Determination of Cocoa Powder Particle Size Distribution by Using the Buoyancy Weighing-Bar Method

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Abstract. This study aims to examine the determination of the particle size distribution of cocoa powder by using the Buoyancy Weighing-Bar Method (BWM) with ethanol as a liquid medium. Laser diffraction and settling balance method are used as a comparison method in this study. The weighing bar used in BWM consists of cylindrical aluminium with a size of 10 cm x 210 cm. The measurement process is operated at ambient temperature and the measurement is carried out for 180 minutes. The results obtained indicate that the particle size distribution of cocoa powder can be measured by using BWM, and the results obtained are proportional to the measurement results by using the settling balance method, while laser diffraction is not suitable for measuring cocoa powder particle size distribution due to the shape of the cocoa powder that is not a sphere.

1. Introduction
Cocoa powder is a product of the cocoa plant that is very widely used in the food industry. Cocoa powder can be used as an additive or a main ingredient in the food industry. The particle size of cocoa powder is one of the parameters that determine the quality of the cocoa powder. In the chocolate industry, chocolate quality is influenced by the particle size of cocoa powder because the particle size of cocoa powder affects appearance and flavour strength [1].

Figure 1. The shape of cocoa powder particle
The determination of the cocoa powder particle size distribution can be done using the settling balance method and the sieve tray method, while the laser diffraction method is not suitable for determining the cocoa powder particle size distribution because the cocoa powder particle shape is not sphere [2]. The particle shape of cocoa powder can be seen in Figure 1 [3]. In this study, the Buoyancy Weighing-Bar Method (BWM) is applied to estimate the particle size distribution of cocoa powder using ethanol as a liquid medium. This BWM is a method that has been proven capable of determining the size distribution of various particles, such as cement, alumina, glass bubbles, and others [4–7]. Besides being suitable for the Stoke region, BWM has also been shown to be able to measure particles in the Allen region [8] and has also been applied to the determination of the droplet size of different liquid densities [9,10]. One of the advantages of this BWM method is its ability to determine the distribution of particle sizes in irregular shapes. This becomes one of the bases for studying BWM in determining the particle size distribution of cocoa powder which has a flake shape.

2. Methods
In this study, the particle size distribution of cocoa powder will be determined using BWM with ethanol (absolute for analysis) as a liquid medium. The density of the cocoa powder is 1.35 - 1.38 g/cm³, while the density of ethanol is 0.789 g/cm³ so in this study, the cocoa powder particles settle in ethanol. Before measuring, cocoa powder is sieved using a sieve tray, and the sample used is a sample that passes from a tray size of 100 mess and does not pass through a tray size of 140 mess. Water is not suitable as a liquid medium in this study because the cocoa powder will not separate well in water, so it can cause agglomeration of cocoa powder particles in water. The concentration of cocoa powder in ethanol is 10 kg/m³ (± 1 wt.%) [11].

![Figure 2. Schematic diagrams of BWM instrument](image)

In this study, the particle size distribution of cocoa powder is measured according to Stokes law, and the settling balance and laser diffraction method are used as a comparison to the results obtained. Stokes’s law equation can be seen in equation 1 [2]. The measurement process is operated at ambient temperature and the measurement is carried out for 180 minutes. The analytical balance with the accuracy of 0.1 mg is used to detect the migration of cocoa powder particle in ethanol. The weighing bar consist of aluminum (density = 2826.654 kg/m³) with a length of 210 mm and a diameter of 10 mm. Research equipment can be seen in Figure 2.
where $x$ is particle size, $\mu_L$ is liquid viscosity, $v(x)$ is the settling velocity of the particles, $g$ is gravitational acceleration, $\rho_L$ is the liquid density, and $\rho_P$ is the particle density. The settling velocity of the particles is calculated by dividing the length of the rod by the settling time.

3. Results and Discussion

Figure 3 shows the relationship between the settling time of cocoa powder particles and the mass of the rod by using BWM. In the figure, it can be seen that the distribution of cocoa powder particles can be detected using BWM. Cocoa powder particle from the initial measurement until the 40th minute settles quickly, and from the 40th minute to the 120th minute settles slowly, then tends to be constant after the 120th minute. Particles that settle quickly show that at that time, large particles settle first to the bottom of the vessel, while settling from the 40th minute shows that medium-sized particles have also settled, then followed by smaller particles. The constant mass of the rods at 120 minutes showed that all the cocoa powder particles have settled under the weighing bar so that the suspension density is the same as the ethanol density.

![Figure 3. Effect of time against apparent mass on BWM](image)

Figure 4 is the distribution of cocoa powder particles by using BWM, settling balance method, and laser diffraction. The results obtained indicate that the results of measurements by using BWM are comparable to the results obtained using settling balance, while measurements using laser diffraction give significantly different results. In this study, laser diffraction is not suitable for measuring cocoa powder particle distribution because laser diffraction is only suitable for determining the sphere size distribution of particles, while the cocoa powder particle shape is flake or irregular. The results of this study prove that ethanol is suitable for determining the particle size distribution of cocoa powder by using BWM and the settling balance method.
Figure 4. Measurement of cocoa powder particle size distribution by using BWM, settling balance method and laser diffraction

4. Conclusion
BWM can be used to determine the particle distribution of cocoa powder by using ethanol as a liquid. The results obtained are comparable to the results obtained by using settling balance but not comparable to the results obtained by using a diffraction laser. The non-sphere shape of cocoa powder makes laser diffraction unsuitable for determining the particle size distribution of cocoa powder.

5. References
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