Expert System for Drying Schemes of Agricultural Products Based on Fuzzy Control and BP Neural Network

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Abstract

Drying is an important part of crop processing. The parameters before drying have a great impact on the drying results. Therefore, it is necessary to choose a reasonable drying scheme. According to the factors affecting the drying quality of agricultural products, an expert system of drying schemes is designed by us. This system is based on the fuzzy algorithm and BP neural network. We provide a method to improve the reasoning ability of the system. We use the hot air drying process warehouse of agricultural products as the experimental platform, Tremella as experimental object. We perform drying experiments by two mainstream ways of generating drying schemes and our system's method. Simulation results show that the system can not only generate better drying schemes but also can use the drying results to gradually improve its reasoning ability. At present, the accuracy of the system is as high as 80%.

Keywords: Expert system, Fuzzy algorithm, BP neural network

1 Introduction

China is a big country of agricultural products, many agricultural products are produced in this country, such as agaric, mushroom, rice, corn, and so on. often need to be dried [1]. The drying of agricultural products is a complex process, including many physical, chemical, and biochemical changes. Different batches and types of agricultural products in the inappropriate environmental temperature, humidity, time, and other factors will have different degrees of impact on the drying quality of agricultural products [2]. For example, if the drying temperature is too high, the color of the mushroom will turn black, and the mushroom's nutrients will also be lost. But if the temperature is too low, it is not conducive to the drying process, which will spend a longer drying time and cause a waste of energy. When the wind speed is too high in the drying process, the mushroom surface's water will be lost fast and the pores will be closed, which is not good for draining water. Another example is Tremella, which contains a chemical component called "porphyrin". After human consumption and absorption, it will easily cause skin itching, redness, swelling, and other situations when exposed to sunlight. It will even produce edema and other symptoms in serious cases [3]. Without proper drying, the "porphyrin" contained in Tremella will be difficult to be decomposed, but excessive drying will easily damage Tremella. It can be seen that an unreasonable drying process not only wastes energy and time but also reduces the quality of agricultural products. It will Seriously affect the commodity value of agricultural products. Besides, due to the different dryness of the target crops, the size of the drying room, and the ventilation mode, the specific drying process should be applied flexibly according to the specific conditions. Therefore, before drying, we should choose appropriate drying schemes for agricultural products.

This paper proposes an expert system of agricultural product drying schemes based on the fuzzy algorithm and BP neural network. The system can use fuzzy reasoning to match the corresponding experience rules and get the basic drying schemes of the corresponding agricultural products. The BP neural network is used to predict the temperature, humidity, and time of each area in the basic drying scheme and correct the positive and negative correlation, then we can obtain the final drying schemes by using this system. Besides, BP neural network [4-5] has the ability of self-learning, which means if the drying results are fed back to the expert system, the weight of the BP neural network will be optimized. It can improve the accuracy of expert system analysis. The expert system can not only effectively improve the drying quality, but also adapt

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to different drying conditions and agricultural products. This system has good operability and reasoning ability. The simialar work can be applied in some emerging scopes [6-8].

2 System Design and Development

2.1 Overall Structure of the System

The proposed expert system is an intelligent computer program system, which contains a lot of knowledge and experience of experts in a certain field, can simulating the decision-making process of human experts to solve those complex problems that need to be dealt with by human experts.

The general expert system includes the user interface, inference engine, database, knowledge base, and knowledge acquisition device. According to the general structure, the expert system of this paper is mainly divided into database rule base part, reasoning process part, input initial parameters of agricultural products part, reasoning, the results section, drying degree feedback part, and so on. The detailed structure is shown in Figure 1.

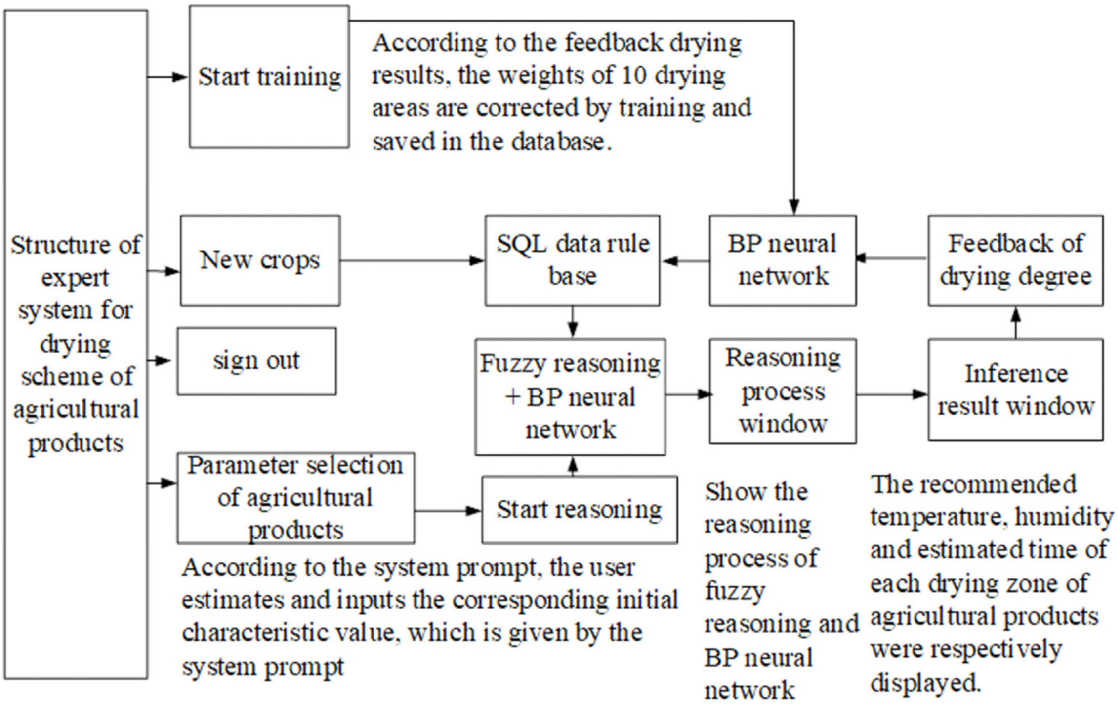

Figure 1. Schematic diagram of expert system structure

The database rule base mainly stores some matching rules of fuzzy algorithm, the weight value of BP neural network matching under different conditions, some formulas, and so on. The initial parameters are mainly composed of three inputs: the type of agricultural products, the characteristics of agricultural products, and the degree of specified drying expectation. After selecting the type of agricultural products, the system will automatically read out the number of features, the specific name of the feature, and the degree value of the feature selection. There are 7 expected drying degree values, which are determined by the system in advance. The correlation between the expected drying degree and the percentage of actual moisture content is shown in Table 1.

Table 1. Comparison between expected degree and actual water content of agricultural products

Expectation level	The actual water content of crops /%
Serious over-drying	Less than 7.5
Medium over dry	10±2.5
A little too dry	15±2.5
Proper drying	20±2.5
Slightly wet	25±2.5
Moderate excess humidity	30±2.5
Severe excessive humidity	Greater than 32.5

The reasoning process is mainly completed by fuzzy reasoning and BP neural network, then the specific reasoning process will be displayed in detail on the system interface. The Inference result is the final drying scheme which includes several stages of drying the agricultural product, the recommended temperature, humidity, and time of each stage. The feedback part of the drying degree is mainly composed of 7 drying degrees to be fed back. The system corrects the inference error by feedback drying degrees so that the system will have higher accuracy when we generating schemes next time. The table of feedback drying degree and actual moisture content of agricultural products is the same as Table 1. In addition, the variety of crops.

2.2 Design of System Knowledge Base

The knowledge base of the expert system is used to save the knowledge of human experts. The quality and quantity of knowledge in the knowledge base determine the quality level of the expert system. The process of system solving problems is to simulate the thinking process of human experts through a large amount of knowledge that saves in the knowledge base and to infer and explain related problems.

The content of the knowledge base mainly includes crop drying process table, crop rule matching gain table, crop basic information table, BP neural network parameter table, and so on.

2.3 Implementation of System Reasoning Mechanism

The reasoning process is to repeatedly match the current known conditions and information with the rules in the knowledge base. If the matching is successful, the reasoning ends and the result of solving the problem is obtained.

The overall reasoning process of the inference engine is shown in Figure 2.

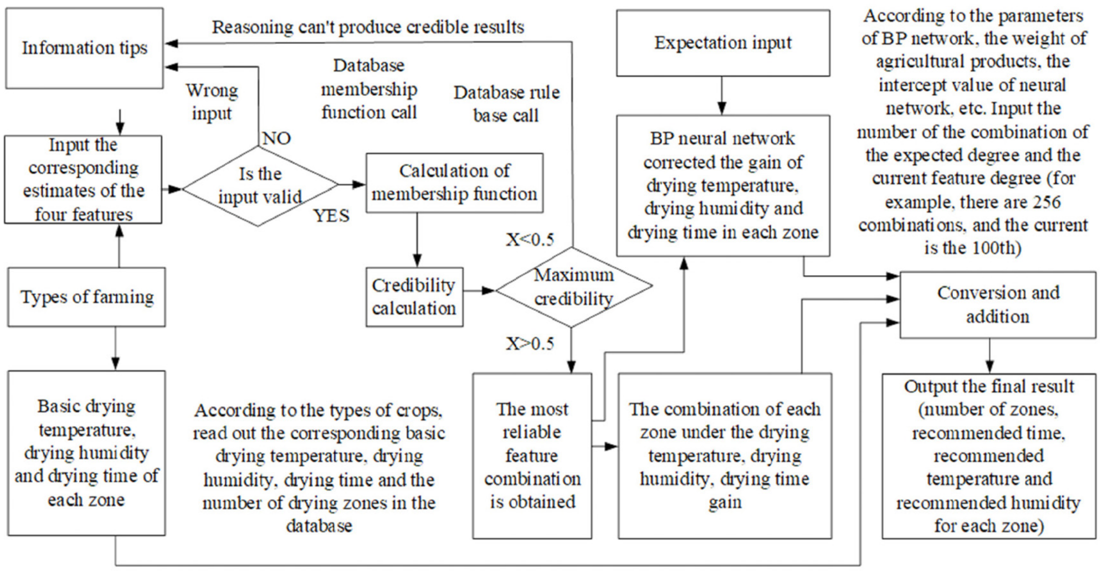

Figure 2. Reasoning flow chart of the system inference engine

This paper used fuzzy reasoning and BP neural network algorithm together. The fuzzy algorithm can judge the degree of the water content of all possible agricultural products through the non-absolute and non-linear relationship between the characteristics of agricultural products and the water content of agricultural products, and select the most likely one to better improve the accuracy of reasoning. Fuzzy reasoning is a kind of reasoning process that can get the possible imprecise conclusion from the imprecise premise set, also known as approximate reasoning [9-11]. BP neural network algorithm is a kind of multilayer feedforward network trained by the error backpropagation algorithm. It is one of the most widely used neural network models. The advantage of using a BP neural network is to use the self-learning ability of it. After each drying, the system is modified by feedback, and the weight value of the BP neural network is updated to optimize the accuracy of the system generation scheme. The BP neural network can learn and store a large number of input-output pattern mapping relationships without revealing the mathematical equations describing the mapping relationships in advance. The parameters of BP neural network are the number of network layers, the number of neurons in each layer, the weight value of neurons, intercept term, activation function, and learning rate.

To judge the drying temperature, humidity, and time through agricultural products, four eigenvalues of Tremella are designed. Feature 1 is Softness and hardness, because the Tremella is usually firm, elastic, and has relatively low water content. The Tremella with a soft hand has higher water content. The second feature is the amount of spore powder, because there is a certain amount of spore powder on the ventral surface of newly harvested mature Tremella, and the moisture content of this kind of Tremella is generally high. The third feature is the thickness of Tremella, such as Tremella harvested from Qingming to Xiaoshu. This kind of Tremella has the characteristics of thick flesh and high water content. Feature 4 is the degree of rotten ears. For example, the quality of Tremella harvested from summer to early autumn is poor, with more rotten ears and lower water content, mainly because of the diseases and pests in this season.

The system will substitute the values of the four features into the formula of the fuzzy set for calculation, as shown in Formula 1. After induction, The most reliable feature combination is calculated. The Membership degree U is as follows, where A, B, C, and D can be customized according to user needs.

$$U = \begin{cases} \frac{b-x}{b}(a \le x \le b) \text{ Corresponding low fuzzy set} \\ \frac{x}{b}(a \le x \le b) \text{ Fuzzy sets in correspondence} \\ \frac{c-x}{b}(b \le x \le c) \text{ Fuzzy sets in correspondence} \\ \frac{x-b}{b}(b \le x \le c) \text{ Corresponding high fuzzy sets} \end{cases} \quad \textbf{(1)}$$

Then, the corresponding drying combination gain scheme is matched. The different feature combinations are related to the water content of agricultural products, and the different gain schemes of drying combinations are also related to the water content of agricultural products. Therefore, the corresponding gain schemes of drying combinations are matched by feature combinations. At the same time, the basic drying scheme is read in the database according to the types of agricultural products, and the basic drying scheme is only related to the types of agricultural products. After normalizing the number of feature combinations and the expected drying degree, it is used as the input of the BP neural network (the extra input is set to 1 as standby), and the BP drying gain scheme is obtained after calculation. The structure of the BP neural network used in this paper is shown in Figure 3.

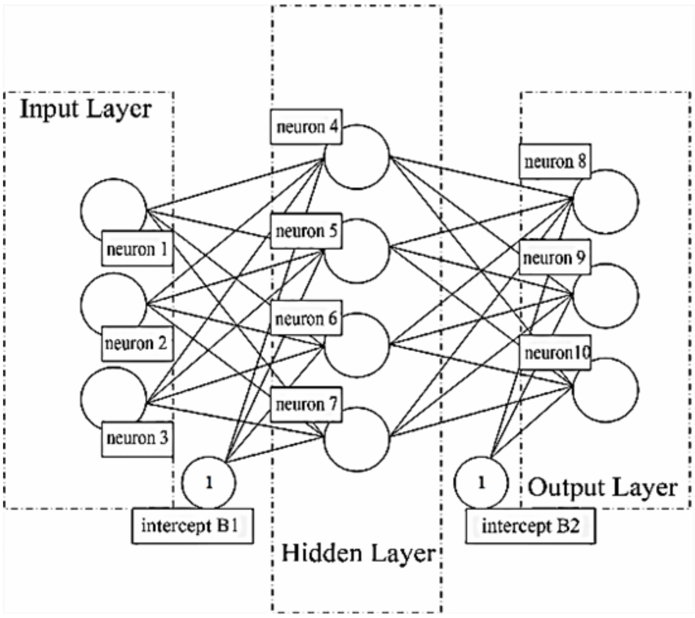

Figure 3. Structure diagram of BP neural network

There are three neurons in the input layer, four neurons in the hidden layer, and three neurons in the output layer. There are also two intercept terms. There are 31 weight values. The tanh function is selected as the activation function, and the learning rate can be set in the system. The default value is 0.12.

The formula of tanh function is as follows [12-13]:

$$f(x) = \tan h(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}} \quad \textbf{(2)}$$

After the conversion and combination of the three schemes, the final total value drying scheme can be obtained, as shown in Table 2 below.

Table 2. Format parameters of three schemes in W area

z	Time			Environmental parameters	
	Hour/H	Minute/M	Second/S	Temperature/°C	Humidity/%
Basic drying scheme	AW	BW	CW	X2	X3
BP drying gain scheme	DW	EW	FW	Y2	Y3
Drying combined gain scheme	GW	HW	C	Z2	Z3
Total value drying scheme	U1	U2	U3	Total2	Total3

Here, W is one of several drying intervals for the crop, which is a separate drying interval (stage). X2 and X3 are the recommended temperature, humidity. AW, BW, and CW are the recommended time (hours, minutes, seconds) in the w stage. Y2 and Y3 are the temperatures, humidity, DW, EW, and FW recommended by the BP drying gain scheme in the w stage. Z2 and Z3 are the recommended temperature, humidity, GW, HW, IW are the recommended time (hours, minutes, seconds) in the w stage. Total2 and total3 are the temperature and humidity recommended by the total numerical scheme in phase W. U1, U2, and U3 are the recommended time (hours, minutes, and seconds) of the scheme. The total numerical scheme is the summary scheme of the first three schemes. The calculation methods of U1, U2, U3, total2, and total3 are shown in Formula 3, 4, 5, 6, and 7.

$$U_1 = A_w + B_w + C_w \quad \textbf{(3)}$$

$$U_2 = D_w + E_w + F_w \quad \textbf{(4)}$$

$$U_3 = G_w + H_w + I_w \quad \textbf{(5)}$$

$$Toatl_2 = X_2 + Y_2 + Z_2 \quad \textbf{(6)}$$

$$Toatl_3 = X_3 + Y_3 + Z_3 \quad \textbf{(7)}$$

The final time, final temperature, and final humidity of each drying stage are calculated as shown in the table. The specific values of different drying stages are different, but the calculation method is the same. The parameters of the total numerical drying scheme will be used as the final scheme, which is divided into three zones, each zone has its own recommended temperature, humidity, and drying time. As is shown in Table 3.

Table 3. Format parameters of final drying scheme

Partition	Time			Environmental parameters	
	Hour/H	Minute/M	Second/S	Temperature/°C	Humidity/%
Area 1	H1	M1	S1	T1-t1	R1-R1
Area 2	H2	M2	S2	T2	R2
……	……	……	……	……	……
Area N	HN	MN	SN	TN	RN

The first zone in the table is the rising (falling) temperature stage, and the second zone is the constant temperature stage. The rising (falling) temperature stage and the constant temperature stage are not fixed and may appear in any region. H1, M1, and S1 correspond to the time value (hour, minute, and second) in the total numerical scheme of zone one, T1 corresponds to the temperature value in the total numerical scheme of zone one, and R1 corresponds to the humidity value in the total numerical scheme of zone one. The temperature in the dryer should rise (fall) from T1 to T1 in H1, M1, and S1 seconds. The humidity should rise (fall) from R1 to R1. H2, M2, and S2 correspond to the time value in the two zones total numerical scheme, T2 corresponds to the temperature value in the two zones total numerical scheme, and R3 corresponds to the humidity value in the two zones total numerical scheme. The temperature and humidity of the dryer should be maintained near T2 and R3 in H2, M2, S2, and S2. And so on, all the way to the last n-zone.

2.4 Realization of BP Neural Network Self-learning

After drying according to the final drying scheme. The corresponding drying results can be fed back in the expert system. If the expected drying degree is different from the feedback drying degree, the two degrees are converted into corresponding values for subtraction. The expected degree is divided into severe over dry, moderate over dry, slightly over dry, proper drying, slightly over wet, moderate over wet, and severe over wet. The feedback degree is the same, and the relationship between feedback degree and water content can be referred to in Table 1. After drying, the drying result can be judged by the moisture detector. According to the measured moisture, the corresponding feedback degree is selected. After the training, the weight value of the correlation network can be optimized to improve the accuracy of the next prediction. As shown in Figure 4.

3 Design of Main Function Modules of the Software

The software mainly consists of ES system initial setting module, crop type selection module, feature degree selection module, reasoning start module, reasoning process, and result module, generated drying scheme module, result feedback module, network weight module, other operation modules, etc. As shown in Figure 5 and Figure 6.

Initial setting window mainly provides the functions of modifying the language and adding drying objects.. The crop type selection window is mainly used to select the crops to be dried. When you click the button behind the crop types, the system will automatically read the crop types available. The feature degree

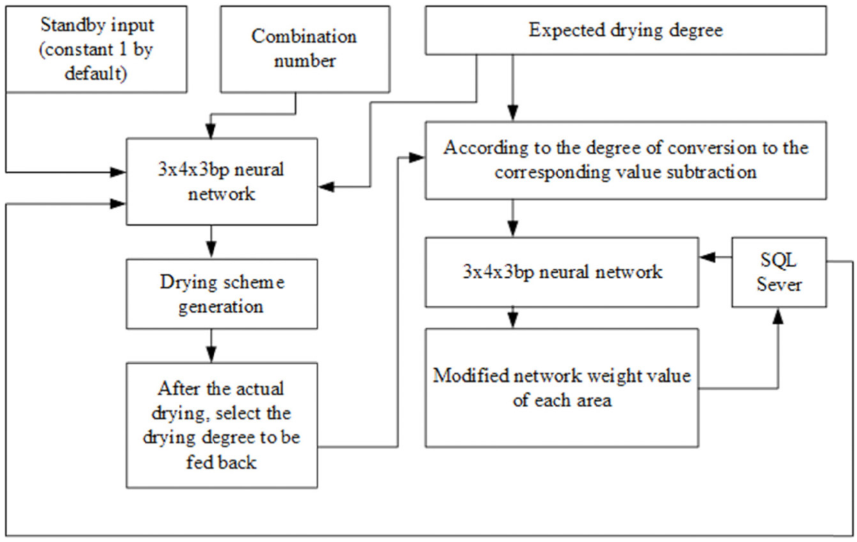

Figure 4. BP neural network self-learning diagram

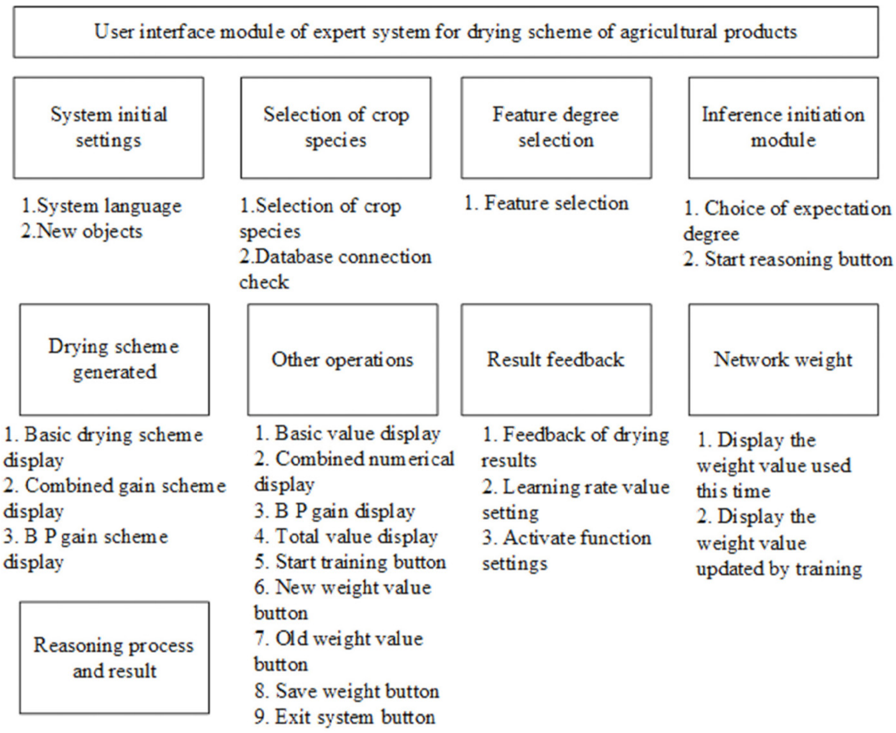

Figure 5. Software interface module overview

Figure 6. Software overall user interface diagram

selection window is mainly used to select the feature degree value of the crop. As long as the crop is selected, the name of the feature value will automatically change, and the available values will bedisplayed in the drop-down bar of the feature. The reasoning start module is mainly used to determine the expected value and decide whether to start reasoning. The expected degree is divided into severe over dry, moderate over dry, slightly over dry, suitable drying, slightly over wet, moderate over wet, and severe over wet. After setting, click Start reasoning. The reasoning process will be displayed in the reasoning process and result column, and the network weight value will be displayed in the network weight window. The final generated scheme will be displayed in the drying stage section bar. Click the basic value button, combination value button, BP gain button, and total value button to view the corresponding scheme separately, and the parameters of the scheme will be updated and displayed in the partition column of the drying stage. Click the confirm scheme button to import the scheme data into the lower PLC and start drying. The results feedback window is mainly used to feedback the results after drying. Click the drop-down bar after drying result feedback, there are also serious over-drying, medium over-drying, slightly over-drying, proper drying, slightly over wet, medium over wet, and serious over wet. If the expected result is the same as the feedback result, the system will not make any corrections. If the expected result is wetter than that of the feedback result, the system will get a negative gain, and the value is related to the degree of deviation. If the expected result is drier than the feedback result, a positive gain is obtained. This gain will be used as the error value of BP neural feedback, after the reverse operation, to correct the weight value. After setting, click the start training button in other operation bars to start the self-learning optimization of the system. After training, the updated weight value will be automatically displayed in the network weight window. If you want to permanently save the newly generated weights, click the save weights button in other operation windows. You can click the old weight value button in the operation window. As shown in Figure 7.

Figure 7. Updated weight value graph

4 Experimental Results and Analysis

90 groups of Tremella in different states (origin, storage time, harvest season, appearance, and so on.) were selected for drying. The scheme generated by the system was tested.

30 groups of Tremella were randomly selected for each of the three methods, and the drying scheme used under the manual judgment method is shown in Table 4. Only the best drying method is listed here. 30 groups of Tremella were used to judge 30 schemes. Table 5 shows the scheme of drying by copying the existing experience.

Table 4. Drying scheme under manual judgment mode

Partition	Time			Environmental parameters	
	Hour/H	Minute/M	Second/S	Temperature/°C	Humidity/%
Area 1	0	20	0	0-30	50
Area 2	2	0	0	30	60
Area 3	0	10	0	30-35	50
Area 4	2	0	0	35	50
Area 5	0	10	0	35-40	40
Area 6	2	0	0	40	40
Area 7	0	10	0	40-45	40
Area 8	2	0	0	45	30
Area 9	0	10	0	45-50	20
Area 10	2	0	0	50	40

Table 5. Drying scheme based on existing experience

Partition	Time			Environmental parameters	
	Hour/H	Minute/M	Second/S	Temperature/°C	Humidity/%
Area 1	0	30	0	0-40	20
Area 2	1	0	0	45	30
Area 3	4	10	0	45-26	20
Area 4	1	0	0	26-30	20
Area 5	1	0	0	30-33	2
Area 6	2	0	0	33-36	10
Area 7	1	10	0	36-44	10
Area 8	1	0	0	44-50	10
Area 9	5	0	0	50	10
Area 10	3	0	0	50-60	10

The drying scheme of batch Tremella used by the system is shown in Table 6. This paper only lists the best drying scheme generated by the expert system of agricultural products drying scheme. 30 groups of Tremella, and generated 30 programs.

Table 6. Drying scheme under the mode of expert system generation for drying scheme of agricultural products

Partition	Time			Environmental parameters	
	Hour/H	Minute/M	Second/S	Temperature/°C	Humidity/%
Area 1	0	40	0	0-45	25
Area 2	0	57	0	47	20
Area 3	3	40	0	47-30	23
Area 4	1	0	0	30-35	13
Area 5	1	0	0	35-40	16
Area 6	2	0	0	40-45	15
Area 7	1	20	0	45-50	18
Area 8	1	12	50	50-55	13
Area 9	4	32	0	55	12
Area 10	2	44	12	55-59	10

After drying according to the three schemes, the finished products are sampled respectively. The test results are shown in Table 7 and Figure 8.

Table 7. Summary of three drying methods

Scheme name	Degree of excess humidity			Appropriate	Degree of over-drying		
	H	M	L	S	L	M	H
Artificial judgment	9	4	2	1	11	2	1
Copy existing experience	1	3	15	7	3	1	0
System generation scheme	0	1	2	24	2	1	0

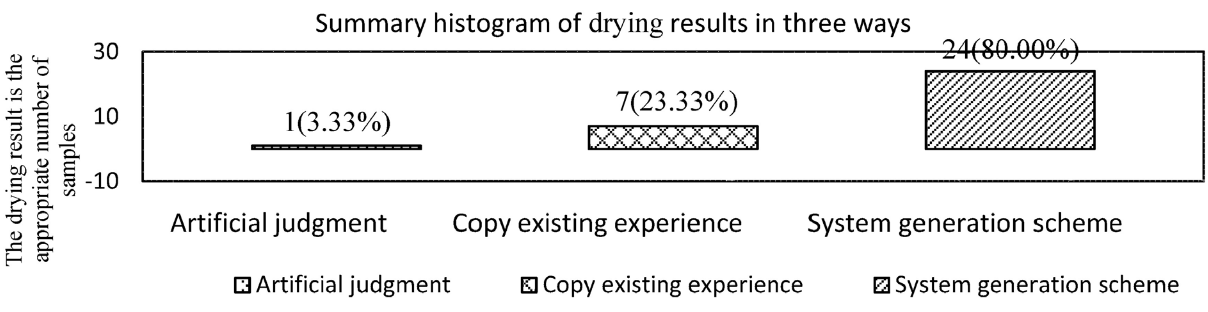

Figure 8. Histogram of three drying methods

H, M, and L denote excessive, moderate, and slight degrees. Refer to Table 1 for the actual water content of crops.

Artificial judgment, copying the existing experience, agricultural drying program expert system generation, these three ways were tested in 30 groups. It can be seen from the experimental results in Table 7 and Figure 9 that the drying results of the scheme generated by the expert system are far better than those of manual judgment and copying the existing experience. The accuracy is higher than 80%.

To verify the BP neural network learning ability, another 60 groups of Tremella in different states were prepared, which were divided into a and B.

A and B agaric were dried by the expert system of drying scheme of agricultural products. When B is drying, the feedback mechanism is used to optimize the accuracy of the system, while A is not used. Drying should be carried out in the order of group numbers from small to large. The drying results are shown in Table 8 and Figure 9.

Table 8. Comparison of drying results with and without feedback

Number of drying group	Drying results of group A and B			
	Group A (no feedback)		Group B (have feedback)	
	Appropriate	Inappropriate	Appropriate	Inappropriate
Group 1-15	10	5	9	5
Group 16-30	11	4	11	4
Group 31-45	10	5	13	2
Group 46-60	11	4	14	1

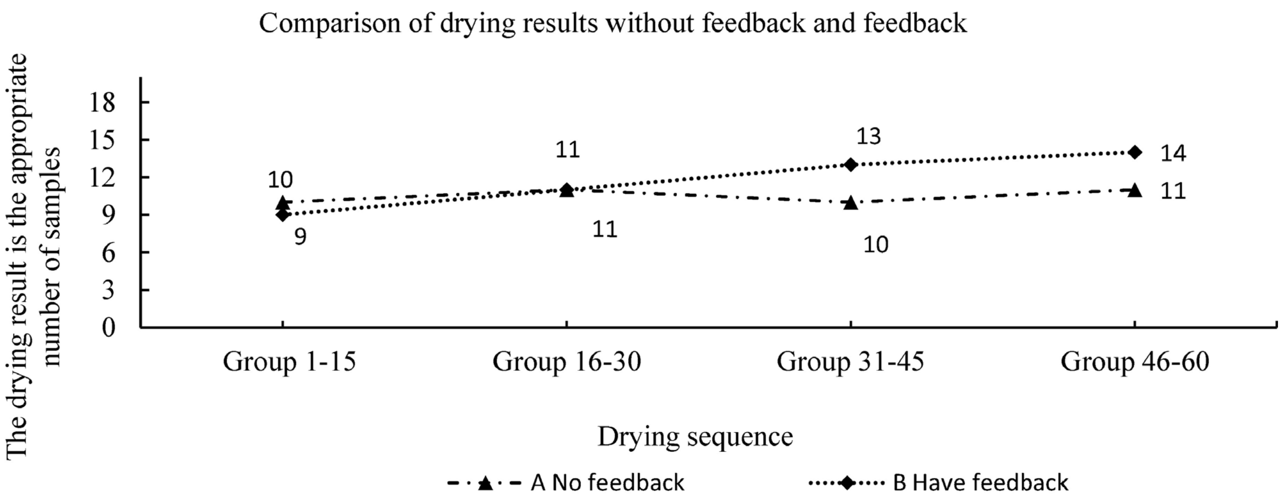

Figure. 9 Comparison of drying results without feedback and feedback

It can be seen from Table 8 and Figure 9 that after feedback, with the increase of drying times, the proportion of suitable drying results increases gradually. It is proved that BP neural network can optimize the generation of system schemes in a certain range.

5 System Features

(1) Application: we can enrich the judgment types of the expert system by increasing the types of crops. For some crops without drying history, the system can be used to explore new drying schemes. Through learning, it can automatically adapt to different performance drying equipment.

(2) Accuracy: the system will decide whether to give up the current conclusion according to the credibility of the conclusion, to avoid suggestions with low accuracy. At the same time, due to the use of fuzzy and BP neural network algorithms. Every time the feedback and the weight value of the network are corrected, the prediction of the system will become more accurate.

(3) Popularization: the system is based on Windows 10 platform. All the reasoning is completed by the system itself, and users are not required to learn the relevant knowledge. The system has good generalization.

6 Conclusion

This paper mainly develops an expert system of agricultural product drying schemes based on fuzzy control and BP neural network [14-16]. An optimized drying scheme for producing agricultural products. It not only provides a way to ensure the drying quality of agricultural products for China, a big agricultural product country. It also provides a means to explore a new drying scheme for agricultural products. It solves the problem that it is difficult to judge the drying scheme without relevant professional knowledge and experience. The simple integrated system is convenient to use and greatly improves the popularity of the system.

Acknowledgements

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Biographies

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