Study on the Optimization of Energy Saving and Consumption Reducing Process of Tobacco Leaf Beating*

Yang Yang¹, *, Yuhai Zhang², *, Mingyi Ou¹, Shuang Gong¹, Lei Han¹, Youxiang Wu¹, Shuang Gong¹, Sucan Liu¹ and Hongqing Xu¹

¹Technical Center, China Tobacco Guizhou Industrial Co., Ltd., Guiyang, China
²Technology laboratory, Zhengzhou Tobacco Research Institute of CNTC, Zhengzhou, China

*Corresponding author e-mail: yancaozhangyuhai@126.com, a470503299@qq.com

Abstract. In order to realize energy saving and consumption reduction in the threshing and rebaking of flue-cured tobacco, this study conducted a process optimization study on reducing the intensity of leaf clotting on the premise of not affecting the current tobacco structure of the finished sheet. The results showed that “Low moisture and low strength” beating and rebaking can improve energy saving, consumption reduction and tobacco quality; using a wetting export moisture 17.5%, two outlet temperature 50 ℃, a kind of roll speed 400 r/min parameters can realize leaf energy saving is obtained; the energy saving and reducing effects of the moisture, temperature, speed of the first dozen rollers, C3F rebaking intensity and B2F rebaking intensity were respectively 10.26%, 13.79%, 27.27%, 3.89% and 5.20%.

1. Introduction

The threshing and redrying process is an essential part in cigarette manufacturing [1]. Since State Tobacco Monopoly Administration proposed [2] the major special project of upgrading the threshing and redrying technology, threshing and redrying enterprises and cigarette industrial enterprises have done lots of researches on it. At present, relevant researches on threshing and redrying get involved in slitting process[3], screening re-threshing process [4], structure optimization of defoliator [5], flavoring and casing process before drying [6-7], chemical stalk-removing purification process, stem content in lamina of different grades [9], near-infrared threshing and redrying technology [10], and impacts of conditioning mode on tobacco quality [11], but scholars seldom study energy saving and cost reduction of threshing and redrying. It is widely believed that China is the great power of cigarette manufacturing. A huge number of tobaccos are used for threshing and redrying process every year. Therefore, energy saving cost reduction [12] of technological innovation undoubtedly will create high benefits to threshing and redrying processing enterprises. In this research, targeted at threshing and redrying process with “low moisture and low strength” (suitable reduction of conditioning strength, rolling strength and redrying strength), the process research was done under the precondition of guaranteeing quality of flue-cured tobacco lamina before drying, hoping to achieve the goal of energy saving and cost reduction for threshing and redrying process.
2. Materials and methods

2.1. Materials

2.1.1. Raw materials. C3F and B2F flue-cured tobaccos from Bijie, Guizhou Province were purchased by China Tobacco Guizhou Industrial Co., Ltd.

2.1.2. Main equipment. 12000kg/h threshing and redrying lines and testing equipment in the Bijie Redrying Plant

2.2. Methods

The process flow diagram of the Bijie Redrying Tobacco was shown in Figure 1. Threshing and redrying functions are codetermined by the conditioning section (first conditioning and second conditioning), threshing section (twelve parts with five times of threshing), and redrying wetting-back section [1]. The second conditioning outlet moisture and temperature are final representations of the effect in the conditioning section. The first rolling speed is the core factor to affect the flue-cured tobacco lamina structure. The research idea was that under the precondition of guaranteeing flue-cured tobacco lamina structure before drying, “threshing and redrying process technology with “low moisture and low strength” was used to realize energy saving and cost reduction. The previous researches indicated that the second conditioning tobacco temperature had the positive correlation with the first rolling speed, while the second conditioning tobacco moisture content also had the positive correlation with wind speed at all levels. Thus, the author in this research reduced the second conditioning outlet moisture, the second conditioning temperature, and the first rolling speed, so as to decrease the redrying strength and develop a role of energy saving and cost reduction.

Figure 1. Process flow chart of leaf redrying in Bijie Redrying plant
2.2.1. The single factor experiment. The single factor experiment was adopted to the second conditioning outlet moisture, the second conditioning outlet temperature, and the first rolling speed. According to the principles of energy saving and cost reduction, two gradients were designed to the lower process parameter setting to make a comparison with conventional process parameters. The test was repeatedly for three times. According to relevant standards [14-16], the flue-cured tobacco lamina before drying in each test was detected and conducted statistical analysis.

2.2.2. The low-strength parameter combination test. The suitable low-strength parameters of the second conditioning outlet moisture, the second conditioning outlet temperature and the first rolling speed were chosen from the 1.2.1 test results for combination, while other parameters were unchanged to compare with conventional process parameters. The test was repeatedly for three times. The flue-cured tobacco lamina before drying was detected and conducted statistical analysis.

2.2.3. Realistic records of the redrying strength process. The flue-cured tobacco lamina threshed with 1.2.2 optimized parameters and the flue-cured tobacco lamina threshed with conventional process parameters were respectively re-dried. Since moisture of the flue-cured tobacco lamina threshed with low-strength parameters before entering into the dryer had a difference with conventional parameters, the redrying strength was suitably lowered according to the demands of the finished product flue-cured tobacco lamina. Realistic records of redrying-strength process parameters between them were conducted. The sensory quality of the finished product flue-cured tobacco lamina was compared in accordance with YC/T-1998.

2.2.4. Effect comparison of energy saving and cost reduction. The effect calculation formula of energy saving and cost reduction was shown in Formula. The total temperature of redrying was the temperature sum of the first drying zone, the second drying zone, the third drying zone, the fourth drying zone, the fifth drying zone, and the sixth drying zone.

**Formula:**

\[
\text{The effect of energy saving and cost reduction} = \frac{\text{Before optimization} - \text{After optimization}}{\text{Before optimization}} \times 100\%
\]

3. Results and analysis

3.1. The impacts of the second conditioning outlet moisture on the finished product

The active second conditioning outlet moisture in the threshing and redrying plant was investigated. On the basis of active parameter 19.5%, 1% and 2% were respectively reduced for processing, marked as T1 and T2 to do the single factor contrast test with the conventional process parameter CK. After the equipment was stably operated, the flue-cured tobacco lamina before drying was conducted the sampling detection. The test results see Table 1.

| Tobacco grades | Dispose | Second conditioning export moisture /% | Large and medium-sized pieces of tobacco leaf /% | Small pieces of tobacco leaf /% | Broken tobacco leaf /% | Stem content in leaves /% | Leaf content in stem /% |
|----------------|---------|----------------------------------------|-----------------------------------------------|-----------------------------|-----------------------|-------------------------|------------------------|
| C3F            | T2      | 17.5                                   | 81.09 a                                       | 13.58 a                     | 0.45 a                | 1.38 a                  | 0.84 a                 |
|                | T1      | 18.5                                   | 82.08 a                                       | 13.24 a                     | 0.51 a                | 1.31 a                  | 0.78 a                 |
|                | CK      | 19.5                                   | 82.32 a                                       | 12.76 a                     | 0.41 a                | 1.34 a                  | 0.80 a                 |
| B2F            | T2      | 17.5                                   | 80.67 a                                       | 15.08 a                     | 0.59 a                | 1.34 a                  | 1.18 a                 |
|                | T1      | 18.5                                   | 82.82 a                                       | 14.85 a                     | 0.54 a                | 1.36 a                  | 1.01 a                 |
|                | CK      | 19.5                                   | 81.97 a                                       | 14.55 a                     | 0.52 a                | 1.31 a                  | 1.08 a                 |

Note: Same letter means no significant difference (P < 0.05), same as below.
It could be observed from Table 1 that T1 and T2 didn’t have an obvious impact on the C3F and B2F flue-cured tobacco lamina before drying, showing that when the second conditioning moisture was decreased to 17.5%, it didn’t cause an obvious impact on the flue-cured tobacco lamina before drying. From the perspective of energy saving and cost reduction, the second conditioning outlet moisture could consider T2 17.5% with the lower energy saving.

3.2. The impacts of the second conditioning outlet temperature on the finished product flue-cured tobacco lamina

The active second conditioning outlet temperature in the threshing and redrying plant was investigated. On the basis of the active parameter 58℃, 3℃ and 8℃ were respectively reduced for processing, marked as T3 and T4 to do the single factor contrast test with the conventional process parameter CK. After the equipment was stably operated, the flue-cured tobacco lamina before drying was conducted the sampling detection. The test results see Table 2.

| tobacco grades | dispose | second conditioning outlet temperature /% | large and medium-sized pieces of tobacco leaf /% | small pieces of tobacco leaf /% | broken tobacco leaf /% | stem content in leaves /% | leaf content in stem /% |
|----------------|---------|------------------------------------------|-----------------------------------------------|-------------------------------|------------------------|--------------------------|------------------------|
| C3F            | T4      | 50                                       | 83.63 a                                       | 12.76 a                       | 0.56 a                 | 1.37 a                   | 0.86 a                 |
|                | T3      | 55                                       | 83.65 a                                       | 12.96 a                       | 0.51 a                 | 1.26 a                   | 0.91 a                 |
|                | CK      | 58                                       | 83.31 a                                       | 12.48 a                       | 0.51 a                 | 1.39 a                   | 0.81 a                 |
| B2F            | T4      | 50                                       | 81.73 a                                       | 13.50 a                       | 0.63 a                 | 1.40 a                   | 1.02 a                 |
|                | T3      | 55                                       | 82.48 a                                       | 13.03 a                       | 0.56 a                 | 1.33 a                   | 1.05 a                 |
|                | CK      | 58                                       | 82.78 a                                       | 13.08 a                       | 0.55 a                 | 1.35 a                   | 0.92 a                 |

It could be observed from Table 2 that T3 and T4 didn’t have an obvious impact on the C3F and B2F flue-cured tobacco lamina before drying, showing that when the second conditioning temperature was decreased to 50℃, it didn’t cause an obvious impact on the finished product flue-cured tobacco lamina. From the perspective of energy saving and cost reduction, the second conditioning outlet temperature could consider 50℃ with the lower energy saving.

3.3. The impacts of the first rolling speed on the finished product flue-cured tobacco lamina

The active first rolling speed in the threshing and redrying plant was investigated. On the basis of the active parameter 550r/min, 50r/min and 100r/min were respectively reduced for processing, marked as T5 and T6 to do the single factor contrast test with the conventional process parameter CK. After the equipment was stably operated, the flue-cured tobacco lamina before drying was conducted the sampling detection. The test results see Table 3.

| tobacco grades | dispose | first rolling speed/(r/min) | large and medium-sized pieces of tobacco leaf /% | small pieces of tobacco leaf /% | broken tobacco leaf /% | stem content in leaves /% | leaf content in stem /% |
|----------------|---------|----------------------------|-----------------------------------------------|-------------------------------|------------------------|--------------------------|------------------------|
| C3F            | T6      | 450                        | 81.79 a                                       | 10.71 a                       | 0.39 a                 | 1.25 a                   | 0.61 a                 |
|                | T5      | 500                        | 81.17 a                                       | 13.31 a                       | 0.46 a                 | 1.78 a                   | 0.91 a                 |
|                | CK      | 550                        | 81.69 a                                       | 13.16 a                       | 0.50 a                 | 1.63 a                   | 1.01 a                 |
| B2F            | T6      | 450                        | 81.79 a                                       | 10.71 a                       | 0.39 a                 | 1.25 a                   | 0.61 a                 |
|                | T5      | 500                        | 81.65 a                                       | 14.06 a                       | 0.48 a                 | 2.01 a                   | 1.07 a                 |
|                | CK      | 550                        | 80.66 a                                       | 13.79 a                       | 0.51 a                 | 1.68 a                   | 0.99 a                 |
It could be observed from Table 3 that T5 and T6 didn’t have an obvious impact on the C3F and B2F flue-cured tobacco lamina before drying, showing that when the first rolling speed was decreased to 450r/min, it didn’t cause an obvious impact on the finished product flue-cured tobacco lamina. From the perspective of energy saving and cost reduction, the first rolling speed could consider 450r/min with the lower energy saving.

3.4. Process certification of optimized parameters

It could be observed from 2.1-2.3 that the second conditioning outlet moisture, the second conditioning outlet temperature, and the first rolling speed with the low-strength parameters didn’t have an obvious impact on the finished product flue-cured tobacco lamina. Three low-strength parameters of the second conditioning outlet moisture (17.5%), the second conditioning outlet temperature (50°C), and the first rolling speed (450r/min) were combined to compare with the conventional process parameter CK. The results were described in Table 4.

**Table 4.** Optimize process parameters before and after optimization on the structure of finished sheet smoke

| tobacco grades | dispose | large and mediumsized pieces of tobacco leaf /% | small pieces of tobacco leaf /% | broken tobacco leaf /% | stem content in leaves /% | leaf content in stem /% |
|---------------|---------|-----------------------------------------------|--------------------------------|------------------------|---------------------------|------------------------|
| C3F           | T7      | 80.89 a                                       | 11.21 a                        | 0.42 a                 | 1.55 a                    | 1.31 a                 |
|               | CK      | 81.09 a                                       | 12.16 a                        | 0.51 a                 | 1.65 a                    | 1.01 a                 |
| B2F           | T7      | 80.29 a                                       | 13.71 a                        | 0.59 a                 | 1.65 a                    | 0.91 a                 |
|               | CK      | 80.46 a                                       | 13.39 a                        | 0.55 a                 | 1.58 a                    | 0.89 a                 |

It could be observed from Table 4 that process parameters before and after optimization didn’t cause an obvious impact on the C3F and B2F flue-cured tobacco lamina before drying.

3.5. Realistic records of the redrying strength process

Under the precondition of meeting moisture safety for the flue-cured tobacco lamina quality, the flue-cured tobacco lamina with low-strength parameters before drying (after optimization) and the flue-cured tobacco lamina with conventional parameters (before optimization) were respectively conducted redrying process. The realistic records of the process were observed in Table 5, which showed that inlet moisture of the dryer after optimization was obviously lower than the result before optimization. After optimization, except for the temperature in the fourth wetting-back zone, other strength parameters of C3F tobaccos were significantly reduced. After optimization, except for material thickness, the temperature in the sixth wetting-back zone, and the temperature in the first wetting-back zone, other strength parameters of B2F tobaccos were significantly reduced. Redrying strength of C3F and B2F tobaccos after optimization was significantly lower than the result before optimization, showing that threshing with “low moisture and low strength” resulted in “low-strength” redrying.

**Table 5.** Comparison of rebaking intensity before and after optimization

| tobacco grades | before and after optimization | moisture in the grill inlet | dry zone temperature-1 | dry zone temperature-2 | dry zone temperature-3 | dry zone temperature-4 | dry zone temperature-5 | dry zone temperature-6 | redrying strength |
|----------------|------------------------------|----------------------------|-------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------|
| C3F            | before                       | 16.16 a                    | 60.51 a                 | 67.53 a                | 69.09 a                | 67.32 a                | 59.69 a                | 60.90 a                | 385.04 a          |
|                | after                        | 17.98 b                    | 64.50 b                 | 72.42 b                | 74.18 b                | 71.40 b                | 62.39 b                | 62.24 b                | 407.13 b          |
| B2F            | before                       | 15.45 a                    | 60.00 a                 | 67.70 a                | 68.53 a                | 68.01 a                | 60.89 a                | 60.29 a                | 385.42 a          |
|                | after                        | 17.44 b                    | 63.50 b                 | 73.57 b                | 74.70 b                | 71.88 b                | 61.21 b                | 60.25 a                | 405.11 b          |
Table 6. Influence of technological parameters on the sensory quality of post-baking smoke before and after optimization

| tobacco grades | before and after optimization | smoking aroma quality/score | volume of aroma /score | taste/ score | mixed gas/ score | pungent smell/score |
|----------------|-----------------------------|-----------------------------|------------------------|-------------|----------------|---------------------|
| C3F            | T7                          | 8.3                         | 8.35                   | 9.35        | 7.8            | 7.8                 |
|                | CK                          | 8.3                         | 8.3                    | 9.35        | 7.7            | 7.7                 |
| B2F            | T7                          | 8.15                        | 8.15                   | 9.1         | 7.8            | 7.7                 |
|                | CK                          | 8.1                         | 8.1                    | 9.1         | 7.7            | 7.7                 |

It could be seen from Table 6 that the process after optimization could improve the sensory quality of the finished product flue-cured tobacco lamina to some extent, reflecting in fragrance, offensive odor and irritant.

3.6. The effect comparison of energy saving and cost reduction

It could be observed from 2.1-2.6 that under the precondition of not affecting the flue-cured tobacco lamina, the threshing and redrying process with “low moisture and low strength” could develop a role of energy saving and cost reduction and could suitably improve the tobacco quality. Table 7 indicated that the energy-saving and cost-reducing effect of the second conditioning outlet moisture, the second conditioning outlet temperature, the first rolling speed, C3F redrying strength and B2F redrying strength in the threshing and redrying process with “low moisture and low strength” successively reached 10.26%, 13.79%, 18.18%, 5.43% and 4.86%, revealing the good energy-saving and cost-reducing effect.

Table 7. Efficiency of energy saving and consumption reduction before and after optimization

| parameter                        | before   | after   | energy saving |
|----------------------------------|----------|---------|---------------|
| second embellish leaf export moisture | 19.50%   | 17.50%  | 10.26%        |
| second embellish leaf export temperature | 58°C     | 50°C    | 13.79%        |
| first play roller speed          | 550 r/min| 450 r/min| 18.18%        |
| C3F redrying strength            | 407.13°C | 385.04°C| 5.43%         |
| B2F redrying strength            | 405.11°C | 385.42°C| 4.86%         |

4. Conclusions and discussions

By reducing the second conditioning outlet moisture and temperature, the threshing and redrying process with “low moisture and low strength” could successively reduce the first rolling speed and redrying strength, so as to develop a role of energy saving and cost reduction, as well as improve tobacco quality. The research results indicated that the threshing and redrying process with “low moisture and low strength” (17.5% of the second conditioning outlet moisture, 50°C of the second conditioning outlet temperature, and 450r/min of the first rolling speed) didn’t cause an obvious impact on the flue-cured tobacco lamina. The energy-saving and cost-reducing effect of the second conditioning outlet moisture, the second conditioning outlet temperature, the first rolling speed, C3F redrying strength and B2F redrying strength in this process successively reached 10.26%, 13.79%, 18.18%, 5.43% and 4.86%.

The findings were based on demands of China Tobacco Industrial Co., Ltd, production lines of the Bijie Redrying Plant and Bijie tobacco materials. The energy-saving and cost-reducing idea could be available for other enterprises’ reference. Limited by test conditions, the energy saving and cost reduction in this research only conducted the primary investigation from directivity, but specific energy saving(water, electricity and gas or something else) didn’t conduct detail statistics. Therefore, the descendants can do the further study on the energy saving and cost reduction of threshing and redrying the flue-cured tobaccos from the perspective of “low moisture and low strength”.


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