Correlations of quality indicators of winter jujube slices during drying process

Huan Liu[1,3,4], Xuedong Yao1,3,4*, Yongzhen Zang[1,3,4], Yubao Niu[1,3,4], Shiyu Wei[2], Yuxue Cao[1,3,4], Qiang Wang[1,3,4] and Xia Zheng[1,3,4]

[1] College of Mechanical and Electrical Engineering, Shihezi University
CN-832000 Shihezi
[2] College of Mechanical Engineering and Automation, Northeastern University
CN-110000 Shenyang
[3] Key Laboratory of Northwest Agricultural Equipment, Ministry of Agriculture
CN-832000 Shihezi
[4] Key Laboratory of Agricultural Machinery of Corp
CN-832000 Shihezi
*E-Mail: yaoxuedong@126.com

Correlations between color, vitamin C content (VC, dry base, db), reducing sugar (dry base, db) and total acid (dry base, db) during the drying process of winter jujube were studied at different temperatures (55, 60, 65 and 70 °C). Then models of quality prediction for winter jujube slices were established by Partial Least Squares Regression (PLSR), Stepwise Multiple Linear Regression (SMLR) and Principal Component Regression (PCR). Finally, the optimal model was obtained by analysis and comparison. Results showed that: the correlation coefficient (Rp) of the prediction model for the vitamin C content (db) was 0.769; the predicted Root Mean Square Error (RMSEP) was 0.59; the predicted relative deviation (RPD) value was 2.1. The Rp of the prediction model for the reducing sugar content (db) was 0.816, the RMSEP was 0.56, and the RPD value was 2.2. PLSR model was the most suitable for the prediction of the vitamin C content (db), and the PCR model was better for predicting reducing sugar content.

Keywords: winter jujube slices, quality indicators, correlation, model evaluation

Korrelationen von Qualitätsindikatoren von Jujube-Scheiben während des Trocknungsprozesses. Korrelationen zwischen Farbe, Vitamin C-Gehalt (VC, Trockenbasis, db), reduzierendem Zucker (Trockenbasis, db) und Gesamtsäure (Trockenbasis, db) während des Trocknungsprozesses von Scheiben der Chinesischen Jujube (*Ziziphus jujuba* Mill.) wurden bei verschiedenen Temperaturen untersucht (55, 60, 65 und 70 °C). Anschließend wurden Modelle zur Qualitätsprognose durch Partielle-kleinste-Quadrate-Regression (PLSR), Schrittweise-multiple-lineare-Regression (SMLR) und Hauptkomponentenregression (PCR) erstellt. Dann wurde das optimale Modell durch Analyse und Vergleich bestimmt. Die Ergebnisse zeigten Folgendes: Der Korrelationskoeffizient (Rp) des Vorhersagemodells für den Vitamin C-Gehalt (db) betrug 0,769; der vorhergesagte Root Mean Square Error (RMSEP) betrug 0,59; der vorhergesagte Wert für die relative Abweichung (RPD) betrug 2,1. Der Rp des Vorhersagemodells für den Gehalt an reduzierendem Zucker (db) betrug 0,816, der RMSEP betrug 0,56 und der RPD-Wert betrug 2,2. Das PLSR-Modell war am besten für die Vorhersage des Vitamin C-Gehalts (db) geeignet, und das PCR-Modell war besser für die Vorhersage des Gehalts an reduzierendem Zucker.

Schlagwörter: Jujube-Scheiben, Qualitätsindikatoren, Korrelation, Prognosemodell

The jujube (*Ziziphus Jujuba* Mill.) is rich in nutrients, having positive effects on stomach and heart protection and even the postponing of senility, therefore it is also called "live vitamins" (L. Zhang et al., 2016). But due to the high moisture content of fresh jujube, it is difficult to store and transport, so dehydration is the most common commercial method to prolong its shelf-life (Zhao et al., 2019). At present, jujube products mainly include dried jujube products, beverage products and fermented products, and about 80 % of jujubes are dried in China, drying is an important part of the production of jujube products (Liu et al., 2019).

With the improvement of living standards, consumer expectations require a higher quality for jujube slices. Not only good-looking appearance, but also health and hygiene are required. Quality indicators of jujube slices can be divided into two categories: sensory indicators and nutritional indicators. Color is the most direct sensory quality indicator of dry products among the sensory indexes and bright color of jujube slices is preferred by consumers; sugar and acid content determine the sugar-acid ratio, directly determining the taste of the jujube slices; additionally, jujube slices are rich in vitamin C, which is an antioxidant, which has been paid more and more attention to. But VC is highly susceptible to degradation during the drying process. Therefore, color, sugar, acidity and VC content can be used as the representative indicators for the quality evaluation of jujube slices (Forsido et al., 2019; Picard, 2020).

The quality changes of jujube slices mainly occur in the drying process (Zhou et al., 2018). Only when the dynamic changes of various quality indexes are well recognized in real time during the drying process, appropriate control mechanisms can be applied in a targeted manner, thereby improving the quality of dried jujube products. Among the commonly used quality indicators of jujube slices, color can be measured by non-destructive rapid measurements by a color difference meter, while sugar, acid and VC contents are usually detected by complex chemical experiments, which are time-consuming and inefficient, causing huge difficulties to the real-time monitoring of nutrient indicators in the drying process.

However, only few papers have been published about the dynamics of the changes of fruit quality, it is difficult to be used as the basis for the optimal design of fruit drying processes. Lambelet et al. (2009) studied tomato after drying, and found that there was a certain correlation between the thermal degradation of lycopene and color. Chen et al. (2011) and Zou et al. (2017) studied the degradation of anthocyanin in mulberry juice and blueberry juice, finding that the change of color was closely related to the degradation of anthocyanin. You et al. (2013) studied the relationship between internal quality and color during the ripening process of mountain pepper and established corresponding regression equations; therefore, the essential oil content can be predicted according to the color of mountain pepper. Wang et al. (2014) studied the relationship between chlorophyll and surface color of broccoli at different temperatures and different vacuum conditions, establishing a prediction model for the chlorophyll content based on the green/red value. Mohammad et al. (2015) used a hot air drying method to dry apple slices. The color parameters and moisture content of apple slices were correlated with drying variables and drying time by MLP and ANN. The results showed that the correlation coefficient between color and moisture content was 0.92. Xu et al. (2017) extracted lycopene from red grapefruit and heated it at different temperatures. It was found that there was a linear correlation between lycopene content and color in red grapefruit juice. Magdalena et al. (2018) used microwave vacuum on cranberry drying, experimental results showed that the higher the contents of total anthocyanins and flavonoids of cranberry, the brighter the color of cranberry after drying. Liu et al. (2019) studied the mechanism of sunburn of apple slices. The results showed that the green/red value of apple slices decreased, the contents of carotene, phenols and flavonoids increased, and the accumulation of chlorophyll and anthocyanins was inhibited. According to previous studies, there was a certain correlation between color and internal quality of fruit and vegetables.

Therefore, in this study, the focus is on the correlation between color, VC content, reducing sugar content and total acid content of winter jujube slices. A mathematical model of correlation should be established and evaluated. Furthermore methods and data support for real-time monitoring of quality indicators of winter jujube slices during the drying process should be provided.

Materials and methods

Experimental equipment and instruments

The applied pulsed air impingement drying device was independently developed by the dry laboratory of Shihezi University; the structural diagram is shown in Figure 1.

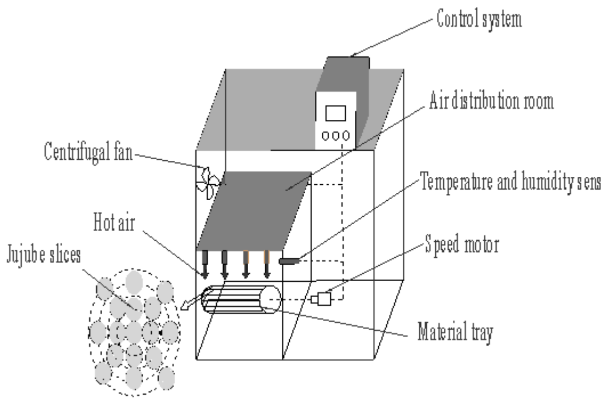

Fig. 1: Scheme of pulsed air impingement dryer

Experimental devices

BCD-267G Rongsheng Freezer (Hisense Rongsheng (Guangdong) Freezer Co., Ltd) was used to equalize wet materials; SQ2119N Xibeile Multifunctional Food Processing Machine (Shanghai Shuaijia Electronic Technology Co., Ltd) was used to break materials; KW-1000DC Digital Thermostatic Water Bath (Jintan City Instrument Co., Ltd) was used for heating mixture; BSM220.4 Electronic balance (Shanghai Zhuojing Electronic Technology Co., Ltd) was used for weighing; SMY-2000SF Color difference meter (Beijing Sheng Mingyang Technology Co., Ltd) was used for color detection.

Jujube slice samples

Fresh winter jujubes were bought from Shihezi Comprehensive Wholesale Market, China. The selected maturity is the same (production place, harvest time is the same, uniform color, uniform size), the shape is regular (longitudinal diameter 30 ± 2 mm, transverse diameter 26 ± 2 mm), then Hotan winter jujube fruit without mechanical damage were put into the freezer with temperature and relative humidity of 4 ± 1 °C and 96 ± 2 %, respectively, for 24 hours, and the slices (thickness 7 ± 1mm) were cleaned and wiped as experimental material (The average moisture content of wet base determined by oven method after slicing is 80 ± 1.0 %.)

Pulsed air impingement drying experiment of winter jujube slices

In this study, the drying temperature range of winter jujube slices was set 55 to 70 °C, the hot air speed range was selected from 3 to 9 m/s, and the fixed pulsation ratio was 6 r/min; the drying experiment arrangement is shown in Table 1.The single layer of the experimental material was placed neatly on the material tray, 40 ± 1 g per line (Wang, 2016). And a row of samples was weighed every 30 minutes during the drying process. After calculating, the jujube slices were sealed and placed in a freezer. When the moisture content of jujube slices was less than 7 %, the experiment was over.

Table 1: Design for single experiments

Number	*T*/°C	*V*/m/s	*R*/r/min
1	60	3	
2	55	6	
3	60	6	6
4	65	6	
5	70	6	
6	60	9	

Determination of moisture content

The moisture content (wb) was measured by drying the sample until constant weight was reached at 105 °C in a hot air oven (GB 5009.7-2016).

Reducing sugar content measurement

GB 5009.7-2016, direct-titration

Determination of total acid content

GB/T 12456-2008, acid base titration

Vitamin C content measurement

GB5009.86-2016, 2,6-dichloroindophenol titration

Statistical analysis

To ensure the accuracy of the test data, each determination was conducted, processed and analyzed in triplicate by SPSS17.0, Excel 2010 and origin2018.

Kinetic analyses

The curves of a* values of winter jujube slices dried at different hot air temperatures are shown in Figure 2. With increasing temperatures or drying time the a* values of winter jujube slices increased gradually. And under different drying temperatures, the increase of a* values was faster in the early stage and slower in the later stage, the main reason for the phenomenon may be that the enzyme activities involved in enzymatic browning and non-enzymatic browning are relatively high in the early stage of drying, however the enzyme activity gradually decreases in the late drying stage (Cao et al., 2018).
To determine whether air temperature has a significant effect on the change of a* value of winter jujube slices during drying process, analysis of variance was performed, it can be seen from Table 2 that P is 0.0001, less than the significance level of 0.05, thus the effect of the hot air temperature on the reducing sugar content (db) of winter jujube slices is significant.

The curves of the VC contents (db) during the drying process at different hot air temperatures are shown in Figure 3. It can be seen that the VC content (db) of jujube slices decreased with the increasing drying time at the same temperature, and the slope was steeper in the early stage, then tended to be less steep in the later stage. The reason for this phenomenon may be that the temperature increased by hot air heating, and the activity of various enzymes is relatively high in the early stage, so the rate of VC oxidative decomposition is higher because of the catalytic action of the enzyme (Zhang et al., 2016). As the drying progress continued, the moisture content of jujube slices gradually decreased, the activity of the enzyme also decreased, and the degradation rate of VC also decreased (Ordóñez-Santos and Martínez-Girón, 2020).
The VC content (db) of winter jujube slices decreased with the increasing drying temperature. This was mainly due to the easier oxidation and decomposition of VC under higher temperatures. Similar results are also found in the degradation kinetics of vitamin C in kiwi juice (Gao et al., 2006) and on the stability of VC in spinach juice (Wang et al., 2010).

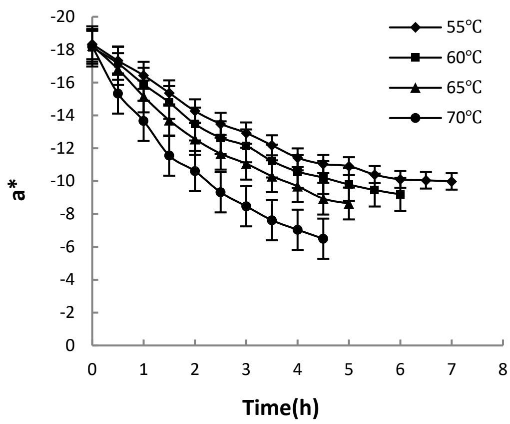

Fig. 2: Curves of a* values of jujube slices during the drying process at different hot air temperatures

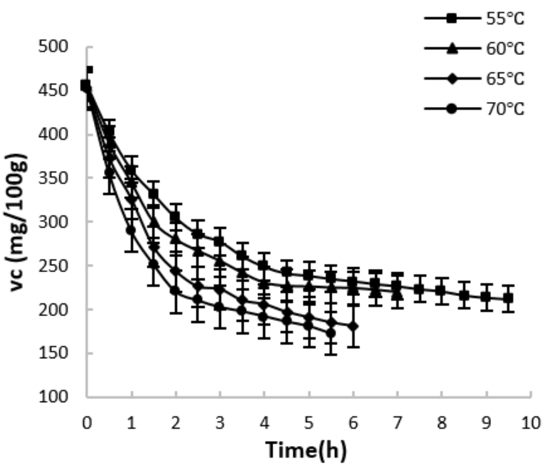

Fig. 3: Curves of VC contents (db) of jujube slices during the drying process at different hot air temperatures

Determining by the analysis of variance whether air temperature has a significant effect on the changes of VC content (db) in the drying process, it can be seen from Table 3 that P is less than 0.001, less than the significance level of 0.05, and the effect of the hot air temperature on the VC content (db) of winter jujube slices is significant.
The curves of reducing sugar content (db) that varied with time at different drying hot air temperatures are shown in Figure 4. It can be seen that the higher the drying temperature, the steeper the slope of the curves at the same drying conditions, which indicates that the reducing sugar of the jujube slices degraded more easily as the temperature increased. The reducing sugar content decreased rapidly in the early stage and the curve became flat at the same dry temperature in the later stage. This was mainly because the reducing sugar participated in the Maillard reaction at low temperature conditions, and a part of the reducing sugar participated in the Maillard reaction, and another part underwent the caramelization reaction at high temperature conditions (Zhang, et al., 2006). Similar results are found with the browning degree of jujube (Zhang, 2014).
To determine whether air temperature has a significant effect on the change of reducing sugar content (db) with winter jujube slices during the drying process, analysis of variance was performed. Results from Table 4 show that P is 0.002, less than the significance level of 0.05, and the effect of the hot air temperature on reducing sugar content (db) of winter jujube slices is significant.

In Figure 5 it can be seen that the total acidity (db) of the winter jujube slices decreases slightly with increasing temperatures or drying time. Both drying time and temperature have little effect on the total acidity (db). The reason for this may be that volatilization of the volatile acid of the jujube slices takes place as the drying progresses, and the higher the temperature, the faster the volatilization (Jin et al., 2014).
The one-factor experimental variance analysis is shown in Table 5. It can be seen that P is 0.205, which is higher than the significance level of 0.05. The effect of hot air temperatures on the total acid content (db) of winter jujube slices was not obvious.

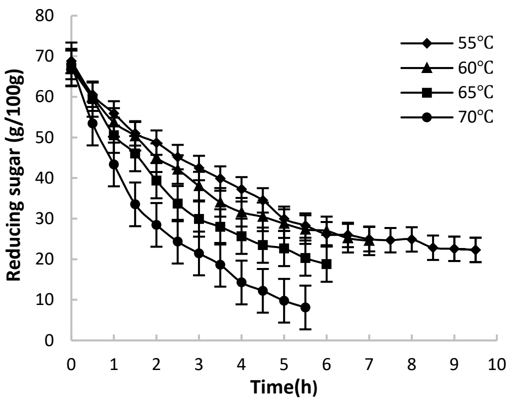

Fig. 4: Curves of reducing sugar content (db) of jujube slices during the drying process at different hot air temperatures

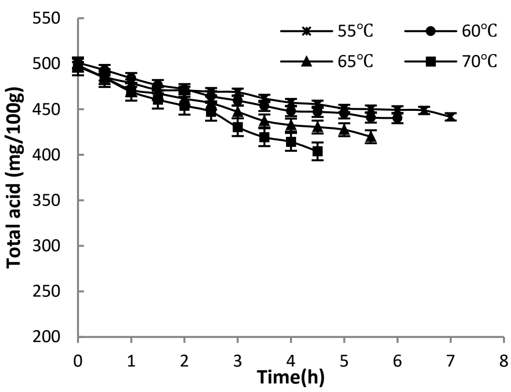

Fig. 5: Curves of total acidity (db) of jujube slices during the drying process at different hot air temperatures

Table 2: Variance analysis of a* value changes during the drying process of jujube slices at different hot air temperatures

Source of difference	SS	df	MS	F	P-value
Intergroup	130.323	3	43.441	4.396	0.0001
Intragroup	444.69	45	9.882		
Total	575.013	48			

Note: significance level is 0.05

Table 3: Variance analysis of VC content (db) during the drying process of jujube slices at different hot air temperatures

Source of difference	SS	df	MS	F	P-value
Intergroup	0.351	3	0.117	9.036	<0.001
Intragroup	0.585	45	0.013		
Total	0.936	48			

Note: significance level is 0.05

Table 4: Variance analysis of reducing sugar content (db) during the drying process of jujube slices at different hot air temperatures

Source of difference	SS	df	MS	F	P-value
Intergroup	141.879	3	47.293	8.242	0.002
Intragroup	258.21	45	5.738		
Total	400.089	48			

Note: significance level is 0.05

Table 5: Variance analysis of total acid content(db) during the drying process of jujube slices at different hot air temperatures

Source of difference	SS	df	MS	F	P-value
Intergroup	0.0027	3	0.0009	0.03	0.205
Intragroup	1.395	45	0.031		
Total	1.398	48			

Note: significance level is 0.05

Results and discussions

Correlation analysis of quality indexes of winter jujube slices during drying process

According to the kinetic analysis, a*value, VC and reducing sugar content of winter jujube slices changed obviously over the drying process, but the total acidity shows no obvious changes (db). Therefore, the correlation between a*, VC and reducing sugar (db) quality indexes can be studied to provide data support for the real-time detection of the quality of jujube slices during drying process.

It can be seen from Figure 6, that there is a significant positive correlation between the a* value and VC content (db) of winter jujube slices at different drying temperatures. This may be due to a series of decarboxylation reactions occurring in the drying process after the oxidation and decomposition of the ascorbic acid, resulting in the formation of dark brown substances(Fang et al., 2010).

It can be seen from Figure 7 that there is also a significant positive correlation between a* value and reducing sugar content (db) at different drying temperatures. This may be because a part of the free carbonyls of reducing sugar reacts with the free amino acids to form complex black complexes, another part of reducing sugar is dehydrated by heating to make it blackened, and a part of reducing sugar is cracked under high temperature to form small molecules of aldehydes and ketones, and small molecules of aldehydes and ketones are further polymerized into dark brown substances. The accumulation of dark brown substances resulted in the change of the color of winter jujube slices in the drying process.

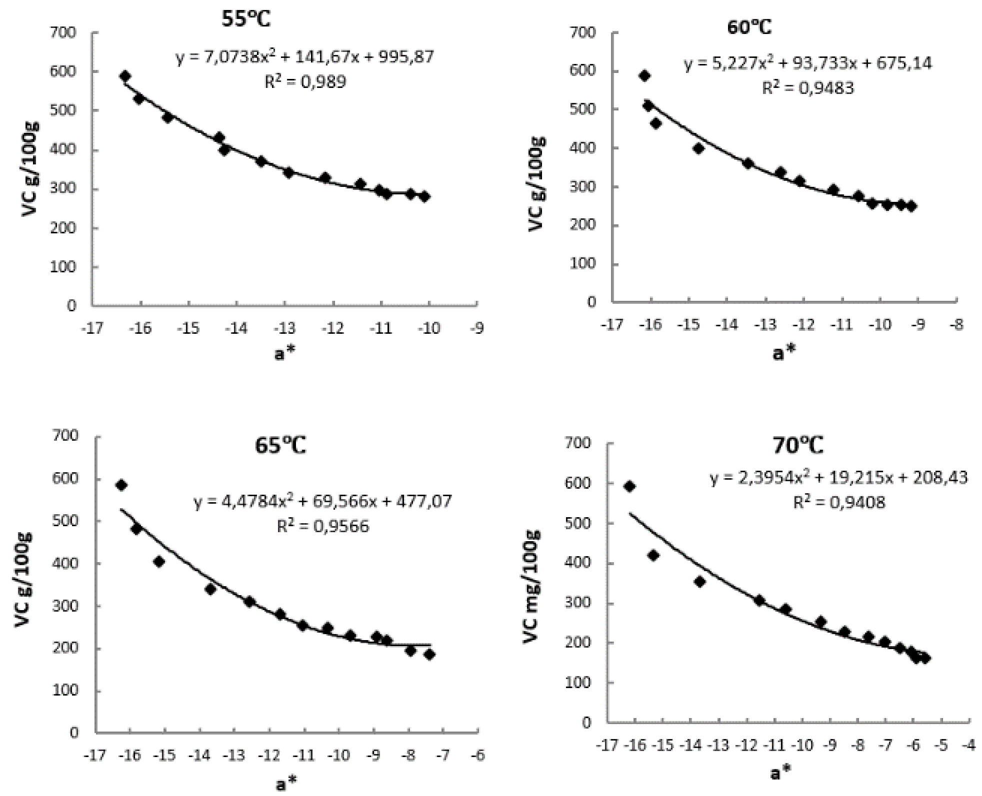

Fig. 6: Correlation between a* value and VC content (db) of jujube slices during the drying process at different drying temperatures

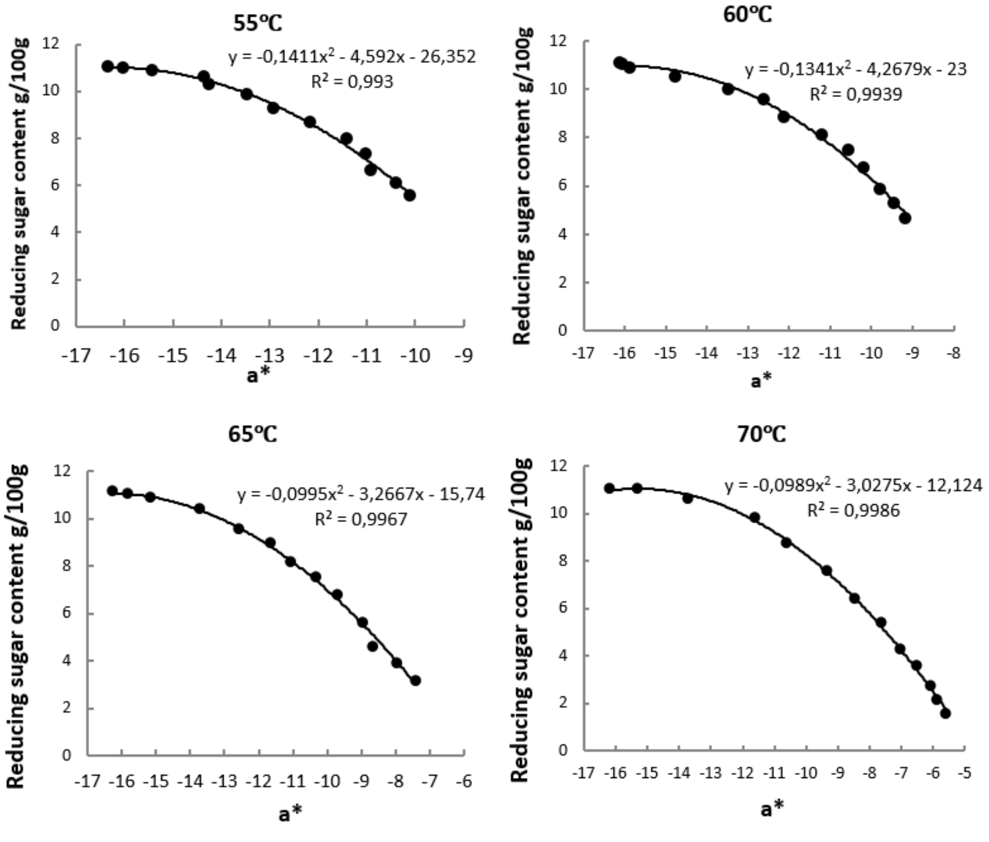

Fig. 7: Correlation between a* value and reducing sugar content (db) of jujube slices during the drying process at different drying temperatures

Model evaluation parameter

The accuracy of the model is determined by the sample training set correlation coefficient Rc, the prediction set correlation coefficient Rp, the training root mean square error (RMSEC), the predicted root mean square error (RMSEP), and the predicted relative deviation (RPD). The higher the values of Rc, Rp and RPD of the model, the lower the values of RMSEC and RMSEP, and the smaller the difference of absolute value between the RMSEC value and the RMSEP value, the higher the prediction accuracy of the model (Sun et al., 2016). When the RPD value of the model is between 1.5 and 2, it indicates that the model has a predictive ability to a certain extent; between 2 and 2.5, the model can predict better; between 2.5 and 3, it indicates the model has high prediction accuracy *(*Nicolar et al., 2007).

Establishment and evaluation of a VC content (db) prediction model for jujube slices during the drying process

The experimentally measured VC data and the green/red value (a*) data were correlated by Partial Least Squares Regression (PLSR), Stepwise Multiple Linear Regression (SMLR) and Principal Component Regression (PCR) to establish a training set prediction model. In order to evaluate the prediction accuracy of the VC prediction model, the hot air temperature, the speed and the pulsation ratio was set at 60 °C, 6 m/s, and 6 r/ min, respectively, through the verification experiment to evaluate the VC prediction model. Modeling results are shown in Table 6.

Table 6: Results of three different modeling methods for VC content (db) prediction

Modeling method	**Sample size**	**Training set**		**Prediction set**		**RPD**
		Rc	**RMSEC**	**Rp**	**RMSEP**	
PLSR	42	0.935	0.54	0.769	0.59	2.1
SMLR	42	0.927	0.56	0.681	0.63	1.9
PCR	42	0.923	0.57	0.592	0.65	2.1

From the modeling results (Table 6) and the VC prediction model modeling results, it can be seen that compared with SMLR and PCR modeling, the model of Rc, Rp and RPD established by PLSR are the largest, 0.935, 0.769 and 2.1, respectively. Both RMSEC and RMSEP are the smaller, 0.54 and 0.59, respectively. Therefore, the PLSR modeling was more suitable for the prediction of VC content (db) of winter jujube slices drying. The modeling results of the three VC prediction models are shown in Figure 8.

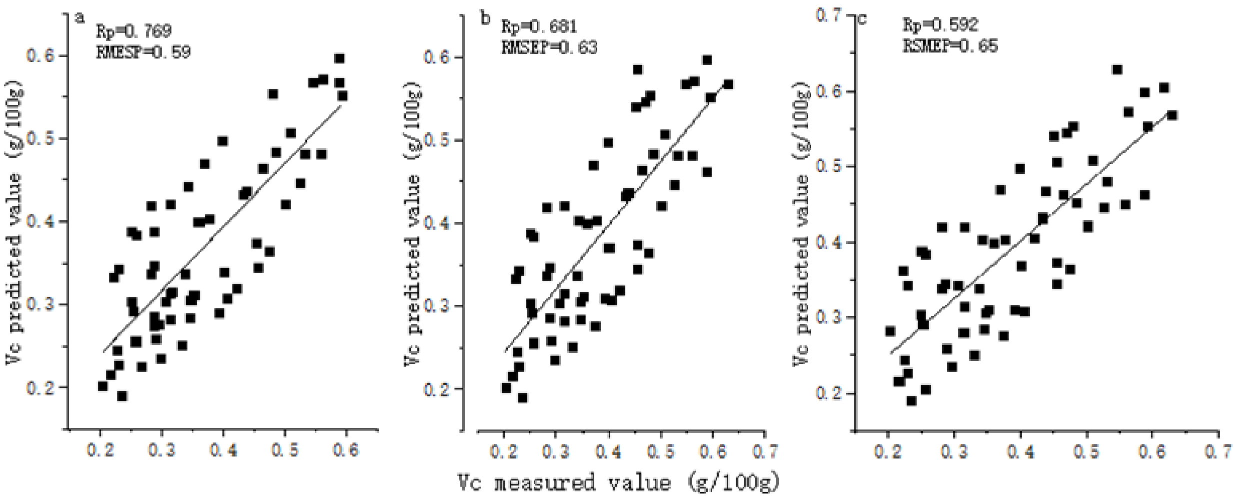

Fig. 8: Result of the VC content (db) prediction model of PCR during the drying process

Establishment and evaluation of a reducing sugar content (db) prediction model for winter jujube slices during the drying process

PLSR, SMLR and PCR were used for correlating the reducing sugar content (db) data with the green/red a* data to establish a training set prediction model. The prediction accuracy of the reducing sugar prediction model was evaluated. The hot air temperature was set at 60 °C, the hot air speed at 6 m/s, and the pulsation ratio at 6 r/min for verification experiments. The verification experiment was carried out to evaluate the reducing sugar content prediction model for winter jujube slices. The modeling results of the three reducing sugar content prediction models are shown in Table 7.

Table 7: The results of three different modeling

Modeling method	Sample size	Training set		Prediction set		RPD
		Rc	RMSEC	Rp	RMSEP	
PLSR	42	0.924	0.52	0.756	0.63	2.2
SMLR	42	0.922	0.53	0.732	0.64	2.1
PCR	42	0.927	0.46	0.816	0.56	2.1

From the modeling results and the reducing sugar prediction model modeling results, it can be seen that compared with PLSR and SMLR modeling, the values of the model Rc, Rp and RPD established by PCR are the largest, 0.927 ,0.816 and 2.1, respectively. Both RMSEC and RMSEP values are the smaller, 0.46 and 0.56, respectively. Therefore, PCR modeling was more suitable for reducing sugar content (db) prediction of winter jujube slices, and it could roughly predict reducing sugar content (db) of winter jujube slices in the drying process. The modeling results of the three reducing sugar prediction models are shown in Figure 9.

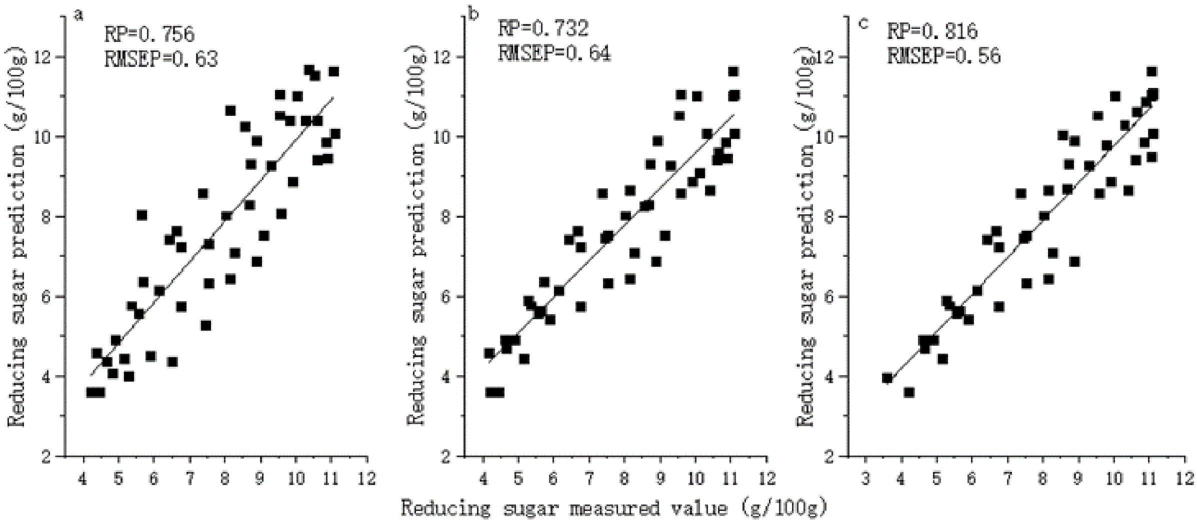

Fig. 9: Result of the reducing sugar content (db) prediction model of PLSR during the drying process

Conclusions

Correlation analysis of the a*value, the VC content and the reducing sugar content of winter jujube slices was carried out (db). The quality indexes were correlated and prediction models were established. Finally, the accuracy of the prediction model was evaluated by validation experiments.

The a* value, the VC content and the reducing sugar content of winter jujube slices are significantly correlated at 0.01 level at different air temperature conditions (db). In order to explore the correlations between color green/red value a* and VC content (db) at different drying temperatures, and the correlations between green/red value a* and reducing sugar content (db) PLSR and SMLR were carried out and a training set prediction model was established by PCR. PLSR modeling was more suitable for VC content (db) prediction. PCR modeling was more suitable for reducing sugar content (db) prediction.

Through the verification experiment, the prediction accuracy of VC content (db) prediction model and the reducing sugar content (db) prediction model for the winter jujube slices was evaluated. The VC content (db) prediction model Rp was 0.769, the RMSEP was 0.59, and the RPD value was 2.1. The model could roughly predict VC content (db) of winter jujube slices during the drying process. The Rp of the reducing sugar content (db) prediction model was 0.816, the RMSEP was 0.56, and the RPD value was 2.2. The model could roughly predict reducing sugar content (db) of winter jujube slices during the drying process.

Acknowledgement

This study was financially supported by the National Natural Science Foundation of China (Grant No. 31960488).

References

Che, Z. M. 2000: Extraction and stability of VC from jujube leaves, Science and Technology of Food Industry, 02:29-31. https://doi.org/10.3969/j.issn.1002-0306. 2000. 02.011

Chen, W., Fang, D. and Cao, S. Q. 2011: Thermal degradation kinetics of anthocyanin and visual color of mulberry juice. Food Science and Technology 36(04): 151-155. https://doi.org/10.13684/j.cnki.spkj.2011.04.021

Cao, Y., Wang, G., Huang, Y., Zhu, R., Wang, Q., Wei, S. and Yao, X. 2018: Colour change and kinetics of winter Jujube slices during pulsed air-jet impingement drying. Czech Journal of Food Sciences 36(4): 302–308. https://doi.org/10.17221/259/2017-CJFS

Fang, S. Z., Wang, Z. F., Hu, X. S., Li, H., Long, W. R. and Wang, R. 2010: Shrinkage and quality characteristics of whole fruit of Chinese jujube (Zizyphus jujuba Miller) in microwave drying. International Journal of Food Science and Technology 45(12): 2463-2469. https://doi.org/10.1111/j.1365-2621.2010.02367.x

Forsido, S. F., Duguma, H. T., Lema, T. B., Sturm, B. and Hensel, O. 2019: Nutritional and sensory quality of composite extruded complementary food. Food Science and Nutrition 7(2): 882–889. https://doi.org/10.1002/fsn3.940

Guo, B.Y. and Zhang, Z.X. 2011: Optimization of processing parameters for freeze-drying winter jujube. Food Science 32(04): 135-138.

Gao, Y.J., Hao, L.H., Zhang, X., Nan, H.J. and Hao, Y.Q. 2006: Degradation kinetics of ascorbic acid in kiwi fruit juice. T*ransactions of* the Chinese Society of Agricultural Engineering 05: 157-160. https://doi.org/10.3321/j.issn: 1002-6819.2006. 05.034

Jin, X., Oliviero, T., van der Sman, R. G. M., Verkerk, R., Dekker, M. and van Boxtel, A. J. B. 2014: Impact of different drying trajectories on degradation of nutritional compounds in broccoli (Brassica oleracea var. italica). *LWT* - Food Science and Technology 59(1): 189–195. https://doi.org/10.1016/j.lwt.2014.05.031

Lambelet, P., Richelle, M., Bortlik, K., Franceschi, F. and Giori, A.M. 2009: Improving the stability of lycopene z-isomers in isomerised tomato extracts. Food Chemistry 112(01): 156-161. https://doi.org/10.1016/j.foodchem.2008.05.053

Liu, Y., Chen, N., Zuo, C., Wu, Y., Che, F. and Chen, B. 2019: The mechanism of color fading in sunburned apple peel. ACTA PHYSIOLOGIAE PLANTARUM 41(01): 01-08. https://doi.org/10.1007/s11738-018-2792-7

Liu, Q.L., Yang, L.F., Ma, C. and Wu, M.Y. 2019: Research Progress on Jujube Fermented Products. China Fruit & Vegetable 39(02):15-18. https://doi.org/10.19590/j.cnki.1008-1038.2019.02.004

Ministry of health of the People's Republic of China. 2016: Determination of vitamin C content in fruits and vegetables in GB/T 5009.86-2016. Beijing: China standard press.

Ministry of health, People's Republic of China. 2016: Determination of reducing sugars in food in GB/T 5009.7-2016. Beijing: China standard press.

Ministry of health, People's Republic of China. 2008: Determination of total acids in food in GB/T 12456-2008. Beijing: China standard press.

Mayer-Miedach, E., Behsnilian, D., Regier, M. and Schuchmann, HP. 2005: Thermal processing of carrots: lycopene stability and isomerisation with regard to antioxidant potential. Food Research International 8/9:1103-1108. https://doi.org/10.1016/j.foodres.2005.03.018

Magdalena, Z., Zielinska, D. and Markowski, M. 2018: The Effect of Microwave-Vacuum Pretreatment on the Drying Kinetics, Color and the Content of Bioactive Compounds in Osmo-microwave-vacuum dried cranberries (vaccinium macrocarpon). Food and Bioprocess Technology 11(03): 585–602. https://doi.org/10.1007/s11947-017-2034-9

National Bureau of Statistics, Chinese Yearbook. 2014. Beijing: China Statistics Press.

Nicolar, B.M., Beullens, K., Bobelyn, E., Peirs, A., Saeys, W., Theron, K. and Lammertyn, J. 2007: Nondestructive measurement of fruit and vegetable quality by means of NIR *spectroscopy. Postharvest Biology and Technology 46 (02): 99-118.* https://doi.org/10.1016/j.postharvbio.2007.06.024

Ordóñez-Santos, L. E. and Martínez-Girón, J. 2020: Thermal degradation kinetics of carotenoids, vitamin C and provitamin A in tree tomato juice. *International Journal of Food* Science and Technology *55*(1): 201–210. https://doi.org/10.1111/ijfs.14263

Picard, M. G. 2020: Current Advances in Meat Nutritional, Sensory and Physical Quality Improvement. Foods 9(i): 321–325. https://doi.org/10.3390/foods9030321

Pareek, S. 2013: Nutritional composition of jujube fruit. Emirates Journal of Food and Agriculture, 25(6): 463-470. https://doi.org/10.9755/ejfa.v2516.15552

Sun, J.T., Ma, B.X., Dong, J., Yang, J. and Jiang, W. 2016: Characteristic wave length selection-based prediction of soluble solids content of hami big jujubes using the hyperspectral imaging technology. Modern Food Science and Technology 32(09): 174-179+223. https://doi.org/10.13982/j.mfst.1673-9078.2016.9.026

You, Y.M. and Zhou, M. 2013: Quality prediction of litseacubeba during ripening period based on color difference. Science and Technology of Food Industry 34(23): 108-111. https://doi.org/10.13386/j.issn1002-0306.2013.23.025

Wang, L.J., Zhang, S.J., Li, W.X., Wang, S.K. and Sun, S.J. 2014: Prediction model for chlorophyll content in post-harvest broccoli based on color parameter changes in micro-vacuum condition. Journal of Food Science and Biotechnology 33(02): 204-209.

Wang, G. 2016: Pulsed air-impingement drying characteristics and quality of jujube slices, Shihezi University.

Wang, Y.N., Li, S., Cui, C., Cong, P.J. and Ai, G.H. 2010: Studying on stability of Vc in spinach juice. Journal of Zhejiang Agricultural Sciences 03: 554-557. https://doi.org/10.16178/j.issn.0528-9017.2010.03.001

Xu Y. and Pan S.Y. 2017: Thermal Degradation Kinetics and Mechanism of Lycopene and Color in Red Grape Fruit. Food Science. 38(11):81-88. https://doi.org/10.7506/spkx1002-6630-201711014

Xu, H.Y. 2011: Effect of thermal treatment on non-enzymatic browning of Chinese jujube juice. Academic Periodical of Farm Products Processing.05:39-42. https://doi.org/10.3969/j.issn.1671-9646(X).2011.05.011.

Zou, B., Xu, Y.J., Wu, J.J., Fu, M.Q., Xiao, G.S. and Lu, S.W. 2015: Effect of storage temperature on single anthocyanin degradation in blueberry Juice. Modern Food Science and Technology, 12:256-262+276. https://doi.org/10.13982/j.mfst.1673-9078.2015.12.038.

Zhang, J., Han, H., Xia, J. and Gao, M. 2016: Degradation Kinetics of Vitamin C in Orange and Orange Juice during Storage. *Advance* Journal of Food Science and Technology 12(10): 555–561. https://doi.org/10.19026/ajfst.12.3303

Zhang, L., Li, S., Dong, Y., Zhi, H. and Zong, W. 2016: Tea polyphenols incorporated into alginate-based edible coating for quality maintenance of Chinese winter jujube under ambient temperature. LWT - Food Science and Technology 70: 155–161. https://doi.org/10.1016/j.lwt.2016.02.046

Zhao, Y., Zhu, X., Hou, Y., Wang, X. and Li, X. 2019: Effects of nitric oxide fumigation treatment on retarding cell wall degradation and delaying softening of winter jujube (Ziziphus jujuba Mill. cv. Dongzao) fruit during storage. Postharvest Biology and Technology *156*(May): 110954. https://doi.org/10.1016/j.postharvbio.2019.110954

Zhou, X., Li, R., Lyng, J. G. and Wang, S. 2018: Dielectric properties of kiwifruit associated with a combined radio frequency vacuum and osmotic drying. Journal of Food Engineering 239(September 2017): 72–82. https://doi.org/10.1016/j.jfoodeng.2018.07.006

Received October, 29th, 2020