Effect of drying temperature on the moisture loss, acidity and characteristics of Amla fruit

A Raafl, N Suriaini1, F Djafar2, Y Syamsuddin1 and MD Supardan1,3*

1 Chemical Engineering Department, Universitas Syiah Kuala. Jl. Syech Abdur Rauf No. 7, Banda Aceh, Indonesia 23111
2 Institute for Research and Standardization of Industry Banda Aceh, Jl. Cut Nyak Dhien No. 377 Lamteumen Timur Banda Aceh 23236, Indonesia
3 Pusat Riset Halal, Universitas Syiah Kuala, Banda Aceh, Indonesia 23111

*E-mail: m.dani.supardan@unsyiah.ac.id

Abstract. This study investigated the effect of drying conditions on the Amla fruit. Experiment is conducted using a lab-scale oven dryer at temperature 40 °C and 50 °C. Amla slices were dried with a thickness of 0.5 cm and length 0.1 cm. The dried products were evaluated with moisture loss and acidity. The results showed that the temperature greatly influences the moisture content, acidity, and the dried product's microscopic. The moisture loss at the drying temperature of 50 °C was higher than 40 °C. Meanwhile, the acidity of dried Amla powder produced at a drying temperature of 40 °C was higher than 50 °C. Based on X-ray diffractometer analysis, the microstructure of Amla was crystalline-amorphous. Results of Fourier Transform Infrared Spectroscopy analysis showed O-H, C-O, and C=O forms that indicated polyphenols, pectin, and ascorbic acid compounds in Amla fruit. Oven dryer temperatures had significant effects on the microstructure based on scanning electron microscope analysis.

1. Introduction
Amla (Emblica officinalis), commonly known as Indian gooseberry, is widely distributed in tropical and subtropical countries like China, India, Indonesia and Southeast Asia. It belongs to the family Euphorbiaceae [1]. The tree is similar to cermai fruit whose vertical stem can reach 18 m high, and the fruit has a bitter and sour flavor that is less preferred [2]. Amla is unsuitable for direct consumption due to highly acidic and astringent in taste, and hence, they are consumed mainly in the processed form. The richness nutritional of Amla fruit makes it an excellent medicinal plant [3]. Besides its medicinal properties, this fruit is also widely used in the food and cosmetic industries [4].

Many researchers widely reported the study of Amla fruit processing. Liu et al. [1] conducted a fractionation and purification process to identify Amla fruit's antioxidative components. Meanwhile, Raj et al., [3] evaluated the changes in Amla juice's different quality attributes during thermal and thermal assisted high-pressure processing. A comparative study on Amla drying using freeze and cabinet drying was reported by Sarangam and Chakraborty [5].

Drying is one of the simplest and least expensive processes for food preservation. It requires a combination of warm temperatures and good air circulation. The drying process aims to reduce the water content bacteria, yeasts, and molds need to grow. The dehydrated materials will shelf-stable if...
adequately dried and properly stored. However, drying affects the product's quality, such as the nutritional content and color of the dried product. Thus, proper control of the drying process is essential in minimizing the loss of the nutritional and medicinal compounds of the products as well as maximizing the yield of product [6]. There is an intense quest to develop an efficient, time-saving, economically functional and environmentally friendly drying process at the laboratory and industrial scale, preserving the dried product's nutritional value.

There are several different methods to dry material. Methods that work well in most climates include solar drying, conventional ovens, or an electric dehydrator. Generally, solar drying is an easy operation than oven drying, which much input is needed. The disadvantages of solar drying include unpredictable weather and climate conditions and uncontrollable temperatures. Besides, solar drying is prone to dust contamination, air pollution, dirt, or insects. Meanwhile, oven drying has an advantage that the drying temperature can be adjusted according to desired conditions [7,8]. A further study of dried Amla products' behavior and characteristics through experimental tests is still needed to minimize the product's quality loss. Therefore, this study aims to determine the drying process's characteristics and dried Amla produced using an oven dryer.

2. Materials and Methods

2.1. Drying of Amla fruit
Amla fruit was procured from Aceh Besar, Blang Bintang. The fruit was washed to remove impurities before used in the experiments. Furthermore, it was peeled and cut to a thickness of 0.5 cm and 1 cm to maintain a relatively equal size in the drying process. Amla fruit slices with an initial weight of 0.3 g were put into a lab-scale oven dryer made of stainless steel. The samples were dried temperatures of 40 ℃ and 50 ℃ until they reach a constant weight. During drying, the Amla moisture loss was recorded every 10 min using electronic balances with an accuracy of 0.01 g.

2.2. Methods of analysis
Samples are characterized in the form of dried Amla powder. The acidity of Amla fruit was analyzed with the titrimetric method as per SNI 01-3722-1995 procedures. Amla fruit extract was titrated with 0.1 N NaOH standard solution using the phenolphthalein indicator. The results of titration are obtained when the solution turns pink. Microscopic characterization of the sample includes an analysis of the sample structure using an X-ray diffractometer (XRD). The functional group content of the dried Amla product was analyzed by Fourier Transform Infrared Spectroscopy (FTIR) Shimadzu Prestige 6400. Meanwhile, the surface morphology of samples was provided by a scanning electron microscope (SEM) TM 3000 (Hitachi). SEM analysis was presented with 2500× magnification.

3. Results and Discussion

3.1. Drying curve of Amla fruit
Water content is a crucial factor in determining the quality of a food product. The lower the water content, the longer the shelf life of the product will be. The moisture content in food products can be removed using a drying process.

Figure 1 showed the Amla fruit's moisture ratio during the drying process using an oven dryer with a temperature of 40 ℃ and 50 ℃. At the beginning of the drying process, the moisture ratio decreased rapidly. The water content in Amla fruit is a constant amount of decrease because heat around the surface of the material is equal to the amount of heat absorbed by the material. The drying temperature has a significant effect in controlling the drying rate. Higher drying temperature provides high heat energy to dry material so that loss of moisture occurs faster at temperature 50 ℃, and the faster drying time is obtained [9]. Similar results of researches have been reported on the drying process of various products such as pears [10], Amla [11,12], apples [13], persimmon [14], and kiwi [15]. During the drying process, the moisture content lost using the drying temperature of 40 and 50 ℃ was 73.33% and 80%, respectively.
3.2. Acidity
Amla has high vitamin C content that can be detected by its acidity. The acidity of fresh Amla fruit was 2.98%. This value is higher than the acidity of Amla fruit, processed into juice with an acidity of 1.40% as reported by Jain and Khurdiya [16]. Meanwhile, the acidity of dried Amla powder produced at a drying temperature of 40 and 50 °C was 18.81 and 17.16%, respectively. This result confirmed that as the drying temperature increases, the acidity of the dried product decreases. Amla fruit with different varieties has a range of acidity values ranging from 11-12% [17]. Fruit variety, post-harvest treatment, and various processing processes on Amla fruit influence the final product's nutritional content, such as acidity [18].

3.3. Microscopic Characteristics
3.3.1. XRD analysis. XRD analysis of dried Amla powder at temperatures of 40 and 50 °C is shown in Figure 2. It can be seen that the molecular structure of Amla powder is crystalline-amorphous. This is indicated by the series of sharp peaks as a crystal indicator and a wide range of peak patterns as an amorphous indicator on the XRD spectrum of Amla powder. A similar trend in the experimental result was observed by Caparino et al. [19]. Besides, the results XRD spectrum of Amla powder is almost identical with several fruits that contain vitamin C, such as mango [19], Jamun pulp powder [20], papaya, sapota, and guava [21]. The diffraction peaks of amorphous structures at 9° and 19° are the specific diffraction peaks of Amla fruit. It only appears in Amla fruit and does not appear in other fruits containing vitamin C. It can also be seen that the higher the drying temperature, the more significant diffraction peaks at 9° and 19°. Lacerda et al. [22] previously reported that increasing the drying temperature can reduce crystal structure to amorphous structures. Thus, the increase in the diffraction peak value indicates that the drying had progressed well.

3.3.2. FTIR analysis. The result of the FTIR analysis is shown in Figure 3. The Amla powder spectrum indicated the existence of hydroxyl groups (O–H) in wave numbers 3220-3560 cm⁻¹. From the specific peaks, it can be seen that there are C–O compounds at wavenumbers 1000-1200 cm⁻¹. The wavenumber 1690 cm⁻¹ indicates the presence of a carbonyl (C=O) group. The results of this spectrum analysis are consistent with the chemical characteristics of the Amla fruit. The existence of O–H, C–O, and C=O groups indicated that the presence of polyphenol, pectin, and ascorbic acid compounds in Amla [17,23].
Figure 2. XRD spectrum of Amla powder at a drying temperature of 40 °C and 50 °C.

Figure 3. FTIR spectra of Amla fruit at drying temperature 40 °C and 50 °C.

3.3.3. SEM analysis. The morphological characteristic of Amla powder can be seen from SEM analysis in Figure 4. The morphological structure of Amla powder produced with a drying temperature of 40 °C is fused and tends to wrinkle (Figure 4a). Meanwhile, Amla powder dried at a drying temperature of 50 °C produced a structure that tends to separate into small particles (Figure 4b). It was observed that an increase of drying temperature causes microstructure damage and destroys cell walls of dried samples [23,24]. It was also observed that the amount of water in the material dried at a temperature of 50 °C was smaller than 40 °C.
4. Conclusion

In this study, the drying of Amla fruit using a lab-scale oven was investigated. The experimental results showed that the drying temperature affects the moisture loss of the Amla fruit. The drying temperature had a significant effect on acidity. The molecular structure of Amla fruit observed by XRD showed that the Amla powder is crystalline-amorphous. Meanwhile, FTIR analyses have shown the physicochemical properties of Amla fruit with O–H, C=O and C–O in Amla fruit, which were confirmed the phenolic, pectin and ascorbic acid content. The morphological structure analysis showed that as the drying temperature increased, the Amla fruit structure separates into small particles.

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