中国烟草总公司 郑州烟草研究院
ZHENGZHOU TOBACCO RESEARCH INSTITUTE OF CNTC

Development of an On-line Method for Separating Stems from Tobacco Lamina Based on Low-Energy X-Ray Imaging

Zhu Wenkui, Liu Bin, Mao Junwei, Zhong Kejun,
Xi Jianping, Zhang hui, Wang Yibin, Chen liangyuan, Wang Bin

ZHENGZHOU TOBACCO RESEARCH INSTITUTE OF CNTC

OUTLINE

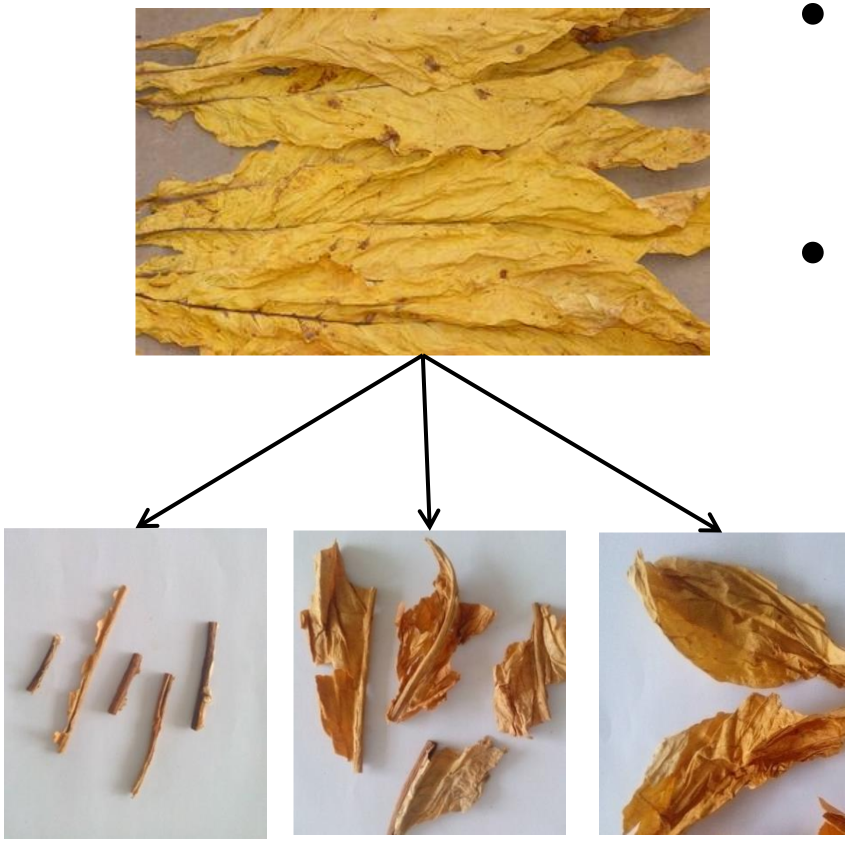
- Background
- Experimental apparatus
- Stem identification method
- Results and discussion
- Conclusions

1 BACKGROUND

- The purity of tobacco materials is an important control index in tobacco primary processing. As a major impurity in cut tobacco, stem sliver has obviously negative impact on the cigarette combustion and its sensory quality.

- Stem content in tobacco materials was influenced directly by tobacco threshing and redrying processing. During this processing, stems need to be removed from threshed materials, and only leaf strips were exported for next handling.

1 BACKGROUND



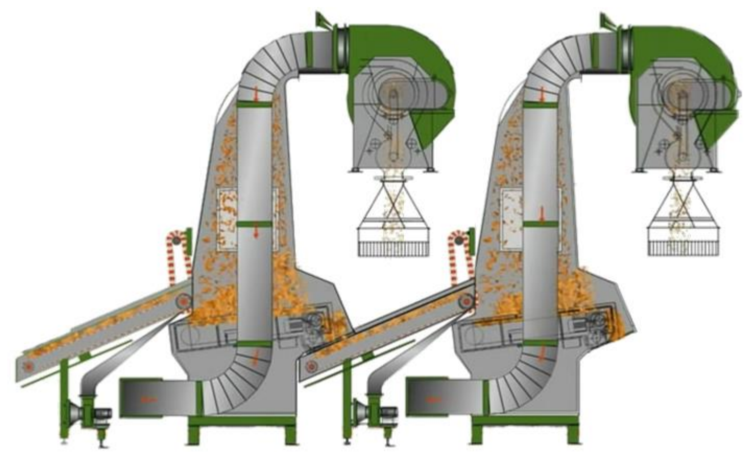
Free stems

Leaf strips containing stems

Pure leaf strips

Threshed materials

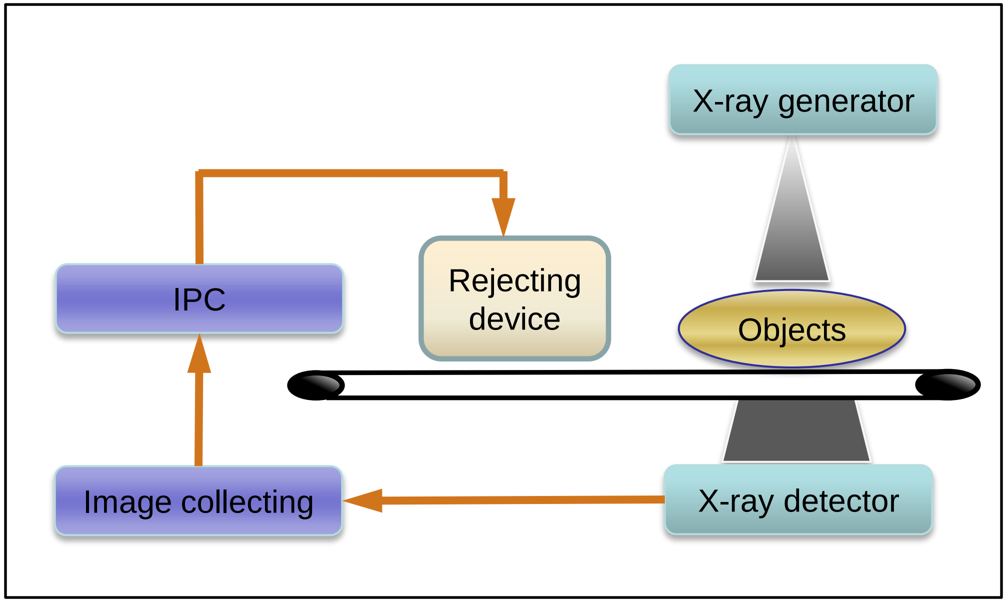
- Tobacco leaves after curing are threshed into **pure leaf strips**, **free stems** as well as **leaf strips containing stems**. The pure leaf strips was generally extracted from threshed materials by air classification method.
- **Leaf strips containing stem** often has similar suspension velocity with pure leaf strips in air flow, and is difficult to be removed from threshed materials by air classifier. It limits the separation efficiency of air classification method.



Air classifier

1 BACKGROUND

- Developing an accurate detection method for stems is necessary for improvement of separation efficiency of stems and leaves.
- Low energy X-ray imaging has been widely used for detection and classification of agriculture products, such as fruits, vegetables and seeds.
- Due to its non-destructive testing, X-ray imaging also gives a possible way for online detection and separation of stems from threshed tobacco leaves.



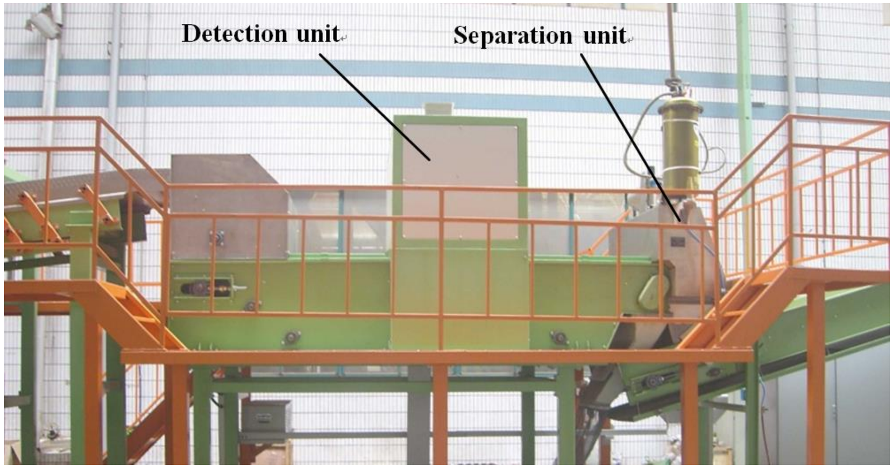
X-ray detection and classification method

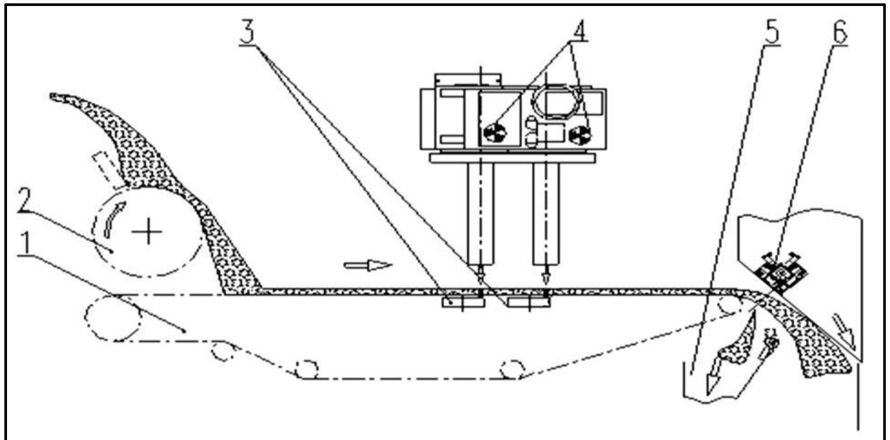
2 EXPERIMENTAL APPARATUS

- **Low energy X-ray generator** with a radiation voltage of 30KeV-120keV (XYG-160, Dandong Radiative Instrument Ltd Co.) was used.

- **Imaging detector** with a high scanning speed of 4K/S were installed under the convey belt. Scanning resolution of detectors is up to 0.4 mm *0.6mm.

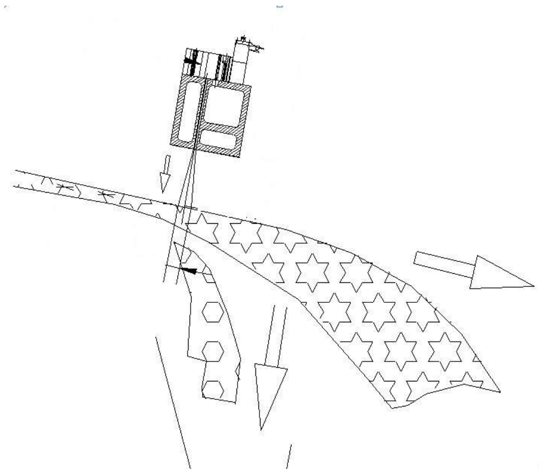
- The speed of **convey belt** can be adjusted within the range of 0-2.2m/s. **High-speed IPC** with multi-core CPU was used as the image processing unit.

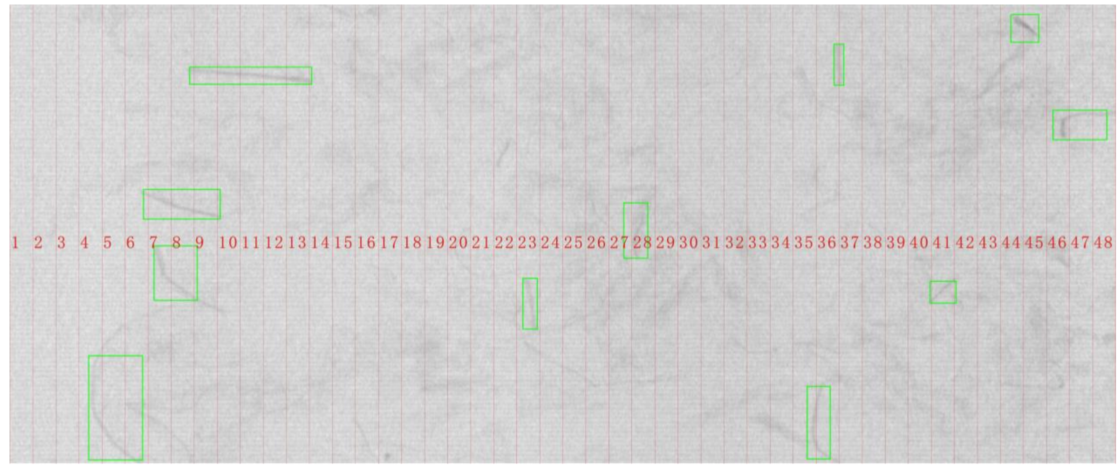




Schematic diagram of experimental platform
1. Convey belt 2. Paving roll 3. Imaging detector 4. X-ray generator 5. Stem hopper 6. Rejecting valves

2 EXPERIMENTAL APPARATUS





- **On-line separation unit** was designed at the end of belt. 80 rejecting valves in separation unit were arranged linearly along the direction vertical to belt speed, which used air blowing to reject stems from test materials.

- When stems were identified, the identification signals were sent to separation unit. According to the position information of identified stems on belt, the valve at corresponding position was opened and compressed air rejected stem into a single hopper.

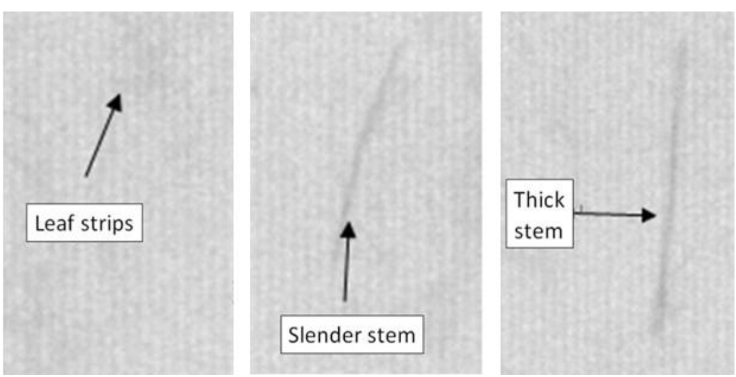
3 STEM IDENTIFICATION METHOD

X-ray attenuation equation:

$$I = I_0 \times \exp(-\frac{\sigma N}{A} \rho x)$$

I-Initial intensity, *I0*-after attenuation, *A*-atomic number, *σ*-atomic section area, *N*-Avogadro Constant , ***ρ*-density, *x*-thickness**:

- Due to the differences in porosity and thickness for stem and leaves, X-ray will show different attenuation according to its attenuation equation. This makes it possible for stem identification from X-ray image.

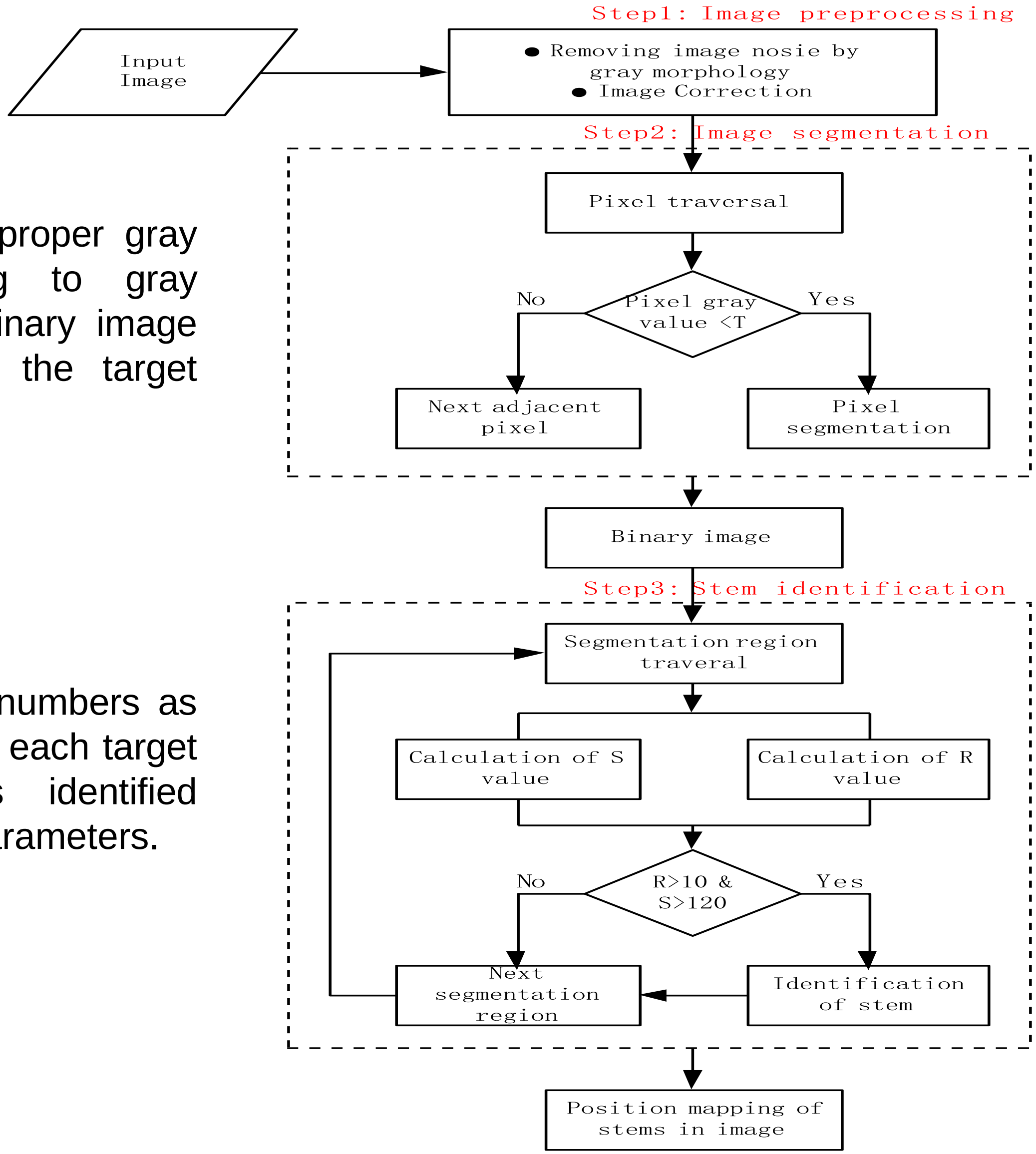


X-ray image for different tobacco materials

- Both slender and thick stems in X-ray images showed the lower gray level less than 37000, while the value for tobacco leaf is over 43000. The gray level of background in images is generally higher than 47000.

3 STEM IDENTIFICATION METHOD

Stem identification algorithm

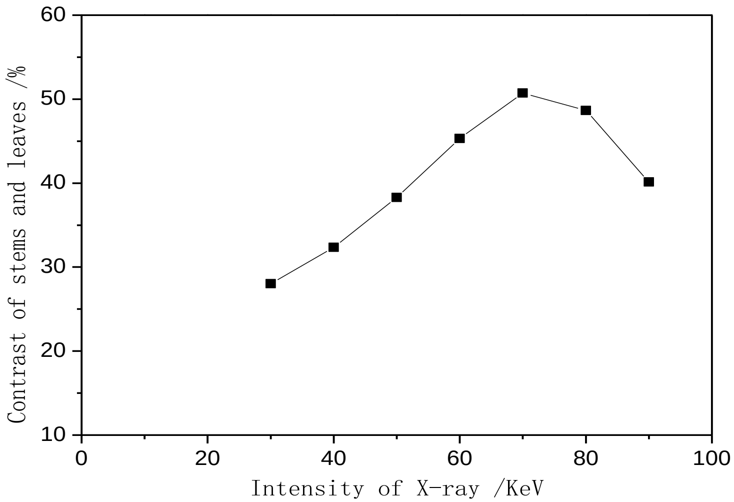


- In the step of image segmentation, a proper gray threshold was determined according to gray difference of leaves and stems. The binary image was obtained by dividing image into the target regions and background region.

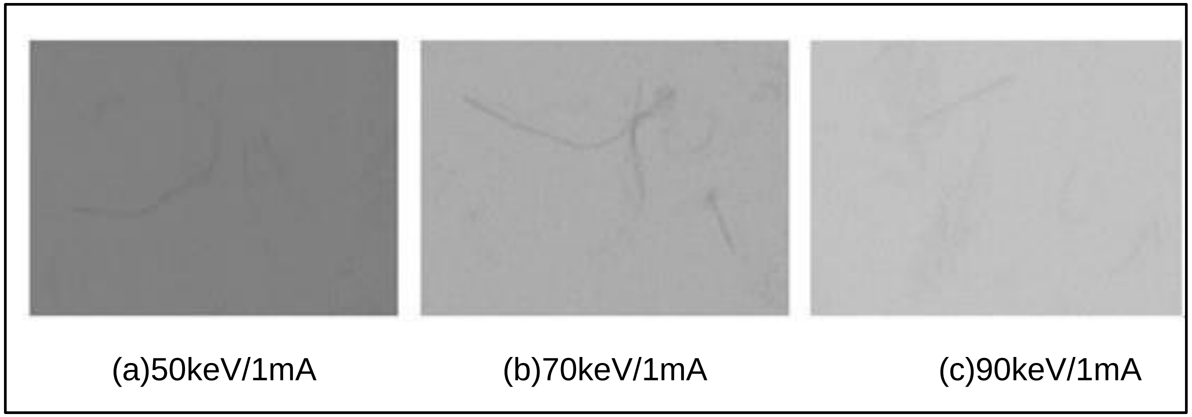
- In the step of stem identification, pixel numbers as well as the ratio of length to diameter for each target region were calculated. Stem was identified according to the above size and shape parameters.

4 RESULTS AND DISCUSSION

4.1 Optimization of **X-ray intensity** and belt speed



Contrast of stem and leaves *vs.* X-ray intensities



X-ray images obtained with different intensities

- Both over high and low intensity of X-ray caused the lower contrast of stem and leaves in image. The highest contrast was obtained at the intensity of 70KeV. It was determined as the optimal testing condition of X-ray generator in order to improve identification rate of stem.

中国烟草总公司 郑州烟草研究院 ZHENGZHOU TOBACCO RESEARCH INSTITUTE OF CNTC

4 RESULTS AND DISCUSSION

4.1 Optimization of X-ray intensity and **belt speed**

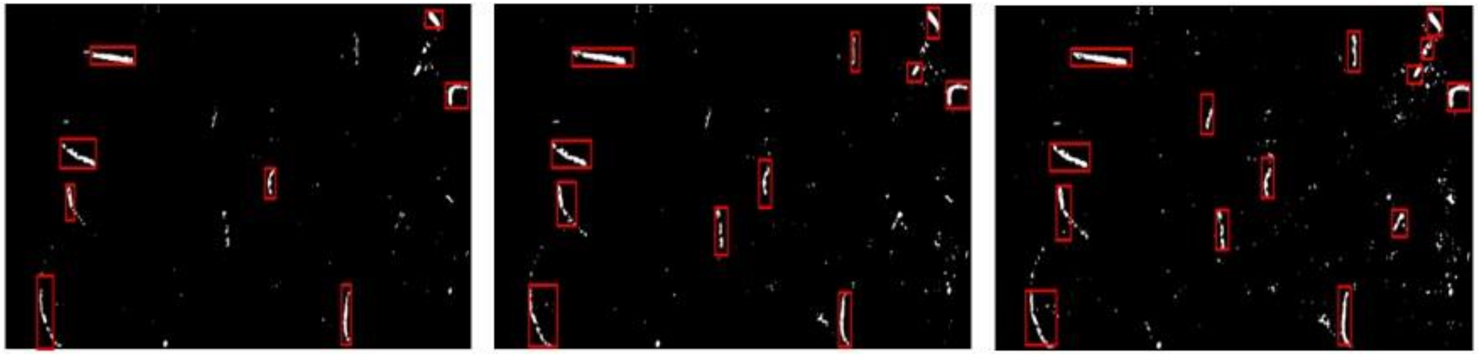
(a) 1.2m/s. (b) 1.6m/s. (c) 1.8m/s

X-ray images obtained with different speed of convey belt

- The highest belt speed given a poor image definition. Images obtained at the speeds of 1.2m/s and 1.6m/s have better definition. Considering the testing efficiency, the speed of 1.6m/s was set as the proper value.

4 RESULTS AND DISCUSSION

4.2 Determination of **gray threshold**



(a) 39000 (b) 40000 (c) 41000

Identified images with different gray thresholds

- Obvious missing identification occurred when low gray threshold was used in stem identification algorithm. While, the extra identified objects at the gray threshold of 41000 were confirmed to be basically clustering leaves. The finial gray threshold was determined as 40000.

4 RESULTS AND DISCUSSION

4.3 Experimental validation of detection system

Test No.	Number of identified stems	Identification accuracy	Number of rejected stems	Rejection accuracy
1	198		190	
2	197	98.8%	189	95.2%
3	198		192	

- 200 **free stems** were firstly used as test samples to investigate the performance of detection system. By analyzing identified images and separated samples, identification accuracy and rejection accuracy of free stems were calculated out.
- The average identification accuracy for 3 repeated tests was over 98%. The average rejection accuracy for 3 tests was also over 95 %.

4 RESULTS AND DISCUSSION

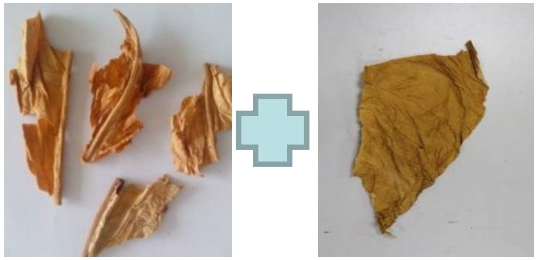
4.3 Experimental validation of detection system

Test No.	Number of identified stems	Identification accuracy	Number of rejected stems	Rejection accuracy
1	198		194	
2	196	98.2%	193	96.2%
3	195		190	

- The average identification accuracy for **leaves containing stems** approached the result of free stems. While, the average rejection accuracy had a slight increase in comparison with that of free stems. The validation results indicated the developed method also performed well for leaves containing stems.

4 RESULTS AND DISCUSSION

4.3 Experimental validation of detection system



Test No.	Number of identified stems	Identification accuracy	Number of rejected stems	Rejection accuracy
1	191		187	
2	186	94.5%	183	92.5%
3	190		185	

- 200 **leaves containing stems** were mixed with 50kg **pure leaves** to investigate the actual performance of experimental system by identifying and separating stems from blend materials.

- Identification accuracy and rejection accuracy were up to 94% and 92%. The test results for blend materials indicated that, although target samples were diluted into plenty of pure leaves, they still could be identified and rejected from blend materials accurately.

5 CONCLUSIONS

- In the present work, an on-line detection and separation system of stem from tobacco lamina was developed by low-energy X-ray imaging and digital image analysis technology. Optimal detection conditions were investigated and determined.

- The free stems and leaves containing stems were respectively used as target samples to test system availability. High identification accuracy was obtained for both free stems and leaves containing stems. For mixed materials of pure leaves and leaves containing stems, the system also showed high separation rate of stems.

- The validation tests indicated that developed system was completely reliable for online detection and separation of stems from threshed tobacco leaves in tobacco primary processing. The method can also be used as a new and fast sorting tool in stem content determination.

中国烟草总公司 郑州烟草研究院
ZHENGZHOU TOBACCO RESEARCH INSTITUTE OF CNTC

Thanks！