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Development of egg yolk powder using a small-scale double drum dryer: Influence of steam pressure on physical properties

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Abstract. Egg yolk powder is a versatile and widely used food ingredient. Double drum dryers have been widely used in the food industry for many years, but no report was found that utilize drum dryer to produce powdered eggs. This study aimed to investigate double drum drying process conditions, especially steam pressures which consisted of three different conditions: 2.5, 3, and 3.5 bar with drum rotation of 2 revolutions per minute (rpm) to produce chicken egg yolk powder. Once egg yolk powder resulted, the products were evaluated in terms of yield, moisture content (MC), water activity (a_w), bulk densities (ρ_B) and tapped densities (ρ_T), and color (L*/a*/b* coordinates). Results showed that steam pressures affected several parameters including yield, MC, a_w and color properties of egg yolk powder but did not affect ρ_B and ρ_T. The egg yolk powder yielded was in range of 48–52%. MC and a_w of egg yolk powder were in a range of 3.6–5.1% and 0.38–0.43, respectively. In terms of density, the egg yolk powders had 0.40-0.43 g/cm^3 and 0.46-0.48 g/cm^3, for ρ_B and ρ_T, respectively. Regarding color, egg yolk powder was medium bright (59–62), less red (5–6), and yellowish (26-28). The double drum dryer is a promising technology for producing chicken egg yolk powder and prolonging its shelf life.

1 Introduction

Egg yolk powder is a versatile and widely used food ingredient derived from the nutrient-rich yolk portion of eggs. It serves as a concentrated source of essential nutrients and functional properties that find applications across various industries, including food, bakery, confectionery, and nutrition [1].

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Egg yolk powder offers a multitude of functions and benefits that make it a valuable ingredient in food formulation. Rich in proteins, lipids, vitamins, and minerals, egg yolk powder contributes to the nutritional profile of products [2]. Its emulsifying properties aid in stabilizing and enhancing the texture of emulsions, such as mayonnaise and dressings [3]. Additionally, egg yolk powder improves color, flavor, and moisture retention in baked goods, while its binding capabilities enhance the structure of various products. Also, it had better emulsification capacity (74%) and stability (72.4%) compared to whole egg and white egg [4].

Indonesia has a rapidly growing food industry, with many small and medium enterprises (SMEs) producing various food products, including powdered eggs. However, these SMEs often need help with the cost and efficiency of their production processes. One key area where improvements can be made is the drying of powdered eggs, typically done using traditional methods that are time-consuming and require much manual labor. Chinese people have been drying eggs in the open air since the Middle Ages. They then let cracked and whipped eggs sit in the sun to dry. Flaked materials were sun-dried, pounded into a fine powder, and then stored in airtight containers [1].

In the modern era, techniques like pan drying, foam drying, freeze drying, oven drying, and spray drying are frequently used to dry egg whites and yolks. The most popular technique for making egg white and yolk powder is spray drying [1, 2, 5, 6]. Koç et al. [7] reported that optimum spray dryer conditions were determined as the inlet air temperature of 171.9 °C, outlet air temperature of 72.5 °C and atomization pressure of 392 kPa, for whole egg powder to be used as an ingredient in bakery foods. However, the use of a spray dryer requires high operating costs because it requires a high operating temperature and a high-pressure compressor.

Alternatively, double drum dryers have been widely used in the food industry for many years [8], but no report was found that utilize drum dryer to produce powdered eggs. In a typical process, the liquid egg mixture is potential to be dehydrated using drum dyer. The methods that can be used is by spreading the liquid egg onto the surface of two rotating drums. The drums are heated from the inside, and as the liquid spreads out, it forms a thin film on the surface of the drums. The film is dried as it passes through the drying area and is then scraped off the drum surface as a dry powder.

Based on the above explanation, the present study aimed to utilize a small-scale double drum dryer for egg yolk powder production. The study will involve designing and building a prototype of the double drum dryer and testing its drying efficiency and product quality performance. The results of this study are expected to provide valuable insights and practical recommendations for SMEs in Indonesia looking to improve their powdered egg production processes.

2 Materials and methods

2.1 Materials

Fresh egg chicken was purchased from the local market in Subang, West Java, and egg yolk was used as the main ingredient for egg powder production. Maltodextrin (Dextrose Equivalent = 10-12.5) 17% (w/v) was utilized as drying agent and foam stabilizer. A double drum dryer used was designed and developed at our laboratory (Fig. 1).

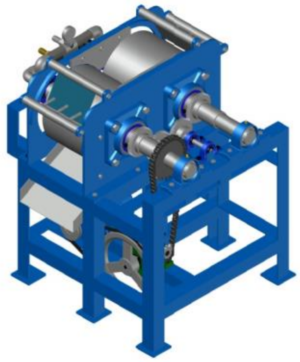

Fig. 1. A double drum dryer used for experiment.

2.2 Drum-drying experiment

About 450 g of egg yolk chicken (without skin) was weighed using digital balance and was then placed in a plastic bowl. Maltodextrin of 17% (w/w) was incorporated into whole egg chicken. The whole egg and maltodextrin were then mixed and whipped using a hand blender (Philips), at maximum velocity, for 10 minutes. Previously, a double drum dryer was set up to reach the appropriate pressure and speed (Fig. 1). The drum dryer pressure used was 2.5, 3, and 3.5 bar, while the drum dryer velocity set was 2 rpm. The egg yolk-maltodextrin mixture was then poured between two drums and dried layer was collected in the bottom section of drum dryer. Afterward, the dried layer was ground using dry-mill machine (Philips, Indonesia), at maximum speed, for 1 min. The powdered egg was sieved (80 mesh) and was removed into aluminum foil-zip pack. All powdered samples in aluminum foil-zip were kept in the air-conditioned room (15-16 ºC) until further analysis within 14 days.

2.3 Yield determination

The yield was defined as the ratio of the mass of powders obtained at the end of the drum-drying period, to the mass of initial substances, including fresh whole egg and maltodextrin, based on dry mass content (Fang et al). The yield (expressed in percent) calculation is as follows Eq. 1.

$$Yield = \frac{EYP\ (g)}{\mathrm{EY\ (g)} + m_{dx}\ (g)} \times 100 \quad (1)$$

Where, *EYP* is egg yolk powder (g), *EY* is egg yolk (g), and m_{dx} is maltodextrin (g).

2.4 Moisture content determination

Moisture content of samples were determined using oven drying method [9]. Oven dried evaporating dish was weighed, 5 g powder was added, transferred to hot air electric oven (Model J. 02707 Michel, England) set at 105°C for 3 hrs, cooled in desiccators for 1 hr and weighed. Moisture content was calculated using Eq. 2.

$$MC = \frac{m_i - m_f}{m_i} \times 100 \quad (2)$$

Where, *MC* is moisture content (%), m_i is initial mass of sample (g), and m_f is final mass of sample after drying (g).

2.5 Water activity analysis

A total of 1 g of powder was placed in the sample pan, and the empty sample pan handler and the heating module were closed. The drying time for each sample fell within 2–5 min. For measurement of water activity, 0.5 g of sample powders was carefully weighed and analyzed using a *Smart Water Activity Meter (*HD-3A).

2.6 Bulk and tapped density

The bulk density (ρ_B) was determined according to the method presented in Yuksel [10], with slight modifications. ρ_B was determined by placing 1 g of the powder into a 10 ml graduate cylinder. The volume occupied by the powder was measured without tapping the cylinder (Eq. 3). ρ_T was determined by tapping the loaded cylinder 15 times from a height of 10 cm, and the final volume was recorded Eq. 4.

$$\rho_B = \frac{w}{V} \quad (3)$$

$$\rho_T = \frac{w}{Vt} \quad (4)$$

Where, ρ_B is bulk density (g/cm^3), ρ_T is tapped density (g/cm^3), *w* is mass of sample (g), *V* is bulk volume (cm3), and *Vt* is volume after tapping (g).

2.7 Color analysis

Color measurement followed the method by Darniadi et al [11]. The color value of drum-dried whole egg powder was measured using a Chromameter (3nh NH310, China) which produced the CIE L* a*b*.

2.8 Statistical analysis

The processed treatments were duplicated, and the means of the results were reported. Analysis of variance (ANOVA) was done to establish the presence or absence of significant differences between means. Multiple comparisons were performed using the Tukey test and significance level was set at $p < 0.05$. All statistical analyses were carried out using SPSS 21 (IBM Corp., USA).

3 Result and discussion

The results presented in this study provide valuable insights into the influence of steam pressure on the physical properties of egg yolk powder produced using a small-scale double-drum dryer. The data collected encompasses a range of steam pressures, including 2.5 bar, 3.0 bar, and 3.5 bar, and evaluates key physical attributes such as yield, moisture content, bulk density, tapped density, color (L*, a*, b* values), and water activity.

The result of yield is presented in Fig. 2. The yield of egg yolk powder is an essential parameter that reflects the efficiency of the drying process. Interestingly, the results show that at both 2.5 bar and 3.0 bar steam pressures, the yield remains relatively consistent (52.35% and 52.15% respectively). However, a noticeable decrease in yield is observed at 3.5 bar (48.25%). This reduction in yield could be attributed to increased heat and pressure at higher steam pressures, potentially leading to thermal degradation of the egg yolk proteins, which may result in decreased powder recovery.

Based on the previous published paper, it was shown that there is a correlation between steam pressure and drum temperature with a strong correlation (R^2 is 0.9667) [8]. The higher the steam pressure, the higher the drum temperature.

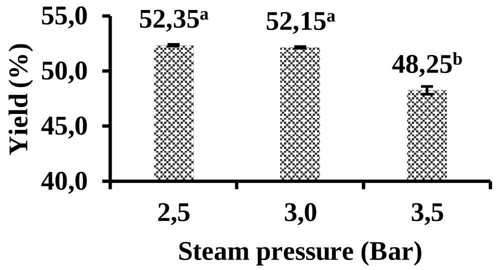

Fig. 2. Yield of egg yolk powder as affected by steam pressure.

Regarding the moisture content, the result is presented in Fig. 3. The moisture content of egg yolk powder is a critical factor for its shelf stability. The data demonstrates a decreasing trend in moisture content as steam pressure increases. This inverse relationship between steam pressure and moisture content can be attributed to the enhanced drying capability of the double drum dryer at higher pressures, promoting more efficient moisture removal. It is noteworthy that at 3.5 bar, the moisture content reaches its lowest value of 3.62%, indicating the effectiveness of the drying process at this pressure level.

Regarding the standard moisture content for egg yolk powder in Indonesian, it was only available for white egg powder (SNI 01-4323-1996), but for whole and egg yolk powder were not available. However, several researcher reported that the maximum water content of egg flour is 5% [12] based on the imported standard for egg flour. Moreover, according to Koç et al. [7], egg flour has a water content of 3-6%.

Based on this reported, it was found that the required MC was achieved by using steam pressure above 3.0 bar.

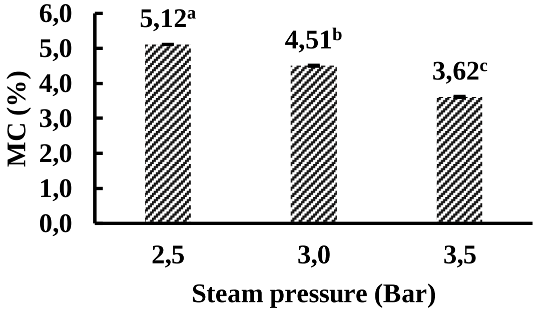

Fig. 3. Moisture content of egg yolk powder as affected by steam pressure.

Regarding the water activity, the result is presented in Fig. 4. Water activity is a crucial parameter governing microbial stability and shelf life of powdered products. Lower water activity values are generally associated with increased shelf stability. The data reveals a decreasing trend in water activity as steam pressure increases. This reduction in water activity at higher steam pressures indicates that the drying process is effective in removing moisture from the egg yolk powder, thereby enhancing its shelf stability and inhibiting microbial growth.

Due to decreased microbiological and chemical activity, products with lower moisture and water activity typically last longer in storage. If flour has a lot of moisture, caking, which is characterized by the formation of lumps from the agglomeration of particles, may occur. This can result in a decline in the functioning and quality of the flour [13].

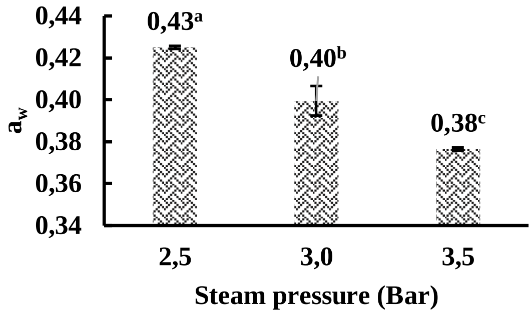

Fig. 4. Water activity of egg yolk powder as affected by steam pressure.

For the density analysis, the result is shown in Fig. 5. Bulk and tapped density are key indicators of the physical characteristics and flowability of powdered materials. The data reveals a consistent trend in bulk and tapped density across all steam pressure levels. Bulk density remains relatively stable, while tapped density exhibits slight variability. This suggests that the particles exhibit similar packing behavior regardless of steam pressure. The marginal differences in tapped density could be attributed to variations in particle size distribution resulting from the drying process.

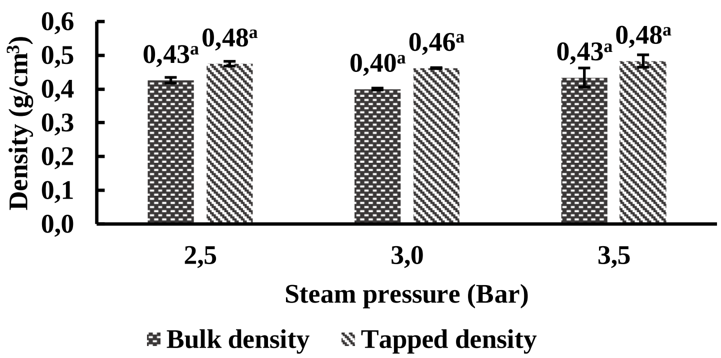

Fig. 5. Bulk and tapped density of egg yolk powder as affected by steam pressure.

Color analysis through L*, a*, and b* values provide insights into the changes in egg yolk powder color due to Maillard reactions and other chemical transformations during drying. The L* value represents lightness, with higher values indicating a lighter color. The a* and b* values correspond to color attributes such as redness and yellowness, respectively. The L* value showed significant different across all steam pressures, suggesting that the overall lightness of the powder was decreased. This also occurred to a* and b* values which exhibited subtle variations, potentially indicating slight alterations in color hue and intensity due to Maillard reactions induced by the drying process. According to Hayuningtyas [12], the difference in drying treatment results in the interaction of different melanoidin pigment formation due to the the Maillard reaction. In this result, it was shown that the L* value decreased with the increase in steam pressure, indicating that the intensity of the brown color was higher. The color values of egg yolk powder can be seen in Table 2.

Table 1. Color values of egg yolk powder.

Steam Pressure (Bar)	L*	a*	b*
2.5	61.79 ± 0.01[a]	5.09 ± 0.01[a]	28.29 ± 0.01[b]
3.0	61.37 ± 0.01[b]	5.64 ± 0.03[c]	28.01 ± 0.01[c]
3.5	59.58 ± 0.01[c]	5.53 ± 0.02[b]	28.97 ± 0.02[a]

Note: Values are expressed as mean ± standard deviation. Different letter values in the same column are significantly different at the 95% confidence interval with the Turkey test.

The findings of this study highlight the significant impact of steam pressure on various physical properties of egg yolk powder produced using a small-scale double drum dryer. The observed trends in yield, moisture content, density, color, and water activity provide valuable insights for optimizing the drying process. Researchers and practitioners in the food processing industry can utilize these results to tailor the drying parameters for the production of egg yolk powder with desired attributes. However, it is important to note that while higher steam pressures appear to improve certain properties, such as moisture removal and water activity, the potential trade-offs, such as decreased yield, should be carefully considered in process optimization.

4 Conclusion

In this study, the influence of steam pressure on the physical properties of egg yolk powder produced using a small-scale double drum dryer was systematically examined. The data revealed intriguing insights into the impact of steam pressure on yield, moisture content, density, color attributes, and water activity of the egg yolk powder, where steam pressures affected several parameters including yield, moisture content, water activity and color properties of egg yolk powder but did not affect ρ_B and ρ_T.

In summary, the results underscore the intricate relationship between steam pressure and various physical attributes of egg yolk powder. These findings offer valuable guidance for optimizing the drying process to attain desired product qualities. The trade-offs between improved moisture removal, water activity, and yield emphasize the need for a balanced approach in process parameter selection.

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