Microstructure changes of taro (*Colocasia esculenta* L. Schott) chips and grains during drying

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Abstract. Microstructure changes of taro (*Colocasia esculenta* L. Schott) chips behaviour during drying at elevated temperature of 50°C, 60°C and 70°C were studied. Scanning electron microscope (SEM) images of taro chips samples taken at the end of each drying step. Series of SEM images shows a fresh section of raw taro chips which honeycomb form cells are clearly observed and distinguishably filled with starch grains. The cells are tightly connected to each other, with approximately has 50-80 µm size. The compound of starch grain, i.e. amyloplasts, has similar size of approximately 5-15 µm, yet the cohesion between amyloplast are differs. When subjected to drying temperature of 50°C, corm cells opened. Compound and individual starch grains are clearly visible. By increasing the time, the membrane cells were quietly disappeared, meanwhile the grains shrank. However, there is no significant size decrease of the grains along the increasing of drying time up to 7 hours. This phenomenon is in line with the moisture content measurement, because since 160 minutes, the low moisture content observed and it’s constant for the rest of drying process. As for samples of 60°C, the membrane cells opened further, and the starch grains were mostly appeared in individual granular. The grain size is comparable regardless the drying time. By increasing the temperature to 70°C, the impact to grains sizes is quite significant. The polyhedral shape is still observed but is in smaller grains. Therefore, microstructure of taro chips most likely related to their drying behavior at certain subjected drying temperature.

1. Introduction
Taro (*Colocasia esculenta* L. Schott) is a rich-starch corm widely grown in Indonesia, with Malang as one of its major producers. According to Arici et al. [1], taro is also grown in 43 countries in the world, with around 32% of total production is in Asia. Some previous researches were reported that taro has high nutritional benefit, e.g. medium glicemic index and potential antioxidant [2]; highly digestible [3]; and include fiber, protein, vitamins, phosphorous, and calcium [4]. Due to its nutritional benefit, the commodity has attracted attention of researchers in recent years. The corm is consumed in limited ways, i.e. taro flour as raw material for sweet-sticky cake (locally known as ‘dodol’) and taro-stick snack [5]. The recent derivative of taro-based product that recently draws attention from researchers, especially in Indonesia, is taro flour. Taro flour is prospective to be developed due to various end-products that have economic value on food and
beverages sector in Indonesia as raw material as well as substitute or complementary material. It also can eliminate post-harvest losses of taro corm by processing of them into flour form and enhance its shelf life. One of the critical steps in agro-based products, as well as flour production is drying since it can affect the final product quality attributes [6]. Previously, reports have been made regarding physicochemical, thermal properties of six taro flours and starches [7]; microstructures and creep-recovery of taro-based paste from freeze dried taro chips [8]; and the influence of cooking conditions of taro on its texture, microstructure, and physicochemical characteristic [9]. Hawa et al. [10] also reported the detailed drying behavior of taro chips in convective tray dryer, i.e. moisture equilibrium, drying rate, and thin-layer drying curve model at 50°C, 60°C, 70°C of drying temperature.

However, to the best of author knowledge, there is no report has been made regarding the microstructure changes of taro chips as affected by different hot air temperature during convective drying. Since drying causes numerous physical and chemical changes in plant tissue, which caused mostly by temperature gradient and elevated temperature [11], it is beneficial to get better understanding of taro chips microstructure changes for better quality of taro flour. It is therefore, the aim of present work was to investigate alteration of microstructure of taro chips subjected to different hot air temperature during convective drying. Understanding of microstructure change might be advantageous in analysis of quality shift caused by drying. Moreover, knowledge of the microstructure changes of taro chips during drying might be used to design required taro flour quality by the preferred of proper mode of drying condition.

2. Materials and methods
2.1. Material preparation
Taro corms were taken from the local plantation in Malang, Indonesia, in August, 2015. The corms identified have the same characteristic as previously reported by Quero-Garcia et al. [12]. The corms were washed, peeled, re-washed and sliced into chips of 1±0.2 mm of thickness by kitchen knife. The initial average moisture content of the chips was 77.28±1.7% (dry basis), as determined with AOAC (Association of Official Analytical Chemists) standard gravimetric method [13]. Subsequently, the taro chips were divided into small group with same weight (5 g) for each subjected drying condition.

2.2. Drying procedure
A custom build laboratory scale convective dryer with static-tray type which used by Hawa et al. [10] in previous report was used in present study. The dryer has insulated drying chamber (55 cm in length, 50 cm in width and 45cm in height) and equipped with 2000 W electric heater placed at the bottom of drying chamber. It also has digital thermo control system that maintaining hot air at desirable temperature with ±2°C of accuracy. The dryer was installed in a surrounding condition with about 70-75% of relative air humidity and about 28°C of ambient air temperature.

Before drying process performed, the dryer system was started to reach a preferable steady state for each examined temperature conditions, i.e. 50°C, 60°C, and 70°C. The prepared samples were loaded into the dryer for dehydration process and finally removed after 300, 360, and 420 min of drying time for all subjected temperatures. During dehydrated process, the samples were weighted at regular intervals. At initial stage, weighing was made at short interval (every 10 min) and eventually increased to the maximum every 30 min using precision balance (PL303 series, Mettler Toledo, USA) with 0.001 g of accuracy. The selected drying time were considered based on report by Hawa et al. [10] which revealed that the moisture equilibrium of taro chips in convective tray dryer at subjected temperature, i.e. 330, 330 and 360 min at 50°C, 60°C and 70°C, respectively. After the dehydration process ended, the samples of taro chips then placed in plastic airtight container to avoid adsorption prior further analysis.

2.3. Scanning electron microscopy (SEM)
The dried taro chips subjected to each drying temperatures at drying times was photographed scanning electron microscopy (FEI Inspect S50) to reveal their microstructure alterations as affected by each
drying condition. Details on the SEM are explained elsewhere [14]. For comparison, the fresh taro chips also scanned using the same apparatus.

3. Results and discussion

3.1. Moisture content alteration during drying process

Figure 1 showed the chip’s moisture content change during drying process. The drying process is marked by a progressive decrease in moisture content with time.

![Figure 1: Chip’s moisture content change during drying process at different drying temperature.](image)

The Figure 1 reveals that by increasing the hot air temperature, the initial negative slope of moisture content curves becomes more significant, and made short time periods required to remove the moisture content of the chips, i.e. gradual decrease moisture content of chips at 50°C and sharp decrease at 70°C.

3.2. Fresh taro chips microstructure

Observing microstructure of cells could help to provide a better understanding of its drying behaviour. SEM images of fresh taro chips samples depicted in Figure 2.

![Figure 2: SEM images of microstructure of fresh taro chip under different magnification: 500x (left) and 1800x (right).](image)

As shown in the Figure 2, a fresh section of raw taro chips, in which honeycomb form cells are clearly observed and distinguishably filled with starch grains. The cells are tightly connected to each other, with approximately has 50-80 µm size, quite bigger compared with the observation of Njintang et al. [15]. The compound of starch grain, i.e. amyloplasts, has similar size of the cells, yet the cohesion between amyloplast are differs. An amyloplast grain has size approximately 5-15 µm. Figure 2 also depicted the presence of free water in between starch grains.

3.3. Dehydrated taro chips microstructure

The dehydrated taro chips microstructure with 50°C of drying temperature depicted in Figure 3.
As shown in Figure 3 the corm cells of taro chips opened due to drying processes. The compound and individual starch grains are clearly visible. By increasing the drying time, the membrane cells were quietly disappeared and the grains shrunk. However, there is no significant size decrease of the grains along the increasing of drying time up to 420 min. This phenomenon is in line with previous report by Hawa et al. [10], which stated that the moisture content of taro chips with 50°C convective drying has relatively small changes after 160 min of drying time and reach its moisture equilibrium at 330 min with 3.03% (dry basis). As for dried taro chips of 60°C drying temperature, the membrane cells opened further and the starch grains were mostly appeared in individual granular (Figure 4). The grain size is comparable, whether for the sample taken from 300, 360 or 420 min of drying time. The moisture content of taro chips with 60°C convective drying has relatively small changes after 140 min of drying time and reaches its moisture equilibrium at 330 min with 1.40% (dry basis) [10].

By increasing the drying temperature to 70°C, the impact to grains sizes was quite significant (Figure 5). The polyhedral shape was still observed, but was in smaller grains compared with the samples taken from 50°C and 60°C. There was no rupture observed during the drying of the chips. The significant shrinkage of grain size at 70°C may due to the low moisture content of taro chips which came early than two other lower drying temperatures, i.e. at 85 min, and has relatively small changes after that. The exposure to high drying temperature for a long time with small amount of water remained in the chips may lead to significant shrinkage of grains size. The moisture equilibrium of the chips at 70°C also came early than two lower drying temperatures with 2.03% (dry basis) [10].

**Figure 3.** SEM images of microstructure of dehydrated taro chip with 50°C drying temperature, i.e. (A) 300 min, (B) 360 min, and (C) 420 min drying time, under different magnification: 500x (left) and 1800x (right).
3.4. Starch grain size changes
Following the drying process, taro chips were milled to obtain taro flour. Taro flour utilized as food materials, used individually or combined with wheat flour. Observing grains microstructure of taro flour are also required for a better understanding of drying processes. As shown in Figure 6, compound of grains were observed for taro flour produced with drying temperature of 60°C and 70°C. On the other hand, individual grains or smaller compounds were observed from the sample taken from drying temperature of 50°C. For individual grain size were measured from the images, ranging approximately from 8-30.1 µm; 6.8-11.8 µm and 7.92-18.7 µm taken from samples of temperature drying of 50°C, 60°C and 70°C, respectively. The grain size is most likely not complementary with the moisture content of taro flour. The grain size distribution was also quite wide, although details analysis of particle size and distribution is needed [16]. Wide particle distribution contributed by the resulted compound or agglomerated grains.

Figure 4. SEM images of microstructure of dehydrated taro chip with 60°C drying temperature, i.e. (A) 300 min, (B) 360 min, and (C) 420 min drying time, under different magnification: 500x (left) and 1800x (right).

Figure 5. SEM images of microstructure of dehydrated taro chip with 70°C drying temperature, i.e. (A) 300 min, (B) 360 min, and (C) 420 min drying time, under different magnification: 500x (left) and 1800x (right).
Figure 6. SEM images of microstructure of taro flour with 360 min of drying time and different drying temperatures, (A) 50, (B) 60, and (C) 70°C.

4. Conclusion
The present study was reported the microstructure changes of taro chips under different temperature of drying air. The applied temperature of drying air affected the size of grains. However, there is no significant size decrease of the grains were detected by increasing the drying time. The microstructure of taro chips might be related to their drying behavior at certain subjected drying temperature. The compound of grains were observed for taro flour with 60°C and 70°C, and the grain size is not related to the moisture content of taro flour.

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