Effect of outlet temperature and total soluble solid in 2-stage spray dryer on black tea powder extract production

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Abstract. The black tea powder extract produced through the spray drying technique is an alternative to tea steeping or brewing in the industry. The production of black tea powder extract using the 2-stage spray dry method still has problems such as different colour, product swelling or inflate and blocking. To determine the source of the problem, this study used varied outlet temperatures 105°C, 110°C, 115°C, 120°C and total soluble solids (TSS) 31.3, 35.2, 37.2, 43.9, 44.1, 47.4. Spraying through 2-stage spray dryer with combi fluid bed and high nozzle pressure atomizer model SC 40 SDX III by Delavan. The results show a significant difference between the outlet chamber temperatures with the flowrates, the pressures, and the densities. An increase in outlet temperatures by a multiple of 10°C can significantly reduce the pressure and the flow rate, while the temperatures multiple of 20°C can significantly reduce the densities, but not for the moisture contents and the powder colours. Changes in the outlet temperatures did not have a 0.2% effect on the steeping colours but were affected by TSS. The higher TSS’s value gives an increase in flow rate, pressure, moisture content and steeped powder colours of 0.2%.

1. Introduction
Powder quality and productivity is now a major concern in production. This is related to the energy, material and human power needs that will be required. In general, we all prefer to compact powders, fast production flows, attractive colours, low energy consumes and more efficient machine maintenance. Black tea is a tea that is very often found and liked in Asia. Black tea has 2 types, orthodox and CTC. The orthodox process uses rolling and tray drying, while CTC uses crushing-tearing-curling maceration [1]. Preparation of black tea powder extract ready for drink requires a filtration process to the encapsulation component. The components for encapsulation in spray drying are commonly used as emulsion fillers so that they can be atomized. In general, encapsulation properties are colourless and tasteless like maltodextrin [2].

The problem that usually arises with the use of spray drying is a non-uniformity the powder colours and an expanding the powder densities due to the temperature changing and material composition, which causes changes in the quality of the product [2, 3]. Practically, the technique of single-stage type for trial in lab-scale cannot scale up into several stages in the spray dryer due to lack of several modifications. There are various types and modifications to spray dry according to the categories, namely based on the stages (single, two & multi-stage), chamber positions (vertical & horizontal), and the type of atomizers (rotary / centrifugal atomizer, pressure spray nozzle atomizer & twin fluid atomizer) [4].
2. Materials and methods

2.1. Liquid emulsion treatment and observation
An emulsion from several materials contains maltodextrin that has been mixed by Haldin to fulfill a specific purpose. The black tea liquid emulsions in this study were obtained from PT. Haldin Pacific Semesta as 6 batches to be used in the spray drying process as 6 replications. All of emulsion obtain will be treated with pasteurization within 90°C in 30 minutes. In the end, emulsions were observed to determine their TSS with a refractometer (°Brix) and pH before spraying. Data of 6 batches shown in Table 1.

| Batch | TSS (°Brix) | pH  |
|-------|-------------|-----|
| 1     | 35.2        | 7.36|
| 2     | 44.1        | 7.63|
| 3     | 37.2        | 6.81|
| 4     | 43.9        | 7.35|
| 5     | 47.4        | 7.80|
| 6     | 31.3        | 6.62|

Mean ± Standard Deviation (SD) 39.40 ± 5.63 7.26 ± 0.46  

2.2. Spray drying processing
Processing emulsions into solid are using spray drying 2-stage type (stage 1: atomization, stage 2: combo fluidization) manufactured by CPS in industrial-scale at Haldin, Bekasi. Atomization with nozzle pressured single-fluid model SDX III manufactured by Delavan. This experimental design was arranged in a complete randomized design with 2 treatment factors, the treatment is the change of temperature chamber outlet as 4 treatments (105°C, 110°C, 115°C, 120°C) and the other as a change of TSS as 6 treatments (31.2, 35.2, 37.2, 43.9, 44.1, 47.4). Several setpoints are assumed stable controlled with PID Controller. The products were observed and analyzed on their productivity (flowrates & pressures) and their quality (moisture contents, colours, and densities). The flowrates were calculated manually, besides the pressures monitored with pressure indicator installed on PLC. The moisture contents were measured by Moisture Analyzer (Mettler Toledo), the colours were measured by Colorimeter (ColorQuest XE Hunter Lab), and the densities were calculated manually. All obtained data were analyzed statically using analysis of variance (ANOVA) with 5% Duncan’s Multiple Range Test (DMRT). The setpoints are set with a various point are shown in Table 2.

| No | Set Point            | Set     |
|----|----------------------|---------|
| 1  | Chamber Inlet Temperature | 185°C   |
| 2  | Pressure Chamber     | -2.0 mbar|
| 3  | Internal Fluid Bed Temperature | 150°C   |
| 4  | External Fluid Bed Temperature | 25°C    |
| 5  | Inlet Blower Fan     | 60%     |
| 6  | Internal Fluid Bed Blower Fan | 40%     |
| 7  | External Fluid bed Blower Fan | 50%     |
3. Results and discussion

The results, changes of outlet temperature and TSS affects the feed pressures, flowrates, moisture contents, tapped densities, bulk densities, powder colours, and steeping colours in the spray dry process. The setting is of outlet temperatures controlled by the PID Controller algorithm with proportion 4.1 times, integral 55 seconds, and derivative 95 seconds. The PID Controller will control the high-pressure pump motor to regulate the pressure in such a way that the desired outlet temperature is reached. The results are shown in Table 3 and 4.

### Table 3. Data effects on different outlet temperature of several parameters

| Parameters                      | Temperature (°C) |
|--------------------------------|-----------------|
|                                | 105             | 110             | 115             | 120             |
| Pressure Feed (bar)            | 62.17±23.99<sup>a</sup> | 55.55±30.94<sup>ab</sup> | 33.77±13.31<sup>bc</sup> | 25.35±11.49<sup>c</sup> |
| Flowrate (kg/hour)             | 73.48±14.51<sup>a</sup> | 60.23±18.90<sup>ab</sup> | 52.75±14.25<sup>bc</sup> | 37.93±8.55<sup>c</sup> |
| Moisture Content (%)           | 3.33±1.20<sup>a</sup> | 3.21±1.32<sup>ab</sup> | 3.09±1.30<sup>b</sup> | 2.81±1.17<sup>a</sup> |
| Tapped Density (gr/ml)         | 0.50±0.06<sup>a</sup> | 0.46±0.04<sup>ab</sup> | 0.45±0.04<sup>ab</sup> | 0.43±0.05<sup>b</sup> |
| Bulk Density (gr/ml)           | 0.49±0.07<sup>a</sup> | 0.45±0.04<sup>ab</sup> | 0.45±0.06<sup>bc</sup> | 0.40±0.04<sup>b</sup> |
| L* Powder Direct               | 19.02±1.15<sup>a</sup> | 18.38±1.33<sup>a</sup> | 18.36±1.20<sup>a</sup> | 18.35±0.85<sup>a</sup> |
| a* Powder Direct               | 5.78±1.33<sup>a</sup> | 5.70±1.73<sup>a</sup> | 5.28±1.44<sup>a</sup> | 5.10±0.86<sup>a</sup> |
| b* Powder Direct               | 5.97±1.62<sup>a</sup> | 5.57±1.77<sup>a</sup> | 5.16±1.51<sup>a</sup> | 4.99±1.05<sup>a</sup> |
| L* Steeping                    | 44.93±2.78<sup>a</sup> | 44.53±1.41<sup>a</sup> | 44.76±2.49<sup>a</sup> | 45.43±1.42<sup>a</sup> |
| a* Steeping                    | 23.23±1.31<sup>a</sup> | 23.81±1.90<sup>a</sup> | 23.50±1.63<sup>a</sup> | 22.92±1.91<sup>a</sup> |
| b* Steeping                    | 54.63±2.00<sup>a</sup> | 55.28±2.52<sup>a</sup> | 54.89±2.80<sup>a</sup> | 54.69±2.15<sup>a</sup> |

Mean (± SD) values with a different superscript in a column are significantly different (p<0.05)

### Table 4. Data effects on different total soluble solid of several parameters

| Parameters                      | Total Soluble Solid (°Brix) |
|--------------------------------|------------------------------|
|                                | 31.3 | 35.2 | 37.2 | 43.9 | 44.1 | 47.7 |
| Pressure (bar)                 | 45.5± | 31.9± | 45.1± | 25.5± | 49.2± | 68.1± |
| Flowrate (kg/hour)             | 20.99<sup>ab</sup> | 12.20<sup>b</sup> | 18.94<sup>a</sup> | 5.77<sup>a</sup> | 39.25<sup>bc</sup> | 30.33<sup>a</sup> |
| Moisture Content (%)           | 30.9± | 61.3± | 66.6± | 57.2± | 59.6± | 61.1± |
| Tap Density (gr/ml)            | 11.63<sup>a</sup> | 18.94<sup>b</sup> | 21.26<sup>b</sup> | 16.75<sup>b</sup> | 10.63<sup>b</sup> | 17.57<sup>b</sup> |
| Bulk Density (gr/ml)           | 1.68± | 2.72± | 4.33± | 4.98± | 2.99± | 5.14± |
| L* Powder                       | 0.44± | 0.43± | 0.50± | 0.49± | 0.49± | 0.38± |
| a* Powder                       | 0.26± | 0.34± | 1.12± | 0.41± | 0.17± | 0.20± |
| b* Powder                       | 0.97± | 1.62<sup>a</sup> | 0.57± | 1.77<sup>a</sup> | 0.56± | 1.05± |
| L* Steeping                     | 44.93±2.78<sup>a</sup> | 44.53±1.41<sup>a</sup> | 44.76±2.49<sup>a</sup> | 45.43±1.42<sup>a</sup> | 45.43±1.42<sup>a</sup> | 45.43±1.42<sup>a</sup> |
| a* Steeping                     | 23.23±1.31<sup>a</sup> | 23.81±1.90<sup>a</sup> | 23.50±1.63<sup>a</sup> | 22.92±1.91<sup>a</sup> | 22.92±1.91<sup>a</sup> | 22.92±1.91<sup>a</sup> |
| b* Steeping                     | 54.63±2.00<sup>a</sup> | 55.28±2.52<sup>a</sup> | 54.89±2.80<sup>a</sup> | 54.69±2.15<sup>a</sup> | 54.69±2.15<sup>a</sup> | 54.69±2.15<sup>a</sup> |

Mean (± SD) values with a different superscript in a column are significantly different (p<0.05)

3.1. Pressures and flowrates

The changes in outlet temperatures have a significant effect on the feed pressures and flowrates if it is carried out more than 10°C. Otherwise, the changes in some TSSs are effects significantly in pressures...
and flowrates. The pressure and flowrate changes were adjusted according to the outlet temperatures to achieve an optimal drypoint. Variations in outlet temperatures will affect the feed flow or inlet air [5]. The outlet temperatures will affect the flowrates, wherein the nozzle pressure will also be affected. There is an interaction between variables such as inlet and outlet temperatures, flowrate rates, feed properties that compose the concentrations, diffusion coefficients of solute and latent hot solvents to regulate the morphology of the final particles [2]. Descriptively, based on table 3, the effect of outlet temperatures will decrease the pressures and flowrates value, besides table 4, the increases of TSSs will increasing the pressures and flowrates values.

3.2. Densities of powder

Based on the results in table 3, both tap and bulk densities does not have a significant effect if the temperature increases by 15°C, but changes significantly if it is done more than 15°C. The temperatures of 105°C and 120°C have a significant difference, but not for 110°C and 115°C. There is the influence of the pressure difference from the atomizer which gives the diameter of each particle different[5]. The densities changes in powders were due to an influence on temperatures and its self-material compositions [6]. The difference in TSSs table 4, did not show a significant difference from 31.3 to 43.9. This proves that changes in TSSs do not necessarily affect densities. There are other factors besides TSS that affect densities [7]. The increase in solid concentrations in the emulsions can reduce the densities, but it has more effect on the inlet temperatures than the solid concentrations. The densities changes will have a significant effect on the different temperatures [2].

3.3. Moisture contents

The results of measuring the moisture contents showed a decrease in moistures along with the increase in outlet temperatures. However, the decrease in moisture contents along with the increase in outlet temperatures was not significantly different from the four outlet values. This proves that the outlet temperatures setting will have an impact on moisture contents [5]. The temperature drop is likely to have a significant effect on the moisture if it is carried out over 20°C. Research Ozdikicierler [8] states that temperatures have a large effect on the moisture contents of a powder extract.

Besides, changes in TSS to moisture contents have different changes for each TSS. These results cannot be further analysed by ANOVA and Duncan because the results obtained are not homogeneous for each TSS. Descriptively, the results showed that the increases in TSS were not sufficient to prove an increase in moisture contents. The changes in moisture contents are greatly influenced by temperatures, solid contents in a solution and the flows of air used during the process. These results when graphed will show fluctuating results and tend to increase with increasing TSS. This is because higher TSS contents require high energy [9].

3.4. Powder colours

The results of Figure 1 are measured using a colourimeter shown on Table 4 with the value of L = 19.02 which decreases to L = 18.35 as the temperature increases. This value is quite dark because the value is below 30 but these results do not show a significant difference between the four temperatures. This has been observed also in a sumac extract that decreases with increasing temperatures [10]. The results of the measurement of the values of L*, a*, and b* show a symmetrical decrease with the increase
in temperature changes. This proves that the three degrees of colour (L*, a*, b*) decrease as the temperature increases.

The TSS’s that was tested resulted in a significantly different TSS 44.1 against 31.3 and 43.9, but not significantly different between 31.3 and 43.9. This proves that the changes in TSS do not necessarily affect the colour brightness (L*) of the powder. The microencapsulation agent is needed that is by the active ingredients in tea so that it can save different colours [11]. The instability of this colour in each TSS in addition to the content of the bioactive components is also influenced by the temperature during the spray drying process [8].

3.5. Steeping colours

Based on the results of measurements with a colourimeter table 3 and 4, obtained stable results, not affected by the outlet temperatures, and there was no significant change in the four temperatures. This is due to the very low significance of powder powders so that it is not significant for steeping black tea powder extract 0.2%. The effect of inlet or outlet temperatures does not change the colour of the products, but rather significant changes in the emulsion components [12]. Besides the TSS contribute on colour steeping changes, it caused the bioactive component liked theaflavin, carotene, and caffeine. The number of encapsulation agents likes maltodextrin affected in colour steeped changing [13].

4. Conclusions

Changes in outlet temperature in the chamber affect productivity, such as flowrates and feed pressures, where the higher the outlet temperatures will slow down the flowrates and the pressures, so it will waste energy uselessly. The increases in outlet temperature can affect the densities, powder colours and moisture contents. The changes in outlet temperature did not affect the 0.2% steeped powder colours, but the steeping colours were influenced by the changes in total soluble solids. Total soluble solid affects productivity as well, the higher TSS obtained, it will increase flowrate, pressure feed and moisture content. Total soluble solid affect the densities and colours but depends on the composition of the solution itself.

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