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Performance of Cooled Cone Grinding Machine in Cocoa Cake Processing

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Abstract

The process of cocoa paste pressing has a function to separate the fatty components of cocoa from its cake. Cocoa paste is further processed into cocoa powder using grinding machine for cocoa cake. The cooled cone type of cocoa grinding machine is used to solve the problem of plug in the machine caused by melting of fat in cocoa cake due to hot effect as a result of friction in the grinding machine. Grinding machine of cocoa has conical form of cylinder for grinding and stator wall wrapped by source of cold and closed with jacket wool. Research was conducted at Kaliwining Experimental Station of Indonesian Coffee and Cocoa Research Institute using cocoa cake containing 26.8% cocoa fat originated from Forastero type of cocoa seed. The capacity and recovery of the machine was influenced by space between rotor cylinder and stator wall. Grinding machine operated at cooling temperature of 25.5^{O}C and space between rotor–stator 0.9 cm and the capacity of 187.5 kg/hour with recovery of 200 mesh cocoa powder as much as 24%. The maximum power of machine required was 2.5 kW with efficiency of energy transfer of 97%. Results of proximate analysis showed that there was no change of protein content, however, protein and carbohydrate content increased after processing, i.e. from 5.70% and 59.82% into 5.80% and 61.89% respectively.

Keywords: cocoa cake, cooling, grinding, cocoa powder

INTRODUCTION

Cocoa powder is used as additional material or as flavor and aroma of food. Cocoa powder can also be used as natural colouring matter and as food layering substance such as in bisquit and ice cream (Kox, 2000). Cocoa powder is obtained from grinding and sieving of cocoa cake, which is the product of pressing process of cocoa paste to separate from fat component. Particle size of cocoa powder accepted for food material according to SNI 01-3747-1995 is about 200 mesh. Cocoa powder has variation of fat content in accordance with condition of operation during pressing. Cocoa cake with high fat content tends to melt if it is ground at the temperature of 27-30^{O}C (Mulato & Suharyanto, 2012). The roll type of grinding machine according to Sri-Mulato *et al.* (2010) has not yet produced 200 mesh powder size if it is only ground once during processing. The fat of cocoa consisted of stearic acid (33.2%), oleic acid (32.6%), myristic acid (0.1%), and linolenic acid (0.1%) (Endarti, 2007). Theobromine content of cocoa powder can reach 12.22 mg (Maleyki *et al.*, 2008).

Grinding machines normally used in the industry consisted of three types *i.e.* primary grinder, secondary grinder, and tertiary grinder each of which refers to range of particle size to be produced. The smallest size of powder is produced in the tertiary grinder step which can reach 100 mesh to 1250 mesh (Beckett, 2008). Temperature increase during process of grinding may influence physical and chemical properties of material to be ground. Heat can be produced by friction in the machine or friction between materials, therefore to prevent heating coolant can be used. The purpose of this experiment is to evaluate the performance of cooled grinding machine for cocoa cake with high fat content, and to determine physical quality or fineness of powder and chemical quality of cocoa powder using proximate analysis.

MATERIALS AND METHODS

Experiment was conducted at Departmen of Postharvest Processing of Indonesian Coffee and Cocoa Research Institute (ICCRI). Experiment was divided into three steps, i.e. designing grinding part, grinding machine for cocoa cake, testing the performance of the machine, and evaluation of the quality of cocoa powder produced consisting of recovery, fineness and nutritional content. Material of experiment was cocoa cake containing 26.8% fat, product of cocoa paste pressing. The cocoa cake was originated from Forastero cocoa seed with moisture content of 7.05% obtained from Kaliwining Experimental Garden of ICCRI. Instruments for testing were data acquisition Fluke, *Ni-CrNi* sensor, and computer for allocation of temperature data, tachometer, and oven.

The conical cooled grinding machine for cocoa cake had four main parts, i.e. feeding part, grinding part, moving power, and cooling unit (Figure 1). Feeding part consisted of flat spoon plate made of aluminium with diameter of 40 cm supplied with slider. Grinding part consisted of spoon cone with diameter of 20 cm and height of 40 cm, and had vertical destroyer spoon with 2 cm thickness and its distance could be changed by means of delicate wall (clearance). Moving power consisted of single phase electrical motor with voltage of 220 V and rotation power of 1400 rpm that moved rotation axis cushion. The transmission of power from source of moving power to grinding cylinder used pulley system and rubber belt single V, reduction of rotation using gear box with rotation ratio of 1:50 and size of 60. Proportion of gear wheel from gear box to rotation axle cushion was 1:1. Cooling unit or coolant used wrapping system consisted of condensor, compressor, and freon. Coolant wrapped on grinding part was also wrapped by woolen jacket for reducing heat transfer from environment to the machine. Temperature scale of cooling source was regulated with lowest temperature of 10^{O}C under condition of production space temperature of 29^{O}C.

Performance and product quality

Performance of grinding machine for cocoa cake was evaluated at distance of clearance as much as 0.6 cm, 0.9 cm, and 1.2 cm and cooling temperature of 26^{O}C, 25.5^{O}C and 25^{O}C respectively. Working capacity of machine (Cm) was calculated according to equation:

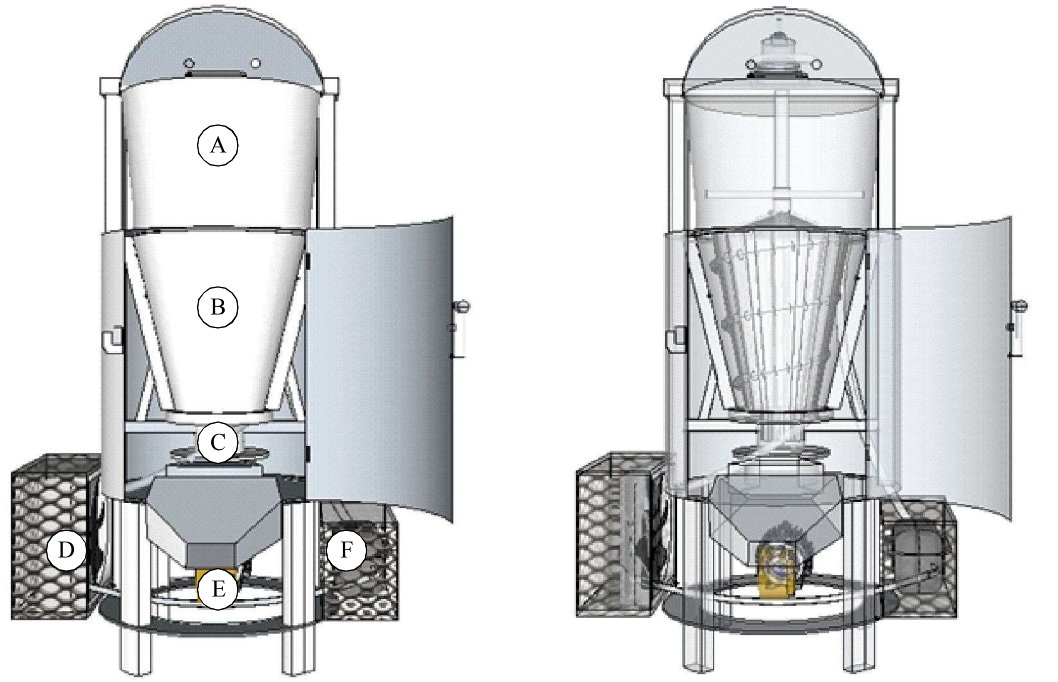
$$\text{Cm, kg/hour} = \frac{\text{Feeding material, kg}}{\text{Grinding time, hour}} \quad (1)$$

Power needed was calculated based on equation:

$$\text{P. Watt} = \text{I x V} \quad (2)$$

Notes:
I = current measured during machine operation (ampere)
V = voltage (volt)

Efficiency of power transmission (ηd) was calculated using equation:



Notes:
a. Feeding part
b. Grinding part
c. Clearance
d. Cooling unit
e. Moving power/motor
f. Compressor

Figure 1. Design of cooled cone grinding machine

$$\eta d). \% (\%) = \frac{n_2 \text{ x } d_2}{n_1 \text{ x } d_1} \text{ x } 100\% \qquad (3)$$

Notes:
n_1 = rotation of cylinder axle of moving motor (rpm)
n_2 = rotation of main cylinder axle of grinding pulley (m)
d_1 = diameter of grinding pulley (m)

The powder produced by grinding was sieved using 25 mesh, 100 mesh, and 200 mesh sized sieve and the recovery was calculated. Cocoa powder was analyzed with proximate analysis, by testing carbohydrate content using Luff Schoorl method, testing protein content by means of micro Kjeldahl, and testing fat content using Soxhlet method.

RESULTS AND DISCUSSION

Cocoa cake could have fat content between 10% and 22% depending on condition of pressing its paste. The high fat content in cocoa cake became a problem in the process of grinding because it would produce heat due to friction between rotor and stator, or between grinder and the material ground. The excessive heat caused heating of the cocoa cake up to its melting point at 27-30^{O}C. The melting cocoa cake during grinding would plug the machine and increased the occurrence of oxydation of fatty component inside and therefore increased the potential of rancidity (Morris, 1954). The excessive heat in the machine could be reduced by installing cooling apparatus to prevent change of quality of the material processed (Meursing & Zijderveld, 1999). The installation of cooling source in ground space wouldlike to absorve heat so that the material of cocoa cake with high fat content did not melt (Rowe & Jin, 2001).

Grinding process temperature

Low temperature in the grinding space of cocoa cake was produced by Freon system wrapped and isolated the whole surface of grinding space. Temperature of cooling source (T_0) was arranged at 26^{O}C, 25.5^{O}C, and 25^{O}C, and distance between grinding cylinder and wall (S) or clearance was settled at 0.6 cm, 0.9 cm and 1.2 cm. Results of evaluation of machine temperature in grinding 25 kg cocoa cake with arrangement of cooling temperature (T_0) and distance between rotor and stator (S) showed different temperature fluctuation as illustrated in Figure 2, *i.e.* at T_0 26^{O}C, 25.5^{O}C, and 25^{O}C, each of which reached temperature range of 23-19^{O}C, 21-10^{O}C, and 18-6^{O}C. The narrow distance between rotor-stator (S) increased the temperature (Figure 2a) with smallest S tended to be in the upper side (Figure 2c). Difference temperature between grinding space (T_i) and cooling temperature (T_0) was not always the same, in which at T_0 = 26^{O}C could differ about 6^{O}C, while at T_0 = 25.5^{O}C the difference was about 11^{O}C. This showed that cooling temperature (T_i) beside influenced by clearance it was also influenced by environmental condition (Geankoplis, 1983) like change of specific mass of water vapour by change of air density and space temperature. Grinding machine operated at space temperature of 29^{O}C and 75% humidity according to Smith & Van Ness (1987) would expose water vapour around at dew point temperature (24^{O}C), so that temperature of cooling source was arranged minimum at 25^{O}C to prevent the grinding machine exposed to excess of water originated from water vapour in the air. The results showed that grinding machine could be operated at temperature of cooling source at 25-26^{O}C without plug although dew existed in grinding space. Water vapour from the environmental air was still relative low to be able to wet cocoa cake and therefore it did not disturb performance of the machine.

Working capacity

Grinding machine of cocoa cake had been developed beforehand by Widyotomo & Sri-Mulato (2004) without using cooling system, the capacity of which was 5 to 10 kg for one time grinding that required 30 minutes processing time. Working capacity of grinding machine for cocoa cake with fat content of 26.75% at different cooling temperature (T_0) and clearance (S) was presented in Figure 3. The highest temperature T_0 at 25.5^{O}C did not much influence to the capacity of the grinding machine, but at temperature above 25.5^{O}C the capacity of machine tended to decrease in accordance with decrease of clearance distance. Machine capacity at clearance (S) 0.9 cm and 1.2 cm was a little bit higher than clearance = 0.6 cm for temperature condition. Average capacity of grinding machine was 185 kg/hour, and optimum capacity was observed at cooling temperature of 25.5^{O}C with clearance of 0.9 cm and 1.2 cm, i.e. 187.5 kg/hour, whereas capacity at 26^{O}C with clearance of 0.9 cm and 1.2 cm was 183.8 kg/hour.

Power requirement and efficiency

Cooling source in grinding machine would hand to hand with source of power when being operated, and therefore power requirement was influenced by temperature of cooling source and distance (clearance)

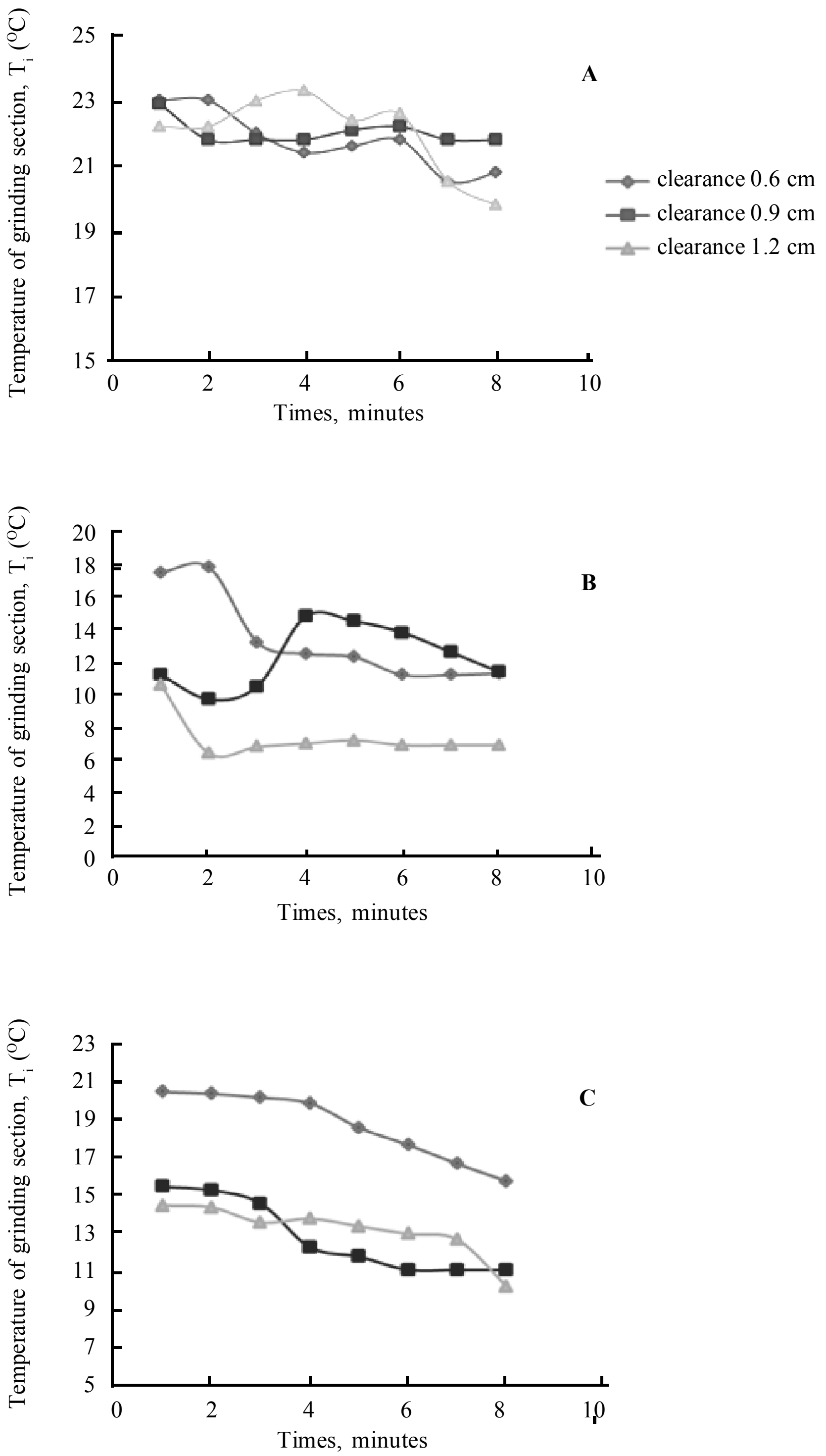


Figure 2. Temperature profile of grinding section by cooling temperature arranged at 26^{O}C (A), 25.5^{O}C (B) and 25^{O}C (C)

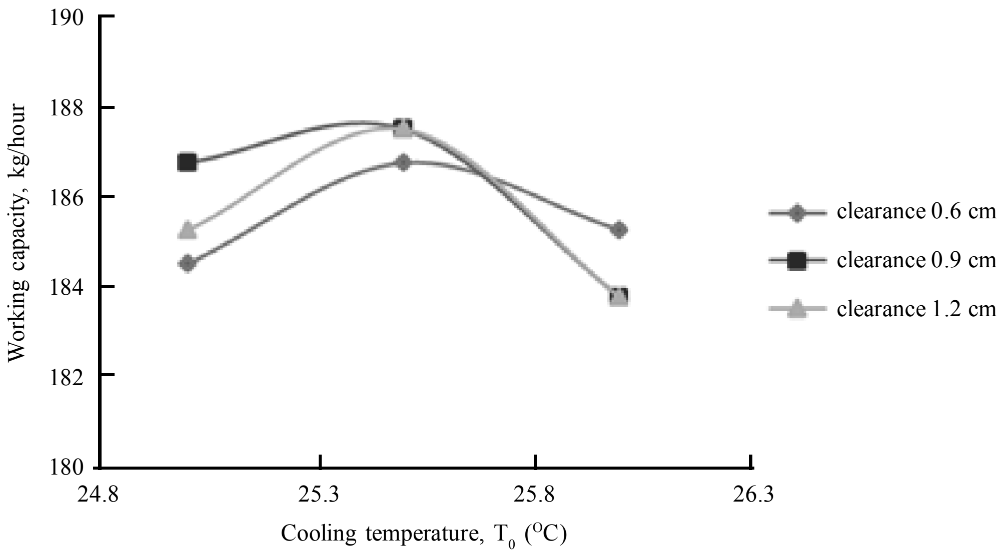


Figure 3. Working capacity of cocoa cake grinding machine

used. Figure 4 showed that in the same loading capacity the power required was proportional to increase of temperature and clearance. The higher the temperature of cooling unit used to cool grinding space the smaller was the power needed, and the higher the clearance used the lower also the power needed. Each 1°C temperature increase of cooling source decreased the power needed by 1.25 kW for clearane of 1.2 cm, 0.78 kW for clearance of 0.9 kW and 0.52 kW for clearance of 0.6 cm. The highest power needed for grinding was 2.5 kW.

Table 1 showed linear regression equation and correlation coefficient (R^2) between temperature of cooling source and capacity of machine produced. Linear regression equation was used to predict the power requirement of cocoa cake grinding machine if the temperature of cooling source was 25-26°C and clearance distance was 0.6 cm to 1.2 cm. Power requirement in grinding process followed linear regression equation $Y = -280.5X + 1984$ with corellation coefficient = 1. X was temperature of cooling source (°C) and Y was power requirement (Watt) of the grinding machine.

The efficiency of cocoa cake grinding machine was evaluated by means of power transmission efficiency. By adding cooling unit efficiency of power transmission of the machine at different condition of grinding was more than 95%. Value of power transmission efficiency was presented in Figure 5 which showed effect of temperature of cooling source on value of power transmission efficiency. The lower temperature of cooling source was proportional with level of power transmission efficiency, so that the lowest temperature woul dlike to produce optimum efficiency. At cooling source temperature of 25°C the efficiency was better than at temperature of 26°C. Clearance distance of 0.6 cm with efficiency value of 97.8% was the efficient distance for grinding cocoa cake and did not produce broken cocoa that was difficult to grind or left in the machine.

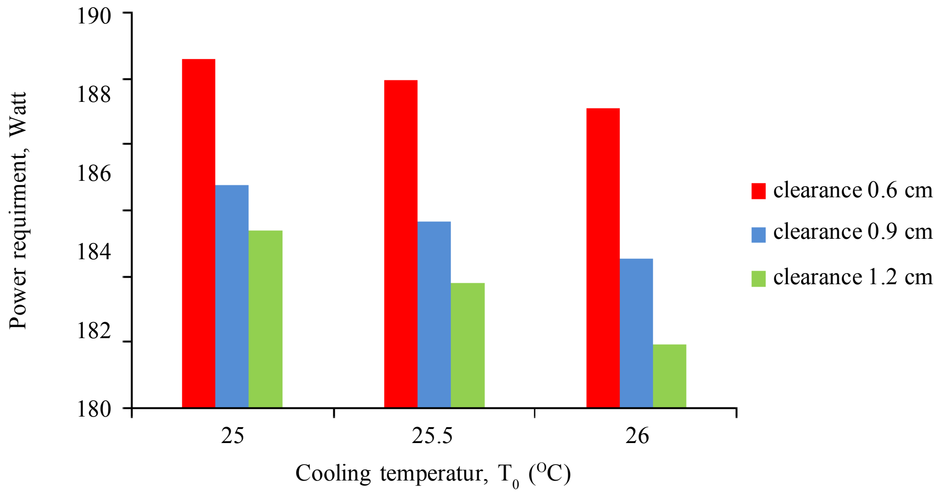


Figure 4. Power requirement of cocoa cake grinding machine

Cocoa powder accepted in the market generally had specification of particle size that was able to penetrate 200 mesh sieve following SNI 3747-2009 standard. Recovery of cocoa powder produced by grinding machine was sieved using 25 mesh, 100 mesh, and 200 mesh size of sieve to determine if the machine was of the first fine type (<100 mesh). Figure 6 showed effect of cooling source temperature and clearance on recovery of 200 mesh powder with highest recovery as much as 24% obtained at temperature of cooling unit (T_0) of 25.5^{O}C and optimum distance of 0.9 cm. Recovery of cocoa powder with the size of 25 mesh or smaller had higher percentage so that this grinding machine was more appropriate to be used as early grinding machine, and should be followed by further process of grinding in order to get higher recovery for 200 mesh powder size.

Product quality of cocoa powder was also determined by nutrition content that revealed from proximate analysis on content of carbohydrate, protein, fat, moisture, and ash for determining its change during processing. Results of quality evaluation was presented in Table 2 where decrease of moisture content was also followed by increase of carbohydrate and fat content. Protein content of the product remained the same at different moisture content, possibly due to denaturation of the protein. According to Lehninger (1998) denaturation of protein could happen in processing at moderate temperature (60-90^{o}C) during about one hour, however temperature of grinding process did not reach that temperature so that damage of protein might be due to mechanical treatment such as grinding. Mechanical treatment might cause stretching of protein chain structure to that protein was liable to damage (Muchtadi, 1989).

Table 1. Equation requirement of cocoa cake grinding machine

Clearance	Liniear regression equation	Correlation coefficient, r
0.6	Y = -183.7X + 2843	0.993
0.9	Y = -280.5X + 1984	1.000
1.2	Y = -431.2X + 1797	0.998

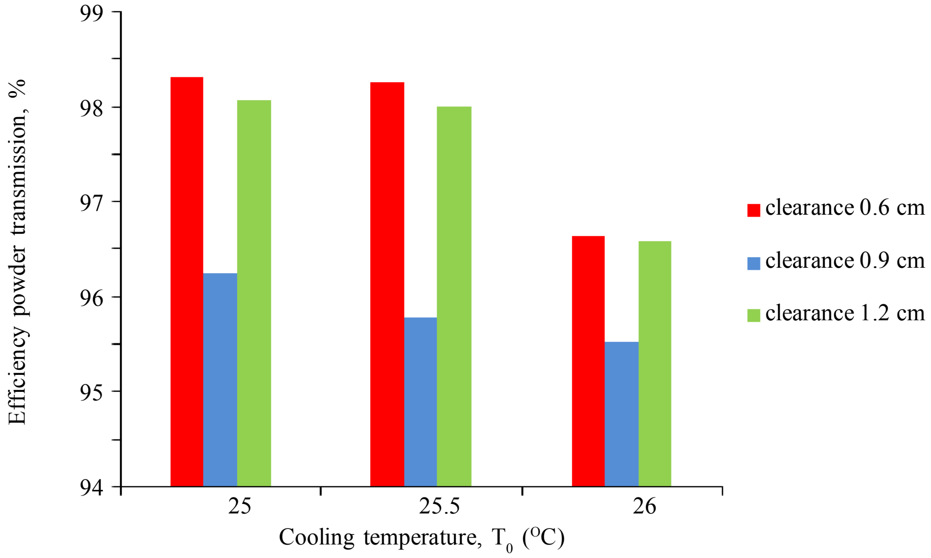


Figure 5. Powder transmission efficiency of cocoa cake grinding machine

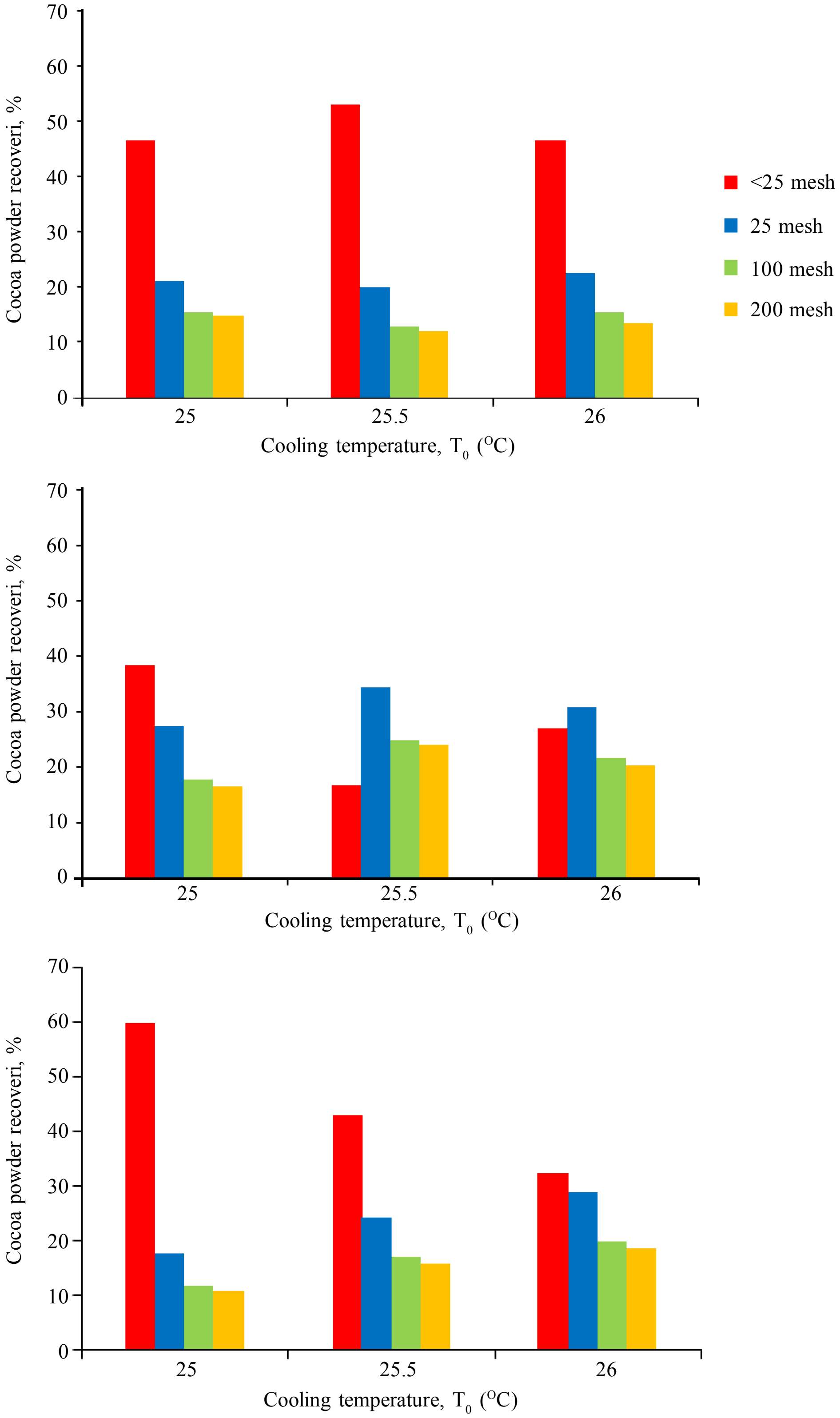


Figure 6. Cocoa powder recovery on clearance 1,2 cm (A); 0,9 cm (B); and 0,6 cm (C) as affected by cooling temperature

Tabel 2. Result of proximate analysis of cake and cocoa powder

Component	Cocoa cake, %	Cocoa powder, %
Carbohydrate	59.82	61.89
Fat	5.70	5.80
Protein	22.59	22.59
Ash	4.15	4.29
Water	5.13	5.03

CONCLUSION

1. Grinding machine of cocoa cake could be well operated by installing unit of cooling source in grinding space at the temperature of 25-26^{o}C with optimum capacity of 187.5 kg/hour, in which melting process of the cake during processing was prevented.
2. Power requirement at optimum condition was 2.5 kW per batch whereas efficiency of power transmission was 97.8%.
3. Recovery of cocoa powder with optimum particle size of 200 mesh was only 24%, while the majority of particle size was <25 mesh, so that this machine was included in primary grinder, and therefore further grinding was needed.
4. The process of grinding had only small influence on decrease of protein content in cocoa powder produced.

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