Comprehensive Quality Evaluation of Finished Tobacco Strips Based on the Improved TOPSIS Method

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Abstract. The quality of threshed and redried tobacco strips directly affects the processing effects of cigarette making and the quality of cigarettes. However, there is a lack of effective comprehensive evaluation methods for quality. This study selected samples of threshed and redried tobacco strips from the 2017 to 2022 seasons provided by nine redrying factories commissioned by Sichuan Zhongyan. Multiple quality indicators of the samples were tested, and the improved TOPSIS method was applied to calculate the comprehensive quality index of the finished tobacco strips, providing a comprehensive evaluation of their quality. The results indicate: (1) There are significant differences in various quality indicators and the comprehensive quality index of finished tobacco strips processed by different factories in the same season. The ranking of TOPSIS relative closeness for different factories is H > F > A > D > G > E > C > I > B. (2) The overall quality trend of finished tobacco strips processed by the same factory in different seasons is improving, but there is a certain degree of fluctuation. The ranking of TOPSIS relative closeness for different flue-curing seasons is: 2018 > 2022 > 2020 > 2017 > 2019 > 2021. (3) The quality of finished tobacco strips from different processing batches in the same season and factory is basically stable, with minor fluctuations in some indicators between batches. The ranking of TOPSIS relative closeness for different batches is: first batch > third batch > second batch. Overall, there are significant differences in the quality of finished tobacco strips from different factories in the same season, the quality of finished tobacco strips from the same factory in different seasons tends to improve, and the quality of finished tobacco strips from different processing batches in the same season and factory is basically stable, indicating the effectiveness of this method. The application of this method by cigarette industrial enterprises for comprehensive evaluation of the quality of threshed and redried tobacco strips is beneficial for a comprehensive understanding of the quality of tobacco strips processed by different factories, providing a basis for selecting processing points and establishing regional processing centers. It is also conducive to scientifically assessing the stability of processing quality between years and batches at each factory, and promptly proposing improvement suggestions for identified deficiencies. By optimizing the threshing and redrying processing points and establishing

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regional processing centers, the quality of the raw materials and the stability of the processing procedures for cigarettes can be monitored and ensured, thereby enhancing the sensory quality and consistency of the cigarettes.

Keywords: Threshing and redrying; Redried tobacco strips; Comprehensive evaluation of quality; TOPSIS method

1 Introduction

Threshing and redrying serve as the link between tobacco agricultural cultivation and cigarette industrial production [1], and its process quality directly affects the effectiveness of cigarette making and the quality of cigarettes. Threshing and redrying mainly involve the separation of stems and leaves, and the tasks of screening and drying the separated tobacco strips, creating conditions for the subsequent aging and storage of the strips, and ensuring that the strips meet the requirements for cigarette making production [2].

As the cigarette industry moves towards higher quality development, the "big process" concept oriented by product demand continues to deepen, leading to significant changes in the quality evaluation system of threshed and redried tobacco strips. In the past, attention to the quality of threshed and redried tobacco strips was mostly limited to individual indicators such as chemical composition [3-5], stem content in leaves [6], moisture content [7-9], breakage [10], and packaging density [11]. Currently, cigarette industrial enterprises place greater emphasis on the synergistic effects of multiple indicators, including the level of homogenization processing, industrial applicability of leaf structure, control of stem content in leaves, and purity. They have higher requirements for the comprehensive quality and stability of threshed and redried tobacco strips. Existing research mainly focuses on evaluating the stability of tobacco strip structure in redrying enterprises [12], but there is a lack of comprehensive quality evaluation of threshed and redried tobacco strips from one or multiple redrying enterprises. The main challenges in comprehensive evaluation are: there are complex associations between multiple quality indicators, the importance of different indicators varies, and it is necessary to consider the quality fluctuation characteristics of both time dimension (different seasons) and space dimension (different factories) simultaneously.

Based on the above background, this study selects the improved TOPSIS method to construct a comprehensive quality evaluation model for finished tobacco strips from threshing and redrying [13]. The TOPSIS method is a decision analysis tool used to select the best alternative among multiple options. It helps us by comparing the distance of each option from the ideal best and worst scenarios, that is, by calculating the relative closeness of each evaluated object to the ideal solution, thereby identifying the solution that is closest to the ideal optimal solution.This method can effectively handle multi-criteria decision-making problems, taking into account the influence of both positive and negative ideal solutions, making it suitable for comprehensive evaluation of complex systems. By analyzing the comprehensive quality of finished tobacco strips from different factories in the same season, different seasons in the same factory, and different processing batches in the same season and factory, the aim is to scientifically assess the processing quality level and stability of finished tobacco strips from threshing and redrying. The research findings can provide a basis for decision-making for cigarette industrial enterprises to optimize their processing layout and establish regional processing centers. A rational processing layout and the selection of processing points can ensure the quality and consistency of tobacco leaves during the processing, thereby directly affecting the final quality of cigarettes. This has significant importance for improving the quality management level of the tobacco industry.

2 Materials and Methods

2.1 Materials

The samples were provided by nine threshing and redrying enterprises commissioned by Sichuan Zhongyan for the 2017 to 2022 seasons. For each factory, the XQ2 module grade was selected for comprehensive quality evaluation. Additionally, Factory A selected three processing batches of the XQ1 module grade for comprehensive quality evaluation in the 2022 season. For each module grade, 30 samples were evenly selected at intervals based on box numbers. Each sample weighed (300±30) g and was divided into two parts, one for testing the moisture content of the tobacco strips and the other for analyzing chemical components, while also checking the impurities in the finished product of the box. Furthermore, for each module grade, samples weighing (3000±300) g were taken every 200 boxes based on box numbers to test the leaf structure.

2.2 Indicator Measurement Methods

The moisture content of tobacco flakes is measured according to YC/T 31-1996; the chemical composition of tobacco leaves is determined using a near-infrared spectrometer; the operation method for impurity detection is carried out according to YC/T 147-2010; the method for leaf structure detection is conducted according to GB/T 21137-2007; and the method for stem content in leaves detection is performed according to GB/T 21136-2007.

2.3 Quality Evaluation Based on the Improved TOPSIS Method

2.3.1 Screening of Quality Evaluation Indicators for Finished Tobacco Strips

Based on the processing requirements of Sichuan Zhongyan, the deviation of the mean moisture content from the control center value and the coefficient of variation of moisture content were selected as indicators for evaluating the uniformity of moisture content in finished tobacco strips. According to the results of the grey relational clustering analysis of conventional detection indicators for chemical components of tobacco strips by He Jiexiang et al. [14], nicotine and the sugar-to-nicotine ratio are more suitable as indicators for evaluating the uniformity of chemical components.There are many leaf structure indicators with complex relationships. Selecting a few indicators with typical representativeness for quality analysis can improve the operability of the work. Referring to existing research [12], the large and medium flake rate, medium flake rate, and small flake rate were chosen as representative evaluation indicators for leaf structure. In summary, the quality of finished tobacco strips from threshing and redrying was evaluated using 10 representative indicators: the deviation of mean moisture content from the center value, the coefficient of variation of moisture content, the coefficient of variation of nicotine, the coefficient of variation of the sugar-to-nicotine ratio, the large and medium flake rate, the medium flake rate, the small flake rate, the stem content in leaves, and the presence of first and second class impurities.

2.3.2 Data Standardization

The standardization of quality indicators for finished tobacco strips is performed using membership functions. There are three main types of membership functions commonly used in comprehensive evaluations: inverse S-shaped, S-shaped, and parabolic. The inverse S-shaped membership function is mainly used for quantitative factors that only have an upper limit and no lower limit in their impact on the target. The S-shaped membership function is primarily used for quantitative factors that only have a lower limit and no upper limit in their impact on the target. The parabolic membership function is mainly used for quantitative factors that have both an upper and a lower limit in their impact on the target. Based on the characteristics of different membership functions and referring to the internal control standards for the quality of threshed and redried tobacco strips from Sichuan Zhongyan, the type and threshold of the membership function corresponding to each quality evaluation indicator for finished tobacco strips were determined (Table 1).

Table 1. Membership function type and threshold of the quality indicators

Evaluation Indicator	Membership Function Type	Lower Limit L	Upper Limit U
Deviation of Mean Moisture Content from Center Value	Inverse S-shaped Function	0.2	0.5
Coefficient of Variation of Moisture Content	Inverse S-shaped Function	2.0	3.5
Coefficient of Variation of Nicotine	Inverse S-shaped Function	3	6
Coefficient of Variation of Sugar-to-Nicotine Ratio	Inverse S-shaped Function	5	8
Large and Medium Strip Rate	S-shaped Function	71	75
Medium Strip Rate	S-shaped Function	35	45
Small Strip Rate	Inverse S-shaped Function	0.3	0.5
Stem Content in Leaves	Inverse S-shaped Function	1.0	1.3
First Class Impurities	Inverse S-shaped Function	0	3
Second Class Impurities	Inverse S-shaped Function	3	8

The eight indicators of deviation of mean moisture content from the center, coefficient of variation of moisture content, coefficient of variation of nicotine, coefficient of variation of sugar-to-nicotine ratio, small strip rate, stem content in leaves, first class impurities, and second class impurities are standardized using Equation (1). The two indicators of large and medium strip rate and medium strip rate are standardized using Equation (2).

Inverse S-shaped Function:

$$Y=\begin{cases}1.0 & a \le L\\ 1.0-0.9(x-L)/(U-L) & L<a<U\\ 0.1 & a \ge U\end{cases} \tag{1}$$

S-shaped Function:

$$Y=\begin{cases}1.0 & a \ge U\\ 0.1+0.9(x-L)/(U-L) & L<a<U\\ 0.1 & a \le L\end{cases} \tag{2}$$

*L is the lower limit, U is the upper limit, and a is the indicator value.

To address the potential contradictions and median line issues that may arise in the traditional TOPSIS method, this study applies a secondary standardization to the original data's standardized matrix Y using Equation (3). This process sets the maximum value to 1 and the minimum value to 0.5, ensuring that all data are constrained within the right upper square of the perpendicular line connecting the positive and negative ideal solutions (Figure 2). This approach effectively resolves the issues of contradictions and the median line.

$$X_{ij}=\frac{1}{2}y_{ij}+\frac{1}{2} \tag{3}$$

To address the potential inversion issue in the traditional TOPSIS method, where the ranking of other evaluation objects may be reversed when some evaluation objects are added or removed, optimizations have been made. The absolute positive ideal solution is set to 1. To prevent contradictions and median line issues from arising again during the evaluation process, the absolute negative ideal solution is set to 0. This ensures that the ideal solutions do not change with the addition or removal of evaluation objects.

2.3.3 Determination of Weights

The determination of the weight W for the quality indicators of finished tobacco strips: Different indicators contribute differently to the overall quality of finished tobacco strips, and it is necessary to assign appropriate weights to each indicator to avoid errors caused by balanced evaluation. In this study, the Delphi method is used to assign different weights to each indicator in the comprehensive quality evaluation of finished tobacco strips. The specific weight assignments are shown in Table 2.

Table 2. Weight calculation of the quality indicators

Evaluation Indicator	Weight **W**	Evaluation Indicator	Weight **W**
Deviation of Mean Moisture Content from Center Value	0.1	Medium Strip Rate	0.1

Coefficient of Variation of Moisture Content	0.15	Small Strip Rate	0.05
Coefficient of Variation of Nicotine	0.2	Stem Content in Leaves	0.1
Coefficient of Variation of Sugar-to-Nicotine Ratio	0.1	First Class Impurities	0.1
Large and Medium Strip Rate	0.05	Second Class Impurities	0.05

2.3.4 Calculation of Closeness to Ideal Solutions Using the Improved TOPSIS Method

In the traditional TOPSIS method, when calculating distances, the sum of the squared weights no longer equals 1, which amplifies the influence of the weights and thus increases their impact on the decision-making results. In this study, the approach of first weighting and then calculating the Euclidean distance is changed to calculating the Euclidean distance while weighting, ensuring that the relationship structure between the standardized data is not altered.

The distance of each evaluation object to the positive ideal solution S_i^+ and the distance to the negative ideal solution S_i^- can be rewritten as:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} w_j (x_{ij} - 1)^2} \tag{4}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} w_j (x_{ij} - 0)^2} = \sqrt{\sum_{j=1}^{n} w_j x_{ij}^{\;2}} \tag{5}$$

Calculate the closeness degree *Ti* of each evaluation object to the ideal solution:

$$T_i = \frac{S_i^-}{S_i^- + S_i^+} \tag{6}$$

$T_i \in [0, 1]$ The larger the *Ti*, the better the overall quality of the finished tobacco strips for that evaluation object.

3 Results and Analysis

3.1 Comprehensive Quality Evaluation of Finished Tobacco Strips Processed by Different Factories in the Same Season

From the quality data of the XQ2 module grade finished tobacco strips processed by different factories in the 2017 season (Table 3), it is evident that there are significant differences in the quality of finished tobacco strips processed by different factories. The deviation of the mean moisture content from the center value is the smallest for Factory G, at 0.03%, and the largest for Factory C, at 0.33%; the coefficient of variation of moisture content is the smallest for Factory G, at 0.88%, and the largest for Factory B, at 3.78%; the coefficient of variation of nicotine is the smallest for Factory E, at 1.24%, and the largest for Factory C, at 4.47%; the coefficient of variation of the sugar-to-nicotine ratio is the smallest for Factory C, at 3.18%, and the largest for Factory G, at 7.02%; the large and medium strip rate is the smallest for Factory E, at 73.66%, and the largest for Factory G, at 77.00%; the medium strip rate is the smallest for Factory B, at 35.65%, and the largest for Factory H, at 50.56%; the small strip rate is the smallest for Factory H, at 0.19%, and the largest for Factory B, at 0.71%; the stem content in leaves is the smallest for Factory B, at 0.58%, and the largest for Factory I, at 1.36%; regarding impurities, Factory E has the best situation with no impurities detected, while Factory I has the worst situation with 2 first-class impurities and 5 second-class impurities detected.

Table 3. Quality Data of Finished Tobacco Strips Processed by Different Factories in the 2017 Flue-curing Season

Factory	Deviation of Mean Moisture Content from Center Value (%)	Coefficient of Variation of Moisture Content (%)	Coefficient of Variation of Nicotine (%)	Coefficient of Variation of Sugar-to-Nicotine Ratio (%)	Large and Medium Strip Rate (%)	Medium Strip Rate (%)	Small Strip Rate (%)	Stem Content in Leaves (%)	First Class Impurities (Count)	Second Class Impurities (Count)
A	0.14	1.47	3.86	5.10	73.79	41.51	0.42	0.87	0	2
B	0.08	3.78	1.85	5.44	74.13	35.65	0.71	0.58	1	4
C	0.33	1.21	4.47	3.18	76.48	40.35	0.63	1.03	0	4
D	0.07	1.41	2.96	5.00	74.70	43.20	0.37	1.08	2	0
E	0.07	2.18	1.24	4.49	73.66	38.76	0.41	1.27	0	0
F	0.16	1.81	3.09	5.68	74.39	44.78	0.41	0.91	1	3
G	0.03	0.88	4.39	7.02	77.00	45.46	0.49	0.82	0	3
H	0.29	1.98	2.48	4.12	73.84	50.56	0.19	0.83	0	2
I	0.22	1.79	3.90	5.18	73.82	39.76	0.45	1.36	2	5
Overall Average	0.15	1.83	3.14	5.02	74.65	42.23	0.45	0.97	0.67	2.56

*Note: The names of the factories are represented by the English letters A, B, C, D, E, F, G, H, and I.

After standardizing the quality data of finished tobacco strips using membership functions, a radar chart was created to show the quality of finished tobacco strips from each factory (Figure 1), which facilitates identifying the areas where each factory's processing quality needs improvement.

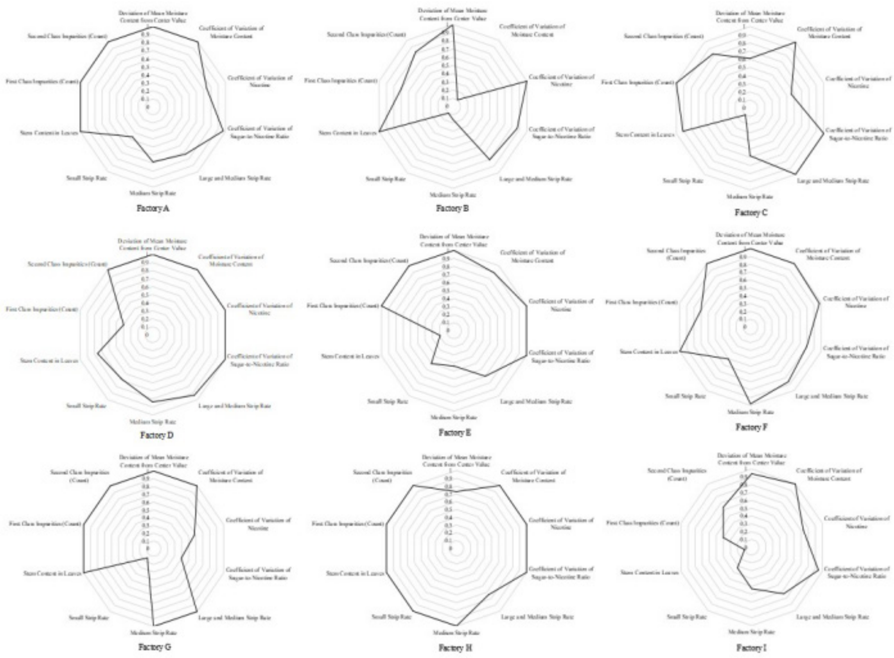

Fig. 1. Radar Chart of Finished Tobacco Strip Quality from Different Factories in the 2017 Flue-curing Season

The area of the radar chart can reflect the overall quality of the finished tobacco strips from each factory. From the chart, the radar charts of factories H, F, D, and A have larger areas, with relatively balanced distribution of various quality indicators. The radar charts of factories B and I have smaller areas, with uneven distribution of indicators. Specifically, the moisture content coefficient of variation, medium strip rate, and small strip rate of finished tobacco strips from factory B need significant improvement. For factory I, the control of impurities, stem content in leaves, and small strip rate of finished tobacco strips need significant improvement.

After performing a secondary standardization of the quality indicators of finished tobacco strips, the TOPSIS relative closeness of the finished tobacco strips from different factories was calculated (Table 4).

Table 4. TOPSIS Relative Closeness of Finished Tobacco Strips from Different Factories in the 2017 Flue-curing Season

Factory	Deviation of Mean Moisture Content from Center Value (%)	Coefficient of Variation of Moisture Content (%)	Coefficient of Variation of Nicotine (%)	Coefficient of Variation of Sugar-to-Nicotine Ratio (%)	Large and Medium Strip Rate (%)	Medium Strip Rate (%)	Small Strip Rate (%)
A	1	1	0.871	0.985	0.864	0.843	0.73
B	1	0.55	1	0.934	0.902	0.579	0.55
C	0.805	1	0.78	1	1	0.791	0.55
D	1	1	1	1	0.966	0.919	0.843

E	1	0.946	1	1	0.849	0.719	0.753
F	1	1	0.987	0.898	0.931	0.99	0.753
G	1	1	0.792	0.697	1	1	0.573
H	0.865	1	1	1	0.87	1	1
I	0.97	1	0.865	0.973	0.867	0.764	0.663

Factory	Stem Content in Leaves (%)	First Class Impurities (Count)	Second Class Impurities (Count)	S	S	T
A	1	1	1	0.1019	0.9401	0.9022
B	1	0.85	0.91	0.2485	0.8577	0.7753
C	0.955	1	0.91	0.1692	0.8925	0.8406
D	0.88	0.7	1	0.1113	0.945	0.8946
E	0.595	1	1	0.1701	0.9142	0.8431
F	1	0.85	1	0.0815	0.9577	0.9216
G	1	1	1	0.1644	0.9167	0.848
H	1	1	1	0.0517	0.9811	0.9499
I	0.55	0.7	0.82	0.2164	0.8481	0.7967

*Note: The names of the factories are represented by the English letters A, B, C, D, E, F, G, H, and I.

From the data in Table 5, it can be seen that the TOPSIS relative closeness of finished tobacco strips from Factory H is the highest, at 0.9499, indicating the best overall quality. In contrast, Factory B has the lowest TOPSIS relative closeness, at 0.7753, indicating the poorest overall quality. The ranking of TOPSIS relative closeness for finished tobacco strips from different factories, from highest to lowest, is as follows: H > F > A > D > G > E > C > I > B.

3.2 Comprehensive Quality Evaluation Results of Finished Tobacco Strips from Different Seasons at the Same Factory

From the quality data of the XQ2 module grade finished tobacco strips from Factory A for the 2017-2022 seasons (Table 5), it can be observed that the overall quality of the finished tobacco strips of the same module grade has improved and remained relatively stable. The coefficient of variation (CV) for nicotine and the sugar-to-nicotine ratio have continued to decrease, but there is some inter-annual quality fluctuation. The deviation of the mean moisture content from the center value was the smallest in the 2022 season, at 0.03% and the largest in the 2021 season, at 0.21%. The coefficient of variation for moisture content was the smallest in the 2020 season, at 1.28%, and the largest in the 2021 season, at 1.91%. The coefficient of variation for nicotine was the smallest in the 2022 season, at 2.04%, and the largest in the 2017 season, at 3.86%. The coefficient of variation for the sugar-to-nicotine ratio was the smallest in the 2022 season, at 3.17%, and the largest in the 2017 season, at 5.10%. The large and medium strip rate was the smallest in the 2017 season, at 73.79%, and the largest in the 2020 season, at 75.68%. The medium strip rate was the smallest in the 2017 season, at 41.51%, and the largest in the 2022 season, at 46.68%. The small strip rate was the smallest in the 2020 season, at 0.31%, and the largest in the 2019 season, at 0.48%. The stem content in leaves was the smallest in the 2017 season, at 0.87%, and the largest in the 2020 season, at 1.08%. Regarding impurities, the 2017 season was the best with no first-class impurities detected and 2 second-class impurities, while the 2021 season was the worst with 2 first-class impurities and 6 second-class impurities detected

Table 5. Quality Data of Finished Tobacco Strips from Factory A for the 2017-2022 Flue-curing Seasons

Flue-curing Seasons	Deviation of Mean Moisture Content from Center Value (%)	Coefficient of Variation of Moisture Content (%)	Coefficient of Variation of Nicotine (%)	Coefficient of Variation of Sugar-to-Nicotine Ratio (%)	Large and Medium Strip Rate (%)	Medium Strip Rate (%)	Small Strip Rate (%)	Stem Content in Leaves (%)	First Class Impurities (Count)	Second Class Impurities (Count)
2017	0.14	1.47	3.86	5.10	73.79	41.51	0.42	0.87	0	2
2018	0.18	1.72	3.42	4.33	74.04	44.31	0.36	0.98	1	1
2019	0.17	1.42	2.48	3.72	75.13	42.37	0.48	1.06	0	7
2020	0.19	1.28	2.58	4.73	75.68	45.74	0.31	1.10	1	6
2021	0.21	1.91	2.48	4.12	74.37	45.94	0.44	1.00	2	6
2022	0.03	1.58	2.04	3.17	74.87	46.68	0.41	1.06	1	4
Overall Average	0.15	1.56	2.81	4.20	74.65	44.43	0.40	1.01	0.83	4.33

After standardizing the quality data of finished tobacco strips using membership functions, a radar chart was created to show the quality of finished tobacco strips from Factory A for the 2017-2022 flue-curing seasons (Figure 2). This facilitates understanding the overall trend of quality changes in different seasons.

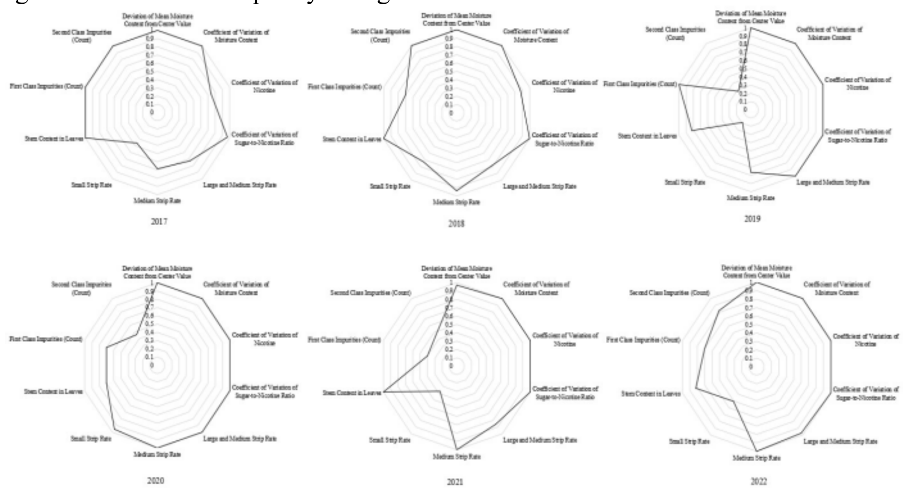

Fig. 2. Radar Chart of Finished Tobacco Strip Quality from Factory A for the 2017-2022 Flue-curing Seasons

From Figure 2, it can be seen that the radar chart of finished tobacco strip quality for the 2022 season has a larger area and the distribution of various quality indicators is relatively balanced. The radar charts for the 2019 and 2021 seasons show an uneven distribution of indicators, with significant room for improvement in the control of impurities and the small strip rate.

After performing a secondary standardization of the quality indicators of finished tobacco strips, the TOPSIS relative closeness of finished tobacco strips from different seasons at Factory A was calculated (Table 6).

Table 6. TOPSIS Relative Closeness of Finished Tobacco Strips from Different Flue-curing Seasons at Factory A

Flue-curing Seasons	Deviation of Mean Moisture Content from Center Value (%)	Coefficient of Variation of Moisture Content (%)	Coefficient of Variation of Nicotine (%)	Coefficient of Variation of Sugar-to-Nicotine Ratio (%)	Large and Medium Strip Rate (%)	Medium Strip Rate (%)	Small Strip Rate (%)
2017	1	1	0.871	0.985	0.864	0.843	0.73
2018	1	1	0.937	1	0.892	0.969	0.865
2019	1	1	1	1	1	0.882	0.595
2020	1	1	1	1	1	1	0.978
2021	0.985	1	1	1	0.929	1	0.685
2022	1	1	1	1	0.985	1	0.753

Flue-curing Seasons	Stem Content in Leaves (%)	First Class Impurities (Count)	Second Class Impurities (Count)	S^+	S^-	T
2017	1	1	1	0.1019	0.9401	0.9022
2018	1	0.85	1	0.0681	0.9586	0.9337
2019	0.91	1	0.64	0.13	0.948	0.8794
2020	0.85	0.85	0.73	0.0904	0.9586	0.9138
2021	1	0.7	0.73	0.1337	0.943	0.8758
2022	0.91	0.85	0.91	0.0809	0.9609	0.9224

From the data in Table 7, it can be seen that the TOPSIS relative closeness of finished tobacco strips from the 2018 flue-curing season is the highest, at 0.9337, indicating the best overall quality. In contrast, the 2021 season has the lowest TOPSIS relative closeness, at 0.8758, indicating the poorest overall quality. The ranking of TOPSIS relative closeness for finished tobacco strips from different flue-curing seasons, from highest to lowest, is as follows: 2018 > 2022 > 2020 > 2017 > 2019 > 2021.

3.3 Comprehensive Quality Evaluation Results of Finished Tobacco Strips from Different Processing Batches at the Same Factory and Season

From the quality data of the XQ1 module grade finished tobacco strips from different processing batches at Factory A in the 2022 flue-curing season (Table 7), it can be observed that the quality of the finished tobacco strips is generally stable and remains at an excellent evaluation level. However, there is still significant room for improvement in controlling the large and medium strip rate and the small strip rate. There are minor fluctuations between batches, primarily in the management of stem content in leaves and non-tobacco substances.

Table 7. Quality Data of Finished Tobacco Strips from Different Processing Batches at Factory A in the 2022 Flue-curing Season

Processing Batches	Processing Time	Deviation of Mean Moisture Content from Center Value (%)	Coefficient of Variation of Moisture Content (%)	Coefficient of Variation of Nicotine (%)	Coefficient of Variation of Sugar-to-Nicotine Ratio (%)	Large and Medium Strip Rate (%)
First	2022.12	0	1.5	1.73	3.08	71.99
Second	2023.3	0.04	1.64	2.7	4.56	71.07
Third	2023.5	0.04	1.2	1.71	3.04	72.49
Overall Average		0.03	1.45	2.05	3.56	71.85

Processing Batches	Processing Time	Medium Strip Rate (%)	Small Strip Rate (%)	Stem Content in Leaves (%)	First Class Impurities (Count)	Second Class Impurities (Count)
First	2022.12	45.7	0.47	1.08	0	0
Second	2023.3	46.32	0.43	1.18	0	0
Third	2023.5	45.41	0.45	1.14	1	3
Overall Average		45.81	0.45	1.13	0.33	1

After standardizing the quality data of finished tobacco strips using membership functions, a radar chart was created to show the quality of finished tobacco strips from different processing batches at Factory A in the 2022 flue-curing season (Figure 3). This facilitates an intuitive understanding of the overall trend of quality changes in different processing batches at the same factory.

Fig. 3. Radar Chart of Finished Tobacco Strip Quality from Different Processing Batches at Factory A in the 2022 Flue-curing Season

The radar charts of finished tobacco strip quality for the three processing batches of Factory A in the 2022 season show a consistent overall trend. All indicators indicate a lack of control in the large and medium strip rate and small strip rate, which need to be prioritized for improvement.

After performing a secondary standardization of the quality indicators of finished tobacco strips, the TOPSIS relative closeness of finished tobacco strips from different processing batches at Factory A in the 2022 season was calculated (Table 8).

Table 8. TOPSIS Relative Closeness of Finished Tobacco Strips from Different Processing Batches at Factory A in the 2022 Flue-curing Season

Processing Batches	Deviation of Mean Moisture Content from Center Value (%)	Coefficient of Variation of Moisture Content (%)	Coefficient of Variation of Nicotine (%)	Coefficient of Variation of Sugar-to-Nicotine Ratio (%)	Large and Medium Strip Rate (%)	Medium Strip Rate (%)	Small Strip Rate (%)
First	1	1	1	1	0.661	1	0.618
Second	1	1	1	1	0.558	1	0.708
Third	1	1	1	1	0.718	1	0.663

Processing Batches	Stem Content in Leaves (%)	First Class Impurities (Count)	Second Class Impurities (Count)	S	S	T
First	0.88	1	1	0.1204	0.9583	0.8884
Second	0.73	1	1	0.1461	0.9455	0.8662
Third	0.79	0.85	1	0.1278	0.9393	0.8802

From the data in Table 8, it can be seen that among the three processing batches of that year, the first batch of finished tobacco strips has the highest TOPSIS relative closeness, at 0.8884, indicating the best overall quality. The second batch has the lowest TOPSIS relative closeness, at 0.8662, indicating the poorest overall quality. The ranking of TOPSIS relative closeness for finished tobacco strips from different batches, from highest to lowest, is as follows: First Batch > Third Batch > Second Batch.

4 Conclusion

Within the same season, there are significant differences in various quality indicators and the comprehensive quality index of finished tobacco strips processed by different factories. Factory C has the largest deviation of mean moisture content from the center value, reaching 0.33, and Factory B has the highest coefficient of variation of moisture content, reaching 3.78, indicating that the control of moisture uniformity in finished tobacco strips from Factories B and C needs improvement. Factory G has relatively high coefficients of variation for nicotine and the sugar-to-nicotine ratio, both above the lower limit of evaluation, suggesting weaker control of chemical component uniformity compared to other factories. In terms of leaf structure, Factory H is relatively optimal, with the highest medium strip rate, the lowest small strip rate, and the large and medium strip rate within an acceptable range. Factory B has the lowest stem content in leaves, at only 0.58%, but its small strip rate is also the highest, at 0.71%, which is not ideal. In contrast, Factory H has a stem content in leaves of 0.83%, which is at a good level, with minimal leaf breakage and ideal results. Regarding impurities, Factory E has the best control, with no impurities detected, while Factory I has weaker control, with 2 first-class impurities and 5 second-class impurities found. Factory H has the highest TOPSIS relative closeness for finished tobacco strips, at 0.9499, indicating the best overall quality, while Factory B has the lowest TOPSIS relative closeness, at 0.7753, indicating the poorest overall quality.(2) The overall quality of finished tobacco strips processed by the same factory in different seasons is improving, but there is a certain degree of fluctuation. From the data of six consecutive years, from the 2017 season to the 2022 season, the level of moisture uniformity control remains stable, the ability to control chemical component uniformity is improving year by year, and the leaf structure increasingly meets the needs of cigarette making coordination.(3) The quality of finished tobacco strips from different processing batches at the same factory and season is generally stable, with minor fluctuations in some indicators between batches.

This study is guided by the demand for cigarette products and has selected several quality indicators for comprehensive evaluation. The focus is on exploring the comprehensive evaluation methods for the quality of finished tobacco strips.Overall, there are significant differences in the quality of finished tobacco strips from different factories in the same season, the quality of finished tobacco strips from the same factory in different seasons tends to improve, and the quality of finished tobacco strips from different processing batches at the same factory and season is generally stable, indicating the effectiveness of this method. The application of this method by cigarette industrial enterprises for comprehensive evaluation of the quality of threshed and redried tobacco strips is beneficial for a comprehensive understanding of the quality of tobacco strips from different factories, providing a basis for selecting processing points and establishing regional processing centers. It is also conducive to scientifically assessing the stability of processing quality between years and batches at each factory, and promptly proposing improvement suggestions for identified deficiencies.

This study is oriented towards the demand for cigarette products and has selected several quality indicators for comprehensive evaluation. The focus is on exploring the comprehensive evaluation method for finished tobacco strip quality. The number of samples included in the evaluation from each roasting factory is limited, therefore, the ranking of the comprehensive quality of finished tobacco strip processed by each factory in the text does not fully represent the processing capabilities and quality control levels of each factory. To comprehensively, accurately, and truly evaluate the quality of finished tobacco strip from different roasting factories, further in-depth research is needed.

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