# STUDY ON DRYING KINETICS OF MACE

Roopaljith KM and Vignesh CP

Department of Food Technology, TKM Institute of Technology Kollam, Kerala, India

## *ABSTRACT*

*Mace is a unique-flavored spice from the nutmeg tree. Ground mace is a ground spice that derives from the dried aril of the nutmeg seed. In this review we examine the drying kinetics of mace, overviewing relationship between moisture content, drying rate and drying time for the description of drying characteristics. To optimize the drying process as well as to maintain the quality of the product knowledge of drying kinetics is important. During drying, the mace loses about 60 percent of its weight as moisture. If drying delayed, mace become highly susceptible to mold and insect contamination.*

## *KEYWORDS*

*Nutmeg, Mace, Drying Characteristics*

## 1. INTRODUCTION

India is also known as 'Land of Spice', where each state cultivates one or the other spices and are used as a condiment in culinary preparations and preparing traditional medicines. Just nine per cent of our spice production is exported. India holds a prominent position in the world spice trade with a 45 per cent share in volume and 30 per cent in value. Nutmeg (*MyristicafragransHoutt.*) is a unique tree spice, processed for two of its spices namely nutmeg and the mace. The Nutmeg fruit consist of three parts; kernel, rind or pericarp and mace. Nut of the fruit is called nutmeg and mace is the dried aril that surrounds the single seed within the fruit. It belongs to the family Myristicaceae., comprising of 19 genera and almost 400 □species.

It is widely grown across the tropics including Guangdong and Yunnan in China, Taiwan, Indonesia and parts of South-East Asia. [1] In India the distribution of nutmeg plantation is seen majorly on the eastern slopes of Nilgiris at Tamil Nadu, Ernakulam, Kottayam, Thiruvananthapuram at Kerala and is cultivated on small scale in Karnataka, Andhra Pradesh and some parts of Maharashtra

Mace however has more economic importance since it is composed of higher concentration of essential oils, more intense aroma and flavour than nutmeg seed. Dried mace is an inevitable in the preparation of its extractives and volatile oils. Drying to optimum moisture level without losing its inherent properties is important for consumption and storage.

The most followed method of drying is drying on the Chula. This traditional method is unhygienic. This increases the risk of contamination of products by smoke and dust. The second most followed method is open sun drying, which need large drying time. [2] The uncontrollable temperature level degrades the final quality of mace. For controlled drying at known temperatures and to analyze the various drying parameters a tray drying method is preferred. The temperature and time of exposure is considered as the important factors in drying. If drying temperature is altered and time is delayed, mace has high chance of mould and insect contamination.

Figure 1. Nutmeg, mace and its rind

Drying is a mass transfer process. It is the removal of water by evaporation from a solid, semisolid or liquid. Heat is used to vaporize the water. The water present in the food and on the food surface is removed. Removal of moisture content is a technique used in food preservation. The water activity in the product by decreased by removal of water thus inhibits the development of microorganisms and prolong the shelf life of the product.

## 2. MATERIALS AND METHODOLOGY

The various materials required and method used in the present study were given below with suitable heading. The materials required for the study were: Nutmeg and its aril mace, the weight was recorded using a weighing balance. A Tray dryer was used to perform drying at controlled temperature.

### 2.1. Raw Material and Sample Preperation

Mace used in the experimental procedures were obtained from the nutmeg. The mace, the reddish seed covering(aril) of the nutmeg seed is manually separated from the nutmeg. This red aril is cleaned up and put on for drying.

### 2.2. Tray Drying Method

The drying of nutmeg mace was performed in a tray dryer operated on electricity for heating of air and circulating it in the drying chamber. Drying by tray dryer is a method of drying which reduces the moisture content at a high speed. Determination of moisture content and drying characteristics of nutmeg is easily done by this method.

## 3. MOISTURE CONTENT DETERMINATION

### 3.1. Principle

Moisture refers to the amount of free water and volatile substance that are lost by drying a food under controlled temperature in a dryer. Determination of the loss of mass on drying of material under specified condition gives the measure of moisture content present in the sample.

## 3.2. Procedure

1. This method is based on the drying of sample under controlled temperature until a constant rate is obtained.
2. Weigh accurately about 5gms of nutmeg and 2gms of mace in the moisture dish. The dish was air dried to eliminate existing moisture.
3. Place the dish in the trays of the dryer for drying. The temperature was maintained at 130$^{o}$C for 2 hours, cooled and weighed.
4. Repeat the process until constant weights are obtained


Figure 2. Tray dryer

## 3.3. Calculation

Percentage Moisture content = (initial weight – final weight) / initial weight

$$MC = \frac{W1-W2}{W1} \times 100$$

where, $w_1$= initial weight of sample, g $w_2$=final weight of sample, g

## 3.4. Drying Characteristics Determination

### 3.4.1. Drying Rate

Weigh accurately about 5gms of nutmeg and 2gms of mace in the moisture dish. The drying of nutmeg was carried out at 50$^{o}$C, 55$^{o}$C and 60$^{o}$C and that of mace was carried out at 45$^{O}$C, 55$^{O}$C and 60$^{O}$C.The weight of mace was note down at 10-minute interval and that of nutmeg was note down at 30-minute interval. Repeat the process until constant weight is achieved to obtain drying rate.

The drying rate of the sample was determined by following formula.

$$R = \frac{Wm}{T}$$

Where,
R = drying rate
Wm=amount of water removed
T=Time interval
The rate of drying shows the loss in moisture.

### 3.4.2. Drying Curve Determination

The following curves are plotted to study the drying characteristics;
Moisture content-time curve, Drying rate-time curve, Drying rate-moisture content curve

## 4. RESULTS AND DISCUSSION

The moisture content in nutmeg and mace is determined, drying characteristics of nutmeg and mace are studied and the drying curves are plotted.

### 4.1. Moisture Content

Table 4.1: Percentage Moisture content

| Sl.no | Sample | Initial weight of sample (g) | Final weight of sample (g) | Moisture content (%) | Dry matter Content (%) |
|---|---|---|---|---|---|
| 1 | Nutmeg | 5 | 3 | 40 | 60 |
| 2 | Mace | 2 | 0.86 | 57 | 43 |

The moisture content of nutmeg is found to be 40% and that of mace is 57%. In record fresh mace and nutmeg have moisture content ranging between 40-80

Figure 3. Dried nutmeg and dried mace

## 4.2. Drying Characteristics

The amount of moisture, moisture content in wet basis, moisture content in dry basis, moisture ratio and drying rate at 50°C, 55°C ,60°C in 10 minutes time interval are obtained. The relationship between drying rate, moisture content and drying time are understood from drying curves.

### 4.2.1. Drying Characteristics of Mace at 50°c

Table 3. Drying of sample 1 at 50°C

| Sl No: | Time interval | Weight of sample | Amount of water | Moisture content in wet basis | Moisture content in dry basis | Moisture ratio | Drying rate |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 2 | 1.14 | 0.57 | 1.325581395 | | |
| 2 | 10 | 1.88 | 1.02 | 0.51 | 1.186046512 | 0.894737 | 0.013953 |
| 3 | 20 | 1.76 | 0.9 | 0.45 | 1.046511628 | 0.882353 | 0.006977 |
| 4 | 30 | 1.68 | 0.82 | 0.41 | 0.953488372 | 0.911111 | 0.003101 |
| 5 | 40 | 1.61 | 0.75 | 0.375 | 0.872093023 | 0.914634 | 0.002035 |
| 6 | 50 | 1.56 | 0.7 | 0.35 | 0.813953488 | 0.933333 | 0.001163 |
| 7 | 60 | 1.5 | 0.64 | 0.32 | 0.744186047 | 0.914286 | 0.001163 |
| 8 | 70 | 1.46 | 0.6 | 0.3 | 0.697674419 | 0.9375 | 0.000664 |
| 9 | 80 | 1.4 | 0.54 | 0.27 | 0.627906977 | 0.9 | 0.000872 |
| 10 | 90 | 1.37 | 0.51 | 0.255 | 0.593023256 | 0.944444 | 0.000388 |
| 11 | 100 | 1.35 | 0.49 | 0.245 | 0.569767442 | 0.960784 | 0.000233 |
| 12 | 110 | 1.33 | 0.47 | 0.235 | 0.546511628 | 0.959184 | 0.000211 |
| 13 | 120 | 1.32 | 0.46 | 0.23 | 0.534883721 | 0.978723 | 9.69E-05 |
| 14 | 130 | 1.32 | 0.46 | 0.23 | 0.534883721 | 1 | 0 |

Table 4. Drying of sample 2 at 50°C

| Sl No: | Time interval | Weight of sample | Amount of water | Moisture content in wet basis | Moisture content in dry basis | Moisture ratio | Drying rate |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 2 | 1.14 | 0.57 | 1.325581395 | | |
| 2 | 10 | 1.86 | 1 | 0.5 | 1.162790698 | 0.877193 | 0.016279 |
| 3 | 20 | 1.75 | 0.89 | 0.445 | 1.034883721 | 0.89 | 0.006395 |
| 4 | 30 | 1.66 | 0.8 | 0.4 | 0.930232558 | 0.898876 | 0.003488 |
| 5 | 40 | 1.57 | 0.71 | 0.355 | 0.825581395 | 0.8875 | 0.002616 |
| 6 | 50 | 1.49 | 0.63 | 0.315 | 0.73255814 | 0.887324 | 0.00186 |
| 7 | 60 | 1.42 | 0.56 | 0.28 | 0.651162791 | 0.888889 | 0.001357 |
| 8 | 70 | 1.37 | 0.51 | 0.255 | 0.593023256 | 0.910714 | 0.000831 |
| 9 | 80 | 1.34 | 0.48 | 0.24 | 0.558139535 | 0.941176 | 0.000436 |
| 10 | 90 | 1.31 | 0.45 | 0.225 | 0.523255814 | 0.9375 | 0.000388 |
| 11 | 100 | 1.3 | 0.44 | 0.22 | 0.511627907 | 0.977778 | 0.000116 |
| 12 | 110 | 1.29 | 0.43 | 0.215 | 0.5 | 0.977273 | 0.000106 |
| 13 | 120 | 1.28 | 0.42 | 0.21 | 0.488372093 | 0.976744 | 9.69E-05 |
| 14 | 130 | 1.28 | 0.42 | 0.21 | 0.488372093 | 1 | 0 |

Table 5. Drying of sample 3 at $50^0$C

| Sl No: | Time interval | Weight of sample | Amount of water | Moisture content in dry basis | Moisture content in wet basis | Moisture ratio | Drying rate |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 2 | 1.14 | 1.325581 | 0.57 | | |
| 2 | 10 | 1.85 | 0.99 | 1.151163 | 0.495 | 0.868421 | 0.017442 |
| 3 | 20 | 1.76 | 0.9 | 1.046512 | 0.45 | 0.909091 | 0.005233 |
| 4 | 30 | 1.67 | 0.81 | 0.94186 | 0.405 | 0.9 | 0.003488 |
| 5 | 40 | 1.59 | 0.73 | 0.848837 | 0.365 | 0.901235 | 0.002326 |
| 6 | 50 | 1.5 | 0.64 | 0.744186 | 0.32 | 0.876712 | 0.002093 |
| 7 | 60 | 1.43 | 0.57 | 0.662791 | 0.285 | 0.890625 | 0.001357 |
| 8 | 70 | 1.36 | 0.5 | 0.581395 | 0.25 | 0.877193 | 0.001163 |
| 9 | 80 | 1.33 | 0.47 | 0.546512 | 0.235 | 0.94 | 0.000436 |
| 10 | 90 | 1.31 | 0.45 | 0.523256 | 0.225 | 0.957447 | 0.000258 |
| 11 | 100 | 1.3 | 0.44 | 0.511628 | 0.22 | 0.977778 | 0.000116 |
| 12 | 110 | 1.29 | 0.43 | 0.5 | 0.215 | 0.977273 | 0.000106 |
| 13 | 120 | 1.28 | 0.42 | 0.488372 | 0.21 | 0.976744 | 9.69E-05 |
| 14 | 130 | 1.28 | 0.42 | 0.488372 | 0.21 | 1 | 0 |

The following curves are obtained.

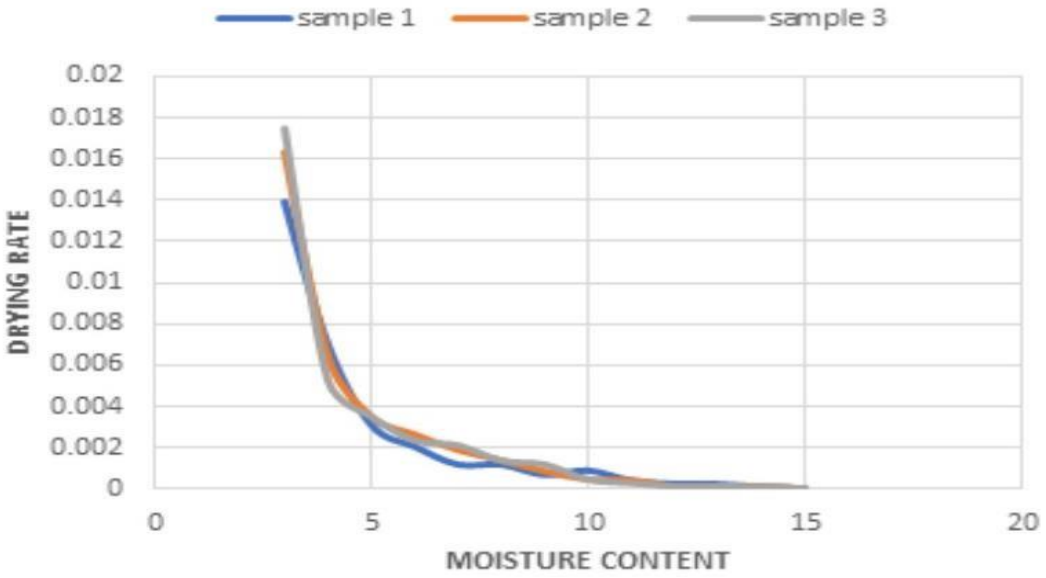


Figure 4. Relationship between drying rate and drying time at 50ºC

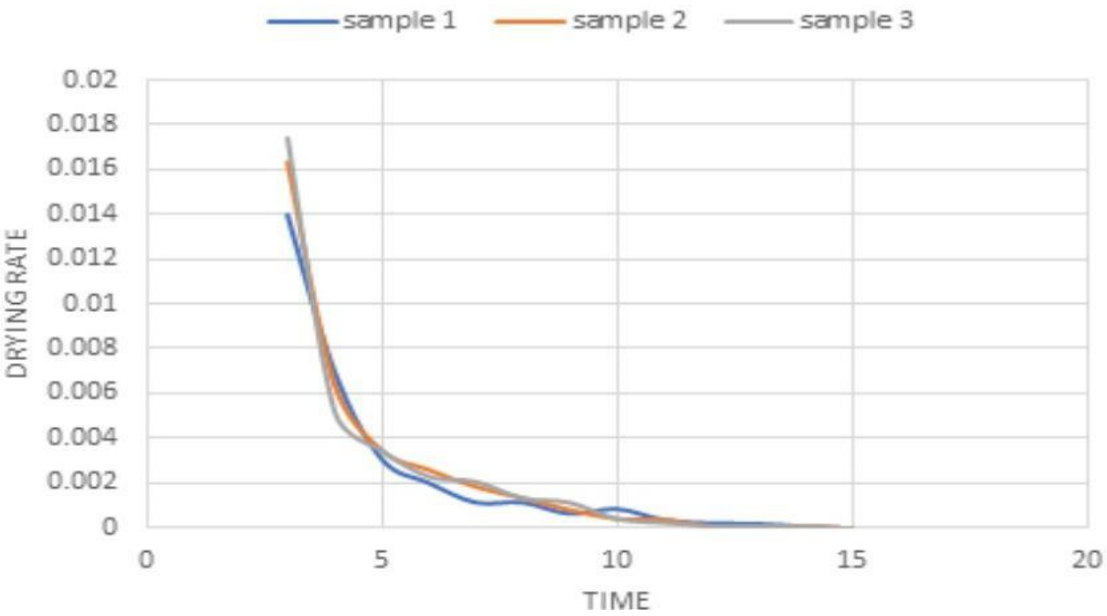


Figure 5. Relationship between drying rate and moisture content

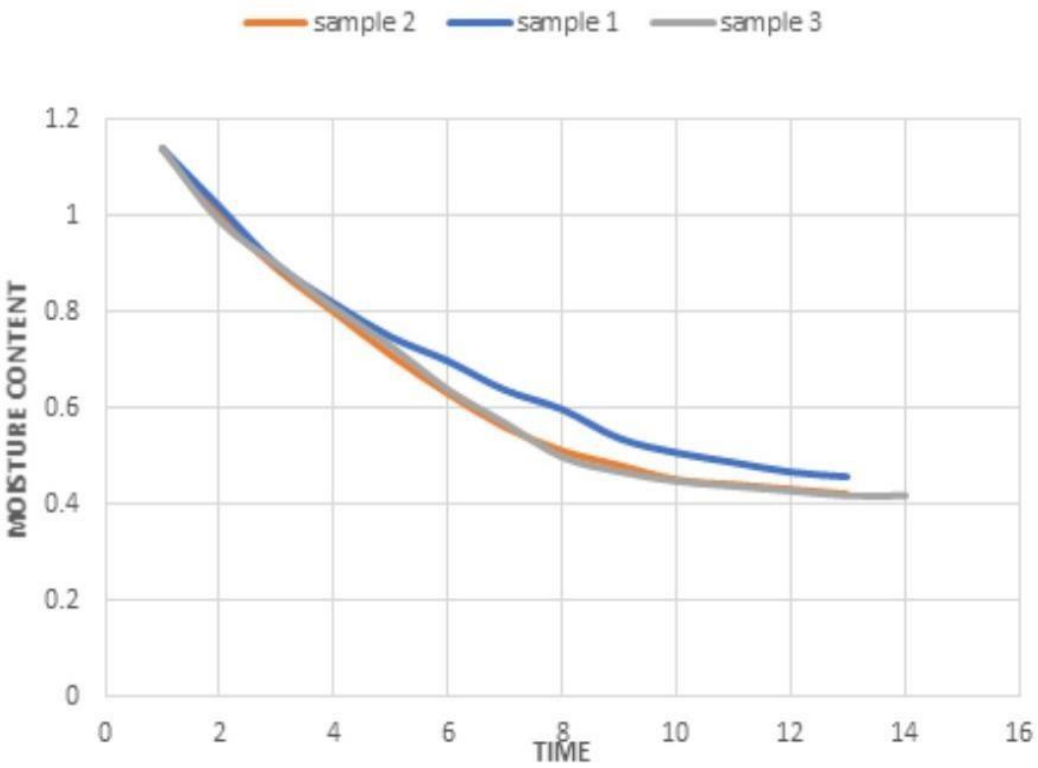


Figure 6. Relationship between moisture content and time

### 4.2.2. Drying Characteristics of Mace at 55°c

Table 6. Drying of sample 1 at 55 °C

| Sl No: | Time intervel | Weight of sample | Amount of water | Moisture content in wet basis | Moisture content in dry basis | Moisture ratio | Drying rate |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 2 | 1.14 | 0.57 | 1.325581 | | |
| 2 | 10 | 1.82 | 0.96 | 0.48 | 1.116279 | 0.842105 | 0.02093 |
| 3 | 20 | 1.61 | 0.75 | 0.375 | 0.872093 | 0.78125 | 0.012209 |
| 4 | 30 | 1.5 | 0.64 | 0.32 | 0.744186 | 0.853333 | 0.004264 |
| 5 | 40 | 1.41 | 0.55 | 0.275 | 0.639535 | 0.859375 | 0.002616 |
| 6 | 50 | 1.34 | 0.48 | 0.24 | 0.55814 | 0.872727 | 0.001628 |
| 7 | 60 | 1.27 | 0.41 | 0.205 | 0.476744 | 0.854167 | 0.001357 |
| 8 | 70 | 1.2 | 0.34 | 0.17 | 0.395349 | 0.829268 | 0.001163 |
| 9 | 80 | 1.17 | 0.31 | 0.155 | 0.360465 | 0.911765 | 0.000436 |
| 10 | 90 | 1.15 | 0.29 | 0.145 | 0.337209 | 0.935484 | 0.000258 |
| 11 | 100 | 1.14 | 0.28 | 0.14 | 0.325581 | 0.965517 | 0.000116 |
| 12 | 110 | 1.14 | 0.28 | 0.14 | 0.325581 | 1 | 0 |

Table 7. Drying of sample 2 at 55 $^0$C

| Sl No: | Time intervel | Weight of sample | Amount of water | Moisture content in wet basis | Moisture content in dry basis | Moisture ratio | Drying rate |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 2 | 1.14 | 0.57 | 1.325581 | | |
| 2 | 10 | 1.82 | 0.96 | 0.48 | 1.116279 | 0.842105 | 0.02093 |
| 3 | 20 | 1.59 | 0.73 | 0.365 | 0.848837 | 0.760417 | 0.013372 |
| 4 | 30 | 1.44 | 0.58 | 0.29 | 0.674419 | 0.794521 | 0.005814 |
| 5 | 40 | 1.37 | 0.51 | 0.255 | 0.593023 | 0.87931 | 0.002035 |
| 6 | 50 | 1.33 | 0.47 | 0.235 | 0.546512 | 0.921569 | 0.00093 |
| 7 | 60 | 1.28 | 0.42 | 0.21 | 0.488372 | 0.893617 | 0.000969 |
| 8 | 70 | 1.25 | 0.39 | 0.195 | 0.453488 | 0.928571 | 0.000498 |
| 9 | 80 | 1.22 | 0.36 | 0.18 | 0.418605 | 0.923077 | 0.000436 |
| 10 | 90 | 1.2 | 0.34 | 0.17 | 0.395349 | 0.944444 | 0.000258 |
| 11 | 100 | 1.19 | 0.33 | 0.165 | 0.383721 | 0.970588 | 0.000116 |
| 12 | 110 | 1.19 | 0.33 | 0.165 | 0.383721 | 1 | 0 |

Table 8. Drying of sample 3 at 55 $^0$C

| Sl No: | Time intervel | Weight of sample | Amount of water | Moisture content in wet basis | Moisture content in dry basis | Moisture ratio | Drying rate |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 2 | 1.14 | 0.57 | 1.325581 | | |
| 2 | 10 | 1.8 | 0.94 | 0.47 | 1.093023 | 0.824561 | 0.023256 |
| 3 | 20 | 1.63 | 0.77 | 0.385 | 0.895349 | 0.819149 | 0.009884 |
| 4 | 30 | 1.53 | 0.67 | 0.335 | 0.77907 | 0.87013 | 0.003876 |
| 5 | 40 | 1.43 | 0.57 | 0.285 | 0.662791 | 0.850746 | 0.002907 |
| 6 | 50 | 1.31 | 0.45 | 0.225 | 0.523256 | 0.789474 | 0.002791 |
| 7 | 60 | 1.29 | 0.43 | 0.215 | 0.5 | 0.955556 | 0.000388 |
| 8 | 70 | 1.28 | 0.42 | 0.21 | 0.488372 | 0.976744 | 0.000166 |
| 9 | 80 | 1.26 | 0.4 | 0.2 | 0.465116 | 0.952381 | 0.000291 |
| 10 | 90 | 1.24 | 0.38 | 0.19 | 0.44186 | 0.95 | 0.000258 |
| 11 | 100 | 1.23 | 0.37 | 0.185 | 0.430233 | 0.973684 | 0.000116 |
| 12 | 110 | 1.23 | 0.37 | 0.185 | 0.430233 | 1 | 0 |

The following curves are obtained

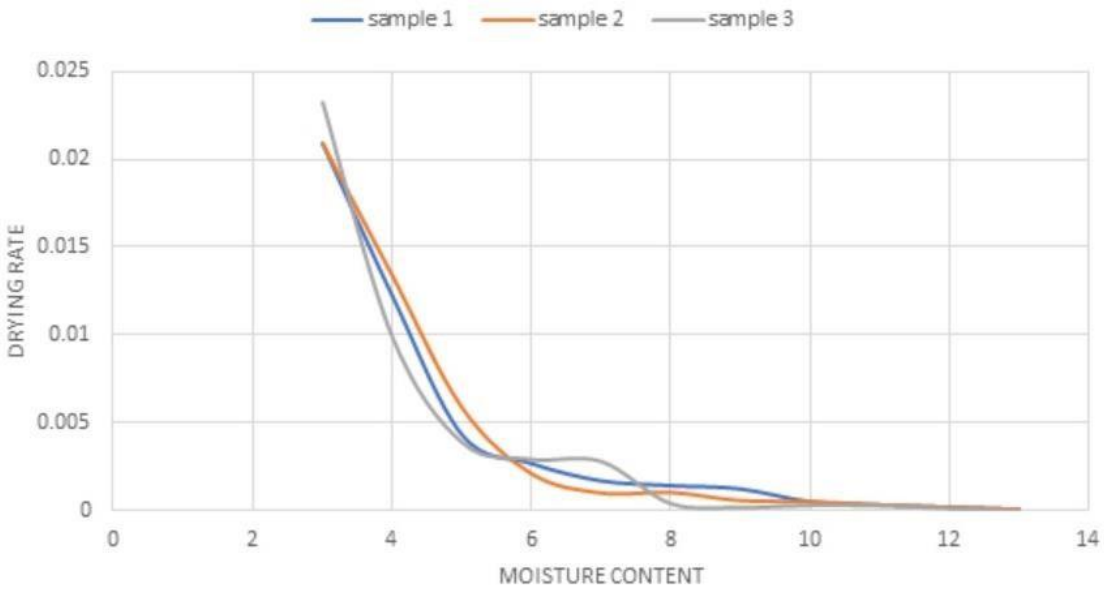


Figure 7. Relationship between drying rate and drying time

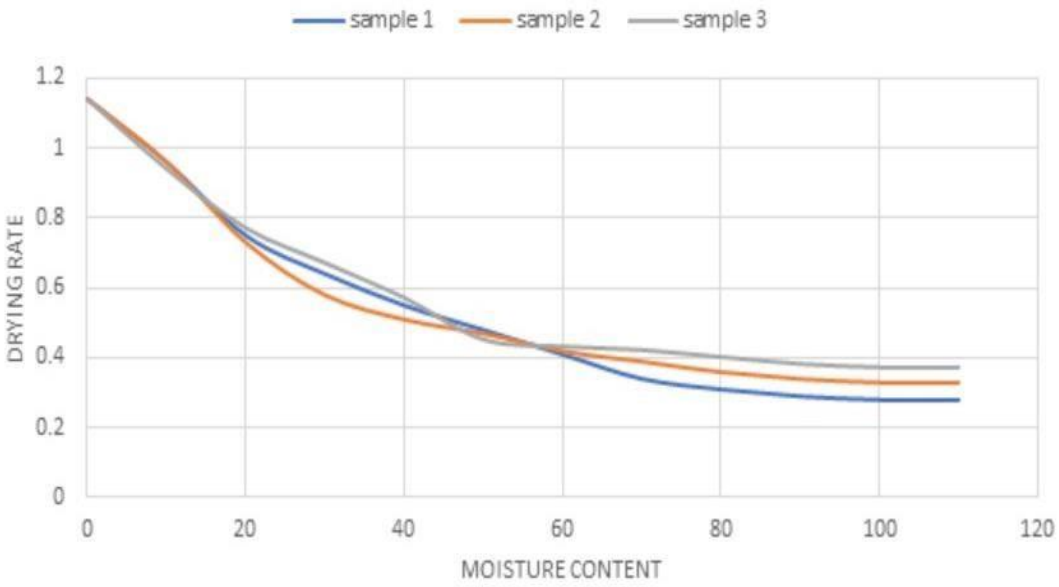


Figure 8. Relationship between drying rate and moisture content

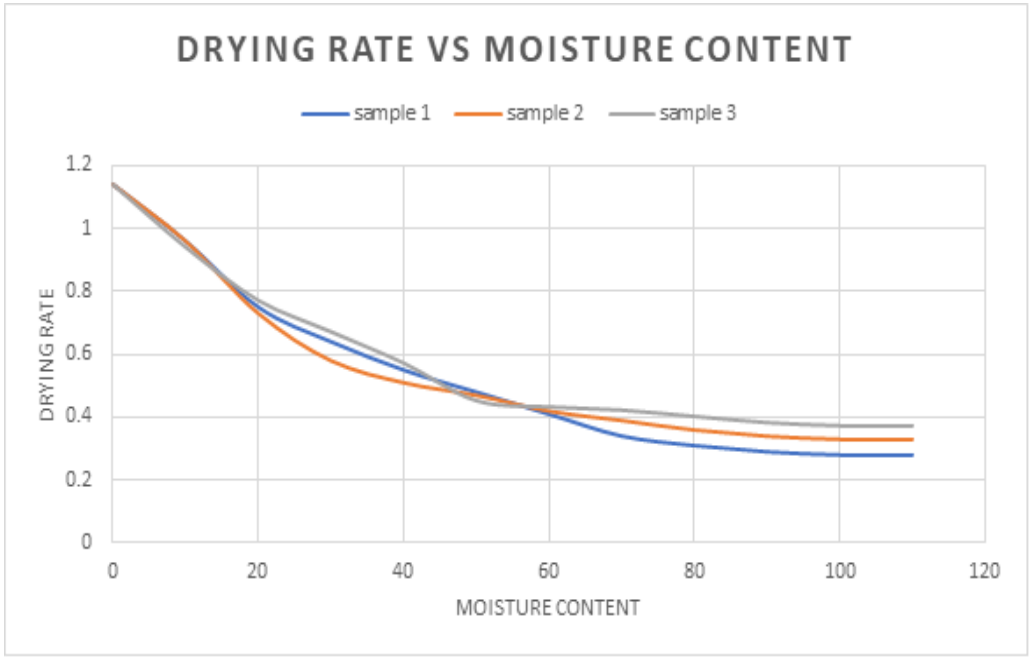


Figure 9. Relationship between drying rate and moisture content

### 4.2.3. Drying Characteristics of Mace at 55°c

Table 9. Drying of sample 1 at 60 °C

| Sl No: | Time intervel | Weight of sample | Amount of water | Moisture content in wet basis | Moisture content in dry basis | Moisture ratio | Drying rate |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 2 | 1.14 | 0.57 | 1.325581 | | |
| 2 | 10 | 1.46 | 0.6 | 0.3 | 0.697674 | 0.526316 | 0.062791 |
| 3 | 20 | 1.36 | 0.5 | 0.25 | 0.581395 | 0.833333 | 0.005814 |
| 4 | 30 | 1.27 | 0.41 | 0.205 | 0.476744 | 0.82 | 0.003488 |
| 5 | 40 | 1.22 | 0.36 | 0.18 | 0.418605 | 0.878049 | 0.001453 |
| 6 | 50 | 1.18 | 0.32 | 0.16 | 0.372093 | 0.888889 | 0.00093 |
| 7 | 60 | 1.15 | 0.29 | 0.145 | 0.337209 | 0.90625 | 0.000581 |
| 8 | 70 | 1.12 | 0.26 | 0.13 | 0.302326 | 0.896552 | 0.000498 |
| 9 | 80 | 1.1 | 0.24 | 0.12 | 0.27907 | 0.923077 | 0.000291 |
| 10 | 90 | 1.09 | 0.23 | 0.115 | 0.267442 | 0.958333 | 0.000129 |
| 11 | 100 | 1.09 | 0.23 | 0.115 | 0.267442 | 1 | 0 |

Table 10. Drying of sample 2 at $60^0$C

| Sl No: | Time intervel | Weight of sample | Amount of water | Moisture content in wet basis | Moisture content in dry basis | Moisture ratio | Drying rate |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 2 | 1.14 | 0.57 | 1.325581 | | |
| 2 | 10 | 1.53 | 0.67 | 0.335 | 0.77907 | 0.587719 | 0.054651 |
| 3 | 20 | 1.44 | 0.58 | 0.29 | 0.674419 | 0.865672 | 0.005233 |
| 4 | 30 | 1.37 | 0.51 | 0.255 | 0.593023 | 0.87931 | 0.002713 |
| 5 | 40 | 1.3 | 0.44 | 0.22 | 0.511628 | 0.862745 | 0.002035 |
| 6 | 50 | 1.25 | 0.39 | 0.195 | 0.453488 | 0.886364 | 0.001163 |
| 7 | 60 | 1.17 | 0.31 | 0.155 | 0.360465 | 0.794872 | 0.00155 |
| 8 | 70 | 1.15 | 0.29 | 0.145 | 0.337209 | 0.935484 | 0.000332 |
| 9 | 80 | 1.13 | 0.27 | 0.135 | 0.313953 | 0.931034 | 0.000291 |
| 10 | 90 | 1.12 | 0.26 | 0.13 | 0.302326 | 0.962963 | 0.000129 |
| 11 | 100 | 1.1 | 0.24 | 0.12 | 0.27907 | 0.923077 | 0.000233 |
| 12 | 110 | 1.1 | 0.24 | 0.12 | 0.27907 | 1 | 0 |

Table 11. Drying of sample 3 at 60 $^0$C

| Sl No: | Time intervel | Weight of sample | Amount of water | Moisture content in wet basis | Moisture content in dry basis | Moisture ratio | Drying rate |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 2 | 1.14 | 0.57 | 1.325581 | | |
| 2 | 10 | 1.61 | 0.75 | 0.375 | 0.872093 | 0.657895 | 0.045349 |
| 3 | 20 | 1.48 | 0.62 | 0.31 | 0.72093 | 0.826667 | 0.007558 |
| 4 | 30 | 1.37 | 0.51 | 0.255 | 0.593023 | 0.822581 | 0.004264 |
| 5 | 40 | 1.33 | 0.47 | 0.235 | 0.546512 | 0.921569 | 0.001163 |
| 6 | 50 | 1.26 | 0.4 | 0.2 | 0.465116 | 0.851064 | 0.001628 |
| 7 | 60 | 1.22 | 0.36 | 0.18 | 0.418605 | 0.9 | 0.000775 |
| 8 | 70 | 1.2 | 0.34 | 0.17 | 0.395349 | 0.944444 | 0.000332 |
| 9 | 80 | 1.18 | 0.32 | 0.16 | 0.372093 | 0.941176 | 0.000291 |
| 10 | 90 | 1.17 | 0.31 | 0.155 | 0.360465 | 0.96875 | 0.000129 |
| 11 | 100 | 1.17 | 0.31 | 0.155 | 0.360465 | 1 | 0 |

The following curves are obtained.

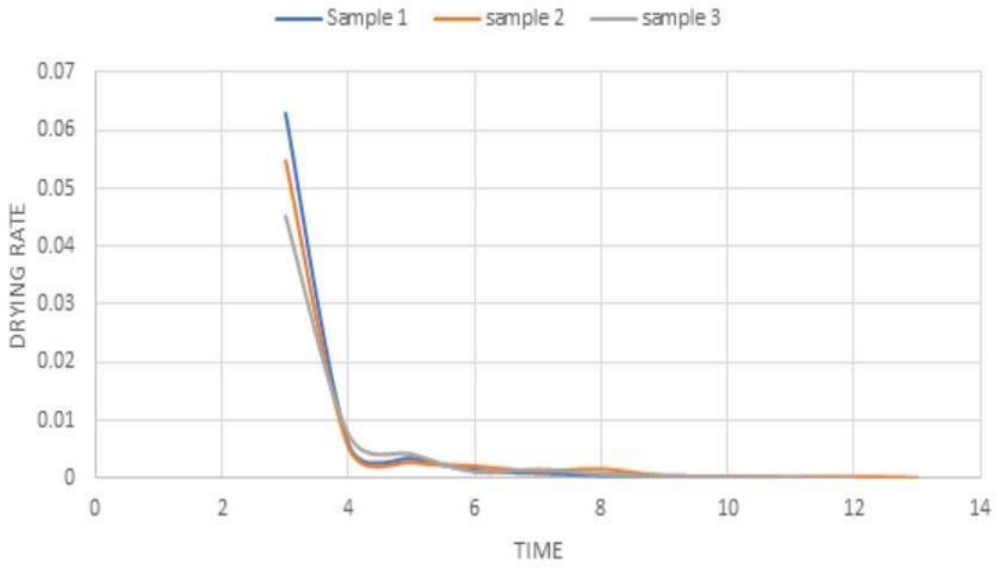


Figure 10. Relationship between drying rate and time

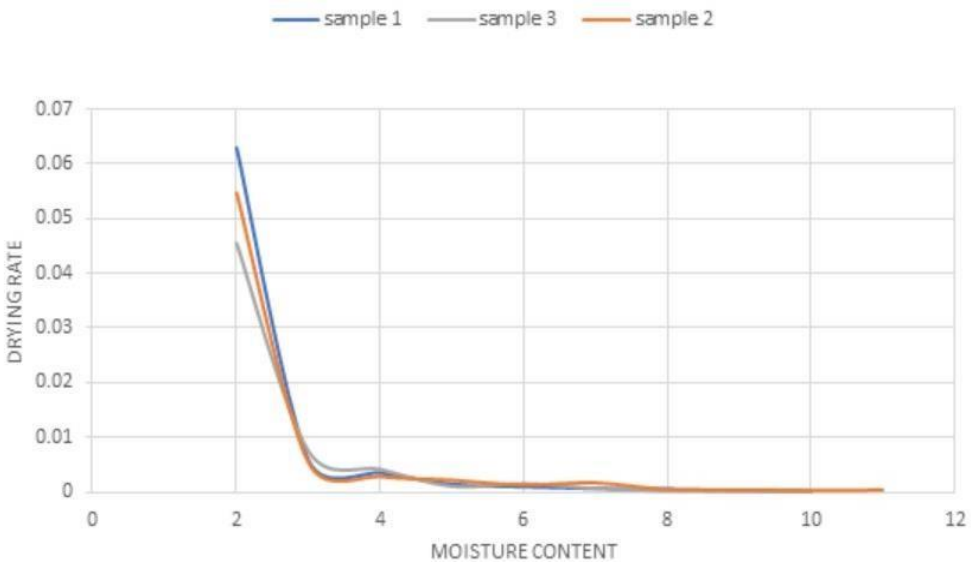


Figure 11. Relationship between drying rate and moisture content

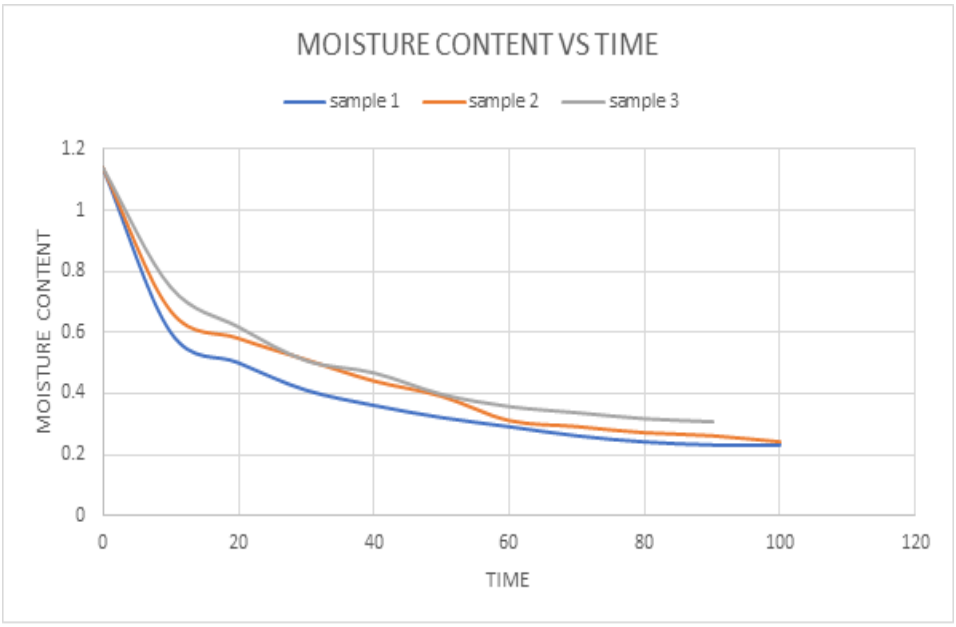


Figure 12. Relationship between moisture content and time

## 5. CONCLUSION

The above graphs show drying at 60 degrees Celsius. These graphs shows that when drying time increases moisture content also decreases. The second graph is the relationship between drying rate vs moisture content which shows a decrease in moisture content when drying rate increases. The third graph shows drying rate increases with time. At 50 degree it took 130 min. Similarly, 110 and 100 minutes for 55 and 60 degrees Celsius respectively. During drying, the initial scarlet red colour of mace was changed to light red to reddish brown colour. The mace become brittle with reduced thickness and crispier nature. The mold growth is reduced. The crispness is retained for many days. The aroma has become more intense after drying. Nutmeg gets hardened and

colour changes from cream yellow to darkened brown. No identifiable change in aroma and texture is observed.

In products with a relatively high beginning moisture content, an initial linear reduction of the average product moisture content as a function of time may be observed for a limited time, which is sometimes referred to as a "constant drying rate phase." Typically, surface moisture outside individual particles is removed during this time period. During this time, the drying rate is largely determined by the rate of heat transmission to the substance being dried. As a result, the highest attainable drying rate is believed to be heat-transfer limited. If drying is sustained, the slope of the curve, or the drying rate, gets less steep (falling rate period) and eventually goes to almost horizontal at very long times. The product moisture content is then constant at the "equilibrium moisture content," where it is, in practise, in equilibrium with the dehydrating medium. During the falling-rate period, water migrates from the product's inside to the surface.

Mace and nutmeg are spices of great importance. Drying is an inevitable method of preservation of nutmeg and mace. Mechanical drying method is preferred rather than traditional methods. The moisture content of nutmeg was found to be 60% and that of mace as 57%. The rate of moisture content is found to decreased with increase in drying rate. The drying rate decreases with time since moisture content get reduced with drying time. The drying curves described these findings. On drying sensory and organoleptic properties are changed. The mould growth is found less in the dried samples. The drying characteristics can be applied in process design of nutmeg and mace processing

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## AUTHORS

**Mr Roopaljith KM** is a Btech Food Technology Graduate from TKM Institute of Technology Kollam, Kerala, India who is now the District resource Person at Kannur under the Prime Minister's Formalisation of Micro Enterprises Scheme

**Vignesh CP** is a BTech Food Technology Graduate from TKM Institute of Technology Kollam, Kerala, His research interests are food additives, bio colours, sustainable packaging, food spoilage etc