In-store drying application on shallot postharvest handling

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Abstract. The yield loss of shallot after harvest at farmers’ level could be reduced by using an appropriate treatment, such as using a modified drying process. A process that includes aeration and heat control system is also possible to be developed in rural-scale. It is designed to prevent shallot damage and reduced quality that usually occur to the shallot which were having a natural or conventional drying process. The purposes of this research were to measure the effects of two drying techniques (sun drying and in-store drying) on shallot quality and to measure in-store drying performance. The research used an experimental method with T-test, consist of 2 treatments, conventional drying method (sun drying) and in-store drying method. The observed parameters include physical properties, tuber hardness, sensory properties, chemical properties, tuber damage, equipment performances and financial feasibilities. The results showed that the application of in-store drying technology has a good efficiency (58.26%), financially feasible (R/C 1.27, BEP 200.92, PBP 4.8 months and net B/C 1.85) and significantly better than conventional way.

1. Introduction

Shallot (Allium cepa L.) is one of horticulture commodities with high economic value. Allium genus is a spice that content of antifungal, antiviral, antiprotozoal, antihelmintic [1] and antioxidant [2]. It is usually used in a small volume, but it is an essential ingredient for every household. It is not surprising if in recent years, this commodity becomes more important and affects the life of the farmers, determine the rate of inflation and furthermore, it influences the country’s economy.

The shallot production in Indonesia reaches 14,338,094 tons [3]; with the average production of shallot in Java Island around 9.00 - 11.43 tons/hectare [4]. In West Java Province, shallot total production reaches 1,291,477 which calculated from several districts: Cirebon (317,888 tons); Bandung (372,590 tons); Majalengka (324,082 tons); Garut (220,385 tons) and a small portion of 8 other districts with the average production of 120 - 32,353 tons [5].

The increase in production cannot be fully utilized by farmers. In the peak season, shallot price at farmers’ level is very low and lead to the imbalance between revenue and the production cost. This is because of the peak occurs in rainy season and the quality of shallot reduces during a poor drying time. The price could decrease by 10-15% and cannot cover the cost of production.

The critical points of the shallot post-harvest handling during the rainy season are at the stage of leaf littering and tuber drying. The failure on leaf littering process can cause a bacterial infestation on rot, while the failure of the drying tubers can cause shorter shelf life, rapid rot, sprout, and root out. The economic loss of these damages can reach 20-40% [6, 7]. Farmers usually run these processes by using a conventional drying technique which only depends on the availability of the sunlight. It could
take a long time, around 7-9 days, since the intensity of the sunlight could be uncertain or fluctuating. In the cloudy or even rainy weather shallot becomes quickly rot. This damage occurs after shallot are stored, either at the farm level for seed purposes (3-6 months) or at the household level (1-2 months). Furthermore, sun drying takes huge place and a lot of human resources which lead to shallot prone to contamination [6].

To overcome this problem, Center for Agricultural Post-Harvest R&D (BB Pascapanen) has introduced an In-store Drying technology. This technology uses a storage facility which the space can be adjusted according to the optimum conditions for shallot drying process. In this study, the storage room is built for the capacity of 5-10 tons of shallot. It is 6 x 6 x 3 m in size. The roof is made of tin roof equipped with air aeration (ball window). The walls are made of fiberglass and the racks made of bamboo sticks. The advantages of this drying technology are: 1) The drying process is 2 days faster compared to the conventional way; and 2) The value of weight loss reaches 0.94% lower than conventional way.

Previous researches showed that shallot drying by in-store drying can be done faster, resulting in lower damage than by conventional way. It can be done within 3 days with damage only ranges from 0.24% - 0.72%. It is much lower compared with sun drying, which the damage rate can reach 1.68%. The process of shallot littering with in-store drying was also faster than sun drying (12:27 hours) with shrinkage weight 4.97% and 4.03% respectively [8]. Another study showed that In-store drying system could take 2 days faster than sun drying and has a lower damage rate (0.83% for in-store drying and 3.82% for conventional way) [9]. Therefore, the purposes of this research were to measure the application of these two drying techniques on shallot quality and to measure in-store drying performance.

2. Material and methods
The research was conducted in Bojong village, Ciledug sub-district, Cirebon district, involving Subur Tani Farmers group. The material used was the shallot of Bima varieties, which are harvested at 60 days. Other auxiliaries were packing nets, ropes, bamboo, name plate, labels, wood, mica plastic, cement, stone, plastic sheeting, blower, thermometer, hygrometer, drying tools, humidity gauges, temperature gauges, scales, etc.

The research method used an experimental method with T-test. Samples tested were 10 samples. The attempted treatment were:
- Conventional drying (p1)
- In-store drying (p2)

2.1. Conventional drying (p1)
Shallot drying process was performed by sun drying method. Shallot was harvested at the age of 60-65 days, cleaned from soil, then tied in groups of 1 kg, arranged on clean and dry ground, dried them under the sun with the position of tuber below and then in the reverse way.

2.2. In-store drying (p2)
Shallot drying process was performed by in-store drying method. Shallot harvested at the age of 60-65 days, cleaned from soil, tied in groups of 1 kg, then hanged them under the shelf for having drying process by the heat of the sun or fireplace.

The mechanism of the dryer was heat exchanger. In-store drying resort to wood/biomass which is widely available in the field (husk/charcoal husk/coconut shell). The heat flowed from fireplace into the drying chamber by an electric fan. Airflow was also assisted by a vortex fan on the roof of the dryer building. The heat source of in-store drying can also be from sunlight if it was available, so it is not always using heat from fireplace. Tin roofs deliver heat from the sun and trap heat in the drying chamber, creating a greenhouse effect. This causes the temperature in the dryer room always hotter than the ambient temperature. The greenhouse effect causes the in-store drying building to have
warmer temperatures and lower humidity, providing an ideal condition for storage in addition to its function as a dryer.

The observation parameters for both methods consist of: physical properties (weight shrinkage, tuber size (weight and diameter), bulb strength, and sensory loss (tuber shape, freshness condition, outer shell color and aroma), chemical properties (moisture content, ash content, TPT/TSS), equipment performance, financial feasibility (R/C, BEP, PBP and Net B/C). Measurement of moisture content and ash content used thermogravimetry method and TPT content used Refractometer.

2.3. The percentage value of drying efficiency
The percentage value of drying efficiency (Eff) was calculated from parameters such as: fuel weight (m.s), teak’s calorie (N<sub>bb</sub>), initial weight of shallot (F), weight of shallot after dried (P), delta temperature between drying temperature and ambient temperature (∆T), the initial weight of drying material (m), and specific calorie of shallot (Cp), with the formula as shown:

\[
Q_{\text{input}} = m \times N_{\text{bb}} \quad (1)
\]
\[
V = F - P \quad (2)
\]
\[
Q_1 = V \times H_{\text{fg}} \quad (3)
\]
\[
Q_2 = m \times C_p \times \Delta T \quad (4)
\]
\[
Q_{\text{output}} = Q_1 + Q_2 \quad (5)
\]
\[
\text{Eff} = Q_{\text{output}}/Q_{\text{input}} \times 100\% \quad (6)
\]

3. Result and Discussion
3.1. Physical characteristics
The effects of the drying process on the physical properties and the appearance of the shallot senses are presented in Table 1 and Table 2. Physical properties observed were weight loss (%), tuber size (weight and diameter), bulbiness and sensory properties (tuber shape, freshness, outer shell color and aroma). The purpose of drying process was only to remove the water content in the outer shell and the neck of the stem (the tip of the bulb). Thus the tubers did not experience a high weight loss and did not shrink (porous) and reduce the damage caused by tuber blight during storage. Curing shallot after harvest aims to heal wounds caused by harvesting, preventing the microorganisms infection, drying off roots and onion skin, and reducing water loss [10].

Table 1 showed the physical properties of shallot dried by in-store drying compared to conventional way. There are significant differences in weight loss. The weight loss of ‘in-store drying’ shallot was lower than the conventional way. This demonstrated that the application of in-store drying was able to decrease the potential loss of yield for about 6% at drying stages. This is in line with the previous study which state that littering by hot air can reduce weight loss and maintain color [11]. Furthermore, shallot curing in 80 hours and 92 hours produced good quality of tubers for 6 weeks storage at room temperature without damage the tubers [12,13].

| No. | Drying          | Weight loss (%) | Average weight of tubers (g) | Average of tuber diameter (cm) | Hardness (mm. s<sup>-1</sup>, 100g<sup>-1</sup>) |
|-----|-----------------|-----------------|-----------------------------|--------------------------------|-----------------------------------------------|
| 1.  | Conventional    | 35.18 b         | 6.96 a                      | 2.09 a                         | 1.55 a                                         |
| 2.  | In-store Drying | 29.24 a         | 7.01 a                      | 2.08 a                         | 1.93 a                                         |

Note: Means in the same column sharing the same letter did not differ significantly according to T-test
Table 2 showed the sensory properties of shallots of both methods. They were not significantly different. Consumer acceptances were significantly different in the outer shell color and freshness. Shallot drying by conventional way had a better acceptance value than in store drying. According to Rismunandar, factors affecting the quality of shallot are: 1) Color; glossy bright red color indicates good and preferred shallot quality, 2) density, odor and taste; the smell of fragrant and spicy taste are much more liked, 3) form; the ovoid shape is more preferred rather than the tapered, 5) resistance; the quality is good if it is still shiny in a long period [14].

### Table 2. Sensory properties of the shallot after drying.

| No. | Drying          | Outer skin color | freshness | Shape | Odor    | Hardness |
|-----|----------------|------------------|-----------|-------|---------|----------|
| 1.  | Conventional   | 4.27 b           | 4.33 b    | 4.07 a| 3.07 a  | 4.27 a   |
| 2.  | In-store Drying| 3.73 a           | 3.80 a    | 3.93 a| 3.00 a  | 4.07 a   |

Note: Means in the same column sharing the same letter did not differ significantly according to T-test

#### 3.2. Chemical properties

The observed chemical properties included moisture content, ash content, Total Soluble Solid (TSS) was shown in Table 3. The T-test showed that moisture content and ash content of shallot dried by conventional way and by in-store drying were not significantly different. The only difference was total soluble solids (TSS). TSS yields of shallot dried by in store drying method were better and distinctly different. This indicated that in-store drying was able to maintain and even improve the chemical quality of shallots.

### Table 3. Chemical properties of shallot after drying by conventional and in-store drying method.

| No. | Drying          | Moisture (%) | Ash (%) | TSS (%) |
|-----|----------------|--------------|---------|---------|
| 1.  | Conventional   | 82.17 a      | 0.80 a  | 15.72 a |
| 2.  | In-store Drying| 82.00 a      | 0.82 a  | 17.43 b |

Note: Means in the same column sharing the same letter did not differ significantly according to T-test

#### 3.3. Equipment performance

The performance of the equipment was measured by using the percentage value of drying efficiency. The parameters observed were drying temperature, the initial weight and the final weight of the dried product and the volume of the fuel used during the drying. The fuel was teak which has specific calorific value. The parameters can be seen in Table 4.

### Table 4. In-store drying parameters.

| No. | Parameter                      | Symbol | Value | Unit   |
|-----|--------------------------------|--------|-------|--------|
| 1.  | Fuel weight                    | m.s    | 82    | kg     |
| 2.  | Teak’s calorie                 | N_{bb} | 30,150| kJ/kg  |
| 3.  | Initial weight of shallot      | F      | 2,000 | kg     |
| 4.  | After dried weight of shallot  | P      | 1,415.2| kg |
| 5.  | Drying temperature             | T      | 40.47 | °C     |
| 6.  | Ambient temperature            |        | 31.13 | °C     |
| 7.  | Weight of initial drying material | m   | 2,000 | kg     |
| 8.  | Specific calorie of shallot    | C_{p}  | 1.8   | kJ/kg°C|
The percentage value of drying efficiency of in-store method was calculated from those parameters. The result is 58.26%. This is better than the efficiency of a similar method that was used by other research, such as greenhouses gasses, which only has value of 39.9% [14].

3.4. Financial feasibility

3.4.1. Revenue cost ratio (R/C)

The economic feasibility of the revenue cost ratio or R/C is a simple analysis to look at the economic feasibility of the revenue and cost ratio of shallot drying. The Comparison of R/C conventional and in-store drying method can be seen in the following table (Table 5). The duration of both treatments was over 32 hours (1.5 days) and 5 days respectively. The R/C analysis was measured based on the optimum drying capacity which was 500 kg.

| No. | Component     | Price (IDR) | Conventional way | In-store drying |
|-----|---------------|-------------|------------------|----------------|
|     |               | Vol | Cost (IDR) | Vol | Cost (IDR) |
| 1.  | Cost          |     |           |     |            |
| 1.1 | Fixed Cost    |     |           |     |            |
|     | Employee (day people) | 100,000 | 7 | 700,000 | 4 | 400,000 |
|     | oil (package) | 40,000 | - | - | 1 | 40,000 |
| 1.2 | Unfixed cost  |     |           |     |            |
|     | Shallot (kg)  | 10,000 | 500 | 5,000,000 | 500 | 5,000,000 |
|     | Teak (m³)     | 100,000 | - | - | 1 | 100,000 |
|     | Diesel fuel (liter) | 6,700 | - | - | 8 | 53,600 |
|     | Total Cost    | 5,700,000 | - | - | 5,593,000 |
| 2.  | Revenue       |     |           |     |            |
|     | Dried shallot | 18,000 | 324.1 | 5,833,800 | 353.8 | 6,368,400 |

R/C analysis showed that the application of In-store drying technology can increase the R/C of shallot drying value from 1.17 to 1.27. This indicated that the application of In-store Drying technology in shallot drying process is more economical than conventional way.

3.4.2. Break-even point (BEP)

The Break-even point was calculated based on the fixed cost divided by the price per unit of raw material minus the variable price per unit. BEP calculations can be seen in Table 6.

| Description     | Conventional way | In-store drying |
|-----------------|------------------|----------------|
| Fix cost (IDR)  | 700,000          | 440,000        |
| Price per unit (IDR) | 18,000          | 18,000         |
| Variable cost/unit (IDR) | 17,587          | 15,810         |
| BEP             | 1,695.59         | 200.92         |

The result of BEP analysis showed that the use of In-store drying was able to shorten the break-even / BEP of the drying unit as much as 1,695.59 kg to 200.92 kg units. This means that the break-even point of conventional way can only occur when the farmers do the drying of 1,696 kg per drying process or drying process running 3.29 times with a capacity of 500 kg per drying. It is different with in-store drying, where BEP occurs at 1 time drying with drying capacity only around 40% of the installed capacity.
3.4.3 Pay-back period (PBP)
Payback period (PBP) indicates the payback period of the investment / capital of the amount of profit earned at a given time unit. The PBP comparison can be seen in Table 7.

| Description                        | Conventional way | In-store drying |
|------------------------------------|------------------|-----------------|
| Capital investment (IDR)           | 5,000,000        | 37,000,000      |
| Tarpaulin, size 8 x 10 5 units @ IDR 1,000,000 | 5,000,000    |                 |
| Building and racks (IDR)           |                 | 10,000,000      |
| Blower & heat exchanger (IDR)      |                 | 24,000,000      |
| Built cost (IDR)                   |                 | 3,000,000       |
| Benefit per drying (IDR)           | 133,800          | 774,800         |
| Drying capacity per month (IDR)    | 4                | 10              |
| Benefit per month (IDR)            | 535,200          | 7,748,000       |
| PBP (month)                        | 9.3              | 4.8             |

Payback period of investment (PBP) of in-store drying technology was faster than the conventional way although it required more expensive investment. The optimum use of drying for 10 x per month was projected able to accumulate capital in-store drying investment in less than 5 months.

3.4.4 Net benefit cost ratio (net B/C)
Net B/C was calculated based on net profit earned over the life time of the equipment. In-store drying facilities especially the buildings were assumed to have a lifespan of 5 years. Operation of drying both conventional and in-store drying was assumed to last for 3 months in 1 year. The interest rate used as discount factor (DF) is 18%. The calculation of Net B/C can be seen in Table 8.

| Year | Conventional way | In-store Drying |
|------|------------------|-----------------|
|      | Net Benefit      | DF | PV     | Net Benefit | DF | PV     |
| 0    | -5 000 000       | 1.0000        | -5000000 | -37 000 000 | 1.0000        | -37 000 000 |
| 1    | -3 394 400       | 0.8475        | -2876610 | -13 756 000 | 0.8475        | -11 657 627 |
| 2    | -1 788 800       | 0.7182        | -1284688 | 9 488 000   | 0.7182        | 6 814 134    |
| 3    | -183 200         | 0.6086        | -111501  | 32 732 000  | 0.6086        | 19 921 706   |
| 4    | 1 422 400        | 0.5158        | 73 3658  | 55 976 000  | 0.5158        | 28 871 798   |
| 5    | 3 028 000        | 0.4371        | 1 323 567 | 79 220 000  | 0.4371        | 34 627 792   |
| Net B/C | 0.22          |                | 1.85       |

The results showed that Net B/C of in-store drying was greater than 1.0 which means the application of in store drying technology was predicted as economically feasible. The B/C value of in-store drying was much greater than that of conventional one.

4. Conclusion
The in store drying method on shallot can produce better quality than conventional drying (sun drying). It also showed good efficiency (58.26%) and financially feasible (R / C 1.27, BEP of 200.92, PBP of 4.8 months and net B/C of 1.85). Therefore, the in store drying technology was better than the conventional way.

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