Asian Agricultural Research 2018, 10(11): 68 – 74 DOI: 10.19601/j.cnki.issn1943 – 9903.2018.11.013

Curing Technology for Improving the Quality of Upper Tobacco Leaves

Weijun ZHANG[1 *], Xiangli DONG[1], Musen LIN[1], Zhimo LI[1], Yi WANG[2], Zhixiao YANG[2], Haiqian XIA[2], Shengdong XIE[2]

1. Fenggang Branch of Guizhou Tobacco Company, Fenggang 564200, China; 2. Guizhou Academy of Tobacco Sciences, Guiyang 550081, China

Abstract In order to improve the curing quality and industrial availability of upper tobacco leaves, the effects of different temperature differences between dry and wet bulbs in yellowing stage on the chemical composition, aroma substances and economic characters of upper tobacco leaves were investigated using field test and indoor test. The results showed that when the dry bulb temperature was 38℃ and the temperature difference between dry and wet bulbs was 1.5℃, the coordination of chemical constituents and the content of aroma substances in the upper tobacco leaves were increased, the appearance quality and sensory evaluation quality were significantly improved, and the economic characters after curing were improved, thereby improving the yield and quality of the upper tobacco leaves.

Key words Flue-cured tobacco, Upper, One-time harvesting, Yellowing stage, Temperature difference between dry and wet bulbs, Yield and quality

1 Introduction

Flue-cured tobacco production requires certain curing equipment and supporting curing process. The purpose is to create an environment with suitable temperature and humidity to make fresh tobacco leaves yellow and dry and substances in the tobacco leaves transformed reasonably and orderly in a direction favorable to the quality of the tobacco leaves, thereby improving the curing quality of tobacco leaves[1]. Liu Hailun *et al.* [2 – 7] found that curing equipment and temperature and humidity conditions, activities of related enzymes and physiological changes of intracellular substances in the curing process all affect the quality of tobacco leaves. Wu Shengjiang *et al.* [8] and Liang Bin *et al.* [9] found that in the production of flue-cured tobacco in China, there are problems in the upper tobacco leaves such as high nicotine content, insufficient starch degradation, heavy offensive odor, and strong irritation, which seriously reduce the usability. Xu Zicheng *et al.* [10] believe that yellowing stage is a critical period for the curing process of tobacco leaves. During this period, macromolecular organic matter is decomposed into small molecular aroma substances or precursors of aroma substances. Therefore, the change of temperature difference between dry and wet bulbs in the yellowing stage has a great influence on the quality of tobacco leaves. Ji Chengcan *et al.* [11 – 13] found that one-time harvesting of the upper six leaves is conducive to the improvement of the quality of the tobacco leaves. However, there are few reports on the one-time harvesting and curing process of the upper leaves. The temperature change during curing largely determines various physiological and biochemical changes in the tobacco leaves and the transformation of various biological macromolecules[14]. In view of this, the upper tobacco leaves were harvested simultaneously as the test material, and combining the field test and indoor test, the effects of different temperature differences between dry and wet bulbs in yellowing stage on the chemical composition, aroma substances and economic characters of the upper tobacco leaves were investigated so as to improve provide a theoretical basis for improving the curing quality of upper tobacco leaves harvested at one time.

2 Materials and methods

2.1 Materials

2.1.1 Flue-cured tobacco. The upper six leaves of the flue-cured tobacco variety K326 were collected simultaneously, and they were divided into two parts: top 1 – 3 and top 4 – 6. Field management was carried out in accordance with local high-quality flue-cured tobacco production technical management regulations. Harvesting was based on the maturity standard for upper leaves.

2.1.2 Instruments and equipment. The used instruments and equipment included electric heated airflow descending oven with stocking density of 70 kg/m^3 (Shandong Xintai Company), VERCTOR 22/N Fourier transform near-infrared spectrometer (BRUKER, German), and HP5890 II-5972 GC/MS (USA).

2.2 Methods

2.2.1 Experimental design. A total of four treatments were designed. In the yellowing stage, the temperature of dry bulb was set as 38℃, and the temperature differences between dry and wet bulbs were set as 1.5℃ (T_1), 2.5℃ (T_2) and 3.5℃ (T_3), respectively. The temperature difference between dry and wet bulbs of 2.0℃ in the conventional curing process was used as the control (CK). A modified electric heated airflow descending oven was used. The rest of the curing parameters were the same with the one-time plucking and curing technology.

2.2.2 Measured indexes. (i) Chemical constituents. The in-

Received: September 22, 2018 Accepted: November 2, 2018

* Corresponding author. E-mail: 845224407@qq.com

tegrating sphere diffuse reflection detector of VERCTOR 22/N Fourier transform near-infrared spectrometer (BRUKER, German) was used to detect the chemical composition of the tobacco leaves with a gold-plated diffuse reflector. A certain amount (50 g) of tobacco leaf powder was placed into a quartz measuring cup, which was then added with a sample presser. Subsequently, a spectral scan was performed in the rotating table. Scanning conditions were as follows: resolution 8 cm, scanning times 64, spectral range 4 000 – 8 000 cm, room temperature is 24℃, and relative humidity 60%. This method can be used to determine the contents of nicotine, total sugar, reducing sugar, total nitrogen, protein, potassium and chlorine in tobacco leaves[15].

(ii) Contents of total phenols and free amino acids. The contents of total phenols and free amino acids were determined by Folin reagent colorimetric method and the ninhydrin colorimetric method, respectively[16].

(iii) Appearance quality. According to GB2635-92 (*Flue-cured Tobacco*), the appearance quality of the flue-cured tobacco leaves, such as maturity, leaf structure, body, color, oil and color intensity were evaluated. The score of each index was 10 points. The minimum integral unit for each individual index was 0.5 points. The average score was calculated by the following formula:

Average score = (Maturity × 35%) + (Oil × 25%) + (Body × 15%) + (Looseness × 25%).

(iv) Aroma substances. The tobacco leaf samples were qualitatively analyzed using the HP5890 II-5972 GC/MS. The GC/MS analysis conditions were as follows: column, hp-5 (60 m × 0.25 mm *i. d.* × 0.25 μm *d. f.*); carrier gas, He; flow rate, 0.8 mL/min; inlet temperature, 250℃, transfer line temperature, 280℃, and ion source temperature, 177℃. The heating program was as follows: 50℃ for 5 min; rising to 120℃ at 5℃/min for 5 min; rising to 180℃ at 5℃/min for 5 min; rising to 250℃ at 6℃/min for 15 min. The split ratio was 1∶15. The injection volume was 2 μL. The ionization voltage was 70 eV. The ionization model was E1. The mass number ranged from 50 to 500 amu. The MS library is the NIST library.

(v) Sensory quality. The sensory quality of the flue-cured tobacco leaves was evaluated by relevant experts organized by Shanghai Tobacco Group Technology Center according to YC/T138.1998 (*Tobacco and Tobacco Products: The Sensory Evaluation Methods*). The sensory quality evaluation indexes included aroma quality, aroma amount, concentration, soft fineness, aftertaste, offensive odor, irritation, combustibility and soot color. The score of each of them was 10 points. The minimum integral unit of each individual index was 0.5 points. The concentration and strength are the characteristics of tobacco leaf style, and they were not included in the calculation of the total score. The total score was calculated according to the following formula:

Total score = (Aroma quality × 20%) + (Aroma amount × 35%) + (Offensive odor × 20%) + (Irritation × 10%) + (Aftertaste × 15%).

(vi) Economic characters of flue-cured tobacco leaves. According to GB2635-92 (*Flue-cured Tobacco*), the flue-cured tobacco leaves were graded. The yield of flue-cured tobacco of each treatment was calculated. Then, the output value, average price and the proportion of superior tobacco leaves were calculated.

2.3 Data statistics and analysis Data processing and analysis were performed using DPS 17.0 and EXCEL 2010.

3 Results and analysis

3.1 Chemical composition and coordination of upper tobacco leaves at different temperature differences between dry and wet bulbs in yellowing stage

3.1.1 Contents of chemical components. As shown in Table 1, as the temperature difference between dry and wet bulbs increased, the contents of nicotine, total nitrogen, starch, protein and chlorine in the upper tobacco leaves gradually increased, and the contents of total sugar, reducing sugar, potassium, total phenols and free amino acids decreased. (i) Top 1 – 3. The contents of nicotine, total nitrogen, starch, protein and chlorine in the T_1 group were reduced by 10.88%, 8.81%, 4.61%, 2.12% and 5.26%, respectively compared those of the CK. Compared with the CK, the contents of nicotine were increased by 2.12% and 3.74%, respectively, and the contents of chlorine were increased by 10.53% and 15.79%, respectively in the T_2 and T_3 treatment groups. Compared with those in the CK, the content of total sugar was reduced by 5.41%, the content of reducing sugar was increased by 7.71%, the content of total phenols was increased by 0.35%, the content of free amino acids was increased by 5.51%, and the content of potassium was increased by 1.18% in the T_1 treatment group. Compared with those in the CK, the contents of total sugar were reduced by 1.48% and 1.66%, respectively, the contents of reducing sugar were reduced by 2.87% and 11.46%, respectively, the contents of potassium were reduced by 1.18% and 2.96%, respectively, the contents of total phenols were reduced by 0.35% and 1.73%, respectively, and the contents of free amino acids were reduced by 6.55% and 12.54%, respectively in the T_2 and T_3 treatment groups. (ii) Top 4 – 6. Compared with those in the CK, the contents of nicotine, total nitrogen, starch, protein, chlorine, and total sugar were reduced by 10.89%, 19.25%, 21.00%, 14.26%, 5.88% and 4.12%, respectively, and the contents of reducing sugar, total phenols, free amino acids and potassium were increased by 2.81%, 0.35%, 22.69% and 0.67%, respectively in the T_1 treatment group. Compared with those in the CK, the contents of nicotine were increased by 7.26% and 9.22%, respectively, the contents of total nitrogen were increased by 3.29% and 11.74%, respectively, the contents of starch were increased by 11.82% and 12.91%, respectively, the contents of protein were increased by 2.29% and 2.71%, respectively, and the contents of chlorine were increased by 0.15% and 2.71%, respectively, the contents of total sugar were reduced by 5.90% and 11.27%, respectively, the contents of reducing sugar were reduced by 8.10% and 10.55%, respectively, the contents of potassium were reduced by 8.16% and 9.48%, respectively, the contents of total phenols were reduced by 0.35% and 4.21%, respectively; and the contents of free amino acids were reduced by 10.69% and 14.29%, respectively in the T_2 and T_3 treatment groups.

In terms of the effects of different temperature differences between dry and wet bulbs on the chemical composition of top 1 – 3 and top 4 – 6 tobacco leaves, at the temperature difference between dry and wet bulbs of 1.5℃, the contents of chemical components in the upper tobacco leaves were most suitable, indicating that this treatment were better than other treatments.

Table 1 Effects of different temperature differences between dry and wet bulbs in yellowing stage on chemical composition of upper tobacco leaves

Treatment	Nicotine %	Total nitrogen %	Total sugar %	Potassium %	Chlorine %	Reducing sugar %	Starch %	Protein %	Total phenols %	Free amino acids μg/mg
Top 1 – 4										
T_1	3.85	2.07	23.57	1.71	0.18	20.68	6.42	9.69	2.90	11.11
T_2	4.54	2.35	22.03	1.67	0.21	18.65	7.76	10.11	2.88	9.84
T_3	4.58	2.41	21.99	1.64	0.22	17.00	7.98	10.27	2.84	9.21
CK	4.32	2.27	22.36	1.69	0.19	19.20	6.73	9.90	2.89	10.53
Top 4 – 6										
T_1	3.19	1.72	28.08	2.11	0.16	25.25	5.08	8.24	2.86	15.03
T_2	3.84	2.20	25.21	1.94	0.17	22.57	7.19	9.83	2.84	10.94
T_3	3.91	2.38	23.93	1.91	0.19	21.97	7.26	9.87	2.73	10.50
CK	3.58	2.13	26.97	2.11	0.17	24.56	6.43	9.61	2.85	12.25

3.1.2 Coordination of chemical constituents. It is generally considered that the suitable ranges of the ratio of sugar to alkali, ratio of nitrogen to alkali, ratio of potassium to chlorine, ratio of total sugar to reducing sugar, and Schmuck value are 6 – 9, 0.8 – 1.0, 4 – 10, > 0.8 and 2.0 – 2.5, respectively. As shown in Fig. 1, as the temperature difference between dry and wet bulbs in yellowing stage increased, the ratio of sugar to alkali, ratio of total sugar to reducing sugar, ratio of potassium to chlorine, and Schmuck value of the upper tobacco leaves all decreased, while the ratio of nitrogen to alkali changed slightly. The ratio of sugar to alkali (6.12) and the ratio of total sugar to reducing sugar (0.88) were both highest in the T_1 treatment group. They were reduced in the T_2 (4.85, 0.85) and T_3 (4.53, 0.77) treatment groups compared with those in the CK. The ratio of sugar to alkali of the T_1 treatment group and the ratio of total sugar to reducing sugar of the T_1 and T_2 treatment groups were in line with the requirements of high-quality tobacco leaves. The ratio of potassium to chlorine of the four treatment groups all reached the requirements of high-quality tobacco leaves. Among them, the ratio of potassium to chlorine in the T_1 treatment group (9.5) was greatest, followed by that in the CK, and the ratio in the T_3 treatment group (7.44) was the smallest. The Schmuck value in the T_1 treatment group was 2.3, reaching the requirements of high-quality tobacco leaves. The Schmuck values in the other treatment groups were greater (T_3, 3.6; T_2, 3.2; CK, 2.9).

3.2 Appearance quality of upper tobacco leaves at different temperature differences between dry and wet bulbs in yellowing stage As shown in Table 2, as the temperature difference between dry and wet bulbs in yellowing stage decreased, the maturity of the upper tobacco leaves increased. The maturity of the tobacco leaves was dominated by ripe, the leaf structure was improved, and the proportion of tobacco leaves that reached the degree of open increased. Among them, the proportion of tobacco leaves that reached the degree of open was highest in the T_1 treatment group, 85%. In addition, decreasing the temperature difference between dry and wet bulbs during the yellowing period could make the body of tobacco leaves to be moderate, and the proportion increased. The proportion of thick and slightly thicker tobacco leaves decreased. The proportion of orange tobacco leaves increased gradually, and the proportion of greenish tobacco leaves decreased. The oil content increased, and the color became thicker. On the whole, reducing the temperature difference between dry and wet bulbs during the yellowing period is beneficial to improving the appearance quality of the upper tobacco leaves. Among the treatment groups, the appearance quality of upper tobacco leaves in the T_1 treatment group was the best.

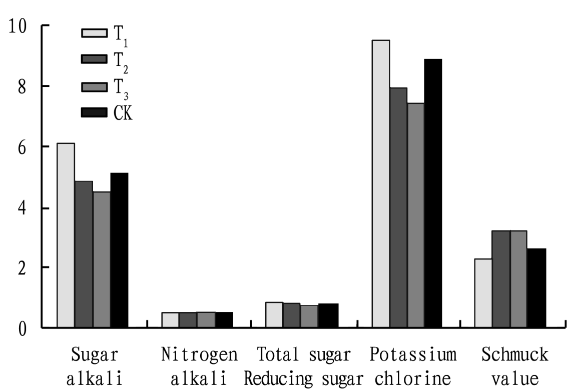

Fig. 1 Effects of different temperature differences between dry and wet bulbs in yellowing stage on the coordination of chemical components of upper tobacco leaves

3.3 Contents of aroma substances of upper tobacco leaves at different temperature differences between dry and wet bulbs in yellowing stage As shown in Table 3, a total of 29 compounds that played a significant role in the aroma of tobacco leaves were detected by GC/MS. Among them, the contents of furfural, solanone, β-damascenone, β-damascone, geranylacetone, dihydro kiwifruit lactone, farnesyl acetone and neophytadiene were higher.

With the temperature difference between dry and wet bulbs in yellowing stage increased, the total amount of aroma substances decreased. Compared with that in the CK, the total amount of aroma substances in the T_1 was increased by 14.84%, and those in the T_2 and T_3 treatment groups were reduced by 17.43% and 25.69%, respectively.

At the same time, the variation of aroma substances content in different treatment groups was basically the same. The content of phenylalanine degradation products in the T_1 treatment group was slightly lower than that of the CK, while the contents of carotenoids degradation products, browning products degradation products and cembranoid degradation products and neophytadiene of all the treatment groups decreased as the temperature difference between dry and wet bulbs increased.

Table 2 Effects of different temperature differences between dry and wet bulbs in yellowing stage on the appearance quality of upper tobacco leaves

Treatment	Maturity	Leaf structure	Body	Color	Oil	Color intensity
T_1	Ripe 100%	Open 85%	Fleshy 15%	Golden yellow 20%	Rich 25%	Deep 10% Strong 60%
		Firm 15%	Medium 85%	Orange 80%	Oily 75%	Moderate 30%
T_2	Ripe 90%	Open 60%	Heavy 15%	Golden yellow 40%	Rich 15%	Strong 55%
	Unripe 10%	Firm 40%	Fleshy 35%	Orange 45%	Oily 85%	Moderate 45%
			Medium 50%	Greenish 15%		
T_3	Ripe 75%	Open 50%	Heavy 25%	Golden yellow 45%	Oily 100%	Strong 45%
	Unripe 25%	Firm 30%	Fleshy 25%	Orange 30%		Moderate 40%
		Close 20%	Medium 50%	Greenish 25%		Weak 15%
CK	Ripe 100%	Open 75%	Fleshy 25%	Golden yellow 30%	Rich 20%	Deep 15%
		Firm 25%	Medium 75%	Orange 70%	Oily 80%	Strong 65%
						Moderate 20%

Table 3 Effects of different temperature differences between dry and wet bulbs in yellowing stage on content of aroma substances in upper tobacco leaves

μg/g

Aroma substances	Aroma ingredients	T_1	CK	T_2	T_3
Phenylalanine degradation products	Benzaldehyde	0.77	0.21	0.17	0.49
	Benzyl alcohol	0.71	0.57	0.36	0.53
	Phenylacetaldehyde	0.14	0.18	0.20	0.20
	Phenylethanol	1.21	0.51	0.80	0.14
	Linalool	0.35	0.36	0.17	0.18
	Total	3.18	1.83	1.70	3.24
Browning products degradation products	Furfural	10.45	3.23	2.56	7.52
	Furfuryl alcohol	0.17	0.11	0.09	0.11
	2-Acetyl furan	0.35	0.12	0.07	0.19
	5- Methylfurfural	0.31	0.32	0.27	0.32
	3,4-Dimethyl-2,5-furan	1.81	0.98	1.08	1.08
	2-Acetylpyrrole	0.08	0.11	0.10	0.07
	4-Vinyl-2-methoxyphenol	0.23	0.11	0.18	0.28
	Total	13.39	4.97	4.34	9.57
Cembranoid degradation product	Solanone	38.49	20.59	24.06	34.40
	Total	38.49	20.59	24.06	34.40
Carotenoids degradation products	β-damascone	2.30	0.36	0.97	2.10
	β-damascenone	20.99	9.20	8.41	15.23
	Geranylacetone	4.92	3.04	3.82	2.69
	Dihydro kiwifruit lactone	1.77	0.95	1.49	1.11
	Dehydrogenated β-ionone	0.37	0.22	0.24	0.15
	Megastigmatrienone 1	0.09	0.19	0.12	0.09
	Megastigmatrienone 2	0.09	0.36	0.46	0.37
	Megastigmatrienone 3	1.30	0.45	1.33	0.47
	3-Hydroxy-β-damascone	0.50	0.44	0.44	0.33
	Megastigmatrienone 4	1.20	0.61	0.57	0.49
	Solavetivone	0.10	0.83	1.06	0.96
	Farnesylacetone	2.90	3.34	3.89	2.19
	Oxidized isophorone	0.20	0.06	0.17	0.17
	6-methyl-5-hepten-2-o	0.29	0.29	0.18	0.26
	Total	38.26	20.57	23.28	26.98
Chlorophyll degradation product	Neophytadiene	282.97	217.39	183.49	251.06
Total content of aroma substances		395.01	284.02	255.59	343.97

3.4 Sensory quality of upper tobacco leaves at different temperature differences between dry and wet bulbs in yellowing stage As shown in Table 4, as the temperature difference between dry and wet bulbs in yellowing stage narrowed, the aroma quality and combustibility of the upper tobacco leaves became better, the amount of aroma, soft fineness, and soot color were improved, the aftertaste was more comfortable, and the offensive odor was decreased, leading to improved sensory quality. Among them, the sensory score of the upper tobacco leaves in the T_1 treatment group was highest, while that in the T_3 treatment group was lowest. It indicated that reducing the temperature difference between dry and wet bulbs during the yellowing period can effective improve the sensory evaluation quality of the upper tobacco leaves, which in turn increases the industrial availability of the upper tobacco leaves.

Table 4 Effects of different temperature differences between dry and wet bulbs in yellowing stage on sensory evaluation quality of upper tobacco leaves

Treatment	Aroma quality	Aroma amount	Soft fineness	Aftertaste	Offensive odor	Irritation	combustibility	Soot color	Total score
T_1	6.06	6.31	6.31	6.06	5.94	6.00	6.00	5.75	54.81
T_2	5.94	6.10	6.25	5.94	5.63	5.81	5.75	5.25	52.92
T_3	5.94	6.00	5.88	5.88	5.69	5.81	5.75	5.00	52.08
CK	6.00	6.31	6.25	5.94	5.75	6.06	5.75	5.50	54.06

3.5 Economic characters of upper tobacco leaves at different temperature differences between dry and wet bulbs in yellowing stage As shown in Table 5, with the increase of temperature difference between dry and wet bulbs in yellowing stage, the yield, output value and proportion of superior tobacco leaves showed a downward trend. Among different treatment groups, the yield and output value of tobacco leaves in the T_1 treatment group were highest, 5.08% and 2.91%, respectively higher than those in the CK ($P < 0.05$). The yield and output value of tobacco leaves in the T_2 and T_3 treatment groups were 3.35% and 1.15%, and 20.74% and 16.22% lower than those in the CK. The yield and output value of tobacco leaves in the T_3 treatment group were significantly different from those in the CK and T_2 groups ($P < 0.05$), while there were no significant differences between CK and T_2 groups. The proportion of superior tobacco leaves in the T_1 treatment group was highest (87.69%), and that in the T_3 treatment group was lowest (56.41%). The differences in the proportion of superior tobacco leaves of different treatment groups were significant ($P < 0.05$). The price of tobacco leaves was highest in the T_1 treatment group, and it was 0.33 yuan/kg higher than that in the CK; and the prices of tobacco leaves in the T_2 and T_3 treatment groups were 0.35 and 0.85 yuan/kg lower than that in the CK ($P < 0.05$).

Table 5 Effects of different temperature differences between dry and wet bulbs in yellowing stage on economic characters of upper tobacco leaves

Treatment	Output value//yuan/ha	Yield//kg/ha	Proportion of superior tobacco leaves//%	Price//yuan/kg
T_1	21 335.40 a	1 326.60 a	1 326.60 a	16.08 a
T_2	19 622.55 b	1 274.25 b	64.55 c	15.40 c
T_3	16 092.00 c	1 080.00 c	56.41 d	14.90 d
CK	20 303.40 b	1 289.10 b	75.84 b	15.75 b

Note: Different lowercase letters in the same column indicate significant differences at the 0.05 level.

4 Conclusions and discussion

Curing is the key link in the production of flue-cured tobacco. Tobacco leaves produce a series of complex physiological and biochemical reactions during the curing process[17]. In the yellowing stage of tobacco leaf curing process, the yellowing speed and dehydration speed are coordinated mainly through slow yellowing and slow softening at low temperature, so that the internal ingredients of tobacco leaves are fully transformed to produce rich aroma base materials, laying a good foundation for color fixing of tobacco leaves. The operating principle is to stabilize the dry bulb temperature and adjust the wet bulb temperature, thus prolonging the yellowing period and making sure the leaves are fully yellow and soft. Yang Lijun *et al.* [18] confirmed that when the wet bulb temperature is 1 – 4℃ lower than that of the dry bulb temperature in yellowing stage, the internal components of tobacco leaves can be fully transformed to produce rich aroma base materials, and the yellowing speed and dehydration speed can be coordinated to lay a food foundation for color fixing of tobacco leaves. This study showed that different from the treatments with temperature differences between dry and wet bulbs of 2.5℃ and 3.5℃, the treatment with temperature difference between dry and wet bulbs of 1.5℃ reduced the contents of nicotine, total nitrogen, starch, protein and chlorine, and increased the contents of total sugar, reducing sugar, potassium, total phenols and free amino acids in upper tobacco leaves to make the internal chemical composition more harmonious. At the same time, it increased the aroma amount and improved the economic characters of cured tobacco leaves. The appearance quality and sensory quality were also significantly improved, thereby improving the yield and quality of upper tobacco leaves.

Zeng Zhisan *et al.* [19] pointed out that from the perspective of balancing average price and superior tobacco leaf ratio and practical consideration of production operations, the temperature and relative humidity during the yellowing stage should be constant at 37.5 – 38.0℃ and 85.0% – 88.0%, respectively. That is, the temperature difference between dry and wet bulbs is preferably 1.5 – 2.0℃. Ai Fuqing *et al.* [7] found that the when the temperature and relative humidity in the yellowing stage of upper tobacco leaves were constant at about 34.0℃ and 88.0%, *i. e.*, the temperature difference between dry and wet bulbs is about 1.5℃, the activity of protease was maintained at a high level. The results of the study confirmed that under the conditions of dry bulb temperature of 38℃ and temperature difference between dry and wet bulbs of 1.5℃ in the yellowing stage, the upper tobacco leaves had the highest economic benefit and good quality, which is basically consistent with the results of previous studies. The study results of Cai Xianjie *et al.*[20] showed that during the curing process, when the dry bulb temperature was 38℃ and the temperature difference between dry and wet bulbs ranged from 3℃ (relative humidity 79%) to 1.5℃ (relative humidity 89%), the activity of amylase was highest, which was beneficial to the full transformation of starch in tobacco leaves. In this study, when the dry bulb temperature was 38℃ and the temperature difference between dry and wet bulbs was 1.5℃, the coordination of chemical constituents and the amount of aroma substances in the upper tobacco leaves were increased, the appearance quality and sensory quality were significantly improved, and the economic characters of cured tobacco leaves were also improved. This was mainly because that at the temperature difference between dry and wet bulbs in yellowing stage of 1.5℃, the moisture loss rate of the tobacco leaves slowed down, the yellowing time of the tobacco leaves was correspondingly extended, so that the tobacco leaves have enough time to maximize the decomposition, transformation and accumulation of the internal components, thereby promoting the formation of more aroma substances[21]. In addition, as the flow rate of air at the temperature difference between dry and wet bulbs of 1.5℃ slowed down, the loss of gland secretions decreased, so the problem of insufficient aroma of tobacco leaves was also improved to some extent. The upper tobacco leave were harvested according to the standards for one-time plucking. The maturity of the upper tobacco leaves was higher, so the moisture content of the tobacco leaves was low. Gong Changrong[22] considers that for tobacco leaves with low moisture content, the temperature difference between dry and wet bulbs can be reduced to about 1℃ to maintain the moisture and extend the yellowing duration. Some studies[23-25] have suggested that low temperature yellowing is beneficial to the formation and accumulation of aroma precursors in tobacco leaves, so that the amount and types of aroma substances in the tobacco leaves after curing are increased. Simultaneously, starch and protein can be fully degraded, and the decomposition of insoluble nitrogen is promoted to increase the contents of total sugar, reducing sugar and amino acids and reduce the contents of total nitrogen and nicotine in upper tobacco leaves. This may be because that under the conditions of low temperature and suitable humidity, the water loss rate and yellowing rate of tobacco leaves become lower, leading to longer yellowing time. As a result, the inside of tobacco leaves can maintain a suitable moisture content for a long time[26], and the cell membrane structure and function can maintain activity for a longer term, thereby fully degrading and transforming the organic matter in the upper tobacco leaves, which is conducive to promoting the formation of aroma substances in tobacco leaves[10]. However, at high temperature or large temperature difference between dry and wet bulbs in yellowing stage, the dehydration rate of tobacco leaves will be too fast, and cell membrane lipid peroxidation is prone to occurring, which lead to the generation of scalded tobacco leaves and reduce the appearance quality and intrinsic quality of tobacco leaves[27]. At the same time, high temperature and high humidity can lead to sharp increase in membrane lipid peroxidation, destroying cell structure, increasing the activity of various enzymes sharply but with a short duration. This is not conducive to the degradation, transformation and accumulation of various internal components in tobacco leaves[21].

References

[1] DENG YL, CUI GM, ZHANG ST. Effects of different type of flue-curing barns and the according curing-procedures on the starch content of the tobacco leaf[J]. Journal of Yunnan Agricultural University, 2004, 19(2): 63-67. (in Chinese).

[2] LIU HL. Mechanism of producing gradually yellowish tobacco under soft temperature using three-phase-drying method[J]. Journal of Northwest A & F University (Natural Science Edition), 2001, 29(3): 45-47. (in Chinese).

[3] WANG Y, CHEN LY, LIU KL, *et al.* Effects of single- and multi-stage drum drying on drying efficiency and aroma quality of flue-cured cut tobacco[J]. Journal of Southern Agriculture, 2015, 76(1): 117-122. (in Chinese).

[4] ZHOU C, JIN H, FANG B, *et al.* Effect of different curing techniques on main qualitative character of tobacco variety NC297 introduced from America[J]. Journal of Southern Agriculture, 2015, 76(7): 1275-1279. (in Chinese).

[5] WEI FJ, SHI QH, WANG HT, *et al.* Effects of flue-curing in different on the neutral aroma components types of flue-curing barns in flue-cured tobacco leaf[J]. Journal of Henan Agricultural University, 2007, 41(6): 595-599. (in Chinese).

[6] ZHANG ST, ZHU ML, YANG XB. Effect of flue-curing condition on the change of bacteria during curing of flue-cured tobacco[J]. Tobacco Science & Technology, 2001, 45(4): 42-43. (in Chinese).

[7] AI FQ, WEI Y, CHEN LP. Influence of yellowing condition on protease activity of upper leaves of flue-cured tobacco[J]. Hubei Agricultural Sciences, 2010, 49(3): 83-85. (in Chinese).

[8] WU SJ, SONG ZP, XU ZC, *et al.* Cell wall physiological changes of tobacco leaves during curing process[J]. Chinese Tobacco Science, 2010, 31(3): 73-77. (in Chinese).

[9] LIANG B, WEI YJ, ZHOU YB, *et al.* The unmarketable reason of the upper leaves of tobacco and countermeasure in agricultural production[J]. Journal of Anhui Agricultural Sciences, 2002, 30(2): 285-286. (in Chinese).

[10] XU ZC, HUANG PJ, SU FQ, *et al.* Effects of different picking methods on quality of upper leaf in flue-cured tobacco[J]. Journal of Northwest A & F University (Natural Science Edition), 2005, 33(11): 13-17. (in Chinese).

[11] JI CX, WANG SL, XU XX, *et al.* Agronomic measures to improve upper leaf availability and reduce upper leaf proportion[J]. Chinese Tobacco Science, 2001, 22(4): 19-22. (in Chinese).

[12] ZHAO YK. Experiment on flue-curing of top leaves with stalk[J]. Tobacco Science & Technology, 2004, 48(4): 36-37. (in Chinese).

[13] WANG J, YANG YG, WANG SF, *et al.* Harvest method of upper leaves of flue-cured tobacco variety Honghuadajinyuan[J]. Chinese Tobacco Science, 2010, 31(2): 15-19. (in Chinese).

[14] WANG HZ, YANG HW, GUO HY. Effects of temperature and humidity on starch degradation and related enzyme activities of flue-cured tobacco during flue-curing process[J]. Acta Agronomica Sinica, 2006, 32(2): 313-316. (in Chinese).

[15] FU QJ, DU YM, CHANG AX, *et al.* Correlation between physical characters and chemical compositions in flue-cured tobacco leaves and establishment of NIR calibration models[J]. Chinese Tobacco Science, 2009, 15(6): 41-43. (in Chinese).

[16] WANG RX, HAN FG, YANG SQ. Chemical quality analysis of tobacco leaves[M]. Zhengzhou: Henan Science and Technology Press, 1998. (in Chinese).
[17] YIN YX, ZHANG FM, PENG JQ, *et al*. Effects of two curing technologies on major quality characters of Honghuadajinyuan tobacco variety [J]. Guizhou Agricultural Sciences, 2017, 45(4): 102 – 105. (in Chinese).
[18] YANG LJ, GONG CR. The operating technique of three-stage curing of flue-cured tobacco[J]. Tobacco Science & Technology, 2003, 47(7): 46 – 48. (in Chinese).
[19] ZENG ZS, AI FQ, ZHONG L, *et al*. Study on regularity of average price and rate of first class of flue-cured tobacco in different yellowing environment of flue-curing[J]. Chinese Agricultural Science Bulletin, 2007, 23(11): 117 – 121. (in Chinese).
[20] CAI XJ, YIN QS, WANG XM, *et al*. Effects of temperature and humidity on amylase activity in flue-cured tobacco during curing[J]. Tobacco Science & Technology, 2006, 50(12): 43 – 45, 64. (in Chinese).
[21] WANG ZS, WANG Z, PAN YH, *et al*. Effects of different fan frequency on flavor precursors and smoking quality of flue-cured tobacco leaves in a bulk curing barn with four layers[J]. Guizhou Agricultural Sciences, 2017, 45(3): 33 – 36. (in Chinese).
[22] GONG CR. Tobacco modulation[M]. Beijing: China Agriculture Press, 2006. (in Chinese).
[23] GAO YZ, WANG WF, ZHANG J, *et al*. Effects of different temperature and humidity yellowing conditions on neutral aroma constituents of tobacco leaves during bulk curing[J]. Journal of Yunnan Agricultural University, 2008, 23(2): 215 – 219. (in Chinese).
[24] WANG L, MIAO GY, LIU HS, *et al*. Effects of temperature and moisture of flue-curing on the aroma in tobacco leaves[J]. Journal of Henan Agricultural Sciences, 2007, 36(8): 28 – 30. (in Chinese).
[25] DONG ZJ, CHEN JH, GONG CR. Study on changes of main chemical components in flue cured tobacco leaf under different yellowing and colour-fixing temperature[J]. Chinese Tobacco Science, 2000, 21(3): 21 – 24. (in Chinese).
[26] DAI L, HUANG YC, GONG CR, *et al*. Effects of different temperature and humidity yellowing conditions on aroma constituents of tobacco leaves during bulk curing[J]. Acta Agriculturae Boreali-Sinica, 2008, 23(6): 148 – 152. (in Chinese).
[27] HUANG S, YANG HQ, ZHANG FM, *et al*. Effect of baking temperature and humidity change on leaf membrane lipid peroxidation to the different varieties of flue-cured tobacco[J]. Journal of Hunan Agricultural University, 2009, 35(5): 485 – 492. (in Chinese).

(From page 47)

4.6 Enhancing the integration of the primary, secondary, and tertiary industries, and developing the gardening experience in the expansion of functions At weekends and in holidays, hundreds of thousands citizens of Wuhan City go sightseeing. Such demand is a great stimulation for grape industry. President Deng Xiuxin of Huazhong Agricultural University highly praised the new form of "gardening experience", which combines agriculture and tourism and is a feasible solution to the development of grape industry in Wuhan City. Through properly arranging and matching grape trees, other fruit trees, flowers, vegetables, and aquatic products, it is feasible to build experience gardens, to attract citizens to go sightseeing and take part in some interactive activities, such as fruit trees and flowers planting management, and extraction of simple functional components, to make them enjoy the fun, so as to promote the healthy development of the grape industry in Wuhan City.

References

[1] Statistics Bureau of Wuhan Municipality. The statistical bulletin of Wuhan national economic and social development in 2017[EB/OL]. http://www.tjcn.org/tjgb/17hb/35419_2.html, 2018-05-26. (in Chinese).
[2] Statistics Bureau of Wuhan Municipality. The third national agricultural census main data bulletin in Wuhan City[EB/OL]. http://www.whtj.gov.cn/details.aspxid=3937, 2018-03-14. (in Chinese).
[3] HE HP, ZHANG XW. The situation and development of grape vines in Hubei Province[J]. News of Citrus and Subtropical Fruit, 1994, 2(4): 10 – 11. (in Chinese).
[4] HE HP, ZHANG HG, ZHANG XW. The performance of twelve fresh grapes in Wuhan[J]. South China Fruits, 2001, 30(3): 48. (in Chinese).
[5] HE HP, GONG LZ, GU X. The situation and development of grape vines in Hubei Province[J]. Hubei Agricultural Sciences, 2002, 48(6): 84 – 86. (in Chinese).
[6] ZHONG Q, FU W, LUO L, *et al*. Grape cultivation techniques in Chengdu Region[J]. Science and Technology of Sichuan Agriculture, 2018, 48(3): 9 – 10. (in Chinese).
[7] LU H. Techniques of early cultivation of grapes[J]. Agricultural Technology Service, 2017, 34(1): 112, 114. (in Chinese).
[8] CHEN JY, LU ZW, GU H, *et al*. Present situation, problems and development suggestions of grape industry in Zhengzhou[J]. Fruit Growers Friend, 2017, 18(4): 37 – 39. (in Chinese).
[9] MAO NN, LIU WZ, JI MX, *et al*. Introduction and cultivation techniques of "sunshine rose" grape[J]. Jiangsu Agricultural Sciences, 2016, 44(12): 204 – 205. (in Chinese).
[10] YU LJ. The new model of labor saving cultivation in vineyard[J]. Journal of Liaoning Agricultural College, 2017, 19(4): 4 – 6. (in Chinese).
[11] MENG XZ, WANG AW, WANG JF, *et al*. Analysis on grape industry in Hefei area and its development strategies[J]. Sino – Overseas Grapevine & Wine, 2017, 42(4): 12 – 14. (in Chinese).
[12] XIANG JQ, WANG YX. Study on "Internet +" sales model innovation of Dalian LVshun cherry[J]. Journal of Chifeng College: Natural Science Edition, 2018, 34(3): 59 – 61. (in Chinese).