Design And Performance Of Tea Shoots Chopper: Optimization Of Stems And Leaves Separation

Agus Sutejo, Sutrisno Suro Mardjan, Wawan Hermawan, Desrial

Abstract: The quality of dried tea depends on the condition of raw materials and processing methods. The problem in the tea processing is the mixture of crushed stems and leaves. This research aims to examine the performance of tea shoots chopping machine to obtain optimum stems and leaves separation based on the aerodynamic properties of the material. The design concept of the chopping machine is a vertical type chopper with five main components, i.e., hopper and output unit, chopping blade, power source, transmission system, and the frame. The performance of the chopper was conducted by calculating the chopping effectiveness and determining three physical appearance of chopped tea shoots, namely: a) chopped leaves, b) tea shoots which not chopped properly, and c) chopped stems. The combination of three different blade gaps (6 mm, 8 mm, and 10 mm) and three different blade rotation speeds (450 rpm, 630 rpm, and 950 rpm) in the chopping machine performance test resulted the most optimal combination of the chopping process is 8 mm blade gap and 630 rpm blade rotation where the effectiveness of the chopping process was obtained 88.05%.

Keywords: Tea shoots, chopping machine, chopping effectiveness

1 INTRODUCTION

TEA (Camellia sinensis) is one of the main commodities of Indonesian plantation. In 2011, Indonesia was in the eighth position as a tea producer in the world, with a market share of 3.24%. In addition, Indonesia is also the world's ninth largest tea exporter with a market share of 2.40% [1]. However, over the past ten years, the performance of Indonesian tea agribusiness has declined. This is indicated by the decline in tea plantation area by 2.02% per year, followed by a decrease in production by 2.49% [2]. The main problems facing tea plantations today are quality degradation, increasing costs and decreasing quantity of tea produced. Suprihatini et al. [3] shows the condition of technological component (techno ware, human ware, info ware, and organ ware) owned by Indonesian tea industry is in medium category. The strategies that can be done to improve the quality of tea product are: 1) Produce product according to customer's wishes, 2) Technical response or production process priority: handling quality of tea bud, withering, and roll-milling, 3) Application of ISO 9001 management system [4]. The quality of tea product is strongly influenced by the potential of its own shoots quality as well as its processing method and technology. Tea product in Indonesia is divided into three classes, first grade (generally distributed for export market), second grade (generally distributed for domestic market) and off grade (generally distributed for domestic traditional market) [5].

- ***Agus Sutejo, Sutrisno Suro Mardjan, Wawan Hermawan, Desrial***
- *Department of Mechanical and Biosystem Engineering, Bogor Agricultural University, Indonesia, E-mail: dtm_cyber@yahoo.com*
- *Department of Mechanical and Biosystem Engineering, Bogor Agricultural University, Indonesia, E-mail: kensutrisno@yahoo.com*
- *Department of Mechanical and Biosystem Engineering, Bogor Agricultural University, Indonesia, E-mail: w_hermawan@ipb.ac.id*
- *Department of Mechanical and Biosystem Engineering, Bogor Agricultural University, Indonesia, E-mail: desrial@ipb.ac.id*

Hence the quality improvement becomes one of the critical factors in the effort to save the national tea industry. Sa'id et al. [6] suggests that if a company lacks the capability of process and product innovation, it must at least have the ability to implement incremental changes to existing technologies according to consumer demand. Efforts to improve the quality of tea product to obtain more objective results are conducted through analysis of physical and chemical quality of tea products. Physical quality analysis of tea was conducted through image processing application [7], [8], [9], [10], analysis of chemical quality especially aroma with application of electronic nose sensor [11], [12], and artificial intelligence application using Fuzzy logic [13], [14], [15]. But the application of these technologies was only implemented on the final product of tea, so there is no effort to repair and improve the quality of tea on the first step of tea processing technology. The weakness in the tea processing is the mixing of stems and tea leaves. The mixing of the stems and tea leaves can decrease the quality of the end product of the dried tea This is because the main product of high-quality processed tea comes from tea leaves, while the stem is more functioning as an impurity when the stem skin is released. The advantage of separating the stems and tea leaves is the increased quality of the final tea product. The quality of tea derived from the leaves will increase the selling value of the product. But if the stem of tea leaves is not detached the skin, it will be processed into a high special quality tea. The first step before separating the stems and tea leaves is by designing a crusher machine capable of crushing the stems and tea leaves into certain sizes for proper edible use. This research aims to design and examine the performance of withered tea shoot crusher machine for the first step of tea stems and tea leaves separation system.

2 MATERIAL AND METHOD

The research was conducted with design and fabrication and was continued testing the performance of the chopping machine to ensure the machine is running properly.

2.1 Design of the Chopping Machine

This machine was designed with 200 kg/hour chopping capacity, by using an electric motor as power source. The chopping machine was designed per part, with four main parts of the machine, i.e., hopper and output unit, chopping blade, frame, motor, and transmission system.

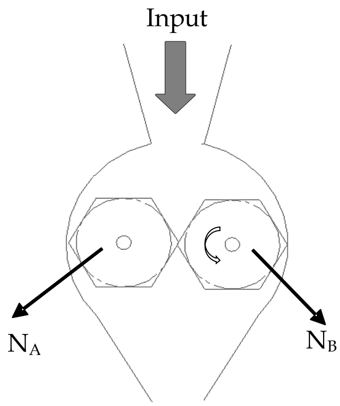

Fig. 1. *Conceptual design vertical type chopper with static blades (N_A) and clockwise rotating blades (N_B).*

The design criteria of the chopping machine refers to the output of the final product where the stems and leaves are should be separated easily. Criteria of the chopping machine, including: 1) stems and leaves should be separated or not tied to one another; 2) There is no friction between the blades when the chopping takes place. To meet the desired design criteria, the design concept of the chopping machine is a vertical type chopping machine with a series of rotating blades and a series of other static blades (Fig. 1). A series of blades rotates clockwise. This mechanism aims to overcome friction between the blades, because the gap between the blades is quite tight.

2.2 Chopping Machine Performance

To ensure the chopper operate in accordance with the objectives and criteria to be achieved then the performance test was conducted by ten replications. The combination of chopping rotation speeds (450 rpm, 630 rpm, and 950 rpm) with three different blade gaps (6 mm, 8 mm, 10 mm) was expected to produce optimal chopping system for stems and leaves separation. From the two factors, then obtained the treatment combinations as follows: The material used in this performance test was withered tea shoots with water content 68.68% obtained from PTP Nusantara VIII plantation, Cianten, Bogor, West Java. Measurement of stem and leaf yield from tea shoots chopping was conducted to determine the velocity of the airflow to suck the tea leaves and as a reference to the separation capacity criteria. Yield of stems and tea leaves of the chopping methods were measured by a randomly sampling method. 200 gram chopped tea shoots snippet randomly, and was separated into several parts, namely: chopped leaves, chopped stems, and not chopped properly. Each of these sections was then weighed and the proportions were calculated using Equation 1, 2, and 3.

Table 1
Treatment combination on chopping machine performance test

Blade gap (mm)	Rotation speed (rpm)		
	450 (A)	630 (B)	950 (C)
6	6A	6B	6C
8	8A	8B	8C
10	10A	10B	10C

$$R_s = \frac{W_s}{W} x\ 100\% \quad (1)$$

$$R_l = \frac{W_l}{W} x\ 100\% \quad (2)$$

$$R_m = \frac{W_m}{W} x\ 100\% \quad (3)$$

The chopping effectiveness was determined by calculating the percentage of chopped material to the overall weight of the material as follows:

$$E = \frac{W_s + W_l}{W} x\ 100\% \quad (4)$$

Analysis of Variance (Anova) and Duncan's Multiple Range Test (DMRT) were used in data analysis.

3 Results and Discussion

3.1 Chopping Machine Design

The chopping machine design is shown in Fig. 5. The machine components are: 1) Hopper and Output Unit: Hopper was made of stainless steel plate 304 with a thickness of 2 mm. This hopper was shaped like a rectangular inverted prism with a beam-shaped buffer that was also as a hopper holder. Hopper was removable that aimed to simplify the process of cleaning the chopping blades. Hopper can be seen in Figure 2. Chopping capacity is calculated based on hopper volume and cutting speed. Capacity was designed to be 200 kg/hour.

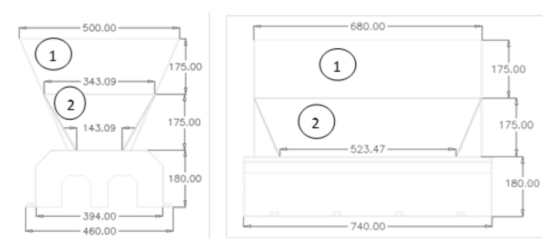

Fig. 2. *Hopper and output unit.*

2) Chopping Blade: There are two axes as a holder of rectangular polygon chopping blades. The gap between the blades on the shaft was determined by the treatments in chopping machine performance test. A series of cutting blades rotates clockwise and the other series is a static cutting blade, accordingly the stems and leaves coming into the chopper blades will be squashed and cut off. The Chopping blade design is shown in Figure 3.
3) Machine Frame: Machine Frame was made of UNP50 steel. There are two main holder position, at the top is used as a holder for chopping blade and hopper while at the other side as a power source holder.

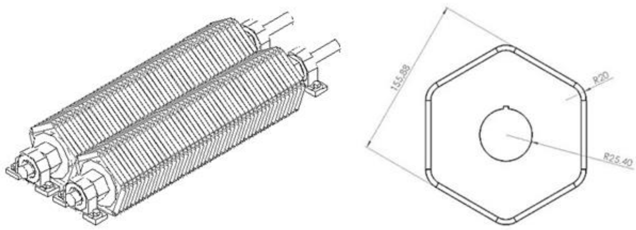

Fig. 3. *Chopping blade.*

4) Power Source and Transmission Systems: A 1 HP electric motor with initial rotation speed of 1400 rpm was used as power source. Power transmitted from electric motor to chopping blade by pulley and belt transmission system. The motor will drive the pulley 1 which is directly connected to the motor shaft. The belt which is connected to the pulley 2 directly drives the main chopping blade shaft. The diameter ratio of pulley 1 and pulley 2 is 1:2. Pulley 2 will rotate the shaft of the main chopping blade in clockwise direction. The arrangement of frame, power source, and power transmission is shown in Fig. 4.

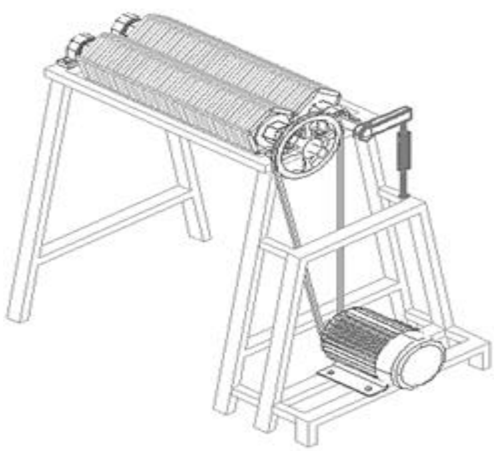

Fig. 4. *The arrangement of frame, power source, and power transmission.*

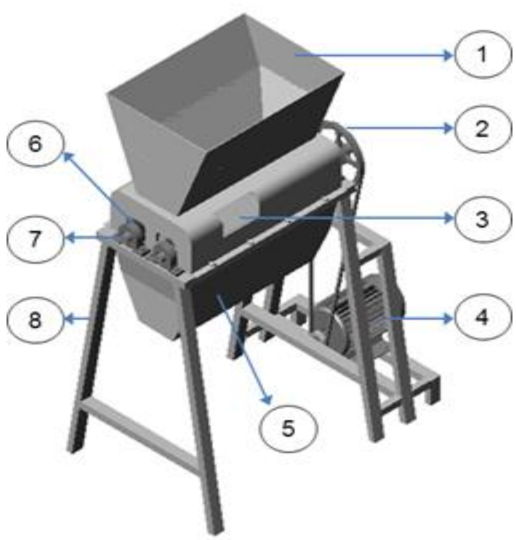

Fig. 5. *Design of the tea shoots chopping machine, 1) hopper; 2) transmission system; 3) chopping blades; 4) electric motor; 5) output unit; 6) bearing; 7) chopping blades shaft; 8) frame.*

3.2 Results of Chopping Machine Performance Test

The results of the chopping machine performance test focused on the capability of the machine in chopping the withered tea shoots perfectly, i.e., stems and leaves properly separated. Thus, the proportion of tea shoots which not chopped properly was expected to be as small as possible. Fig. 6 shows the result samples of the chopping machine. There were three physical appearances of chopped tea shoots, namely: chopped leaves, not chopped properly, and chopped stems.

Fig. 6. *Physical appearance of chopped tea shoots, (a) chopped leaves, (b) not chopped properly, and (c) chopped stems*

The results in Fig. 7 shows that at 6 mm and 8 mm blades gap, the character of the chopped tea shoots is not significantly different at 450 rpm, 630 rpm, and 950 rpm blade rotation respectively. This is indicated by the proportion of each fraction which value is not much different. Nevertheless, on 6 mm blade gap test, congestion due to both friction between the chopping blades and the excessive feeding caused the material squashed between the blades. Testing with a 10 mm blade spacing resulted in a smaller proportion of chopped stems and chopped leaves, while for the proportion of tea shoots which not chopped properly was much greater than that with a blade gap of 6 mm and 8 mm. In an experiment with a 10 mm blade gap, the difference in rotation of the chopping blades showed different results of cuttings. The higher blade rotation, the higher proportion of tea shoots which not chopped properly. The difference was caused by the wider gap of the blade, allowing the material just passed, especially if the position of the material perpendicular to the arrangement of the blade at the time of feeding. In addition, the higher blade rotation caused the material to pass quickly through the chopping blades and more potentially to not being chopped properly.

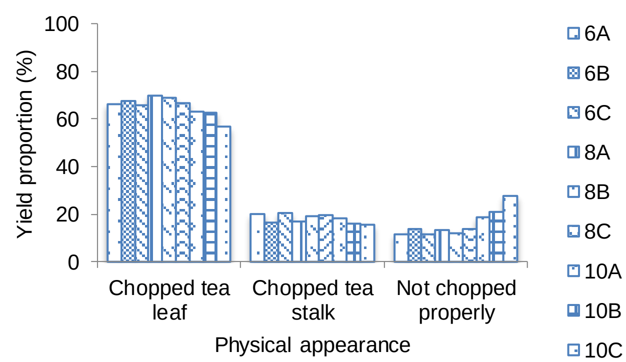

Fig. 7. *Chopping yield proportion of each performance test treatment.*

Fig. 8 shows the chopping effectiveness. From the histogram, the highest chopping effectiveness is 88.05 %. This score was obtained from the test with a blade gap of 8 mm and 630 rpm blade rotation. This combination is expected to be the most optimum result in tea shoots chopping before the proper separation of tea stems and tea leaves pneumatically.

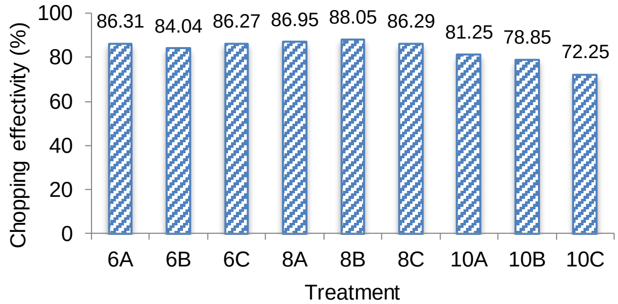

Fig. 8. *Chopping effectiveness of each performance test treatment.*

Nevertheless, the results of the Anova test at the 95% confidence level indicate a factor that has more significant effect on the observation results is the blade gap. Meanwhile, the blade rotation factor and the interaction between the two factors did not give a significant effect on the results. Pairwise comparison test results for blade gap (mm) and blade rotation (rpm) using DMRT is shown in Table 2. In addition, the mass and the projection area of the chopped stems and chopped leaves were also measured. These measurements are expected to be used in the analysis of aerodynamic properties of the material as a reference for the stems and tea leaves separation pneumatically. Measurement results are shown in Table 3.

TABLE 2

SUMMARY OF PAIRWISE COMPARISON TEST USING DMRT FOR CHOPPING YIELD AND CHOPPING EFFECTIVENESS

	Chopping yield			Chopping effectivenes s (%)
	chopped leaves (%)	chopped stems (%)	unchopped properly (%)	
6A	66.241^{ab}	20.073^{a}	13.686^{a}	86.314^{a}
6B	67.500^{ab}	16.538^{a}	15.963^{ab}	84.037^{ab}
6C	65.821^{ab}	20.453^{a}	13.725^{a}	86.275^{a}
8A	69.880^{a}	17.075^{a}	13.045^{a}	86.955^{a}
8B	68.962^{ab}	19.083^{a}	11.955^{a}	88.045^{a}
8C	66.688^{ab}	19.605^{a}	13.707^{a}	86.293^{a}
10A	62.890^{bc}	18.360^{a}	18.750^{bc}	81.250^{bc}
10B	62.811^{bc}	16.037^{a}	21.153^{c}	78.847^{c}
10C	56.567^{c}	15.678^{a}	27.755^{d}	72.245^{d}

The value in the column with the same letter are not differ significantly

TABLE 3

AVERAGE OF MASS AND PROJECTION AREA OF CHOPPED STEMS AND LEAVES

	Average of mass (g)		Average of projection area (mm^2)	
	Choppe d leaves	Choppe d stem	Chopped leaves (parallel to face)	Chopped stem (normal to axis)
6A	0.068^{a}	0.120^{a}	404.444^{a}	6.689^{a}
6B	0.077^{a}	0.112^{a}	408.953^{a}	5.160^{a}
6C	0.085^{a}	0.137^{a}	382.936^{a}	5.512^{a}
8A	0.104^{ab}	0.210^{a}	505.444^{ab}	7.236^{a}
8B	0.103^{ab}	0.102^{a}	451.172^{ab}	4.502^{a}
8C	0.101^{ab}	0.204^{a}	484.240^{ab}	7.883^{a}
10A	0.139^{bc}	0.118^{a}	661.324^{bc}	5.247^{a}
10B	0.174^{c}	0.158^{a}	860.278^{c}	6.846^{a}
10C	0.164^{c}	0.137^{a}	790.714^{c}	5.791^{a}

The value in the column with the same letter are not differ significantly

The results show that the average of mass and projection area of chopped stems are not differ significantly for all blade gap and blade rotation combinations. However, for the chopped leaves there were observed different value of the average of mass and projection area due to the treatments as a result of pairwise comparison test for blade gap (mm) and blade rotation (rpm) using DMRT at the 95% convidence level.

4 CONCLUSIONS

The prototype of the tea shoot chopping machine has been manufactured with a vertical cutting system. The main components of the chopping machine are: hopper and output unit, chopping blades, power source, transmission system, and the frame. The results of machine performance testing shows the optimal combination of the chopping process is 8 mm blade gap and 630 rpm blade rotation where the effectiveness of the chopping process obtained was 88.05%.

5 REFERENCES

[1] [FAO] Food and Agriculture Organization in http://faostat.fao.org. [accessed on 17th February 2014].

[2] [BPS] Statistics Indonesia. 2011. Plantation Statistics 2011. Direktorat Jenderal Perkebunan, Departemen Pertanian.

[3] Suprihatini R, Sa'id EG, Marimin, Mangunwidjaja D. 2005. Analisis kondisi komponen-komponen teknologi pengolahan di industri teh curah Indonesia. J. Teknol. Ind. Pertanian. 14(3):101-106.

[4] Marimin, Karmila E. 2004. Kajian strategi peningkatan kualitas teh hitam orthodoks di PT. Perkebunan Nusantara VIII (PTPN VIII Persero) Unit Kebun Gedeh, Kabupaten Cianjur. J. Teknol. Ind. Pertanian. 14(1):6-16.

[5] [PPTK] Pusat Penelitian Teh dan Kina. 2007. Petunjuk Teknis Pengolahan Teh. Edisi Kedua. Bandung: Pusat Penelitian Teh dan Kina.

[6] Sa'id EG, Rachmayanti, Muttaqin MZ. 2001. Manajemen Teknologi Agribisnis, Kunci Menuju Daya Saing Global Produk Agribisnis. PT. Ghalia Indonesia dan MMA-IPB.

[7] Suwardi IS, Jenie RP. 2008. Rancang bangun perangkat lunak analisa hubungan antara variabel fisik dan kelas mutu teh hitam. in Seminar Nasional Teknologi Informatika – Yogyakarta. 22 November 2008.

[8] Gill GS, Kumar A, Agarwal R. 2011. Monitoring and grading of tea by computer vision – A review. Journal of Food Engineering. 106 (2011): 13–19.

[9] Gill GS, Kumar A, Agarwal R. 2013. Nondestructive grading of black tea based on physical parameters by texture analysis. J. Biosystems Engineering. 116 (2013): 198 – 204.

[10] Laddi A, Prakash NR, Sharma S, Mondal HS, Kumar A, Kapur P. 2012. Significant physical attributes affecting quality of Indian black (CTC) tea. Journal of Food Engineering. 113 (2012): 69–78.

[11] Nugroho J, Muryani D, Rahayoe S, Bintoro N. 2008. Aplikasi jaringan syaraf tiruan untuk identifikasi aroma teh menggunakan electronic nose in Seminar Nasional Teknik Pertanian – Yogyakarta. 18-19 November 2008.

[12] Banerjee R, Chattopadhyay P, Tudu B, Bhattacharyya N, Bandyopadhyay R. 2014. Artificial flavor perception of black tea using fusion of electronic nose and tongue response: A Bayesian statistical approach. Journal of Food Engineering. 142 (2014): 87–93.

[13] Suprihatini R, Marimin. 2000. Penerapan teknik pengambilan keputusan – kelompok fuzzy untuk penilaian mutu teh hitam indonesia dan strategi peningkatannya. J. Teknol. Ind. Pertanian. 9(3): 127 – 132.

[14] Kastaman R, Zain S, Prayudo SB. 2007. Penerapan logika fuzzy untuk penilaian mutu teh hitam orthodox. JTEP. 21(3): 283 – 294.

[15] Rohmatullah, Marimin. 2007. Logika fuzzy dan jaringan syaraf tiruan untuk peningkatan mutu teh hitam. J. Teknol.Ind.Pangan. 18(2): 96 – 101.