Research on the Physical Properties of Cut Tobacco under Different Storage Conditions

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Abstract. In order to explore the influence of different storage conditions on the physical properties of cut tobacco during storage, this study measured the changes in moisture content, moisture activity, and physical properties of cut tobacco. Based on these indicators, the relationship between various physical properties was investigated. The selected storage conditions were a temperature of 23-25℃, humidity of 55%-65%, and storage time of 3-25 h. The results showed that maintaining the appropriate moisture content of 60% and a storage temperature of 25℃ was beneficial for preserving the physical properties of cut tobacco. Among the storage conditions, humidity had the most significant impact on the physical properties of cut tobacco, followed by temperature. Within the limited time range, the storage time had a relatively less noticeable effect on the quality of cut tobacco.

Keywords: cut tobacco; storage conditions; physical properties.

1. Introduction

In general, cut tobacco is placed in a filament storage cabinet for storage in the factory production, so the filament storage has a great influence on the physical properties of the cut tobacco in the actual production process[1]. During the storage of cut tobacco, the moisture content of cut tobacco will change with the change of environmental temperature[2], humidity and time, which will affect the physical properties of cut tobacco, such as water activity, hardness, elasticity, etc. Therefore, the control of time, humidity and temperature in the process of filament storage plays an important role in the quality of cigarettes, and whether the moisture of cut tobacco is properly grasped directly affects the flexibility and processing resistance of cut tobacco, which in turn affects the sensory quality of cigarettes, and even has a negative impact on the cost of cigarette production and sales revenue[3].

Selvin H. Edwards et al. explored the quantitative measurement of harmful and potentially harmful constituents, pH, and moisture content in 16 commercial smokeless tobacco products[4]. Jun Sun et al. explored Identification of moisture content in cut tobacco plant leaves using outlier sample eliminating algorithms and hyperspectral data[5]. At present, the environmental temperature and humidity of the storage process, the storage time has process requirements, but the storage time is relatively wide (3-120h)[6], and cut tobacco is a porous medium, and there will be hygroscopic and dehumidification phenomena in the storage process, and there are few studies on the moisture and water activity of cut tobacco in the produce process [7], in order to further study the law of moisture and texture change of cut tobacco in the storage process, this study is specially carried out in order to provide data support for the storage of cut tobacco.

2. Materials and Methods

2.1 Materials

Cut tobacco , Zhangjiakou Cigarette Factory Co. Ltd

2.2 Simulated cut tobacco storage environment.

Placing 10.0 g of cut tobacco in a constant temperature and humidity chamber (Kunshan Bailingda Testing Equipment Co. Ltd.) to simulate factory storage environment. The temperature is controlled within the range of 23℃ to 27℃, humidity between 55% to 65%, and the samples are left undisturbed for a duration of 3 h to 25 h. The experimental setup is shown in Fig .1.

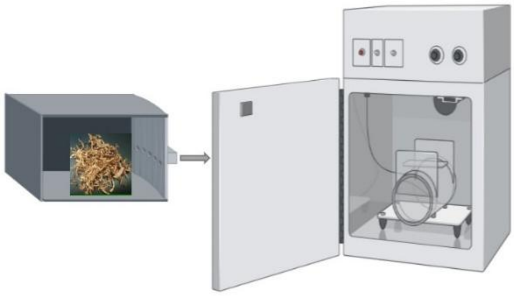

Fig .1 The experimental equipment.

2.3 Response surface of cut tobacco moisture content.

Placing 10.0 g of cut tobacco in a constant temperature and humidity chamber, controlling the temperature within the range of 23℃ to 27℃, and humidity between 55% to 65%, for a duration of 3 h to 25 h. The moisture content of the cut tobacco was determined using the oven-drying method by weighing[8]. After removing the tobacco from the constant temperature and humidity chamber, it was placed in a 105°C oven (DHG-924385-Ⅲ) for 8 h or until a constant weight was reached(Because there is a certain gap between the amount of cut tobacco in the factory storage cabinet and the amount of cut tobacco contained in the laboratory storage environment, the drying time in the actual production should be appropriately shortened, and the cut tobacco can be dried to a constant weight).

$$\omega = \frac{m_1 - m_2}{m_1} \times 100\%$$

While, w is the moisture content of cut tobacco,%; m1 is the tobacco weight before drying, g; m2 is the tobacco weight after drying, g.

2.4 Response surface of cut tobacco moisture activity.

Placing 10.0 g of cut tobacco in a constant temperature and humidity box to control the temperature of 23 °C ~ 27 °C and the humidity of 55% ~ 65% for 3 h ~ 25 h, and the cut tobacco was taken out of the constant temperature and humidity box for 1.0 g, and the moisture activity of the cut tobacco was read by the digital water activity meter method (HD-3A).

2.5 Response surface of cut tobacco hardness and elasticity.

Placing 10.0 g of cut tobacco in a constant temperature and humidity chamber, controlling the temperature within the range of 23℃ to 27℃, and humidity between 55% to 65%, for a duration of 3 h to 25 h. After removing the cut tobacco from the constant temperature and humidity chamber, The TA.XT plus texture analyzer was used to measure cut tobacco, and the TPA test conditions were as follows: the probe was P/36R, and the three speeds were set before, during and after the test, and the three speeds were 1.00 mm/s, 2.00 mm/s, and 1.00 mm/s, respectively. The degree of compression is 70%, and the trigger form is Auto-5.0 g; Compression interval 5 s. Data processing: The test was repeated 3 times, and the results were expressed as mean ± standard deviation.

2.6 Statistical Analysis

In this study, the response surface design software DesignExpert-13 and Origin drawing software were used for experimental design and plot analysis.

3. Results and Discussion

3.1 Variation in cut tobacco moisture content.

3.1.1 The influence of time and humidity under the same temperature conditions.

The moisture content of cut tobacco is an important indicator that affects the quality of cut tobacco products[9]. The response surface model for the moisture content of cut tobacco under different humidity levels and storage times at the same temperature conditions is shown in Fig. 2. The effect of storage time on the moisture content of cut tobacco varies with different humidities[10]. At a constant temperature of 25℃ and humidity of 55%, the moisture content of the cut tobacco initially decreases from 12.2% to 11.6% and then increases to 12.1% as the storage time extends from 3 h to 25 h. The significant fluctuation may be attributed to the fact that the environmental humidity is not optimal for storing cut tobacco, resulting in unstable moisture content. On the other hand, at a temperature of 25℃ and humidity of 60%, the moisture content of the cut tobacco decreases from 12.8% to 12.7% and then increases to 13.0% with increasing storage time. The relatively stable fluctuation in moisture content may imply that the storage environment with 60% humidity is more suitable. However, at a temperature of 25℃ and humidity of 65%, the results differ. As the storage time prolongs, the moisture content of the cut tobacco increases continuously from 13.1% to 13.6%. This could be due to the excessively high humidity in the storage environment, reaching the critical point that disrupts the equilibrium of bound moisture in the cut tobacco. Consequently, it can be concluded that the optimal storage humidity for cut tobacco is 60%.

The effect of storage humidity on the moisture content of cut tobacco is more intuitive. The moisture content of the cut tobacco increases with the increase in environmental humidity. Taking a temperature of 25℃ and a storage time of 3 h as an example, as the humidity increases from 55% to 65%, the moisture content of the cut tobacco increases from 12.2% to 13.1%. This indicates that humidity has a more direct impact on the moisture content of cut tobacco, and the same trend can be observed for the change in moisture content with storage temperature at 25°C and storage times of 14 h and 25 h.

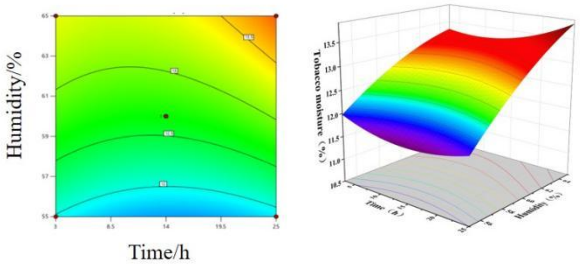

Fig. 2 Response surface of the moisture content of cut tobacco with respect to time and humidity.

3.1.2 The influence of time and temperature under the same humidity conditions.

The response surface model of the moisture content of cut tobacco under different temperatures and times at the same humidity conditions is shown in Fig. 3. The influence of storage time on the moisture content of cut tobacco is limited by the ambient temperature[11]. Under a humidity of 60% and a temperature of 23°C, as the storage time increases, the moisture content of the cut tobacco first decreases from 13.7% to 13.4% and then increases to 13.8% with little fluctuation. This may be attributed to the lower temperature and suitable humidity for cut tobacco storage. Under a humidity of 60% and a temperature of 25°C, with the increase in storage time, the moisture content of the cut tobaccos decreases from 12.8% to 12.6% and then increases back to 12.8%, showing even smaller fluctuations. This indicates that the temperature, humidity, and time are all more suitable for storage. At a humidity of 60% and a temperature of 27°C, the moisture content of the cut tobacco fluctuates significantly. As the storage time increases, the moisture content first decreases from 12.5% to 11.9% and then increases to 12.7%. This may be due to the excessively high environmental temperature leading to the disruption of the water-holding balance of the cut tobacco.

The effect of storage temperature on the moisture content of cut tobacco is more pronounced compared to storage time. Under a humidity of 60% and a storage time of 3 h, as the storage temperature increases, the moisture content of the cut tobacco linearly decreases from 13.7% to 12.4%. The same trend is observed for storage times of 14 h and 25 h, indicating that the effect of storage temperature on the moisture content of cut tobacco is more direct and remains consistent regardless of the variation in storage time.

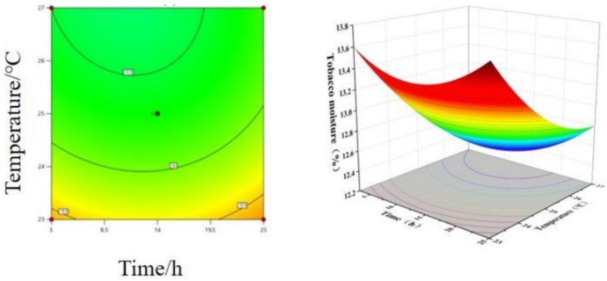

Fig. 3 The response surface of cut tobacco moisture content with respect to time and temperature.

3.1.3 The effects of temperature and humidity with the same storage time.

The response surface of cut tobacco moisture content with respect to different temperatures and humidity within the same storage time is shown in Fig. 4. At a storage time of 14 h and a humidity of 55%, as the temperature increased from 23° C to 27° C, the moisture content of cut tobacco gradually decreased from 12.1% to 11.2%. Similarly, at a storage time of 14 h and humidities of 60% and 65%, the moisture content decreased from 13.3% to 12.4% and from 14.1% to 13.4%. Moreover, higher environmental humidity caused a slower decrease in cut tobacco moisture content with increasing temperature. This indicates that temperature has a significant impact on cut tobacco moisture content and can be influenced by changes in humidity. On the other hand, the effect of storage humidity on cut tobacco moisture content demonstrated a linear increase. At a storage time of 14 h and a temperature of 23° C, as the humidity increased from 55% to 65%, the moisture content gradually increased from 12.1% to 14.1%. Similarly, at a storage time of 14 h and temperatures of 25° C and 27° C, the moisture content increased from 11.7% to 13.3% and from 11.2% to 13.4%. Higher environmental temperature resulted in a slower rate of moisture increase with increasing humidity. This also indicates that humidity has a significant impact on cut tobacco moisture content, along with subsequent temperature changes. These results suggest that, under the same temperature, storage humidity has a more pronounced effect on cut tobacco moisture content compared to storage time.

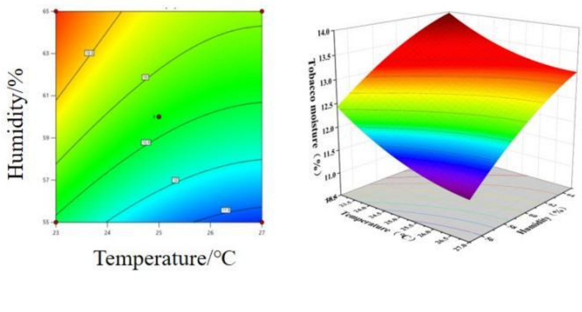

Fig. 4 Response Surface of Cut tobacco Moisture Content with Temperature and Humidity

3.2 Variation of Cut tobacco Moisture Activity

3.2.1 The effects of time and humidity under the same temperature conditions.

Cut tobacco moisture activity refers to the ratio of the equilibrium vapor pressure of cut tobacco in a closed space to the saturated vapor pressure of pure water at the same temperature[12]. It reflects the state of moisture presence and indicates the degree of moisture binding with cut tobacco[13]. The response surface model of cut tobacco moisture activity under different humidity and time conditions at the same temperature is shown in Fig. 5. At a constant temperature of 25° C and humidity of 55%, as the storage time (3-25 h) extends, the cut tobacco moisture activity decreases from 0.519 aw to 0.513 aw, indicating a relatively strong binding of moisture in cut tobacco and stable quality. At a temperature of 25° C and humidity of 60%, the cut tobacco moisture activity remains around 0.485, with a comparably lower value than that at 55% humidity. This low moisture activity is more conducive to inhibiting microbial growth and reducing chemical changes. Under a constant temperature of 25° C and humidity of 65%, the cut tobacco moisture activity decreases from 0.449 aw to 0.435 aw as the storage time extends. Furthermore, it has the lowest moisture activity compared to 55% and 60%, possibly due to excessively high environmental humidity, leading to a higher degree of water binding in cut tobacco, which aligns with the results of moisture content. The influence of storage humidity on cut tobacco moisture activity is evident. As observed from the Fig. 5, the cut tobacco moisture activity decreases with increasing storage humidity, with distinct color differences. At a constant temperature of 25° C and a storage time of 3 h, as the environmental humidity increases from 55% to 65%, the cut tobacco moisture activity decreases from 0.519 aw to 0.449 aw. It is evident that the moisture activity varies directly and is opposite to the changes in moisture content. The same trend applies to a storage time of 14 h and 25 h at a temperature of 25° C.

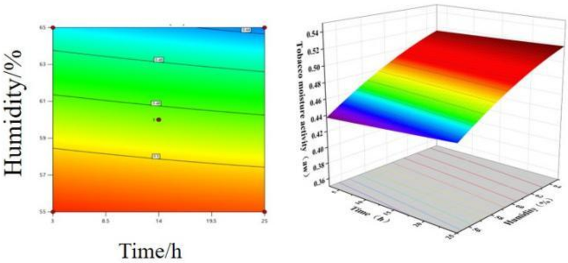

Fig. 5 Cut tobacco moisture activity and time, humidity response surface

3.2.2 The influence of time and temperature under the same humidity conditions

Under the same humidity conditions, the model of cut tobacco moisture content response surface at different temperatures and different times is shown in the Fig. 6. The influence of storage time on the moisture activity of cut tobacco is limited by the ambient temperature, in the humidity of 60%, the temperature of 23 ° C conditions, with the increase of storage time, the moisture activity of cut tobacco changes greatly, from 0.474 aw to 0.465 aw, which is the opposite of the change of moisture content, may be due to the low temperature and humidity suitable for storage, the degree of cut tobacco binding moisture does not change much. Therefore, when the humidity is 60% and the temperature is 25 ° C, with the increase of the storage time, the moisture activity of cut tobacco decreases from 0.490 aw to 0.480 aw. When the humidity is 60% and the temperature is 27 ° C, the moisture activity of cut tobacco reaches the peak and the fluctuation is minimal, with the increase of the storage time, the moisture activity of cut tobacco decreases from 0.496 aw to 0.492 aw, which is due to the increase of temperature leading to the loss of cut tobacco combined with water caused by the increase of water activity and maintain a certain stability. The influence of storage temperature on the moisture activity of cut tobacco is also not obvious, at 60% humidity and 3 h storage time, with the increase of storage temperature, the moisture activity of cut tobacco increases from 0.475 aw to 0.495 aw, and the change trend is also the same with the storage time is 14 h and 25 h, which indicates that the influence of storage temperature and time on cut tobacco moisture activity is not as obvious as the environment humidity.

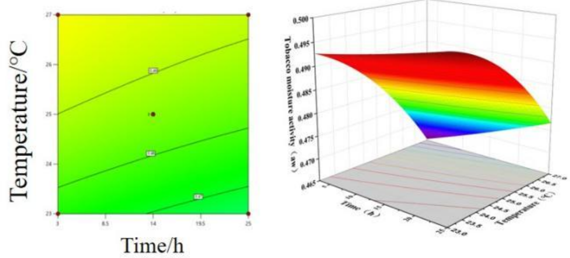

Fig. 6 Cut tobacco moisture activity, time, temperature response surface

3.2.3 The influence of temperature and humidity at the same time

The response surface of cut tobacco moisture activity changes at different temperatures and different humidity within the same storage time is shown in the Fig. 7. When the constant storage time is 14 h and the humidity is 60%, with the increase of temperature of the filament, the moisture activity increases from 0.475 aw to 0.49 aw, the moisture activity decreases compared with the humidity is 55%. When the constant storage time is 14 h and the humidity is 65%, with the increase of the temperature of the storage cut tobacco, the water activity increases from 0.425 aw to 0.452 aw. The influence of filament storage humidity on cut tobacco moisture activity increases linearly, when the storage time is 14 h and the temperature is 23 ° C, the moisture activity of cut tobacco gradually decreases with the increase of humidity (55%~65%), from 0.50 aw to 0.43 aw, and the color change is very obvious. When storage time was 14 h and the temperature was 25° C, the moisture activity of cut tobacco decreased from 0.51 aw to 0.44 aw with the increase of humidity, the moisture activity decreased from 0.52 aw to 0.45 aw at storage time 14 h and temperature is 27 ° C, which indicated that moisture activity trend tended to be consistent at different temperatures.

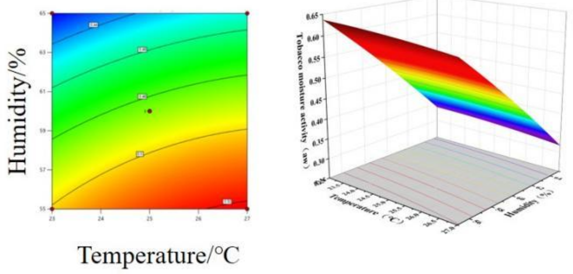

Fig. 7 Cut tobacco moisture activity, temperature and humidity response surface

3.3 Textural properties of Cut tobacco

3.3.1 The influence of time and humidity under the same temperature conditions

Textural properties of cut tobacco is an important factor affecting the quality of cigarettes, and high-quality cut tobacco has a relatively soft place and a certain elasticity, which are also related to the moisture content of cut tobacco[14]. Under the same temperature, the response surface model of cut tobacco texture characteristics at different humidity and different times is shown in the Fig. 8. When the constant temperature is 25 ° C and the humidity is 55%, with the extension of the storage time (3~25h), the hardness of cut tobacco decreases from 114.3 g to 113.1 g, the elasticity increases from 0.638 Pa to 0.641 Pa, When the constant temperature is 25 ° C and the humidity is 60%, with the storage time increasing, and the hardness of cut tobacco has been maintained at about 99.8 g, compared with 55%, the hardness decreases, indicating the increase in humidity will soften the cut tobacco, and the elasticity increases from 0.655 Pa to 0.658 Pa, which indicates that the ambient temperature and humidity are more suitable for cut tobacco storage. The hardness of cut tobacco remained at about 86.9 g, and the elasticity increased from 0.679 Pa to 0.684 Pa, which shows that under the same temperature, the increase of storage time has little effect on the texture characteristics of cut tobacco. At a temperature of 25 ° C and a storage time of 3 h, with the increase of environment humidity (55%-65%), the hardness of cut tobacco decreased from 109.6 g to 86.9 g, elasticity increased from 0.639 Pa to 0.680 Pa, and the large change of cut tobacco texture characteristics showed that environment humidity is the main influencing factor, temperature 25 ° C, storage time 14 h and 25 h, with the increase of environment humidity.

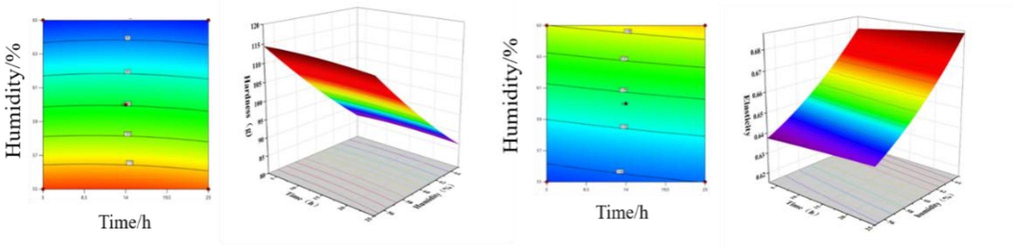

Fig. 8 Cut tobacco texture and response surface of time and humidity

3.3.2 Influence of time and temperature under the same humidity conditions

Under the same humidity conditions, the model of cut tobacco texture characteristics response surface at different temperatures and times is shown in the Fig. 9. It can be seen from the color change in the figure that when controlling constant humidity 60%, constant temperature conditions (23° C, 25° C, 27° C), with the increase of storage time, the hardness and elasticity of cut tobacco do not fluctuate much, while controlling constant humidity of 60%, constant storage time (3 h, 14 h, 25 h), the change trend is the same. This may be because the environment humidity is the most significant factor affecting the texture of cut tobacco compared with the temperature and time of the cut tobacco, and the constant humidity is controlled.

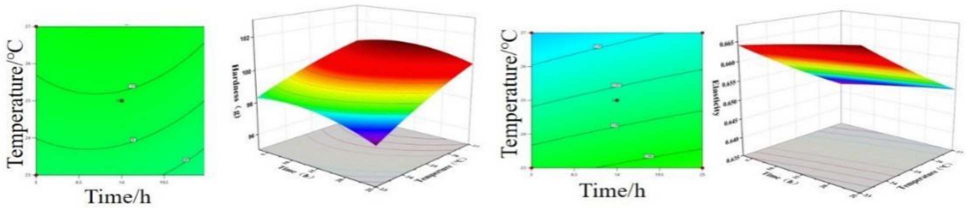

Fig. 9 Cut tobacco texture and response surface of time and humidity

3.3.3 Influence of temperature and humidity within the same time

The response surface of cut tobacco texture characteristics of different temperature and humidity is shown in the Fig. 10. During the same storage time, and the influence of temperature and humidity changes on cut tobacco texture characteristics is explored by controlling the constant storage time. With the increase of the storage temperature (23~27 ° C), the hardness and elasticity of cut tobacco do not change significantly, which may be due to the little change in ambient temperature, so there is no obvious effect on the texture characteristics of cut tobacco.

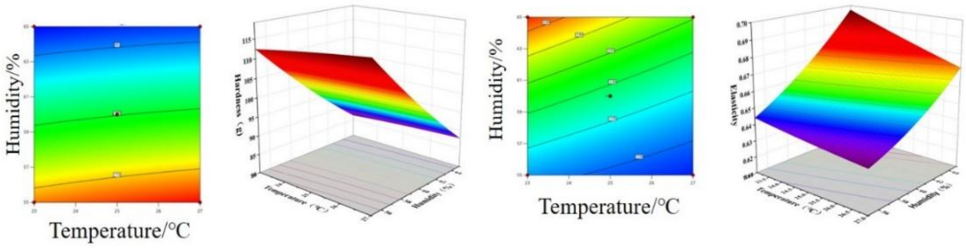

Fig. 10 Cut tobacco texture and temperature and humidity response surface

4. Conclusion

The response surface model shows that among the three factors of storage environment humidity, storage temperature and storage time, the influence of environment humidity on the physical properties of cut tobacco such as moisture content, moisture activity and texture is the most significant, and the humidity suitable for cut tobacco storage is 60%, and the temperature is 25 °C, while the influence of limited storage time on the physical characteristics of cut tobacco is not obvious, and further exploration is required for follow-up experiments.

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