Eurasia Journal of Science and Technology
Print ISSN: 2663-1024
Online ISSN: 2663-1016
DOI: https://doi.org/10.61784/ejst3138

EXPERIMENTAL DATA FITTING AND INFLUENCING FACTORS ANALYSIS OF TEA WITHERING

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Abstract: With the continuous progress of tea factory intelligence and modernization, the construction of tea withering mode plays the important role on the product quality in the process of tea withering. It is very important to analyze the construction of tea withering model and the analysis of influencing factors for the improvement of product quality in the process of tea withering. In this paper, the weight of each factor of tea withering on the trend and time of water loss and weight loss of the whole withering was successfully analyzed by means of multiple regression analysis. When withering to 50 % weight loss, the weight of each factor from large to small is temperature, humidity, tea green layer number, tea green density. At the same time, multiple regression analysis was used to predict the trend of withering water loss and weight loss under different conditions. The model data fitting can better control the withering time, and has positive significance for the post-mortem investigation of the withering process.
Keywords: Withering process; Factor analysis; MATLAB curve fitting; Multiple regression analysis; Stability evaluation

1 INTRODUCTION

With the development of factory automation, modern production has gradually developed from manual to automation and intelligence [1]. Data fitting and influencing factors analysis is very import to withering [2]. The first process in the production of white tea, black tea, rock tea and other teas is withering. During the withering process, the water content of fresh leaves decreased, and the leaves changed from brittle to soft, which was convenient for rolling into strips. The substances contained in the leaves undergo different degrees of transformation [3]. Normal and effective withering, so that the grassy fresh leaves fade and produce fragrance, and fruit or flower aroma, tea taste mellow but not bitter [4]. However, if the withering temperature and humidity are not suitable, it will lead to tea deterioration, bitter taste, and even affect human health. At present, most of the tea production enterprises are small in scale, many of which belong to family workshops, small-scale peasant production, and the degree of organization of tea production and management is not high [5]. The withering process mostly depends on human experience. Therefore, it is very important to analyze the influencing factors of tea withering and optimize the process of tea withering to improve the quality of products [6]. Therefore, MATLAB is used to fit the curve of tea withering data, as well as theoretical analysis, which provides guiding significance for withering. At present, the industry 's discussion on the withering model mainly focuses on the following points :
(1) Different temperature and humidity will inevitably lead to different time and effect of withering. It is difficult to meet the standardization requirements by relying on sensory evaluation. If the tea processing is developed in the direction of continuity and automation through the withering model.
(2) There are many categories of rock tea. Although the yield of cinnamon and narcissus is huge at present, whether the withering data of only one tea variety is universal.
(3) What are the qualitative indicators of the effects of withering processing temperature, processing humidity, the number of tea leaves, and the density of tea leaves on the withering of tea leaves, and whether the trend prediction can be achieved ;
This paper mainly solves the third point. At present, this problem has attracted wide attention. Literature studied the relationship between the water content of withered tea and its physical properties (elasticity, plasticity, flexibility and texture) during the withering process [5]. The texture analyzer was used to test the elasticity and flexibility of withered tea with different water content. The sensory evaluation of Congjiang black tea showed that moderate withering was better than long-term withering, and withering during processing and long-term withering were better than non-withering. Moisture content was significantly correlated with the flexibility and plasticity of withered tea. In the study of Reference [6], supplementary metabolomics and proteomics analysis were carried out on the sun and indoor withered oolong tea leaves and the newly harvested tea as a control to reveal the initial formation mechanism of some flavor determinants in the early stage. After picking fresh leaves, if the weather is not good, such as no sunshine and relatively low temperature is not conducive to the natural withering of tea, tea manufacturers generally use indoor heating withering, through heating channels, air ducts, air conditioners, humidifiers and other equipment to control the temperature and humidity of the withering workshop. At present, the indoor heating withering of Fuding Tea Factory is mainly through the withering trough, as shown in Figure 1.

Figure 1 Indoor Withering trough in Tea Factory

The specification of the withering trough is that the length of the trough is 10 m, the width of the trough section is 1.5 m and the height is 1.2 m. With hot air as the drying medium, through the pressure of the fan, through the fresh leaves spread on the trough, the fresh leaves are heated, the water in the leaves evaporates and gradually softens. The tea factory master first spread the fresh leaves evenly in the leaf frame of the withering trough, and heated the bottom to open to keep the room temperature stable. Thanks to the indoor heating withering is a relatively closed area, and the amount of withering is relatively large, the whole tea withering process can be well observed by the humidity during the withering period. The temperature and humidity of partial withering for 36 hours after the tea plant master put the fresh leaves into the withering tank are shown in Figure 2.

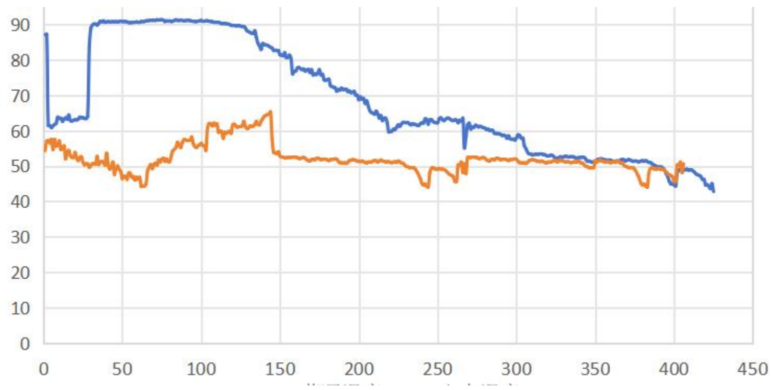


Figure 2 Tea Plant Withering Humidity

Note : Blue curve withering temperature, orange curve indoor humidity

In the initial stage of withering, due to the high water content in the fresh leaves, the water speed of the fresh leaves is faster, which makes the humidity around the tea green increase significantly. In the next 12 hours, with the continuous loss of water at a high speed, the tea leaves obviously lost water and shrank from the fresh leaf state, showing a typical ' wilting ' state. The leaves lost their original fullness and began to shrink slightly. With the deepening of the withering process, the water walking speed gradually decreased, which was because the freely lost water in the leaves gradually decreased. The tea green state gradually darkened, and the texture of the leaves gradually became fragile. When the withering time reaches 24 hours, the masters will turn the tea leaves over to ensure that the withering of the leaves is more uniform. Within 12 hours after the turning, the withering enters the end. At this time, the moisture content of the leaves is reduced to an appropriate level, and the color is transformed into a typical gray-green color, which is one of the symbols of high-quality tea products. The schematic diagram of the withering process of the specific tea plant is shown in Figure 3.

(a) Fresh tea green state (0h) (b) Water loss and atrophy of tea green (12h)

(c) Withering state at 24h (d) Tea green state at the end of withering.

Figure 3 The Whole Process of Tea Withering

2 EXPERIMENTAL ENVIRONMENT CONSTRUCTION

Most of the workshops on the market are small tea factories and small workshops. Most of the workshops do not have large-scale withering and heating withering equipment, which is greatly affected by the environment. Therefore, this paper takes the single-layer indoor natural withering environment as the research object, and studies the water movement of tea under different temperature and humidity conditions[7]. Because it is a single-layer withering environment, it is necessary to design a solid frame as the basic structure of the tea withering platform, and the withering platform needs to have a sufficiently large flat area to place the tea. This area should be well ventilated and presented in the form of grids. The left and right sides are supplemented by fan ventilation, and finally the bottom kick line heater is added to control the temperature. According to the above design ideas, the final single-layer withering platform is 150 cm long, 86 cm wide, and 60 cm high. The first generation design sketch is shown in Figure 4.

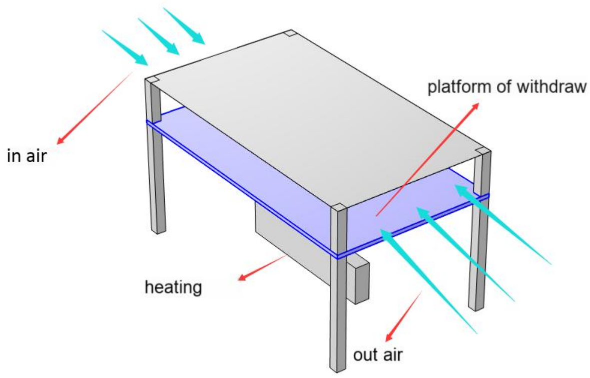


Figure 4 Single-Layer Simulated Withering Diagram

Because the length of a single withering platform is too long, the temperature is inconsistent, so the area of a single withering platform is reduced. Because the size of the withering area is reduced, the laboratory can accommodate more withering platforms at one time, and increase the number of withering platforms to 3, so that multiple sets of data can be measured at one time, and the withering variables can be better controlled. The second-generation simulated withering platform is shown in Figure 5.

Figure 5 Improved Simulated Withering Platform

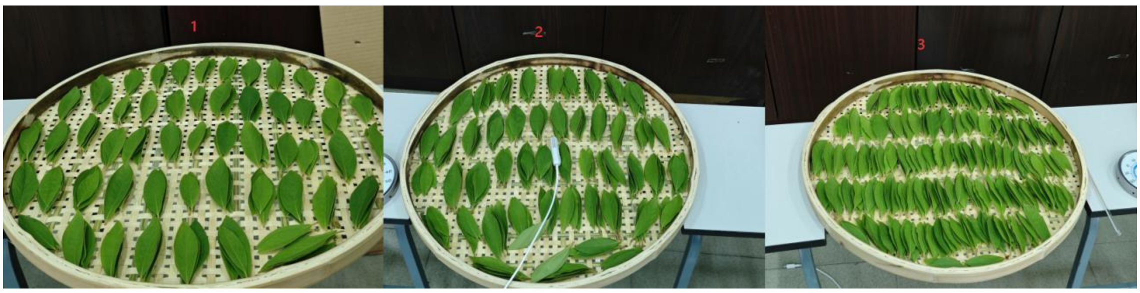
2.1 Parameter Setting of Simulated Withering

In order to facilitate the experiment, this paper takes the fresh leaves of Rhododendron as the raw material, and takes the weight reduction to 50 % as the experimental stop condition to simulate the weight change during the withering process of tea. After collecting the fresh leaves of rhododendron, the fresh leaves of rhododendron were pretreated first, and the bud heads and old leaves with larger size were removed. Although the bud of immature leaves is a good material for tea making, it is not enough to support the demand for fresh leaves in this paper due to the limitation of quantity and picking time. The old leaves with large size are not good raw materials for tea making, and the water is not easy to lose, resulting in a long experimental span and great error, which is not conducive to the study of the influence of temperature and humidity on water walking, so it is removed. After pretreatment of fresh leaves, the fresh leaves were placed into the withering platform in a certain way. In the first generation withering platform, because only one set of experiments can be completed at a time, the placement of fresh leaves is unified by three layers of fresh leaves, and the withering area is covered (high density). In the second generation withering platform, because of the optimization, three groups of experiments can be completed at one time. The way of fresh leaf pendulum is shown in Table 1 and Figure 6.

Table 1 Classification of fresh leaf placement

NO.	layer	interval (density)
(a)	3	1.5cm, low density
(b)	6	1.5cm, low density
(c)	3	No interval, high density

Note : (a) Way to simulate the case of few fresh leaves withering. (b) The effect of leaf thickness on withering was analyzed. (C) to simulate normal withering.



(a) (b) (c)

Figure 6 Classification of Fresh Leaves

2.2 Data Collection Process

Before placing, the temperature and humidity of the withering area are controlled to create a tea withering environment with different temperature and humidity. When the withering area is stable, the fresh leaves are placed and the temperature and humidity of the withering area are monitored in real time. The temperature exceeds the predetermined value by 2 °C and the humidity exceeds the predetermined value by more than 5 %. It is necessary to regulate the temperature and humidity of the withering area in time to avoid affecting the experimental results. During the experiment, the weight of fresh leaves was measured every 6 hours. It is worth noting that because the second generation withering platform uses a bamboo sieve, and the bamboo sieve will change its weight due to external humidity conditions, resulting in a significant increase in measurement error. Therefore, fresh leaves need to be temporarily removed from the withering platform and placed in a special container for weight measurement to ensure experimental accuracy. When the weight of fresh leaves was reduced to 50 % of the original, the experiment was stopped, the consumption time was recorded, and the leaf status after the withering of fresh leaves was observed to complete a set of data collection. When the fresh leaves of rhododendron were just picked down, the leaves were full and relatively flat, because the leaves were full of water, the cells were full, and the leaf tension was uniform. During the subsequent withering process, the leaves lost water and shrank, and the water in the cells gradually evaporated, resulting in different degrees of twists and curls in the leaves. This curling phenomenon is an important feature of tea withering process, which affects the appearance quality and subsequent processing of tea to a certain extent.

3 DATA FITTING PROCESS

After summarizing the collected data of water loss and weight loss of tea withering, it is necessary to analyze the data. When performing MATLAB curve fitting, it is necessary to select a suitable fitting function. According to the trend of tea withering water loss and weight loss data[8], it can be found that the rate of tea withering water loss and weight loss shows a gradual decrease trend, approaching a certain data., the withering water loss and weight loss equation conforms to the hyperbolic function model, so the initial fitting function can be conjectured. The data is fitted and analyzed using the user-defined function types (Custom Equations) in the CFTOOL toolbox. The custom hyperbolic fitting formula(1) is as follows :

$$f(x) = a + \frac{b}{x+c} \tag{1}$$

The data of tea withering water loss and weight loss over time were imported into CFTOOL, and then the hyperbolic curve fitting formula was input for curve fitting. The final fitting state is shown in Figure 7. It can be found that the fitted curve R-square : 0.9996. It can be seen that the function of tea water loss and weight loss over time conforms to the hyperbolic function. It can also further predict the future trend of withering water loss and weight loss, which plays an important role in analyzing the trend of tea withering.

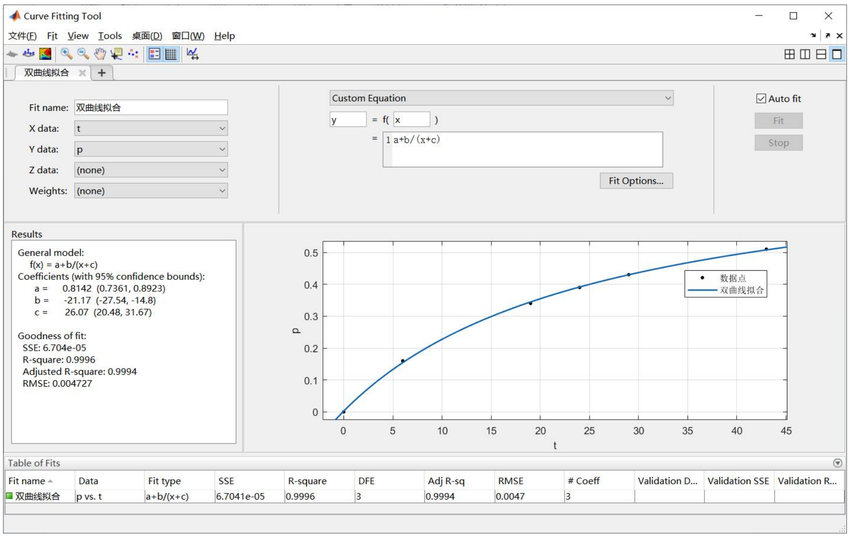


Figure 7 The Principle Diagram of Curve Fitting

3.1 Regression Analysis Method of Water Loss and Weight Loss Function of Tea Withering

Through the regression function regression analysis of the withering influencing factors (independent variables) and the curve fitting function (dependent variables), the three variables a, b, and c in the curve fitting function were subjected to regression analysis, and the withering water loss and weight loss function curve was predicted in this way. Based on this, the core code for multiple regression analysis in the MATLAB editor is shown below. The influence of different influencing factors on the function can be obtained, and the function diagram under different influencing factors can be derived.

```
X = data(:, 1:4); %
Y = data(:, 5:end); %
X_with_const = [ones(size(X, 1), 1), X];
b_a = regress(Y(:, 1), X_with_const);
b_b = regress(Y(:, 2), X_with_const);
b_c = regress(Y(:, 3), X_with_const);
```

3.2 Weight Regression Analysis Method of Tea Withering Duration

Under different influencing factors, the analysis of the time from withering to 50 % weight loss is also one of the important analyses, which can help the tea factory master to control the withering time reasonably. Through the regress function, the main codes for analyzing the duration of withering to 50 % under different influencing factors are as follows.Usually, in order to more intuitively show the influence of various factors on the duration of withering. The results of multiple linear regression analysis should also be normalized. In order to eliminate the adverse effects between different dimensions.

```
X = [temps', humids', layers', densities'];
Y = times_to_50';
b = regress(Y, [ones(size(X, 1), 1), X]);
```

4 TEA WITHERING DATA SIMULATION AND FACTOR ANALYSIS

4.1 Simulated Withering Experimental Data

According to the process of simulated tea withering experiment, the fluctuation of tea temperature and humidity caused by the lack of reasonable control of experimental equipment during the experiment was excluded, and the influencing factors of withering were affected. As shown in Table 2, the final 10 groups of withering related data were numbered and divided into experimental analysis group and control prediction group. The main function of the experimental analysis group is to perform regression analysis on the experimental data, obtain the influencing factors of the withering weight loss function, and speculate the withering weight loss trend function of the control analysis group according to the influencing factors, and compare it with the actual withering weight loss trend function to verify the conclusion.

Table 2 Tea Withering Data Classification

No.	temperature	humidity	layer	density (sparse is 1, dense is 2)	Remarks Group
1	26.5	65	3	1	Experimental Analysis
2	32	47	6	1	Experimental Analysis
3	20	77	3	1	Experimental Analysis
4	20	77	6	1	Experimental Analysis
5	20	77	3	2	Experimental Analysis
6	24.5	61	3	2	Experimental Analysis
7	25.5	37	3	2	Experimental Analysis
8	28	62	3	2	Experimental Analysis
9	24	70	3	1	Control prediction
10	25.5	65	3	2	Control prediction

4.2 Withering Data Curve Fitting

According to the experimental data collected above, the hyperbolic curve fitting is carried out in the form of code. Curve fitting in the form of code can not only correctly fit the function, but also further process the fitted function. For example, in the figure marked withering to 50 % of the time, and R-square (determine the coefficient), to achieve the purpose of rich graphic elements, as shown in Figure 8 No.7 curve fitting graphics.

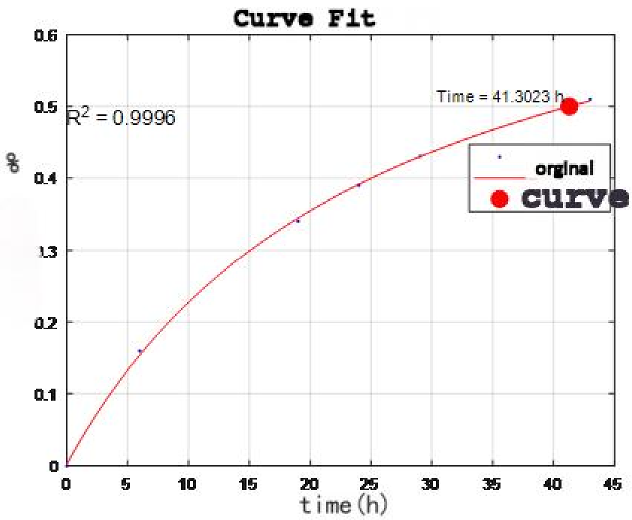


Figure 8 No. 7 Curve Fitting Diagram

The fitting graph clearly marks the time of withering to 50 % and the square of the correlation coefficient between the measured data and the inference data of the fitting function, and the data approaching 1 means that the fitting function is very close to the measured data. More than 0.8 means that the fitting is better. The number 7 fitting function formula (2) is shown below.

$$y = 0.8102 - \frac{21.1679}{x + 26.0728} \tag{2}$$

After curve fitting of all data, the resulting function is shown in Table 3.

Table 3 Curve Fitting Function

NO	fitting function	R-square
1	y = 0.8726 - 29.9502/(x + 34.5818)	0.9961
2	y = 1.0380 - 21.6302/(x + 20.9581)	0.9966
3	y = 1.0145 - 91.8534/(x + 90.2846)	0.9993
4	y = 1.0841 - 116.8818/(x + 107.3145)	0.9980
5	y = 0.9243 - 79.8131/(x + 86.1645)	0.9997
6	y = 0.8312 - 31.9880/(x + 38.5998)	0.9994
7	y = 0.8142 - 21.1679/(x + 26.0728)	0.9996
8	y = 0.9450 - 30.9060/(x + 32.8784)	0.9972
9	y = 0.9162 - 46.9855/(x + 51.3722)	0.9998
10	y = 0.8614 - 29.7210/(x + 34.6643)	0.9986

As can be found from the Table 3, the R-square of number 9 is closest to 1, and the fitting is the best. The R-square fitting degree of No.1 is the worst. However, since the obtained data R-square is very close to 1, indicating that the fitting function is almost the same as the actual point, it can be considered that the fitting function is the tea withering weight loss trend chart, and based on this function, the subsequent weight trend can be predicted to a certain extent. The obtained fitting function diagram is summarized . It can be intuitively seen that under different withering conditions, the trend of water loss and weight loss of tea is obviously different. Among them, number 2 has the highest withering temperature and low humidity, which is the fastest water loss and weight loss among all withering data. Number 4,5 because of the lowest temperature, and high humidity, withering water loss weight loss rate is the slowest.

4.3 Weight Analysis of Withering Influencing Factors

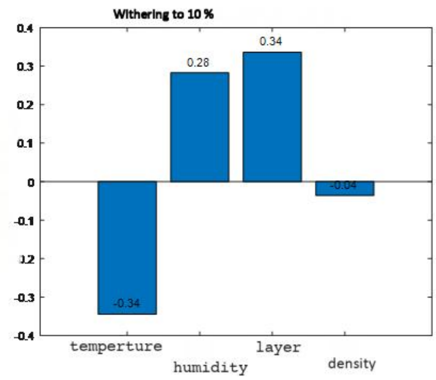
In order to show the influence of different factors on tea withering more intuitively, it is necessary to use regression analysis of tea withering time. Through this analysis, the specific contribution of each factor to the withering process can be quantified and clarified. This method of analysis not only helps to understand the importance of each variable in the withering process, but also guides more accurate adjustments in the actual tea processing process. Based on this, according to the existing simulated withering function, the time required for the weight loss rate of withering water was 0.1,0.2,0.3,0.4,0.5, respectively. The specific time required is shown in Table 4.

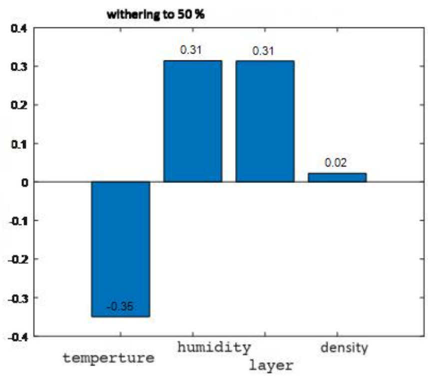
Table 4 The Corresponding Time of Withering Water Loss and Weight Loss Rate

NO.	10%	20%	30%	40%	50%

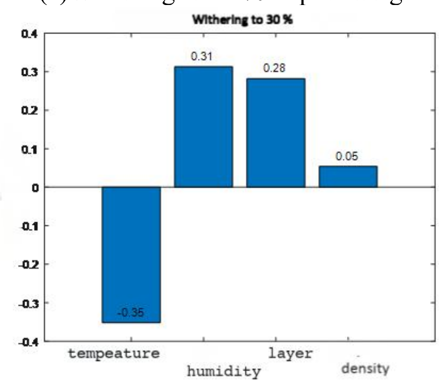
1	4.2	9.9	17.7	28.8	45.8
2	2.1	4.9	8.4	12.9	19.3
3	10.2	22.5	38.3	59.2	88.2
4	11.5	24.9	41.8	63.5	92.8
5	10.7	24.0	41.7	66.1	102
6	5.1	12.1	21.6	35.6	57.9
7	3.6	8.4	15.1	25	41.3
8	3.6	8.6	15	23.8	36.57

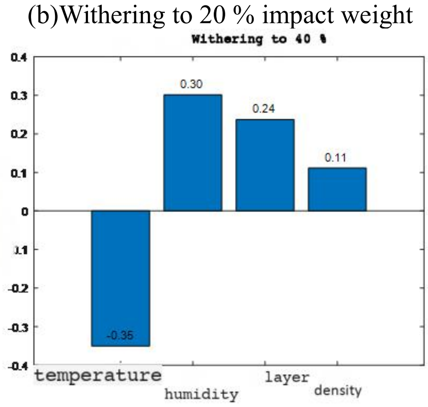
Firstly, taking the weight loss rate of 50 % as an example, in order to more intuitively reflect the influence of various factors on the withering time. The weight of the data needs to be standardized. However, considering that the change range and speed of humidity are much higher than other influencing factors, generally speaking, humidity changes at a speed of 10 %. In order to more intuitively show the influence of humidity on withering time, the weight of humidity influence should be multiplied by 10 before normalization. The adjusted normalized weight of influencing factors is shown in Figure 9.





(a)Withering to 10 % impact weight (b)Withering to 20 % impact weight





(c)Withering to 30 % impact weight (d)Withering to40 % impact weight

Figure 9 The Change of Influence Weight during Withering Process

The analysis results of different influencing factors and withering to 50 % can be obtained according to its positive and negative, which is negatively correlated with temperature, and positively correlated with humidity, layer number and density. Among them, the effects of temperature and humidity on the withering time were highly correlated. The order of the influence weight of the final withering time to 50 % is : temperature > humidity > density > number of layers. Of course, for the study of the changes in the weight of each factor in the process of withering to 50 %, it can guide the tea factory masters to control the withering process more accurately and scientifically in actual operation.In order to explore the change of the weight of the influencing factors in the process of withering to 50 %, this paper adopts the withering time of each group to 10 %, 20 %, 30 % and 40 %, so as to further study the influencing factors of withering. The weight of each group withering effect is shown in Figure 9. By carefully analyzing the change of the influence weight in the process of withering, it can be inferred that the influence of different variables on the withering time in the process of tea withering shows a certain dynamic trend. In the initial stage of withering, the number of layers has a significant effect on withering, which may be because the number of layers is directly related to air circulation and water evaporation between leaves, which limits the speed of water loss in the initial stage of withering. The negative correlation of density may indicate that the water around the leaves did not reach saturation at the initial stage, and there was no restriction between them. With the continuous withering, the influence weight of the number of layers on the withering time gradually decreased. This may be due to the fact that the water in the upper leaves has been partially distributed over time, reducing the shielding effect on the lower leaves, so its influence gradually weakened. At the same time, the weight of the effect of density on the duration of withering gradually increased, which may reflect that the humidity around the high-density leaves reached saturation as the water went on, limiting the water loss. The influence weights of temperature and humidity remained relatively stable throughout the withering process, indicating that the effects of these two factors on the withering duration were consistent and stable within the range of withering to 50 %.

5 CONCLUSION

By analyzing the change of influence weight in the process of withering, it can be inferred that the influence of different variables on the withering time in the process of tea withering shows a certain dynamic trend. In the initial stage of withering, the number of layers has a significant effect on withering, which may be because the number of layers is directly related to air circulation and water evaporation between leaves, which limits the speed of water loss in the initial stage of withering. The negative correlation of density may indicate that the water around the leaves did not reach saturation at the initial stage, and there was no restriction between them. As the withering continues, the weight of the number of layers on the withering duration gradually decreases. This may be due to the fact that the water in the upper leaves has partially dissipated over time, reducing the shelter effect on the lower leaves, and thus its impact gradually weakened. At the same time, the weight of the effect of density on the duration of withering gradually increased, which may reflect that the humidity around the high-density leaves reached saturation as the water went on, limiting the water loss. The influence weights of temperature and humidity remained relatively stable throughout the withering process, indicating that the effects of these two factors on the withering duration were consistent and stable within the range of withering to 50 %.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

FUNDING

This paper was supported by the following projects: Fujian Provincial Science and Technology Plan Spark Project (2024-S-0046), Fujian Provincial Science and Technology Plan Project (2025R1035005), Minjiang University high-level talent introduction project (MJY18003), fuzhou science and technology plan major project 'list' project (2024-ZD-009), Fuzhou scientific and technological achievements transformation project (2024-G-10), Fuzhou Science and Technology Innovation Fund Project (2025C0003), The open project fund project of Fujian Key Laboratory of Force Value Measurement and Testing in 2024 (FJLZSYS202402), key project of Minjiang University (ZD202301).

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