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Experimental Characterization and Mathematical Modelling of Natural Drying of Apricots at Low Temperatures

Can Hu [1], Jie Li [1], Qiaonan Yang [2], Xiaokang Yi [1,*], Hui Cheng [1], Chao Xu [1] and Zhenhao Du [1]

[1] College of Mechanical and Electrical Engineering, Tarim University, Alar 843300, China
[2] College of Mechanical and Electrical Engineering, Fujian Agricuture and Forestry University, Fuzhou 350002, China
* Correspondence: yxk@taru.edu.cn

Abstract: To mitigate reduced apricot fruit quality due to mildew, browning and sand dust from natural drying under low temperatures and humidity, we determined the characteristics of three different methods of drying (via hanging) and further established their mathematical models. Various comparative analyses of natural drying by laying apricots in an area of the Gobi Desert, subjecting them to ventilated drying in an air-drying house, and hanging them on trees were conducted. The least and most efficient methods were hanging on trees (302 h) and laying them in an area of the Gobi Desert (>192 h), respectively. The loss rate and the total sugar content were 5.26% and 70.16%, and up to 18.31% and 68.54% for fruits dried by ventilated drying in an air-drying house and those hung on trees, respectively. Fruits dried by ventilated drying in an air-drying house showed the least loss and the best comprehensive quality. Using experimental data from assessments of the drying methods, mathematical models were constructed and fitted to drying mathematical models of seven kinds of porous media. The Wang and Singh model had the best fitting degree, an error value of less than 0.05, and the regression that most accurately explained the drying mathematical model for apricots under natural conditions.

Keywords: apricot; loss rate; moisture ratio; mathematical model

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1. Introduction

Apricots are nutritious, high-quality fruits that are popular in Xinjiang, China [1,2]. Among the various varieties are the small white Saimati, Juana, black leaf, and hanging dried apricots [3–5]. As per the Xinjiang Uygur Autonomous Region Statistics Bureau [6,7], the area under apricot cultivation in Xinjiang in 2020 was about 135,300 hectares, with a yield of 1.9 million tons. Due to the remoteness and limited transport infrastructure in Xinjiang, drying is a common way of primary apricot processing [8,9]. Dried apricots are delicious, light yellow in color, can be stored for long durations, and have great economic value, which in turn generates income for farmers in poverty-stricken areas of Xinjiang [10]. As per the current ripening periods of apricot fruits, Xinjiang farmers harvest apricot fruits thrice, then dry them by spreading them on the Gobi Desert or by ventilating them in an air-drying house, or by hanging them on trees [11,12]. These natural drying processes are easily affected by microorganisms, insects, and birds, and are thus very uncontrollable. Therefore, optimizing this drying process to improve the quality of naturally dried apricot fruit is necessary.

Indeed, an urgent solution is needed to mitigate the effects of mildew, browning, and sand dust on fruit quality during the drying process. Various kinds of apricot fruits [13,14] are dried differently. Xinjiang apricot fruits are dried and their quality is controlled through a variety of local and international drying techniques [15,16], such as hot air dryingand solar energy. In 2010, Wang Ning et al. [17] conducted a low-temperature drying experiment on the main kind of apricot produced in the Aktao region of Xinjiang. They used low-temperature sun drying, traditional drying combined with low-temperature drying, and low-temperature air-room drying. They showed that traditional drying at low temperatures was of benefit to the fruit's color, whereas low-temperature drying in a cool airy room had the advantage of being a controllable environment. In 2011, Wang et al. [18] postulated that the drying model for apricots at low temperatures was related to the Wang–Singh formula, and its coefficients were related to temperature and wind speed. In 2013, Yang Ruiyun et al. [19] investigated the causes of browning by assessing the browning characteristics of small white apricots during the drying process. In 2016, Llave et al. [20] analyzed the changing rules of water loss and volume contraction in the baking process of eggplant by establishing a heat and mass transfer model and a structural mechanics model for it. In 2018, Efimia K. et al. [21] studied the effect of the osmotic dehydration of apricots in OD solution on the heat and mass transfer phenomenon and fruit quality change. In 2019, Magdalena et al. [22] studied the impact of convective drying, freeze drying and microwave vacuum drying on the content and color of bioactive components of cranberries and concluded that microwave vacuum drying under low microwave power produced cranberries of the best sample quality. In 2021, Guo Huijing et al. [23] investigated the fresh-keeping treatment method of hanging dried apricots. Taken together, these studies supported the hypothesis that apricots have a unique natural drying law and mathematical model. Moreover, low-temperature and low-humidity drying in controlled natural environments is key to realizing both the controlled drying of apricots and controllable drying technologies.

To find solutions to the problem of diminished fruit quality due to mildew, browning, sand and other factors in the natural drying of apricots, apricots were sampled from Yongning Town, Alar City, Xinjiang Uygur Autonomous Region, and both their key materials and natural drying environment were characterized. Moreover, the variation law of the drying rate and drying moisture in the drying process was investigated, and mathematical models of moisture variation of apricot fruit were established; the fitted mathematical models of low-temperature and low-humidity drying were verified. This study provides new experimental data that support the natural drying of apricot fruits. Ultimately, it is a beneficial technical reference for the global apricot-drying industry.

2. Materials and Methods

2.1. Experimental Materials

The apricots used in this study were sampled from No. 58 Farm in Yongning Town, Alar City, Xinjiang Uygur Autonomous Region (latitude: 40°25′ N; longitude: 79°38′ E; altitude: 2644 m) in June, July and August of 2022. The harvested apricots were first sorted, and 400 of uniform size, evenly good appearance, and without damage were selected as samples and labeled. These selected samples were refrigerated to maintain fruit quality.

The experiments were conducted at the Key Laboratory of Modern Agricultural Engineering, Tarim University, Alar City, Xinjiang Uygur Autonomous Region from 18 July 2022 to 4 September 2022. During the experiments, three batches of apricots were picked and dried in three different ways for subsequent experiments.

2.2. Experimental Procedures

The three drying methods used were natural laying in an area of the Gobi Desert, ventilated drying in an air-drying house, and natural hanging of fruit on trees, as shown in Figure 1. The natural laying in an are of the Gobi Desert and ventilated drying methods were conducted between 19 July and 28 July, and the natural hanging of fruit on trees method was conducted between 5 August and 4 September 2022.

(**a**)

(**b**)

(**c**)

Figure 1. Three drying methods for apricot. (**a**) Hanging dry Gobi Desert Natural laying drying method, (**b**) Ventilation and drying method of drying room, (**c**) Natural fruit hanging method on trees.

2.2.1. Natural Laying in an Area of the Gobi Desert

In this method, gauze cloth was first spread on Gobi cobblestones, in the direction of the natural convectional wind. A total of 400 apricot samples were selected and randomly placed on mesh gauze. Sample moisture, ambient temperature, and humidity were measured and recorded hourly. The initial moisture was calculated by the absolute dry matter weighing method.

2.2.2. Ventilated Drying in an Air-Drying House

Instead of adding a heat source, traditional air-drying houses mainly rely on ventilation in the natural environment to adjust the internal temperature and humidity during ventilation and drying. This dries the apricots at low temperatures and humidity in a natural environment. Four hundred apricot samples were selected and randomly placed in the air-drying room for ventilation and drying. Concomitant measurements were taken as described in Section 2.2.1.

2.2.3. Natural Hanging on Trees

In this method, two apricot trees were selected, and 400 apricot samples were hung on them to dry. Concomitant measurements were taken as described in Section 2.2.1.

2.2.4. Measurement of Temperature and Humidity

During all three drying methods, the surface radiation temperature of apricots was measured by a thermal imager (model: UTi260B; temperature measurement range: −15 °C~550 °C; infrared resolution: 256 × 192; produced by Guangdong UNI-T Technology Co., Ltd., Guangdong, China). In dry environments, the temperature and humidity were measured by an RS485 temperature and humidity sensor (model: JXBS-3001-TH-HC; produced by Shandong Weihai Jingxun Changtong Electronic Technology Co., Ltd., Weihai, China), which automatically collected and recorded the environmental temperature and humidity changes on the apricot's surface. An electronic precision weighing balance (model: pioneer CP series; range: 0–3200 g; precision: 0.001 g; produced by Jiangsu Ohaus Instrument Co., Ltd., Zhangjiagang, China) was used to weigh the apricot samples every 2 h until samples were dried within the range of safe moisture. During the experiments, the thermal imager and RS485 temperature and humidity sensor were recalibrated before taking measurements. Likewise, the electronic precision weighing balance was leveled and zeroed before each apricot was weighed.

2.3. Drying Evaluation Indexes of Apricots

2.3.1. Total Sugar Content

The total sugar content of dried apricots refers to the sugar content of dried fruits [24,25]. In this study, the measurement standards of the total sugar content of ICUMSA [26] and General Rules of Candied Fruits (GB/T 10782-2006) were used [27]. The sugar content of the harvested apricots was measured by a handheld sugar refraction meter (model: PAL − 1/PAL – 13810 − E18; produced by Atago Co., Ltd., Tokyo, Japan).

The average sugar content m_0 of dried apricots was calculated as shown in Equation (1):

$$m_0 = \frac{\sum m_n}{n} \times 100\% \quad (1)$$

where m_n denotes the sugar content of dried apricots measured each time, with the unit of g/100 g; n is the number of measurements.

2.3.2. Drying Loss Rate

The loss rate S of unqualified apricots was calculated through observation and statistical methods, as shown in Equation (2):

$$S = \frac{X_1}{X_2} \times 100\% \quad (2)$$

where X_1 is the quantity of qualitative changes of dried apricot, n; X_2 is the total number of dried apricots randomly inspected, n.

2.3.3. Dry Base Moisture Content

As per the drying materials method [28], the variation in water content during the natural drying of apricots is represented by dry base water content. The dry base moisture content M_t of apricots was calculated as shown in Equation (3):

$$M_t = \frac{g_t - g_0(1 - M_0)}{g_0(1 - M_0)} \quad (3)$$

where g_t is the total mass of apricots during any drying period, with the unit of g; g_0 is the initial total mass of apricots before drying, with the unit of g; M_0 is the initial wet base moisture content of apricots at the beginning of drying, with the unit of %.

2.3.4. Wet Base Moisture Content

The initial wet base moisture content of an apricot was measured by the absolute dry matter method. The total mass of the apricot was first weighed, and then the apricots were dried to desiccation at high temperatures. The wet base moisture content of apricots was calculated as shown in Equation (4):

$$M_0 = \frac{g_t - g_j}{g_0} \times 100\% \tag{4}$$

where g_j is the absolute dry matter mass, with the unit of g.

2.3.5. Selection of Drying Model of Apricots with Wet Porous Medium

(1) Selection of a drying model

An apricot is a flat material with a wet porous medium and has similar drying characteristics to those of thin-layer drying. In this study, seven classical local and international drying models of wet porous media [29] were selected. Experimental data of apricots were analyzed via multiple regression analyses and model fitting to obtain a natural drying mathematical model of apricots. Seven representative drying models were selected, shown in Table 1.

Table 1. Seven drying models for wet porous media.

Model No	Model Name	Mathematical Expression [30]
1	Newton	$MR = \exp(-kt)$
2	page	$MR = \exp(-kt^n)$
3	Henderson and Pabis	$MR = a \exp(-kt)$
4	Approximation of diffusion	$MR = a \exp(-kt) + (1 - a) \exp(-kat)$
5	Two-term model	$MR = a \exp(-k_0 t) + b \exp(-k_1 t)$
6	Wang and Singh	$MR = 1 + at + bt^2$
7	Logarithmic	$MR = a \exp(-kt) + c$

(2) Evaluation of drying models

Comparisons of the drying models in Table 1 were made. The approximation degree of the model was evaluated by fitting the R^2 coefficient. The closer the R^2 value was to 1, the better the fitting effect. The degree of error in the model was evaluated through mean deviation (SSE) and root mean square error coefficient (RMSE). The closer the SSE and RMSE values were to zero, the better the fitting effect. The SSE and RMSE were calculated using Equations (5) and (6):

$$f_{\mathrm{SSE}} = \sum_{i=1}^{n} (y_{\mathrm{R}jri} - y_{\mathrm{Rexp}i})^2 \tag{5}$$

$$f_{RMSE}D = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (y_{jri} - y_{\exp i})^2} \tag{6}$$

2.4. Data Processing and Analysis

Microsoft Excel 2018 software was used to statistically analyze the experimental data, and Origin 2020 software was used to plot the analyses. The sugar content error of apricot adopted as standard error S.

$$S = \pm\sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n-1}} \tag{7}$$

where x_i is the sugar content of the apricot, $\overline{x}$ is the average number of apricots, and n is the number of apricots taken.

3. Results and Analysis

3.1. Quality Changes under Different Drying Methods

The changes in apricot quality due to different drying methods are shown in Table 2. As seen from the indexes, the three drying methods differed greatly in effect. For the natural laying of apricots in an area of the Gobi Desert, the drying loss rate was 6.19%, the total sugar content was 71.38%, and the total drying duration was 192 h. For ventilated drying in an air-drying house, the drying loss rate was 5.26% (the lowest value among the three), the total sugar content was 70.16%, and the drying duration was 212 h. As for the natural hanging on trees method, the drying loss rate reached 18.31% (the highest among the three), the total sugar content was 68.54%, and the drying duration was 302 h.

Table 2. Quality change results under different drying methods.

Mode Indicators	Drying Loss Rate (%)	Total Sugar Content (%)	Drying Time (h)	Remarks
Natural laying	6.19	71.38	192	Average value of 5 groups
Air drying room ventilation	5.26	70.16	212	Average value of 5 groups
Hanging from trees	18.31	68.54	302	Average value of 5 groups

In terms of quality, the apricots dried by natural hanging had low total sugar content, a sweet and sour taste with a unique flavor. However, this method had a high drying loss rate and is thus unsuitable for large-scale production. The drying method of natural laying of the apricots in an area of the Gobi Desert had a short drying duration, which thus improved the drying efficiency. However, the quality of apricots was inconsistent due to the many uncontrollable factors of the drying field. Moreover, the apricots had a very high total sugar content and relatively sweet taste. Apricots dried through ventilated drying in an air-drying house had a relatively low loss rate and moderate total sugar content, and were processed with relatively suitable drying durations. Taken together, in terms of optimizing the drying performance, the ventilated drying in an air-drying house could be optimized and applied and then applied in the large-scale production of apricots.

3.2. Influence of Different Harvest Batches on Apricots

As shown in Figure 2a, during the method of natural laying in an area of the Gobi Desert, the dry base moisture content roughly exhibited linear drying—including a constant rate drying stage—and the dry base moisture content decreased continuously with time. This method took 192 h. The drying speed was clearly reduced after 176 h and drying ceased when there was no more moisture. Thus, the dry base moisture content decreased from 177.78% to 11.77%. The drying rate change was slightly affected by different harvest batches. The first batch of apricots exhibited drying characteristics similar to those of the latter two batches. From the point that the first batch was harvested (18 July 2022) to the time the last batch was dried (5 August), there were no big changes in the temperature and humidity of the region, which was suitable for laying drying.

As shown in Figure 2b, the dry base moisture content of each batch processed by ventilated drying in an air-drying house decreased with time, and exhibited a certain linear relationship. Ventilation and drying in an air-drying house required 212 h. The drying speed decreased after 194 h and drying ceased when there was no more moisture. Thus, the dry base moisture content decreased from 177.78% to 11.41%. The changes in the drying rate of apricot fruits were only slightly affected by different batches, indicating that the natural temperature and humidity of each batch barely changed during the drying period, and they were thus more suited for laying drying.

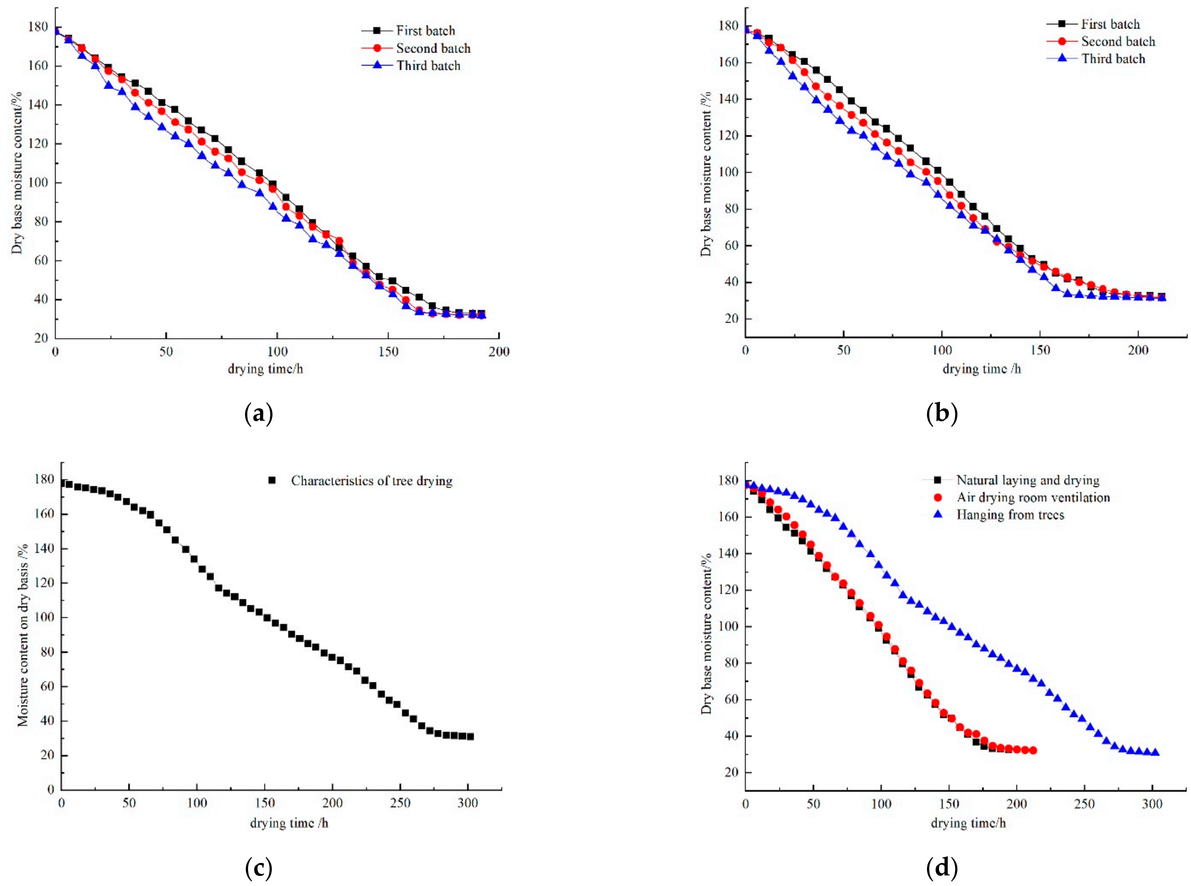

Figure 2. Change rule of moisture content of apricot under different drying methods.(**a**) Variation law of dry moisture content in natural placement, (**b**) Variation law of moisture content of air drying house, (**c**) Water content change rule of tree hanging dry way, (**d**) Comparison of moisture content change of three drying methods.

As shown in Figure 2c, the changes in the dry base moisture content of each batch dried by the natural hanging method differed from the other two methods, as it had a clear constant speed drying stage. The drying process took up to 306 h, and the dry base moisture content decreased from 159.59% to 117.29% after 66 h to 166 h. Due to low air humidity and an ambient humidity of 38.18%, the rate of water loss increased, accelerating the drying rate.

As shown in Figure 2d, the dry base moisture content of the apricots dried by natural laying and ventilated drying in an air-drying house both changed in a like manner with time, but it took longer for the latter method (212 h) compared to the former (192 h) to attain dry safe moisture. The natural hanging on trees method took the longest time to dry and had the lowest drying rate, attaining dry safe moisture after 306 h. Moreover, this method commenced when the apricots were fully mature. As apricots dried by this method tended to absorb too much almond nutrition, the related environmental factors were uncontrollable, resulting in a long drying duration.

3.3. Construction and Fitting of Drying Model

The relationship of change, over time, between the moisture content of apricots and different drying temperatures corresponding to the three drying methods (Figure 2) was converted into a ratio of the change in moisture content of apricot material to the initial moisture MR. The MR values corresponding to these three drying temperatures are shown in Figure 3. The relationship of change is consistent with the rate of change. Using the MR change data, coupled with the seven classical local and international drying models of wet porous media shown in Table 1, the MR values of apricots at the average temperatures of 28.5 °C, 32.4 °C and 27.6 °C were simulated and fitted with the MATLAB 2014 software fitting toolbox. This fitting toolbox estimates the optimal model by calculating and analyzing the fitted model and R^2, SSE, RMSE and other evaluation index values from the model.

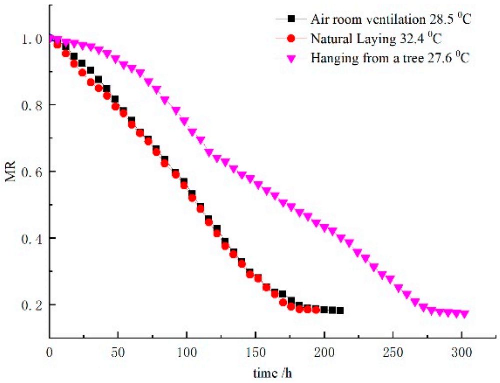

Figure 3. Change in water ratio of apricots under different drying conditions.

The fitting results of the seven classical models are shown in Table 3. The mathematical models of apricots at average temperatures of 28.5 °C, 32.4 °C and 27.6 °C were fitted. The optimal fitting models were the Page, Henderson and Pabis, Wang and Singh, and logarithmic models, all of which had good fitting effects as per the criteria $R^2 > 0.95$, SSE < 0.2 and RMSE < 0.08. The newton model had a poor fitting effect when applied to the air-drying house method, i.e., SSE = 9.661 and RMSE = 0.4975. The approximation of the diffusion model had a relatively good fitting effect, despite its large errors when applied to the air-drying method, i.e., SSE = 5.608 and RMSE = 0.4061. The two-term mode had a poor fitting effect applied to the natural laying method, i.e., $R^2 = 0.6598$, SSE = 1.335 and RMSE = 0.1668. As per the data, this method was unsuitable for the two-term mode model. Among the four models with a good fitting effect, the Henderson and Pabis model had the poorest fitting effect as its SSE value was slightly higher than the rest and it had some errors. The Page, Wang and Singh, and logarithmic models were applicable in a model for the natural drying of apricots. Specifically, the Wang and Singh model had a simple and practical model expression, easily solved the undetermined system, and could be conveniently applied in the drying model. Therefore, the Wang and Singh model was selected as the mathematical model for the natural drying of apricots.

Table 3. Mathematical model fitting under average drying temperature of apricot.

Model No	Average Temperature	Model Constant			R^2	*SSE*	*RMSE*
1	28.5	k = 0.0042120			0.9138	0.338200	0.08224
	32.4	k = 0.1928000			0.8875	8.661000	0.49750
	27.6	K = 0.0070760			0.93907	0.146000	0.06754
2	28.5	K = 0.0001168	*n* = 1.688000		0.9956	0.017360	0.01882
	32.4	k = 0.0004886	*n* = 1.553000		0.9766	0.009976	0.01713
	27.6	K = 0.0005390	*n* = 1.542000		0.9957	0.010400	0.01832
3	28.5	K = 0.0050740	1.147000		0.9566	0.170200	0.05893
	32.4	k = 0.0080610	a = 1.123000		0.9659	0.098740	0.05389
	27.6	K = 0.0080270	A = 1.100000		0.9608	0.094920	0.05533
4	28.5	K = 0.0220800	A = 0.196400		0.9282	0.281600	0.07681
	32.4	K = 0.7208000	A = 1.669000		0.9382	5.608000	0.40610
	27.6	K = 3.0010000	A = 0.002358		0.9397	0.146000	0.06862
5	28.5	K_0 = 0.0043280, k_1 = 0.9160000	A = 1.020000	B = −1.009270	0.6598	1.335000	0.16680
	32.4	K_0 = 0.1436000, k_1 = 0.16240000	A = −10.530000	B=11.040000	0.9874	0.036360	0.03371
	27.6	K_0 = 0.0013680, k_1 = 0.9284000	A = 3.881000	B = −1.127000	0.9937	0.001536	0.02301

Table 3. *Cont.*

Model No	Average Temperature	Model Constant			R^2	*SSE*	*RMSE*
6	28.5		a = −0.002484	b = 0.0001558	0.9958	0.015710	0.02372
	32.4		a = −0.006035	b = 0.0007514	0.9893	0.031040	0.03067
	27.6		A = −0.004687	B = 0.0002643	0.9926	0.017980	0.02408
7	28.5	K = 0.0004472	A = 7.490000	C = −6.3550000	0.9923	0.030330	0.02514
	32.4	K = 0.0029770	A = 2.026000	C = −0.9664000	0.9882	0.034090	0.03214
	27.6	K = 0.0023220	A = 8.594000	C = 0.6104000	0.9937	0.015280	0.02257

A, B, C, a, b, c in the model are the model constants, and K, k are the model constants to be solved.

3.4. Solution of Low-Temperature and Low-Humidity Drying Model for Apricots

According to the results of model fitting, the MR of the selected Wang and Singh model was calculated, as shown in Equation (8):

$$MR = 1 + at + bt^2 \tag{8}$$

where *a* and *b* are the undetermined coefficients of the drying model; *t* is the drying time.

All three natural drying methods are classified as low-temperature and low-humidity drying. Under naturally ventilated conditions, there were different low-temperature and -humidity conditions, yet the impacts of the duration and time of sunlight irradiation were similar. Hence, a relationship model was established according to different low-temperature conditions.

Three drying temperatures, namely, 28.5 °C, 32.4 °C, and 27.6 °C, were used to establish the corresponding quadratic equations. With the low drying temperatures of apricots as the independent variable and the undetermined coefficient as the dependent variable, the quadratic equations were established, as shown in Equation (9):

$$\begin{cases} a = a_1 + b_1 T + c_1 T^2 \\ b = a_2 + b_2 T + c_2 T^2 \end{cases} \tag{9}$$

where *T* denotes the three average temperatures affected by conditions during low-temperature drying of apricots (i.e., 28.5 °C, 32.4 °C and 27.6 °C), and a_1, b_1, c_1, a_2, b_2 and c_2 are the constants to be solved.

By substituting the corresponding a and b fitted values of the Wang and Singh model in Tables 1 and 3 at 28.5 °C, 32.4 °C, and 27.6 °C into Equation (9), the following expression could be obtained:

$$\begin{cases} -0.002484 = a_1 + b_1 28.5 + c_1 28.5^2 \\ -0.006035 = a_1 + b_1 32.4 + c_1 32.4^2 \\ -0.004687 = a_1 + b_1 27.6 + c_1 27.6^2 \end{cases} \tag{10}$$

Additionally:

$$\begin{cases} 0.0001558 = a_2 + b_2 28.5 + c_2 28.5^2 \\ 0.0007514 = a_2 + b_2 32.4 + c_2 32.4^2 \\ 0.0002643 = a_2 + b_2 27.6 + c_2 27.6^2 \end{cases} \tag{11}$$

By solving Equations (10) and (11), the values of a_1, b_1, c_1, a_2, b_2 and c_2 could be obtained, i.e., a_1 = 0.59642656, b_1 = −0.003141, c_1 = 0.0008935, a_2 = −0.012822, b_2 = 0.0002847, and c_2 = 0.000006722.

Then, the mathematical model of the natural drying of apricots at low temperatures and low humidity could be obtained as shown in Equation (12).

$$MR = 1 + at + bt^2 \tag{12}$$

where *a* and *b* were calculated, as shown in Equation (13):

$$\begin{cases} a = 0.596427 - 0.003141T + 0.0008935T^2 \\ b = -0.012822 + 0.0002847T + 0.000006722T^2 \end{cases} \tag{13}$$

This drying model could be applied to the mathematical model of apricots under the three drying conditions.

3.5. Validation of Low-Temperature and Low-Humidity Drying Model for Apricots

To verify the fitting accuracy of the low-temperature and low-humidity drying model for apricots, dates from previous drying experiments were selected to fit the results. The experimentally predicted value of the Wang and Singh model was then obtained. The regression verification was conducted with the original experimental data, and the results were verified via the Mann–Whitney U test, whose resultant p value [31] was assessed for statistical significance (Figure 4).

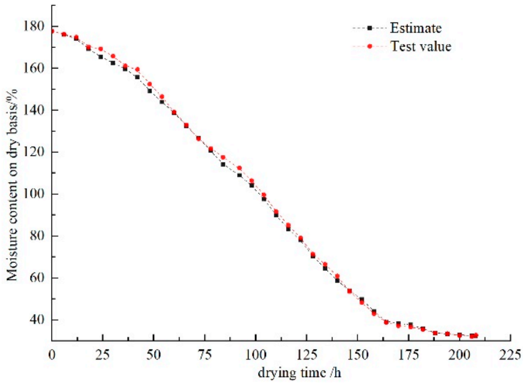

Figure 4. Verification comparison of apricots using the Wang and Singh drying model.

As seen in Figure 4, all predicted p values were >0.05, indicating that there was no significant correlation between the experimental and predicted values. The MR experimental data corroborated the optimized Wang and Singh model data and had an error value of 0.05, indicating good regression. Therefore, the Wang and Singh model best explained the model for drying apricots under natural conditions.

3.6. Discussion

(1) The natural drying of apricots is a kind of thermal radiation drying method under low temperature and low humidity.

The natural drying of apricots took relatively long durations. Among the three kinds of natural drying methods, drying by hanging on trees took the longest duration (>302 h), followed by ventilated drying in an air-drying house (212 h), then natural laying in an area of the Gobi Desert (192 h). The sugar or other substances in the process of drying by tree hanging were still transferred to the apricot fruit. These three methods were used because of the unique geographical environment of Yongning Town, Alar City, Xinjiang Uygur Autonomous Region. This environment experiences temperatures and humidity as it has, highs of 30.4 °C during the day and lows of 16.4 °C at night, and humidity levels of 32.4~44.8%.

(2) Analysis of drying kinetic and classical drying model.

The fit degree of the classical drying Page, Wang and Singh, and logarithmic models were $R^2 = 0.9957$, $R^2 = 0.9958$, and $R^2 = 0.9937$, respectively. Moreover, they met the criteria mean > 0.97, SSE mean < 0.04, and RMSE < 0.04, demonstrating both a high degree of fit and small errors. From their model fitting degree, all were applicable in a dynamic model for the natural drying of apricots, indicating that the classical drying model could explain the natural drying process of apricots. Therefore, the natural drying of apricots was a drying process controlled by the classical drying model. The essence of the natural drying process of apricots was low temperature and low humidity, which is commonly known as "air drying".

(3) Feasibility analysis of simulating the natural drying process.

The natural drying of apricots happens at low temperatures and low humidity. This unique drying method confers to apricots a good sugar content and delicious taste. However, in the natural drying environments, apricots are susceptible to mildew, puncturing, browning and dust, and microorganisms, all of which reduce their fruit quality. Therefore, it was feasible to simulate this drying process by regulating the drying temperatures, ventilation, and reducing the humidity in the late drying stage to ensure an increased quality of the dried fruit.

4. Conclusions

From the comparative analysis of the natural drying of apricots by laying them in an area of the Gobi Desert, subjecting them to ventilated drying in an air-drying house, and hanging them on trees, we concluded the following: First, natural drying by hanging apricots on trees was the least efficient method of drying, taking 302 h. The ventilated drying of apricots in an air-drying house took 212 h, and natural drying by laying apricots in an area of the Gobi Desert took ca. 192 h and had a high drying rate. Second, comparative analyses of fruit quality after using the three drying methods revealed the loss rate of apricots processed by natural drying by laying them in an area of the Gobi Desert was 6.19%, and their total sugar content was 71.38%. For apricots dried by ventilated drying in an air-drying house, the loss rate was 5.26% and their total sugar content was 70.16%. The loss rate for apricots dried by hanging on trees was the highest (reaching 18.31%), and their total sugar content was 68.54%. Thus, fruits dried in an air-drying house had the lowest loss rate and the best comprehensive quality, which could be optimized and improved. Third, the comparison analyses of drying models showed that the Wang and Singh model had the best fitting degree and an error value of less than 0.05, indicating good regression. Thus, it most accurately explains the model for drying apricots under natural conditions.

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