_t \) : Moisture content at any t time (g water g\(^{-1}\) dry matter),
\( M_{t+dt} \) : Moisture content at t+dt time (g water g\(^{-1}\) dry matter),
\( n \) : Number of coefficients in the tested model,
\( N \) : Number of the experimental data,
\( R^2 \) : Coefficient of determination,
\( \text{RMSE} \) : Root mean square error,
\( \chi^2 \) : Chi-square.

6 References

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