STANDARDIZATION OF DEHYDRATION TECHNIQUES IN ANACHUNDA (*Solanum torvum* Swartz.) BLACK NIGHTSHADE (*Solanum nigrum* Linn.) AND LOTUS (*Nelumbo nucifera* Gaertn.)

By

K. J. KURIAKOSE

THESIS

Submitted in partial fulfilment of the
requirement for the degree of

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Faculty of Agriculture
Kerala Agricultural University

Department of Processing Technology
COLLEGE OF HORTICULTURE
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Kerala, India

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DECLARATION

I hereby declare that this thesis entitled "**Standardization of dehydration techniques in `anachunda' (*Solanum torvum* Swartz.), black nightshade (*Solanum nigrum* Linn.) and lotus (*Nelumbo nucifera* Gaertn.)**" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
02-06-1995.

K.J.Kuriakose
(92-12-13)

V.K. Raju
Professor and Head i/c
Department of Processing Technology

College of Horticulture,
Vellanikkara.
02-06-1995.

CERTIFICATE

Certified that this thesis entitled "**Standardization of dehydration techniques in `anachunda' (*Solanum torvum* Swartz.), black nightshade (*Solanum nigrum* Linn.) and lotus (*Nelumbo nucifera* Gaertn.)**" is a record of research work done independently by Mr. K.J. Kuriakose under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

V.K. Raju
Chairman
Advisory committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr. K.J.Kuriakose** a candidate for the degree of Master of Science in Horticulture with Major in Processing Technology agree that the thesis entitled **"Standardization of dehydration techniques in `anachunda' (*Solanum torvum* Swartz.), black nightshade (*Solanum nigrum* Linn.) and lotus (*Nelumbo nucifera* Gaertn.)"** may be submitted by Mr. K.J. Kuriakose in partial fulfilment of the requirement for the degree.

Sri. V.K. Raju
Professor and Head i/c
Department of Processing Technology
(Chairman)

Sri. M.C. Narayanankutty
Assistant Professor
Department of Processing
Technology
(Member)

Sri. P.V. Prabhakaran
Professor and Head
Department of
Agricultural Statistics.
(Member)

Dr.Babu M. Philip
Associate Professor
Campus Development
(Member)

External Examiner

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Dedicated to
my loving parents

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ABBREVIATIONS

LDPE - Low Density Polyethylene

LDPP - Low Density Polypropylene

PP - Polypropylene

PE - Polyethylene

RH - Relative Humidity

g - gram

cm - centi metre

H_z - Hertz

% - Per cent

ppm - parts per million

Introduction

INTRODUCTION

The Indian fruit and vegetable processing industry is now regarded as the "sun rise" industry. It helps to minimise the postharvest losses which is as high as 25-30 per cent of the value of the produce. At this scale it is estimated to be as Rs.3000-4000 crores per annum (Patnaik, 1994). The processing industry helps to prolong the availability period for processed products and helps to create employment opportunities especially in rural areas. Besides this it also makes nutritious and hygenic food products available to the consumers all round the year.

The important food preservation processes are dehydration, canning, fermentation, radiation, freezing, use of chemical preservatives, addition of sugar or salt etc. Of these, dehydration, which is an ancient art of processing fruits and vegetables is one of the most widely accepted methods on a commercial scale. Dehydration industry today is a big business and there are large number of technical options for removal of moisture from commodities, each best suited for a particular commodity/situation.

Sun drying has been used for drying agricultural products from time immemorial. Though this method is very easy and cheap it has got certain disadvantages. Sun drying require more space, labour, and resulting in high loss of nutrient and colour and also require long drying periods. Sun drying is not suited for rainy season and the products do not have uniform quality. But most of the dehydrated vegetable products available in the market are manufactured by cottage level entrepreneurs through sundrying without employing any scientific technology. So attempts for improvement of sundrying technology was attempted in the present study in selected vegetables.

Dehydration in cabinet dryer is the conventional method used for artificial dehydration. Cabinet dryers can be used for batch operations and are usually held at a constant temperature. Cabinet dryers are flexible as to type and size of operation and are highly suitable for small scale operations (Salunkhe *et al.* 1976). Microwave oven dehydration, a recent innovation in dehydration technology, is an efficient system of dehydration (Rao *et al.* 1995). Nowadays microwave ovens are gaining popularity as household appliance. The cabinet dryer and microwave oven are two simple equipments which offer good potential for self employment for rural women. Dehydration is an ideal avenue for self employment for women in urban and rural areas. Hence, in the present study standardisation of procedures for dehydration using cabinet dryers and microwave ovens were tried in comparison with sun drying.

Blanching with or without chemical treatments are also tried as pretreatment for dehydration as they are found to have advantageous results (Kalra, 1990). Chemicals commonly used for pretreatments in vegetables are potassium metabisulphite (KMS), citric acid, sodium chloride etc. (Patil *et al.* 1978). Some of the pretreatmentshave been found to reduce duration of drying time (Salunkhe *et al.* 1976). Thus, while standardising the dehydration technique for a new product it is necessary to assess the effectiveness of selected pretreatments. Thus,in the present study attempt was also made to compare effectiveness of few treatments .

Packaging requirements for dehydrated products vary considerably. Various packaging materials like polyethylene films, polypropylene films, aluminium foils, and laminates are available for packaging of products. The selection of packaging material has to be done carefully after assessing the suitability, length of storage, value addition due to packaging and other factors. Thus, product development necessarily includes a study on the packaging standardization aspect. In the present study some of the popular packaging materials like polyethylene and polypropylene films were used for standardising the packaging requirement.

Bittergourd, chilli, cowpea, okra, carrot, taro, onion, potato, `anachunda'(*Solanum torvum*), black nightshade (*Solanum nigrum*), and lotus (*Nelumbo nucifera*) are some of the important south Indian vegetables used for dehydration. In bittergourd, a popular dehydrated vegetable in Kerala, standardisation of dehydration technique and development of products like intermediate foods were done scientifically (Veenakumari, 1992). The other important dehydrated products available in the market are fruits of `anachunda', black nightshade and stolon slices of lotus.

Anachunda (*S.torvum*),and black nightshade (*S.nigrum*) are two under exploited plant species, belong to Solanaceae family, commonly found in the

Plate 1. *Nelumbo nucifera* - a field view

homesteads of Kerala. Both the plant yield fruits having medicinal and culinary properties. These fruits are also popular among Keralites as a dehydrated vegetable which is consumed as an oil fried (hot oil immersion dehydration) wafer ("*Kondattam*" in Malayalam) as a side dish for rice meals. The stolons of lotus belonging to Nymphaeaceae family, highly nutritive, is also popularly consumed both as a fresh vegetable after cooking and in the dehydrated form after oil frying.

Exploitation of agricultural resources in water bodies is one of the identified targets in the agricultural development policy. Lotus is an aquatic plant of Kerala giving many useful things (plate 1). The lotus flowers are the most needed flower for "poojas" in temples. Lotus flowers are used in garland making also especially for wedding ceremonies. The lotus leaves are also ideal as plates for serving meals just like banana leaves. Besides this lotus stolon is a good vegetable and is used for making "*kondattam*" through dehydration.

No attempt has so far been made to standardise scientific dehydration techniques in any of the above three species. For want of specific standardised techniques, the commercial exploitation of the market potential of these dehydrated vegetables are not being exploited. The changing lifestyles and urbanisation has made life much faster. Thus, dehydrated vegetables have become a consumer item in the supermarkets, which was hither to a leisure time activity of housewives of the joint families. Vegetable dehydration offers considerable scope as a self employment scheme for unemployed persons in rural areas, especially rural women.

Considering all these aspects,an investigation was undertaken to meet the above *desideratum*. The objectives of the study were :

1. To standardise suitable dehydration technique(s) in *Solanum torvum, Solanum nigrum* and *Nelumbo nucifera.*
2. To study packaging and storage requirements of dehydrated samples of *Solanum torvum*, *Solanum nigrum* and *Nelumbo nucifera*.
3. To evaluate sensory qualities of hot oil fried dehydrated samples of *Solanum torvum*, *Solanum nigrum* and *Nelumbo nucifera*.

Review of Literature

REVIEW OF LITERATURE

The relevant literature related to the study is reviewed here under the following titles:

2.1. Effect of pretreatments on the quality of dehydrated vegetables.

2.2. Methods of dehydration

2.3. Packaging and storage of dehydrated products

2.4. Sensory evaluation of dehydrated products

2.1. Effect of pretreatments on the quality of dehydrated vegetables

2.1.1. Effect of blanching on quality

Blanching is a partial pre-cooking treatment in which vegetables or fruits are usually heated in water or in live steam before processing. It is often called as scalding also(Kalra, 1990).

Tandan and Virmani(1949) determined blanching time of different vegetable in different blanching media. They reported that, in bittergourd, blanching in boiling water inactivated catalase and peroxidase enzymes. When water at 200^0F was used for blanching, three minutes blanching was needed.

Kuppuswamy and Rao(1970) conducted studies on dehydration of greenpeas and revealed that blanching time varied with type of blanching. A four minute blanching in water containing preservatives had a favourable effect from the point of view of reduction in cooking time. In steam blanching three minutes was found to be the optimal time.

Srivastava and Sulebele(1975) studied effect of pretreatments on dehydration of cauliflower, They reported that the time required to inactivate catalase and peroxidase by hot water and steam blanching was four and seven minutes respectively. It was also observed that blanched pieces had a slightly higher dehydration coefficient than unblanched pieces.

Sehgal *et al.* (1975) after studying the nutritive value of sun dried green leafy vegetables reported that the loss of ascorbic acid and carotene contents of sun dried leaves varied from 34.4 to 63.5 per cent and 48.0 to 89.8 per cent respectively.

Blanching can cause an increased crystallinity of the cellulose in the product. Blanching or scalding of vegetables for a few minutes in boiling water or steam serve as an additional cleaning operation . By this the properties of the final product were improved and inactivation of enzymes taken place (Salunkhe *et al.* 1976)

Ratnatunga (1978) reported that spinach blanched by hot gas retained 34 mg per cent ascorbic acid as compared to 21 mg per cent by hot water blanching. In chillies the drying time decreased from 12 hours in unblanched sample to 10 hours in blanched sample as reported by Luhadiya and Kulkarni(1978). Both dehydration ratio and rehydration ratio were increased by blanching. Chlorophyll content was also more in blanched chillies (53 to 65 mg/g) than in unblanched product(43 to 62 mg/g). Patil *et al.* (1978) studied the effect of blanching on the quality of dehydrated fenugreek. They observed that samples treated with preservatives potassium meta bisulphite (KMS), magnesium oxide (MgO) and blanched in boiling water for two minutes showed more retention of green colour, ascorbic acid and carotenes. When hot water at 80^0C was used for blanching the time required for blanching was one to five minutes. By increasing the temperature of blanching water to 90^0C to 100^0C, the time of blanching was reduced to three and two minutes respectively. They also reported that with increase in the temperature of blanching water, the percentage loss of chlorophyll and ascorbic acid showed an increasing trend.

Chaudhary and Roy (1979) carried out dehydration studies in fenugreek leaf. Dehydration was carried out without blanching and after blanching in boiling water and also blanching in 0.2 per cent KMS solution. They found that there were considerable losses in total chlorophyll and ascorbic acid during dehydration. Retention of chlorophyll was considerably improved by blanching to 52.2 per cent and 33.8 per cent in unblanched. This was further improved by blanching in sulphite solution to 70.6 per cent. But ascorbic acid retention was more in unblanched sample (69.8 percent) compared to simply blanched sample (43.3 percent). The ascorbic acid content in sulphite treated sample was 56.5 per cent which was about 15 per cent more than that in the hot water blanched sample. Better dehydrated okra was produced by blanching in boiling solution of

0.1 per cent sulphur dioxide for three minutes (Krutman,1981). Akpapunam (1984) found that leafy vegetables blanched in water at 98^{0}C retained more amount of ascorbic acid. In dehydrated pumpkin ascorbic acid losses were more in control than in blanched and sulphited samples (Pawar *et al.* 1985).

Goyal and Mathew (1990) studied the effects of different drying methods with or without blanching on the quality of dried cauliflower including ascorbic acid content and iron. Results showed that blanching followed by drying reduced the drying time, produced best organoleptic properties and caused nutrient losses.

Kumar and Nath (1991) after studying the effect of additives in blanching water on quality of dehydrated green cowpea pods reported that a product of good green colour and superior sensory qualities could be prepared by blanching green cowpea pods for 10 minutes in boiling solution of 0.1 per cent $Na_2 CO_3$ + 0.1 per cent of $NaHCO_3$ + 0.25 per cent of NaMS followed by drying in a cabinet drier at 60 ± 1^0C.

Mulay *et al.* (1994) investigated the suitability of various pretreatments for preparation of dehydrated cabbage. It was reported that retention of ascorbic acid was more in sulphited samples as compared to sugar treated samples. The non-enzymatic browning in potassium metabisulphite treated samples was lower compared to other samples. Sugar treated samples showed higher rehydration coefficients in comparison with sulphited samples. 0.5 per cent KMS solution treatment was superior for most of the sensory qualities of rehydrated cabbage.

2.2 Methods of dehydration

In onion artificial drying reduced microbial infestation (Grone,1971). Sehgal *et al.* (1975) evaluated the effect of sun drying on the nutritive value of three green leafy vegetables viz; mustard, `raya' and spinach. The protein content in these leaf vegetables increased from three to about 32 per cent which was due to loss of moisture. The loss of ascorbic acid and carotene contents of sun dried leaves varied from 34.4 to 63.5 per cent and 48.0 to 89.8 per cent respectively. The ash percentage of dehydrated samples were 20.7, 21.3 and 25.9 in raya, spinach and mustard respectively.

An investigation was conducted for comparing sun drying and cabinet drying by Patil *et al.* (1978). It was found that severe losses of nutrient occurred in sun dried product compared to cabinet dried product. By giving the pretreatment of blanching in boiling water containing 0.5per cent KMS, 0.1 per cent MgO and 0.1 per cent of $NaHCO_3$, loss of chlorophyll was ten per cent in sun dried and 7.25 per cent in cabinet dried. The loss of ascorbic acid was 15.21 and 12.91 per cent respectively in sun dried and dehydrated product.

Maeda and Salunkhe (1981) compared different dehydration methods viz; sun drying and drying in conventional enclosed solar driers, for African spinach, cowpea, sweet potato and cassava leaves. Maximum retention of the two vitamins A and C were obtained by drying vegetables in enclosed solar dryers. Direct sun drying resulted in marginal retention of the vitamins. Mudahar and Bains (1982) compared sun drying and dehydration in cabinet dryer for dehydrating *Agaricus* *bisporus* mushrooms. The study revealed that dehydration using hot air through flow was superior to sun drying. The hot air dried products were attractive looking as compared to the sun dried products which turned perceptibly darker. The rehydration ratio values of sun dried samples were below those of hot air dried samples.

Decareau (1984) reported that microwave processing resulted in shorter processing time, higher yields and better quality than by conventional techniques. Gupta and Nath (1984) studied drying of tomatoes by adopting two methods *viz.*, sundrying and dehydration in a cabinet dryer. It was revealed that sun dried samples had higher moisture levels. The sun dried samples were of lighter colour than those dried in cabinet drier. Loss of total sugar was more in cabinet dried samples. Pawar *et al.* (1985) conducted dehydration studies in pumpkin and reported that losses of ascorbic acid, carotenoids and reducing sugars were more in shreds dried under sun than cabinet dried samples. Cabinet dried samples had shown higher dehydration ratio compared to sun dried samples.

Ruello (1987) reported that fast cooking times of microwave's resulted in the retention of volatile substances which were usually expelled during conventional cooking. It was also reported that microwaved food had appearance and taste quite different from conventionally cooked food.

Ramana *et al.* (1988) conducted a study on the effect dehydration methods on the colour of dehydrated fenugreek and mustard leaves. They found that sundried samples showed considerable change in hue as well as chlorophyll content when compared to the solar cabinet dried and tray dried samples. Pawar *et al.* (1988) compared the effect of drying in solar dryers with that in mechanical and open air drying in onion. It was found that drying rate was faster in mechanical cabinet dryer. Solar dried samples retained slightly less ascorbic acid than mechanically dried. Ascorbic acid content in open air dried sample varied from 1.95 to 3.1 mg/g, whereas that in mechanical cabinet dried samples was 2.78 mg to 4.6 mg/g. Solar cabinet dried samples showed higher scores for colour, flavour, texture and overall acceptability than the dehydrated samples.

Goyal and Mathew (1990) compared open sun drying, shade drying and drying in solar dryer, for the dehydration of cauliflower. The study revealed that with respect to drying time, retention of nutrients and organoleptic characteristics, the blanching process as predrying treatment, and solar drying as drying condition could be the best method for obtaining better quality in the dried products. Jayaraman *et al.* (1991) reported a significant loss of pigments and development of rancid odour due to lipid oxidation in direct sun drying of carrots and green peas. While indirect sundrying inside a cabinet minimised these changes and gave products comparable to artificially dried.

Gopalakrishnan and Thomas (1992) studied the extent of green colour retention in fresh pepper subjected to treatments such as microwave exposed boiling water blanching and direct boiling water blanching. They reported that best colour retention was observed in the microwave exposed boiling water blanched samples. Chen and Chen (1993) studied the effects of microwave cooking and stability of chlorophyll and carotenoids in sweet potato leaves. They reported that the content of each pigment decreased with increasing heating time. Chlorophyll and epoxy containing carotenoids were most susceptable to heat loss. Rao *et al.* (1995) reported that microwave processing resulted in the excellent retention of nutritional and sensory value of foods.

2.3. Packaging and storage of dehydrated products

Mahadevaiah *et al.* (1976) studied the packaging and storage requirements of dried ground and white chillies (*Capsicum annum*) in flexible consumer packages. The study revealed that 300 gauge low density polyethylene film pouches were suitable for 500 g consumer unit packs for ground chilli powder to give a shelf life of three and six months under accelerated and normal conditions of storage respectively and under tropical condition. Two hundred gauge low and high density polyethylene films were suitable for packaging of whole chilli in units of 250g.

Mahadevaiah *et al.* (1977) conducted packaging studies in pulses and cereal flours in flexible films. The study revealed that long term storage of about 8-10 months and to withstand physical and environmental hazards, low density polyethylene pouches of 400 gauge were quite suitable in offering the desired protection for pulses in unit packs of 500g. 200 gauge LDPE film was quite adequate for short-term storage of about 3-4 months. Under both accelerated

(38°C and 92±2%RH) and normal environmental conditions (27°C and 65±2%RH) of storage 200 gauge low and high density polyethylene film pouches were found suitable for the packaging of cereal (wheat) flours in unit packs of 500g.

Balasubrahmanyam and Anandaswamy (1979) studied the packaging requirements for fried potato chips and found that potato chips had 15days storage life in 100 gauge high density polyethylene and cello/poly laminate. Balasubrahmanyam *et al.* (1979) reported that for long term storage aluminium foil laminate pouch was quite suitable in offering maximum protection against ingress of moisture and volatile oil loss in asafetida products. Cellophane and Saran/cello/ polylaminate have limited use for long term storage under high humid conditions even though they offerred a good protection against volatile oil loss. Under accelerated conditions of storage high density polyethylene pouch was suitable in offering desired protection to the product during storage.

Kumar *et al.* (1980) conducted packaging and storage studies on two types of dehydrated mushrooms by packing in 400 gauge high density polyethylene and paper/PE/ foil/PE laminated pouches under normal and accelerated conditions of storage. The blanched and treated sample at normal storage conditions indicated a shelf life of three months when packed in foil laminate and only one month when packed in high density polyethylene pouches. The product kept well for one month at the accelerated condition, and the foil laminate packed sample was found better than high density polyethylene packaged sample.

Krishnamurthi *et al.* (1981) investigated suitability of flexible packages and inert gas packing in sealed tins for the storage of fried `Nendran' banana chips. It was found that for banana chips fried in fresh coconut oil, 300 gauge high density polyethylene bag packaging were satisfactory upto two months while packing in tins under CO_2 was satisfactory upto six months at room temperature (28-32^{0}C).

Kalra (1981) studied the storage problems of solar dehydrated peas. The dehydrated peas were stored in high density (HD) polyethylene, black polyethylene and butter paper pouches at ambient temperature (23^{0}C to 36^{0}C). The initial moisture of four to five per cent changed very little in butter paper but varied in the other two. Most of the samples in HD polyethylene and black polyethylene were spoiled within two months of storage while butter paper bags proved more suitable.

Kaur and Singh (1981) reported that high density polyethylene bags of 500 gauge were best compared to aluminium foil laminated polyethylene bags for the storage of dehydrated cauliflower.

Bhatia and Mudahar (1982) reported that intermediate moisture mushroom with 20 per cent moisture content packed in 300 gauge polyethylene pouches, with an outer cardboard cover had a shelf life of about three months at 37^{0}C and 42 to 74 per cent Relative Humidity. Optimum quality retention of tomato powder was achieved with a paper / polyethylene / aluminium foil / polyethylene laminate. This packaging retained the nutrient contents in a better way (Gvozdenovic *et al.*1983).

Intermediate moisture okra had a shelf life of 40 days when packed in low density polyethylene bags (Thorat *et al.* 1988). Rao *et al.* (1991) reported three months storage life at 37^{0}C and six months at ambient temperature for coconut chutney packed in flexible pouches.

Manan *et al.* (1991) reported that colocassia snack products was acceptable only upto thirty days storage at 30 to 35^{0}C and RH 30 to 65 per cent, when packed in 120 gauge polyethylene pouches. Premavalli *et al.* (1991) reported that potassium sorbate treated carrot and pumpkin halwa remained stable upto one and two months in aluminium foil and polyethylene laminate pouches respectively.

2.4.Sensory evaluation of dehydrated products

Sensory quality of the food is the consumers reaction to the physical and chemical constituents of the food in its prepared and formulated form. Sensory evaluation is the main technique for evaluating consumer acceptance and preference, relative importance of sensory attributes in relation to food type for the consumer, consumer response to non-sensory characteristics in relation to quality of food, and changes in consumer food preferences (Govindarajan,1979).

Pruthi *et al.* (1978) studied the dehydration of tropical paddy straw mushroom and evaluated the products organoleptically by a panel of five judges for colour, texture,taste, aroma and overall acceptability by using a hedonic scale.

Patil *et al.* (1978) in their study of effect of blanching factors on quality and durability of sun dried and dehydrated fenugreek (methi) evaluated the culinary quality of dried products by a taste panel of ten semi - trained judges using hedonic scale. It was reported that the product blanched at boiling temperatures for two minutes with 0.5 per cent KMS + 0.1 per cent MgO + 0.1 per cent $NaHCO_3$ and dried in cabinet drier got maximum score and was the best.

Krishnamurthi *et al.*(1981) studied the over all quality of deep-fat fried `Nendran' banana chips by using a 7-point hedonic scale ranging from "like extremely" to "dislike extremely". For assessing the quality of intermediate moisture (IM) carrot preserve the organoleptic evaluation was carried out by a panel of seven judges using a 9-point Hedonic scale (Sethi and Anand, 1982). Organoleptic evaluation for finding out best dehydration methods of mango slices was done by a panel of six judges following hedonic scale as reported by Teotia *et al.* (1987).

Ramana *et al.* (1988) studied the colour of some dehydrated green leafy vegetables and compared the products dried in solar cabinet dryer and tray dryer. The dehydrated product was evaluated by a panel of ten semi trained judges for colour attributes by using 9-point hedonic scale. Sensory evaluation revealed that there was a significant difference between the products dried by different dehydration methods when evaluated for their colour attributes. However, the mean scores corresponding to tray dried, solar cabinet dried and sun dried were 6.8, 7.5 and 5.3 for fenugreek and 8.1, 8.0 and 7.3 for mustard leaves respectively.

Kulkarni *et al.* (1988) evaluated different new okra cultivars suited for dehydration. Quality evaluation of dehydrated and that of rehydrated okra varieties in respect of colour, texture, flavour and general acceptability was done by a panel of judges. The varieties were then graded depending upon the total score obtained.

Pawar *et al.* (1988) after studying solar drying of white onion flakes reported that the sulphited samples from various solar dryers received the maximum scores for colour, texture and overall acceptability in sensory evaluation. The sensory evaluation of the dried onion flakes in terms of colour, flavour, texture and overall acceptability was performed by a panel of eight judges on a 9-point Hedonic scale varying from "like extremely" (rating 9) to "dislike extremely" (rating 1).

Goyal and Mathew (1990) studied the physico chemical characteristics of cauliflower dried under different drying conditions. For organoleptic evaluation the samples dried under the three conditions *viz.*,open sun drying, shade drying, and solar drying were served to a panel of five members to score the colour, texture, taste, flavour and appearance on Hedonic scale. Unblanched samples had significantly lesser scores as compared to their blanched counterparts. Among the drying conditions solar dried samples scored more as compared to open sun dried and shade dried counterparts. Premavalli *et al.* (1991) assessed the overall acceptability of carrot halwas by a team of taste panellists using a 9-point Hedonic scale rating. Samples receiving acceptability score of six and above were considered acceptable.

Mulay *et al.* (1994) studied the effect of pretreatment on quality of dehydrated cabbage. The dehydrated samples were evaluated for sensory qualities such as taste, flavour, colour,texture and overall acceptability by a panel of five trained judges using one to four scale indicating one as poor and four as excellent quality. The pretreatment significantly influenced the sensory quality attributes. The score for flavour and overall acceptability was higher for potassium metabisulphite treated samples. They reported that 0.5 per cent KMS treatment of cabbage proved to be suitable in preserving the sensory quality attributes of dehydrated cabbage.

Materials and Methods

MATERIALS AND METHODS

Investigations on some aspects of postharvest technology of three crops *viz.* `anachunda' (*Solanum torvum* Swartz.), blacknightshade (*Solanum nigrum* Linn.) and lotus (*Nelumbo nucifera* Gaertn.) were conducted in the department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala from September 1993 to February 1995. The place is situated at $10^0 32'$N latitude 76^0E longitude and at an altitude of 40 m above MSL.

Solanum torvum is known as `anachunda' in Malayalam and `sundaikai' in Tamil. A spiny shrub, 3-4 m tall and found throughout the tropical parts of India and in Andaman (plate 2). Fruits of the plant are cooked and eaten as a vegetable. They are considered useful in case of liver and spleen enlargement. Analysis of dried fruits gave the following values: moisture 12.3, protein 8.3, fat 1.7, minerals 5.1, crude fibre 17.6 and other carbohydrates 55.0 g/100 g. The mineral constituents (mg/g material) are Ca 390, P 180 and Fe 22.2 (ionisable Fe 1.5) Vit.A 750 IU (CSIR,1972). Fruits also contain two alkaloids sterolin (sitosterol-d-glucoside) and Solasonine (Chopra *et al.* 1956).

Solanum nigrum is commonly called `manathakkali' both in Malayalam and Tamil. A herbaceous plant 30-40 cm height, found throughout India in dry parts upto an elevation of 2,100 m (plate 3). Berries are considered to possess tonic,diuretic and Cathartic properties and useful in heart diseases. They are domestic remedy for fevers, diarrhoea ulcers and eye ailments. Fruits contain glucose and fructose (15-20 per cent) Vit.C and carotene. Seeds forming 9.5 per

Plate 2. Branch of *Solanum torvum*

cent of the weight of the fresh fruits, contain 17.5 per cent protein on dry weight basis (CSIR,1972). Fruits also contain two alkaloids solanine and saponin (Chopra *et al.* 1956).

The lotus (*Nelumbo nucifera*) is grown for its elegant flowers. The stolons are collected and sold as vegetable (plate 4). The stolons show in cross section a few large cavities surrounded by several small ones. They are fleshy and when cut exude a mucilaginous juice. They are somewhat fibrous and soften after prolonged boiling. Analysis of fresh stolons gave the following values: Water 83.80, crude protein 2.70, fat 0.11, reducing sugar 1.56. sucrose 0.42, starch 9.5, fibre 0.80, ash 1.10 and Ca 0.06 per cent. The vitamins reported to be present are as follows (in mg/g): Thiamine 0.22, riboflavin 0.06, niacin 2.2 and ascorbic acid 15. They also contain aspargin two per cent (CSIR,1966).

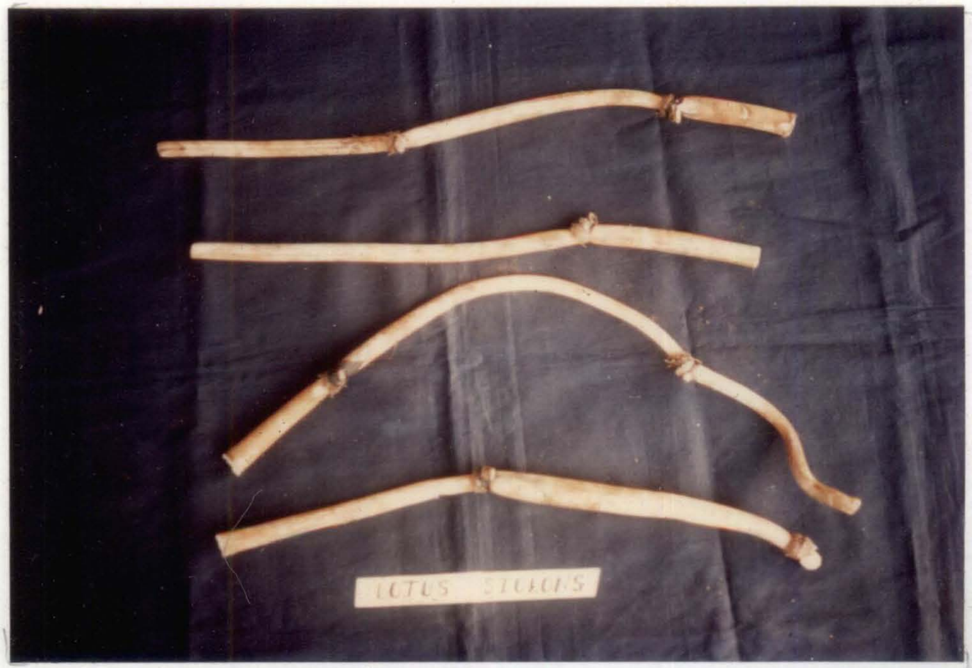
The study was divided into three experiments as given below:

1. Standardisation of dehydration techniques for *Solanum torvum*, *Solanum nigrum* and *Nelumbo nucifera.*
2. Packaging and storage studies of dehydrated samples of *Solanum torvum*, *Solanum nigrum* and *Nelumbo nucifera*.
3. Sensory evaluation of hot oil fried dehydrated samples of *Solanum torvum*, *Solanum nigrum* and *Nelumbo nucifera.*

Fruits of *S. torvum*, *S. nigrum* and stolons of *N.nucifera* were collected fresh from the local farmers growing these species. For all these studies, fruits and

Plate 3. A bearing plant of *Solanum nigrum*

Plate 4. Fresh stolons of *N.nucifera*


LOTUS STOLONS

stolons of uniform maturity were used. In *N. nucifera* stolons were collected from plants producing white flower only. The lotus stolons were having a creamy white colour and a diameter of two centimetre. Process standardisation was done in the processing unit attached to the Department of Processing Technology. Chemical analysis were done in the analytical laboratory attached to the Department of Processing Technology and in the laboratory of the Biochemistry Division.

3.1 Experiment -1 Standardisation of dehydration techniques for *S.torvum, S.nigrum* and *N.nucifera.*

3.1.1 Variety

Mature green fruits of local varieties of *S.torvum* and *S.nigrum* and mature stolons of *N. nucifera* were used for the study since there were no released varieties available.

3.1.2 Season

Experiments on *S.torvum, S.nigrum* and *N.nucifera* were conducted on September 1993 to February 1995.

3.1.3 Lay out

The experiment was carried out under laboratary conditions. Statistical design was completely randomised design with eight treatments and three replications. The fresh fruits of *S.torvum* and *S.nigrum* were first prepared by sorting out over mature, immature and malformed fruits. The fruits of *S.torvum* were punctured using a stainless steel knife. The stolons of *N.nucifera* were thoroughly washed and cut into thin slices of about 0.5 cm thickness. Then the fresh samples were given the following pretreatments before subjecting to the dehydration process. Afterwards they were subjected to three dehydration techniques *viz*., sun drying, dehydration in cabinet dryer and dehydration in microwave oven.

3.1.4 Pretreatments

3.1.4.1 T_1 - Hot water blanching in boiling water for three minutes.

Fruits of *S.torvum* and stolon slices of *N.nucifera* were tied loosely in seperated nylon nets and blanched in boiling water for three minutes in separate stainless steel vessels. Fruits of *S.nigrum* were not subjected to this pretreatment because of bursting of fruit skin when put in boiling water for three minutes. For 50 g of fresh sample of fruit/stolon slices two litres of water was taken for boiling.

3.1.4.2 T_2 - Hot water blanching in water at 85^0C for three minutes.

Fruits of *S.torvum* and *S.nigrum* and stolon slices of *N.nucifera* were tied loosely in separate nylon nets and blanched in hot water at 85^0C for three minutes in separate stainless steel vessels.

3.1.4.3 T_3 - Hot water blanching in four per cent brine at 85^0C for three minutes.

Fruits of *S.torvum* and *S.nigrum* and stolon slices of *N.nucifera* were blanched in a solution of four per cent brine at 85^0c for three minutes as explained 3.1.4.2. Forty grams of sodium chloride was dissolved per litre of water for preparing the solution. Powdered common salt available in the market under the trade name 'MSC' manufactured by Vinayaka salt company, Tuticorin was used for the purpose.

3.1.4.4 T_4 - Blanching in four per cent brine + one per cent citric acid at 85°C for three minutes.

Fruits of *S.torvum* and *S.nigrum* and stolon slices of *N.nucifera* were blanched in a solution of four percent brine and one percent citric acid at 85°C as explained in 3.1.4.2. Forty grams of sodium chloride and ten grams of citric acid were dissolved per litre of water for preparing the solution for blanching.

3.1.4.5 T_5 - Blanching in one percent citric acid at 85°C for three minutes.

Fruits of *S. torvum* and *S. nigrum* and stolon slices of *N.nucifera* were blanched in one percent citric acid solution at 85°C for three minutes. Ten grams of citric acid was dissolved per litre of water for preparing the solution.

3.1.4.6 T_6 - Blanching in four percent brine + 0.5 percent KMS at 85°C for three minutes.

Fruits of *S.torvum* and *S.nigrum* and stolon slices of *N.nucifera* were blanched in four percent brine and 0.5 percent potassium metabisulphite (KMS) at 85°C for three minutes as explained in 3.1.4.2. Fourty grams of sodium chloride and five grams of KMS were dissolved per litre of water for preparing the solution.

3.1.4.7. T_7 - Blanching in 0.5 percent KMS at 85°C for three minutes.

Fruits of *S. torvum* and *S. nigrum* and stolon slices of *N.nucifera* were blanched in 0.5 percent KMS at 85°C as explained in 3.1.4.2. For preparing the solution five grams of KMS was dissolved per litre of water.

3.1.4.8 . T_8 - Control

No blanching was done in this treatment. The samples of *S.torvum*, *S.nigrum* and *N.nucifera* were directly subjected to the three dehydration processes along with other pretreated samples.

3.1.5 Sun drying

All the blanched samples and control sample were sun dried by spreading them in aluminium trays to a moisture content of 7±1 per cent. Trays were kept in sun from 9A.M. to 4P.M. for three days for *S.nigrum* and *N.nucifera* and four days for *S.torvum.* The drying was conducted during the period from October 1993 to December 1993. The meterological data for the period are given in Appendix - 1.

3.1.6 Dehydration in cabinet dryer

A cabinet dryer of 0.9x1x0.61 m (inner dimensions) with 2.5KW heating capacity for the dehydration purpose was used. All the blanched samples were dehydrated in the cabinet dryer at a temperature of 60 ± 2^0C to a final moisture content of 7±1 percent. For *S.torvum* eighteen hours dehydration was required. For *S.nigrum* and *N.nucifera* time taken was four hours and fifteen minutes and five hours and thirty minutes respectively.

3.1.7 Dehydration in microwave oven

The microwave oven used for dehydration was T - 23 Touch Electronic model manufactured by M/S Kelvinator. The size of oven was 394x279x213 mm(inner dimensions) and 578x305x308 mm (outer dimensions) with 23 litre capacity. The power output was 700 watts with microwave frequency of 2450 MH_z. These electromagnetic waves (non ionising electromagnetic waves) penetrate the food from all directions simultaneously to a depth of 3/4 to 1.5 inches, causing the molecules to vibrate 2,450 million times per second.

Fruits of *S.torvum* were dehydrated to a moisture content of 7±1 percent. The power level selected for dehydration was 90 per cent for a period of fifteen minutes for blanched samples. Unblanched samples required 90 seconds more.

Fruits of *S.nigrum* were dehydrated to a moisture content of 7±1 percent. Dehydration was done at two power levels. They were first given a heating at 30 per cent power for 20 minutes. Then they were again heated at 90 per cent power level for 13 minutes for blanched samples and 15 minutes for unblanched samples. The fruits of *S.nigrum* were not given a heating at 90 per cent power level initially because of severe bursting of fruits during dehydration.

Stolon slices of *N.nucifera* of thickness 0.5 cm and diameter 2 cm were dehydrated in microwave oven at 90 per cent power level for a period of 12 minutes for blanched samples. Control sample required 90 seconds more.

3.1.8. Observations

The following observations were taken from Experiment -1.

a. Weight of sample before blanching.

b. Weight of sample after blanching.

c. Colour of sample before blanching.

d. Colour of sample after blanching.

e. Weight of sample after drying.

f. Colour of sample after drying.

3.1.9. Quality analysis

Both fresh samples and dried samples were analysed for the following quality components:

a. Moisture

Moisture content was estimated gravimetrically by drying the sample in a hot air oven at 70^{0}C for 30-32 hours for *Solanum torvum* and 10-12 hours for *Solanum nigrum* and *N.nucifera.* Drying was repeated till the sample attained constant weight. Moisture content was expressed in percentage (Rangana, 1977).

b. Ascorbic acid

Ascorbic acid content of *S.torvum* and *S.nigrum* was estimated volumetrically by titration with 2,6-dichlorophenol-indophenol dye (A.O.A.C., 1960). The value was expressed as milli gram of ascorbic acid per gram of dried fruit.

c. Iron

Iron content of the samples of *S.torvum, S.nigrum* and *N.nucifera* was determined by converting the iron to ferric form using oxidising agent potassium per sulphate and treating thereafter with potassium thiocyanate. The red colour developed was measured at 480 nm in a spectrophotometer (Rangana,1977). The value was expressed as milli gram per gram of dried fruit.

d. Dehydration ratio

The fruits of *S.torvum* and *S.nigrum* and prepared slices of *N.nucifera* were weighed before drying. After the completion of drying, weight was again found out. From these values dehydration ratio was calculated (Srivastava and Sulebele, 1975).

e. Rehydration ratio

Rehydration ratio of dehydrated samples were determined by rehydrating the samples (10g) for ten minutes in boiling water (100ml). From the weight of dehydrated samples and corresponding weight of the rehydrated sample, rehydration ratio was calculated (Anon, 1944).

f. Starch content

Starch content of *N.nucifera* was found out by hydrolysing starch into simple sugars and measuring the quantity of simple sugars colorimetrically. The sample was treated with 80per cent alcohol to remove sugar and then the starch was extracted with perchloric acid. The starch was then hydrolysed to glucose and dehydrated to hydroxy methyl furfural. This compound formed a green coloured product with anthrone and it was read at 630 nm. Starch content was expressed as percentage (Sadasivam and Manickam,1992).

g. Total sugar, reducing sugar and non reducing sugar

Total sugar, reducing sugar and non reducing sugar samples of *S.nigrum* were estimated by determining the volume of the solution required to completely reduce a measured volume of Fehling's solution (Rangana, 1977). The value was expressed as percentage.

h. Carbohydrate content

Carbohydrates of samples of *S. torvum* and *S. nigrum* were first hydrolysed into simple sugars which was then dehydrated to hydroxy methyl furfural. This compound with anthrone formed green colour which was measured at 630 nm. The value was expressed as percentage. (Sadasivam and Manickam,1992).

i. Crude fibre

The samples were first treated with acid and subsequently with alkali. The residue obtained after final filteration was weighed, incinerated, cooled and weighed again. The crude fibre content was given by the loss in weight and expressed as percentage (Sadasivam and Manickam, 1992).

j. Total alkaloid content

The alkaloids of samples of *S.torvum* and *S.nigrum* were estimated by extracting the alkaloids using chloroform and ammonia solution and subsequent filteration through silica gel and drying. The alkaloid content was expressed as percentage (Cromwell, 1955 ; Sahu, 1983).

3.2. Experiment - 2. Packaging and storage studies of dehydrated samples of *Solanum torvum, Solanum nigrum* and *Nelumbo nucifera.*

Based on the results of the experiment I, following treatments were selected for storage studies in each crop.

3.2.1. Treatments selected in *S.torvum*

3.2.1.1. Sundrying

T_3 - Hot water blanching in four per cent brine at 85^0C for three minutes.

T_5 - Blanching in one per cent citric acid at 85^{0}C for three minutes.

T_7 - Blanching in 0.5per cent KMS at 85^{0}C for three minutes.

3.2.1.2. Dehydration in cabinet dryer

T_3 - Hot water blanching in four per cent brine at 85^{0}C for three minutes.

T_6 - Blanching in four per cent brine + 0.5 per cent KMS at 85^{0}C for three minutes.

T_7 - Blanching in 0.5 per cent KMS at 85^{0}C for three minutes.

3.2.1.3. Dehydration in microwave oven

T_3 - Hot water blanching in four per cent brine at 85^{0}C for three minutes.

T_6 - Blanching in four per cent brine + 0.5 per cent KMS at 85^{0}C for three minutes.

T_7 - Blanching in 0.5 per cent KMS at 85^{0}C for three minutes.

3.2.2. Treatments selected in *S.nigrum*

3.2.2.1. Sundrying

T_2 - Blanching in four per cent brine at 85^{0}C for three minutes

T_4 - Blanching in one per cent citric acid at 85^{0}C for three minutes.

T_5 - Blanching in four per cent brine + 0.5 per cent KMS at 85^{0}C for three minutes.

3.2.2.2. Dehydration in cabinet dryer

T_2 - Blanching in four per cent brine at 85^{0}C for three minutes.

T_4 - Blanching in one per cent citric acid at 85^{0}C for three minutes.

T_5 - Blanching in four per cent + 0.5 per cent KMS at 85^{0}C for three minutes.

3.2.2.3. Dehydration in microwave oven

T_3 - Blanching in four per cent brine + one per cent citric acid at 85^{0}C for three minutes.

T_4 - Blanching in one per cent citric acid at 85^{0}C for three minutes.

T_5 - Blanching in four per cent brine + 0.5 per cent KMS at 85^{0}C for three minutes.

3.2.3. Treatments selected in *N.nucifera*

3.2.3.1. Sundrying

T_4 - Blanching in four per cent brine + one per cent citric acid at 85^{0}C for three minutes.

T_6 - Blanching in four per cent brine + 0.5 per cent KMS at 85^0C for three minutes.

T_7 - Blanching in 0.5 per cent KMS at 85^0C for three minutes.

3.2.3.2. Dehydration in cabinet dryer

T_4 - Blanching in four per cent brine + one per cent citric acid at 85^0C for three minutes.

T_5 - Blanching in one per cent citric acid at 85^0C for three minutes.

T_6 - Blanching in four per cent brine + 0.5 per cent KMS at 85^0C for three minutes.

3.2.3.3. Dehydration in microwave oven

T_5 - Blanching in one per cent citric acid at 85^0C for three minutes.

T_6 - Blanching in four per cent brine + 0.5 per cent KMS at 85^0C for three minutes.

T_7 - Blanching in 0.5 per cent KMS at 85^0C for three minutes.

3.2.4. Lay out

The experiment was carried out under laboratory condition. Weekly mean temperature and relative humidity during the storage trial is given in the Appendix II. Statistical design for the experiment was completely randomised design with ten treatments with three replications.

3.2.5. Packaging treatments

P_1 - Packaging in polypropylene bags of 80 gauge thickness.

P_2 - Packaging in low density polyethylene (LDPE) bags of 100 gauge thickness.

P_3 - Packaging in LDPE bags of 150 gauge thickness.

P_4 - packaging in LDPE bags of 200 gauge thickness.

3.2.6. Observations

Weight gain/loss, colour, texture and consumer acceptability were recorded at two month intervals for a period upto six months. Colour, texture and consumer acceptability were evaluated by scoring based on the five point Hedonic scale given below. Scoring was got done by a panel of ten semi trained judges.

1. Score chart for colour of *S. torvum* and *S.nigrum*

Description		Score
A Light green	-	1
B Brownish green	-	2
C Yellowish brown	-	3
D Brown	-	4
E Burnt appearance	-	5

2 a. Score chart for colour of *N.nucifera*

Description	Score
A Cream	1
B Whitish yellow	2
C Yellow	3
D Yellowish brown	4
E Light brown	5

b. Score chart for texture

Description	Score
A Very crisp	1
B Moderately crisp	2
C Neither crisp nor hard	3
D Hard	4
E Very hard	5

c. Score chart for consumer acceptability.

Description	Score
A Acceptable fully	1
B Acceptable somewhat	2
C Neither acceptable nor unacceptable	3

D Unacceptable

somewhat - 4

E Not acceptable - 5

3.3. Experiment 3. Sensory evaluation of hot oil fried dehydrated samples of *S. torvum, S. nigrum* and *N.nucifera.*

All the samples were fried in coconut oil medium for a period of 45-60 seconds. For each frying fresh coconut oil was used. Temperature for frying was 110-120^{0}C for *S.torvum,* 140-150^{0}C for *S.nigrum* 125-135^{0}C for *N.nucifera*. Fifty milli litre of oil was used for samples of 25 g each. Residue of oil was measured each time. The fried samples were served to a semitrained tasting panel consisting of ten persons and they were asked to score the product on a nine point `Hedonic Scale' as given below for characters *viz.*,taste, colour and overall acceptability.

3.3.1. Hedonic Scale.

Numerical designation		Word description
1	-	Like extremely
2	-	Like very much
3	-	Like moderately
4	-	Like slightly
5	-	Neither like nor dislike
6	-	Dislike slightly
7	-	Dislike moderately

8 - Dislike very much
9 - Dislike extremely

3.4. Statistical analysis.

The data on the effect of pretreatments and dehydration methods on the different quality parameters were subjected to statistical analysis suggested by Panse and Sukhatme (1954). The mean values for each parameter were calculated and analysed by analysis of variance technique. Critical difference was found out for comparing the treatments, dehydration methods and interaction between treatments and dehydration methods. The data obtained after sensory evaluation for colour, texture, consumer acceptability and taste were analysed by Kruskell Wallies' one way analysis of variance (Fischer, 1973).

Results and Discussion

RESULTS AND DISCUSSION

The data collected from the three experiments were statistically analysed and the results obtained are presented and discussed in this chapter.

4.1. Standardisation of dehydration techniques for *S. torvum*, *S. nigrum* and *N. nucifera*.

4.1.1. *S. torvum*

4.1.1.1. Effect of blanching on colour and weight of fresh fruits.

The data on the effect of pretreatments on the colour and weight are presented in Table 1. There was no significant variation between pretreatments on the colour of fruits immediately after blanching. The mean values of weight of fruits after blanching which varied between 48.83 g to 50.07 g, was not statistically significant. The sample weight was 50 g. In all treatments except fruits blanched in boiling water (T_1) a reduction in weight was noticed. The slight increase in weight in the boiling water blanching treatment may be due to the reason that some quantity of water would have gained entry into the fruit due to the boiling action of water, whereas in the other hot water blanching treatments, the treatment would only have triggered the evaporation of some quantity of water from the fruits. Part of the soluble solids also would have been lost during the blanching resulting in a weight loss.

The fact that the colour scores did not differ significantly after blanching indicated that the chlorophyll degradation or browning due to blanching was not evident. On the contrary, blanching would have inactivated some of the enzymes

Table 1. Effect of pretreatments on colour and weight of fruits of *S. torvum*

Treatments	Colour (score)	Weight (g)		
		Before treatment	After treatment	Variation + or -
T_1 (Boiling water)	1.2	50.00	50.07	+0.07
T_2 (Hot water at 85°C)	2.4	50.00	49.33	-0.67
T_3 (4% brine at 85°C)	2.6	50.00	49.37	-0.63
T_4 (4% brine + 1% citric acid at 85°C)	2.6	50.00	49.37	-0.63
T_5 (1% citric acid at 85°C)	2.8	50.00	48.83	-1.17
T_6 (4% brine + 0.5% KMS at 85°C)	2.2	50.00	49.00	-1.00
T_7 (0.5% KMS at 85°C)	2.2	50.00	49.20	-0.80
T_8 (control)	1.0	50.00	50.00	0.00
CD	NS		NS	

Score chart of colour -
Light green - 1
Brownish green - 2
Yellowish brown - 3
Brown - 4
Burnt appearance - 5

involved in the breakdown of chlorophyll and also in the browning reactions. Retention of original colour of the raw material is one of the important considerations in vegetable dehydration. To that extent the blanching treatments in the experiment were effective.

4.1.1.2. Effect of pretreatments and methods of dehydration on colour and weight of fruits.

The results showed that pretreatments had no significant effect on the colour of dehydrated fruits (Table 2). But dehydration methods were found to have significant effect on colour retention. In microwave dehydration colour retention was maximum as indicated by a low score (1.5). In the other samples which were dried in sun and in cabinet drier colour retention was much poor. (plates 6, 7 and 8).

The microwave oven dehydration was much shorter in duration when compared to other two methods. The loss in colour is due to chlorophyll degradation and the enzymatic and non enzymatic browning reaction which are directly correlated with temperature (Salunkhe *et al.*, 1976). Exposure to moving air accelerates enzymatic browning which is occuring in sun drying and in cabinet dryers, whereas in microwave oven, dehydration takes place inside a closed chamber. Also the pattern of heat transfer in microwave oven dehydration is much efficient than sundrying and dehydration in cabinet dryer. The colour breakdown in the microwave oven was lesser. Gopalakrishnan and Thomas

Table 2. Effect of pretreatments and methods of dehydration on colour and weight of fruits of *S. torvum*

Treat-ments	Methods of dehydration							
	Sun	Cabinet dryer	Micro-wave oven	Mean	Sun	Cabinet dryer	Micro-wave oven	Mean
	Colour (score)				Weight (g)			
T_1	3.8	1.2	1.2	2.07	13.25	13.20	13.30	13.25
T_2	3.6	4.4	1.4	3.13	13.37	13.37	12.93	13.22
T_3	3.2	4.8	1.4	3.13	13.13	13.60	12.97	13.23
T_4	3.8	4.4	1.6	3.27	13.20	13.13	13.57	13.30
T_5	3.6	4.8	1.6	3.33	12.93	13.40	13.20	13.18
T_6	3.8	4.4	1.2	3.13	13.67	13.40	12.80	13.29
T_7	3.6	4.4	1.6	3.20	13.20	13.10	13.13	13.14
T_8	3.6	4.8	2.0	3.47	13.03	12.97	12.73	12.91
Mean	3.6	4.2	1.5		13.22	13.27	13.03	

H* for		CD for	
Treatments	NS	Treatments (T)	0.25*
Dehydration methods	74.12	Dehydration methods (D)	0.16*
		T x D	0.44*

H* - Kruskell Wallies Statistic   * Significant at 1% level

Score chart for colour: Light green-1, Brownish green-2, Yellowish green-3, Brown-4, Burnt appearance-5

(1992) observed the best colour retention in pepper when subjected to microwave heating.

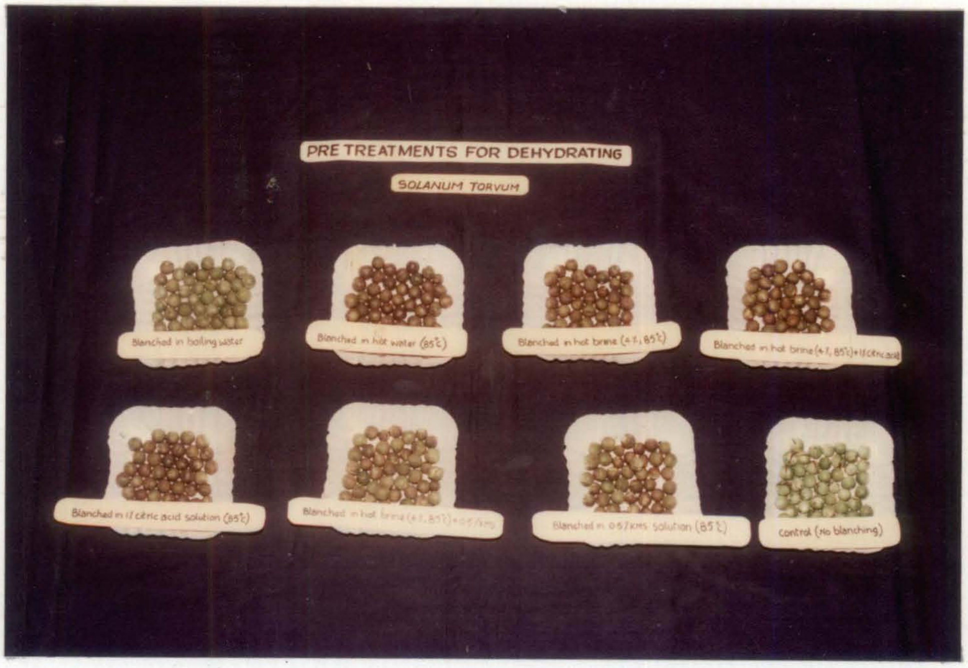
The significant loss of colour in sundried samples and also in cabinet dehydration treatments was obviously due to degradation of chlorophyll and also due to the extensive browning reaction. It is evident from the table that pretreatments did not deteriorate the colour of the samples. This colour loss occurred due to the drying process. In all the cases, the pre-treated samples showed better colour retention than the untreated control sample. This indicated that some of the pretreatments are capable of reducing colour degradation during dehydration. Under microwave oven dehydration, the treatments which retained good colour were T_1 (Boiling water), T_6(four per cent brine + 0.5 per cent KMS at 85^0C), T_2 (Hot water at 85^0C) and T_3 (four per cent brine at 85^0C). Under the cabinet dehydrated samples better colour retention was observed in T_1 (Boiling water).

The better colour retention in boiling water blanched samples may be due to the fact that enzyme inactivation was more during boiling water blanching and therefore, enzymatic browning was prevented resulting in better colour retention (plates 5 and 7).

The data on weight after dehydration are presented in Table 2. All the pretreatments showed a significant effect on the weight of dried fruits after dehydration over control. Maximum weight was obtained in T_4 (four per cent

Plate 5.   Pretreatments for dehydrating *S.torvum*

Plate 6. Sundried products of *S.torvum*


PRE TREATMENTS FOR DEHYDRATING
SOLANUM TORVUM
Blanched in boiling water
Blanched in hot water (85°C)
Blanched in hot brine (4%, 85°C)
Blanched in hot brine (4%, 85°C) + 1% citric acid
Blanched in 1% citric acid solution (85°C)
Blanched in hot brine (4%, 85°C) + 0.5% KMS
Blanched in 0.5% KMS solution (85°C)
Control (No blanching)


SUN DRIED
PRODUCTS OF
SOLANUM TORVUM
Blanched in boiling water
Blanched in hot brine (4%, 85°C)
Blanched in hot water (85°C)
Blanched in 1% citric acid solution (85°C)
Blanched in hot brine (4%, 85°C) + 0.5% KMS
control (no blanching)

brine + one per cent citric acid at 85^{0}C) which was on par with other pretreatments. Lowest weight recovery was obtained in unblanched fruits. This indicated that pretreatments were beneficial for better recovery percentage.

Dehydration in cabinet dryer, which was statistically on par with sundrying was found significantly superior with respect to weight over microwave oven dehydration (Table 2). Further studies are needed to ascertain whether the drying time in microwave dehydration can be further reduced so that recovery will be still better and thus cost reduction can be achieved.

The interaction between pretreatments and dehydration methods was found to be significant. Fruits treated with four per cent brine + 0.5 per cent KMS (T_6) and hot water at 85^{0}C (T_2) and dried in sun, fruits treated with hot water at 85^{0}C (T_2), four per cent brine at 85^{0}C (T_3) and four per cent brine + 0.5 per cent KMS (T_6) and dehydrated in cabinet dryer, fruits treated with boiling water (T_2) and four per cent brine + one per cent citric acid at 85^{0}C (T_4) and dehydrated in microwave oven were found as superior combinations. Fruits dehydrated in microwave oven without giving any pretreatment recorded maximum weight loss. These results indicate that the pretreatments have specific effect under different drying environments. This also emphasized the need for process standardisation in every type of dehydration method.

4.1.1.3. Qualitative characters

Results of data on quality parameters *viz.*, moisture, carbohydrates, crude fibre, ascorbic acid, total alkaloids and iron content are presented in Tables 3 and 4.

The pretreatments and dehydration had no significant effect on the moisture content of dehydrated products. The experiment was so calibrated as to have a more or less uniform moisture content in the products by adopting variable drying time and temperature. Hence this result is justified.

A perusal of data on carbohydrate content of fruits showed that there was significant difference between pretreatments (Fig. 1). Fruits blanched with boiling water (T_1) retained maximum carbohydrate which was statistically on par with one per cent citric acid at 85^0C (T_5). All pretreatments were significantly superior over control.

Fruits dehydrated in microwave oven had shown highest retention of carbohydrate, which was superior to cabinet dryer and sun dried products. It was also observed that products dehydrated in cabinet dryer was superior to sundried products.

As far as dehydration methods were concerned microwave oven dehydration was the best treatment compared to rest two (Fig. 2). Cabinet drying was significantly superior to sundrying also. In sun drying since sample was kept in an open environment, a part of carbohydrate would have been converted to liquid and gaseous products by the microorganisms during the initial stages of drying resulting in weight loss. Such a condition was not existing in cabinet dryer

Table 3. Effect of pretreatments and methods of dehydration on moisture, carbohydrate and crude fibre content of fruits of *S. torvum* (dry weight basis)

Treatments	Method of dehydration											
	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean
	Moisture (%)				Carbohydrate (%)				Crude fibre (%)			
T_1	7.40	7.40	7.20	7.33	10.40	14.50	25.10	16.67	45.75	46.80	54.22	48.93
T_2	7.37	7.53	7.23	7.38	9.60	9.00	24.40	14.33	47.48	51.49	46.69	48.55
T_3	7.40	7.50	7.27	7.39	9.40	7.60	18.40	11.80	44.02	43.06	52.23	46.44
T_4	7.47	7.53	7.20	7.40	7.20	15.40	19.80	14.13	45.72	44.71	45.54	45.32
T_5	7.43	7.53	7.20	7.39	14.00	11.40	23.10	16.17	47.67	52.80	48.15	49.54
T_6	7.57	7.40	7.27	7.41	8.60	9.80	17.10	11.83	46.65	54.84	48.39	49.96
T_7	7.40	7.40	7.17	7.32	8.20	8.60	22.60	13.13	46.85	44.11	56.07	49.01
T_8	7.47	7.43	7.20	7.37	11.87	8.60	10.40	10.29	45.61	40.72	46.15	44.16
Mean	7.44	7.47	7.22		9.91	10.61	20.11		46.22	47.32	49.68	

CD for			
Treatments (T)	NS	0.54*	2.32*
Dehydration methods (D)	NS	0.35*	1.42*
T x D	NS	0.98*	4.02*

*Significant at 1% level

or microwave oven. It is believed that microwave ovens inactivate microbes by conventional thermal mechanism namely thermal denaturation of microbial proteins. At a molecular level, microwaves could interfere with the mechanism of bonding of dipicolinic acid to calcium and or cause reorientation in the thermostable protein content in the DNA of microbes (Khalil and Villota, 1986). This phenomenon, coupled with short process time would have arrested any possible microbial degradation of carbohydrates and other materials in the samples kept in microwave oven.

The interaction between pretreatments and dehydration methods was also significant. Fruits treated with T_1 (boiling water) T_2 (hot water at 85^0C) treatments followed by microwave oven dehydration were the superior combinations. It was closely followed by treatments T_5 (one per cent citric acid at 85^0C) and T_7 (0.5 per cent KMS at 85^0C) under microwave oven dehydration itself. The lowest value for carbohydrate content was obtained in fruits treated with four per cent brine + one per cent citric acid at 85^0C (T_4) and sundried.

The interaction effect also supports the observation that microwave oven dehydration was superior in the retention of carbohydrate and indicated that some of the pretreatments had a better capability in the retention of carbohydrates. But this was evident only under the microwave oven dehydrated samples.

Perusal of data on crude fibre content of fruits showed that all pretreatments were significantly superior over control in retaining the crude fibre

Fig. 1. Effect of pretreatments on moisture, carbohydrate, crude fibre and total alkaloid contents of *S. torvum*

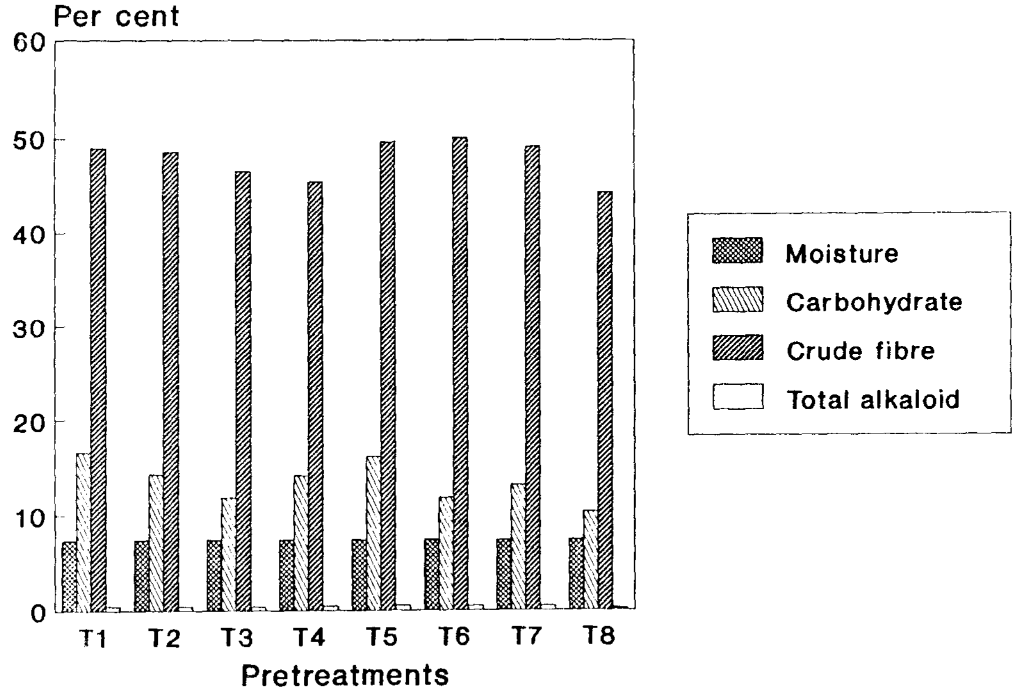
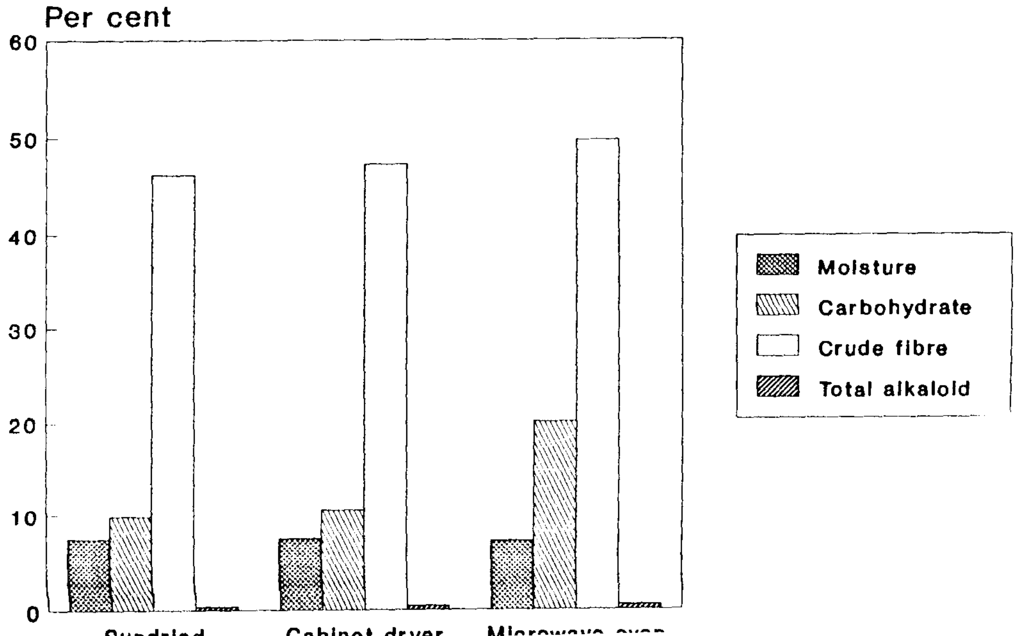


Fig. 2. Effect of dehydration methods on moisture, carbohydrate, crude fibre and total alkaloid contents of *S. torvum*



content (Fig. 1). Maximum crude fibre was in fruits treated with four per cent brine + 0.5 per cent KMS at 85⁰C (T_6). This pretreatment was statistically on par with T_1 (boiling water), T_2 (hot water at 85⁰C), T_5 (one per cent citric acid at 85⁰C) and T_7 (0.5 per cent KMS at 85⁰C). Crude fibre content of fruits dehydrated without subjecting to any pretreatments was minimum.

The polysaccharidic substances cellulose, hemicellulose along with pectin and lignin contribute to the fibre content of vegetables. Pectin substances constitute on a dry weight basis about 30 per cent the material of primary cell walls of vegetables (Luh and Woodroof, 1988). Pectin degradation, which occurs by demethylation and depolymerization (Van Buren, 1979) can be enzymatic or chemically catalysed by acid. In unblanched fruits enzymatic activities [illegible] relatively high and pectin degradation would have taken place. This may be the reason for low crude fibre content of unblanched fruits.

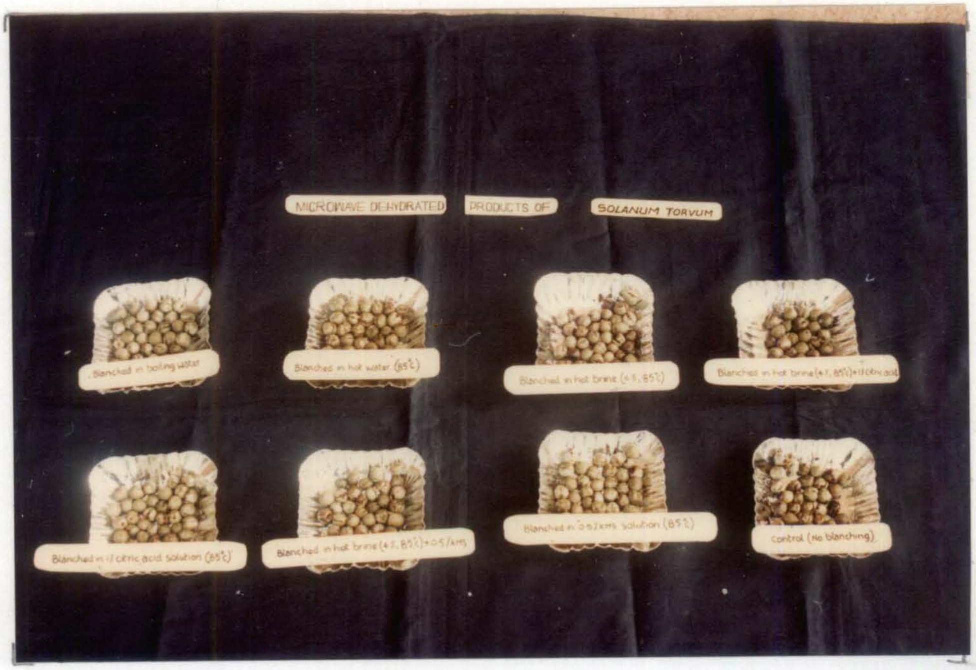
As far as dehydration methods were concerned, crude fibre content of samples under microwave oven dehydration was significantly superior to both sun drying and dehydration in cabinet dryer which were statistically on par with each other (Fig. 2). The degradation and depolymerisation of cellulose may be possibly associated with the length of process time also. The extended process time during cabinet and sundrying process would have resulted in lower crude fibre content. This chance is very much restricted under microwave oven treatment.

The superior treatment combinations were T_7 (0.5 per cent KMS at 85⁰C),

Plate 7. Products of *S.torvum* dehydrated in cabinet dryer

Plate 8. Microwave dehydrated products *S.torvum*


PRODUCTS OF SOLANUM TORVUM DEHYDRATED IN CABINET DRIER
AFTER SUBJECTING TO DIFFERENT PRETREATMENTS
Blanched in boiling water
Blanched in hot water (85°C)
Blanched in hot brine (4%, 85°C)
Blanched in hot brine (4%, 85°C)+1% citric acid
Blanched in 1% citric acid solution (85°C).
Blanched in hot brine (4%, 85°C)+0.5% KMS
Blanched in 0.5% KMS solution (85°C)
Control (No blanching)


MICROWAVE DEHYDRATED PRODUCTS OF SOLANUM TORVUM
Blanched in boiling water
Blanched in hot water (85°C)
Blanched in hot brine (4%, 85°C)
Blanched in hot brine (4%, 85°C)+1% citric acid
Blanched in 1% citric acid solution (85°C)
Blanched in hot brine (4%, 85°C)+0.5% KMS
Blanched in 0.5% KMS solution (85°C)
Control (No blanching)

T_1 (boiling water) and T_3 (four per cent brine at 85^0C) under microwave oven dehydration and T_5 (one per cent citric acid at 85^0C) and T_6 (four per cent brine + 0.5 per cent KMS at 85^0C) followed by dehydration in cabinet dryer . The lowest value for crude fibre was obtained when fruits were dehydrated in cabinet dryer without subjecting to any pretreatment. KMS and brine are antimicrobial antienzymatic agents. Thus,these treatments would have checked the break down of carbohydrates. The increased acidity due to addition of citric acid also would have posed certain restrictions on microbial and enzymatic activity on the samples. The fact that untreated samples registered the lowest value suggests that pretreatments had positive effect in the retention of crude fibre.

The data on ascorbic acid content are presented in Table 4. Fruits treated with 0.5 per cent KMS at 85^0C werefound to retain maximum ascorbic acid which was significantly superior to all other treatments (Fig. 3). It was closely followed by T_6 (four per cent brine + 0.5 per cent KMS at 85^0C) which was superior to all other treatments. Ascorbic acid may be destroyed during non-enzymatic browning, but sulphiting before drying retards browning by ascorbic acid (Ranganath and Dubash, 1981). Pawar *et al.* (1988) studied solar drying of white onion flakes and reported that retention of ascorbic acid was more in samples treated with 0.25 per cent KMS for five minutes than in the control. Mulay *et al.* (1994) reported that KMS treated samples retained higher amount of ascorbic acid in dehydrated cabbage. They attributed this to the inhibition of oxidative changes of ascorbic acid by SO_2.

Table 4. Effect of pretreatments and methods ofdehydration on ascorbic acid, iron and alkaloid content of fruits of *S. torvum* (dry weight basis)

Treatments	Methods of dehydration											
	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean
	Ascorbic acid (mg/100 g)				Iron (mg/100 g)				Total alkaloid (%)			
T_1	22.96	26.2	32.75	26.64	1.25	3.05	5.35	3.22	0.39	0.48	0.50	0.46
T_2	32.75	36.68	39.30	36.24	1.78	2.90	3.40	2.69	0.34	0.31	0.58	0.41
T_3	32.75	42.75	39.30	38.60	2.80	4.00	5.80	4.20	0.21	0.41	0.61	0.41
T_4	20.96	39.3	26.2	28.82	1.58	3.15	3.50	2.74	0.23	0.54	0.71	0.49
T_5	42.75	23.58	39.3	35.21	2.00	2.60	5.45	3.35	0.54	0.55	0.58	0.56
T_6	52.40	56.77	52.40	53.86	1.37	4.65	5.20	3.74	0.41	0.60	0.37	0.46
T_7	52.40	56.77	56.76	55.31	1.95	4.26	4.48	3.56	0.46	0.25	0.68	0.46
T_8	39.30	39.30	42.75	40.45	1.65	2.90	5.10	3.21	0.18	0.16	0.28	0.21
Mean	38.70	39.20	40.28		1.80	3.44	4.78		0.35	0.41	0.54	
CD for												
Treatments (T)				1.39*				0.58*				0.08*
Dehydration method (D)				0.86*				0.35*				0.05*
T x D				2.42*				0.99*				0.14*

* Significant at 1% level

The ascorbic acid content was minimum in boiling water blanched fruits. This may probably be due to the reason that, the ascorbic acid being readily water soluble and heat sensitive this loss would have taken place (Salunkhe *et al.*, 1976).

In microwave oven dehydrated fruits ascorbic acid retention was maximum (Fig. 4). The loss of ascorbic acid was very high in sun dried fruits. The shorter duration of drying in microwave oven could be the possible reason for the higher retention of ascorbic acid as compared to the other two drying methods. Rapid drying retains greater amounts of ascorbic acid than does slow drying (Salunkhe *et al.*, 1976). Campbell *et al.* (1958) noted that the ascorbic acid contents of cabbage and broccoli cooked with microwave oven were significantly higher than those cooked with conventional heating. Dietrich *et al.* (1970) compared microwave, steam and water blanching and reported that microwave blanching resulted in better ascorbic acid retention in brussel sprouts. Quenzer (1980) reported that cell structure remained intact during microwave blanching and so it was the best method for ascorbic acid retention in spinach.

The interaction of pretreatments and dehydration methods was also found significant. Fruits treated with 0.5 per cent KMS at 85^{0}C and dehydrated in microwave oven and fruits treated with four per cent brine + 0.5 per cent KMS at 85^{0}C and dehydrated in cabinet dryer were the best treatment combinations. There was a significant reduction of ascorbic acid in fruits blanched in boiling water and dried in sun. The beneficial effect of KMS treatment was more pronounced under microwave oven dehydration. The beneficial effect of KMS and brine in retention of ascorbic acid is already explained. This indicates that there is scope for exploitation of these pretreatments in different drying procedures for getting products of better nutritional value.

Data on the iron content of fruits are presented in Table 4. Maximum iron content was in fruits treated with four per cent brine at 85°C (T_3) and four per cent brine + 0.5 per cent KMS at 85°C (T_6) which was significantly superior to all other treatments including control. Lowest iron content was found in fruits treated with hot water at 85°C. Veenakumari (1992) observed a higher retention of iron in five per cent brine pretreated bittergourd slices.

In the case of dehydration methods, iron retention was maximum in fruits dehydrated in microwave oven which was significantly superior to dehydration in cabinet dryer and sundrying. Dehydration in cabinet dryer was also found superior to sundrying (Fig. 4).

There was a significant effect for interaction between pretreatments and dehydration methods. The best combinations were T_1 (boiling water), T_3 (four per cent brine at 85°C), T_5 (one per cent citric acid at 85°C) and T_6 (four per cent brine + 0.5 per cent KMS at 85°C) followed by dehydration in microwave oven for retaining the iron content of fruits. The minimum iron content was found in fruits blanched in boiling water and dehydrated in cabinet dryer.

Total alkaloids were significantly influenced by pretreatments as presented in Table 4. All pretreatments were significantly superior to control in alkaloid

Fig. 3. Effect of pretreatments on ascorbic acid and iron contents of *S. torvum*

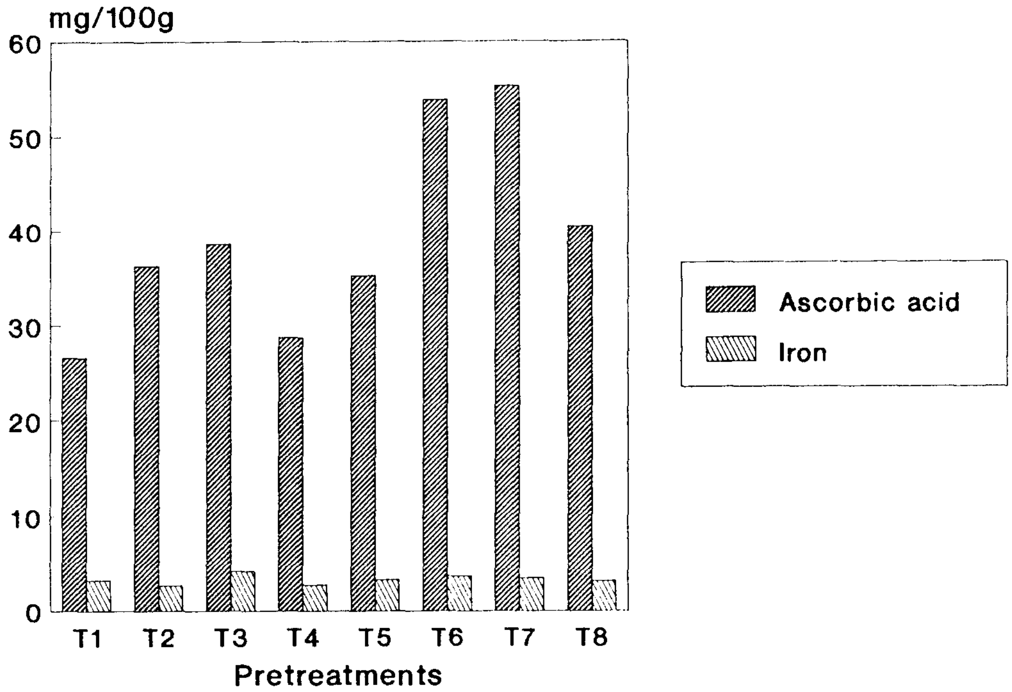
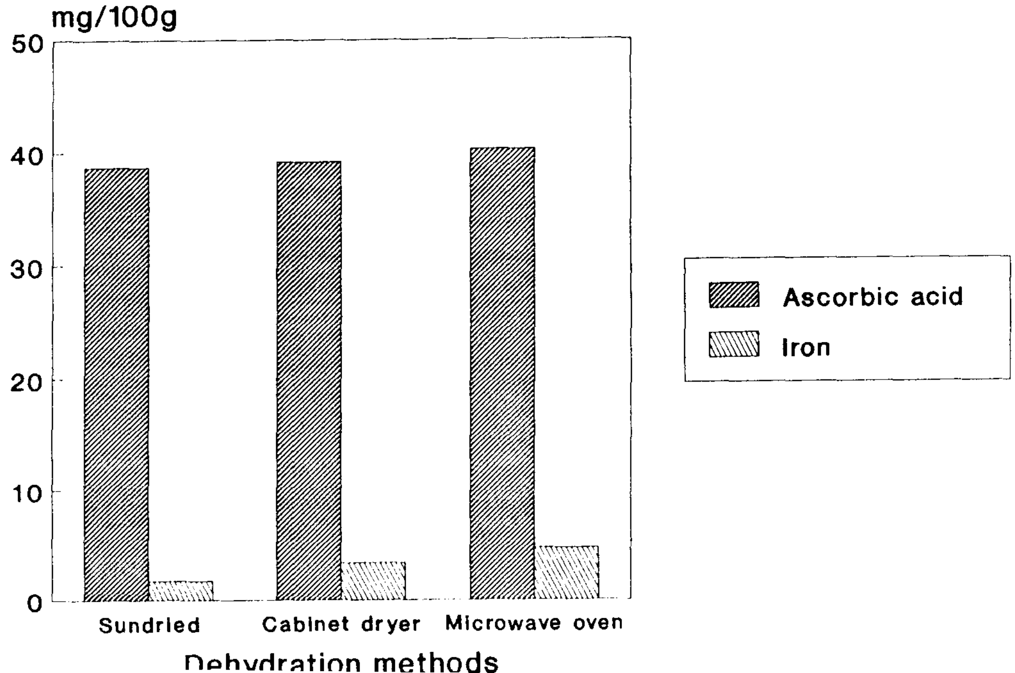


Fig. 4. Effect of dehydration methods on ascorbic acid and iron contents of *S. torvum*



retention. Fruits treated with one per cent citric acid alone or in combination with four per cent brine was found statistically superior to all other treatments. They were closely followed by T_7 (0.5 per cent KMS at 85^0C), T_6 (four per cent brine + 0.5 per cent KMS at 85^0C) and T_1 (boiling water).

The major alkaloids present in *S. torvum* are steroline and solasonine (Chopra *et al.,* 1956). The increased acidity due to citric acid treatment would have resulted in the checking of chemical processes resulting in the loss of alkaloids. A similar effect would have been achieved by the KMS and brine treatments also. Further studies are required to ascertain the exact mechanism of action of pretreatments on the alkaloid content in the samples.

The data also showed that microwave oven dehydration was highly superior with respect to alkaloid retention compared to dehydration in cabinet dryer and sundrying. Dehydration in cabinet dryer was also found superior to sundrying. It may probably be due to the difference in the duration of time for these drying procedures.

The significant treatment combinations as evident from the table were T_4 (four per cent brine + one per cent citric acid at 85^0C), T_5 (one per cent citric acid at 85^0C), T_7 (0.5 per cent KMS at 85^0C), T_6 (four per cent brine + 0.5 per cent KMS at 85^0C) and T_3 (four per cent brine at 85^0C) under microwave oven dehydration. Though these treatment combinations were statistically on par, T_4 (four per cent brine + one per cent citric acid at 85^0C) resulted in the maximum alkaloid content after subjecting to microwave oven dehydration. Lowest alkaloid content was noticed in control under the three dehydration methods tried. To explain the exact reason for this specific effect of alkaloid retention with the brine and citric acid treatment, detailed studies are required.

4.1.1.4. Dehydration ratio

The data on dehydration ratio are presented in Table 5. Better dehydration ratio (3.75:1) was recorded in fruits treated with four per cent brine + 0.5 per cent KMS at 85^{0}C which was statistically on par with all other treatments except T_4 (four per cent brine + one per cent citric acid). Poor dehydration ratio (3.85:1) was found in T_4. Increased concentration of KMS solution would have helped an increased dehydration ratio as it increases energy absorption by the product (Van Arsdel *et al.*, 1973). Luhadiya and Kulkarni (1978) studied dehydration of green chillies and found that highest dehydration ratio was in samples treated with SO_2. Mulay *et al.* (1994) studied the effect of pretreatment on quality of dehydrated cabbage and reported that dehydration ratio was higher in samples treated with 0.5 per cent KMS solution. The data suggests that pretreatments could have an influence on the dehydration ratio. As the pretreatments can affect the microbial and enzymatic processes taking place in the samples during drying, such variations are possible. In the present study, the actual figures did not show much variation with respect to dehydration ratio. Studies with larger samples may be required to ascertain this phenomenon correctly.

Table 5. Effect of pretreatments and methods of dehydration on dehydration ratio and rehydration ratio of fruits of *S. torvum*

Treatments	Methods of dehydration							
	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer oven	Microwave	Mean
	Dehydration ratio				Rehydration ratio			
T_1	3.78:1	3.78:1	3.76:1	3.78:1	1:2.50	1:2.50	1:2.91	1:2.64
T_2	3.75:1	3.75:1	3.82:1	3.78:1	1:2.31	1:2.38	1:2.92	1:2.54
T_3	3.81:1	3.66:1	3.86:1	3.78:1	1:2.57	1:2.50	1:2.84	1:2.64
T_4	3.79:1	3.81:1	3.94:1	3.85:1	1:2.40	1:2.61	1:2.61	1:2.54
T_5	3.71:1	3.86:1	3.78:1	3.78:1	1:2.65	1:2.46	1:2.57	1:2.56
T_6	3.82:1	3.72:1	3.70:1	3.75:1	1:2.43	1:2.78	1:2.73	1:2.65
T_7	3.75:1	3.81:1	3.81:1	3.79:1	1:2.65	1:2.87	1:2.92	1:2.81
T_8	3.89:1	3.73:1	3.67:1	3.76:1	1:2.33	1:2.17	1:2.42	1:2.30
Mean	3.78:1	3.77:1	3.79:1		1:2.48	1:2.53	1:2.74	
CD for								
Treatments (T)				0.08*				0.05*
Dehydration methods (D)				NS				0.03*
T x D				0.10*				0.09*

*Significant at 1% level

As far as dehydration methods were concerned there was no significant difference. Since the drying procedures were so standardised to arrive at a more or less similar moisture content, such a result was anticipated.

Interaction between pretreatments and dehydration methods was found significant. T_2 (hot water at 85^{0}C), T_3 (four per cent brine at 85^{0}C), T_6 (four per cent brine + 0.5 per cent KMS at 85^{0}C) followed by dehydration in cabinet dryer, and T_2 (hot water at 85^{0}C), T_5 (one per cent citric acid at 85^{0}C) and T_7 (0.5 per cent KMS at 85^{0}C) after sundrying and T_6 (four per cent brine + 0.5 per cent KMS at 85^{0}C) under microwave oven dehydration were the superior treatment combinations which resulted in better dehydration ratio. Fruits dried in sun without subjecting to any pretreatment resulted in poorer dehydration ratio. The significant effect of some of the interaction suggest that there exist scope for recommending such pretreatments during drying of *S. torvum*. The cumulative effect of better retention of carbohydrates, crude fibre etc. by the pretreatments, which is already explained earlier would have resulted in this net effect of dehydration ratio.

4.1.1.5. Rehydration ratio

The data on rehydration ratio showed that T_7 (0.5 per cent KMS at 85^{0}C) was significantly superior to all other treatments. It was followed by T_6 (four per cent brine + 0.5 per cent KMS at 85^{0}C), T_3 (four per cent brine at 85^{0}C) and T_1 (boiling water). All pretreatments were superior over control (T_8) which showed the lowest rehydration ratio.

All the pretreated samples had higher rehydration ratio than the unblanched sample. This may be attributed to increased water absorption due to increased porousness of cell wall in dried samples which received a blanching treatment (Srivastava and Sulebele, 1975). Pruthi *et al.* (1978) studied the dehydration of tropical paddy straw mushroom (*Volvariella volvaceae*) and found that samples treated with KMS had higher rehydration ratio. Better rehydration ratio indicates better retention of the cellular configuration even after drying. Thus rehydration ratio can be considered as an indicator of the cellular integrity of the dehydrated sample.

Highest rehydration ratio was recorded in samples dehydrated in microwave oven which was superior to dehydration in cabinet dryer and sundrying. Dehydration in cabinet dryer was also found superior to sundrying. In microwave treatment, the uniform penetrability of the microwaves offers least resistance, as compared to the other dehydration treatments on the cell walls of the samples. This may be reason for the smooth appearance of the samples dehydrated in microwave oven. Wherever the shape retention is better, rehydration will also be more efficient. This is the reason for the better performance of samples dehydrated in microwave oven. In sundrying, the shape disruption is maximum due to uneven moisture loss from individual cells ultimately resulting in poor rehydration.

Mudahar and Bains (1982) studied the pretreatment effect on quality of dehydrated mushroom (*Agaricus bisporus*) and found that rehydration values of sun dried samples were below those of hot air dried samples. The present study also supports this view.

The interaction between pretreatments and dehydration method was also significant. T_1 (boiling water),T_2 (hot water at 85°C),T_3 (four per cent brine at 85°C) and T_7 (0.5 per cent KMS at 85°C) followed by dehydration in microwave oven and T_7 (0.5 per cent KMS at 85°C) under dehydration in cabinet dryer were resulted in rehydration ratio which were superior to all other treatment combinations. The interaction effect suggests the possibility of finding out the best possible pretreatment under each drying situation. Further studies with larger samples may have to conducted before arriving at such conclusions.

4.1.2. *Solanum nigrum*

4.1.2.1. Effect of blanching on colour and weight of fresh fruits.

The data on the effect of pretreatments on the colour and weight are presented in Table 6. There was no significant variation between pretreatments on the colour of fruits immediately after blanching (plate 9). There was significant reduction in weight after blanching in treatments T_2 (four per cent brine at 85°C) and T_3 (four per cent brine + one per cent citric acid). All other pretreatments were on par with the unblanched treatment. The weight reduction may possibly be due to the loss of some soluble solids and that of water due to

Table 6. Effect of pretreatments on colour and weight of fruits of *S. nigrum*

Treatments	Colour (score)	Weight (g)		
		Before treatment	After treatment	Variation + or -
T_1 (Hot water at 85°C)	1.6	50.00	49.67	-0.33
T_2 (4% brine at 85°C)	1.4	50.00	48.33	-1.67
T_3 (4% brine + 1% citric acid at 85°C)	1.4	50.00	48.00	-2.00
T_4 (1% citric acid at 85°C)	1.4	50.00	49.33	-0.67
T_5 (4% brine + 0.5% KMS at 85°C)	1.6	50.00	49.33	-0.67
T_6 (0.5% KMS at 85°C)	1.4	50.00	49.67	-0.33
T_7 (Control)	1.0	50.00	50.00	0.00
CD	NS		0.89*	

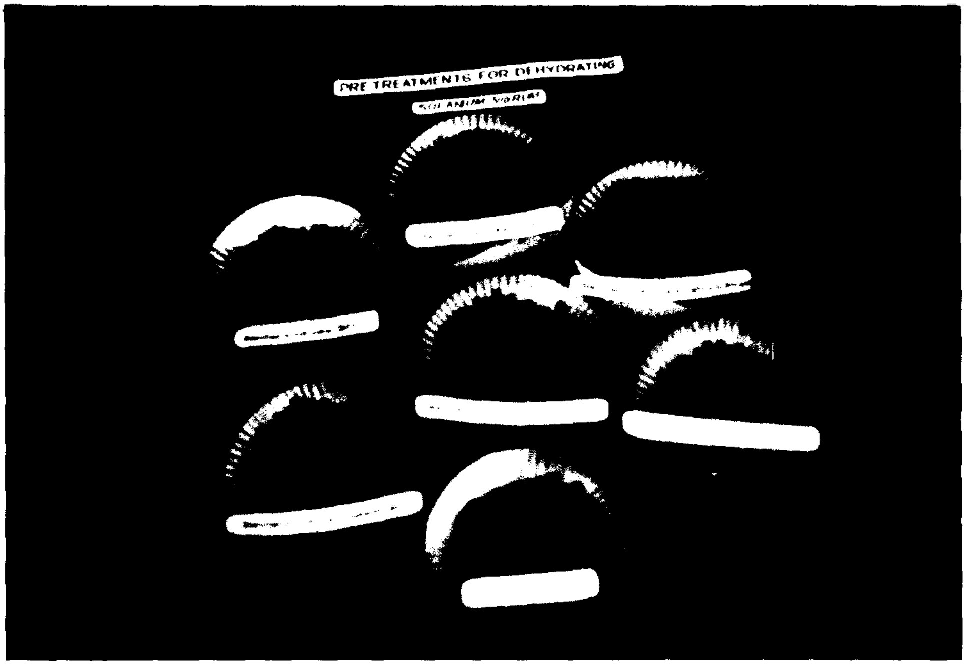
Score chart for colour -

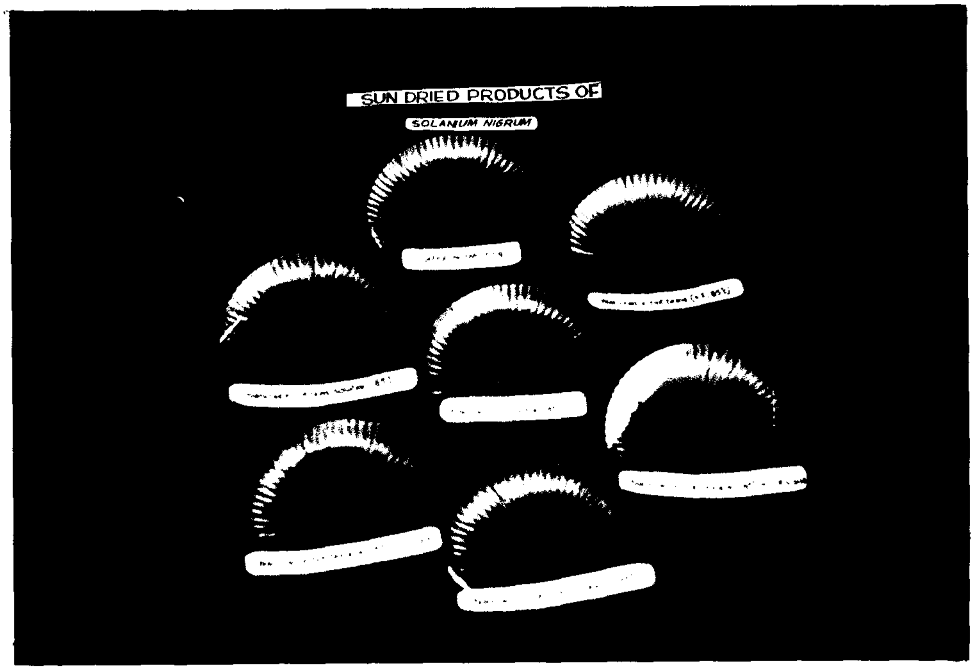
Light green	1
Brownish green	2
Yellowish brown	3
Brown	4
Burnt appearance	5

*Significant at 1% level

Plate 9. Pretreatments for dehydrating *S.nigrum*

Plate 10. Sundried products of *S.nigrum*


PRE TREATMENTS FOR DEHYDRATING
SOLANUM NIGRUM


SUN DRIED PRODUCTS OF
SOLANUM NIGRUM

osmotic action and evaporation. Lee (1958) reported that small weight losses of blanched snap beans were due to vapourisation or exudation of cellular juices.

4.1.2.2. Effect of pretreatments and method of dehydration on colour and weight of fruits.

The results of analysis showed that pretreatments had no significant effect on the colour of dehydrated fruits (Table 7). But dehydration methods had significant effect on colour. It can be seen there was general degradation of green colour in all dehydrated samples as compared to the fresh sample. However, treatments did not differ significantly. In sundried samples colour retention was very poor (plates 10, 11 and 12). Gupta and Nath (1984) studied drying of tomatoes and reported that sun dried samples had lighter colour than those dried in cabinet dryer. Ramana *et al.* (1988) conducted a study on the effect of dehydration methods on the colour of dehydrated fenugreek and mustard leaves and reported that sun dried samples had considerable changes in chlorophyll contents compared to solar cabinet dried and tray dried samples. Jayaraman *et al.* (1991) reported a significant loss of pigments in direct sundrying of peas . The present study also supports this view. Eventhough, in the case of *S. torvum*, colour retention was better in microwave oven dehydration, the same trend was not seen in this case. This may probably be due to the reason that *S. nigrum* fruits have a thin skin compared to *S. torvum* and therefore, effect of browning and chlorophyll degradation became more evident. Another reason could be that, in this case the drying time in the microwave oven was thirty

Table 7. Effect of pretreatments and methods of dehydration on colour and weight of fruits of *S. nigrum*

Treatments	Methods of dehydration							
	Sun	Cabinet dryer	Micro-wave oven	Mean	Sun	Cabinet dryer	Micro-wave oven	Mean
	Colour (score)				Weight (g)			
T_1	3.2	1.6	4.4	3.07	8.27	8.13	8.07	8.16
T_2	3.2	1.8	4.4	3.13	8.03	8.13	8.13	8.10
T_3	3.4	1.6	4.2	3.07	8.20	8.00	8.50	8.23
T_4	2.8	1.8	4.2	2.93	8.50	8.16	8.53	8.40
T_5	3.2	2.0	4.8	3.33	8.30	7.93	8.03	8.09
T_6	3.6	1.6	4.6	3.27	8.33	8.16	8.20	8.23
T_7	3.2	1.4	4.6	3.07	8.10	7.96	8.04	8.03
Mean	3.23	1.69	4.46		8.25	8.07	8.21	

Colour score for fresh sample : 1.0

H* for		CD for	
Treatments	NS	Treatments (T)	0.12*
Dehydration methods	82.09	Dehydration methods (D)	0.07*
		T x D	0.20*

H* - Kruskell Wallies Statistic *Significant at 1% level

Score chart for colour: Light green-1, Brownish green-2, Yellowish brown-3, Brown-4, Burnt appearance-5 minutes at thirty per cent and ninety per cent power levels. Probably this extended drying time also paved way for more loss of green colour. Chen and Chen (1993) studied the effects of microwave cooking and stability of chlorophyll and carotenoids in sweet potato leaves and reported that the content of each pigment decreased with increasing heating time. Thus for better colour retention in *S. nigrum* further refinements in the process time may be required under microwave dehydration.

Maximum weight recovery was obtained in T_4 (one per cent citric acid at 85^0C) which was statistically superior to all treatments. It was followed by T_1 (Hot water at 85^0C), T_3 (four per cent brine + one per cent citric acid at 85^0C) and T_6 (0.5 per cent KMS at 85^0C) which were statistically on par. Lowest value for weight was obtained in unblanched fruits. A similar trend was obtained in *S. torvum* also. Mulay *et al.* (1994) have reported a similar gain in KMS treated cabbage after dehydration. He has explained that the increased water absorption due to increased porousness of cell wall in dried sample because of the blanching could be the possible reason for the increased weight.

Dehydration in microwave oven, which was statistically on par with sundrying, was found significantly superior with respect to weight over dehydration in cabinet dryer. The better efficiency of microwave oven in higher recovery is observed here. The lower weight recovery in cabinet dryers may probably be due to the high treatment temperature and movement of hot air

Plate 11. Products of *S.nigrum* dehydrated in cabinet dryer

Plate 12. Microwave dehydrated products of *S.nigrum*


PRODUCTS OF SOLANUM NIGRUM DEHYDRATED IN CABINET DRIER
AFTER SUBJECTING TO DIFFERENT PRETREATMENTS
*Blanched in 1% citric acid solution (85°C)
Blanched in hot brine (4%, 85°C)+1% citric acid
Blanched in hot brine (4%, 85°C)+0.5%KMS
Control (No blanching)
Blanched in 0.5%KMS solution (85°C)
Blanched in hot water (85°C)
Blanched in hot brine (4%, 85°C)


MICROWAVE DEHYDRATED PRODUCTS OF SOLANUM NIGRUM
Blanched in hot brine (4%, 85°C)

which would have resulted in more evaporation of water, volatiles and loss of solids.

The interaction between pretreatments and dehydration methods was also found significant. Fruits treated with four per cent brine + one per cent citric acid (T_3) and one per cent citric acid (T_4) under microwave oven dehydration and fruits treated with one per cent citric acid at 85⁰C (T_4) and 0.5 per cent KMS at 85⁰C (T_6) and sundried were found as superior combinations. Fruits dehydrated in cabinet dryer without giving any pretreatments recorded maximum weight loss. This indicates that specific pretreatments have to be standardised for each method of dehydration. The drying methods being quite different in their characteristics, the effects of blanching treatments may also have different net effect.

4.1.2.3. Qualitative characters.

Results of data on quality parameters *viz.*, moisture, carbohydrate, crude fibre, total sugar, reducing sugar, non reducing sugar, ascorbic acid, iron and total alkaloid content are presented in Tables 8, 9 and 10. The pretreatments and dehydration methods had no significant effect on the moisture content of dehydrated products (Fig. 5 and 6). This was purposefully done by adjusting the drying time, temperature etc. so that the dried samples does not show significant variability with respect to moisture content.

Perusal of data on carbohydrate content of dehydrated fruits showed that there was significant difference between pretreatments (Fig. 5). Fruits blanched

Table 8. Effect of pretreatments and methods of dehydration on moisture, carbohydrate, crude fibre content of fruits of *S. nigrum* (dry weight basis)

Treatments	Methods of dehydration											
	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean
	Moisture (%)				Carbohydrate (%)				Crude fibre (%)			
T_1	7.50	7.53	7.30	7.44	21.20	20.67	17.20	19.69	25.24	31.51	38.56	28.44
T_2	7.50	7.50	7.17	7.39	18.67	13.80	21.00	17.82	28.67	29.08	29.23	28.99
T_3	7.40	7.40	7.17	7.32	14.60	18.80	25.00	19.47	26.94	27.69	28.49	27.71
T_4	7.50	7.57	7.20	7.42	14.60	16.20	22.80	17.87	26.62	30.55	32.30	29.82
T_5	7.50	7.53	7.23	7.42	17.60	19.00	17.00	17.87	23.38	28.92	30.13	27.48
T_6	7.50	7.60	7.23	7.44	13.20	17.20	21.00	17.13	26.26	28.61	28.17	27.68
T_7	7.50	7.53	7.20	7.38	12.20	13.20	21.00	15.47	24.95	29.64	27.81	27.47
Mean	7.49	7.52	7.21		16.01	16.98	20.71		26.01	29.42	29.24	

CD for			
Treatments (T)	NS	1.13*	1.59*
Dehydration methods (D)	NS	0.74*	1.01*
Tx D	NS	1.96*	2.74*

*Significant at 1% level

with hot water at 85^0C retained maximum carbohydrate content which was statistically on par with fruits treated with four per cent brine + one per cent citric acid at 85^0C (T_3). Treatments T_2 (four per cent brine at 85^0C),T_5 (four per cent brine + 0.5 per cent KMS at 85^0C), T_4 (one per cent citric acid at 85^0C) and T_6 (0.5 per cent KMS at 85^0C) were on par but had higher carbohydrate content than the control treatments. Fruits dehydrated without subjecting to any pretreatment showed minimum value for carbohydrate content.

Citric acid which is an acidulent can also act as a sterilising aid (Gardner, 1977). Bacteria and many spores of other organisms are more easily killed in acid media (Williams, 1951). Organic acids prevent spore germination at a much higher P^H than do inorganic acids. So citric acid would have posed certain restrictions on microbial and enzymatic activity on the sample. This may be the reason for higher carbohydrate content in fruits treated with citric acid. The fact that untreated samples registered the lowest value suggest that the pretreatments had positive effects on the retention of carbohydrate.

Fruits dehydrated in microwave oven had shown highest retention of carbohydrate which was significantly superior to products dehydrated in cabinet dryer and dried in sun (Fig. 6).

As far as dehydration methods were concerned microwave oven dehydration stood as the best treatment compared to the rest two. In sundrying, since samples kept in an open environment a part of carbohydrate would have

Fig. 5. Effect of pretreatments on moisture, carbohydrate, crude fibre and total alkaloid contents of *S. nigrum*

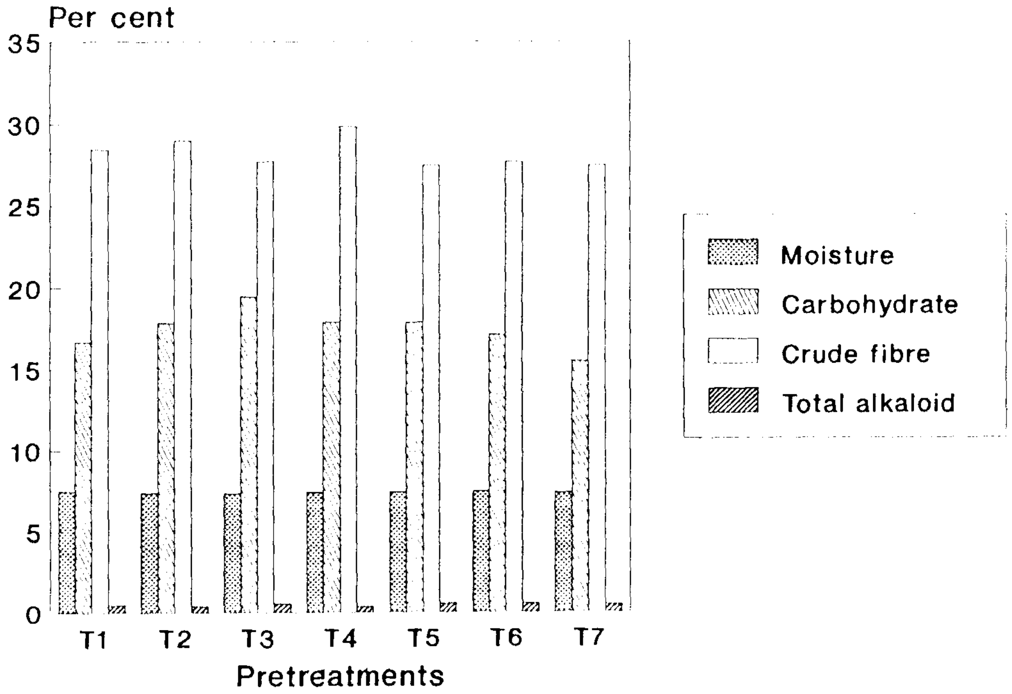
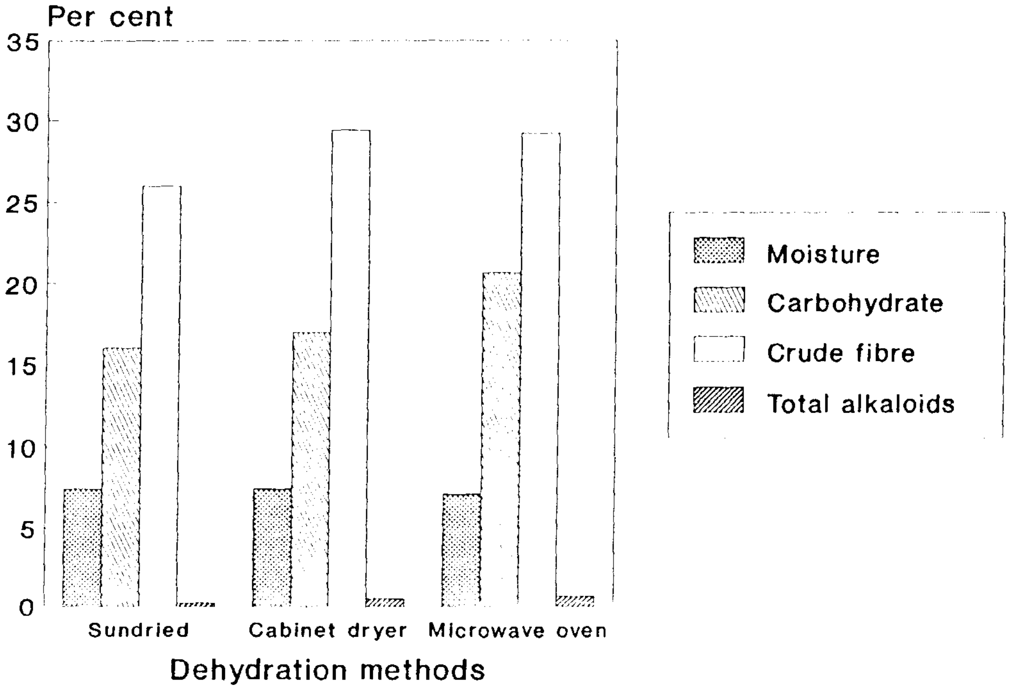


Fig. 6. Effect of dehydration methods on moisture, carbohydrate, crude fibre and total alkaloid contents of *S. nigrum*



been converted to liquid and gaseous products by the microorganisms during the initial stages of drying resulting in weight loss. Such a condition was not existing in microwave oven. It is believed that microwaves inactivate microbes by conventional thermal mechanisms *viz*., thermal denaturation of microbial protein. At a molecular level microwaves could interfere with the mechanism of bonding of dipicolinic acid to calcium and or cause reorientation in thermostable protein content in the DNA of microbes (Khalil and Villota, 1986). This phenomenon, coupled with short process time would have arrested any possible microbial degradation of carbohydrates and other materials in the samples kept in microwave oven.

The interaction between pretreatments and dehydration methods was also significant. Fruits treated with four per cent brine + one per cent citric acid at 85°C (T_3) and dehydrated in microwave oven showed highest retention of carbohydrate content. It was followed by T_2 (four per cent brine at 85°C), T_4(one per cent citric acid at 85°C) and T_6 (0.5 per cent KMS at 85°C) under microwave oven dehydration and T_1 (hot water at 85°C) under sundrying. Sun dried fruits without subjecting to any pretreatments resulted in minimum carbohydrate content.

The interaction effect also supports the observation that microwave oven dehydration is superior in the retention of carbohydrate and indicates that some of the pretreatments have a better capability in the retention of carbohydrates. But this is evident only under the microwave oven treated samples. This also supports the view that sundrying results in more carbohydrate loss which is already discussed in the previous paras.

The data on crude fibre content of fruits showed that maximum value for crude fibre was obtained in fruits treated with one per cent citric acid at 85^0C (T_4) which was significantly superior to all other treatments (Fig. 5). It was closely followed by T_2 (four per cent brine at 85^0C). Minimum value for crude fibre was obtained in fruits dehydrated without subjecting to any pretreatment, which was statistically on par with T_1 (hot water at 85^0C), T_3 (four per cent brine + one per cent citric acid at 85^0C), T_5 (four per cent brine + 0.5 per cent KMS at 85^0C) and T_6 (0.5 per cent KMS at 85^0C).

The polysaccharidic substances cellulose hemicellulose along with pectin and lignin contribute to the fibre content of vegetables. Pectin substances constitute on a dry weight basis about 30 per cent the material of primary cell wall (Luh and Woodroof, 1988). Pectin degradation, which occurs by demethylation and depolymerization can be enzymatic or chemically catalysed by acid. In unblanched fruits enzymatic activities is relatively high and pectin degradation would have taken place at faster rate compared to other treatments. This may be the reason for low crude fibre content of unblanched fruits. Similar results were obtained in *S.torvum* also.

As far as dehydration methods were concerned, crude fibre content of samples dehydrated in cabinet dryer was statistically on par with those dehydrated in microwave oven. The sundried samples recorded significantly inferior values for crude fibre (Fig.6). The degradation and depolymerization of cellulose may possibly be associated with the length of process time also. The extended process time during cabinet and sundrying process would have caused more degradation and resulted in lower crude fibre content. This chance was very much restricted under microwave oven treatment, where the process time was only very short as compared to the other methods.

The superior treatment combinations were T_4 (one per cent citric acid at 85^0C) and T_5 (four per cent brine + 0.5 per cent KMS at 85^0C) and microwave oven dehydration, and T_1 (hot water at 85^0C) and T_4 (one per cent citric acid at 85^0C) followed by dehydration in cabinet dryer.

Citric acid which is an acidulent can also act as a sterilising aid (Gardner,1977). Bacteria and many types of other organisms are more easily killed in acid media (Williams, 1951). These properties of citric acid would have posed certain restrictions on microbial and enzymatic activity on the samples. KMS and brine also are antimicrobial, antienzymatic agents. Thus these treatments would have checked degradation of crude fibre. The sundrying due to the slow pattern of moisture removal would not have clearly established the beneficial effects of the pretreatments in retention of crude fibre.

The data on total sugar, reducing sugar and non reducing sugar are presented in Table 9. Maximum sugar (Total, reducing and non reducing)

Table 9. Effect of pretreatments and methods dehydration on total sugar,reducing sugar and non reducing sugar contents of fruits of *S. nigrum* (dry weight basis)

Treat-ments	Methods of dehydration											
	Sun	Cabi-net dryer	Micro-wave oven	Mean	Sun	Cabi-net dryer	Micro-wave oven	Mean	Sun	Cabi-net dryer	Micro-wave oven	Mean
	Total sugar (%)				Reducing sugar (%)				Non reducing sugar (%)			
T_1	2.08	3.62	2.79	2.83	1.71	2.95	2.63	2.43	0.37	0.67	0.16	0.40
T_2	2.69	4.11	2.90	3.23	2.27	3.12	2.70	2.69	0.41	0.99	0.19	0.53
T_3	3.13	2.90	1.37	2.45	2.77	2.41	1.20	2.12	0.32	0.49	0.18	0.33
T_4	3.35	3.56	1.63	2.85	2.86	2.98	1.47	2.43	0.48	0.58	0.20	0.42
T_5	3.02	3.10	1.25	2.46	2.61	2.81	1.11	2.17	0.41	0.29	0.13	0.27
T_6	2.56	3.22	1.25	2.31	2.15	2.50	1.06	1.90	0.31	0.39	0.19	0.29
T_7	2.42	2.86	2.04	2.44	2.02	2.34	3.88	2.08	0.39	0.52	0.15	0.35
Mean	2.74	3.34	1.89		2.34	2.73	1.72		0.38	0.56	0.17	

CD for			
Treatment (T)	0.21*	0.16*	0.03*
Dehydration methods (D)	0.14*	0.10*	0.02*
T x D	0.37*	0.28*	0.05*

* Significant at 1% level

content was observed in fruits treated with four per cent brine at 85^{0}C (T_2) which was significantly superior to all other treatments (Fig. 7). It was closely followed by T_1 (Hot water at 85^{0}C) and T_4 (one per cent citric acid at 85^{0}C). Lowest value for total sugar and reducing sugar was in fruits treated with 0.5 per cent KMS at 85^{0}C. But lowest value for non reducing sugar was in fruits treated with four per cent brine + 0.5 per cent KMS at 85^{0}C (T_5). Pawar *et al.* (1985) studied drying and dehydration of pumpkin and reported that samples treated with 1000 ppm of KMS showed minimum content of reducing sugars. The present study also supports this view.

As far as dehydration methods were concerned dehydration in cabinet dryer was found superior to sundrying and dehydration in microwave oven. Sundrying was also found superior to dehydration in microwave oven (Fig. 8).

Fruits of *S. nigrum* contain 15-20 per cent glucose and fructose (CSIR,1972). Usually microwaves are attracted to moisture, fat and sugar molecules in the food causing them to vibrate rapidly and in turn produce heat to cook the food. In the material being dehydrated, heating due to incident microwaves causes increasing temperature accompanied by increasing sensitivity of the material. As sensitivity increases, the rate of absorption of microwave energy increases and the temperature of material rises even more rapidly (Salunkhe *et al.*,1976). Crystallization of sugars caused by drying may also produce a conduction normally associated with metals (Copson,1962). More over sugars like fructose caramelise more quickly and easiiy (Feather and Harris,1973).

Fig. 7. Effect of pretreatments on total, reducing and non-reducing sugar contents of *S. nigrum*

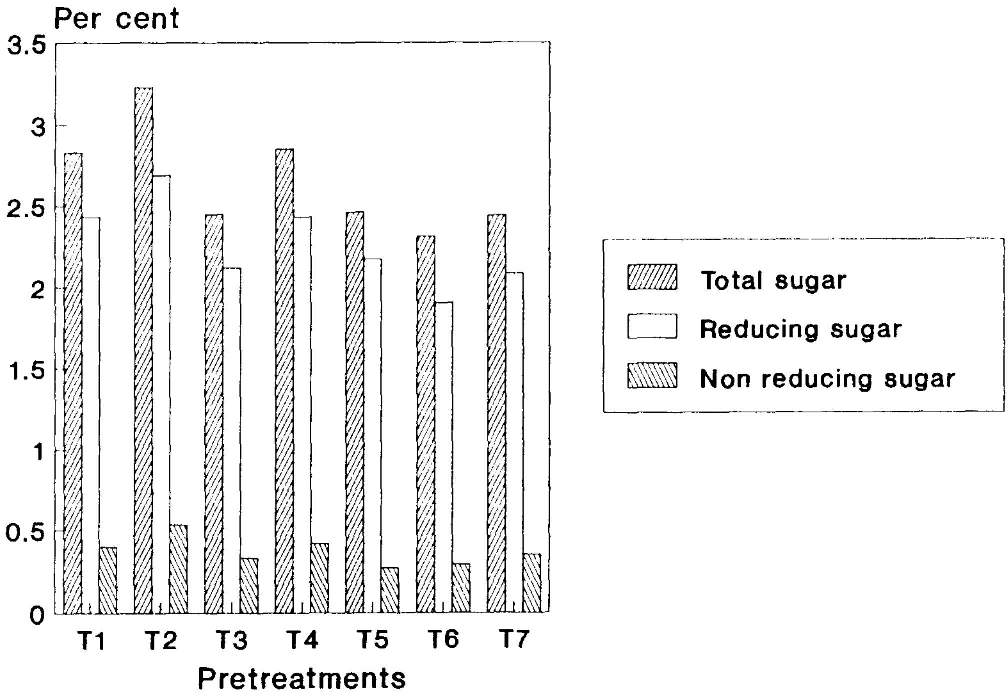
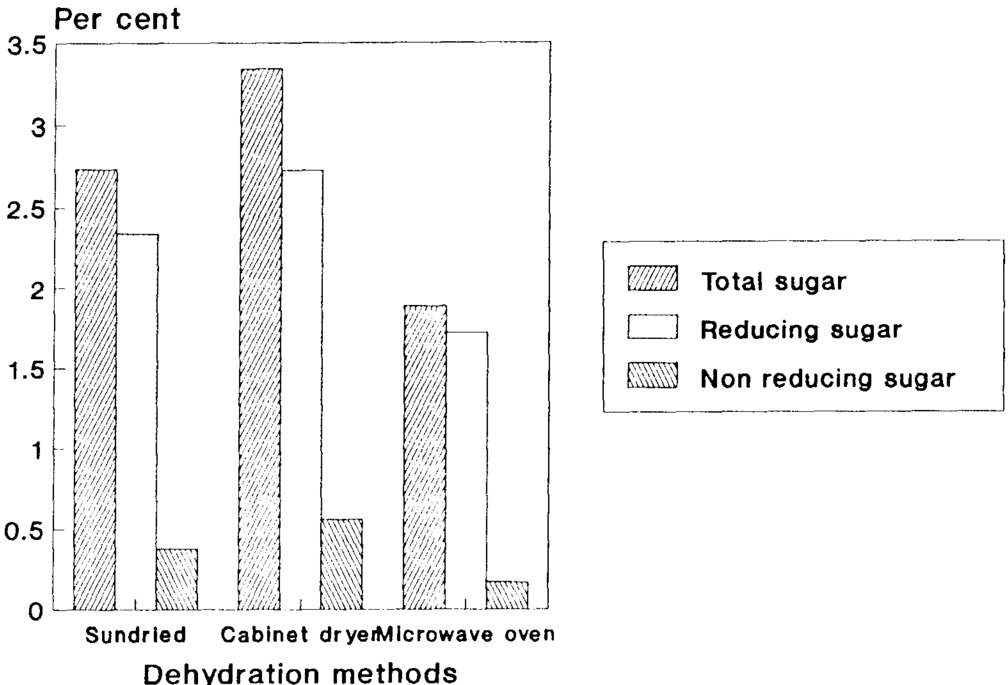


Fig. 8. Effect of dehydration methods on total, reducing and non-reducing sugar contents of *S. nigrum*



All these factors may be attributed to the reduction in sugar content of microwave dehydrated samples. Pawar *et al.* (1985) reported that losses of reducing sugar was more in shreds of pumpkin dried under sun than cabinet dried sample. Goyal and Mathew (1990) reported that the low value in sugar of the samples of cauliflower dried under sun was mainly due to the prolonged exposure of samples to sunlight. The present study was in accordance with the above findings.

There was a significant effect for interaction between pretreatments and dehydration methods. Fruits treated with four per cent brine at 85^{0}C (T_2) and dehydrated in cabinet dryer was found to retain maximum total sugar and reducing sugar. Minimum total and reducing sugar was in fruits treated with 0.5 per cent KMS at 85^{0}C (T_6) and dehydrated in microwave oven. Maximum non reducing sugar was obtained in fruits treated with four per cent brine at 85^{0}C (T_2) and dehydrated in cabinet dryer.

The data on ascorbic acid, iron and total alkaloid content are presented in Table 10. Fruits treated with 0.5 per cent KMS at 85^{0}C (T_6) were found to retain maximum ascorbic acid which was significantly superior to all other treatments (Fig. 9). It was closely followed by T_5 (four per cent brine + 0.5 per cent KMS at 85^{0}C) which was superior to all other treatments. Ascorbic acid was minimum in fruits dehydrated without subjecting to any pretreatment (T_7) which was on par with T_4 (one per cent citric acid at 85^{0}C).

Ascorbic acid may be destroyed during non - enzymatic browning, but

Table 10. Effect of pretreatments and methods of dehydration on ascorbic acid, iron and alkaloid content of fruits of *S. nigrum* (dry weight basis)

Treatments	Methods of dehydration											
	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean
	Ascorbic acid (mg/100 g)				Iron (mg/100 g)				Alkaloid (%)			
T_1	52.40	39.30	78.62	56.77	3.50	5.00	5.00	4.50	0.29	0.32	0.81	0.47
T_2	39.30	52.40	78.80	56.83	2.85	5.75	5.50	4.70	0.18	0.61	0.42	0.40
T_3	26.20	39.30	91.70	52.40	3.10	5.23	6.00	4.77	0.16	0.87	0.72	0.58
T_4	39.30	39.30	65.50	48.03	2.80	5.75	5.40	4.65	0.13	0.32	0.68	0.38
T_5	52.40	52.40	104.80	69.86	1.08	5.50	6.00	4.39	0.37	0.42	0.92	0.57
T_6	56.77	56.77	104.80	72.78	1.90	6.25	5.75	4.63	0.22	0.64	0.81	0.56
T_7	26.20	39.30	78.60	48.03	2.08	4.75	5.75	4.19	0.35	0.57	0.57	0.49
Mean	41.79	45.53	86.11		2.56	5.46	5.62		0.24	0.54	0.70	

CD for			
Treatments (T)	1.67*	0.50*	0.08*
Dehydration methods (D)	0.11*	0.32*	0.05*
T x D	2.90*	0.87*	0.13*

*Significant at 1% level

sulphiting before drying retards browning by ascorbic acid (Ranganath and Dubash, 1981). Pawar *et al.* (1988) reported that retention of ascorbic acid was more in samples treated with 0.25 per cent KMS for five minutes than in the control. Mulay *et al.* (1994) reported that KMS treated samples retained higher amount of ascorbic acid in dehydrated cabbage. They attributed this to the inhibition of oxidative changes of ascorbic acid by SO_2. The present study also support this view. The results also indicate that citric acid may not be good pretreatment for retention ascorbic acid.

In microwave oven dehydrated fruits ascorbic acid retention was maximum which was significantly superior to both dehydration in cabinet dryer and sundrying (Fig. 10). The loss of ascorbic acid was maximum in sundried fruits. The shorter duration of drying in microwave oven could be the possible reason for the higher retention of ascorbic acid as compared to other two drying methods. Rapid drying retains greater amounts of ascorbic acid than does slow drying (Salunkhe *et al.*, 1976). Campbell (1958) noted that the ascorbic acid contents of cabbage and broccoli cooked with microwaves were significantly higher than those cooked with conventional heating. Dietrich *et al.*(1970) compared microwave, steam and water blanching and reported that microwave blanching resulted in better ascorbic acid retention in brussel sprouts. Quenzer (1980) reported that cell structure remained intact during microwave blanching and so it was the best method for ascorbic acid retention in spinach.

The interaction of pretreatments and dehydration methods was also found significant. Fruits treated with 0.5 per cent KMS at 85^{0}C and four per cent brine + 0.5 per cent KMS at 85^{0}C and dehydrated in microwave oven were the best treatment combinations. There was a significant reduction of ascorbic acid in fruits dehydrated without subjecting to any pretreatments. A similar reduction was also noticed in fruits treated with four per cent brine + one per cent citric acid (T_3) followed by sundrying. The slow pace of sundrying would not have been efficient in ascorbic acid retention even with pretreatments involving KMS. The beneficial effect of KMS and brine in retention of ascorbic acid is already explained. This indicates that there is scope for exploitation of these pretreatments for dehydration for evolving products of better nutritional value.

Perusal of data on iron content of fruits showed that all the pretreatments had a significant effect over control (T_7) (Fig. 9). Maximum iron content was found in fruits treated with four per cent brine + one per cent citric acid at 85^{0}C (T_3) followed by fruits treated with four per cent brine at 85^{0}C. All the pretreatments were statistically on par. Lowest iron content was in fruits dehydrated without giving any pretreatment. Gardner (1977) reported that citric acid was a potent metal chelating agent and it readily formed chelates with iron. This may be the reason for high content of iron in citric acid treated fruits. Veenakumari (1992) observed a higher retention of iron in five per cent brine pretreated bittergourd slices. The present study also support this view.

As far as dehydration methods were concerned dehydration in microwave oven and cabinet dryer were statistically on par. However, these two methods

Fig. 9. Effect of pretreatments on ascorbic acid and iron contents of *S. nigrum*

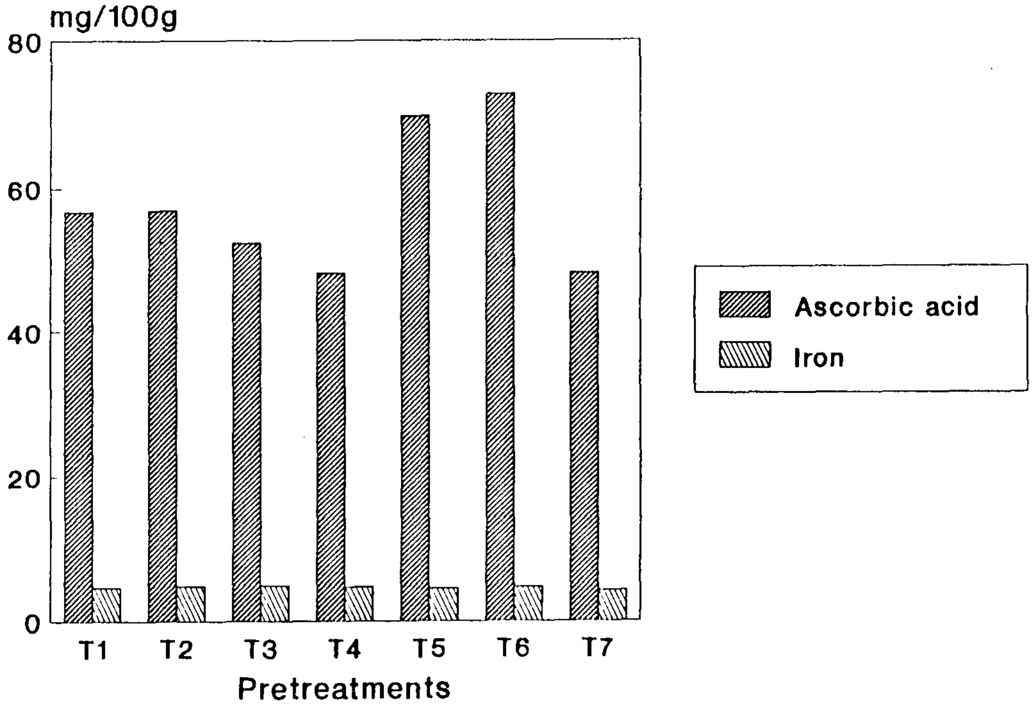
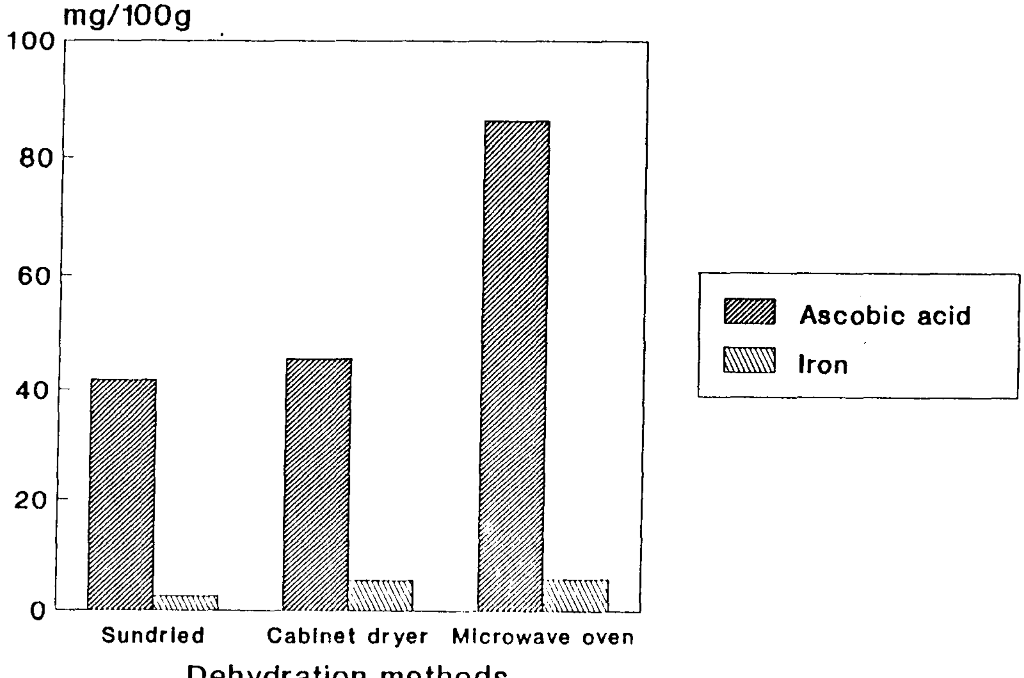


Fig.10. Effect of dehydration methods on ascorbic acid and iron contents of *S. nigrum*



were superior over sundrying (Fig. 10). Similar situation was observed in *S. torvum* also.

There was a significant effect for interaction between pretreatments and dehydration methods. T_2 (four per cent brine at 85^0C), T_3 (four per cent brine + one per cent citric acid at 85^0C), T_4 (one per cent citric acid at 85^0C), T_5(four per cent brine + 0.5 per cent KMS at 85^0C), T_6 (0.5 per cent KMS at 85^0C) and T_7 (Control) followed by microwave dehydration. T_2 (four per cent brine at 85^0C), T_3 (four per cent brine + one per cent citric acid at 85^0C), T_4 (one per cent citric acid at 85^0C) and T_6 (0.5 per cent KMS at 85^0C) followed by dehydration in cabinet dryer were found statistically superior combinations. Lowest value for iron content was in T_5 (four per cent brine + 0.5 per cent KMS at 85^0C) followed by sundrying. The interaction effects also indicated that pretreatments with citric acid and sodium chloride had beneficial effect in the iron content of samples.

Total alkaloids were significantly influenced by pretreatments (Fig. 5). Maximum alkaloid content was in fruits treated with four per cent brine + one per cent citric acid which was statistically on par with T_5 (four per cent brine + 0.5 per cent KMS at 85^0C) and T_6 (0.5 per cent KMS at 85^0C).

The major alkaloids present in *S. nigrum* are solanine and saponin (Chopra *et al.*, 1956). A similar effect was found in alkaloid retention of fruits of *S. torvum* when treated with citric acid. The increased acidity due to citric acid treatment would have resulted in the checking of chemical process resulting in the loss of alkaloids. A similar effect would have been achieved by the KMS and brine treatment also. Further studies are required to ascertain the exact mechanism of action of pretreatments on the alkaloid content in the samples.

The dehydration method also significantly varied with respect to alkaloid content of fruits. Microwave oven dehydration was found superior to sundrying and dehydration in cabinet dryer. Dehydration in cabinet dryer was also found superior to sundrying (Fig. 6). It may probably be due to the difference in the duration of time and environment that resulted in a lower retention of alkaloids in the sun dried product.

The significant combinations as evident from the table were T_1 (Hot water at 85^{0}C), T_5 (four per cent brine + 0.5 per cent KMS at 85^{0}C) and T_6 (0.5 per cent KMS at 85^{0}C) under microwave oven dehydration and T_3 (four per cent brine + one per cent citric acid at 85^{0}C) followed by dehydration in cabinet dryer. Fruits treated with one per cent citric acid at 85^{0}C and dried under sun showed lowest alkaloid content. To explain the exact reason for specific effect of brine, KMS and citric acid treatments on the alkaloids detailed studies may be required.

4.1.2.4. Dehydration ratio

The data on dehydration ratio are presented in Table 11. Better dehydration ratio of 5.95:1 was recorded in fruits treated with one per cent citric acid at 85^{0}C (T_4) which was significantly superior to all other treatments. It was followed by T_6 (0.5 per cent KMS at 85^{0}C) and T_3 (four per cent brine + one per

Table 11. Effect of pretreatments and methods of dehydration on dehydration ratio and rehydration ratio of fruits of *S. nigrum*

Treatments	Methods of dehydration							
	Sun	Cabinet dryer	Micro-wave oven	Mean	Sun	Cabinet dryer	Micro-wave oven	Mean
	Dehydration ratio				Rehydration ratio			
T_1	6.05:1	6.17:1	6.27:1	6.16:1	1:1.72	1:1.73	1:2.22	1:1.89
T_2	6.23:1	6.17:1	6.15:1	6.18:1	1:1.69	1:1.92	1:2.66	1:2.09
T_3	6.10:1	6.25:1	5.88:1	6.08:1	1:1.61	1:1.71	1:2.22	1:1.85
T_4	5.88:1	6.12:1	5.86:1	5.95:1	1:1.78	1:1.88	1:2.50	1:2.05
T_5	6.12:1	6.21:1	6.23:1	6.19:1	1:1.90	1:1.82	1:2.83	1:2.18
T_6	6.12:1	6.12:1	6.09:1	6.07:1	1:1.81	1:1.63	1:2.47	1:1.97
T_7	6.17:1	6.12:1	6.23:1	6.24:1	1:1.69	1:1.72	1:1.95	1:1.79
Mean	6.09:1	6.17:1	6.10:1		1:1.74	1:1.77	1:2.41	
CD for								
Treatments (T)				0.05*				0.04*
Dehydration methods (D)				NS				0.02*
TxD				0.10*				0.07*

* Significant at 1% level

cent citric acid at 85^{0}C). Fruits dehydrated without subjecting to any pretreatment showed poorer dehydration ratio (6.24:1). The data suggest that pretreatments can have influence on the dehydration ratio. As most of the pretreatments can affect the microbial and enzymatic processes taking place in the samples during drying, such variations are justifiable. Citric acid which is an acidulent can also act as sterilizing aid (Gardner, 1977). This may be the reason for higher dehydration ratio in fruits treated with citric acid. In the present study the actual figures did not show much variation with respect to dehydration ratio. Studies with larger samples may be required to ascertain this phenomenon correctly.

As far as dehydration methods were concerned there was no significant difference. However, it may be noted that drying time was only thirty minutes in microwave oven as compared to five hours and fifteen minutes in cabinet dryer and approximately eighteen hours in sundrying. It indicates that duration of drying could be a critical factor for choosing a particular method of drying, though there was no significant difference between drying methods. Under real situations the total duration for completion of drying of one batch of product at a comparatively lower cost may be the ultimate consideration for choosing a particular method of drying.

Interaction between pretreatments and dehydration methods was also found significant. T_4 (one per cent citric acid at 85^{0}C) and T_3 (four per cent brine + one per cent citric acid at 85^{0}C) under microwave oven dehydration and T_4 (one per cent citric acid at 85^{0}C) followed by dehydration in cabinet dryer were found superior combinations. The beneficial effects of citric acid and brine would have complemented synergestically to the beneficial effect of microwaves or cabinet dehydration technique to give this result. Lowest dehydration ratio was in T_1 (Hot water at 85^0C) followed by dehydration in microwave oven.

4.1.2.5. Rehydration ratio.

The data on rehydration ratio are presented in Table 11. Highest rehydration ratio was in fruits treated with four per cent brine + 0.5 per cent KMS at 85^0C which was found superior to all other treatments. It was followed by T_2 (four per cent brine at 85^0C) and T_4 (one per cent citric acid at 85^0C) which were statistically on par. Lowest rehydration ratio (1:1.79) was in T_7 (control).

All the pretreated samples had higher rehydration ratio than the unblanched samples. This may be attributed to increased water absorption due to increased porousness of cell wall in dried samples which received a blanching treatment (Srivastava and Sulebele, 1975). Pruthi *et al.* (1978) studied the dehydration of tropical paddy straw mushroom (*Volvariella volvaceae*) and found that samples treated with KMS had higher rehydration ratio. Better rehydration ratio indicates better retention of the cellular configuration even after drying. Thus rehydration ratio can be considered as an indicator of the cellular integrity of the dehydrated sample.

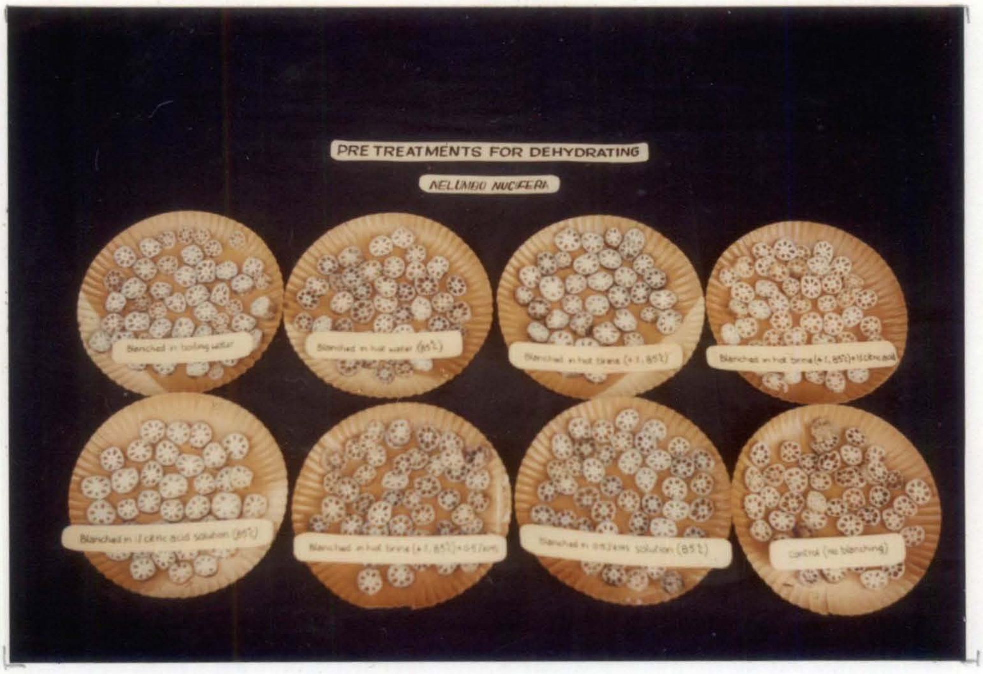
The dehydration methods had significant effect on rehydration ratio of samples. Samples dehydrated in microwave oven showed highest rehydration ratio (1:2.41) which was superior to both sundrying and dehydration in cabinet dryer.

In *S. torvum* also samples dehydrated in microwave oven recorded highest rehydration ratio. In microwave treatment the uniform penetrability of microwaves offers least resistance, as compared to the other dehydration treatments on the cell wall of the samples. This may be the reason for the smooth and superior appearance of the samples dehydrated in microwave oven. Whenever the shape retention is superior, rehydration may also be more efficient. This may be the reason for better rehydration of samples dehydrated in microwave oven. In sundrying the shape disruption was maximum, due to uneven moisture loss from individual cells ultimately resulting in poor rehydration.

The interaction between pretreatments and dehydration methods was also found significant. Highest rehydration ratio was in fruits treated with four per cent brine + 0.5 per cent KMS at 85°C (T_5) and dehydrated in microwave oven. It was followed by T_4 (one per cent citric acid at 85°C) and T_6 (0.5 per cent KMS at 85°C) followed by microwave dehydration which were statistically on par. The lowest rehydration ratio was in T_3 (four per cent brine + one per cent citric acid) followed by sundrying. The interaction effects suggested that KMS treatment resulted in higher rehydration ratio of the dehydrated samples (Pruthi *et al.*, 1978). It also suggested that the effects of KMS treatments were more pronounced under microwave dehydration.

Plate 13. Pretreatments for dehydrating *N.nucifera*

Plate 14. Sundried products of *N.nucifera*


PRE TREATMENTS FOR DEHYDRATING
NELUMBO NUCIFERA
Blanched in boiling water
Blanched in hot water (85°C)
Blanched in hot brine (1%, 85°C)
Blanched in hot brine (1%, 85°C) + 1% citric acid
Blanched in 1% citric acid solution (85°C)
Blanched in hot brine (1%, 85°C) + 0.5% KMS
Blanched in 0.5% KMS solution (85°C)
Control (no blanching)


SUN DRIED PRODUCTS OF
NELUMBO NUCIFERA
Blanched in boiling water
Blanched in hot water (85°C)
Blanched in hot brine (1%, 85°C)
Blanched in hot brine (1%, 85°C) + 1% citric acid
Blanched in 1% citric acid solution (85°C)
Blanched in hot brine (1%, 85°C) + 0.5% KMS
Blanched in 0.5% KMS solution (85°C)
Control (no blanching)

4.1.3. *Nelumbo nucifera*

4.1.3.1. Effect of pretreatments on colour and weight of fresh lotus stolon slices.

The data on the effect of pretreatments on the colour and weight of fresh slices of lotus stolons are presented in Table 12. There was no significant difference between pretreatments on the colour of fresh slices, which was cream in colour when cut fresh, and also after blanching (plate 13).

The whitish cream colour of the stolon has good eye appeal. If this colour is carried to the product also, the acceptability will be much better. The conventional products available in the market are dark brown or blackish in colour which is having a poor eye appeal. Thus in the dehydration of the lotus stolons, retention of the original colour of the stolon is an important consideration. In the present study, none of the treatments significantly improved or deteriorated the natural colour of the lotus stolons.

The pretreatments had significant effect on the weight of the samples after blanching. All samples gained weight after subjecting to the pretreatments. Samples treated with hot water at 85^{0}C showed maximum weight gain after blanching which was statistically superior to all pretreatments. It was followed by T_7 (four per cent brine + 0.5 per cent KMS at 85^{0}C).

The gain in weight of samples treated with boiling water (T_1) was minimum which was statistically on par with other pretreatments T_3 (four per cent brine at 85^{0}C), T_4 (four per cent brine + one per cent citric acid at 85^{0}C), T_5 (one per cent

Table 12. Effect of pretreatments on colour and weight of stolon slices of *N. nucifera*

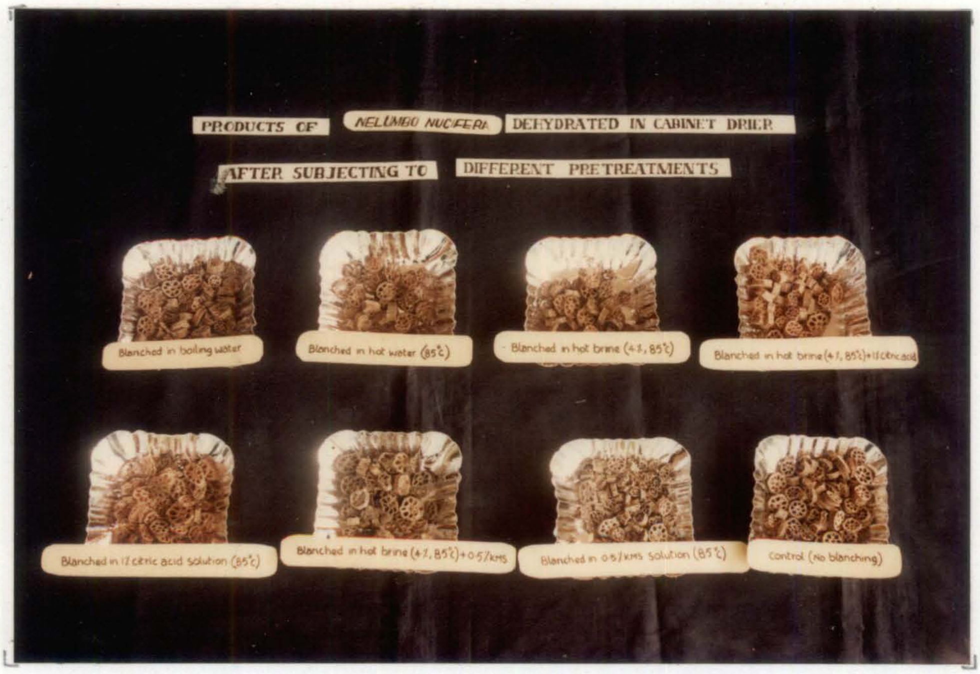
Treatments	Colour (score)	Weight (g)		
		Before treatment	After treatment	Variation + or -
T_1 (Boiling water)	1.2	50.00	42.80	+2.80
T_2 (Hot water at 85°C)	1.4	50.00	56.33	+6.33
T_3 (4% brine at 85°C)	2.4	50.00	53.67	+3.67
T_4 (4% brine + 1% citric acid at 85°C)	2.8	50.00	53.00	+3.00
T_5 (1% citric acid at 85°C)	2.8	50.00	53.67	+3.67
T_6 (4% brine + 0.5% KMS at 85°C)	2.2	50.00	53.67	+3.67
T_7 (0.5% KMS at 85°C)	1.8	50.00	54.67	+4.67
T_8 (Control)	1.0	50.00	50.00	0.00
CD	NS		0.87*	

Score chart for colour -		
	Cream	- 1
	Whitish yellow	- 2
	Yellow	- 3
	Yellowish brown	- 4
	Light brown	- 5

*Significant at 1% level

Plate 15. Products of *N.nucifera* dehydrated in cabinet dryer

Plate 16. Microwave dehydrated products of *N.nucifera*


PRODUCTS OF
NELUMBO NUCIFERA
DEHYDRATED IN CABINET DRIER
AFTER SUBJECTING TO
DIFFERENT PRETREATMENTS
Blanched in boiling water
Blanched in hot water (85°c)
Blanched in hot brine (4%, 85°c)
Blanched in hot brine (4%, 85°c)+1% citric acid
Blanched in 1% citric acid solution (85°c)
Blanched in hot brine (4%, 85°c)+0.5% KMS
Blanched in 0.5% KMS solution (85°c)
Control (No blanching)


MICROWAVE DEHYDRATED PRODUCTS OF
NELUMBO NUCIFERA
Blanched in boiling water
Blanched in hot water (85°c)
Blanched in hot brine (4%, 85°c)
Blanched in hot brine (4%, 85°c)+1% citric acid
Blanched in 1% citric acid solution (85°c)
Blanched in hot brine (4%, 85°c)+0.5% KMS
Blanched in 0.5% KMS solution (85°c)
Control (No blanching)

citric acid at 85^{0}C) and T_6 (four per cent brine + 0.5 per cent KMS at 85^{0}C).

Contrary to the effect of blanching treatments in *S. torvum* and *S. nigrum*, the lotus stolons registered a weight gain due to the hot water/boiling water blanching treatments. The fact that lotus stolons have hollow tubular spaces inside may be the reason for this weight gain. During the blanching treatments, water gets close access to the intercellular spaces as a result of the increased surface area exposed to water unlike the earlier two cases. When blanching is done with boiling water there is increased softening of the lotus stolons resulting in lesser water retention as compared to hot water blanching. Blanching removes intercellular air from the tissues (Salunkhe *et al.,* 1976; Kalra, 1990). Goyal and Mathew (1990) studied physicochemical characteristics of cauliflower dried under different drying conditions and reported that the weight gain after blanching was due to the replacement of entrapped air by water and adhering superficial water. The present study supports this view.

4.3.1.2. Effect of pretreatments and methods of dehydration on colour and weight of stolon slices of lotus.

The results of analysis showed that pretreatments had significant effect on the colour of dehydrated samples (Table 13 and plates 14, 15 and 16). The samples treated with four per cent brine + 0.5 per cent KMS at 85^{0}C (T_6) and one per cent citric acid at 85^{0}C (T_5) received lowest score (3.47) which indicated a better colour retention. But the dehydration methods had no influence on colour retention (plates 14, 15 and 16). The extent of prevention of browning

Table 13. Effect of pretreatments and methods of dehydration on colour and weight of stolon slices of *N. nucifera*

Treatments	Methods of dehydration							
	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean
	Colour (score)				Weight (g)			
T_1	4.6	4.8	4.6	4.7	13.27	12.67	13.00	12.98
T_2	4.8	4.8	4.8	4.8	13.13	12.63	13.27	13.01
T_3	4.4	4.4	4.4	4.4	13.03	13.00	13.13	13.06
T_4	3.6	3.8	3.8	3.7	12.93	13.23	13.23	13.13
T_5	3.0	3.6	3.8	3.5	13.03	13.43	12.93	13.13
T_6	4.0	3.0	3.4	3.5	12.97	13.67	13.03	13.22
T_7	4.2	4.2	4.2	4.2	12.83	13.40	13.43	13.22
T_8	4.8	4.8	4.8	4.8	12.30	12.53	12.90	12.58
Mean	4.2	4.2	4.2		12.94	13.07	13.12	

H* for		CD for	
Treatments	53.33	Treatments (T)	- 0.33*
Dehydration methods	NS	Dehydration methods (D)	- 0.20*
		T x D	- 0.57*

H* - Kruskell Wallies Statistic *Significant at 1% level

Score chart for colour: Cream-1, Whitish yellow-2, Yellow-3, Yellowish brown-4, Light brown-5 reaction (enzymatic and non-enzymatic) results in better retention of colour in lotus stolons. Sodium chloride, potassium metabisulphite and citric acid are reported to have antibrowning properties. SO_2 has long been used as an economically efficient way of retarding enzymatic and non-enzymatic browning (Salunkhe *et al.,* 1976). Gardner (1977) reported that browning in dehydrated fruits and vegetables could be prevented by soaking of the cut or peeled products in citric acid. Pruthi *et al.* (1978) reported that blanching followed by steeping of mushrooms in 0.2 per cent KMS solution containing 0.2 per cent citric acid for three hours slightly improved the colour of mushroom. The present study also supports this view.

The data on weight after dehydration revealed that all the pretreatments had a significant positive effect on the weight of dehydrated samples over control. Maximum weight was obtained in T_7 (0.5 per cent KMS at 85^0C) which was on par with other pretreatments. Lowest value for weight was obtained in unblanched samples. In the case of lotus stolons, all the blanching treatments had registered a weight gain. This weight gain is naturally reflected in the product weight also after the drying treatment.

Dehydration in microwave oven, which was statistically on par with dehydration in cabinet dryer, was found significantly superior to sundrying. Sundrying was on par with dehydration in cabinet dryer. The better weight recovery in microwave oven may be due to the short process time, efficient way of heat transfer and the enclosed nature of the drying chamber. Sundrying, being carried out in open condition, is always susceptible to microbial attack over a longer period of time which would have resulted in the conversion of a small quantity of the constituents in the stolons into other products.

Interaction between pretreatments and dehydration methods was also found to be significant. T_7 (0.5 per cent KMS at 85°C), T_4 (four per cent brine + one per cent citric acid at 85°C), T_3 (four per cent brine at 85°C), T_2 (Hot water at 85°C) under microwave oven. T_7 (0.5 per cent KMS at 85°C), T_6 (four per cent brine + 0.5 per cent KMS at 85°C), T_5 (one per cent citric acid at 85°C), T_4 (four per cent brine + one per cent citric acid at 85°C) followed by dehydration in cabinet dryer and T_1 (Hot water at 85°C) followed by sundrying were found as superior combinations. Samples dried in sun without giving any pretreatment recorded maximum weight loss. This again shows that pretreatments have to be specifically standardised for each drying method. This is due to the reason that the process of each of the drying system varied widely. Treatments T_7 (0.5 per cent KMS at 85°C) and T_4 (four per cent brine + one per cent citric acid at 85°C) are found commonly beneficial for microwave ovens and cabinet dryers.

4.1.3.3. Qualitative characters.

Results of data on quality parameters *viz*., moisture, starch, crude fibre and iron are presented in Table 14.

The pretreatments and dehydration methods had no significant effect on the moisture content of dehydrated products (Fig. 11 and Fig. 12). The reason

Table 14. Effect of pretreatments and methods of dehydration on moisture starch, crude fibre and iron content of stolon slices of *N. nucifera*

Treatments	Methods of dehydration															
	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean
	Moisture (%)				Starch (%)				Crude fibre (%)				Iron (mg/100 g)			
T_1	8.44	8.00	7.97	8.00	14.7	12.00	6.10	10.93	3.22	4.73	8.34	5.43	8.80	10.75	12.45	10.67
T_2	8.04	8.00	8.00	8.00	14.7	12.90	7.90	11.83	5.11	6.45	8.26	6.61	8.75	9.11	14.50	10.79
T_3	8.04	8.00	7.93	7.99	12.00	13.70	6.30	10.67	4.61	4.41	8.96	5.99	13.75	12.15	14.00	13.30
T_4	8.03	8.03	7.93	8.00	12.90	12.00	10.40	11.77	5.71	4.64	6.19	5.51	10.65	15.50	13.00	13.95
T_5	8.04	7.97	7.93	7.98	16.70	9.90	7.90	11.50	3.75	5.93	8.58	6.10	11.17	15.50	12.45	12.71
T_6	8.03	8.03	7.97	8.01	10.90	8.20	9.50	9.53	4.05	7.35	7.26	6.22	12.25	10.90	10.85	11.33
T_7	8.03	7.97	7.97	7.99	14.70	9.33	8.70	10.91	5.83	7.14	7.04	6.67	7.55	11.65	15.35	11.52
T_8	8.04	7.97	7.97	7.99	3.80	3.60	4.00	3.80	3.87	3.41	5.26	4.18	8.40	11.35	10.65	10.13
Mean	8.04	8.00	7.96		12.55	10.20	7.60		4.52	5.51	7.49		10.17	12.11	12.78	
CD for																
Treatments (T)				NS				0.73*				0.91*			0.69*	
Dehydration methods (D)				NS				0.44*				0.56*			0.42*	
T x D				NS				1.26*				1.58*			1.19*	

*Significant at 1% level

for this is already explained under 4.1.1.3.

Perusal of data on starch content of slices of lotus stolons showed that all pretreatments were superior over control (Fig.11). Samples treated with four per cent brine + one per cent citric acid at 85^{0}C (T_4), one per cent citric acid at 85^{0}C (T_5) and hot water at 85^{0}C (T_2) were found significantly superior to all other pretreatments and they were on par. It was followed by T_1 (boiling water), T_3 (four per cent brine at 85^{0}C) and T_7 (0.5 per cent KMS at 85^{0}C). Lowest value for starch content was obtained in T_8 (control). The pretreatments have beneficial effects in retaining starch content of samples.

Stolon slices of lotus dried in sun showed highest retention of starch, which was superior to dehydration in cabinet dryer and microwave oven (Fig. 12). Dehydration in cabinet dryer was also found superior to microwave oven dehydration. Dehydration in cabinet dryer and microwave oven would have caused gelatinisation of starch. Gelatinisation is the process of swelling and eventual bursting of starch granules, when starch is heated (Birch, 1977). But in sundrying the temperature of drying is very low compared to other two methods. This may be the reason for high starch content of sundried samples. Dorfer and Eckert (1983) studied complex thermal modification of wheat flour by graded microwave processing and reported starch damage of wheat flour by microwaves using a 2 KW microwave oven operating at 2375 H_z. The present study also supports this view.

Fig.11. Effect of pretreatments on moisture, starch and crude fibre contents of *N. nucifera*

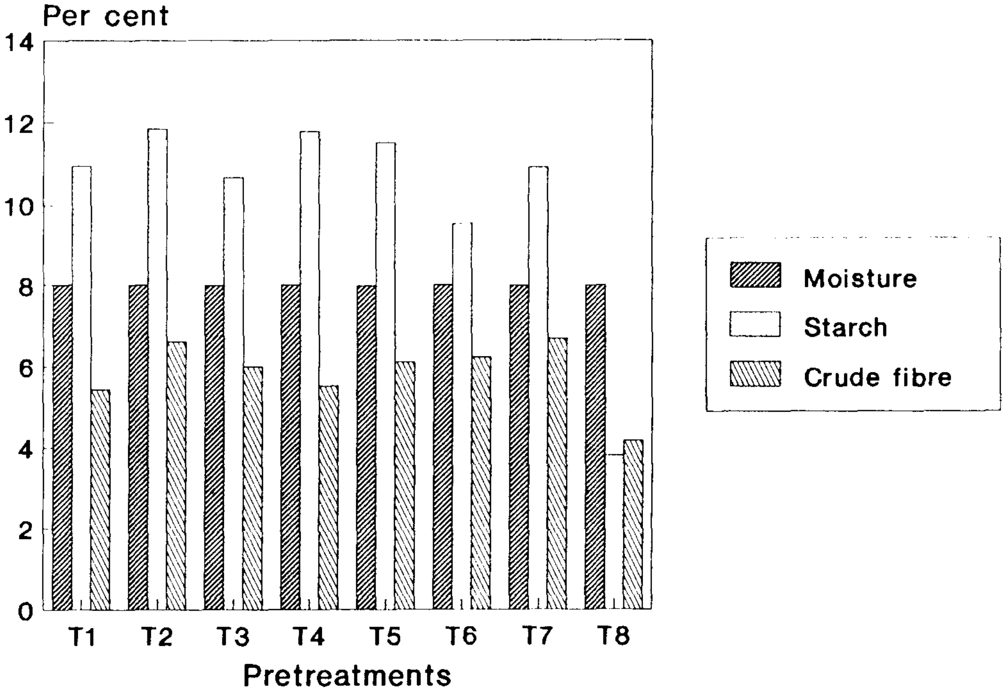
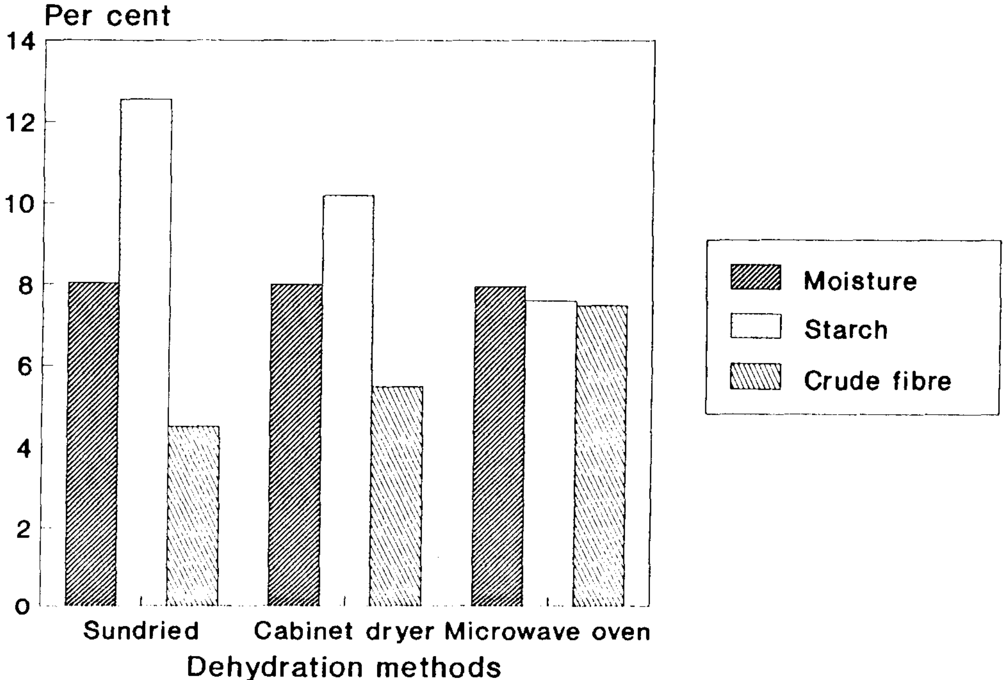


Fig.12. Effect of dehydration methods on moisture, starch and crude fibre contents of *N. nucifera*



The interaction between pretreatments and dehydration methods was also significant. Samples treated with one per cent citric acid at 85^{0}C and dried in sun showed maximum starch content. It was followed by T_1 (boiling water), T_2 (Hot water at 85^{0}C) and T_7 (0.5 per cent KMS at 85^{0}C) under sundrying. Starch content of lotus stolon slices was minimum in control treatment in all the three methods of dehydration. The interaction effects also supports the view that pretreatments are better for retention of carbohydrate. In stolon slices the expulsion of air has taken place. This had a beneficial effect in products rich in starch that cells beneath the surface were effectively protected from the adverse effects of oxygen in the air. But in unblanched samples due to the presence of air the adverse effect of oxygen was not prevented (Salunkhe *et al.,* 1976). This may be the reason for loss of starch in unblanched samples.

The data on crude fibre content of slices of lotus stolons are presented in Table 14. All the pretreatments showed a significant effect with respect to crude fibre content over control (T_8). Maximum value for crude fibre was in T_7 (0.5 per cent KMS at 85^{0}C) which was statistically on par with T_2 (Hot water at 85^{0}C), T_5 (one per cent citric acid at 85^{0}C), T_6(four per cent brine + 0.5 per cent KMS at 85^{0}C) and T_3 (four per cent brine at 85^{0}C). Lowest value for crude fibre was in unblanched sample (Fig. 11). A similar result was obtained for *S. torvum* also. The explanation for this trend is already furnished under 4.1.1.3.

As far as dehydration methods were concerned, crude fibre content of samples under microwave oven dehydration was significantly superior to both sundrying and dehydration in cabinet dryer. Dehydration in cabinet dryer was also superior to sundrying (Fig. 12). This indicated that under microwave dehydration the crude fibre retention was maximum. A similar result was obtained in *S. torvum* and *S. nigrum* also. The explanation for this trend is already explained under 4.1.1.3.

Interaction for pretreatments and dehydration methods was also found significant. T_1 (Boiling water), T_3 (four per cent brine at 85^0C), and T_5 (one per cent citric acid at 85^0C) under microwave oven dehydration were the superior combinations. It was closely followed by T_6 (four per cent brine + 0.5 per cent KMS at 85^0C) and T_7 (0.5 per cent KMS at 85^0C) under dehydration in microwave and cabinet dryer. Lowest value for crude fibre was in samples dried in sun without subjecting to any pretreatments. The interaction effects indicated that pretreatments were beneficial for maximum retention of crude fibre. The superiority of microwave oven dehydration in crude fibre retention was again observed.

Data on the iron content of samples are presented in Table 14. Maximum iron content was in samples treated with four per cent brine at 85^0C (T_3) which was statistically on par with T_4 (four per cent brine + one per cent citric acid at 85^0C), T_5 (one per cent citric acid at 85^0C) and T_6 (four per cent brine + 0.5 per cent KMS at 85^0C) (Fig. 13). Lowest value for iron content was in control (T_8) which was statistically on par with T_1 (boiling water) and T_2 (Hot water at 85^0C). The pretreatments like sodium chloride, citric acid etc. were beneficial for better

Fig.13. Effect of pretreatments on iron content of *N. nucifera*

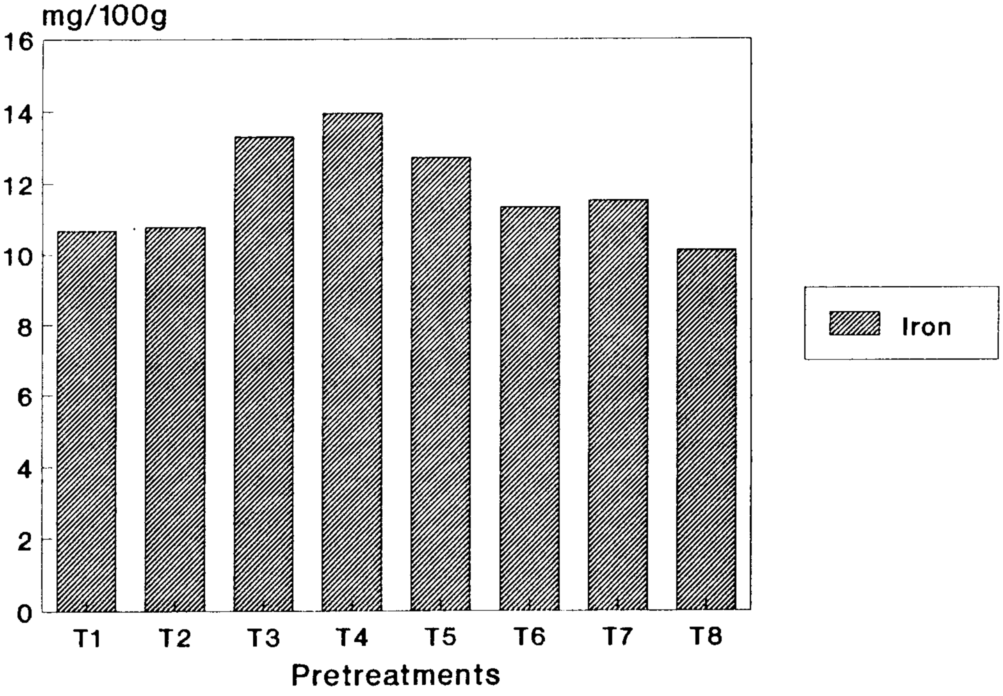
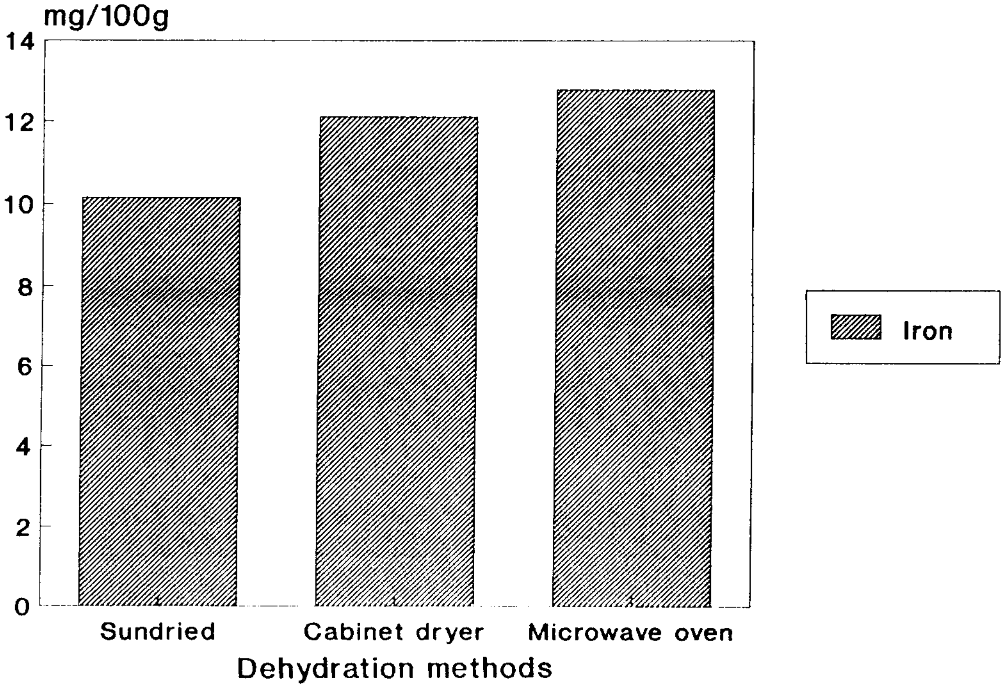


Fig.14. Effect of dehydration methods on iron content of *N. nucifera*



iron retention. A similar result was obtained in *S. nigrum* also. The explanation for this effect is already furnished under 4.1.2.3.

In the case of dehydration methods iron retention was maximum in stolon slices dehydrated in microwave oven which was significantly superior to dehydration in cabinet dryer and sundrying. Dehydration in cabinet dryer was also found superior to sundrying (Fig. 14).

There was a significant effect for interaction between pretreatments and dehydration methods. The best combinations were T_4 (four per cent brine + one per cent citric acid at 85°C) and T_5 (one per cent citric acid at 85°C) followed by dehydration in cabinet dryer, and T_7 (0.5 per cent KMS at 85°C) and T_2 (Hot water at 85°C) under microwave oven dehydration. It was closely followed by T_3 (four per cent brine at 85°C) under microwave oven dehydration and sundrying. Lowest value for iron was in samples dried under sun without blanching. The interaction effects also showed that pretreatments like sodium chloride and citric acid were beneficial for retention of iron. A similar trend was obtained in *S. torvum* and *S. nigrum*.

4.1.3.4. Dehydration ratio.

The data on dehydration ratio are presented in Table 15. All pretreatments also showed a significant difference over control (T_8). Better dehydration ratio of 3.80:1 was recorded in samples treated with 0.5 per cent KMS at 85°C (T_7) which was statistically superior to all other pretreatments. It

Table 15. Effect of pretreatments and methods of dehydration on dehydration ratio and rehydration ratio of stolon slices of *N. nucifera*

Treatments	Methods of dehydration							
	Sun	Cabinet dryer	Micro-wave oven	Mean	Sun	Cabinet dryer	Micro-wave oven	Mean
	Dehydration ratio				Rehydration ratio			
T_1	4.00:1	3.79:1	3.85:1	3.88:1	1:2.62	1:2.49	1:2.94	1:2.68
T_2	4.14:1	3.72:1	3.75:1	3.87:1	1:2.32	1:2.56	1:2.65	1:2.51
T_3	3.77:1	3.98:1	3.80:1	3.85:1	1:2.41	1:2.53	1:3.01	1:2.65
T_4	3.81:1	3.83:1	3.90:1	3.85:1	1:2.56	1:2.33	1:2.59	1:2.49
T_5	3.87:1	3.91:1	3.72:1	3.83:1	1:2.48	1:2.45	1:2.77	1:2.57
T_6	3.78:1	3.86:1	3.82:1	3.82:1	1:2.80	1:2.55	1:2.91	1:2.75
T_7	3.66:1	3.97:1	3.83:1	3.80:1	1:2.83	1:3.02	1:2.67	1:2.84
T_8	4.07:1	3.88:1	3.99:1	3.98:1	1:2.17	1:2.40	1:2.61	1:2.39
Mean	3.88:1	3.86:1	3.83:1		1:2.52	1:2.50	1:2.77	
CD for								
Treatments (T)				0.01*				0.07*
Dehydration methods (D)				0.01*				0.05*
T x D				0.03*				0.13*

*Significant at 1% level

was followed by T_6 (four per cent brine + 0.5 per cent KMS at 85^{0}C)which was on par with T_5 (one per cent citric acid at 85^{0}C). Poor dehydration ratio (3.98:1) was found in T_8 (control). The data suggested that pretreatments could have influence in the dehydration ratio and treatments like KMS were beneficial. A similar result was obtained in *S.torvum* also. The reason for this trend is already furnished under 4.1.1.4.

In the case of dehydration methods products dehydrated in microwave oven showed a better dehydration ratio which was superior to both sundrying and dehydration in cabinet dryer. Dehydration in cabinet dryer was also found superior to sundrying.

In microwave treatment the uniform penetrability of microwaves offers least resistance as compared to other methods of dehydration. Moreover dehydration system is more efficient. This may be the reason for higher dehydration ratio compared to other two methods.

Pawar *et al.* (1985) conducted dehydration studies in pumpkin and reported that cabinet dried samples had higher dehydration ratio compared to sundried samples. The present study also supports this view.

Interaction between pretreatments and dehydration method was also found significant. Samples after subjecting to 0.5 per cent KMS at 85^{0}C (T_7) and dried in sun resulted in better dehydration ratio which was statistically superior to all other treatment combinations. It was followed by T_5 (one per cent citric acid at

85^0C) and T_2 (Hot water at 85^0C) under microwave oven dehydration, and T_2(Hot water at 85^0C) followed by dehydration in cabinet dryer. Poor dehydration ratio was found in samples treated with hot water at 85^0C and dried in sun. It was also found that unblanched samples dried under all the three methods resulted in poor dehydration ratio. The interaction effect suggests the possibility of finding out the best possible pretreatment under each drying situation.

4.1.3.5. Rehydration ratio.

The data on rehydration ratio showed that T_7 (0.5 per cent KMS at 85^0C) was significantly superior to all other treatments including control (T_8). It was followed by T_6 (four per cent brine + 0.5 per cent KMS at 85^0C) and T_1 (boiling water) which were on par. Lowest rehydration ratio was found in T_8 (control). KMS treatment was found highly beneficial for getting products with higher rehydration. A similar result was obtained in *S. torvum* and *S. nigrum* also. The reason for this is already explained under 4.1.1.5.

Highest rehydration ratio was recorded in samples dehydrated in microwave oven which was found superior to sundrying and dehydration in cabinet dryer. This shows the superiority of microwave oven for getting products with higher rehydration ratio. A similar result was obtained in *S. nigrum*. The explanation for this increased rehydration of samples dehydrated in microwave oven is already furnished under 4.1.2.5.

The interaction of pretreatments and dehydration methods was also found significant. Samples treated with 0.5 per cent KMS at 85^0C and dehydrated in cabinet dryer showed highest rehydration ratio which was statistically on par with T_6 (four per cent brine + 0.5 per cent KMS at 85^0C) and T_1 (Boiling water) followed by dehydration in microwave oven. Unblanched samples dried under sun resulted in the lowest rehydration ratio 1:2.17. Sundrying of samples without subjecting to any pretreatment resulted in poor rehydration ratio suggests that this was the poor treatment combination. The interaction effects also suggest that KMS treatment resulted in higher rehydration ratio. The same result was obtained in *S. nigrum* also. The explanation for this effect is already furnished under 4.1.2.5.

The foregoing discussion on standardisation of dehydration techniques in *S. torvum*, *S. nigrum* and *N. nucifera* has given useful information on the influence of pretreatments and dehydration methods on the colour, nutritive value, dehydration ratio and rehydration ratio of dehydrated products. It was observed that pretreatments with KMS 0.5 per cent, brine four per cent and citric acid one per cent were more useful for getting dehydrated product with better quality in combination with the methods of dehydration employed.

In *S. torvum*, fruits treated with four per cent brine at 35^0C showed better colour retention, highest iron content, and rehydration ratio under sundrying. Fruits treated with one per cent citric acid at 85^0C showed maximum retention of carbohydrate, crude fibre and alkaloid and highest dehydration and rehydration ratio under sundrying. While 0.5 per cent KMS at 85^0C resulted in better dehydration and rehydration ratio, better retention of iron, crude fibre, alkaloid and maximum retention of ascorbic acid under sundrying.

Fruits treated with four per cent brine showed better retention of ascorbic acid and iron and highest dehydration and rehydration ratio under dehydration in cabinet dryer. Fruits treated with four per cent brine + 0.5 per cent KMS at 85°C resulted in better iron content, rehydration ratio and maximum retention of colour and ascorbic acid under dehydration in cabinet dryer. Under microwave oven dehydration, fruits treated with four per cent brine showed highest dehydration ratio, maximum iron content, and better retention of ascorbic acid and alkaloid. Fruits treated with four per cent brine + 0.5 per cent KMS at 85°C resulted in maximum colour retention, highest dehydration ratio, better retention of ascorbic acid and iron under microwave dehydration. While 0.5 per cent KMS at 85°C resulted in maximum retention of ascorbic acid, iron and alkaloid under microwave dehydration. Thus the superior treatments for *S. torvum* were 0.5 per cent KMS at 85°C and 4 per cent brine at 85°C followed by four per cent brine + 0.5 per cent KMS at 85°C.

In *S. nigrum*, fruits treated with four per cent brine resulted in maximum retention of carbohydrate, crude fibre sugars under sundrying. Fruits treated with one per cent citric acid at 85°C resulted in maximum colour retention, highest dehydration ratio and better sugar content and rehydration ratio under sundrying. Treating fruits with four per cent brine + 0.5 per cent KMS at 85°C resulted in maximum retention of ascorbic acid, iron, alkaloid and highest rehydration ratio under sundrying. For dehydration in cabinet dryer fruits treated with four per cent brine showed better retention of ascorbic acid and iron and highest rehydration ratio. Fruits treated with one per cent citric acid at 85°C resulted in maximum sugar and crude fibre content, highest dehydration ratio and better rehydration ratio under dehydration in cabinet dryer. While treating fruits with four per cent brine + 0.5 per cent KMS at 85°C resulted in maximum retention of colour, carbohydrate and ascorbic acid under dehydration in cabinet dryer. Fruits treated with four per cent brine + one per cent citric acid at 85°C showed maximum retention of colour, better retention of ascorbic acid and iron, and highest dehydration ratio under microwave dehydration. Fruits treated with one per cent citric acid showed maximum retention of colour, and crude fibre and highest dehydration ratio under microwave dehydration. While treating fruits with four per cent brine + 0.5 per cent KMS at 85°C resulted in maximum retention of carbohydrate, ascorbic acid and alkaloid and highest rehydration ratio. Thus the superior pretreatments for *S. nigrum* were one per cent citric acid at 85°C and four per cent brine + 0.5 per cent KMS at 85°C followed by four per cent brine at 85°C.

In *N. nucifera*, samples treated with four per cent brine + one per cent citric acid at 85°C showed maximum retention of crude fibre and better dehydration and rehydration ratio. Under sundrying, samples treated with four per cent brine + 0.5 per cent KMS at 85°C resulted in highest rehydration ratio and better retention of iron under sundrying. Samples treated with 0.5 per cent

KMS at 85^{0}C and sundried showed maximum retention of crude fibre and highest dehydration and rehydration ratio. For dehydration in cabinet dryer samples treated with four per cent brine + one per cent citric acid at 85^{0}C showed maximum retention of iron and highest dehydration ratio. Samples treated with one per cent citric acid and dehydrated in cabinet dryer resulted in maximum retention of iron and better dehydration and rehydration ratio. While samples treated with four per cent brine + 0.5 per cent KMS at 85^{0}C showed highest dehydration ratio, maximum retention of colour and crude fibre and better rehydration ratio under dehydration in cabinet dryer. Under microwave dehydration samples treated with one per cent citric acid at 85^{0}C resulted in maximum retention of crude fibre and highest dehydration ratio. Samples treated with four per cent brine + 0.5 per cent KMS at 85^{0}C showed maximum retention of colour and starch and better dehydration ratio under microwave dehydration. Samples treated with 0.5 per cent KMS at 85^{0}C resulted in highest rehydration ratio, maximum retention of iron and better dehydration ratio under microwave dehydration. Thus the superior pretreatments in *N. nucifera* were four per cent brine + 0.5 per cent KMS at 85^{0}C followed by 0.5 per cent KMS at 85^{0}C and one per cent citric acid at 85^{0}C.

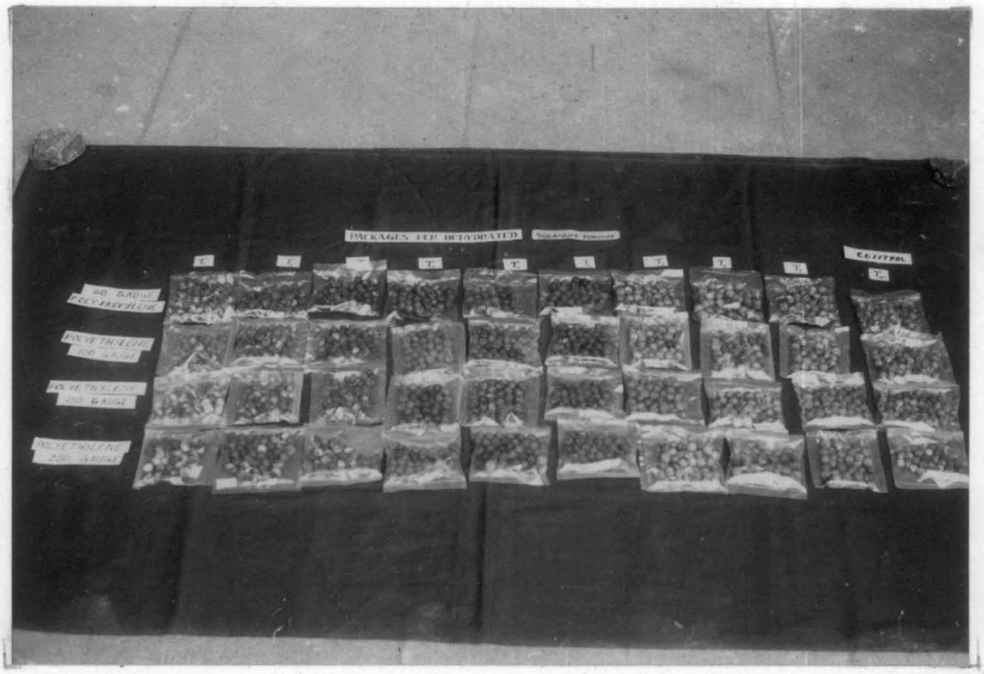
It can be further concluded that the best pretreatment was four per cent brine + 0.5 per cent KMS at 85^{0}C on an overall basis. The beneficial effects of sulphites is mainly by antimicrobial action (sulphurous acid inhibits yeasts moulds and bacteria) and prevention of enzymatic and non enzymatic discoluration

(Salunkhe *et al.,* 1976, Chichester and Tanner, 1977). The application of sulphites to vegetables before dehydration increases the storage life, preserves colour and flavour, aids in retention of ascorbic acid and gives better rehydrated products (Salunkhe *et al.,* 1976, Chichester and Tanner, 1977; Ranganath and Dubash, 1981; Pawar *et al.,*1988; and Mulay *et al.,*1994). The other superior pretreatments were 0.5 per cent KMS at 85^{0}C, one per cent citric acid at 85^{0}C, and four per cent brine at 85^{0}C. Sodium chloride inhibits microbial growth and thus preserves the food. It reduces the amount of water available to microorganisms for growth process. The sodium and chloride ions also inhibit some microorganisms independent of changes in water activity of this food. Other detrimental effects include plasmolysis of cells, reduced solubility of oxygen in water, sensitization of cells to CO_2 and interference with the action of proteolytic enzymes (Johnson and Peterson, 1974). Sodium chloride in combination with an acidulent prevents browning in dehydrated vegetable (Gardner, 1977). Citric acid aids in sterilization, chelation, product standardisation and enhancement of flavours (Johnson and Peterson, 1974). Citric acid also helps in prevention of browning which is one of the major problem in the dehydration of fruits and vegetables (Gardner, 1977).

The study has also revealed that microwave dehydration was significantly superior to dehydration in cabinet dryer and sundrying. Microwave dehydration resulted in maximum retention of ascorbic acid, iron, alkaloid, carbohydrate and crude fibre content of all the three species studied. In *S. torvum* retention of

Plate 17. Packages for dehydrated products of *S.torvum*

Plate 18. Packages for dehydrated products of *S.nigrum*


PACKAGES FOR DEHYDRATED
SOLANUM TORVUM
CONTROL
60 GAUGE POLYPROPYLENE
POLYETHYLENE 100 GAUGE
POLYETHYLENE 150 GAUGE
POLYETHYLENE 200 GAUGE


PACKAGES FOR DEHYDRATED
SOLANUM NIGRUM
CONTROL
60 GAUGE POLYPROPYLENE
POLYETHYLENE 100 GAUGE
POLYETHYLENE 150 GAUGE
POLYETHYLENE 200 GAUGE

green colour was maximum under microwave dehydration. Microwave dehydration also resulted in highest rehydration ratio in all the three species. The study has clearly revealed that simple pretreatments can bring about significant changes in the final quality of even sundried products. Thus the study on the dehydration techniques has indicated that the following treatment combination are superior compared to the rest in the respective species:

The treatments foun superior in *S.torvum* were:

Sundrying

T_3 - Hot water blanching in four per cent brine at 85°C for three minutes.

T_5 - Blanching in one per cent citric acid at 85°C for three minutes.

T_7 - Blanching in 0.5 per cent KMS at 85°C for three minutes.

Dehydration in cabinet dryer

T_3 - Hot water blanching in four per cent brine at 85°C for three minutes.

T_6 - Blanching in four per cent brine + 0.5 per cent KMS at 85°C for three minutes.

T_7 - Blanching in 0.5 per cent KMS at 85°C for three minutes.

Dehydration in microwave oven

T_3 - Hot water blanching in four per cent brine at 85°C for three minutes.

T_6 - Blanching in four per cent brine + 0.5 per cent KMS at 85°C for three minutes.

T_7 - Blanching in 0.5 per cent KMS at 85°C for three minutes.

The superior treatments found in *S.nigrum* were:

Sundrying

T_2 - Blanching in four per cent brine at 85^0C.

T_4 - Blanching in one per cent citric acid at 85^0C.

T_5 - Blanching in four per cent brine + 0.5 per cent KMS at 85^0C.

Dehydration in cabinet dryer

T_2 - Blanching in four per cent brine at 85^0C.

T_4 - Blanching in one per cent citric acid at 85^0C.

T_5 - Blanching in four per cent brine + 0.5 per cent KMS at 85^0C.

Dehydration in microwave oven

T_3 - Blanching in four per cent brine + one per cent citric acid at 85^0C.

T_4 - Blanching in one per cent citric acid at 85^0C.

T_5 - Blanching in four per cent brine + 0.5 per cent KMS at 85^0C.

The treatments found superior in *N.nucifera* were:

Sundrying

T_4 - Blanching in four per cent brine + one per cent citric acid at 85^0C.

T_6 - Blanching in four per cent brine + 0.5 per cent KMS at 85^0C.

T_7 - Blanching in 0.5 per cent KMS at 85^0C.

Dehydration in cabinet dryer

T_4 - Blanching in four per cent brine + one per cent citric acid at 85^0C.

T_5 - Blanching in one per cent citric acid at 85^0C.

T_6 - Blanching in four per cent brine + 0.5 per cent KMS at 85^0C.

Dehydration in microwave oven

T_5 - Blanching in one per cent citric acid at 85^{0}C.

T_6 - Blanching in four per cent brine + 0.5 per cent KMS at 85^{0}C.

T_7 - Blanching in 0.5 per cent KMS at 85^{0}C.

4.2. Packaging and storage studies of dehydrated products of *S.torvum, S.nigrum* and *N.nucifera.*

4.2.1. *Solanum torvum.*

Out of the eight treatments tried for drying of *S. torvum* three treatments were selected under each method of dehydration for packaging and storage studies based on the overall merits of each process. The ten treatments thus selected for the study were as follows:

T_1 - Samples treated with four per cent brine at 85^{0}C and sundried.

T_2 - Samples treated with one per cent citric acid at 85^{0}C and sundried.

T_3 - Samples treated with 0.5 per cent KMS at 85^{0}C and sundried.

T_4 - Samples treated with four per cent brine at 85^{0}C and dehydrated in cabinet dryer.

T_5 - Samples treated with four per cent brine + 0.5 per cent KMS at 85^{0}C and dehydrated in cabinet dryer.

T_6 - Samples treated with 0.5 per cent KMS at 85^{0}C and dehydrated in cabinet dryer.

T_7 - Samples treated with four per cent brine at 85^{0}C and dehydrated in microwave oven.

T_8 - Samples treated with four per cent brine + 0.5 per cent KMS at 85°C and dehydrated in microwave oven.

T_9 - Samples treated with 0.5 per cent KMS at 85°C and dehydrated in microwave oven.

T_{10} - Control - Samples sundried without subjecting to any pretreatments.

The products were packaged in 15 cm x 10 cm sized bags of polypropylene 80 gauge, polyethylene 100 gauge, polyethylene 150 gauge and polyethylene 200 gauge and stored for a period of six months (plate 17). The dehydrated products of vegetables available in the market are usually packaged in films of polyethylene and polypropylene. These transparent flexible packages maximise the use of available packaging space and are also comparatively cheaper than the other packaging films like aluminium foil, cellophane etc. The properties of plastic films which influence the storage stability are sealing, shrinking, stretching, permeability to gases and water vapour, transparency, gloss and adhesion of printing inks (Peleg, 1985). Thus to assess the efficacy of the commonly used polymeric films, the above packages were seleted for the study.

4.2.1.1. Weight gain in packaged product during storage.

The data on weight gain are presented in Table 16. The results did not show any significant variation with respect to weight gain. During the entire storage period of six months the weight gain due to moisture absorption was almost negligible in all the packages for all the treatments.

Table 16. Weight gain in dehydrated and packaging products of *S. torvum* during storage

Package	P_1 (80 gauge polypropylene)				P_2 (100 gauge polyethylene)				P_3 (150 gauge polyethylene)				P_4 (200 gauge polyethylene)			
	Weight gain (g)															
Treatments	2 months after storage	4 months after storage	6 months after storage	Mean	2 months after storage	4 months after storage	6 months after storage	Mean	2 months after storage	4 months after storage	6 months after storage	Mean	2 months after storage	4 months after storage	6 months after storage	Mean
T_1	0.36	0.36	0.37	0.36^{+}	0.36	0.37	0.36	0.36^{+}	0.37	0.37	0.35	0.36^{+}	0.37	0.36	0.37	0.37^{+}
T_2	0.18	0.17	0.18	0.18^{+}	0.18	0.18	0.18	0.18^{+}	0.18	0.18	0.18	0.18^{+}	0.17	0.18	0.18	0.18^{+}
T_3	0.49	0.36	0.37	0.41^{+}	0.36	0.37	0.37	0.32^{+}	0.37	0.36	0.37	0.37^{+}	0.37	0.37	0.37	0.37^{+}
T_4	0.20	0.19	0.20	0.20^{+}	0.20	0.20	0.20	0.20^{+}	0.20	0.20	0.19	0.20^{+}	0.20	0.20	0.19	0.20^{+}
T_5	0.24	0.24	0.23	0.24^{+}	0.23	0.24	0.24	0.24^{+}	0.24	0.24	0.24	0.24^{+}	0.24	0.24	0.23	0.24^{+}
T_6	0.19	0.19	0.19	0.19^{+}	0.19	0.18	0.19	0.19^{+}	0.19	0.18	0.19	0.19^{+}	0.19	0.19	0.19	0.19^{+}
T_7	0.27	0.26	0.27	0.27^{+}	0.27	0.27	0.27	0.27^{+}	0.27	0.27	0.27	0.27^{+}	0.27	0.27	0.27	0.27^{+}
T_8	0.32	0.32	0.32	0.32^{+}	0.32	0.32	0.33	0.32^{+}	0.32	0.32	0.32	0.32^{+}	0.32	0.31	0.32	0.32^{+}
T_9	0.24	0.25	0.24	0.25^{+}	0.25	0.25	0.25	0.25^{+}	0.24	0.24	0.25	0.25^{+}	0.25	0.25	0.25	0.25^{+}
T_{10}	0.28	0.28	0.28	0.28^{+}	0.28	0.28	0.28	0.28^{+}	0.28	0.28	0.28	0.28^{+}	0.28	0.28	0.27	0.28^{+}

+ Not significant

The loss or gain in moisture from the sample was mainly due to water vapour transmission property of plastic films (Dabhade and Khedkar, 1980). The water vapour transmission (at 37.8^{0}C and 90 per cent RH) of polyethylene and polypropylene are 1.2 - 1.4g/645mm^2/24hr and 0.5 - 0.7g/645mm^2/24hr respectively. Specific gravity is one of the most important film attributes. Even small changes in specific gravity drastically changes film properties. The specific gravity of low density polyethylene and polypropylene is same, i.e. 0.90. Gas transmission rate (at 23^{0}C and 50 per cent RH) for polyethylene is 500cm^3/645mm^2/24hr and 900cm^3/645mm^2/24hr respectively for oxygen and carbondioxide (Peleg, 1985).

When the dehydrated samples were kept in the open without any packaging, the average moisture uptake was 0.02g/g/24hr. The samples became very soft within one week. This gives an indication of the hygroscopicity of the dehydrated product. It is very evident that without the packaging it will not be possible to store the material for more than a week. The package acts as an efficient barrier to the moisture protecting the important properties of the dehydrated product and thus imparting the storage stability. Paine and Paine (1983) have reported that dried foods with 2 - 8 per cent moisture have equilibrium relative humidity values in 10 - 30 per cent region. As the humidity of ambient air is rarely in this range such food absorbs water vapour freely from the air surrounding them.

From the packaging view point hygroscopicity of dehydrated or dried food is very important and is influenced by the moisture content of the product itself

(Pruthi, 1978). The initial moisture content of dehydrated products are also very important with respect to storage stability (Salunkhe *et al.*, 1976). Mahadevaiah *et al.* (1977) conducted packaging studies on pulses and cereal flours and reported that low density polyethylene 250 gauge was suitable for long term storage of 8 - 10 months with desired protection against ingress of moisture. They also reported that product with higher moisture content (13 per cent) stored for short period (120 days) compared to low moisture food (8.8 per cent) which was stored for than 190 days. Kalra *et al.* (1987) studied the preparation, packaging and storage of potato snacks from cold stored potatoes and reported that raw potato snack (unfried) products packaged in 150 gauge LDPE bags were acceptable upto six months storage and might be consumed after deep fat frying.

The results of the present study indicate that, all the four polymeric film packages used were efficient to protect the product for a period of six months as far as moisture uptake was concerned.

4.2.1.2. Sensory qualities of the packaged products during storage.

The results of sensory evaluation of colour, texture and consumer acceptability of samples are presented in Tables 17, 18 and 19. The statistical analysis as per Kruskell Wallies' one way analysis showed there was no significant variation in colour, texture and consumer acceptability of products packed in polypropylene 80 gauge, polyethylene 100 gauage, polyethylene 150 gauge and polyethylene 200 gauge. for a period of six months.

Table [illegible] Storage stability of colour of dehydrated and packaged products of *S. torvum*

	Mean score values															
Package	P_1 (80 gauge of polypropylene)				P_2 (100 gauge polyethylene)				P_3 (150 gauge polyethylene)				P_4 (200 gauge polyethylene)			
Treatments	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage
T_1	3.58	3.63	3.63	3.70	3.59	3.59	3.68	3.71	3.56	3.58	3.64	3.68	3.58	3.61	3.65	3.68
T_2	3.33	3.37	3.36	3.45	3.34	3.39	3.43	3.43	3.35	3.35	3.41	3.44	3.33	3.38	3.37	3.39
T_3	3.45	3.48	3.48	3.53	3.47	3.49	3.55	3.51	3.46	3.46	3.49	3.53	3.44	3.47	3.49	3.49
T_4	4.80	4.83	4.84	4.88	4.82	4.84	4.83	4.84	4.81	4.87	4.87	4.88	4.82	4.82	4.86	4.89
T_5	4.43	4.45	4.48	4.48	4.42	4.46	4.48	4.49	4.42	4.44	4.47	4.50	4.43	4.46	4.46	4.60
T_5	4.41	4.45	4.45	4.45	4.48	4.20	4.44	4.60	4.50	4.42	4.43	4.48	4.49	4.41	4.42	4.48
T_6	1.50	1.42	1.45	1.45	1.48	1.43	1.44	1.46	1.48	1.42	1.42	1.48	1.51	1.43	1.44	1.46
T_8	1.25	1.27	1.29	1.30	1.25	1.26	1.26	1.29	1.26	1.29	1.26	1.30	1.26	1.26	1.27	1.27
T_9	1.61	1.63	1.63	1.68	1.61	1.64	1.67	1.66	1.66	1.63	1.61	1.63	1.66	1.68	1.68	1.68
T_{10}	3.65	3.67	3.68	3.72	3.64	3.67	3.67	3.71	3.65	3.68	3.69	3.73	3.66	3.66	3.71	3.71

Note: All figures are not significantly different

Score: 1. Light green, 2. Brownish green, 3. Yellowish green, 4. Brown,
5. Burnt appearance

The shelf life of a dehydrated food like any other food product depends on a number of factors some of which can be influenced by packaging and others not. These factors are (1) moisture uptake, (2) oxygen, (3) flavour contamination and (4) mechanical damage. The maintenance of dry state is of two fold importance. The major deteriorative chemical reaction in dehydrated food (notably non-enzymatic browning) is retarded at very low moisture level (Murthi, 1982). The moisture content of dehydrated fruits of *S. torvum* was low ie. 7 ± 1 per cent. So this may be the probable reason for the stability in colour during the storage period. Mahadevaiah *et al.* (1976) conducted packaging and storage studies on dried, ground and whole chillies (*Capsicum annum*) in flexible consumer packages and reported that the colour values in chilli powder had decreased with increase in moisture content. The storage stability in texture and consumer acceptability may also due to the low moisture content of dehydrated products.

As far as packages were concerned there was no significant changes between different packages *viz*., polypropylene 80 gauge, polyethylene 100gauge, polyethylene 150 gauge, and polyethylene 200 gauge. Eventhough thinner films like polypropylene 80 gauge, polyethylene 100 gauge have less gas and moisture barrier property compared to the other two, it did not influence the colour, texture and consumer acceptability upto six months, indicating that the product was stable under the protection of different packages. Veenakumari (1992) studied packaging and storage of dehydrated bittergourd slices in polyethylene

Table 18. Storage stability of texture of dehydrated and packaged products of *S. torvum*

Mean score values																
Packages	P_1 (80 gauge polypropylene)				P_2 (100 gauge polyethylene)				P_3 (150 gauge polyethylene)				P_4 (200 gauge polyethylene)			
Treatments	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of sotrage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage
T_1	2.75	2.79	2.81	2.83	2.68	2.68	2.70	2.73	2.74	2.75	2.75	2.75	2.73	2.79	2.82	2.86
T_2	2.63	2.68	2.68	2.70	2.63	2.63	2.69	2.70	2.68	2.72	2.76	2.77	2.65	2.66	2.68	2.71
T_3	2.68	2.73	2.78	2.81	2.65	2.70	2.70	2.74	2.72	2.77	2.83	2.83	2.64	2.64	2.69	2.73
T_4	2.51	2.54	2.54	2.62	2.57	2.58	2.59	2.66	2.56	2.59	2.63	2.66	2.60	2.68	2.72	2.72
T_5	2.98	3.01	3.04	3.05	2.98	2.98	3.03	3.06	2.81	2.85	2.89	2.94	2.88	2.92	2.92	2.94
T_6	2.73	2.73	2.78	2.80	2.75	2.76	2.77	2.77	2.75	2.80	2.81	2.83	2.81	2.83	2.85	2.88
T_7	2.13	2.16	2.21	2.22	2.10	2.11	2.15	2.18	2.18	2.20	2.22	2.25	2.12	2.15	2.16	2.20
T_8	2.25	2.30	2.31	2.34	2.28	2.28	2.28	2.30	2.30	2.20	2.26	2.28	2.32	2.21	2.22	2.27
T_9	2.25	2.30	2.31	2.32	2.25	2.31	2.31	2.31	2.28	2.30	2.36	2.40	2.27	2.30	2.34	2.35
T_{10}	2.51	2.56	2.61	2.63	2.50	2.53	2.57	2.61	2.53	2.56	2.58	2.61	2.54	2.54	2.59	2.60

Note: All figures are not significantly different

Score: 1. Very crisp, 2. Moderately crisp, 3. Neither crisp nor hard, 4. Hard,
5. Very hard

Table 19. Consumer acceptability of dehydrated and packaged products of *S. torvum* during storage

Mean score values

Package	P_1 (80 gauge polypropylene)				P_2 (100 gauge polyethylene)				P_3 (150 gauge polyethylene)				P_4 (200 gauge polyethylene)			
Treatments	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage
T_1	1.78	1.79	1.82	1.84	1.76	1.76	1.82	1.83	1.76	1.81	1.84	1.86	1.83	1.85	1.86	1.90
T_2	2.02	2.07	2.07	2.10	2.11	2.11	2.13	2.13	2.05	2.09	2.12	2.13	1.98	1.98	2.00	2.00
T_3	2.15	2.18	2.21	2.22	2.05	2.09	2.11	2.15	2.23	2.26	2.28	2.30	2.23	2.23	2.25	2.29
T_4	1.78	1.80	1.82	1.82	1.81	1.81	1.84	1.86	1.81	1.83	1.85	1.89	1.78	1.78	1.78	1.80
T_5	1.65	1.68	1.71	1.73	1.64	1.64	1.69	1.71	1.75	1.76	1.77	1.79	1.71	1.76	1.79	1.82
T_6	1.85	1.85	1.89	1.90	1.74	1.74	1.74	1.79	1.78	1.82	1.83	1.86	1.79	1.80	1.81	1.81
T_7	1.82	1.87	1.91	1.92	1.74	1.74	1.79	1.84	1.70	1.75	1.82	1.84	1.74	1.75	1.80	1.82
T_8	2.11	2.12	2.15	2.15	2.13	2.14	2.15	2.20	2.15	2.18	2.21	2.24	2.15	2.19	2.22	2.22
T_9	2.18	2.22	2.22	2.25	2.22	2.25	2.29	2.32	2.25	2.27	2.27	2.32	2.28	2.30	2.35	2.[illegible]
T_{10}	2.51	2.53	2.58	2.62	2.53	2.59	2.62	2.67	2.56	2.56	2.59	2.58	2.58	2.60	2.60	2.[illegible]

Note: All figures are not significantly different

Score: 1. Acceptable fully, 2. Acceptable some what,
3. Neither acceptable nor unacceptable, 4. Unacceptable some what
5. Not acceptable

bags of 150, 300, 450, and 600 gauges and polypropylene 100 gauge and found that polyethylene 600 gauge and polypropylene 100 gauge were efficient upto three months of storage.

In the present study *S. torvum* were packaged with a moisture content of 7 ± 1 per cent. At this level the product stood stable for six months in all the packages tried. When the moisture content is slightly higher (say eight or nine per cent) it will result in a better recovery value and shorter process time. This will reduce the cost of production and increase profitability of the product. However, microbiological stability of the product is also to be worked out before finalising the ultimate moisture content for the product. Murthi (1982) reported that the fundamental function of drying as a method of food preservation was to inhibit the growth of microorganisms.

4.2.2. *Solanum nigrum.*

Out of the eight treatments tried for drying of *S. nigrum* three treatments were selected under each method of dehydration for packaging and storage studies based on the overall merits of each process. The ten treatments thus selected for the study were as follows:

T_1 - Samples treated with four per cent brine at 85^0C and sundried.

T_2 - Samples treated with one per cent citric acid at 85^0C and sundried.

T_3 - Samples treated with 0.5 per cent KMS at 85^0C and sundried.

T_4 - Samples treated with four per cent brine at 85^{0}C and dehydrated in cabinet dryer.

T_5 - Samples treated with one per cent citric acid at 85^{0}C and dehydrated in cabinet dryer.

T_6 - Samples treated with 0.5 per cent KMS at 85^{0}C and dehydratedin cabinet dryer.

T_7 - Samples treated with four per cent brine + one per cent citric acid at 85^{0}C and dehydrated in microwave oven.

T_8 - Samples treated with one per cent citric acid at 85^{0}C and dehydrated in microwave oven.

T_9 - Samples treated with 0.5 per cent KMS at 85^{0}C and dehydrated in microwave oven.

T_{10} - Control (samples sundried without any pretreatments).

The products were packaged in 15 cm x 10 cm sized polypropylene 80 gauge, polyethylene 100 gauge, polyethylene 150 gauge and polyethylene 200 gauge and stored for a period of six months (plate 18).

4.2.2.1. Weight gain in packaged product during storage.

The data on weight gain are presented in Table 20. The results did not show any significant variation with respect to weight gain. During the entire storage period of six months the weight gain due to moisture absorption was very less in all the packages *viz*., 80 gauge polypropylene, 100 gauge polyethylene, 150

Table 20. Weight gain in dehydrated and packaged products of *S. nigrum* during storage

	Weight gain (g)															
Packages	P_1 (80 gauge polypropylene)				P_2 (100 gauge polyethylene)				P_3 (150 gauge polyethylene)				P_4 (200 gauge polyethylene)			
Treatments	2 months after storage	4 months after storage	6 months after storage	Mean	2 months after storage	4 months after storage	6 months after storage	Mean	2 months after storage	4 months after storage	6 months after storage	Mean	2 months after storage	4 month after storage	6 months after storage	Mean
T_1	0.22	0.22	0.21	0.22+	0.22	0.21	0.21	0.21+	0.21	0.21	0.22	0.21+	0.21	0.22	0.22	0.2[illegible]+
T_2	0.38	0.39	0.39	0.39+	0.39	0.39	0.39	0.39+	0.39	0.38	0.39	0.39+	0.39	0.39	0.39	0.39+
T_3	0.36	0.37	0.37	0.37+	0.37	0.37	0.37	0.37+	0.37	0.37	0.37	0.37+	0.37	0.37	0.37	0.37+
T_4	0.18	0.19	0.19	0.19+	0.10	0.19	0.19	0.19+	0.19	0.19	0.19	0.19+	0.19	0.19	0.19	0.19+
T_5	0.23	0.24	0.24	0.24+	0.24	0.24	0.24	0.24+	0.24	0.23	0.24	0.24+	0.23	0.23	0.23	0.23+
T_6	0.28	0.28	0.27	0.28+	0.28	0.28	0.28	0.28+	0.28	0.28	0.28	0.28+	0.28	0.28	0.28	0.2[illegible]
T_7	0.27	0.26	0.26	0.26+	0.27	0.26	0.27	0.27+	0.26	0.26	0.27	0.27+	0.27	0.27	0.27	0.27+
T_8	0.24	0.23	0.23	0.23+	0.24	0.24	0.24	0.24+	0.23	0.23	0.23	0.24+	0.24	0.24	0.24	0.24+
T_9	0.24	0.25	0.24	0.24+	0.25	0.24	0.25	0.25+	0.24	0.24	0.24	0.24+	0.24	0.25	0.24	0.24+
T_{10}	0.27	0.26	0.27	0.27+	0.27	0.27	0.27	0.27+	0.26	0.27	0.27	0.27+	0.27	0.27	0.27	0.27+

+ Not significant

gauge polyethylene and 200 gauge polyethylene for all the treatments.

The same result was obtained in *Solanum torvum* also. In *S. nigrum* the moisture content of fruits was 7 ± 1 per cent as in the case of *S.torvum*. Hence the storage stability of dehydrated product of *S. nigrum* with respect to weight gain was as justified with the explanation already given under 4.2.1.1. When the dehydrated samples kept in open without any packaging the average moisture uptake was 0.03g/g/24hr. The samples became very soft within one week. This moisture uptake was almost similar to that of unpackaged samples of *S. torvum*. This trend again shows that the dehydrated products are highly hygroscopic in nature and which requires protection from the ingress of moisture from the surrounding atmosphere. This trend has been justified as under 4.2.1.1.

4.2.2.2. Sensory qualities of the dehydrated product during storage.

The results of sensory evaluation of colour, texture and consumer acceptability of samples are presented in Tables 21, 22 and 23. The statistical analysis as per Kruskell Wallies' one way analysis showed that there was no significant change in colour, texture and consumer acceptability of products packed in polypropylene 80 gauge, polyethylene 100 gauge, polyethylene 150 gauge and polyethylene 200 gauge for a period of six months. The same result was obtained in *S. torvum* also. This indicated that the colour, texture and consumer acceptability were sufficiently protected by the four packages used for study. Moreover the moisture content was similar to that of *S. torvum* *ie*. 7±1

Table 21. Storage stability of colour of dehydrated and packaged products of *S. nigrum*

	Mean score values															
Packages	P_1 (80 gauge polypropylene)				P_2 (100 gauge polyethylene)				P_3 (150 gauge polyethylene)				P_4 (200 gauge polyethylene)			
Treatments	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storages	2 months after storage	4 months after storage	6 months after storage	At the time of stages	2 months after storage	4 months after storage	6 months after storage
T_1	3.61	3.63	3.64	3.66	3.61	3.61	3.61	3.64	3.63	3.64	3.67	3.71	3.62	3.62	3.64	3.69
T	3.22	3.23	3.26	3.29	3.20	3.25	3.26	3.30	3.21	3.22	3.23	3.25	3.21	3.22	3.24	3.24
T	3.31	3.35	3.35	3.38	3.31	3.34	3.34	3.36	3.30	3.31	3.33	3.35	3.32	3.32	3.34	3.36
T_4	3.10	3.13	3.14	3.18	3.13	3.14	3.17	3.20	3.73	3.14	3.14	3.15	3.11	3.11	3.13	3.16
T_5	3.11	3.12	3.15	3.19	3.12	3.12	3.14	3.16	3.14	3.17	3.20	3.20	3.12	3.15	3.16	3.17
T_6	3.15	3.17	3.19	3.20	3.16	3.16	3.18	3.19	3.15	3.18	3.20	3.23	3.15	3.15	3.15	3.16
T_7	4.31	4.32	4.35	4.36	4.35	4.36	4.36	4.37	4.39	4.35	4.40	4.41	4.32	4.35	4.36	4.40
T_8	4.71	4.73	4.75	4.79	4.74	4.74	4.76	4.79	4.71	4.71	4.75	4.76	4.73	4.75	4.79	4.80
T_9	4.62	4.64	4.66	4.66	4.62	4.62	4.64	4.66	4.62	4.63	4.65	4.67	4.63	4.64	4.64	4.68
T_{10}	3.75	3.76	3.79	3.80	3.75	3.75	3.79	3.80	3.76	3.77	3.78	3.81	3.75	3.78	3.82	3.82

Note: All figures are not significantly different

Score: 1. Light green, 2. Brownish green, 3. Yellowish brown, 4. Brown,
5. Burnt appearance

Table 22. Storage stability of texture of dehydrated and packaged products of *S. nigrum*

Mean score values																
Packages	P_1 (80 gauge polypropylene)				P_2 (100 gauge polyethylene)				P_3 (150 gauge polyethylene)				P_4 (200 gauge polyethylene)			
Treatments	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage
T_1	2.75	2.77	2.77	2.50	2.75	2.76	2.78	2.81	2.76	2.79	2.79	2.80	2.79	2.83	2.84	2.84
T_2	2.68	2.69	2.72	2.74	2.69	2.71	2.73	2.74	2.70	2.72	2.74	2.76	2.70	2.71	2.74	2.77
T_3	2.51	2.53	2.54	2.57	2.50	2.52	2.53	2.56	2.51	2.53	2.54	2.55	2.51	2.52	2.55	2.55
T_4	3.25	3.26	3.27	3.27	3.25	3.27	3.28	3.29	3.26	3.29	3.29	3.24	3.25	3.27	3.25	3.28
T_5	3.33	3.35	3.35	3.37	3.33	3.36	3.38	3.38	3.32	3.34	3.36	3.37	3.34	3.34	3.36	3.37
T_6	3.41	3.43	3.45	3.46	3.44	3.45	3.47	3.48	3.42	3.44	3.45	3.45	3.43	3.45	3.46	3.[illegible]
T_7	1.75	1.77	1.77	1.79	1.74	1.76	1.78	1.79	1.74	1.78	1.79	1.79	1.73	1.74	1.76	1.77
T_8	1.65	1.66	1.67	1.67	1.68	1.69	1.72	1.73	1.65	1.66	1.67	1.69	1.66	1.67	1.68	1.70
T_9	1.84	1.85	1.88	1.88	1.84	1.86	1.87	1.88	1.86	1.87	1.88	1.90	1.87	1.87	1.89	1.90
T_{10}	2.13	2.14	2.14	2.16	2.14	2.15	2.16	2.17	2.15	2.17	2.18	2.18	2.15	2.16	2.17	2.19

Note: All figures are not significantly different

Score: 1. Very crisp, 2. Moderately crisp, 3. Neither crisp or hard, 4. Hard, 5. Very hard per cent. This would have attributed to the storage stability of the above sensory qualities. While discussing the sensory qualities of packaged products of *S. torvum* this trend has been explained.

4.2.3. ***Nelumbo nucifera.***

Out of eight treatments tried for drying of *N. nucifera* three treatments were selected under each method of dehydration for packaging and storage studies based on the overal merits of each process. The ten treatments thus selected for the study were as follows:

T_1 - Samples treated with four per cent brine + one per cent citric acid at 85^0C and sundried.

T_2 - Samples treated with four per cent brine + 0.5 per cent KMS at 85^0C and sundried.

T_3 - Samples treated with 0.5 per cent KMS at 85^0C and sundried.

T_4 - Samples treated with four per cent brine + one per cent citric acid at 85^0C and dehydrated in cabinet dryer.

T_5 - Samples treated with one per cent citric acid at 85^0C and dehydrated in cabinet dryer.

T_6 - Samples treated with four per cent brine + 0.5 per cent KMS at 85^0C and dehydrated in cabinet dryer.

T_7 - Samples treated with one per cent citric acid at 85^0C and dehydrated in microwave oven.

Table 23. Consumer acceptability of dehydrated and packaged products of *S. nigrum*

Mean score values																
Packages	P_1 (80 gauge polypropylene)				P_2 (100 gauge polyethylene)				P_3 (150 gauge polyethylene)				P_4 (200 gauge polyethylene)			
Treatments	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage
T_1	2.66	2.66	2.68	2.70	2.66	2.67	2.68	2.69	2.67	2.69	2.69	2.72	2.68	2.70	2.70	2.72
T_2	2.48	2.49	2.51	2.53	2.49	2.49	2.52	2.54	2.49	2.51	2.51	2.53	2.48	2.49	2.51	2.54
T_3	2.53	2.54	2.56	2.57	2.53	2.53	2.55	2.56	2.51	2.52	2.54	2.55	2.52	2.54	2.55	2.56
T_4	2.13	2.14	2.16	2.17	1.25	2.16	2.17	2.18	2.15	2.16	2.18	2.18	2.14	2.15	2.17	2.18
T_5	2.15	2.16	2.16	2.19	2.16	2.17	2.17	2.19	2.17	2.19	2.19	2.20	2.15	2.15	2.17	2.18
T_6	2.25	2.26	2.28	2.29	2.20	2.21	2.23	2.24	2.21	2.22	2.24	2.25	2.22	2.21	2.24	2.25
T_7	1.85	1.86	1.87	1.89	1.85	1.88	1.88	1.90	1.86	1.88	1.90	1.91	1.86	1.86	1.89	1.90
T_8	1.95	1.97	1.99	2.01	1.94	1.94	1.96	2.00	1.95	1.93	1.96	1.99	1.96	1.96	1.98	1.98
T_9	1.75	1.76	1.77	1.79	1.75	1.77	1.75	1.80	1.73	1.74	1.76	1.77	1.74	1.78	1.79	1.80
T_{10}	2.12	2.13	2.15	2.15	2.15	2.15	2.19	2.19	2.13	2.12	2.18	2.17	2.16	2.18	2.19	2.20

te: All figures are not significantly different

core: 1. Acceptable fully, 2. Acceptable some what,
3. Neither acceptable nor unacceptable, 4. [illegible]ptable some what
5. Not acceptable

T_8 - Samples treated with four per cent brine + 0.5 per cent KMS at 85^0C and dehydrated in microwave oven.

T_9 - Samples treated with 0.5 per cent KMS at 85^0C and dehydrated in microwave oven.

T_{10} - Control (Samples sundried without blanching).

The dehydrated products were packaged in 15 cm x 10 cm sized bags of polypropylene 80 gauge, polyethylene 100 gauge, polyethylene 150 gauge and polyethylene 200 gauge (plate 19).

4.2.3.1. Weight gain in packaged product during storage.

The data on weight gain are presented in Table 24. The results did not show any significant variation with respect to weight gain. During the entire storage period of six months the weight gain due to moisture absorption was almost negligible in all packages for all the treatments. The same result was obtained in *S.nigrum* and *S.torvum* also. In *N.nucifera* too the moistre content of dehydrated products was low ie.7 ± 1 per cent. The storage stability of dehydrated products with respect to moisture content has already been explained under 4.2.1.1.

When the samples were kept in open without any packaging the average moisture uptake was 0.06g/g/24hr. This was almost double to that of *S.torvum* and *S. nigrum*. In *S. torvum* and *S. nigrum* the fruit skin may reduce the rate of moisture absorption. Moreover, stolon slices are highly porous in nature. They

Table 24. Weight gain in dehydrated and packaged products of *N. nucifera* during storage

Weight gain (g)																
Packages	P_1 (80 gauge polypropylene)				P_2 (100 gauge polyethylene)				P_3 (150 gauge polyethylene)				P_4 (200 gauge polyethylene)			
Treatments	2 months after storage	4 months after storage	6 months after storage	Mean	2 months after storage	4 months after storage	6 months after storage	Mean	2 months after storage	4 months after storage	6 months after storage	Mean	2 months after storage	4 months after storage	6 months after storage	Mean
T_1	0.14	0.14	0.14	0.14^{+}	14	0.14	0.14	0.14^{+}	0.14	0.14	0.14	0.14^{+}	0.14	0.14	0.14	0.14^{+}
T_2	0.23	0.23	0.23	0.23^{+}	0.23	0.23	0.23	0.23^{+}	0.23	0.23	0.23	0.23^{+}	0.23	0.23	0.23	0.23^{+}
T_3	0.19	0.19	0.19	0.19^{+}	0.19	0.19	0.19	0.19^{+}	0.19	0.19	0.19	0.19^{+}	0.10	0.19	0.19	0.19^{+}
T_4	0.36	0.36	0.36	0.36^{+}	0.35	0.36	0.36	0.36^{+}	0.36	0.36	0.36	0.36^{+}	0.36	0.36	0.36	0.36^{+}
T_5	0.38	0.39	0.39	0.39^{+}	0.39	0.38	0.38	0.38^{+}	0.39	0.39	0.39	0.39^{+}	0.39	0.38	0.39	0.39^{+}
T_6	0.38	0.38	0.38	0.38^{+}	0.37	0.37	0.38	0.38^{+}	0.38	0.38	0.37	0.38^{+}	0.38	0.38	0.38	0.38^{+}
T_7	0.55	0.55	0.54	0.55^{+}	0.55	0.55	0.55	0.55^{+}	0.54	0.54	0.55	0.55^{+}	0.55	0.54	0.55	0.55^{+}
T_8	0.51	0.51	0.52	0.52^{+}	0.52	0.54	0.52	0.52^{+}	0.52	0.52	0.51	0.52^{+}	0.52	0.51	0.52	0.52^{+}
T_9	0.32	0.32	0.33	0.32^{+}	0.33	0.33	0.32	0.33^{+}	0.33	0.33	0.33	0.33^{+}	0.33	0.33	0.32	0.33^{+}
T_{10}	0.56	0.56	0.57	0.56^{+}	0.56	0.57	0.57	0.57^{+}	0.57	0.57	0.56	0.57^{+}	0.57	0.56	0.57	0.57^{+}

+ Not significant

contain small holes in the centre as well as in the periphery. Thus the surface area exposed to air became more as compared to the other two species. This may be the reason for high moisture uptake in *N. nucifera* compared to *S. torvum* and *S. nigrum.* However, the four packages used in the experiment were good enough to offer the required protection from moisture.

4.2.3.2. Sensory qualities of packaged products during storage.

The results of sensory evaluation of colour, texture and consumer acceptability of samples are presented in Tables 25, 26 and 27. The statistical analysis as per Kruskell Wallies' one way analysis showed that there was no significant variation in colour, texture and consumer acceptability of products packed in polypropylene 80 gauge, polyethylene 100 gauge, polyethylene 150 gauge and polyethylene 200 gauge for a period of six months. The same result was obtained in the other two species. This indicates that the effect of packaging was almost similar between the four packages for storing the products for a period of six months without much deterioration in qualities like colour, texture and consumer acceptability. In *N. nucifera* also the products were packaged with an initial moisture content of 7±1 per cent. Eventhough they were more hygroscopic than the other two species all the four packages were efficient to protect the product from the absorption of moisture. This justified the suitability of the four polymeric films for a storage period of six months as explained under 4.2.1.2. The present study revealed that polypropylene 80 gauge could be used for packaging the dehydrated products considering the minimum value addition involved in the

Plate 19. Packages for dehydrated products of *N.nucifera*

Plate 20. Coconut oil fried products of *S.torvum* subjected to different dehydration procedures


PACKAGES FOR DEHYDRATED
NELUMBO NUCIFERA
CONTROL
T
T
T
T
T
T
T
T
T
T
80 GAUGE POLYPROPYLENE
POLYETHYLENE 100 GAUGE
POLYETHYLENE 150 GAUGE
POLYETHYLENE 200 GAUGE


COCONUT OIL FRIED PRODUCTS OF
SOLANUM TORVUM
SUBJECTED TO DIFFERENT
DEHYDRATION PROCEDURES
SUN DRIED
MICROWAVE DEHYDRATE
DEHYDRATED IN CABINET DRIER

Table 25. Storage stability of colour of dehydrated and packaged products of *N. nucifera*

Mean score values																
Packages	P$_1$ (80 gauge polypropylene)				P$_2$ (100 gauge polyethylene)				P$_3$ (150 gauge polyethylene)				P$_4$ (200 gauge polyethylene)			
Treatments	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage
T$_1$	4.11	4.14	4.10	4.20	4.12	4.12	4.14	4.18	4.13	4.16	4.17	4.17	4.11	4.15	4.20	4.23
T$_2$	3.40	3.45	3.46	3.49	3.50	3.50	3.51	3.57	3.45	3.46	3.50	3.53	3.46	3.50	3.51	3.57
T$_3$	4.20	4.24	4.28	4.29	4.22	4.23	4.23	4.26	4.20	4.28	4.32	4.21	4.25	4.26	4.30	4.31
T$_4$	3.95	4.00	4.01	4.03	3.96	3.97	3.97	4.00	3.96	4.01	4.07	4.10	3.97	4.02	4.03	4.04
T$_5$	3.81	3.85	3.88	3.92	3.85	3.88	3.88	3.88	3.82	3.82	3.86	3.91	3.83	3.88	3.90	3.93
T$_6$	4.25	42.9	4.32	4.34	4.26	4.26	4.28	4.28	4.26	4.30	4.31	4.34	4.37	4.34	4.34	4.36
T$_7$	3.85	3.90	3.91	3.91	3.86	3.87	3.87	3.92	3.86	3.90	3.91	3.93	3.87	3.87	3.88	3.91
T$_8$	3,43	3,46	3,49	3.51	3.45	3.50	3.53	3.56	3.46	3.48	3.52	3.54	3.41	3.41	3.44	3.48
T$_9$	4.10	4.12	4.12	4.16	4.11	4.18	4.16	4.19	4.11	4.13	4.17	4.22	4.11	4.14	4.18	4.18
T$_{10}$	4.83	4.86	4.90	4.92	4.85	4.88	4.91	4.94	4.85	4.90	4.92	4.93	4.83	4.85	4.85	4.89

Note: All figures are not significantly different

Score: 1. Cream, 2. Whitish yellow, 3. Yellow, 4. Yellowish brown, 5. Light brown

Table 26. Storage stability of texture of dehydrated and packaged products of *N. nucifera* during storage

	Mean score values															
Package	P_1 (80 gauge polypropylene)				P_2 (100 gauge polyethylene)				P_3 (150 gauge polyethylene)				P_4 (200 gauge polyethylene)			
Treatments	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage
T_1	4.25	4.28	4.31	4.34	4.30	4.32	4.38	4.41	4.28	4.29	4.32	4.36	4.26	4.30	4.33	4.32
T_2	3.85	3.88	3.91	3.93	3.90	3.92	3.95	3.99	3.88	3.93	3.98	4.01	3.88	3.88	3.88	3.91
T_3	3.99	4.03	4.03	4.06	3.99	4.01	4.04	4.10	4.00	4.02	4.02	4.05	3.98	3.99	4.04	4.04
T_4	4.11	4.14	4.16	4.16	4.15	4.16	4.18	4.18	4.15	4.17	4.17	4.20	4.13	4.14	4.16	4.19
T_5	3.75	3.76	3.78	3.79	3.77	3.77	3.77	3.80	3.77	3.81	3.82	3.82	3.80	3.80	3.81	3.84
T_6	4.15	4.18	4.19	4.21	41.6	4.17	4.21	4.21	4.15	4.16	1.46	4.18	4.16	4.19	4.21	4.22
T_7	4.21	4.24	4.25	4.28	4.20	4.21	4.25	4.26	4.25	4.30	4.31	4.33	4.22	4.25	4.28	4.32
T_8	4.00	4.03	4.06	4.06	4.05	4.05	4.06	4.06	4.03	4.04	4.09	4.11	4.05	4.09	4.10	4.10
T_9	4.28	4.31	4.32	4.34	4.30	4.31	4.33	4.33	4.30	4.34	4.35	4.38	4.31	4.32	4.32	4.35
T_{10}	3.85	3.88	3.90	3.91	3.88	3.88	3.93	3.94	3.81	3.82	3.85	3.88	3.85	3.85	3.86	3.86

Note: All figures are not significantly different
Score: 1. Very crisp, 2. Moderately crisp, 3. Neither crisp nor hard, 4. Hard,
5. Very hard

Table 27. Consumer acceptability of dehydrated and packaged products of *N. nucifera* during sotrage

Mean score values

Packages	P_1 (80 gauge polypropylene)				P_2 (100 gauge polyethylene)				P_3 (150 gauge polyethylene)				P_4 (200 gauge polyethylene)			
Treatments	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage	At the time of storage	2 months after storage	4 months after storage	6 months after storage
T_1	1.51	1.55	1.57	1.60	1.51	1.52	1.53	1.53	1.50	1.56	1.56	1.58	1.49	1.52	1.55	1.57
T_2	1.68	1.69	1.73	1.77	1.69	1.69	1.74	1.74	1.70	1.72	1.74	1.77	1.71	1.73	1.75	1.78
T_3	1.65	1.68	1.68	1.70	1.64	1.67	1.70	1.71	1.64	1.65	1.68	1.68	1.66	1.67	1.69	1.69
T_4	1.23	1.25	1.26	1.29	1.22	1.24	1.26	1.28	1.23	1.26	1.27	1.29	1.24	1.26	1.28	1.30
T_5	1.45	1.46	1.48	1.49	1.44	1.47	1.48	1.51	1.43	1.46	1.46	1.50	1.45	1.48	1.50	1.50
T_6	1.51	1.56	1.57	1.58	1.50	1.53	1.54	1.57	1.52	1.54	1.56	1.58	1.51	1.52	1.55	1.57
T_7	1.35	1.38	1.38	1.40	1.34	1.37	1.38	1.38	1.36	1.38	1.39	1.41	1.36	1.39	1.39	1.40
T_8	1.85	1.87	1.88	1.89	1.84	1.86	1.86	1.89	1.84	1.57	1.88	1.90	1.85	1.88	1.89	1.91
T_9	1.65	1.67	1.69	1.73	1.64	1.66	1.68	1.72	1.66	1.68	1.68	1.70	1.67	1.69	1.71	1.72
T_{10}	2.31	2.33	2.36	2.38	2.30	2.34	2.36	2.37	2.32	2.34	2.38	2.39	2.31	2.34	2.37	2.37

Note: All figures are not significantly different

Score: 1. Acceptable fully, 2. Acceptable some what
3. Neither acceptable nor unacceptable, 4. Unacceptable some what
5. Not acceptable

packaging. The average weight of 15 cm x 10 cm sized bags of polypropylene 80 gauge, polyethylene 100 gauge, polyethylene 150 gauge and polyethylene 200 gauge were 0.913 g, 1.791 g, 1.839 g and 1.899 g respectively. The market price of one kg polypropylene or polyethylene covers was Rs. 86/- and Rs. 90/- respectively. Thus, polypropylene 80 gauge was the cheapest of all the packages studied.

4.3. Sensory evaluation of hot oil fried dehydrated samples of *S.torvum,S.nigrum* and *N.nucifera.*

4.3.1. *Solanum torvum.*

Dehydrated fruits of *S. torvum* after frying in coconut oil medium were tasted and evaluated by a panel of ten semi trained judges. They were asked to score for taste, colour and overall acceptability using a nine point Hedonic scale ranging from "Like extremely" to "Dislike extremely". The score values awarded by the panel of judges were statistically analysed. Results of analysis as per Kruskell Wallies' one way analysis are presented in Table 28.

4.3.1.1. Taste.

Results of analysis showed that there was significant difference between the dehydration methods with respect to the taste of the product (Fig. 15). Lowest score (4.16) of microwave oven dehydrated products showed that it was superior over sundried and cabinet dryer product.

Decareau (1984) reported that when matter was treated with microwaves,

Table 28. Sensory evaluation of coconut oil fried products of *S. torvum*

Treatments	Methods of dehydration											
	Taste (score)				Colour (score)				Overall acceptability(score)			
	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean
T_1	4.83	5.00	4.50	4.78	4.16	3.50	4.50	4.05	4.66	4.33	4.83	4.61
T_2	5.66	4.83	4.66	5.05	5.83	4.50	4.50	4.94	5.33	4.83	5.00	5.05
T_3	4.50	4.00	3.66	4.05	4.16	4.00	3.83	4.00	4.66	3.66	3.33	3.88
T_4	4.16	4.33	3.33	3.94	4.83	5.16	4.00	4.66	5.00	4.00	3.83	4.28
T_5	4.33	4.66	3.83	4.27	4.16	4.33	4.16	4.22	4.33	4.33	3.83	4.16
T_6	4.83	5.00	4.16	4.66	4.33	5.00	4.66	4.66	5.00	4.83	4.33	4.72
T_7	4.00	3.50	4.16	3.89	4.16	3.16	4.50	3.94	4.00	3.66	4.00	3.89
T_8	6.16	7.33	5.00	6.16	3.66	7.33	6.50	5.83	4.60	7.33	5.00	5.64
Mean	4.81	4.83	4.16		4.41	4.62	4.58		4.70	4.62	4.27	

H* for			
Treatments	35.67	24.48	34.52
Dehydration methods	7.73	NS	NS

H* - Kruskell Wallies Statistic

Hedonic scale for sensory evaluation

1. like extremely, 2. like very much, 3. like moderately, 4. like slightly, 5. neither like nor dislike, 6. dislike slightly, 7. dislike moderately, 8. dislike very much, 9. dislike extremely

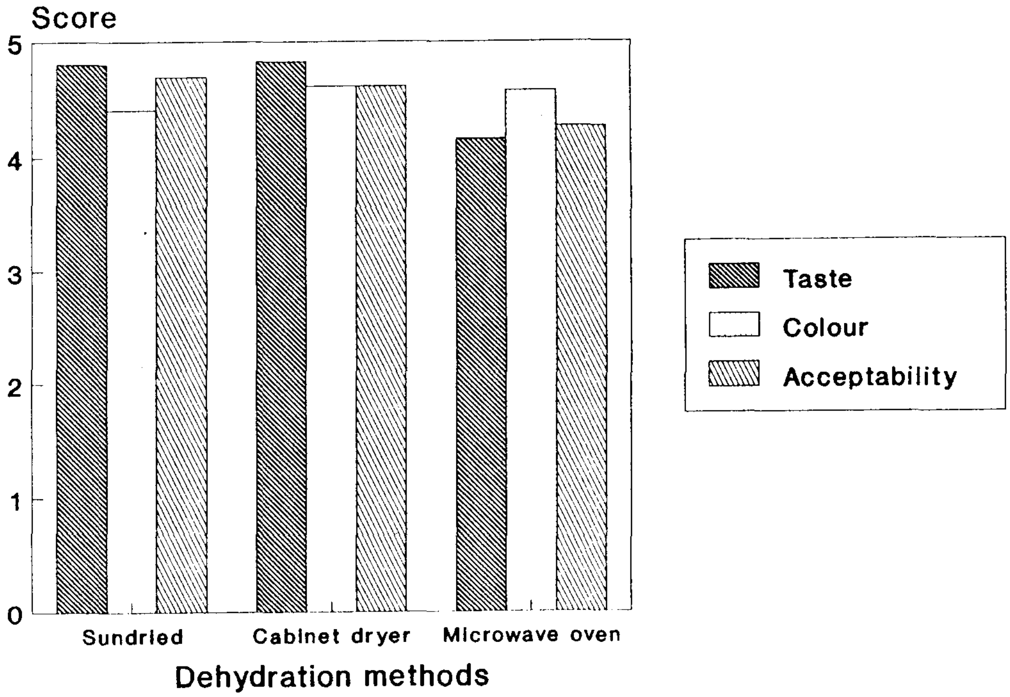
heat generated deep within the material and not at the surface only. This resulted in shorter processing times, higher yield and better quality than conventional techniques. Microwave food had a different taste compared to conventionally cooked foods (Anon, 1985). Ruello (1987) reported that the fast cooking times of microwaves resulted in better retention of volatile substances and microwaved food had taste quite different from conventionally cooked food. The present findings also support this view.

Patil *et al.* (1978) have reported that fenugreek dehydrated in cabinet dryer was more acceptable than sundried product. Mudahar and Bains (1982) studied dehydration process in mushroom and reported that mushroom dehydrated in cabinet dryer with through hot air flow was superior to sundried mushroom. The present findings also support this view.

The pretreatments also varied significantly for taste (Fig. 16). All products except the unblanched products were found in the acceptable range for taste (score 1 to 5). The treatment T_7 (0.5 per cent KMS at 85^0C) received the lowest score (3.89) and was adjudged as the best treatment with respect to taste. It was followed by T_4 (four per cent brine + one per cent citric acid at 85^0C) and T_3 (four per cent brine at 85^0C) as indicated by the low scores of 3.94 and 4.05 respectively. Taste of products dehydrated without giving any pretreatment (T_8) was very poor as indicated by the highest score of 6.16 (Dislike slightly).

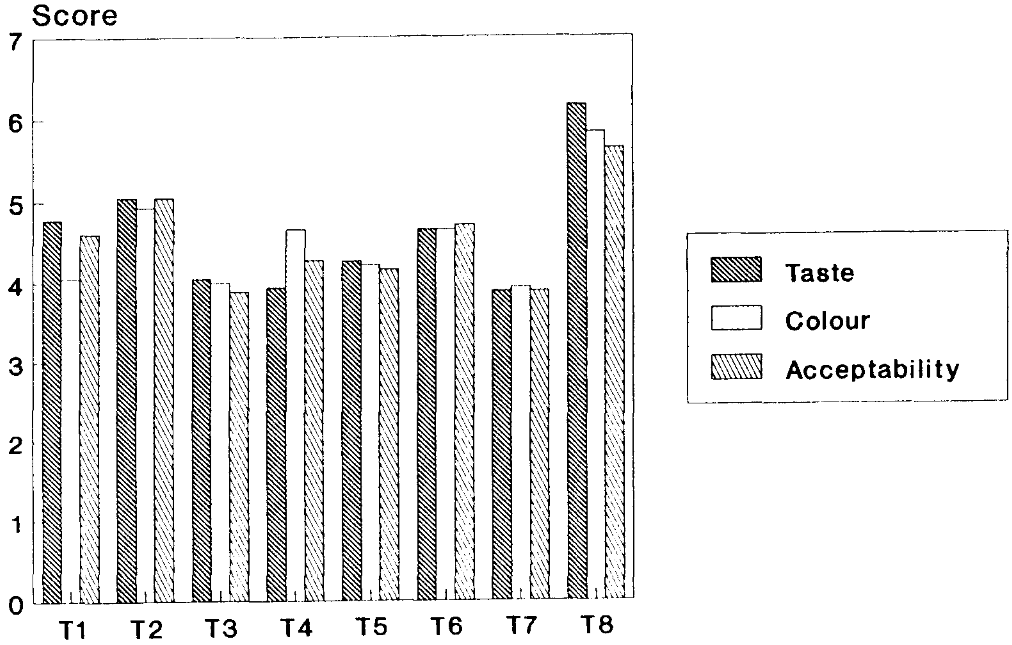
Mulay *et al.* (1994) studied the effect of pretreatments on quality of

Fig.15. Effect of dehydration methods on sensory qualities of *S. torvum*



Low score indicates better quality

Fig.16. Effect of pretreatments on sensory qualities of *S. torvum*



dehydrated cabbage and found that 0.5 per cent KMS had higher score for flavour over all the other samples. The present findings also support this view.

4.3.1.2. Colour.

There was significant difference between pretreatments for the colour of oil fried products (plate 20 and Fig. 16). All samples except unblanched fruits were in the acceptable range of like extremely (1) to neither like nor dislike (5). The score for colour was best for the sample treated with 0.5 per cent KMS at 85^{0}C (T_7) which receive a lowest score of 3.94. It was immediately followed by T_3 (four per cent brine at 85^{0}C). Colour of fried products dehydrated without subjecting to any blanching treatment scored very high (5.83) indicating that the product was not acceptable.

Pawar *et al.* (1988) studied solar drying of white onion flakes and reported that in sensory evaluation, sulphitation with 0.25 per cent KMS gave the best product in terms of colour. Mulay *et al.* (1994) studied the effect of pretreatments on quality of dehydrated cabbage and found that 0.75 per cent and 0.5 per cent KMS had better score for colour over all other samples. Vehgani and Chundawat (1986) studied sundrying of sapota (*Achras zapota*) and reported that fruits treated with two per cent KMS was best for colour.

The better retention of colour due to sulphitation treatment and brine treatment was mainly due to the reduction of browning reaction (Wedzicha and Mc Weeni, 1974; Salunkhe *et al.*, 1976). Thus KMS treatment offers good commercial potential as a pretreatment for dehydration of *S. torvum.*

4.3.1.3. Overall acceptability.

A perusal of sensory quality data for overall acceptability showed that there was no significant difference between dehydration procedures with respect to overall acceptability (Fig. 15).

The oil fried products varied significantly between pretreatments (Fig. 16). All samples except unblanched samples were in the acceptable range (1 - 5). But fruits treated with 0.5 per cent KMS at 85°C (T_7) and fruits treated with four per cent brine at 85°C (T_3) received lowest scores of 3.89 and 3.88 respectively. It was followed by T_5 (one per cent citric acid at 85°C) with a score of 4.16. The overall acceptability was very low in the case of T_8(control) as indicated by highest score of 5.64.

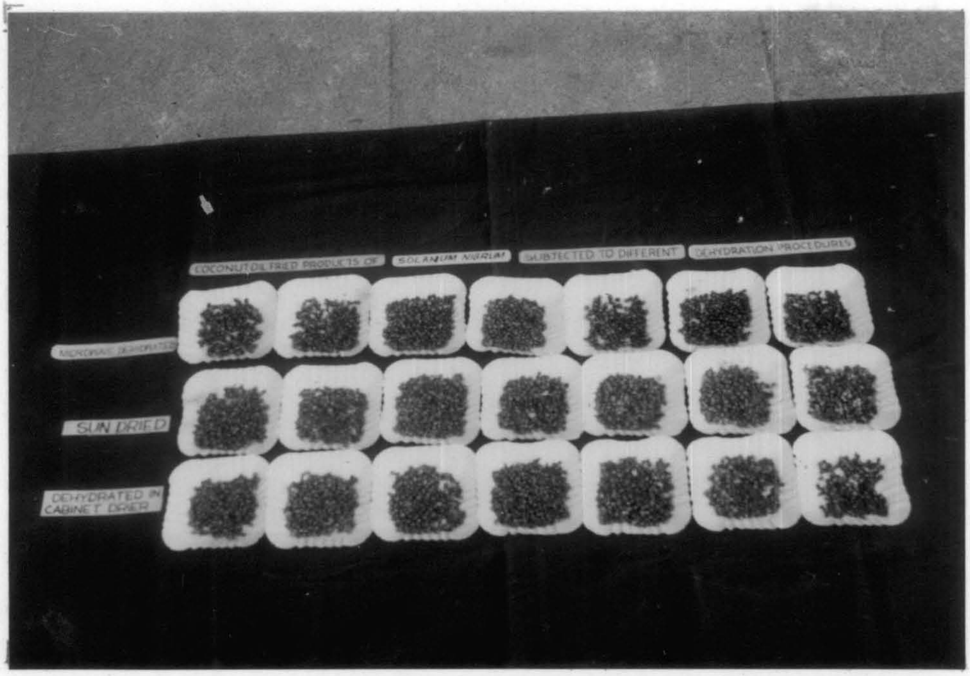
Pawar *et al.* (1988) conducted sensory evaluation of solar dehydrated onion flakes and reported that samples treated with 0.25 per cent KMS was best for over all acceptability. Mulay *et al.* (1994) studied the effect of pretreatments on quality of dehydrated cabbage and reported that overall acceptability of 0.5 per cent KMS treated sample was highest followed by the sample treated with 0.75 per cent KMS. The present study was also in accordance with these findings.

4.3.2. *Solanum nigrum.*

Results of the data on score values awarded by panel of judges on colour,

Plate 21. Coconut oil fried products *S.nigrum* subjected to different dehydration procedures

Plate 22. Coconut oil fried products of *N.nucifera* subjected to different dehydration procedures


COCONUTOIL FRIED PRODUCTS OF
SOLANUM NIGRUM
SUBJECTED TO DIFFERENT
DEHYDRATION PROCEDURES
MICROWAVE DEHYDRATED
SUN DRIED
DEHYDRATED IN CABINET DRIER


COCONUTOIL FRIED PRODUCTS OF
NELUMBO NUCIFERA
SUBJECTED TO DIFFERENT
DEHYDRATION PROCEDURES
DEHYDRATED IN CABINET DRIER
MICROWAVE DEHYDRATED
SUN DRIED

taste and overall acceptability of hot oil fried products (*`Kondattam'*) of *S. nigrum* are presented in Table 29.

4.3.2.1. Taste.

Results of analysis showed that there was no significant difference between dehydration methods on taste of oil fried products (Fig. 17).

The pretreatments varied significantly for taste (Fig. 18). All products except unblanched products were found to be in the acceptable range for taste (score 1-5). Eventhough the score values of all pretreated products were comparable, fruits treated with four per cent brine + one per cent citric acid at 85^0C and fruits treated with one per cent citric acid at 85^0C were found to be rated better as indicated by the low scores of 4.27 and 4.28 respectively. Taste was scored very poor in T_7 (Control) as indicated by high score of 6.50. Gardner (1977) reported that citric acid as an acidulent had appealing effects on the flavour of products.

Mudahar and Bains (1982) studied the pretreatment effect on quality of dehydrated mushroom (*Agaricus bisporus*) and found that sodium bisulphite (0.5 per cent) plus citric acid produced superior dehydrated product with superior culinary properties. Sivakumar *et al.* (1991) studied dehydration of bittergourd (*Momordica charantia* Linn.) rings and reported that blanching in five per cent NaCl gave slightly salty and less bitter products. The results indicate that pretreatments in general are desirable for developing dehydrated products. The *S. nigrum* fruits combined well with four per cent brine and one per cent citric

Table 29. Sensory evaluation of coconut oil fried products of *S. nigrum*

Treatments	Methods of dehydration											
	Sun	Cabinet dryer	Micro-wave oven	Mean	Sun	Cabinet dryer	Micro-wave over	Mean	Sun	Cabinet dryer	Micro-wave oven	Mean
	Taste (score)				Colour (score)				Overall acceptability(score)			
T_1	5.16	4.66	4.83	4.88	4.50	4.50	4.33	4.44	5.16	4.33	4.83	4.77
T_2	4.33	5.16	4.33	4.61	4.16	4.50	4.66	4.44	4.40	4.83	4.33	4.52
T_3	4.33	4.33	4.16	4.27	4.50	4.33	4.50	4.44	5.00	4.50	4.33	4.61
T_4	4.50	4.33	4.00	4.28	4.50	4.33	4.00	4.28	5.16	4.16	4.00	4.44
T_5	5.16	5.00	4.00	4.72	5.50	4.50	4.00	4.67	4.66	5.00	4.16	4.61
T_6	5.00	5.00	5.16	5.05	3.83	4.33	4.66	4.27	4.66	5.16	4.84	4.89
T_7	6.33	6.33	6.83	6.50	6.33	6.66	6.66	6.55	6.33	6.33	6.40	6.35
Mean	4.97	4.97	4.76		4.76	4.74	4.69		5.05	4.90	4.70	

H* for			
Treatments	37.51	41.88	35.33
Dehydration methods	NS	NS	NS

H*-Kruskell Wallies Statistic

Hedomic scale for sensory evaluation
1. like extremely, 2. like very much, 3. like moderately, 4. like slightly, 5. neither like nor dislike, 6. dislike slightly, 7. dislike moderately, 8. dislike very much, 9. dislike extremely

acid pretreatments. The blending of the salty and sour taste would have helped in earning better score for taste. The antimicrobial properties of both brine and citric acid could have also helped to get a product of better quality.

4.3.2.2. Colour.

A perusal of results revealed that oil frying did not affect the colour of product significantly (Fig. 17). In the earlier experiment involving *S.torvum* microwave dehydration resulted in better colour retention. However, such a trend was not evident in this case. The fruits of *S. nigrum* have a thin skin and moisture content is higher than that of *S. torvum*. These features coupled with a longer microwave exposure period in a lower power level would have resulted in increased chlorophyll degradation.

The pretreatments had significant effect (plate 21 and Fig. 18). All the pretreated samples obtained score values in the acceptable range. Fruits treated with 0.5 per cent KMS at 85^0C and fruits treated with one per cent citric acid at 85^0C got low scores of 4.27 and 4.28 respectively indicating better colour retention. The colour was very poor in fruits without subjecting to any pretreatments (T_7) as indicated by a score of 6.55 (dislike slightly).

Gardner (1977) reported that browning problem of dehydrated fruits and vegetables could be prevented by the use of acidulents like citric acid. Mudahar and Bains (1982) studied the pretreatment effect on quality of dehydrated mushroom (*Agaricus bisporus*) and found that sodium bisulphite plus citric acid

Fig.17. Effect of dehydration methods on sensory qualities of *S. nigrum*

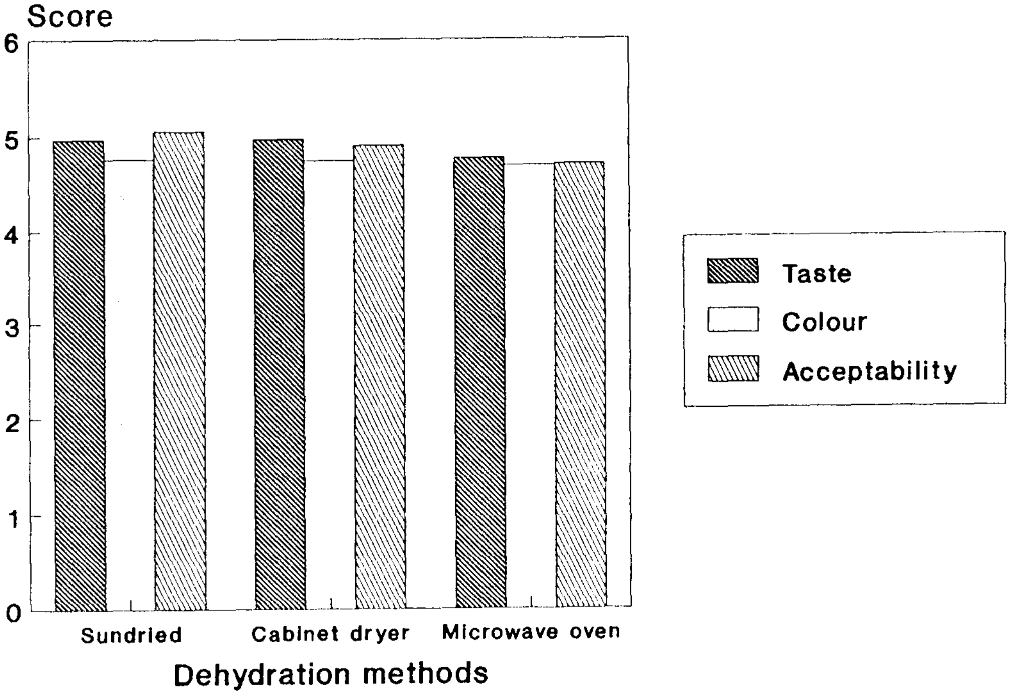
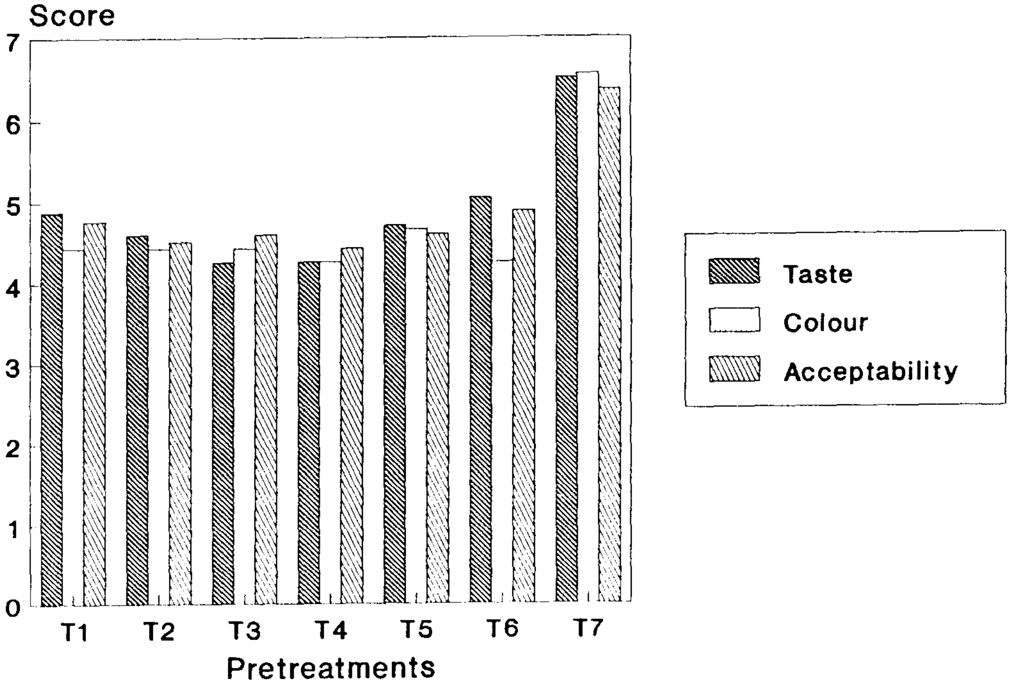


Fig.18. Effect of pretreatments on sensory qualities of *S. nigrum*



produced superior dehydrated product with satisfactory colour. The ability of KMS to reduce the browning reaction would have helped in a better colour retention here also (Salunkhe *et al.*, 1976; Chichester and Tanner, 1977).

4.3.2.3. Overall acceptability.

The results of analysis showed that the different dehydration procedures had no effect on the overall acceptability of oil fried products (Fig. 17). The samples varied significantly with respect to overall acceptability between different pretreatments (Fig. 18). Overall acceptability of all the pretreated samples were comparable. But overall acceptability of samples treated with one per cent citric acid, which received the lowest score (4.44), was best. It was immediately followed by T_2 (four per cent brine at 85^{0}C) with a score of 4.52. The products in T_3 (four per cent brine + one per cent citric acid at 85^{0}C) and T_5 (four per cent brine + 0.5 per cent KMS at 85^{0}C) received the same score 4.61. A very high score of 6.35 (dislike slightly) in T_7 (control) showed that they were very poor with respect to overall acceptability.

Hussain and Choudhary (1986) studied the preparation of dehydrated *mukhi* (*Colocasia esculenta*) chips and found that acid treatment with citric acid improved the appearance and acceptability of *mukhi* chips. Citric acid treatment slightly increases the sour taste of oil fried *`kondattam'* which is liked by Keralites. The habit of consuming large variety of pickles has emerged from this phenomenon of a liking for acidic (sour) food items.

4.3.3. *Nelumbo nucifera*

The score values awarded by the panel of judges for colour, taste and overall acceptability of hot oil fried products of *N.nucifera* are presented in Table 30.

4.3.3.1. Taste.

Results of analysis showed that the different dehydration methods had significant effect on the taste of oil fried products (Fig. 19). The products dehydrated in microwave oven scored low (4.12) which indicated that taste was better in these samples. The taste of samples dehydrated in cabinet dryer was also better compared to sundried samples with a score of 4.66 (Like slightly). The taste of sundried samples was comparatively poor as indicated by high score 5.39 (neither like nor dislike). The reason for this trend has already been explained under 4.3.1.1.

A perusal of data in the table showed that there was a significant difference between products subjected to different pretreatments (Fig. 20). All products except unblanched samples received score values in the acceptable range. Samples treated with four per cent brine + 0.5 per cent KMS (T_6) at 85^{0}C was best for taste as indicated by the low score of 3.66 (Like moderately). It was followed by T_4 (four per cent brine + one per cent citric acid at 85^{0}C) and T_7 (0.5 per cent KMS at 85^{0}C) with score values of 4.38 and 4.11 respectively. Taste was poor in unblanched products which scored high value (6.50).

Table 30. Sensory evaluation of coconut oil fried products of *N. nucifera*

Treatments	Methods of dehydration											
	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabinet dryer	Microwave oven	Mean	Sun	Cabnet dryer	Microwave oven	Mean
	Taste (score)				Colour (score)				Overall acceptability (score)			
T_1	6.16	4.50	4.00	4.89	5.0	5.0	4.00	4.67	5.83	4.16	4.16	4.72
T_2	5.66	4.50	4.33	4.83	5.0	5.0	4.16	4.72	6.16	5.00	4.16	5.11
T_3	5.33	4.50	4.50	4.78	5.0	4.66	4.66	4.77	5.16	4.66	5.16	4.99
T_4	4.66	4.33	4.16	4.38	4.33	4.0	4.66	4.33	4.83	5.33	5.00	5.05
T_5	5.16	5.33	4.50	5.00	4.50	4.66	4.33	4.50	4.50	4.00	4.16	4.22
T_6	4.33	3.33	3.33	3.66	5.0	2.83	3.33	3.72	4.66	3.00	3.00	3.55
T_7	4.83	4.16	3.33	4.11	4.33	3.83	4.16	4.10	4.50	3.83	3.66	4.00
T_8	7.00	6.66	5.83	6.50	7.5	5.83	5.33	6.22	7.33	6.66	5.83	6.61
Mean	5.39	4.66	4.12		5.08	4.48	4.33		5.37	4.58	4.39	

H* for			
Treatments	28.78	34.96	42.95
Dehydration methods	23.51	8.27	17.99

H-Kruskell Wallies Statistic

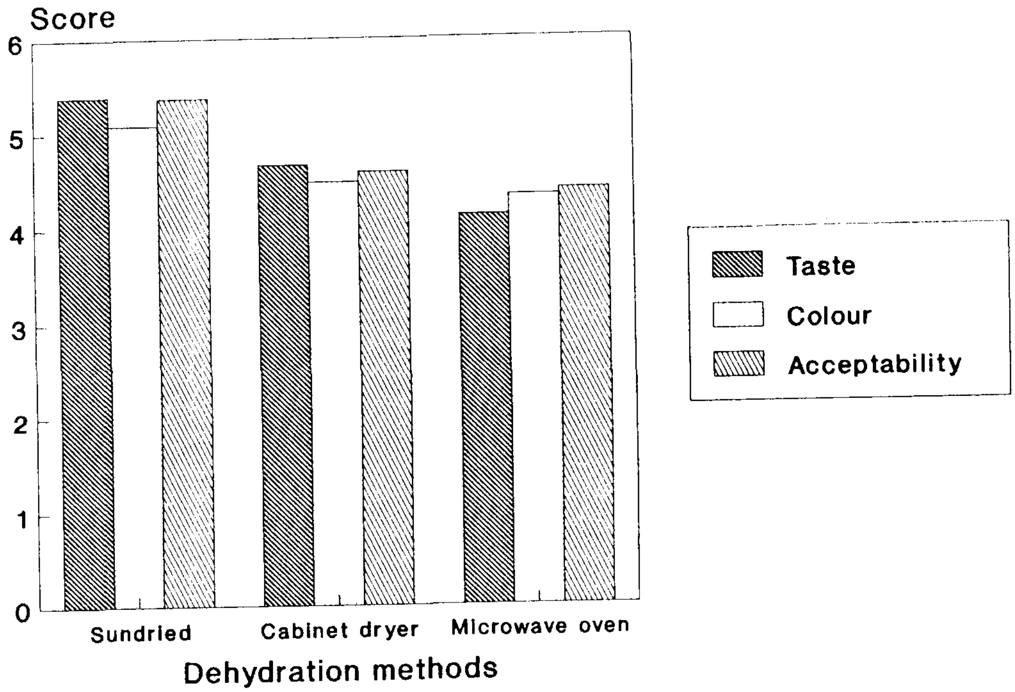
Hedomic scale for sensory evaluation
1. like extremely, 2. like very much, 3. like moderately, 4. like slightly
5. neither like nor dislike, 6. dislike slightly, 7. dislike moderately
8. dislike very much, 9. dislike extrmely

The same trend was observed for *S. torvum* and *S. nigrum* also. Thus the results confirmed that pretreatments like four per cent brine + 0.5 per cent KMS, four per cent brine + one per cent citric acid and 0.5 per cent KMS all at a temperature of 85^{0}C and three minutes long dipping has proved beneficial for getting products of improved taste, colour and overall acceptability. Also the comparative dislike expressed for the untreated samples obviously explain the specific effect of pretreatments on the final product quality. In the current study, however, only fixed concentration of four per cent brine, one per cent citric acid and 0.5 per cent KMS was tried at 85^{0}C for three minutes. Further studies are required with varying concentration of brine, citric acid and KMS along with varied combinations of solution temperatures and treatment time, so that products with still better acceptability could be produced. The results undoubtedly supported the view that all pretreatments selected in this experiment were beneficial for getting products superior to the control with respect to taste, colour and overall acceptability.

4.3.3.2. Colour.

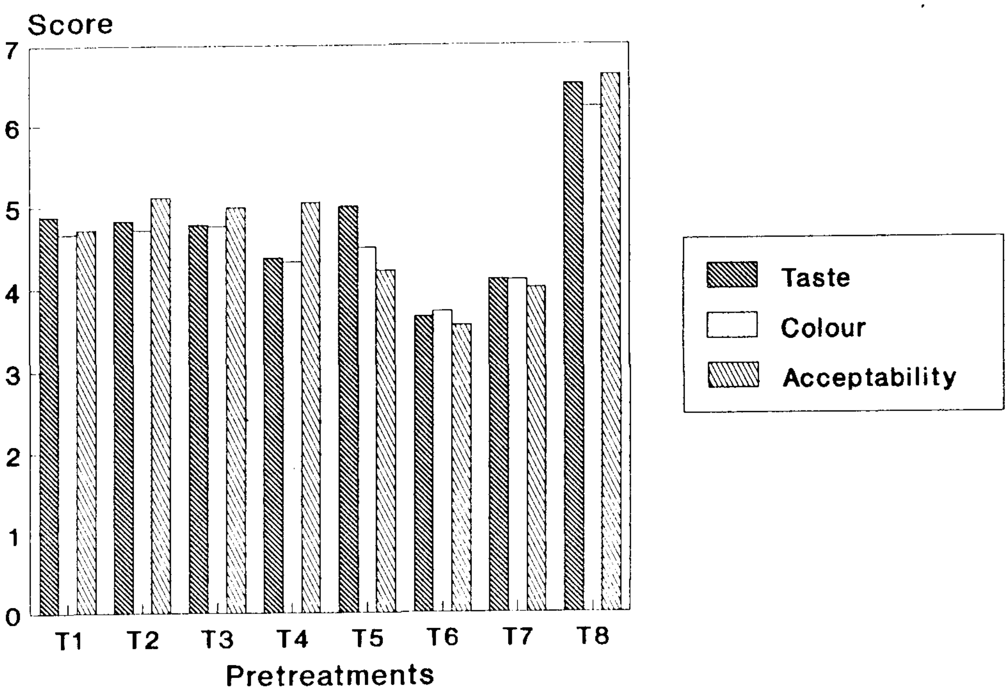
Results of analysis of data on colour showed that there was a significant difference between different dehydration procedures (Fig. 19). Colour was better in fried products of microwave oven dehydration (4.33). It was closely followed by products dehydrated in cabinet dryer with score of 4.48. Colour of most of the sundried products were not in the acceptable range (plate 22).

Fig.19. Effect of dehydration methods on sensory qualities of *N. nucifera*



Low score indicates better quality

Fig.20. Effect of pretreatments on sensory qualities of *N. nucifera*



Low score indicates better quality

Decareau (1984) reported that colour was enhanced in paste product drying. Steinke *et al.* (1989) reported that microwave heated food products were magnificently different from conventionally heated food products in colour. Thus it is justifiable that in this case also the microwave treatment has significantly expressed its superiority over sundrying and cabinet drying. This indicates that scope existsfor commercial exploitation of technology using microwaves for the dehydration of lotus stolons. Plate 22 indicate the promising treatments under microwave dehydration, which are much superior from the untreated sample in all the sensory parameters tested.

The pretreatments also had significant effect on colour of fried products (Fig. 20). T_6 (four per cent brine + 0.5 per cent KMS at 85^{0}C) received lowest score (3.72). It was closely followed by T_7 (0.5 per cent of KMS at 85^{0}C) and (four per cent brine + one per cent citric acid at 85^{0}C) of scores 4.10 and 4.33 respectively. It also showed that all pretreated samples received scores in the acceptable range (1 - 5). The unblanched samples (T_8) which received the highest score of 6.22 (dislike slightly) showed poor colour after frying. The pattern is almost similar to that of *S. torvum* and *S. nigrum*. However, in the case of *N. nucifera*, the beneficial effects of pretreatments were very evident. In produce like mushroom, onion etc. the beneficial effects of KMS, brine and citric acid have been demonstrated by various workers (Gardner,1977 ; Mudhar and Bains, 1982; Pawar *et al.* 1988 ; Mulay *et al.* 1994).

The fresh lotus stolons being creamy white in nature which is more or less similar to the colour of mushroom and onion, it is reasonable that a similar result was manifested in this case also. However, further studies are required to find still better combinations of KMS, brine, citric acid along with varied blanching temperature and time, with different heating arrangements in cabinet dryers and microwave ovens to evolve still better products.

4.3.3.3. Overall acceptability.

The data on overall acceptability showed that there was a significant difference between different dehydration procedures (Fig. 19). Microwave oven dehydrated products scored low (4.39) for overall acceptability indicating microwave oven dehydrated products were highly acceptable compared to products dehydrated in cabinet dryer and sundried products. Overall acceptability of sundried products was poor as revealed by the mean score of 5.37 (neither like nor dislike).

Microwave heated food products were magnificently different from conventionally heated food products in colour, flavour and texture. But conventionally heating of food products results in dehydration of the surface and thus favouring many flavour and colour reactions to take place (Steinke *et al.*1989). Rao *et al.*(1995) reported that microwave foods had more nutritional value and better sensory quality. Results of the present study also support the view.

The pretreatments also showed a significant effect on the overall acceptability of fried products (Fig. 20). Samples treated with four per cent brine + 0.5 per cent KMS at 85^{0}C received the lowest score by the panel indicating that it was the best product with respect to overall acceptability. It was closely followed by T_7 (0.5 per cent KMS at 85^{0}C) and T_5(one per cent citric acid at 85^{0}C). The score (6.61) of unblanched samples indicated that they were poor with respect to overall acceptability. The data also showed that all the pretreated samples were acceptable. The reason for this is already explained under 4.3.1.3.

Thus the study on sensory evaluation can be summed up as follows.

The superior pretreatments in *S. torvum* were:

1. 0.5 per cent KMS at 85^{0}C.
2. Four per cent brine + one per cent citric acid at 85^{0}C.
3. Four per cent brine at 85^{0}C.

The superior pretreatments in *S. nigrum* were:

1. One per cent citric acid at 85^{0}C.
2. Four per cent brine + one per cent citric acid at 85^{0}C.
3. Four per cent brine + 0.5 per cent KMS at 85^{0}C.

The superior pretreatments in *N. nucifera* were:

1. Four per cent brine + 0.5 per cent KMS at 85^{0}C.
2. 0.5 per cent KMS at 85^{0}C.
3. Four per cent brine + one per cent citric acid at 85^{0}C.

Sensory evaluation of oil fried products of dehydrated fruits of *S. torvum*, *S. nigrum* and dehydrated stolons of lotus (*N. nucifera*) has given very useful clues about the wide commercial scope existing for utilising cabinet dryers and microwave ovens. Wherever facilities exist sundrying also can be successfully employed for drying of produce adopting suitable pretreatments. The study has also revealed that simple treatments significantly influenced the product quality even in sundrying procedures.

The study has clearly established the need for having a scientific approach in the traditional system of food preservation like sundrying. It has also been revealed that there exist tremendous scope for the exploitation of microwave dehydration technology in the dehydration of vegetables. An integrated approach starting from the collection of ideal product from the plant, appropriate pretreatments, carefully operated drying procedures, and finally a very suitable packaging system is needed to develop a good quality product that is acceptable, economic and safe to the consumers. Postharvest losses can be reduced considerably through such efforts. It also generates employment in rural areas and helps in increasing the income of farmers in a big way.

Summary

SUMMARY

The present investigation on the standardisation of dehydration techniques in `anachunda' (*Solanum torvum* Swartz.) black nightshade (*Solanum nigrum* Linn.) and lotus (*Nelumbo nucifera* Gaertn.) was conducted in the Processing unit and analytical laboratory of Department of Processing Technology and in the Laboratory of the Biochemistry Division, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala during September 1993 to February 1995. The investigation consisted of the following experiments.

1. Standardisation of dehydration techniques for *S.torvum,S.nigrum* and *N.nucifera*.
2. Packaging and storage studies of dehydrated samples of *S.torvum*, *S.nigrum* and *N.nucifera.*
3. Sensory evaluation of hot oil fried dehydrated samples of *S.torvum, S.nigrum* and *N.nucifera.*

The study on the standardisation of dehydration technique revealed that the superior pretreatments for *S.torvum* were blanching in 0.5 per cent KMS at 85°C for three minutes and blanching in four per cent brine at 85°C for three minutes. Fruits treated with 0.5 per cent KMS at 85°C resulted in highest dehydration and rehydration ratio and maximum ascorbic acid retention under sundrying. Under sundrying maximum retention of colour and iron was obtained when a four per cent brine treatment was given at 85°C for three minutes.

When dehydration was carried out in a cabinet dryer, 0.5 per cent KMS at 85°C resulted in maximum retention of colour and ascorbic acid, four per cent

brine at 85^{0}C resulted in highest dehydration and rehydration ratio, and four per cent brine + 0.5 per cent KMS at 85^{0}C resulted in maximum retention of crude fibre, iron and alkaloid.

It was also noted that under microwave dehydration a pretreatment with 0.5 per cent KMS at 85^{0}C resulted in maximum retention of ascorbic acid, and alkaloid, four per cent brine treatment at 85^{0}C gave the highest rehydration ratio and maximum retention of iron. Four per cent brine + 0.5 per cent KMS at 85^{0}C resulted in maximum retention of colour and highest dehydration ratio.

In *S. nigrum*, one per cent citric acid at 85^{0}C and four per cent brine + 0.5 per cent KMS at 85^{0}C for three minutes were superior followed four per cent brine treatment at 85^{0}C .

Under sundrying, fruits of *S.nigrum* treated with four per cent brine showed maximum retention of carbohydrate, crudefibre, and sugar. Pretreatment with one per cent citric acid resulted in maximum colour retention and highest dehydration ratio, four per cent brine + 0.5 per cent KMS at 85^{0}C showed maximum retention of iron, alkaloid and highest rehydration ratio, and 0.5 per cent KMS at 85^{0}C showed maximum retention of ascorbic acid.

When dehydration was carried out in a cabinet dryer, samples treated with four per cent brine at 85^{0}C resulted in highest rehydration ratio, four per cent brine + one per cent citric acid showed maximum retention of alkaloid, one per cent citric acid showed maximum sugar and highest dehydration ratio, four per cent brine + 0.5 per cent KMS at 85^{0}C resulted in maximum retention of colour and carbohydrate and 0.5 per cent KMS showed maximum retention of ascorbic acid.

Under microwave dehydration, treatment with four per cent brine + 0.5 per cent KMS at 85^{0}C resulted in maximum retention of carbohydrate and alkaloid and highest rehydration ratio, one per cent citric acid at 85^{0}C showed maximum retention of colour, crude fibre and highest dehydration ratio, and 0.5 per cent KMS at 85^{0}C showed maximum retention of ascorbic acid.

In *N.nucifera,* superior pretreatments were four per cent brine + 0.5 per cent KMS at 85^{0}C for three minutes, followed by 0.5 per cent KMS at 85^{0}C for three minutes and one per cent citric acid at 85^{0}C for three minutes .

It was also noted that under sundrying, one per cent citric acid at 85^{0}C showed maximum retention of colour and starch, four per cent brine showed maximum retention or iron, 0.5 per cent KMS at 85^{0}C showed highest rehydration ratio, and four per cent brine + 0.5 per cent KMS at 85^{0}C showed highest dehydration ratio.

Under dehydration in cabinet dryer four per cent brine at 85^{0}C showed maximum iron retention and four per cent brine + 0.5 per cent KMS at 85^{0}C resulted in maximum retention of colour and crude fibre and highest dehydration ratio.

Under microwave dehydration four per cent brine resulted in maximum retention of crude fibre, four per cent brine + one per cent citric acid at 85°C showed maximum retention of starch, one per cent citric acid resulted in highest dehydration ratio, four per cent brine + 0.5 per cent KMS at 85°C resulted in maximum retention of iron and highest rehydration ratio.

The experiment on standardisation of dehydration techniques revealed that the superior pretreatment was four per cent brine + 0.5 per cent KMS at 85°C for three minutes on an overall basis. It was followed by 0.5 per cent KMS at 85°C for three minutes, one per cent citric acid at 85°C for three minutes and four per cent brine at 85°C for three minutes.

The experiment also revealed that microwave dehydration was significantly superior to dehydration in cabinet dryer and sundrying. Microwave dehydration resulted in maximum retention of ascorbic acid, iron, alkaloid, carbohydrate and crude fibre content of all the three species. In *S.torvum* maximum colour retention was obtained under microwave dehydration. But in *S.nigrum* colour retention was poor under microwave dehydration.

Packaging and storage studies revealed that the dehydrated products with an initial moisture content of 7 ± 1 per cent could be stored upto six months without significant deterioration in colour, texture and consumer acceptability. The moisture uptake was also not significantly different between the four packages under study *viz.*, polypropylene 80 gauge, polyethylene 100 gauge, polyethylene 150 gauge and polyethylene 200 gauge. When the dehydrated samples were kept in open the mean moisture uptake was 0.02g/g/24hr for *S. torvum* and *S. nigrum* and 0.06g/g/24hr for *N. nucifera* indicating that moisture proof packaging is essential for storage of these products. In economic terms 80 gauge polypropylene bags was found to be the cheapest.

The experiment on sensory evaluation of hot oil fried products revealed that in *S.torvum,* the superior pretreatments were 0.5 per cent KMS at 85^{0}C for three minutes, four per cent brine + one per cent citric acid at 85^{0}C for three minutes and four per cent brine at 85^{0}C for three minutes. The products treated with 0.5 per cent KMS scored better for taste, colour and overall acceptability. In *S. nigrum,* the super[illegible]pretreatments were four per cent brine + 0.5 per cent KMS at 85^{0}C for three minutes, one per cent citric acid at 85^{0}C for three minutes and four per cent brine + one per cent citric acid scored better for taste, fruits treated with 0.5 per cent KMS at 85^{0}C for three minutes scored better for colour, fruits treated with four per cent brine for overall acceptability. In *N.nucifera* the superior pretreatments were four per cent brine + 0.5 per cent KMS at 85^{0}C for three minutes and four per cent brine + one per cent citric acid at 85^{0}C for three minutes. Stolon slices treated with four per cent brine + 0.5 per cent KMS at 85^{0}C scored better for taste, colour and overall acceptability. It was further concluded that on an overall basis the four per cent brine + one per cent citric acid at 85^{0}C, four per cent brine + 0.5 per cent KMS at 85^{0}C and 0.5 per cent KMS at 85^{0}C were superior. It was also found that microwave oven dehydrated products scored better for taste colour and overall acceptability in all the three species.

References

REFERENCE

Akpapunam, A. 1984. Effects of wilting, blanching and storage temperatures on ascorbic acid and total carotinoid content of some Nigerian fresh vegetables. *Qualitas Plantarum* **34** (3): 177-180

Anonymous 1944. *Vegetables and Fruit Dehydration.*U.S.D.A. Misc. Publ. p. 540

*Anonymous 1985. Microwaves. *Ad week/ Ad Forum* **26** (52):20-21

A.O.A.C. 1960. *Official methods of analysis*. 9th ed. Association of Official Agricultural Chemists, Washington, D C. p. 225-226

Balasubrahmanyam, N. and Anandaswamy, B. 1979. Packaging requirements for fried potato chips. *Indian Fd. Packer* **33** (3):3-7

Balasubrahmanyam, N., Abraham, K.O., Raghavan, B., Shankaranarayana, M.L. and Natarajan, C.P. 1979. Packaging and storage studies on asafetida products. *Indian Fd. Packer.* **33** (3):15-22

Bhatia, B. S. and Mudahar, G.S. 1982. Preparation and storage studies on some intermediate moisture vegetables. *J. Fd. Sci. Technol.* **19**(1/2): 40-43

Birch, G. G. 1977. Chemical, physical and biological changes in carbohydrates induced by thermal processing. *Physical, Chemical and Biological Changes in Food Caused by Thermal Processing.* ed. Hoyem, T. and Kavale, O. Applied Science Publishers, London. p.152-165

*Campbell, C. L., Lin, T. Y. and Proctor, B. E. 1958. MicrowaveVs conventional cooking. I. Reduced and total ascorbic acid in vegetables. *J. Am. Diet. Assoc.* **34** : 365

Chaudhary, A. T. and Roy, B. Y. 1979. Retention of chlorophyll and ascorbic acid in dried fenugreek (*Trigonella foenicum*) *Indian Fd. Packer* **33** (1) : 35-36

*Chen, B. H. and Chen, Y.Y. 1993. Stability of chlorophylls and carotenoids in sweet potato leaves during microwave cooking. *J. agric. Fd. Chem.* **41** (8) :1315-1320

Chichester, D.F. and Tanner, F.W. 1977. Antimicrobical food additives. *Handbook of Food Additives*. Vol.2, ed. Furia, T. E. CRC Press Inc. p 142-147

Chopra, R. N., Nayar, S. N. and Chopra, I.C. 1956. *Glossary of Indian Medicinal Plants*. C.S.I.R., New Delhi. p.229-230

*Copson, D. A. 1962. *Microwave heating.* AVI Publishing Co.,Westport, Connecticut. p.110-115

Cromwell, B. T. 1955. The alkaloids. *Modern Methods of Plant Analysis*. Vol. 4, ed. Paech, K. and Tracy, M. V., Springer Verlag, Berlin. p.367-374

C.S.I.R. 1966. *The Wealth of India. Raw materials*. Vol. 7. Publications and Informations, Directorate, C.S.I.R., New Delhi. p. 8-9

C.S.I.R. 1972. *The Wealth of India. Raw materials*. Vol. 9. Publications and Informations, Directorate, C.S.I.R., New Delhi. p. 391-395

Dabhade, R. S. and Khedkar, D. M. 1980. Studies on drying and dehydration of raw mangoes (amchur) Part VI. Changes in chemical constituents of raw mango powder during storage. *Indian Fd. Packer* **34** (3):48-54

Decareau, R. V. 1984. Microwaves in food processing. *Fd. Technol. Australia* **36** (2):81-86

*Dorfer, J. and Eckert, I. 1983. Complex thermal modification of wheat flour by graded microwave processing. *Backer Konditor* **28** (3):68-71

*Dietrich, W. C., Huxoll, C. C. and Guadagni, D. G. 1970. Comparison of microwave, conventional and combination blanching of brussel sprouts for frozen storage. *Fd. Technol.* **24** : 613-617

*Feather. M. S. and Harris, J. F. 1973. Dehydration reactions of carbohydrates. *Advances in Carbohydrate Chemistry*. Vol. 28. ed. Tipson, R.S. and Horton, D. Academic Press, NewYork. p. 161-224

Fischer, F. E. 1973. *Fundamental Statistical Concepts*. Canfield Press, San Francisco. p. 298-304

Gardner, W. H. 1977. Acidulents in food processing. *Handbook of Food Additives*. Vol. 2. Furia, T. E. CRC Press Inc. p. 242-253

Gopalakrishnan, N. and Thomas, P.P. 1992. Studies on colour retension in pepper subjected to different treatments. *J. Fd. Sci. Technol.* **29** (4):256-257

Govindarajan, V. S. 1979. Sensory evaluation in quality control of processed food. *Indian Fd. Packer* **33** (6) :58-62

Goyal, M. and Mathew, S. 1990. Physico-chemical characteristics of cauliflower dried under different drying conditions. *Indian J. Nutr. Diet.* **27** (2) : 39-41

*Grone, L. 1971. Studies on artificial drying on onions. *Lant brukshogs kolans Meddalender* (156) :44

Gupta, R. G. and Nath, N. 1984. Drying of tomatoes. *J. Fd. Sci. Technol.* **21** (6) : 372-376

Gvozdenovic, J., Curakovic, M. and Vujkovic, [illegible] 1983. Appl[illegible] laminates in packaging of dried foods. *Hrana Ishrana* 24 [illegible]

Hussain, M. and Choudhary, B. L. 1986. Preparation of dehydrated mukhi (*Colocasia esculenta*) chips. *J. Fd. Sci. Technol.* **23** (3) : 167-170

Jayaraman, K.S., Gupta, D.K.D. and Rao, N. B. 1991. Quality characteristics of some vegetables dried by direct and indirect sun drying. *Indian Fd. Packer* **45** (1) :16-23

Johnson, A. H. and Peterson, M. S. 1974. *Encyclopedia of Food Technology* Vol. 2. AVI Publishing Co. Inc. Westport, Connecticut p. 183-184

Kalra, S. K. 1981. Storage problems of solar dehydrated peas. *Indian Fd. Packer* **35** (4) :16-19

Kalra, C.L., Kaur, S., Sharma, T. C., Kulkarni, S. C. and Berry, S. K. 1987. Studies on the preparation, packaging and storage of potato snacks from cold stored potatoes. *Indian Fd. Packer* **41** (5) :30-39

Kalra, C. L. 1990. Blanching of fruits and vegetables. *Indian Fd. Packer* **44** (5) : 3-19

Kaur, B. and Singh, Y. 1981. Effect of dehydration and storage of cauliflower (*Brassica oleracea* Var. botrytis) on the physical characteristics. *Indian Fd. Packer* **35** (1) :23-26

*Khalil, H. and Villota, R. 1986. *Food Engineering and Process Applications* Vol. 1. Applied Science Publishers, Essex, England p. 583

Krishnamurthi, S. Varkey, A. G., Bhat, A. V., Dhanaraj, S. and Narasimhan, S. 1981. Packaging and storage studies of deep fat fried nendran banana chips. *J. Fd. Sci. Technol.* **18** (3) :104-108

Krutman, A. 1981. Development of alternative dehydration methods for okra. *Diss. Abstr. Int.* **42** (2) : 551

Kulkarni, S. G., Seghal, R. C., Kaur, S., Berry, S. K., Kalra, C. L., Sharma, B. R. and Arora, S. K. 1988. Studies on the evaluation of new okra (*Abelmoschus esculentus* L.) cultivars for dehydration. *Indian Fd. Packer* **42** (3) :7-13

Kumar, K. R., Bano, Z., Subramanyam, L. and Anandaswamy, B. 1980. Moisture sorption, storage and sensory quality studies on dehydrated mushrooms. *Indian Fd. Packer* **34** (5): 3-8

Kumar, V. and Nath, N. 1991. Effect of additives in blanching water on quality of dehydrated green cowpea pods. *Indian Fd. Packer* **45** (1) : 37-41

Kuppuswamy, S. and Rao, R. G. 1970. Dehydration of green peas. *J. Fd. Sci. Technol.* 7 (2) : 18-21

Lee, F. 1958. The blanching process. *Advances in Food Research* Vol. 8. ed. Marak, E. M. and Stewart, G. F. Academic Press Inc. p. 87

Luh, B. S. and Woodroof,J. G. 1988. *Commercial vegetable processing.* 2nd ed. Van Nostrand Reinhold, New York p. 665

Luhadiya, A.P. and Kulkarni, P. R. 1978. Dehydration of green chillies. *J. Fd. Sci. Technol.* **15** (4) :139-143

Maeda, E. E. and Salunkhe, D. K. 1981. Retention of ascorbic acid and total karotein in solar dried vegetables. *J. Fd. Sci.* **46** (4):1288-1290

Mahadevaiah, B., Chang, K. S. and Balasubramanyam, N. 1976. Packaging and storage studies on dried, ground and whole chillies (*Capsicum annum*) in flexible consumer packages. *Indian Fd. Packer* **30** (6) :33-40

Mahadevaiah, B., Kumar, K. R. and Balasubramanyam, N. 1977. Packaging studies on pulses and cereal flours in flexible films. *Indian Fd. Packer* **31** (4) :25-31

Manan, J. K., Kalra, C. L., Kulkarni, S. G., Joshi, G. J. and Berry, S. K. 1991. Studies on the preparation, packaging and storage of colocasia snack products. *Indian Fd. Packer* **45** (1): 49-54

Mudahar, G. S. and Bains, G. S. 1982. Pretreatment effect on quality of dehydrated *Agaricus bisporous* mushroom. *Indian Fd. Packer* **36** (2) :19-27

Mulay, S. V., Pawar, V. N., Thorat, S. S., Ghatge, U. M. and Ingle, U. M. 1994. Effect of pretreatments on quality of dehydrated cabbage. *Indian Fd. Packer* 38 (5):11-16

Murthi, H. B. N. 1982. Packaging aspect of dehydrated food. *J. Fd. Sci. Technol.* **19** (1) :38-42

Paine, F. A. and Paine, H. Y. 1983. *A Handbook of Food packaging.* Glasgow, Leonard Hill. p. 221

Panse, V. G. and Sukhatme, P. V. 1954. *Statistical Methods for Agricultural Workers. I.C.A.*R, New Delhi. p. 75-77

Patil, V. R., Kulkarni, D. N., Kulkarni, K. Ingle, U. M. 1978. Effect of blanching factors on quality and durability of sun dried and dehydrated fenugreek. *Indian Fd. Packer* **32** (1) : 43-49

Patnaik, G. 1994. Export of fruit and vegetable products. *International Seminar on Opportunities for Collaboration in Fruit and Vegetable Processing Industry in India.* All India Food Preserver's Association, Vigyan Bhavan, New Delhi. p. 51-64

Pawar, V. D., Patil, D.A., Khedkar, D. M . and Ingle, U. M. 1985. Studies on drying and dehydration of pumpkin (*Cucurbita maxima*) *Indian Fd. Packer* **39** (4) :58-66

Pawar, V.N., Singh, N. I., Dev, D. K., Kulkarni, D. N. and Ingle, U. M. 1988. Solar drying of white onion flakes. *Indian Fd. Packer* **42** (1) : 15-23

Peleg, K. 1985. *Produce Handling, Packaging and Distribution.* AVI Publishing Co., Westport, Connecticut. p. 249-253

Premavalli, K. S., Vidyasagar, K. and Arya, S. S. 1991. Storage behaviour of vegetable halwas. *Indian Fd. Packer* **45** (4):29-34

Pruthi, J. S. 1978. Quality control, packaging and storage of dehydrated foods. *Indian Fd. Packer* 32 (1) :30-40

Pruthi, J. S., Gopalakrisnan, N. and Bhat, A. V. 1978. Studies on the dehydration of tropical paddy straw mushroom (*Volvariella volvacea*). *Indian Fd. Packer* 32 (2) : 7-15

*Quenzer, N. M. 1980. The effects of microwave blanching on the nutritional and textural quality of freeze dried spinach. *Diss. Abstr. Int.* **40** (12): 113

Ramana, S. V., Jayaraman, K. S. and Kumar, K. L. M. 1988. Studies on the colour of some dehydrated green leafy vegetables. *Indian Fd. Packer* **42** (3) : 19-23

Ranganath, D. R. and Dubash, P. J. 1981. Loss of colour and vitamins on dehydration of vegetablels. *Indian Fd. Packer* **35** (4) : 4-10

Rangana, S. 1977. *Manual of Analysis of Fruit and Vegetable Products*. Mc Graw Hill Publishing Co. Ltd., New Delhi. p.95-111

Rao, K. V. S. S., Zanjad, P. N. and Mathur, B. N. 1995. Microwave processing-An emerging alternative to thermal processing of foods. *Indian Fd. Ind.* **14** (1):17-23

Rao, T. S., Kaverappan, M. and Reddy, T. H. P. 1991. Dehydrated coconut chutney. *J. Fd. Sci. Technol.* **28** (2) :73-75

Ratnatunga, M., Sethy, G. R., Saroja, S. and Swamy, A. M. N. 1978. Effect of processing on vitamins and minerals in fruits and vegetables. *Indian Fd. Packer* **32** (6) :25-42

Ruello, J. H. 1987. Seafood and microwaves: Some preliminary observations. *Fd. Technol. Australia* **39** (11) : 82-86

Sadasivam, S. and Manickam, A. 1992. *Biochemical Methods for Agricultural Sciences*. Wiley Eastern Ltd., New Delhi . p. 8-21

Sahu, B. N. 1983. *Rauvolfias- Chemistry and Pharmacology*. Vol. 2. Today and Tomorrow Printers and Publishers, New Delhi. p. 595

Salunkhe, D. K., Do, J. Y. and Bolin, H. R. 1976. Developments in Technology and Nutritive Value of Dehydrated Fruits,Vegetables and their products-*Storage, Processing and Nutritional Quality of Fruits and Vegetables*,ed. Salunkhe, D.K, CRC Press, Ohio. p. 61-75

Sehgal, K. K., Kawatra, B. L. and Bajaj, S. 1975. Studies on the nutritive value of sun dried green leafy vegetables. *J. Fd. Sci. Technol.* **12** (6) :303-305

Sethi, V. and Anand, J. C. 1982. Studies on the preparation, quality and storage of intermediate moisture (IM) carrot preserve. *J. Fd. Sci. Technol.* **19** (4) : 168-170

Sivakumar, S., Kalra, R. and Nath, N. 1991. Dehydration of bitter gourd (*Momordica charantia* Linn.) rings. *J. Fd. Sci. Technol.* **28** (1) :52-53

Srivastava, G. K. and Sulebele, G. A. 1975. Dehydration of cauliflower: Effect of pretreatments of rehydration characteristics. *Indian Fd. Packer* **29** (6) : 5-10

*Steinke, J.A., Frick, C., Strassburger, K. and Gallaher, J. 1989. Interaction of flavour systems in microwave environment. *Cereal Foods World.* **34** (4) :330-332

Tandan, G. L. and Virmani, R.S. 1949. Determination of blanching time of vegetables. *Indian J. Hort.* **6** (1) :11-21

Teotia, M. S., Manan, J. K. and Saxena, A. K. 1987. Green mango processing- A review. *Indian Fd. Packer* **41** (6) :74-86

Thorat, S. S., Kadali, A. M., Kulkarni, D. N. and Ingle, U. M. 1988. Preparation and storage studies on intermediate moisture okra. *Indian Fd. Packer* **44** (3) :47-51

Van Arsdel, W. B., Copley, M. J. and Mogan, A. I. Jr. 1973. *Food Dehydration Practices and Applications*. Vol.2. 2nd ed. AVI Publishing Co. Westport, Connicticut. p.14-147

*Van Buren, J. P. 1979. The Chemistry of texture in fruits and vegetables. *J. Texture Stud.* **10** :1

Veenakumari, D. 1992. Pre and postharvest treatments on storage life and quality of fresh and dried bittergourd (*Momordica charantia* L.). M.Sc.(Hort.) thesis, *Kerala agric. Univ.*, Vellanikkara, Thrissur, Kerala.

Vehgani, S. N. and Chundawat, B. S. 1986. Sun drying of Sapota. *Indian Fd. Packer* **40** (3): 23-28

Wedzicha, B. L. and Mc Weeni, D. J. 1974. Non enzymic browning reactions of ascorbic acid and their inhibition. The identification of 3-deoxy 4-sulphopentosulose in dehydrated, sulphited cabbage after storage. *J. Sci. Fd. Agric.* **25**:589-592

*Williams, O. B. 1951. Preservation of food in hermitically sealed containers. *The Chemistry and Technology of Food and Food Products*. Vol. 3. 2nd ed., ed. Jacobs, M. B. Interscience Publishers Inc. New York. p. 1874

* Originals not seen.

Appendices

APPENDIX-I

Weather data (montly average) for the experimental period
(September 1993 to February 1995)

Month	Total rainfall mm	Temperature Maximum °C	Temperature Minimum °C	Relative humidity % (mean)	Sunshine hours (mean)	Wind speed Kmph	Evaporation mm/day
1993							
September	85.3	30.6	23.1	81	6.4	3.4	110.1
October	519.00	30.7	23.4	83	4.8	6.9	89.6
November	74.6	31.5	23.6	73	5.8	13.0	122.0
December	18.0	31.6	23.1	66	7.5	13.0	164.0
1994							
January	19.4	32.9	22.6	58	9.1	3.8	222.2
February	1.7	34.8	23.1	59	8.7	7.1	169.2
March	21.0	36.2	23.7	59	9.3	3.3	209.2
April	165.2	34.9	24.4	74	8.0	3.7	144.7
May	124.2	33.6	24.7	75	8.0	6.2	137.0
June	955.1	28.9	22.9	90	2.1	3.8	84.2
July	1002.1	28.6	22.4	91	1.4	4.4	86.1
August	509.2	30.0	22.8	85	3.0	2.9	91.4
September	240.5	31.8	23.2	78	7.3	2.9	113.9
October	358.2	32.3	22.7	80	6.7	2.9	97.1
November	125.3	31.8	23.3	68	8.1	2.5	137.9
December	0.0	32.2	22.2	58	10.6	6.2	169.6
1995							
January	0.0	32.9	22.4	59	9.6	7.4	178.5
February	0.5	35.4	23.4	60	10.0	2.6	172.2

Source: Department of Agrometeorology, College of Horticulture, Vellanikkara, Thrissur

APPENDIX-II

Weather data (weekly average) for the experimental period (September 1994 to February 1995)

Month	Week No.	Total rainfall mm	Temperature		Relative humidity		Sun shine hours (mean)	Wind speed (mean) Kmph	Evaporation (mean) mm/day
			Maximum °C	Minimum °C	Forenoon %	After noon %			
1	2	3	4	5	6	7	8	9	10
September 1993	36	23.7	29.4	23.0	93	75	3.9	3.8	3.0
	37	11.5	30.7	23.1	93	69	7.5	3.5	3.5
	38	23.2	31.7	23.4	94	63	8.3	3.8	4.2
	39	14.9	31.0	23.2	91	65	6.7	3.6	3.9
October 1993	40	149.8	29.8	23.4	93	82	3.8	3.5	2.9
	41	181.5	29.3	23.2	95	78	2.1	3.2	2.5
	42	102.7	31.2	2.32	90	74	4.9	3.2	2.8
	43	83.4	31.9	23.5	92	72	6.3	3.0	2.8
	44	3.2	32.5	24.2	80	63	7.1	6.2	3.8
November 1993	45	58.3	30.4	23.9	84	70	8.3	4.0	3.5
	46	12.7	31.8	23.0	91	66	3.9	5.6	3.0
	47	1.2	31.8	23.1	72	54	6.5	7.6	4.6
	48	0.8	31.4	24.1	77	60	11.5	5.8	5.7
December 1993	49	17.0	31.2	22.7	84	62	3.4	6.1	3.4
	50	0.0	32.5	21.9	75	47	5.1	9.0	5.0
	51	1.0	31.0	23.8	75	59	5.5	12.8	5.6
	52	0.0	31.6	23.5	72	47	6.1	12.8	6.1
January 1994	1	0.0	32.6	23.6	69	44	10.0	13.2	7.5
	2	0.0	32.2	22.7	73	43	9.0	12.1	7.3
	3	19.4	33.6	23.7	83	49	7.7	6.0	4.9
	4	0.0	32.8	22.0	65	32	9.2	13.3	9.7
	5	0.0	33.9	21.0	81	37	9.8	6.1	5.9
February 1994	6	0.0	34.6	23.8	77	43	7.8	7.0	6.3
	7	0.0	34.4	23.1	86	45	8.2	5.0	4.7
	8	0.0	35.7	23.0	83	36	7.8	5.3	6.1
	9	0.0	35.8	22.5	56	20	10.2	8.6	8.8
March 1994	10	-	37.2	21.8	71	20	10.1	5.7	7.2
	11	-	37.4	23.7	83	36	9.8	5.4	6.8
	12	1.2	35.2	25.4	90	56	8.8	5.2	5.8
	13	19.8	35.4	25.4	86	57	8.3	4.8	5.6

Contd.

Appendix-II. Continued

1	2	3	4	5	6	7	8	9	10
April 1994	14	37.1	35.8	23.5	85	54	8.3	5.0	5.4
	15	79.8	34.8	23.7	90	58	6.1	4.2	4.9
	16	27.6	34.3	24.5	89	61	8.5	3.8	4.4
	17	20.7	34.6	25.3	86	63	7.0	4.4	4.5
	18	0.0	34.3	25.0	85	58	10.2	3.9	5.1
May 1994	19	11.6	34.1	25.2	84	58	9.0	4.6	4.6
	20	82.2	34.0	24.6	92	62	7.5	4.2	4.5
	21	3.5	33.9	25.3	89	62	7.6	4.6	4.3
	22	171.8	30.2	22.8	95	80	2.8	5.2	2.6
September 1994	36	99.2	30.3	23.1	96	73	5.3	3.4	3.4
	37	8.2	32.2	23.4	93	63	9.0	3.6	3.9
	38	1.2	32.2	22.6	88	55	9.1	3.6	4.2
	39	1.6	33.2	23.8	90	59	7.5	3.4	3.9
October 1994	40	52	3.17	23.3	94	71	5.0	3.8	3.1
	41	52.6	32.6	22.8	90	65	6.9	2.8	3.6
	42	88.2	31.9	22.4	94	69	7.3	3.0	3.0
	43	120.2	33.2	22.8	94	70	7.9	3.0	3.0
	44	68.3	31.9	22.5	91	68	5.9	4.0	2.6
November 1994	45	102.2	31.2	22.8	78	64	7.3	9.5	4.5
	46	0.0	31.3	24.4	77	57	7.8	10.2	5.4
	47	0.0	32.2	24.1	69	52	9.1	8.0	5.3
	48	0.0	32.9	22.1	74	49	10.1	5.7	4.3
December 1994	49	0.0	31.9	21.6	68	43	10.9	8.7	5.0
	50	0.0	32.1	20.1	71	41	10.8	8.8	5.4
	51	0.0	32.2	24.0	75	50	10.4	10.7	5.8
	52	0.0	31.9	23.1	68	44	10.3	12.8	6.1
January 1995	1	0.0	31.8	22.1	71	42	9.5	10.8	5.8
	2	0.0	33.3	21.5	88	49	8.5	9.9	4.1
	3	0.0	33.1	23.8	71	42	9.7	6.2	6.2
	4	0.0	33.3	21.8	66	34	10.4	6.3	6.6
	5	0.0	33.9	24.2	69	37	10.7	7.2	7.0
February 1995	6	0.0	34.7	23.4	71	37	10.3	10.0	7.5
	7	0.0	35.6	22.6	79	39	9.9	4.6	5.6
	8	0.5	36.1	23.4	89	50	9.7	2.8	4.9
	9	0.0	37.2	23.1	90	37	9.0	2.4	5.6

Source: Department of Agrometerology, Ceollege of Horticulture, Vellanikkara, Trichur

APPENDIX-III

Abstract of ANOVA for the effect of pretreatments and dehydration methods on qualitative characters and dehydration and rehydration ratio of *S. torvum* fruits

Source of variation	df	MS								
		Moisture %	Weight after dehydration (g)	Carbohydrate %	Crude fribre %	Ascorbic acid mg/100 g	Total alkaloid %	Iron mg/100 g	Dehydration ratio	Rehydration ratio
Factor T	7	0.009	0.118	44.141*	41.445*	985.192*	0.094*	2.270*	0.008*	0.185*
Factor D	2	0.448	0.239	779.483*	75.103*	15.658*	0.233*	58.183*	0.027*	0.454*
T x D	14	0.010	0.194	33.008*	44.371*	116.359*	0.049*	1.613*	0.015*	0.062*
Error	48	0.262	0.041	0.200	3.331	1.207	0.004	0.204	0.004	0.002

* Significant at 1% level

APPENDIX-IV

Abstract of ANOVA for the effect of pretreatments and dehydration methods as qualitative characters and dehydration and rehydration ratio of *S. nigrum* fruits

Source variation	df	MS											
		Moisture %	Weight after dehydration	Carbohydrate %	Crude fibre %	Total sugar %	Reducing sugar %	Non reducing sugar %	Ascorbic acid mg/100 g	Total alkaloid %	Iron mg/100 g	Dehydration ratio	Rehydration ration
Factor T	6	0.021	0.136	18.258*	7.328*	0.926*	0.652*	0.068*	887.988*	0.060*	0.367*	0.084*	0.183*
Factor D	2	0.998	0.184	129.557*	77.670*	11.126*	5.434*	0.801*	12688.163*	1.142*	62.547*	0.114*	2.960*
T x D	12	0.007	0.052	30.386*	6.601*	0.881*	0.824*	0.049*	217.23*	0.085*	1.086*	0.031*	0.072*
Error	42	0.137	0.008	0.791	1.555	0.029	0.017	0.001	1.73	0.004	0.157	0.002	0.001

*Significant at 1% level

APPENDIX-V

Abstract of ANOVA for the effect of pretreatments and dehdration methods on qualitative characters and dehydration and rehydration ratio of stolen slices of *N. nucifera*

Source of varition	df	MS						
		Moisture %	Weight after dehydration (g)	Starch %	Crude fibre %	Iron mg/100 g	Dehydration ratio	Rehydration ratio
Factor T	7	0.003	0.389	63.545*	5.834*	12.745*	0.028*	0.197*
Factor D	2	1.249	0.445	147.148*	54.803*	44.376*	0.090*	0.448*
T x D	14	0.004	0.220	14.290*	3.961*	12.816*	0.038*	0.085*
Error	48	0.058	0.068	0.326	0.517	0.294	0.000	0.003

* Significant at 1% level

APPENDIX-VI

Abstract of ANOVA for the weight grains of dehydrated and packaged products of *S. torvum* during storage

Source	df	MS									
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Packages (P)	3	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Month (M)	2	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D x M	6	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Error	12	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000

APPENDIX-VII

Abstract of ANOVA for the weight gain of dehydrated and packaged products of *S. nigrum* during storage

Source	df	MS									
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Packages (P)	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Month (M)	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P x M	6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Error	12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

APPENDIX-VIII

Abstract of ANOVA for the weight grain of dehydrated and packaged products of *N. nucifera* during storage

Source	df	MS									
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Package (P)	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.664
Month (M)	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.665
P x M	6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.665
Error	12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.665

APPENDIX-IX
Effect of pretreatments in weight of fruits *S. torvum* and stolan slices of *N. nucifera*

Source	df	MS	
		S. torvum	*N. nucifera*
Treatment	7	0.571	12.548*
Error	16	0.228	0.375

* Significant at 1% level

APPENDIX-X
Effect of pretreatments on weight of fruits of *S. nigrum*

Source	df	MS
Treatment	6	1.651*
Error	14	0.381

*Significant at 1% level

STANDARDIZATION OF DEHYDRATION TECHNIQUES IN ANACHUNDA (*Solanum torvum* Swartz.) BLACK NIGHTSHADE (*Solanum nigrum* Linn.) AND LOTUS (*Nelumbo nucifera* Gaertn.)

By

K. J. KURIAKOSE

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Processing Technology
COLLEGE OF HORTICULTURE
Vellanikkara - Thrissur-680654
Kerala, India

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ABSTRACT

The present investigation on the standardisation of dehydration techniques in `anachunda' (*Solanum torvum* Swartz.) black nightshade (*Solanum nigrum* Linn.) and lotus (*Nelumbo nucifera* Gaertn.) was conducted in the Processing Unit and Analytical Laboratory of Department of Processing Technology and in the Laboratory of the Biochemistry Division, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala during September 1993 to February 1995. The experiments were laid out in completely randomised design with three replications.

Study on standardisation of dehydration technique revealed that the superior pretreatments for *S. torvum* were 0.5 per cent KMS at 85^0C for three minutes and four per cent brine at 85^0C for three minutes. It was followed by four per cent brine + 0.5 per cent KMS at 85^0C for three minutes. In *S. nigrum* the superior pretreatments were one per cent citric acid at 85^0C for three minutes and four per cent brine + 0.5 per cent KMS at 85^0C for three minutes. It was followed by four per cent brine at 85^0C. The superior pretreatments for *N. nucifera* were four per cent brine + 0.5 per cent KMS at 85^0C for three minutes followed by 0.5 per cent KMS at 85^0C for three minutes and one per cent citric acid at 85^0C for three minutes. Thus the superior pretreatment was four per cent brine + 0.5 per cent KMS at 85^0C for three minutes on an overall basis. It was followed by 0.5 per cent KMS at 85^0C for three minutes, one per cent citric acid at 85^0C for three minutes and four per cent brine at 85^0C for three minutes.

The experiment also revealed that microwave dehydration was significantly superior to dehydration in cabinet dryer and sundrying with respect to retention of colour and nutritional qualities.

Packaging and storage studies revealed that the dehydrated products with an initial moisture content of 7 ± 1 per cent could be stored upto six months without significant deterioration in colour, texture and consumer acceptability. The moisture uptake was not significantly different between the four packages under study *viz*., polyethylene 80 gauge, polyethylene 100 gauge, polyethylene 150 gauge and polyethylene 200 gauge. In economic terms polypropylene 80 gauge bags was found to be the cheapest.

The experiment on sensory evaluation of hot oil fried products revealed that on an overall basis the treatments *viz*., four per cent brine + one per cent citric acid at 85^0C for three minutes, four per cent brine + 0.5 per cent KMS at 85^0C for three minutes and 0.5 per cent KMS at 85^0C for three minutes were significantly superior for getting products with better taste, colour and overall acceptability. It was also found that microwave oven dehydrated products scored better for taste, colour and overall acceptability.

The investigations also indicated that tremendous potential exist for exploitation of microwave dehydration technology for the dehydration of vegetables.