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Drying characteristics of Turkish ravioli, mantı

Mantıların Kurutma Karakteristiği

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Abstract

Mantı is a type of ravioli with a unique taste, which has been appreciated by many people in Turkey for years. In this study, two common types of mantı samples (traditional Kayseri mantı produced by wrapping dough sheets into small bags and triangular mantı) were dried to make them microbiologically safe by lowering their water activities to a desired level of less than 0.6. Drying process was carried out in a conventional dryer at 60, 70 and 80°C and the drying kinetics of mantı samples was determined by the Page, Henderson and Pabis, Modified Page, Logarithmic and Newton models. The best-fit model for the drying characteristics of triangular mantı was the Newton model at 60 and 70°C while the Page and Modified Page models were the best at 80°C. Moreover, Page/Modified Page, Newton and Page/Modified Page models were the best-fit models for traditional Kayseri mantı at 60°C, 70°C and 80°C, respectively. Faster drying rates were obtained for triangular mantı, and the desired water activity value for this mantı was reached at drying temperatures of 70°C and 80°C, and only at 80°C for the traditional Kayseri mantı. Drying rates increased with increasing temperature levels.

Anahtar kelimeler: Turkish ravioli, drying kinetics, water activity, modelling, drying rate

Öz

Mantı, Türkiye'de yıllardır birçok insan tarafından tüketilen, özgün tada sahip bir hamur işidir. Bu çalışmada, iki yaygın tipte mantı örneği (hamur tabakalarının küçük torbalar halinde sarılmasıyla üretilen geleneksel Kayseri mantısı ve üçgen mantı) mikrobiyolojik olarak güvenli olmalarını sağlamak amacıyla su aktivitesi değerlerinin 0,6'nın altına düşürülmesi suretiyle kurutulmuştur. Kurutma işlemi konvektif bir kurutucuda 60, 70 ve 80°C'de gerçekleştirilmiş ve örneklerin kurutma kinetiği parametreleri Page, Henderson ve Pabis, Modifiye Page, Logaritmik ve Newton modelleri kullanılarak belirlenmiştir. Üçgen mantının kuruma özelliklerine en uygun modeller 60 ve 70°C için Newton modeli iken, 80°C için en uygun modeller Page ve Modifiye Page modelleridir. Ayrıca, 60°C, 70°C ve 80°C'de geleneksel Kayseri mantı için en uygun modeller sırasıyla Page/Modifiye Page, Newton ve Page/Modifiye Page olarak saptanmıştır. Üçgen mantı için daha yüksek kuruma hızları saptanırken, istenen su aktivite değeri üçgen mantı için 70°C ve 80°C, geleneksel Kayseri mantısı için ise yalnızca 80°C kurutma sıcaklığında elde edilmiştir. Kuruma hızları sıcaklık ile artış göstermiştir.

Anahtar kelimeler: Mantı, kurutma kinetiği, su aktivitesi, modelleme, kuruma hızı

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.auerus* 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 the fresh product more stable by lowering the water content of the product 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 preferred [7], [8]

Several studies on drying processes of mantı like bakery products are available in the literature as pasta [9], [10], [11], [12], noodles [13], [14], [15]. Also, Dağlıoğlu [2] investigated the quality attributes of mantı samples subjected to microwave drying.

During the food drying processes, determining the drying characteristics is highly important 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 mantı 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 mantı and triangular mantı samples were obtained from a national market in Turkey. The average thickness values of triangular and traditional Kayseri mantı samples were 10±0.3 and 12±0.2 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 mantı samples.

Drying operations were performed by natural convection in a preheated oven (FN 500, Nüve, Ankara, Turkey) at 60, 70 and 80°C with 3 replications 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 mantı 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 mantı and 0,029 g water. g^{-1} dry matter for triangular mantı samples. At the end of drying, mantı 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 mantı samples were determined by drying at 105±1°C for 8 h. Moisture contents of mantı samples were calculated based on the Equation 1.

$$\mathrm{M_t} = \frac{\mathrm{m} - \mathrm{DM}}{\mathrm{DM}} \quad (1)$$

where Mt 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 mantı (g).

Moisture ratio values were calculated according to Equation 2:

$$MR = \frac{M_t - M_e}{M_0 - M_e} \quad (2)$$

which 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_0 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.

$$\text{Drying Rate} = \frac{M_{t+dt} - M_t}{dt} \quad (3)$$

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

Drying rates and MR values of mantı 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=aexp(-kt)	[18]
Newton	MR=exp(-kt)	[19]
Page	MR=exp(-kt^n)	[20]
Modified Page	MR=exp(-kt)^n	[21]
Logarithmic	MR=aexp(-kt)+c	[22]

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

$$RMSE = \left[\frac{1}{\mathrm{N}}\sum_{\mathrm{i=1}}^{\mathrm{N}}(\mathrm{MR_{prd,i}} - \mathrm{MR_{exp,i}})^2\right]^{0.5} \quad (4)$$

$$\chi^2 = \frac{\sum_{\mathrm{i=1}}^{\mathrm{n}}(\mathrm{MR_{exp,i}} - \mathrm{MR_{prd,i}})^2}{\mathrm{N} - \mathrm{n}} \quad (5)$$

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 (χ^2) value represents an increase in conformance. The lower values of χ^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 mantı samples, respectively.

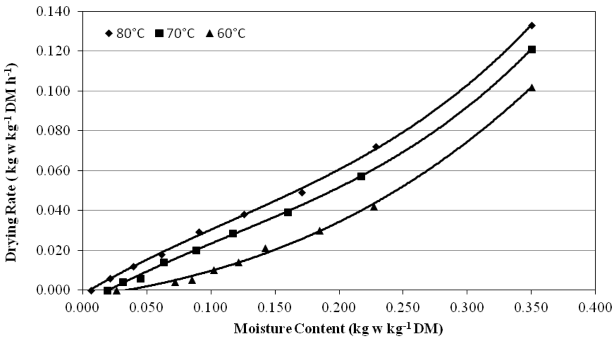

Figure 1: Drying rates and moisture contents of triangular mantı samples at three different temperatures.

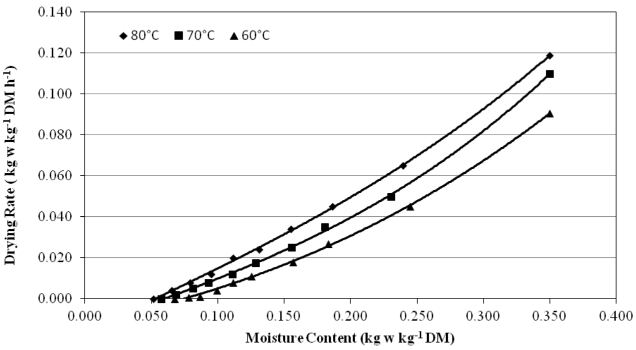

Figure 2: Drying rates and moisture contents of traditional Kayseri mantı samples at three different temperatures.

Drying behavior of both mantı types (Figures 1 and 2) indicated that their drying rate increased with increasing drying temperature, as expected. Due to the rapid movement of moisture, a falling rate period occurred while no constant rate period was detected during drying. Results were similar to other food products reported in the literature such as cassava crackers [23], rice noodles [24] and crisp bread [25]. The highest drying rates were calculated at 80°C.

In terms of water activity (a_w) values, triangular mantı samples were unable to reach the desired a_w value of ≤0.6 at 60°C at the end of 8 h (aw=0.724). At 70°C the water activity of these samples was 0.598 after 7 h of drying while it was 0.690 and 0.346 in samples dried at 80°C for 5 h and 6 h, respectively. Besides, the water activity value of traditional Kayseri mantı samples was 0.605 after 8 h at 80°C. Drying temperatures of 60 and 70°C were barely enough to achieve a desirable water activity value within 8 h of drying process (0.753 and 0.781, respectively).

Results of five different thin layer models are given in Tables 2 and 3 for triangular and traditional Kayseri mantı samples, respectively. The coefficient of determination values of kinetic models were between 0.985 and 0.999. Also, RMSE and χ^2 values for both mantı samples ranged from 0.053 $x10^{-2}$ to $16.687x10^{-2}$ and from $0.003x10^{-3}$ to $30.616x10^{-3}$, respectively.

Table 2: 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 and Pabis	60	k=0.0056	a=1.0359		0.533	2.189	0.993
	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

Table 3: Conformance of experimental results for traditional Kayseri mantı samples with theoretical models by nonlinear regression analysis.

Model	Temperature (°C)	Constant and Coefficients			χ^2(x10^{-3})	RMSE(x10^{-2})	R^2
Henderson and Pabis	60	k=0.0054	a=1.0624		21.593	13.975	0.991
	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

For triangular mantıs dried at 60°C, the Newton model had the smallest RMSE and χ^2 values, which indicated that it explained the drying curves the best. At 70°C, the Newton, Page and Modified Page models explained the drying characteristics of this type of mantı samples similarly, but the Newton model had lower RMSE and χ^2 values than the others. Also, Page and Modified Page models were the most convenient for drying at 80°C with the highest R^2 and lowest RMSE and χ^2 values (Table 2).

According to the Table 3, Modified Page and Page models were the best-fit models for the drying characteristics of the traditional Kayseri mantıs, having the highest R^2 value and the lowest RMSE and χ^2 values at 60°C. For drying at 70°C, the lowest RMSE and χ^2 values were obtained by the Newton model, which explained the drying curves better than other models (Table 3). At the drying temperature of 80°C, Page, Modified Page and Logarithmic models had similar R^2 values but the Logarithmic model had higher RMSE and χ^2 values than former two models.

Figures 3 and 4 show the conformity of the best-fit models for time dependent changes in experimental MR values at different temperatures for triangular and traditional Kayseri mantı samples, respectively.

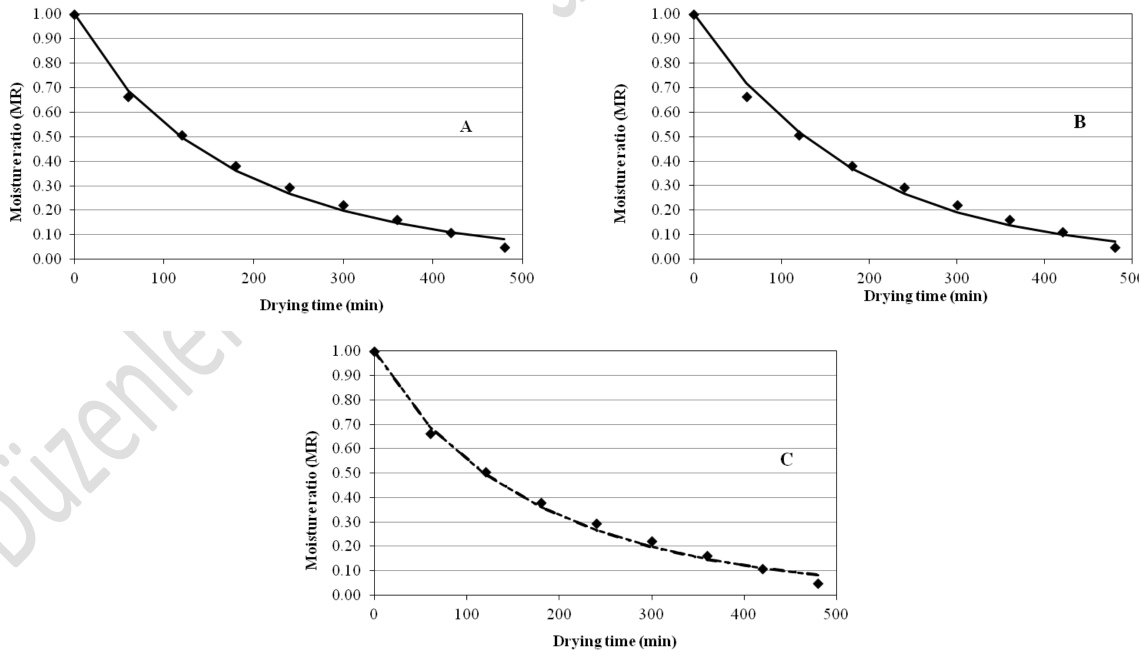

Figure 3: Time-dependent changes in the experimental and theoretical moisture ratio values for triangular mantı samples for the best-fit models a) Newton model at 60°C, b) Newton model at 70°C, c) Page and Modified Page models at 80°C (♦ Experimental MR, ·—· Modified Page, — Newton, and --- Page models).

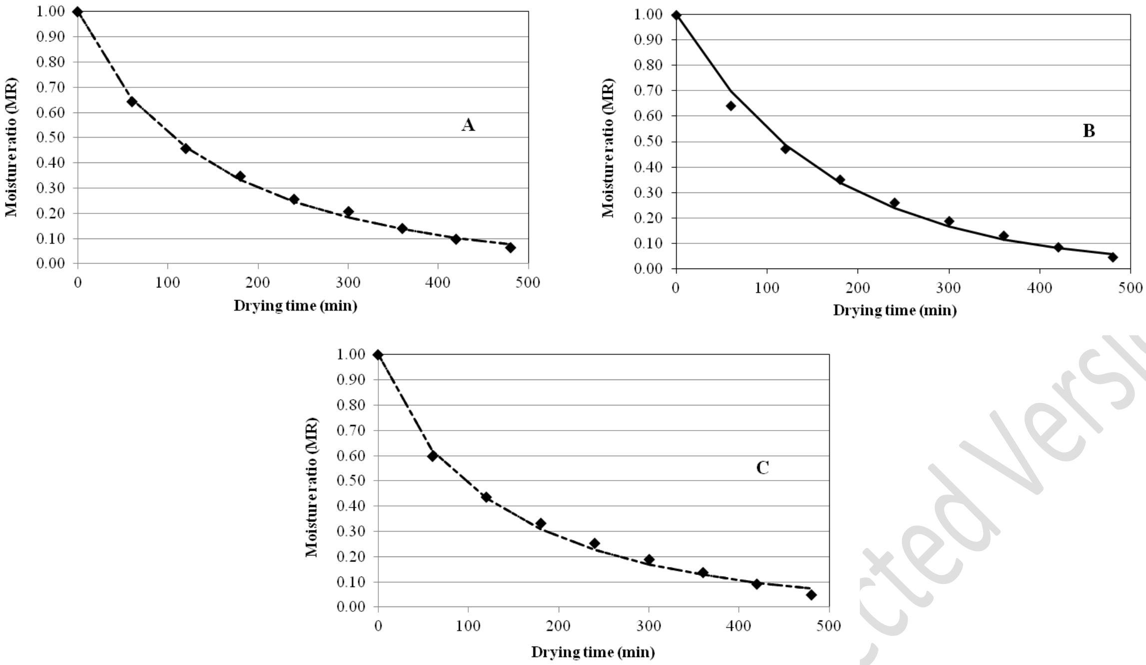

Figure 4: Time-dependent changes in experimental and theoretical moisture ratio values for traditional Kayseri mantı samples for the best-fit models a) Page and Modified Page models at 60°C, b) Newton model at 70°C, c) Page and Modified Page models at 80°C (♦ Experimental MR, ·—· Modified Page, —Newton, and --- Page models).

Pronyk [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].

Lertworasirikul [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.

Nomenclature

a_w: Water activity

DM: Dry matter content of mantı (g)

m: Sample weight (g)

M_0: Initial moisture content (g water g^{-1} dry matter)

MC: Moisture content

M_e: Equilibrium moisture content (g water g^{-1} dry matter)

MR: Moisture ratio

MR_{exp}: Experimental moisture content

MR_{prd}: 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

RMSE: Root mean square error

χ^2: Chi-square

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