Reducing aflatoxin contamination of nutmeg using drying methods

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Abstract. Indonesia’s export of nutmeg to Europe decreases in recent years due to aflatoxins contamination. The study aimed to evaluate four methods of drying nutmeg. The drying methods tested were a fiber-house type with a solar energy source, a hot-box type equipped with a fan heater, drying on bamboo trays. The unshelled nutmeg seeds were dried until vibrated if shaken and shelled. The temperature, humidity, moisture, oil and aflatoxins contents were analysed. The fiber-house and the electric hot-box types dried the seeds faster (2-3 days) compared with the traditional rack methods either uncovered (6-7 days) or covered (5-6 days). The moisture content of the dried seeds was <10% and the total aflatoxins (B1, B2, G1, and G2) <5 μg/kg. Higher aflatoxins found from the uncovered drying seeds, i.e. aflatoxin B1 (302.73 μg/kg), aflatoxin B2 (10.41 μg/kg), aflatoxin G1 (70.73 μg/kg), aflatoxin G2 (76.73 μg/kg), and the total aflatoxin was 389.97 μg/kg. The oil and oleoresin contents of the dried nutmeg fulfilled the standards (11.85% and 11.73%, respectively). This study implies that the drying method with direct sunlight is not recommended. For larger-scale farmers and exporters, the solar house dryer type is recommended.

Keywords: Myristica fragrans, Aspergillus sp., quality

1. Introduction

Nutmeg (Myristica fragrans Hout) is one of the most important export plant commodities of Indonesia. In 2013, the exported nutmeg valued the US $ 122 million. Nutmeg plants were grown by small holder farmers of 168,658 families [1]. Indonesia is the world's largest producer and exporter of nutmegas, followed by Grenada, India, Malaysia, Sri Lanka, and Papua New Guinea [2]. The world supply of nutmeg mainly comes from Indonesia (70%) and Grenada (25%) (ITC, 2010). Indonesian nutmegs have a distinctive taste and aroma and contain high myristicin (± 13.5%). However, the growth of nutmegas exported from Indonesia decreased from 14,186 tons in 2010 to 13,552 tons in 2013, although the export value increased from the US $ 86,096,000 in 2010 to the US $ 122,372,000 in 2013 [3].

In recent years, few Indonesian nutmegas exported to European markets have been rejected due to contamination of aflatoxins. The European Rapid Alert System for Food and Feed (RASFF) monitored that in 16 years period (2000-2016), 53 out of 80 (62%) cases of nutmegas from Indonesia were denied to enter European markets because of high aflatoxin tolerance exceeded the limit, i.e. aflatoxin B1 = 5 μg / kg; total aflatoxins (B1 + B2 + G1 + G2) = 10 μg / kg. This caused exported nutmegas from North Minahasa, one of
the main producing nutmegs in the country, to the EU decreased since 2011 from US $ 20,000 / ton to the US $ 16,500 in 2012. Globally, the decline in EU market demand for nutmeg Indonesia reached 43%, from 41 million euros to 23 million euros in 2012, (http://finansial.bisnis.com/read/20130630/9/147783/biji-pala-indonesia-international-test-quality-test). [4] Aflatoxins are found at all levels of supply chains, i.e. farmers, collectors, and exporters in North Sulawesi. At the farmer level, the aflatoxin contaminations were very high (141 μg/kg) [5]. The study suggested that high level of aflatoxin contamination was attributed with the high moisture content (≥10%) and broken nutmegs (70-76%) which might trigger the growth of Aspergillus flavus and A. parasiticus producing aflatoxins.

It is not uncommon that farmers did not practice the postharvest handling methods of nutmegs recommended by the government [6], such as harvesting young and mature nutmegs. The mature nutmegs are characterised by the splitting of the outer fruits and dark brown colour of the unshelled nutmegs. Farmers also dried nutmeg, unshelled and shelled on plastic sheets or other materials laid directly on the ground, but the recommendation is to be dried on racks about one meter above the ground. The broken and unbroken nutmegs were mixed without quality sortations made. Furthermore, when environmental condition is humid, such as in the rainy season, where nutmegs are not possible to be dried under sunlight, the unshelled and shelled nutmegs are susceptible to fungi, including Aspergillus spp. producing aflatoxins. Proper postharvest handlings are essential to reduce the colonisation of fungi that produce aflatoxins [5]. On soybean, the maximum growth for A. flavus BIO 2237 was at 30 °C temperature with RH of 90%, however, at a higher temperature (40 ºC) and low RH (70%), the fungus did not grow. Factors affecting drying are the air temperature, humidity, drying airflow discharge, initial moisture content, material form, material size, and treatment or drying method [7].

This study was aimed to evaluate several drying models of nutmegs. This study is expected to find a more environmental and effective nutmeg drying method for field conditions.

2. Materials and methods

2.1 Nutmeg seeds
The nutmeg seeds used in the study were purchased from a commercial farmer in Ciapus, Sukabumi, West Java. The nutmegs were harvested manually when the seeds were brownish-black or have broken. The harvesting of nutmegs was using long bamboo sticks equipped with metal hooks. Nutmeg split with a knife and seeds separated by the flesh. The mace covering the shell surface of the nutmeg was released by hand so that the nutmeg with a black-brown shell can be obtained to shiny black to be used as experimental material.

2.2 Experimental design
The treatment consists of 3 types of drying methods, namely (1) home type dryer rack made from fiber and heat source from sunlight, (2) rack type box tray made from triplex wood with heat source from electric fan (electric PTC fan NSB-150x11-1500W heater), (3) sun-dried sunscreen (control)

2.3 Construction of the drying models
Three drying types were tested, i.e. a fiber-house type with a solar energy source, a hot-box type equipped with a fan heater, drying on a bamboo tray (control). The fiber-house drying type used sunlight as energy. The model was based on Wenur et al. with modifications [8] The fiber-house dryer had 1.5 m height, 80 cm wide, and 1 m length; a blower was mounted at the top. Figure 1). Inside the dryer, there were 6 shelves made of steel wire. On the left and right sides, there were two wings of fiber sheets. Several hoes (in diameter) were made at the base of the dryer as ventilation. Maximum drying capacity of 100 kg of nutmegs. The hot-box type dryer was made of multiplex wood of 1m long, 1 m wide, and 1 height. Inside the box
consisted of 3 shelves made of steel wire. At one side of the box as assembled an electric PTC fan heater NSB (150x11-1500W) as the heat energy. The drying capacity of the box was 30 kg nutmegs. The racks of the conventional method of drying were made of the iron positioned at 1 m above the floor level. On the racks were put bamboo trays containing unshelled or shelled nutmegs and dried under sunlight.

![Figure 1](image1.png)

(a) (b)

Figure 1. Construction of the drying types : (a) house type dryer; (b) box dryer

2.4 Testing of drying types

The drying type is tested through drying of shelled nutmeg and peeled nutmeg seeds. Nutmeg is weighed first before being put into the dryer. The drying process of nutmegs in all two-three drying types was stopped when the nutmegs produced sound when shaken as an indication that the inner nutmeg seeds have been detached from the shell. The daily temperature and humidity in all four drying methods were observed every hour. The drying process lasted from 9 AM to 3 PM. Parameters observed after dry nutmeg are drying time, yield, moisture content and oil content.

Dry nutmeg is solved using a hammer made of wood or iron and the inner seeds are dried with a dryer test. The daily temperature and humidity in all four drying methods were observed every hour. Drying is done to obtain peel nutmeg seed moisture content up to 10%. The water content, oil content, oleoresin and yield of the nutmegs from each drying methods were evaluated. Water content was observed by toluene and oleoresin method by maceration. The aflatoxins contents were analysed using the HPLC method at the laboratory of the Quality Assessment Hall, the Directorate of Standardization and Quality Control, the Director-General of Consumer Protection and Commerce, Jakarta.

3. Results and discussions

3.1 Temperature and humidity (RH)

The construction of house-fiber drying type and box-type are shown in Figure 2. The inside temperature of the dryer house type fluctuated depending on the weather. The highest temperature was 42.56°C and the lowest was 37.30°C, whereas the relative humidity percentage ranged between 45.87% (highest) and 30.97% (lowest). The average temperature and humidity of the drying chamber per hour on each different shelf was 42.56°C (RH = 30.97%) on the top shelf, 38.05°C (RH = 44.21) on the middle shelf, and 37.30°C (RH = 45.30) on the bottom shelf. The length of the drying process of the nutmegs in the fiber-house type was 29 hours. The yield of dried nutmeg seeds on the top shelf is 54.74%, the middle shelf is 59.52% and the bottom shelf is 59.52%. The moisture contents of dried nutmegs from the top, middle, and bottom shelf were 16.41%, 15.33%, and 16.17%, respectively, whereas the oil contents were 4.28%, 3.87%, and 4.00%, respectively (Table 1).
Table 1. The effects of three drying methods of nutmegs seeds on their qualities

| Treatment                        | Drying period (hour) | Average Temperature (°C) | Average Humidity (%) | Yield (%) | Water content (%) | Oil content (%) |
|----------------------------------|----------------------|--------------------------|----------------------|-----------|-------------------|----------------|
| House type drying (sundrying)    | Top shelf            | 29                       | 42.56                | 30.97     | 54.74             | 16.41           |
|                                  | Midle shelf          |                          | 38.05                | 44.21     | 59.52             | 15.33           |
|                                  | Bottom shelf         |                          | 37.30                | 45.30     | 59.52             | 16.17           |
| Box type drying (electric fan heater) | Top shelf           | 46                       | 43.13                | 45.87     | 51.11             | 14.00           |
|                                  | Midle shelf          |                          | 43.46                | 45.75     | 46.67             | 16.22           |
|                                  | Bottom shelf         |                          | 42.21                | 45.75     | 51.11             | 16.75           |
| Direct sun drying (control)      | 31                   | 39.47                    | 42.38                | 56.42     | 13.51             | 3.72            |

The length of nutmeg seed drying using box-type shelves dryer was 46 hours to obtain dried nutmeg seeds marked with a loud sound when shaken. The mean temperature and humidity in the drying chamber were 43.13°C (RH = 45.87%) on the top shelf, 43.46°C (45.75%) on the middle shelf, and 42.21°C (45.75%) on the bottom shelf. The highest temperature was 43.46°C and the lowest was 42.21°C, whereas the relative humidity percentage ranged between 45.87% (highest) and 45.75% (lowest). The yield of dried nutmeg seeds on the top shelf is 51.11%, the middle shelf is 46.67% and the bottom shelf is 51.11%. Whereas traditional drying takes 31 hours of drying time with an average temperature above nutmeg at 39.47, humidity 42.38% and yield dry weight yield of 56.42%.

The temperature and humidity are inversely proportional, the higher the temperature of the drying chamber, the humidity (RH) decreases. The drying temperature will affect the humidity of the air inside the drying device and also the rate of drying. Moisture affects the water vapor removal process. If the humidity is high, then the difference in water vapor pressure inside the material with the outside becomes small so that it inhibits the removal of water vapor from the material out [9]. The drying speed is influenced by two factors, namely drying air (temperature and humidity), and the nature of the dried material (shape, size, and
moisture content) [9, 10]. Drying is one of the preservation methods by reducing the moisture content of the material so that it can be stored for a long time. The drying process requires heat to evaporate water from agricultural products and air flow to carry high water content out of the system [11].

Drying with the type of house produces nutmeg seeds dry faster on the upper shelf compared to the bottom shelf. This is likely because the upper shelf is closer to sunlight. This result agreed with Ismoyo’s discovery, drying on the top shelf will dry faster than the bottom shelf [12]. While the type of box, nutmeg on the middle rack dries faster than the top and bottom shelves. This is probably because the middle rack is closer to the heat source coming from the fan. The average temperature of the drying chamber of nutmeg produced from the two types of dryer ranged from 37.30-43.46°C and peeled nutmeg seeds 39.31-43.55°C. While the temperature control treatment ranged from 39.33 to 42.38°C. All types of dryers tested produced temperatures below 45°C so that they meet the requirements for drying nutmeg, because if the temperature is too high it can cause nutmeg to become shriveled.

3.2 Moisture content

The moisture content of the nutmeg seeds produced from drying with drying racks for home, box, and traditional types is still above 10%. The average water content ranges from 15.65% -15.97%, and control 13.51%, although the nutmeg seeds have been released from the shell so it still needs to be dried. The average moisture content of nutmeg seeds between home and box-type dryers is no different, except for direct sun drying (Figure 3). To prolong the shelf life and prevent spoilage, the nutmeg seeds must be reduced its moisture content to below 10%. The moisture content of nutmeg produced from three types of the dryer is still above 10% even though the nutmeg meat has been released from the shell. The results of the drying of the peeled nutmeg seeds using a drying rack type of house, box, and direct sunlight were 5.95-8.94% (Figure 3). The maximum nutmeg content recommended is 10% [13]. The peeled nutmeg seed moisture content produced from both types of dryers below 10%. The yield of nutmeg peel drying results by type of housing an average of 92.48% and 95.31% of type box and indirect sun drying was 87.55% (control).

One important aspect of reducing aflatoxin contamination is the water content related to the drying process. This study shows that the shortest drying period of the peeled nutmeg seeds to reach a water content below 10% can be obtained with a house type dryer totaling 23 hours; while other types take 28 hours. It should be noted that in the present study, the air temperature and humidity were very good. The temperature and humidity in the house type dryer ranges between 39.31-43.55°C (RH= 25.17-28.04%), the box type 41.66-43.83°C (21.15-24.57%) and drying under direct sunlight (control) 39-29°C (25.69%) Tabel 2.

3.3 Oil content
The average oil content of the nutmeg obtained from drying with a rack type of house, box, and direct sunlight was 4.05%, 3.97%, and 3.72%, respectively (Table 1) and peeled nutmeg seeds 11.85%, 9.91% and 10.5% (Table 2). Nutmeg oil content in three different types of dryers the results are not significantly different. Where the content of peeled nutmeg seed oil from drying with a rack type house is higher than the box type and direct sunlight (Figure 4). The content of nutmeg seeds oil is lower than the peeled nutmeg seeds because it contains water high enough so that the speed of oil released during refining is slow so that the oil produced is less. The peeled nutmeg which is dried with a home type drying rack contains higher oil content compared the box type and direct sunlight. Oil content is related to water content, the higher the water content of the oil yield obtained the smaller. The moisture content of the peeled nutmeg seeds between the three types of dryers was not significantly different, ranging from 7.59-8.94%. The distinguishing factor is the drying time, where the drying rack type of the house is shorter than the box type and direct sunlight (Table 2). During the drying process oil evaporation occurs along with water vapor, so the longer the material is dried the more oil is also evaporated.

Table 2. Characteristics of shelled nutmeg seeds treated with different drying methods

| Treatment                        | Drying period (hour) | Average Temperature (°C) | Average humidity (%) | Yield (%) | Moisture content (%) | Oil content (%) | Oleoresin content (%) |
|----------------------------------|----------------------|--------------------------|----------------------|-----------|----------------------|-----------------|-----------------------|
| House type drying (sundrying)    |                      |                          |                      |           |                      |                 |                       |
| Top shelf                        |                      |                          |                      |           |                      |                 |                       |
| Middle shelf                     | 23                   | 43.55                    | 28.04                | 94.77     | 5.95                 | 11.99           | 11.80                 |
| Bottom shelf                     |                      | 40.59                    | 25.17                | 93.17     | 8.94                 | 11.75           | 10.80                 |
| Box type drying (electric heater) |                      |                          |                      |           |                      |                 |                       |
| Top shelf                        |                      | 43.83                    | 23.63                | 95.43     | 8.81                 | 9.31            | 9.40                  |
| Middle shelf                     | 28                   | 43.00                    | 21.15                | 95.40     | 7.73                 | 9.62            | 9.00                  |
| Bottom shelf                     |                      | 41.66                    | 24.57                | 95.11     | 7.68                 | 10.79           | 10.80                 |
| Direct sun drying (control)      | 28                   | 39.33                    | 25.69                | 87.55     | 8.94                 | 10.5            | 10.40                 |

3.4 Aflatoxin

Aflatoxin contamination analysis on the peeled nutmeg seeds dried in the fiber-house, heat oven box, and direct sun drying shelves was presented in Table 3. The result showed the amount of aflatoxin detected in the nutmeg seeds dried in fiber-house and heat oven box were similar. The amount of aflatoxin contamination in nutmeg peeled from drying with a drying rack of a house type and box totals 3.29 μg / kg. The aflatoxin B1 content was 1.07 μg/kg, aflatoxin B2 was 0.39 μg/kg, aflatoxin G1 was 1.35 μg/kg and aflatoxin G2 was 0.48 μg/kg. The result is completely different from aflatoxin contamination in nutmeg peel is dried in direct sunlight. The aflatoxin contamination of nutmeg seeds dried in direct sunlight totaled 389.97 ug / kg. Types of aflatoxin B1 (302.73 μg / kg), B2 (10.41 μg kg), G1 (70.73 μg / kg) and G2 (76.73 μg / kg). The study also revealed that after four months of storage, aflatoxin contamination of nutmeg seeds did not increase as presented in Table 3. The nutmeg peeled using PE plastic packaging types can be retained for 4 months at 25°C [14]. All drying technology tested could reduce aflatoxin and achieve the desired quality of peeled nutmeg produced complied with the standards, except drying under direct sunlight.
According to European standards, total maximum aflatoxin is 10 μg/kg and the maximum aflatoxin type B1 is 5 μg/kg [6].

![Figure 4. The results of the dryer type test on the quality of peeled nutmeg seeds.](image)

The main factor causing high aflatoxin contamination in nutmeg seeds is high moisture content, so easily invaded by fungi, especially *A. flavus*. The peeled nutmeg dried in the direct sunlight produced the same quality as from those the type of house dryer and box. Based on the observations of the dry peel result nutmeg drying in the sun in an open contaminated by aflatoxin exceeds the threshold. This is likely to have dirt that enters into the drying area contaminated with the fungus *A. flavus* because it is open-drying.

**Table 3.** The limit of quantification (LOQ) of aflatoxin in shelled nutmeg after 4 month storage

| Treatment                                | Total aflatoxin (μg/kg) | Aflatoxin B1 (μg/kg) | Aflatoxin B2 (μg/kg) | Aflatoxin G1 (μg/kg) | Aflatoxin G2 (μg/kg) |
|------------------------------------------|-------------------------|----------------------|----------------------|----------------------|----------------------|
| Drying house type (sun drying)          |                         |                      |                      |                      |                      |
| Top shelf                                | 3.29                    | 0.39                 | 1.35                 | 0.48                 | 0.48                 |
| Midle shelf                              | 3.29                    | 0.39                 | 1.35                 | 0.48                 | 0.48                 |
| Bottom shelf                             | 3.29                    | 0.39                 | 1.35                 | 0.48                 | 0.48                 |
| Drying box type (electric fan heater)    |                         |                      |                      |                      |                      |
| Top shelf                                | 3.29                    | 0.39                 | 1.35                 | 0.48                 | 0.48                 |
| Midle shelf                              | 3.29                    | 0.39                 | 1.35                 | 0.48                 | 0.48                 |
| Bottom shelf                             | 3.29                    | 0.39                 | 1.35                 | 0.48                 | 0.48                 |
| Direct sun drying (control)              | 389.97                  | 10.91                | 76.73                | 0.48                 | 0.48                 |
3.5 Effects of storage length on the nutmeg qualities

Oleoresin is one of the most important characters of nutmeg. The highest levels of peeled nutmeg oleoresin were produced from that dried in the drying rack. The oleoresin contents in the dried nutmeg seeds decreased after being stored for 4 months (Figure 5). The average oleoresin content of the peeled nutmeg which was dried by the rack drier was 11.73%, followed with the box dryer (9.73%), and drying under the sunlight (10.40%). After being stored for 4 months the levels of oleoresin changed, respectively to 9.47%, 10.06% and 8.4% (Figure 5). This also applies to oil content, the longer the nutmeg seeds are stored the oil content decreases. The amount of essential oil contained in the peeled nutmeg can increase oleoresin levels so that the yield is higher. Decreased levels of nutmeg oleoresin can be caused by a reduction in nutmeg seed oil which is likely to occur due to the evaporation process. The longer storage, the smaller oleoresin found in the shelled nutmeg seeds. This can be caused by the temperature of the storage room being too high or the packaging used to leak.

![Figure 5. Quality of unshelled nutmeg dried using different methods and then stored after four months](image)

4. Conclusions

Two drying methods of nutmegs have been constructed, i.e. a fiber-house type of dryer using solar energy and heat-box oven. Both types of dryers are effective because the drying time is reduced to 2-3 days, whereas the traditional drying is 6-7 days. In all drying methods, the moisture content of the shelled nutmeg below 10%. The total aflatoxins and aflatoxin types B1, B2, G1, and G2 in the nutmegs dried with the fiber-house and heat box oven type were below 3.295 μg/kg, below the maximum limit of 5 μg/kg. This contrast with the traditional dried, contain aflatoxin total of 389.97 μg/kg with details of aflatoxin B1 was 302.73 μg/kg, B2 (10.41 μg/kg), G1 (70.73 μg/kg), aflatoxin G2 (76.73 μg/kg). The quality of nutmeg yielded fulfilled the requirements, i.e. 11.85% oil content and 11.73% oleoresin. This study shows that drying nutmegs under open sunlight on the ground is not recommended for farmer, while home dryer type are recommended for large scale farmers or exporters, the fiber-house type of drying using solar energy is the most suitable. Large scale farmer and exporters can consider more relevant and suitable fiber-house ovens or heat boxes.

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