CARIBBEAN FOOD CROPS SOCIETY

30

THIRTIETH ANNUAL MEETING 1994

ST. THOMAS, U.S.V.I.

Vol. XXX

DRYING OF THE DASHEEN LEAF

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ABSTRACT

The drying behavior of the dasheen leaf under natural convection conditions at temperatures ranging from 40-70°C was studied in an attempt to develop a dehydrated product from this popular vegetable often used in soups and commonly called - 'callaloo.' The effects of various pretreatments on the drying behavioral of the vegetable at 60°C were also studied, viz. steam blanching (96°C for 6 min.), water blanching (near boiling for 10s) and blanching in 0.06% magnesium carbonate at near boiling for 10 s prior to immersion in a mixed chemical bath consisting mainly of 20% sucrose, for 4 h at 21°C. Two falling rate periods of drying were observed for dasheen leaves dried at 40-70°C. However, a single falling rate period of drying was found for the water and magnesium carbonate blanched-infused vegetable at 60°C. Although drying rates markedly increased with increasing drying temperature, drying at high temperatures particularly at 60°C and 70°C resulted in a deleterious color change from green, typical of the fresh vegetable, to an unattractive olive-brown or brown discoloration. Steam blanching appeared to have no significant effect on the drying rate of the dasheen leaf compared to fresh leaves while for the water blanched vegetable, the drying rate was reduced by 50%. Compared to water blanching, alkali blanching was found to have no significant effect on the drying rate of the dasheen leaf. Blanching in water or alkali resulted in a superior dehydrated product which, unlike the steam blanched vegetable, showed minimal loss of green color.

INTRODUCTION

The dasheen (*Colocasia esculenta* Linn Schott var *esculenta*)is a herbaceous, tuberous perennial with distinctively large leaves. It is cultivated extensively in tropical countries like Trinidad and Tobago, for both the tender leaves and the tubers. Commonly referred to as "dasheen bush" or "callaloo bush" in Trinidad and Tobago, or "taro" by the English, this leafy vegetable has considerable export market potential to immigrant West Indian populations in U.S.A., Canada and Europe (Harvey, 1986). The fresh vegetable is currently exported from Trinidad and Tobago to New York and London. Dasheen leaves however, like all leafy horticultural commodities have high transpiration rates due to their large surface area to volume ratio and thus wilt rapidly under ambient conditions. Consequently, leaf senescence and the attendant decline in post harvest quality e.g. loss of green color and loss of nutritional value is accelerated (Lazan et al., 1987). As a result, the fresh vegetable must be air freighted immediately after harvest.

A possible alternative to the export of the fresh vegetable is the export of a dehydrated product which can be used like spinach in soups, casseroles etc. Dehydration, a simple method of preserving foods to extend their period of availability, has the added advantage of making handling, storage and distribution less difficult and more economical because of reduction in weight and bulk.

There is considerable information on the drying of similar foliaceous type materials. Chen and Johnson (1969) reported the absence of a constant rate period of drying when tobacco laminae was dried at temperatures ranging from 30-50°C. Menzies and O'Callaghan (1971) in their study on the effect of drying temperature on the drying behavior of high moisture grass noted: (i) the "constant rate" period of drying occurred above 200°C and (ii) below 200°C, drying took place in the "falling rate" period essentially through the diffusion mechanism. Below 80°C, up to 3 distinct periods of falling rate drying was found.

For drying in the falling rate period, where the mechanism of moisture removal within the vegetable to the surface is by a diffusional process, the exponential relationship normally used to describe the drying behavior of similar biological materials (Menzies and O'Callaghan, 1971; Rotz and Chen, 1985), is of the form:

$$(m - me)/(mo - me) = Ae^{-kt} \qquad (1)$$

or in the logarithmic form

$$\ln[(m - me)/(mo - me)] = \ln A - kt \qquad (2)$$

where

m	=	variable moisture content, % dry basis
me	=	equilibrium moisture content, % dry basis
mo	=	initial moisture content, % dry basis
k	=	drying constant, h^{-1}
t	=	drying time, h
A	=	constant

Loss of green color and other quality changes, eg loss of Vitamin C (ascorbic acid) are reported to occur during the dehydration of green commodities (Morgan et al., 1945; Weits et al., 1970; Ranganath and Dubash, 1981). The principal degradatory pathway of chlorophyll in the dehydration of green vegetables is the replacement of its magnesium atom by hydrogen and the consequent formation of olive-brown pheophytins (MacKinney and Weast, 1940; Clydesdale et al., 1970; Davidek et al., 1990). The necessity of blanching vegetables prior to dehydration has been recognized since 1929 (Dietrich et al., 1955). MacKinney and Weast (1940) and von Loesecke (1955) stated that blanching was necessary to prevent the formation of off-flavors, odors and colors. Peroxidase activity is widely used as an index of blanching as it is the most heat stable enzyme found in vegetables. Blanching however, is reported to result in some degree of chlorophyll degradation with the subsequent formation of pheophytin. The extent of chlorophyll conversion being related to the degree of blanching (MacKinney and Weast, 1940; Dutton et al., 1943; Lee 1958). Loss of ascorbic acid is also claimed to occur during the blanching process (Farrell and Fellers, 1942; Kincal and Giray, 1987). Considerable effort has been aimed at stabilizing the color of green vegetables during thermal processing. The most widely reported method for the prevention of pheophytin formation is the addition of alkalizing agents e.g. magnesium carbonate (Lioutas, 1989).

The objectives of this study were:

(1) To determine the drying characteristics and quality of dasheen leaves at air drying temperatures of 40, 50, 60 and 70°C.

(2) To determine the drying characteristics and quality of dasheen leaves at 60°C after blanching in steam, water and alkali-infusion.

MATERIALS AND METHODS

Experimental Design

A. Approximately 20 kg of the fresh, green vegetable was obtained from farmers' holdings situated in Central Trinidad. The harvested vegetable was washed, destalked and chopped using a Chuo Boeki Goshi Kaisha Forage Cutter Model No. FC13B at a speed of 850 r.p.m. The vegetable pieces were kept in a sealed polyethylene bag at 10°C until required. 400 g of the chopped vegetable was placed to a depth of 0.034 m in a wire meshed tray (0.38 by 0.4 m) in dimensions and dried to constant weight at 40°C in a natural convection oven (Blue M Stabil Therm Gravity Oven). At hourly intervals except during the night , the tray was removed, quickly weighed and drying continued until there was virtually no change in weight. The drying was repeated using 400 g samples of the chopped vegetable at temperatures of 50, 60 and 70°C.

B. The effect of various pre-drying treatments on the drying behavior and quality of dasheen leaves at 60°C was also investigated. Pre-drying treatments investigated were steam and water blanching, and blanching in alkali followed by infusion in a chemical bath of which the main constituent was sucrose. The blanch times used were sufficient to inactivate the enzymeperoxidase. The shortest blanch time for each method was pre-determined by the peroxidase test outlined by Greensmith (1971). The untreated vegetable served as a con trol.

Steam blanching

400 g of chopped dasheen leaves was blanched in steam at 96°C, 100 psi for 6 min, and cooled under ambient conditions (28°C). 326 g was placed in a gravity oven at 60°C for evaluation of its drying characteristics.

Water blanching

400 g chopped dasheen leaves was immersed in water at 100°C for 10 sec, cooled and allowed to drain for 2 min. 326 g was placed in a gravity oven at 60°C for examination of the drying behavior of the water blanched vegetable.

Chemical treatment

400 g of the chopped vegetable was blanched for 10 sec in hot water at 100°C containing 0.06% magnesium carbonate. The blanched vegetable was allowed to cool before infusion for 4 hours at 21°C in an aqueous infusion bath (5:1 ratio of bath to vegetable) comprising of sucrose - 20%, sodium chloride - 3%, potassium chloride - 0.37%, magnesium carbonate - 0.37%, disodium phosphate - 0.9%, monosodium phosphate - 0.05%, lecithin - 0.5%, tocopherol - 0.05%. After infusion the vegetable was drained and 326 g was dried at 60°C.

Control (untreated)

326 g of the chopped vegetable was placed in a gravity oven at 60°C for evaluation of its drying characteristics.

For all treatments investigated, weights were taken at half hour intervals for the first three hours of drying and as drying progressed intervals increased to one hour.

Measurements

Freshly harvested dasheen leaves as well as the dehydrated products were analyzed for ascorbic acid, chlorophyll, phoephytin, pH and moisture content. Analyses were carried out in duplicate and the resulting data analyzed by the Analysis of Variance Method (ANOVA).

Ascorbic acid in fresh and dehydrated dasheen leaves were extracted and assayed according to the 2, 6 - dichlorophenol indophenol visual titration method of Ranganna (1977). Chlorophyll and pheophytin levels were evaluated by the spectrophotometric method of Vernon (1960) modified by Berset and Caniaus (1983). For pH determination, 5 and 2 g samples of the fresh and dried (ground) vegetable respectively were blended with 40 ml of distilled water. For moisture content, 50 and 10 g samples of fresh and dehydrated dasheen leaves respectively were placed at 105 ¡C in a forced-draft oven for 16 h.

RESULTS AND DISCUSSION

Drying Characteristics of the Dasheen Leaf - Effect of temperature

Figures 1 to 3 show the drying behaviour of the dasheen leaf under natural convection conditions at air temperatures ranging from 40-70°C. A nonuniform decrease in the drying rate was observed as the air drying temperature was lowered (Figure 2). The drying curve at 40°C (Figure 1) was the least steep and spaced further apart relative to those at the other three temperatures investigated. This indicates the positive influence of increasing the temperature on the drying rate of this leafy vegetable over the temperature range 40-70°C.

Drying times markedly decreased with increasing drying temperature, near equilibrium being achieved after 56, 24, 24 and 12 h at 40, 50, 60 and 70°C respectively, with the corresponding final moisture contents of 6.2, 2.5, 3.1 and 1.9% d.b. Plots at 50 and 60°C showed near similar drying behavior and this may have been due to temperature fluctuations in the drying chamber at 50°C only.

Figure 2 shows the absence of a constant rate period of drying, an indication that the rate of moisture evaporation from the surface of the vegetable to the surrounding air was not constant and that the drying rate is internally controlled. The entire drying process for dasheen leaves under natural convection conditions as shown in the Figure, occurs exclusively in the range of the falling rate period.

Fitting the drying data to equation (2), through linear regression analyses yielded correlation coefficients (Figure 3) of the order of $0.850 < R^2 < 0.960$, indicative of a non linear trend in drying. This suggests the inadequacy of a single falling rate period or equation in describing the drying behaviour of dasheen leaves under natural convection conditions. Separation of the drying data into two distinct periods of drying yielded better fits (Figure 4). Transition times of 12.0, 6.0, 6.5 and 2.5 h with corresponding moisture contents of 220.8, 122.3, 154.8 and 320.0% d.b (wet basis range from 55.0-76.2%) were found for the vegetable at air drying temperatures of 40, 50, 60 and 70°C respectively.

Examination of Figure 4 reveals an unusual feature in the drying behaviour of the dasheen leaf. It appears that irrespective of drying temperature, drying proceeds via a relatively short initial phase which is immediately followed by a longer second period having a rate constant higher than the first period of drying i.e $k_2 > k_1$. The initial phase of drying is thought of as an initial "warm up" period and corresponds to the time required for the vegetable to attain or closely approximate the desired drying temperature upon placement in the drying chamber, at which point, the drying rate is increased. The second phase of drying can be considered as the "true" falling rate period. The temperature profiles at 50°C and 70°C (Figure 5) show considerable fluctuation during the early stages of drying i.e. before near attainment of the air dry bulb temperature by the vegetable. This was due to the accumulation of moisture within the bed and around the probe thus accounting for the aberrant drying rates observed. Clearly therefore k_2 values were higher than k_1; because the cropÕs temperature was higher in the latter period of drying.

Drying Characteristics of the Dasheen Leaf - Effect of Pre-drying Treatments

Figures 6 to 8 show the effect of various pre-drying treatments on the drying behaviour under natural convection of dasheen leaves at 60°C. Equilibrium moisture contents expressed on a dry basis were 1.2% for both the steam and water blanched vegetable, occurring after 6 and 8 h of drying respectively. For the magnesium carbonate blanched-infused and untreated (control) vegetable, equilibrium moisture contents were 1.3 and 2.5% d.b respectively occurring after 8 and 7 h of drying respectively.

As shown in Figure 7 drying occurred solely in the range of the falling rate period. Figure 8 shows a linear trend in the drying behavior of the water blanched and magnesium carbonate blanched-infused vegetable with correlation coefficients of 0.996 and 0.995 respectively suggesting that drying is characterized by a single falling rate period. The semilogarithmic plots for both the steam blanched and control (untreated) vegetable (Figure 8) yielded relatively lower correlation coefficients when the drying data was fitted to equation 2. As shown in Figure 9, separation of the data into two periods of drying at transition times of 1.8 and 1.6 h corresponding to critical moisture contents of 200.5 and 201.2 % d.b for the control (untreated) and steam blanched vegetable respectively resulted in good fits. As observed for the fresh vegetable dried at temperatures ranging from 40-70°C, k_2 the rate constant for the second phase of drying was found to be greater than k_1, the rate constant for the first period of drying for both the control (untreated) and steam blanched dehydrated vegetable. The absence of two falling rate periods of drying for water and magnesium carbonate blanched-infused dasheen leaves is probably due to structural changes occurring during heat processing. Dasheen leaves appearing soggy and very soft subsequent to blanching in water and magnesium carbonate. Under these conditions moisture movement during drying may be occurring through capillary action rather than diffusion.

Steam blanching appears to have no significant effect on the rate of moisture removal from the dasheen leaf when compared to the control (untreated) vegetable as differences in drying rates were marginal. As shown in Figure 9, k_1 for the steam blanched and untreated vegetable were 0.562 and 0.550 h^{-1} respectively with corresponding k_2 values of 1.967 and 1.528 h^{-1}.

Both the water blanched and alkali blanched-infused vegetable showed a 50% reduction in drying rate when compared to the control (untreated) dried vegetable. Unlike the steam blanched sample which showed a negligible change in moisture content subsequent to blanching, the moisture content of the vegetable approximately doubled after water blanching probably accounting for the net reduced drying rate observed. Differences in drying rates between the magnesium carbonate blanched-infused vegetable and the untreated (control) may be ascribed to the increased total soluble solids content which tripled following infusion.

Quality Evaluation of Dehydrated Dasheen Leaf - Effect of Temperature

Ascorbic acid

The ascorbic acid (vitamin C) content in fresh and dehydrated dasheen leaves is shown in Table 1. The data represents mean values from two observations. A considerable decline from an initial value of 494 mg/100g DM ($P < 0.001$) for the green, freshly harvested vegetable occurred during the drying process, losses ranging from 91.6-93.9% for the vegetable at air drying temperatures of 40-70°C. As shown in Table 1, changes in drying temperature did not markedly influence ascorbic acid losses. This suggests that drying to near equilibrium at the temperatures investigated was sufficient to bring about an almost complete destruction of the vitamin.

Color, pigment and pH changes

Dramatic visual changes in color from green, typical of freshly harvested dasheen leaves to olive-green and olive-brown occurred as the air drying temperature increased from 40-70 °C. Such undesirable color changes reflect the marked reduction in the chlorophyll content ($P < 0.001$), the pigment responsible for the characteristic green color of the vegetable, from an initial value of 1262 mg/100g DM with increasing drying temperature (Table 1).

Concomitant with the acceleration in chlorophyll degradation, an increase ($P < 0.01$) in pheophytin content was observed with increasing drying temperature (Table 1). There was also a significant decline in pH ($P < 0.001$) from 6.4 for fresh, green dasheen leaves. Chlorophyll and pheophytin contents of the vegetable dried at 40°C to a moisture content of 6.2% d.b, were 953 and 232 mg/100g DM respectively. The dehydrated vegetable, with a pH of 5.8, appeared olive-green showing very little signs of browning. For the vegetable dried at 70°C however, a marked increase in acidity (pH of 4.7) was noted, and loss in green color was severe, reflected by a retention of only 2.8% of its initial chlorophyll content. These deteriorative changes were paralleled by extensive browning of the dried product, consistent with an increase in pheophytin content to 813 mg/100g DM.

The results of this study are supported by the works of Sweeney and Martin (1961), Hudson et al. (1974) and Lioutas (1989) who found that chlorophyll is converted to pheophytin at acidic pH's. The negative correlation observed between chlorophyll and pheophytin concentrations, which increased progressively with air drying temperature is ascribed not only to increased acid formation but also increased susceptibility of chlorophyll to acid action (Meyer, 1960; Davidek et al., 1990).

Quality Evaluation of Dehydrated Dasheen Leaf - Effect of Pre-drying Treatments

Ascorbic acid

Irrespective of pre-drying treatments, a significant decline ($P < 0.001$) in the ascorbic acid content from an initial value of 581 mg/100g DM was found for dasheen leaves dried at 60¡C (Table 2). The ascorbic acid content of control (untreated) dehydrated dasheen leaves was 66 mg/100g DM, representing a severe loss of 89% of its initial vitamin content due to thermal and possibly enzymic degradation. The effects of blanching in magnesium carbonate followed by infusion in a bath comprising mainly of 20% sucrose on the ascorbic acid content of the dehydrated vegetable was more pronounced, resulting in a substantial loss of 98%. This is attributable to the combined effects of thermal degradation and leaching during blanching and osmosis (Farrel and Fellers, 1942; Morgan et al., 1945; Islam and Flink, 1982).

Blanching in steam and water prior to dehydration resulted in ascorbic acid contents of 22 and 45 mg/100g DM respectively . The results of this study highlight the severity of the heat treatment employed in steam blanching i.e 98°C for 6 mins compared to the quick blanch (10 secs at 100°C) used in water blanching, which, though adequate for the inactivation of enzymes, adversely affected the ascorbic acid content of the vegetable. Disruption of cells, claimed to occur during steam blanching, is reported to enhance loss of ascorbic acid (Philippon, 1985).

Color, pigment and pH changes

The pre-drying treatments investigated greatly affected the pH of the dehydrated vegetable, which in turn, directly influenced color and hence pigment (chlorophyll and pheophytin) concentrations (Table 2). Untreated dehydrated dasheen leaves declined significantly in pH ($P < 0.001$) from 6.3 for the fresh, green vegetable to 5.8. The dehydrated vegetable, dull green to olive-brown in color and with a pheophytin concentration of 400 mg/100g DM showed a marked decline in chlorophyll content ($P < 0.001$) from 1091 mg/100g DM for fresh dasheen leaves to 668 mg/100g DM.

For equivalent peroxidase inactivation, blanching in steam resulted in enhanced chlorophyll loss paralleled by increased pheophytin formation in the dehydrated vegetable compared to pre-drying treatments of blanching in water or alkali-infusion (Table 2). Steam blanched dehydrated dasheen leaves, with a pH of 5.6, olive-green to olive-brown in color, reflected a substantial chlorophyll loss of 58% and a high pheophytin content of 695 mg/100g DM.

The water blanched dehydrated vegetable, with a pH of 6.5 and a chlorophyll content of 816 mg/100g DM, corresponding to a loss of 25%, was attractively bright green in color. The dehydrated vegetable showed no signs of browning, however, darkening in the veinal region, typical of the fresh vegetable became prominent following dehydration.

Loss of green color was significantly reduced in the dehydrated vegetable following alkali blanching-infusion. The dehydrated vegetable, with a pH of 7.3 exhibited a chlorophyll loss of 31% and like the water blanched dehydrated vegetable showed no signs of browning. Lioutas (1989) found excellent color stability when broccoli was similarly treated and dehydrated at 110°F (44°C). This author claimed a pH of 7-9 to be crucial in chlorophyll retention since alkali salts prevent or minimize pheophytin formation by neutralizing plant acids released or formed during heat processing. The loss of chlorophyll observed for water and alkali blanched-infused dehydrated vegetable in the absence of pheophytin formation suggests other methods of chlorophyll degradation eg allomerisation of chlorophyll, rupture of the tetrapyrrole ring to form chlorins and purpurins etc.(Clydesdale et al., 1970).

CONCLUSIONS

Drying of fresh dasheen leaves under natural convection at temperatures ranging from 40-70¡C occurred principally in the range of the falling rate period and the total drying period can be divided into 2 falling rate periods of drying. Increasing air drying temperature enhanced loss in green color, concomitant with increased pheophytin formation and was paralleled by a significant decline in pH. Irrespective of air drying temperature, losses in ascorbic acid were high ranging from 91.6 - 93.9 % for the vegetable at air drying temperatures of 40 - 70°C.

Compared to the untreated dehydrated vegetable at 60°C, blanching in steam did not markedly alter the drying rate, both products of dehydration appearing olive-green to olive-brown in color. Blanching in water or magnesium carbonate-infusion appeared to have altered the physical properties of the vegetable as single falling rate periods of drying were distinguished. Water and alkali blanching-infusion, while enhancing ascorbic acid losses, yielded superior dehydrated products showing minimum losses in green color with no signs of browning.

ACKNOWLEDGEMENTS

The authors wish to thank the Organization of American States (OAS) in Washington,D.C. (USA) and the National Institute for Higher Education, Research, Science and Technology (NIHERST) of Trinidad and Tobago for their financial support. We also grateful to Mr. B. Lauckner (Biometrician) of the Caribbean Agricultural Research and Development Institute (CARDI), St. Augustine, Trinidad for statistical analyses of the data.

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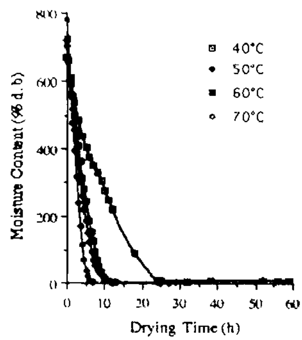


Fig 1 : Drying curves for dasheen leaf at four temperatures

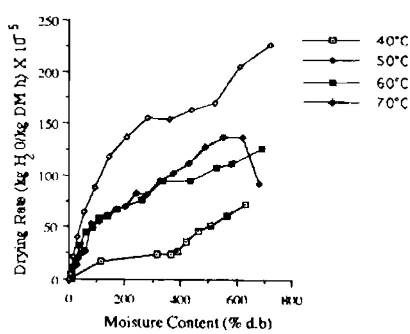


Fig 2 : Drying rate curves for dasheen leaf at four temperatures

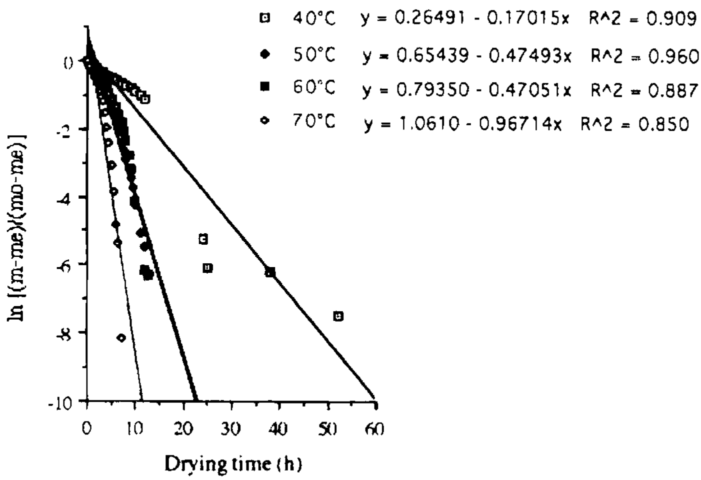


FIG 3 : Semi-logarithmic plots for dasheen leaves at four temperatures

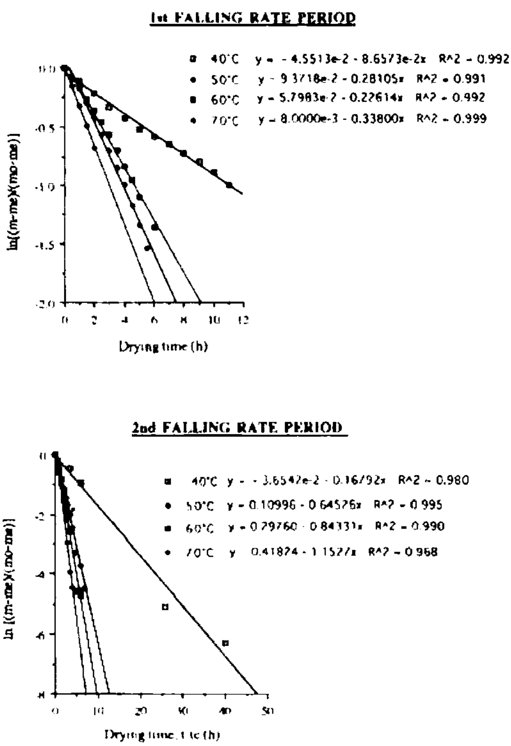


Fig 4 : Semi-logarithmic plots for first and second falling rate periods of drying of dasheen leaf at four temperatures

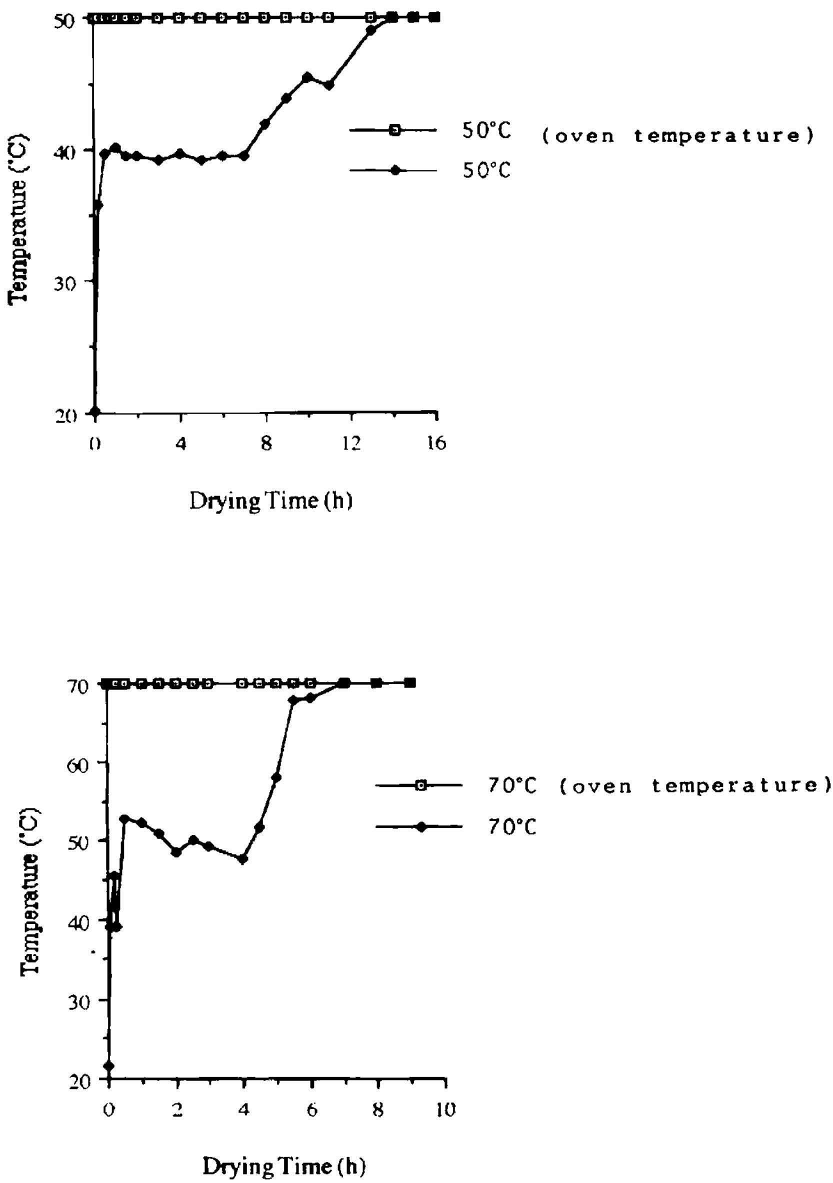


Fig 5 : Temperature profiles of dasheen leaf at 50°C and 70°C

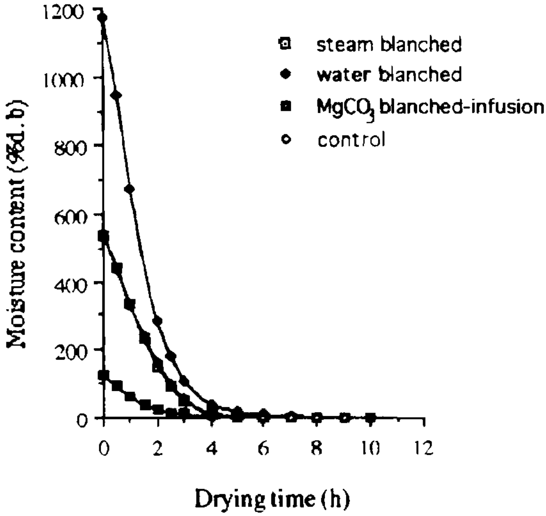


Fig 6 : Drying curves of treated and untreated dasheen leaf dried at 60°C

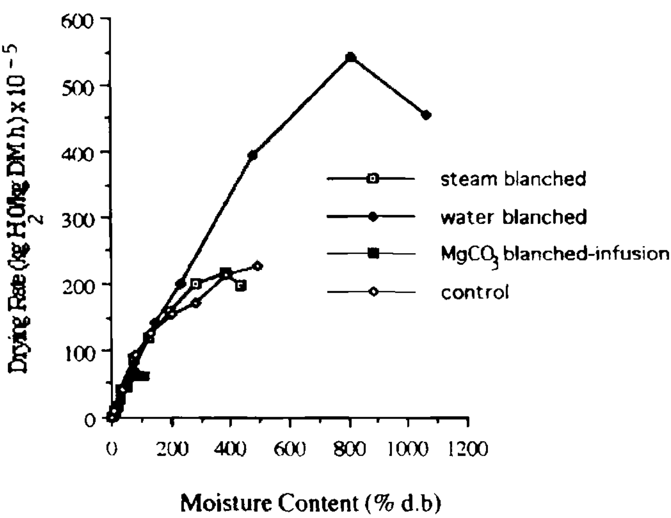


Fig 7: Drying rate curves of treated and untreated dasheen leaf dried at 60°C

- steam blanched — y = 1.0003 - 1.4319x   R^2 = 0.867
- water blanched — y = 0.16663 - 0.85246x   R^2 = 0.996
- $MgCO_3$ blanched-infusion — y = - 4.5356e-3 - 0.81077x   R^2 = 0.995
- control — y = 0.79326 - 1.2499x   R^2 = 0.956

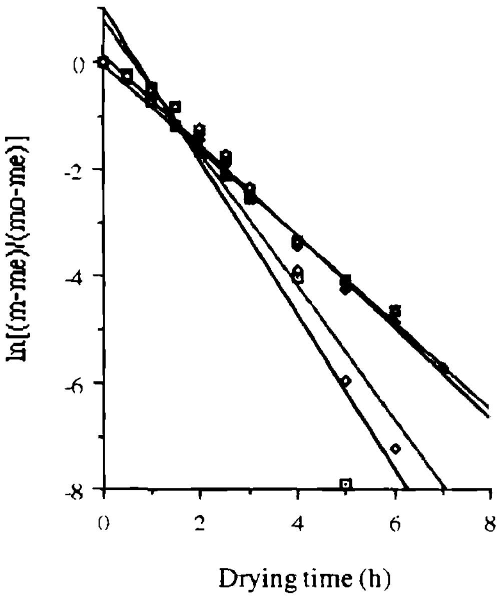
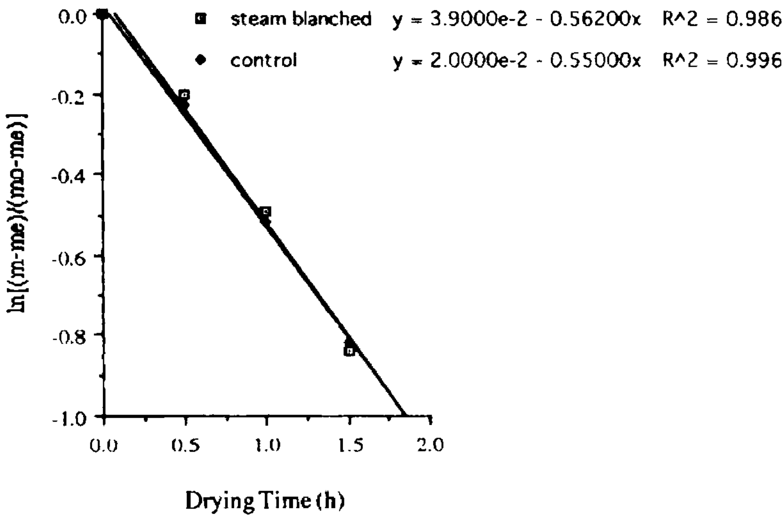


Fig 8 : Semi-logarithmic plots of treated and untreated dasheen leaf dried at 60°C

Ist FALLING RATE PERIOD



2nd FALLING RATE PERIOD

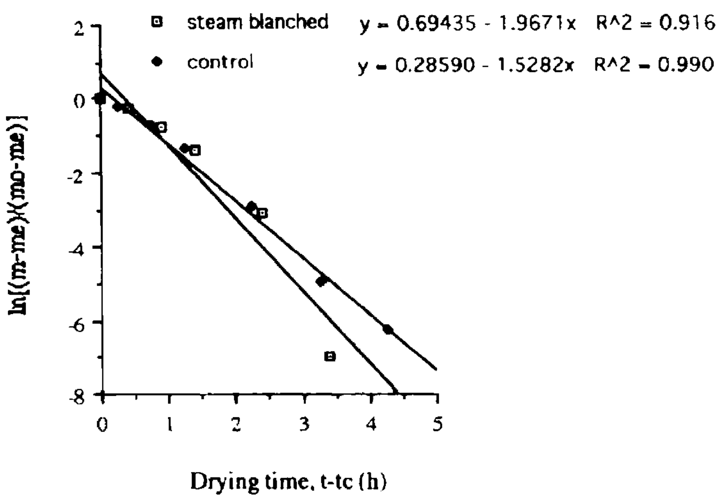


Fig 9 : Semi-logarithmic plots for first and second falling rate periods of drying of treated and untreated dasheen leaf dried at 60°C

Table 1. Chemical properties of fresh and dried dasheen leaf

Product	[a]Ascorbic Acid (mg/100 g DM)	[a]Chlorophyll (mg/100 g DM)	[a]Pheophytin (mg/100 g DM)	[a]pH
Fresh	494	1262	0	6.4
Dried (°C)				
40	34	953	232	5.8
50	30	523	541	5.6
60	42	83	797	4.7
70	40	35	813	4.7

[a] denotes the mean of 2 replications

Table 2. Chemical properties of fresh and dried dasheen leaves subjected to various pre-drying treatments prior to drying at 60°C.

Product	[a]Ascorbic Acid (mg/100 g DM)	[a]Chlorophyll (mg/100 g DM)	[a]Pheophytin (mg/100 g DM)	[a]pH
Fresh	581	1091	0	6.3
Dried				
Steam blanched	22	486	695	5.6
Water blanched	45	816	0	6.5
$MgCO_3$ blanched infusion	13	751	0	7.3
Control	66	668	400	5.8

[a] denotes the mean of 2 replications