Experimental Study on Optimal Parameters of Stem Wetting Procedure
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Abstract. The fluctuation of the moisture content of tobacco stem after storage is the most common problem in the process of tobacco stem treatment. After relevant process parameters analysis on stem wetting procedure by multi-factor orthogonal test and multiple regression analysis, it was found that the water temperature of stem washing is the significant reason for moisture content of the stems after storage, and the fitted model equation shows that the moisture content of tobacco stem after storage reaches the optimum value when the water temperature of the stem washing is 59.7℃.

Introduction
Stem washing machine and stem steaming machine are widely used in domestic cigarette industry at present [1-3]. Through orthogonal experiment, the main and minor factors affecting the moisture content of stem after storage were found out [4-5]. Multiple regression analysis can be used to establish the model equations of these factors and the moisture content of stem after storage, the optimum value of each factor was calculated by the equation and the standard center value of moisture content after storage 32.5%.

Materials and Methods
Materials
The same batch of tobacco stem was used as test material [6].

Moisture Content Detection
After 22±2 hours of storage, tobacco stem was evenly sampled 3 times in the conveyor belt, each sample was made into 5 sets of parallel samples, the moisture content of each sample was detected by oven drying method, and then the average value of the 3 sampling was calculated. All sampling procedures should be carried out in accordance with the technical standards.

Design of Experiment
According to functions of the stem washing machine and stem steaming machine, the pump frequency of stem washing machine, water temperature of stem washing, outlet temperature of stem steaming machine, water flow was selected as experimental factors. Each factor selected 3 levels within the allowable range of process, factors and levels table was shown in Table 1. Using L9 (3^4) orthogonal table, the experimental results were shown in Table 2.

| Levels | A(Pump frequency of stem washing machine)Hz | B(Water temperature of stem washing)℃ | C(Outlet temperature of stem steaming machine) ℃ | D(Water flow) kg/h |
|--------|------------------------------------------|--------------------------------------|-----------------------------------------------|-------------------|
| 1      | 30                                       | 55                                   | 70                                            | 160               |
| 2      | 35                                       | 60                                   | 75                                            | 170               |
| 3      | 40                                       | 65                                   | 80                                            | 180               |
### Table 2. Orthogonal experiment results of L9 (3^4).

| A(Pump frequency of stem washing machine)Hz | B(Water temperature of stem washing)℃ | C(Outlet temperature of stem steaming machine)℃ | D(Water flow) kg/h | Y(moisture content of stem after storage)% |
|------------------------------------------|--------------------------------------|-----------------------------------------------|--------------------|-------------------------------------------|
| 30                                       | 55                                   | 70                                            | 160                | 31.63                                     |
| 30                                       | 60                                   | 75                                            | 170                | 32.27                                     |
| 30                                       | 65                                   | 80                                            | 180                | 33.15                                     |
| 35                                       | 55                                   | 75                                            | 180                | 32.15                                     |
| 35                                       | 60                                   | 80                                            | 160                | 32.39                                     |
| 35                                       | 65                                   | 70                                            | 170                | 33.45                                     |
| 40                                       | 55                                   | 80                                            | 170                | 32.49                                     |
| 40                                       | 60                                   | 70                                            | 180                | 32.52                                     |
| 40                                       | 65                                   | 75                                            | 160                | 32.68                                     |

### Results and Analysis

#### Analysis of Orthogonal Test

The mean response table and the mean principal effect diagram were obtained by orthogonal test analysis according to the data of Table 2 (see Table 3 and Figure 1). Table 3 shows that the order of the factors affecting the moisture content of stem after storage is water temperature of stem washing, water flow, pump frequency of stem washing machine, outlet temperature of stem steaming machine. Figure 1 shows that the moisture content of stem increases with the increase of water temperature of stem washing.

### Table 3. Mean response table.

| Levels | Pump frequency of stem washing machine (Hz) | Water temperature of stem washing (℃) | Outlet temperature of stem steaming machine(℃) | Water flow (kg/h) |
|--------|-------------------------------------------|--------------------------------------|-----------------------------------------------|--------------------|
| 1      | 32.35                                     | 32.09                                | 32.53                                          | 32.23              |
| 2      | 32.66                                     | 32.39                                | 32.37                                          | 32.74              |
| 3      | 32.56                                     | 33.09                                | 32.68                                          | 32.61              |
| Delta  | 0.31                                      | 1.00                                 | 0.31                                           | 0.50               |
| Order  | 3                                         | 1                                    | 4                                              | 2                  |

![Main Effects Plot for Means](image_url)

Figure 1. Mean principal effect diagram.
Multiple Regression Analysis

Multiple regression analysis was carried out by the data of Table 2, the results are shown in Figure 2 and Figure 3. Figure 2 shows that only water temperature of stem washing is significant to the effect of the moisture content of tobacco stem after storage ($P \leq 0.05$). In order to reach the optimum moisture content after storage (32.5%), Figure 3 predicts that the optimum value of water temperature of stem washing is 59.7.

![Figure 2. Multiple regression modeling report of moisture content after stem storage.](image)

![Figure 3. Multiple regression prediction and optimization report of moisture content after stem storage.](image)
Summary and Discussion

(1) The order of the factors affecting the moisture content of stem after storage is water temperature of stem washing, water flow, pump frequency of stem washing machine, outlet temperature of stem steaming machine, and the water temperature of stem washing is the significant influence.

(2) The optimum water temperature of stem washing is 59.7°C, and then the moisture content of stem after storage can reach the central value of process standard (32.5%).

(3) The moisture content after stem storage will not increase with the increase of the water flow, the reason may be that the tobacco stem has been soaked on the surface after the stem washing machine, so it can’t continue to absorb the water in the stem steaming machine.

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