Journal of Modern Crop Science (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/jmcs.2023.020103
ISSN 2616-2075 Vol. 2 Num. 1

Effects of Different Air Volume Supply Controlled by Circulating Fan on Tobacco Curing Characteristics

Guangting Yin[1], Wenyuan Li[1], Qingkai Nie[1], Jianan Wang[2], Lei Wang[1], Jia He[1], Dejian Wan[1], Weidong Duan[1,*]

[1]China Tobacco Henan Industrial Co., Ltd., Zhengzhou, 450000, China
[2]Henan Agricultural University, Zhengzhou, 450000, China
[*]Corresponding author

Keywords: Bulk curing barn, circulating fan, variable-frequency drive, starch degradation, water loss characteristic

Abstract: The air supply volume of the circulating fan directly affects the wind speed between leaves in the bulk curing barn. To find out the effect of different ventilation rates on the degradation and water loss characteristics of tobacco during the curing process, the national standard bulk curing barn simulation oven was used to set different frequencies with 5 gears on the circulating fan to control the rotation speed during the yellowing stage and the leaf drying stage of the different tobacco curing phases for testing. The results showed that with the change of the air supply volume of the circulating fan from low to high, the statistical analysis had a significant impact on the pigment degradation in the yellowing stage, the starch degradation in the yellowing stage and the leaf-drying stage, and the moisture removal of the leaves. The characteristic parameters of the impact related to the rate, process, and the residual amount of the leaves, and the extent of the impact was shown as leaf dehydration>starch degradation>pigment degradation. The results can be used as a reference for the reasonable regulation of the wind speed between leaves in the bulk curing barn according to the needs of the curing technology during tobacco curing process.

1. Introduction

The circulating fan is the power to drive the exchange heat between the smoke loading room and the hot air room of the bulk curing barn and to expel moisture to the outside, and it is the basis to ensure the implementation of the curing technology of Nicotiana tabacum L. At present, the circulating fan in bulk curing barn uses the air volume control with high and low gear (1440/960 r/min), which has the problems of light leaf color and high energy consumption after curing [1]. Accurate curing of tobacco leaves is the inherent requirement of lean production of tobacco leaves under modern agricultural construction [2]. In view of this situation, Liu Guanghui [3] and Liu Chuang [4] first used frequency conversion technology to control the wind speed during the yellowing and leaf-drying stage of tobacco leaves at the same time, and found that it could improve the quality of cured tobacco leaves. Subsequently, Li Xuhua and others [5] added a frequency converter to the circulating fan in the bulk curing barn to control the speed of the fan, and found that

the smoking quality of cured tobacco leaves was obviously improved. Then, many scholars carried out the research on the variable frequency control of fan air volume in cured tobacco curing in different regions. It is generally believed that the quality of cured tobacco leaves, the chemical composition in leaves and the income of tobacco farmers can be improved by using variable frequency control of circulating fan speed [6-10]. However, the above-mentioned research on variable frequency fan control focuses on the analysis and evaluation of the quality of cured tobacco leaves, and there are few reports on the color change and water loss state change of cured tobacco leaves. Based on this, this paper quantifies the output of air volume by controlling the rotation speed of blades through frequency conversion of circulating fan, and studies the effect of different frequency settings on the yellowing and water loss characteristics of tobacco leaves during curing, so as to provide reference for production.

2. Materials and Methods

2.1. Test Treatments

The tests were conducted at two tobacco stations, Tuanjie in Cangyuan County, Lincang City, and Songfeng in Xiangcheng County, Xuchang City, from 2021 to 2022. The selected middle tobacco leaves from the field had a leaf position of 12, medium nutrition levels, and consistent growth, and were harvested after they reached maturity. The leaves were chosen under conditions that ensured they had consistent size, shape, weight, initial water content, growth stage, and yellowing with the test material, and were hung on the blade.

According to the frequency conversion control in yellowing stage and leaf-drying stage in the above literature, taking the wind speed formed between leaves by the fan circulating at a high gear [6] in the current bulk curing barn as the limit value, five treatments are set respectively, namely T1, T2, …, T5. The treatment settings are shown in Table 1 below. In the tobacco curing process, only the frequency conversion control of the circulating fan is carried out, and the curing process is carried out according to the local curing process. During the stem drying stage, the circulating fan runs at the wind speed generated by the operation of the circulating fan at a low gear in the current production.

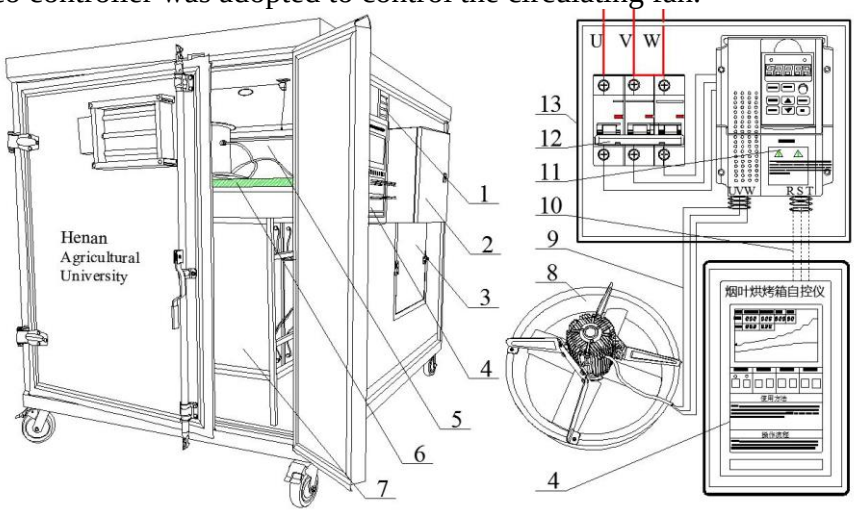
Table 1: Test processing setting/Hz

Test treatments		T1	T2	T3	T4	T5
Yellowing stage	Earlier stage	20	25	30	35	40
	Middle stage	25	30	35	40	45
	Later stage	30	35	40	45	50
Leaf-drying stage	Earlier stage	35	40	45	50	55
	Middle stage	40	45	50	55	60
	Later stage	35	40	45	50	55

2.2. Test Equipment

The standardized bulk curing oven (Figure 1) with a scale of 1:20 to the bulk curing barn specified in Document No.418 of the State. The tobaccos were arranged according to the local production cigarette holder, with a capacity of 20 rods. The tobacco leaves listed in the field were selected as test samples in the sampling window and numbered according to the sampling sequence. When sampling in the curing process, the vacant position of the taken tobacco leaves was replaced by tobacco leaves from other curing houses in the same curing stage to make up for the tuyere caused by sampling. The integrated mode of frequency converter (9600 model, Fuan Weiken Motor)

and cured tobacco controller was adopted to control the circulating fan.



(1) Dehumidifying window, (2) Inverter box, (3) Sample observation and sampling window, (4) Cured tobacco controller, (5) Partition wall, (6) Circulating fan, (7) Electric heating film, (8) Circulating fan, (9) Power cord, (10) Signal wire, (11) Inverter, (12) Air switch of power supply, (13) Inverter box.

Figure 1: Bulk oven and control device used in the test

2.3. Types of Substance Detection

The degradation of starch and pigment was taken as the typical representative substances of substance transformation and yellowing of tobacco leaves, and the dynamic changes of these two substances during the whole curing process were monitored.

2.4. Detection Methods

At the beginning of the sampling in tobacco leaf curing, the tobacco leaves were quickly sampled every 6 hours, and 2 leaves were sampled for each treatment. After sampling, they were dried in the oven, and then crushed and sealed after removing their main vein. The water contained was removed by fixation-based drying; the pigment was extracted from tobacco leaves by acetone soaking [11]; the amylase activity was determined by double wave colorimetry [12].

2.5. Data Analysis

Graph Pad Prism 5.0 (Graph Pad Software, Inc., USA) was used for data analysis and automatic image generation. Stata 16 (Stata Software, Inc., USA) was used for data regression analysis and establishment of regression equation.

3. Results and Analysis

3.1. Effect of Frequency Control on the Degradation of Tobacco Pigment

The degradation of pigment mainly occurs in the yellowing stage of tobacco curing. Figure 2 shows the change of pigment degradation under different frequency cycle control. Under different conditions of variable frequency control of circulating fan, the pigment degradation rate of tobacco leaves during curing can be affected, and the degradation rate is T2 > T3 > T1 > T4 > T5. At the

end of the later stage, there is a slight difference in the residual amount of pigment in leaves. The slight difference shows that the residual amount of T5 control pigment in leaves is relatively high, indicating that the pigment is not fully degraded.

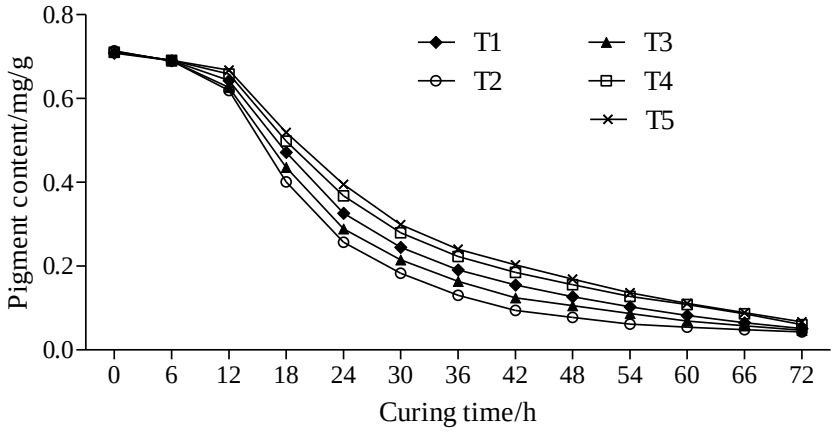


Figure 2: Changes of pigment degradation under the control of circulating fans with different frequencies

3.2. Effect of Frequency Control on Starch Degradation

The rate of starch degradation in cured tobacco leaves is different from that in the early yellowing stage (0-72 h) and the later leaf-drying stage (72-96 h) (Figure 3), which is characterized by fast degradation in the early stage and slow degradation in the later stage; in the early stage, the degradation controlled by high frequency is slow, and in the later stage, it shows the trend of rapid degradation. The starch content reaches the lowest in 84-90 h, slightly higher than that before the leaves were dried. The possible reason is that the degradation of other macromolecules or the nutrient consumption of leaves increases the starch content in the leaves at the end of this stage.

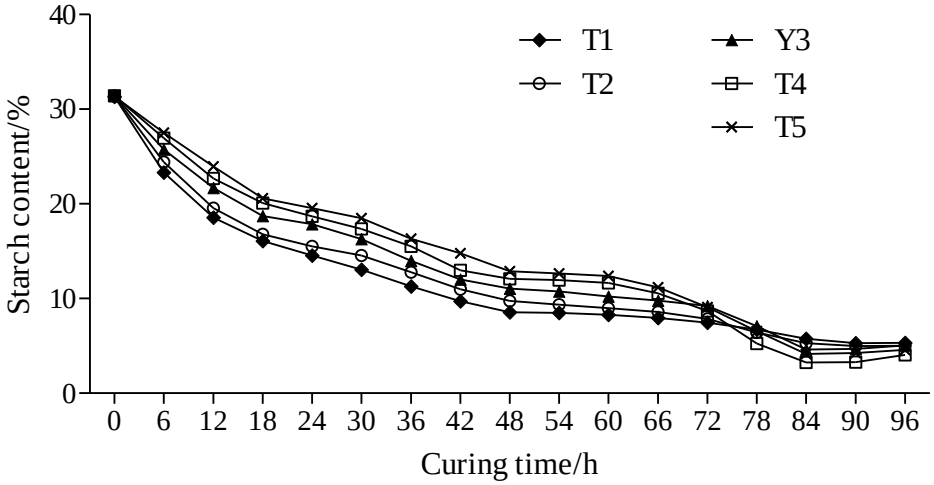


Figure 3: Changes of starch degradation under the control of circulating fans with different frequencies

3.3. Effect of Frequency Conversion Regulation on Blade Dehydration

Figure 4 shows the changes of moisture content of tobacco leaf under the control of circulating fans with different frequencies. The water loss rate is slow in the early stage, and it is rapid in the later stage. The water loss curves between treatments are T5 > T4 > T3 > T2 > T1, with obvious levels and great differences. Especially at the end of 96 h, the difference of water content in leaves between high and low frequency treatments is 15%, which shows that the higher the control frequency, the faster the water loss in leaves.

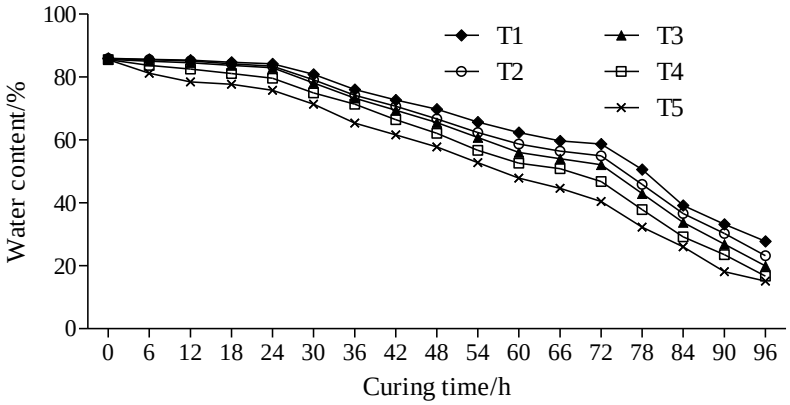


Figure 4: Changes of moisture content of tobacco under the control of circulating fans with different frequencies

3.4. Statistical Analysis

Pigment degradation (Y1), starch degradation (Y2) and leaf dehydration (Y3) were taken as objective functions, and tobacco curing sampling time (x1) and frequency control frequency (x2) were taken as independent variables. The effects of two independent variables, their interactions and quadratic terms on the objective functions were analyzed.

$$Y_1 = 0.551 - 0.010x_1 + 0.003x_2 \quad (1)$$

$$Y_2 = 18.904 - 0.238x_1 + 0.143x_2 \quad (2)$$

$$Y_3 = 115.936 - 0.680x_1 + 0.543x_2 \quad (3)$$

It can be seen from the formulas 1-3 that the regression coefficient values of the circulating fan frequency before the independent variable x2 reach 0.003 (t=1.681, p=0.098<0.1), 0.143 (t=3.649, p=0.000<0.01) and -0.543 (t=-7.258, p=0.000<0.01) respectively. The corresponding model R-squared values are 0.875, 0.888 and 0.947, which are (F=217.988, p=0.000<0.05), (F=326.454, p=0.000<0.05) and (F=739.136, p=0.000<0.05) respectively through the model F test. It shows that the frequency of circulating fan has a significant effect on pigment degradation, starch degradation and leaf dehydration in yellowing and leaf-drying stages of tobacco leaves under the condition of fixed programmed sampling time. There are some differences between R values, which shows that the effect of circulating fan on tobacco curing characteristics is: leaf dehydration > starch degradation > pigment degradation.

3.5. Effect of Wind Speed Regulation on Tobacco Curing Characteristics

Through the above results and statistical analysis, the effects of different wind speed regulation of circulating fan on pigment, substance transformation and water loss of tobacco leaves are obtained (Figure 5). With the increase of frequency conversion frequency, there are three trends in general. With the increase of wind speed between leaves, the speed of yellowing of tobacco leaves increases sharply at first and then decreases slowly. In the yellowing stage and leaf-drying stage of tobacco leaves degradation rate of macromolecular starch shows a trend of: sharp increase-slow decrease-slow increase-sharp decrease. The characteristics of leaf water loss show a trend of slow rise and then sharp rise.

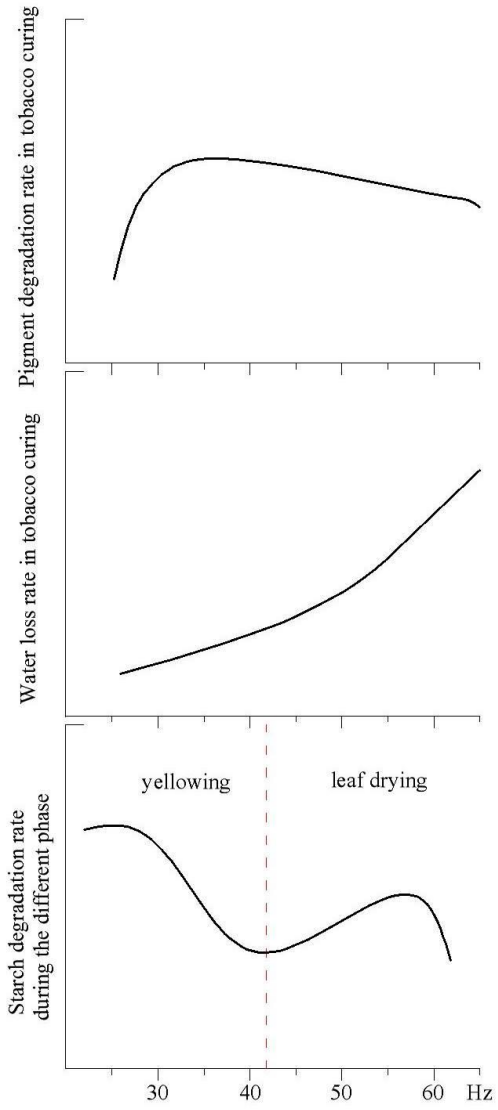


Figure 5: Substance degradation and dehydration under the control of circulating fans with different frequencies

4. Discussion

The degradation of starch in tobacco leaves during curing is a chemical reaction promoted by enzyme catalyst [13,14], and the activity of enzyme is affected by temperature and concentration [15,16]. In this paper, the different dynamic change curves of starch in yellowing stage and

leaf-drying stage of tobacco leaves is maybe because of obvious life characteristics of leaves in yellowing stage, suitable temperature to stimulate enzyme activity, and appropriate wind speed to promote orderly dehumidification of leaves and control enzyme concentration, which are beneficial to improve enzyme activity and accelerate starch conversion; the leaf-drying stage belongs to the drying stage, and the enzyme is gradually inactivated. The larger wind speed can promote the dehydration of leaves, thus increasing the enzyme concentration of leaf cells and accelerating the starch degradation. However, too high wind speed can easily lead to accelerated drying of local areas of leaves (such as leaf base, leaf edge and tip, etc.), and the failure to degrade starch affects the degradation speed of the whole leaf. For example, the rate of starch degradation at high wind speed T5 is obviously lower than that at T4. Therefore, this result can provide reference for reasonable control of the control frequency of circulating fans in tobacco-growing areas where the cured tobacco leaves have high starch content.

In tobacco-growing areas, there is often the case that the same frequency control value is set to adjust the rotation speed of the circulating fan after adding frequency converters, but there is a significant difference in the wind speed between leaves in the bulk curing barn and the appearance quality of the cured tobacco leaves, which affects the technical popularization of frequency conversion control circulating fans. On the one hand, tobacco plants are modified by DNA methylation in different ecological regions, resulting in different types and styles of fresh tobacco quality [17, 18]. This further affects the curing technology of cured tobacco [19]. On the other hand, it may be the reason for using different types of inverters. At present, there are three control types in the domestic inverter market: vector control inverter, synchronous motor inverter and direct torque control inverter, all of which have certain differences in input power factor, large harmonic current and DC loop capacitance [20]. There will be deviations in output power when using different types of inverters. This experiment was carried out in a specific place in the base of Henan CHINA TOBACCO. As for the changes of substances and water loss caused by frequency control of circulating fans in other tobacco-growing areas, further research is needed.

5. Conclusions

To explore the effect of different air supply of circulating fan in bulk curing barn on tobacco curing characteristics, this paper has set up five speed variable frequency values to control air supply at different stages of tobacco curing and has selected representative substances for testing. The results show that different wind speed regulations of circulating fan in bulk curing barn have a significant influence on tobacco curing characteristics, and different frequency conversion treatments can affect the degree and rate of pigment and starch degradation. With the increase of wind speed between leaves, the appearance of tobacco leaves turned yellow, and the change speed first increases sharply and then decreases slowly. The degradation and transformation rate of macromolecular starch in the yellowing stage and leaf-drying stage of tobacco leaves shows a trend of: sharp increase-slow decrease-slow increase-sharp decrease. The characteristics of leaf water loss show a trend of slow rise and then sharp rise.

Acknowledgements

This study was funded by Henan China Tobacco Industry Co., Ltd. (Grant No. 2021410000340261 and 2022410000340099). Fund projects: CHINA TOBACCO HENAN INDUSTRIA CO., LTD. funded projects "Research and Application of Key Technologies to Improve the Matching Rate between Lincang Tobacco Leaves and High-End Gold Leaf Cigarettes (2021410000340261)" and "Optimization and Popularization of Curing Technology for Improving Quality and Aroma of Tobacco Leaves in Henan Province" (202241000340099)"

References

[1] Yang S.X., Wang X.Q., Li L., Shi Q.L. and Meng G. (2019) Frequency conversion technology and its application trend in tobacco curing. Crop Research, 33(2), 136-139, 150.

[2] Bing H., Jian L. and Jiang H.D. (2014) On lean management in tobacco leaf production. Acta Tabacaria Sinica, 20(01), 1-8.

[3] Zhang J.L., Sun C.L., Wei J.Y., Jin Y.B., Jia H.J., Dai L.J., Rang Z.W., Xu Y.Q. and Huang C.J. (2023) Baking performance and benefit analysis of flue-cured tobacco in frequency conversion heat pump dense barn. Crop Research, 37(1):49-54, 61.

[4] Liu C., Chen Z.G., Zhao H.W., Zhang H.L., Li J.P. and Gong C.R. (2010) Effect of fan speed changes on neutral aroma components of cured tobacco during bulk curing. Journal of Hunan Agricultural University (Natural Sciences), 36(06), 640-643.

[5] Li X.H., Qiu M.W. and Wen J. (2012) Effects of frequency motor of bulk curing on tobacco leaf quality. Chinese Tobacco Science, 33(01), 74-77.

[6] Zhan J., Zhou F.F., Zhu H.B., Dong S.F., Rao Z., Wang Z.S. and Zhang X.L. (2016) Effects of frequency control of four-layers bulk curing barn on aroma quality of upper leaves of cured tobacco. Journal of Gansu Agricultura University, 51(04), 43-51.

[7] Li Y.L., Liu M.H., Liu J.W., Gou J.Y., Zhang W.J., Wang T.X. and Lu X.C. (2021) Optimization of tobacco of variable frequency bulk curing process by response surface analysis. Acta Tabacaria Sinica, 27(1), 83-89.

[8] He Y.H., He F., Yang R.S., Sun J.F., Zhang Y.G. and Gong C.R. (2011) Effect of frequency conversion technology of circulating ventilator in bulk curing process on tobacco quality. Acta Agriculturae Boreali-occidentalis Sinica, 20(04), 76-81.

[9] Zhou X.F., Wei J.Y. and Gu M.H. (2015) Effects of frequency motor of bulk curing barn on aroma constituents of cured tobacco. Journal of Guangxi Agriculture, 30(06), 29-33.

[10] Xu Q., Liu Q., Xu G.L. and Zhang J. (2013) Influence of fan rev during late stage of intensive curing on the inner quality of tobacco leaves after curing. Hubei Agricultural Sciences, 52(02), 349-351, 358.

[11] Sun S.B., Li Y.L., Wang B.X., Shi G., Wu W.Q., Wang J., Yang X.L. and Wu D. (2021) Relationship between ecological factors, pigment and starch in cured tobacco during maturity. Acta Agriculturae Jiangxi, 33(07), 81-86.

[12] Duan S.J., Wang P., Zeng Y., Peng Y.H., Jia S.W., Zhang H.Y., Song C.P. and Chen X.L. (2022) Variations of resistant starch contents in tobacco leaves during growth and curing. Tobacco Science & Technology, 56(2), 34-40.

[13] Chen J., Li Y., He X., Jiao F.C., Xu M.L., Hu B.B., Jin Y. and Zou C.M. (2021) Influences of different curing methods on chemical compositions in different types of tobacco. Industrial Crops and Products, 167, 1-11.

[14] Szedljak I., Szantai-Kohegyi K. and Kosary J. (2010) Study of tobacco plant as a possible nutritive protein source. Acta Alimentaria, 39(2), 149-156.

[15] Lourenco C.B., Ataide J.A., Cefali L.C., Novaes L.C.D.L., Moriel P., Silveira E., Tambourgi E.B. and Mazzola P.G. (2016) Evaluation of the enzymatic activity and stability of commercial bromelain incorporated in topical formulations. International Journal of Cosmetic Science, 38(5), 535-540.

[16] Kakie T. (1973) Degradation of starch granules of tobacco-leaves during flue-curing-(studies on saccharide metabolism of tobacco-leaves during curing.2. Journal of the Agricultural Chemical Society of Japan, 47(11), 667-672.

[17] Ma Y.N., Wang R.G., Wu C., Shi Y.W., Wang Z.H., Xie S.D., Zhou S.P., Xu H.M. and Ren X.L. (2012) Developmental analysis on genetic behavior of quality traits of cured tobacco (Nicotiana tabacum) in multiple environments. International Journal of Agriculture & Biology, 14(3), 652-660.

[18] Li J., Yang R., Jiang Y., Sun S., Li J., Gu H., Lin Y., Luo X., He C. and Chen Y. (2022) Comparative proteomic analysis by isobaric tags for the relative and absolute quantification reveals the responses of tobacco (Nicotiana tabacum L.) roots to different soil types. Frontiers in Plant Science, 13.

[19] Zhang P.Y., Wang J.G., Geng Y.P., Dai J.R., Zhong Y., Chen Z.Z., Zhu K., Wang X.Z. and Chen S.Y. (2015) MSAP-based analysis of DNA methylation diversity in tobacco exposed to different environments and at different development phases. Biochemical Systematics and Ecology, 62: 249-260.

[20] Kazakbaev V., Prakht V., Dmitrievskii V., Ibrahim M.N., Oshurbekov S., and Sarapulov S. (2019) Efficiency analysis of low electric power drives employing induction and synchronous reluctance motors in pump applications. Energies, 12(6), 1144.