DEHYDRATION AND STORAGE STUDIES IN FIG (*Ficus carica* L.)

By

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THESIS

submitted in partial fulfilment of the requirements for the degree of

Master of Science in Horticulture

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VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2005

DECLARATION

I hereby declare that this thesis entitled **"Dehydration and storage studies in fig (*Ficus carica* L.)"** is a bonafide record of research work done by me during the course of research and 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.

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CERTIFICATE

Certified that this thesis, entitled **"Dehydration and storage studies in fig (*Ficus carica* L)"** is a record of research work done independently by **Mrs. Habeeba. P.S.** 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 her.

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ACKNOWLEDGEMENT

It is with great respect and devotion, I place on record my deep sense of gratitude and indebtedness to my major advisor ***Dr P. Jacob John*** *Associate Professor and Head, Department of Processing technology and chairman of my Advisory Committee for his sustained and valuable guidance, constructive suggestions, unfailing patience, friendly approach, constant support and encouragement during the conduct of this research work and preparation of the thesis. Always looking for perfection, he corrected me several times, but with understanding and forbearance. I consider myself being fortunate in having the privilege of being guided by him.*

I deeply express my whole hearted thanks to ***Dr. K.B. Sheela,*** *Associate Professor, Department of Processing technology and member of my Advisory Committee for her constructive criticisms, precious suggestions and generous support during my entire study and the completion of this endeavor.*

I thankfully acknowledge ***Dr. Augustin Antony*** *Associate Professor Department of Biochemistry, CPBMB and member of my advisory committee for his unstinted support, critical comments and valuable suggestions during the preparation of this manuscript.*

I respectfully thank ***Dr. Sarah T.George,*** *Associate Professor, Department of Pomolgy and Floriculture and member of my advisory committee for kindly providing facilities and timely help at various stages of my work.*

I wish to extend my wholehearted gratitude to Dr.P.B. Pushpalatha, Assistant Professor, Department of Processing Technology for her timely advice, valuable suggestions, and inspiring encouragement rendered during the course of this research work and my study period.

I would like to specially thank Krishnan Sir, Assistant Professor, Department of Agricultural Statistics, for his relentless support in resolving the statistical intricacies of data.

I extend my profound sense of gratitude to Dr Koshy Abraham, Dr Surendra Gopal for their timely suggestions and encouragement provided through out the course of my study especially during the microbial analysis.

I sincerely acknowledge the whole hearted cooperation and sincere help rendered by Dr Girija, Dr Maicykutty P Mathew, Dr Nandini and all other teaching staff of College of Horticulture.

With deep respect I express my heartfelt gratitude and unforgettable indebtedness to Dr A.D.Joy College of Veterinary& Animal sciences.

I' am greatly thankful to my friends Anuja, Dhanya and SmithaDas for their wholehearted cooperation during the procurement of fruits.

I find it difficult to translate in to words the love, affection, constant prayers and moral support of my friends Sapheera,Sreela,Nashath, Reena,Renitha,Sujatha,, Srikrishna,Resmi,Gayathri, Ampili, andMalini.

With all regards I sincerely acknowldge the whole hearted co-operation and generous help rendered by my class mates Anupama chechi, Femina,Beethi, Simi, Lekha, Smitha, , Nashath, Jitha, Sai Jothi, , Jaisal, John Kutty, Sreejith, , Shankar, Mohan and juniors, Shibi, , Suja, and my seniors Smitha chechi, Mini chechi, Deepthi chechi, Sainamol Chechi, Sunilkumar Sir,Reshmi chechi , Thankamany chechi,Vidhu chechi , Evelin chechi.

I express my sincere thanks to Sri. Krishnettan, Radha chechi of the Department of Processing Technology for the timely and whole hearted co-operation and assistance they always accorded me during the course of investigation. Kind help and co operation extended by Devaki chechi is sincerely acknowledged.

Special thanks to Mini, Kochurani chechi, Roby &Simon.

I am happy to place on record my sincere thanks to my roommate Prathibha for her help and support during the course of this study.

The award of KAU junior research fellowship is greatly acknowledged

A special word of thanks to Santhoshettan for his help rendered during the preparation of manuscript.

Words can't ever express my gratitude to my loving husband, parents, brothers, in-laws and other family members who guided and encouraged me in all my endeavors including this. Without them I would never been able to complete this work. The blessings given by them have been a constant source of inspiration to me.

Finally I acknowledge all others who directly or indirectly helped me in the completion of this work.

Above all I humbly bow my head before the Almighty, who blessed me with will power and courage to complete this endeavor successfully, in spite of the most difficult times faced by me during the period of my study.

Habeeba

DEDICATED
TO MY FAMILY

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ABBREVIATIONS

CAS	-	Controlled atmospheric storage
CD	-	Cabinet drying
CF	-	Commercial fig
cfu	-	Colony forming units
CO_2	.	carbon-di-oxide
CRD	-	Completely randomized design
DMRT	-	Duncan's multiple range test
DR	-	Dehydration ratio
KMS	-	Potassium metabisulphite
KW	-	Kilowatt
LDPE	-	Low-density polyethylene
LF	-	Local fig
LLPE	-	Linear low-density polyethylene
m/s	-	Meters/second
MAP	-	Modified atmospheric packaging
Min	-	Minutes
NAM	-	Nutrient Agar Media
$NaHCO_3$	-	Sodium bi-carbonate
OD	-	Osmotic Dehydration
PDA	-	Potato Dextrose Agar
PE	-	Polyethylene
PLW	-	Physiological loss in weight
ppb	-	Parts per billion
ppm	-	Parts per million
PVC	-	Polyvinylchloride
RR	-	Reconstitution ratio

RS	-	Reducing sugar
SD	-	Sun drying
Sec	-	Seconds
SO_2	-	Sulphur-di-oxide
SR	-	Shrinkage ratio
TS	-	Total sugar
TSS	-	Total soluble solids
TTA	-	Total titrable acidity
TTS	-	Total titrable solids
UV	-	Ultra violet
Viz	-	Namely

Introduction

1. INTRODUCTION

Fig, *Ficus carica* L. belonging to the family Moraceae is a native of Southern Arabia. References to the fig tree were in the earliest chapters of the Bible. It is mainly grown in subtropical countries and is deciduous in growth habit.

The main fig growing countries are Italy, Spain, Turkey, Greece, Portugal and Algeria. The world fig production is shared by India to some extent where in Maharashtra is the leading state followed by Karnataka. The total area under fig cultivation in India is about 1000 hectares of which 400 hectares are in Maharashtra (Singhal, 1998) which further increased to 883 hectares with the production of 2650 metric tonnes (Gawade and Waskar, 2004).

Of late, the fig is a moderately important world crop with an estimated annual production of one million tonnes of fruit (Sadhu, 1990). From nutritional point of view, fig fruits are much valued and contain high sugar and low acid. The mineral content is two to four times than that of other fruits. Figs exert a positive effect on the alkaline reserves in the body and its extracts have been used for medicinal purposes such as in the treatment of Ehrlich sarcoma, cancer and as a laxative.

Even though fig is delicious it is highly perishable therefore the great bulk of the world production is sold in the form of dried products. Its shelf life is not more than two or three days at ambient temperature.

Dried figs are more nutritious compared to other fruits with high sugar and fibre content rich in minerals like Ca, Fe and Cu, but poor in vitamin C (Mortenson and Bullard, 1968).

Fig seen in Kerala is different from that of commercial type; however the characteristics are almost comparable. Thousands of fruits are wasted every year because of lack of knowledge regarding the post harvest operations. Dried products are highly hygroscopic in nature and these get spoiled if not provided with proper packaging.

Hence this study is proposed to generate a suitable technique for dehydrating the local fig now grown in Kerala as a value added product near to the commercial fig presently available in the market and hence the study 'Dehydration and storage studies in fig (*Ficus carica* L.)' has been laid out with the following objectives.

1. Dehydration studies.
2. Packaging and storage studies.

Review of Literature

2. REVIEW OF LITERATURE

Fig (*Ficus carica* L.) belonging to the family Moraceae is a native of Southern Arabia. It is one of the oldest fruits known to man having references in the early chapters of Bible. The edible fig is a small deciduous tree producing a multiple fruit syconium.

Fig is highly nutritious having high mineral content and rich in vitamins. There are different types of fig grown throughout the world. Based on nature of flowering and pollination, there are four distinct classes of fig viz,

1) Common / Adriatic fig: - Individual flowers are pistillate and fruit development takes place without fertilization and pollination.

2) Capri fig: - Most primitive ones having short styled pistillate flowers and functional staminate flowers. Most of the Capri figs are not edible in nature. But in the field these are found to give shelter to a small wasp named *Blastophaga psens*

3) Smyrna fig: -Fruit set takes place after pollination by that wasp that lives in the Capri fig (Male fig). These include the popular Turkish cultivar known as Sarilop in Turkey and Calimyrna in the United States.

4) San Pedro fig: - Here the first crop known as berba will be completely parthenocarpic and in the second crop pollination and fertilization is a must for fruit set.

Fig fruits should be harvested only when they are soft, milky latex exuding from the stem when the fruit is pulled indicates that the fruit is still immature.

Even though fig is delicious it is highly perishable therefore the great bulk of the world production is sold in the form of dried products. At ordinary temperatures they spoil within one or two days which makes marketing difficult.

Figs are consumed as fresh or dried, preserved candies or canned product. When dried and ground it can be used as a substitute for coffee (Sadhu, 1990).

The present study is proposed to generate a suitable technique for dehydrating the local fig seen in Kerala and comparing it with the commercial one.

Since the literature available in fig is meager, the literature on similar work in other crops are mostly reviewed and reported here under the following heads.

2.1 Dehydration

2.2 Packaging and storage studies

2.1 DEHYDRATION

Dehydration or drying is one of the oldest methods of preservation of fruits and vegetables. Dried fruits are unique in taste and very nutritious. Dried fruit tastes sweeter because the water has been removed, thus concentrating the fruits' flavour. Preservation by drying is simple and comparatively cheap.

2.1.1 Preparation for dehydration

2.1.1.1 Pretreatments

These are necessary to ensure a reasonably short drying time and to limit heat induced deteriorative changes to the minimum. These treatments prevent fruits from darkening.

The drying rate was similar in sulphited, blanched and lye treated sample; where as drying at final stage was rapid in control and blanched plus sulphited sample. Maximum TSS was in the fig fruits treated with sugar (Thonta and Patil, 1988). Similar trend was also found in reducing sugars. Pawar *et al.* (1992) observed highest total sugars in sulphited fig fruits followed by blanched plus sulphited ones.

The specific wax structures on grape fruit surfaces varied between cultivars and were destroyed to a varying degree after preliminary processing (treatment with alkaline solution and high temperature, which enhances drying and increases raisin quality). The tendency of grape shape changes (after drying) from spherical to oval or from oval to oblong is statistically significant. Raisin shape is not affected significantly by preliminary treatment of grapes and drying variants (Roichev and Botiyanski, 1998).

Phyllanthus emblica cv. Banarsi fruits were dried in the open sun following various pre-drying treatments (slicing or pricking or a combination of pricking + blanching, pricking + blanching + flaking, pricking + blanching + sulfitation (soaking in 0.1per cent potassium metabisulfite for 5 min) or pricking + blanching + sulfitation + flaking). Ascorbic acid retention after drying was highest (64 per cent) in sliced samples and lowest (18 per cent) in untreated controls. Rehydration parameters were also best in the slicing treatment. All the treatments significantly improved colour and overall acceptability compared with controls, but pricking did not improve texture, taste and appearance (Verma and Gupta, 2004).

a) Blanching

Patil *et al.* (1978) reported the effect of blanching on quality and durability of sundried and dehydrated fenugreek, observed that blanching treatment with 0.5 per cent KMS + 0.1 per cent $NaHCO_3$ and with water was superior to those with NaCl and KMS alone. In general the colour loss is observed during blanching and dehydration of vegetables.

Fig fruits are first soaked in boiling salt water for half a minute then dried for a few hours in the sun and for eight days under shade. At the end of the process the weight is reduced to a little over one third of the fresh weight (Samson, 1980). Blanched fruits have a translucent appearance. Blanching after a preliminary drying in a dry - blanch – dry process, this reduced the syrup loss so that blanching could be applied in grapes (Singh, 1983)

Mazza (1983) reported that factors such as blanching, freezing and sucrose dipping of carrot before air drying affected the moisture, transport and product quality while factors such as blanching, sulphiting, starching did not do so.

Blanching is a hot water treatment in which fruits or vegetables are subjected to heating in water or live steam before processing (Kalra, 1990). This is to inactivate the enzymes to prevent browning in the dried product. The maximum dehydration ratio was 9.57 for blanched carrot and 7.52 for the unblanched one dehydrated at 60^0C and 70^0C respectively. Baloch *et al.* (1997) found that probable reasons for greater loss of TSS in blanched carrot shreds should be the loss of solids during blanching and changes that occurred in the physical properties of the carrot tissues such as destruction of cell membrane.

Kannan and Thirumaran (2000) found that blanching by steaming process for three minutes was the best pretreatment for drying guava. Sadhu and Pashwak (2002) observed that blanching potato cubes in boiling two per cent brine solution followed by dipping in 0.2 per cent KMS solution for ten minutes showed the highest drying rate. Hot water blanching (5 minutes, at 97^0C) was found to be suitable for banana before subjecting to drying (Kar *et al.*, 2003).

Blanching nutmeg mace in 75^0C hot water for two minutes decreased the drying time by 12.5 per cent (Heartwin *et al.*, 2004). Steam blanching helps to retain colour and slow oxidation. However the flavour and texture of the fruits are changed. Blanching fruits in syrup helps it to retain colour fairly well during drying and storage.

b) Sulphuring

For long-term storage of dried fruit sulfuring or sulphite dip are the best pretreatments. Sulphuring is an old method of pretreating fruits. Sublimed sulphur is ignited and burned in an enclosed box with the fruits, for exposing to the sulphur fumes. Common pretreatments like blanching, antioxidant dip and KMS are an essential part and parcel of the process for known reasons (Jackson and Mohammed 1971; Bhardwaj and Kaushal 1990; Sharma *et al.*, 1991).

Apple rings treated with KMS 0.5per cent for 30 minutes and osmotic dip in 70^0Brix at 50^0C for 4.5 hours gave best osmovac dried product with a shelf life of six months at 13-36^0C. Treatment with 2500 ppm SO_2 also gave best quality product (Ramamurthy *et al.*, 1978). 4-hexylresorcinol has shown to be a promising antibrowning agent to control browning in fruit product (Monsalve *et al.*, 1985).

Usually fig fruits are subjected to sulphur fumigation before drying (Sadhu, 1990). Fig fruits were spiked with aflatoxin B_1, B_2, G_1 and G_2 to contain a total 100 ppb. The fruits were then exposed to SO_2 (750, 1500 and 2000 ppm) alone and in combination with heat (45, 55 and 65^0C), UV light and hydrogen peroxide (0.2 per cent at 20^0 C for 10 minutes). Sulphur dioxide alone at 2000ppm gave 68 per cent degradation of aflatoxins. Degradation increased when sulphurdioxide treatment was followed by heating and reached 79 per cent at the two-higher temperatures. The addition of UV light was effective only at 750 ppm SO_2. Treatment with hydrogen peroxide produced significant increases in degradation of aflatoxins. The best combination was 2000 ppm SO_2 + heating at 65^0 C + soaking in 0.2 per cent hydrogen peroxide which removed 95 per cent of the aflatoxins (Icibal and Altug, 1992). Figs (cv Kadota) were washed; lye dipped, sulfured and sundried or solar dried using a batch or cabinet solar drier (El –Razik *et al.*, 1997).

Fig fruits were subjected to sulphitation with two per cent KMS for 30 minutes before drying to prevent fungal growth (Raghupathy *et al.*, 1998). The retention of nutrients was better in steam-blanched amla than the water blanched ones (Ghorai and Sethi, 1998).

Various pre-treatments and their combinations consisting of lye (0.3 per cent boiling NaOH for 3 seconds), dipping oil (2 per cent for 5 min) either prior to sulfuring or after sulfuring (3 g/kg for 3 hour) and dipping oil alone (1.5per cent or 2 per cent initially and again 4 days later) followed by shade-drying were evaluated to find out the best method for raisin making in grape cultivars, Arkavati hybrid and Thompson Seedless. The treatment combinations consisting of lye-treatment + dipping oil + sulfuring + shade drying or lye-treatment + sulfuring + dipping oil + shade drying were best for producing good quality raisins. The dipping oil treatment alone induced soft texture, but it led to the development of brown colour rather than greenish colour. Arkavati was better than Thompson Seedless due to its smaller berry size, round to oval shape, better TSS (23°Brix) and thin skin (Gowda, 2000).

Breadfruit slices blanched in hot water at 90^0C for five minutes were used for drying methods (Pillai, 2001). Gawade and Waskar (2003) observed that blanching + sulphitation was the best pretreatment for dried fig preparation. The dried fig prepared from fig cultivars Poona and Dinkar could be stored for more than 180 days at low temperature, which maintained the physico-chemical characters and rated the highest organoleptic score for better market acceptability.

Ozer and Sen (2003) found that subjecting fig fruits to steam prior to wrapping was best pretreatment. *Prospis cineraria* fruits blanched for three minutes had a higher reconstitution ratio than those blanched for five minutes. Fruits harvested at an immature stage and blanched for three minutes in combination with 0.5 per cent KMS proved to have the best organoleptic quality (Fageria and Choudhary, 2003)

Ber fruits were dipped in water at 40^0C for ten minutes prior to air-drying showed least PLW (Bhat, 2004)

2.1.2 Methods of dehydration or drying

2.1.2.1 Sun drying

The preservation of fruits, dates back many centuries and is based upon sun and solar drying techniques (Arsdel, 1963)

Figs were washed, lye dipped, sulfured and sun dried or solar dried. Results showed that solar dried samples were dried 2.5 –3 times faster than traditional sun dried samples. Organoleptic evaluation showed that sun dried figs was superior followed by solar dried figs with an air speed of two m/s. The best score for colour was for the sun-dried sample (El -Razik *et al.*, 1997).

Solar drying resulted in a weight reduction of 240 g in 42 hours, where as sun drying required 60 hour for the same moisture level. Low capacity bamboo winnowing trays are suitable for fig drying; both reducing the drying duration and improving dehydrated fig quality. Temperature inside the bamboo baskets ranged from 42 to 75^0 C, which was considered suitable for fig dehydration. Moisture content of fruits decreased from 78 per cent initially to 16 per cent after 42 hours in bamboo basket, while fruits dried in direct sunlight took a further 18 hour to reach the same final moisture content (Raghupathy *et al*, 1998).

The moringa pieces can be dried by solar drier. Since loss of nutrients in solar drying is minimal and it's ready to use products can be marketed easily (Amutha and Krishnamurthy, 1999).

The effects of sun, shade and oven drying on the physico-chemical and sensory characteristics of fully matured and ripened grapes were determined. Significant differences due to treatments were not observed in terms of the physico-chemical properties of the dried grapes, except for the drying time which was shortest with oven drying (3 days), followed by sun drying (21 days) and shade drying (24 days). The colour, texture, taste, after taste and overall acceptability of the raisins were highest with shade drying (Maheswari, 2003).

In sun drying method, the amla fruits pretreated with sulfitation showed the fastest drying, particularly during initial stage (Palodkar *et al.*, 2003).

2.1.2.2 Mechanical drying

Latent heat of evaporation has been provided for many centuries mostly by direct sunlight exposition and although at the present time some fruits and vegetables are commonly dried by sun, air dehydration has gained importance because many advantages exist (Canovas and Vega, 1996). Air dehydration is carried out under strictly sanitary conditions. Here drying parameters can be accurately set, controlled and changed over the whole time, thus there will be a more uniform product and less quantity changes. Labour requirement is also very less in this case.

Fig fruits were dried earlier at higher drying air temperature but resulted in poor quality. High quality products were obtained at drying temperatures of 50^0 C. In addition to this lower drying air relative humidity and air velocity of 0.5 m/s is suitable for shortening drying time. In cabinet drying method, alkali treatment showed the fastest drying in case of drying amla fruits (Palodkar *et al.*, 2003).

2.1.2.3 Osmotic dehydration

Advantages of direct osmosis in comparison with other drying process include minimal heat damage to colour and flavour, less discolouration of the fruit by enzymatic oxidative browning (Ponting *et al.*, 1966).

It is a useful technique for the production of safe, stable, nutritious, tasty, economical and concentrated foods obtained by placing the solid food whole or pieces in sugar or salt aqueous solutions of high osmotic pressure. Conventional and mechanical drying gives the product poor organoleptic and rehydration properties. Osmotic dehydration involves two steps. First step is removal of water using (33-45 per cent) concentrated sugar syrup as osmotic agent. The second step is dehydration in air circulation drier where content is reduced to about 15 per cent. In this technique drying period is cut down to a large extent so that the heat damage to colour and flavour is minimized (Teaotia *et al.*, 1976).

Weight reduction reported higher by Bongirwar and Sreenivasan (1977) in osmotic dehydration of banana by using steeping solution in higher ratio. Osmotic dehydration of banana slices in sugar syrup of concentration varying from 60 to 80^0 brix at temperature of 27, 40, 50 and 60^0C revealed that fruit weight was reduced to about 50 per cent of its original weight at 50^0C. The reconstitution of osmotically dehydrated banana slices was only 50-60 per cent as compared to 63-65 per cent for air-dried slices.

According to Setty *et al.* (1978) the main principle involved in osmotic dehydration was partial dehydration of fruit and vegetables by osmosis at comparatively lower temperatures. This reduced the severity of the thermal treatment in the production of dehydrated fruits and vegetables hence could be near to the fresh produce.

Preparation of intermediate moisture banana by air drying of sulphited banana slices envinced that SO_2 treatment increased the firmness of by inactivating the proteolytic enzymes and also increased the dehydration rate by affecting the permeability of certain cellular membrane in plant tissue (Levi *et al.*, 1980). Contreras and Smyrl (1981) noted that osmosis was effective in preventing fruit discolouration by enzymatic oxidative browning thus precluding the use of sulphur dioxide.

According to Islam and Flink (1982) osmotic dehydration increased nutrient retention during the subsequent drying. Mehta *et al.* (1982) and Tomar *et al.* (1990) recorded 37.9 per cent and 40 per cent decline in case of pineapple and pear. Bolin *et al.* (1983) reported that the syrup remaining after osmotic drying can be recycled as table syrup, concentrated beverage, wines and jellies.

Lerici *et al.* (1984) reported that osmotically treated fruits were better in odour and texture than untreated fruits. The shrinkage of the material during osmosis for characterization of the process was considered by Lenart and Flink (1984).

Veghani and Chundavat (1986) opined that sapota slices steeped in 40 per cent sugar solution containing KMS (1 per cent) for 20 minutes or dipped in KMS 20 per cent for two minutes, when dried in sun gave the most stable and quality product. The yield of dried sapota after 33 hours of sun drying ranged from 30 to 34 per cent of which woody slices accounted for 0.38 to 3.75 per cent. Rehydration rate and moisture absorption capacity of the osmo dehydrated blue berries were reduced by intake of sugar (Kim and Toledo, 1987).

According to Le Maguer (1988) osmotic dehydration represent a potential saving in energy and improvement of the overall quality of the product. Shahabuddin and Hawladaar (1990) reported that osmotic dehydration alone could remove 30-40 per cent water content of pineapple fruit. Sugar infused into the pineapple acted as a water-binding agent and increased the internal resistance to moisture movement and gave lower diffusion coefficients (Rahman and Lamb, 1991). Also pointed out that osmotic dehydration improves the quality of products in terms of colour, flavour, aroma and texture.

Osmotic dehydration has now been coined as 'Dewatering and Impregnation Soaking (DIS) process (Raoult wack *et al.*, 1992).

Experiments were carried out to investigate the influence of vacuum treatment on water loss and sugar gain during osmotic dehydration of fruit tissue. Vacuum treatment was shown to have a significant effect on water transfer, making it possible to use lower solution temp. To obtain higher water transfer rate and to obtain good quality of dehydrated fruit products. No significant difference was found in the sugar gain under vacuum and normal pressure treatment. The sugar gain is closely related to the biological characteristics of fresh fruits; fruits with higher porosity are more suitable for vacuum treatment (Shi *et al.*, 1993). According to Choudhari *et al.* (1993) in osmotic dehydration process, there is a simultaneous counter current mass transfer of water from solution to hypertonic solution and of solute from solution in to the sample.

Papaya slices of 15 mm thickness osmotically dehydrated by moisture infusion technique by over night soaking in a solution containing 60 per cent sucrose, 0.1per cent citric acid and 0.1per cent potassium sorbate reached equilibrium at 44^0 brix (Ahmed and Choudhary, 1995).

Bawa and Gujral (2000) evaluated the effect of some osmotic solutions (sucrose and honey) on water loss and solid gain of raisins. The rate of moisture loss in the fruit varied with both the osmotic agents as well as their concentrations. The sensory scores indicated that the honey-treated samples gave better flavour while sugar-treated ones gave better colour (appearance) and overall acceptability.

Dehydration ratio of dehydrated potato slices was good in osmotic dehydration followed by brine blanching + KMS (Kad *et al.*, 2001). Osmotic drying caused a reduction in anthocyanin in cranberries due to leaching in the syrup (Girabowski *et al.*, 2002).

Janowicz *et al.* (2002) analysed mass exchange during osmotic dehydration of fruits with different internal structures. Strawberries (Ducat), cherries (Groniasta), black currants (Ojebyn) and plums (Wegierka) were investigated. Lowering of water content in cherries was maximum, up to 57per cent after 24 hours. The lowest water removal was observed in black currants, at about 9per cent after 24 hours. Cashew apples (*Anacardium occidentale*) were dried under the sun after osmotic pre-treatment in order to obtain a product with intermediate moisture content. Four osmotic pre-treatments were tested:

immersion in sucrose solutions of 45, 55 and 65 degrees Brix and immersion in sequenced solutions of 45, 55 and 65 degrees Brix. The processing involved enzymatic inactivation of the fruits, osmotic dehydration in sucrose solutions (added with preservatives) and solar drying. After drying, the products were packed and stored for 180 days at room temperature (28 ^{0}C). During the entire processing and after obtaining the final product, chemical, physicochemical, microbiological and sensorial analyses were conducted. The results showed that the products have good stability in all the studied parameters (Brandao *et al*, 2003).

Osmotic dehydration is rather a new innovation for producing better quality-dehydrated products. Osmotic dehydration is a technique that makes possible the processing of fruits, obtaining shelf-stable products, or even functional foods by incorporation of physiologically active substances. In addition, combination of osmotic dehydration with traditional process, such as drying or freeze-drying, has showed to reduce time of processing and improve the characteristics of the final product (Sousa *et al.*, 2003).

2.2 PACKAGING AND STORAGE STUDIES

2.2.1 Packaging

Jayaraman *et al.* (1976) reported that the banana slices treated with 300 ppm SO_2 and packed in flexible laminated pouches remained acceptable up to nine months at room temperature and four months at 37^{0}C. With 500 ppm SO_2 the shelf life of the slices was 12 months at room temperature and six months at 37^{0}C.

It is an important factor responsible for improving the quality of saleable product (Pandey *et al*, 1983). The package should be designed in such a way that the product should be delivered to the consumer conveniently and in a good form.

Moreover the product kept inside the package should be free from mechanical injury during transit.

Gorini (1985) reported that the packaging of fruits in polyethylene film of known permeability to modify the internal atmosphere has extended the shelf life and prevent decay. Krishnamoorthy and Khusalappa (1985) reported that fruits could be packed in polyethylene bags as it creates a modified atmosphere with more CO_2 and less oxygen in the air.

Polyethylene packaging was highly effective in checking weight loss and maintaining turgidity and freshness of sapota. But imperforated polythene bags resulted in water soaking of the fruits and made them unmarketable. With increased intensity of perforation this disorder was reduced but PLW increased. The best results were obtained in 1.2 per cent venting of polyethylene bags which gave 100 per cent marketable fruits with only 3.9 per cent total loss on sixth day and 62.5 per cent of fruits lasted for eight days with excellent organoleptic qualities (Desai and Kumbhar, 1986). Arie *et al.* (1991) found that persimmon could be stored in modified atmospheric packs of 0.08 mm LLPE up to eight weeks.

The shelf life of sapota cv Kalipatti could be increased up to nine days with minimum weight loss and rotting when packed in polyethylene bags 100 gauge and stored under ambient conditions (Waskar and Nikam, 1995). Polyethylene and polypropylene are the best available material for the packaging of dried products as suggested by Balasubramanyam (1995).

The highest retention of green colour (20 per cent) was observed in the polythene laminated with aluminium foil packaging treatment (Mandhyan, 1999). Dehydrated guava slices packed in polyethylene bags of 100-guage thickness. The highest moisture absorption was observed in sugar solution treated sample packed in 200-gauge bag (Kannan and Thirumaran, 2000).

The suitable packaging material for Suvarnarekha and Baneshan + Suvarnarekha powders were high-density polyethylene of two mil with aluminium lamination; the storage period was six months (Hymavathi and Khader 2004).

2.2.1.2 Vacuum packaging

Packages with minimal oxygen content have a wide range of application. It was based on the fact that the shelf life of fruits can be greatly extended only when a minimum amount of oxygen is permitted to come in contact with them.

Gorris and Peppelenbos (1993) observed the beneficial effect of modified and vacuum packaging in extending the shelf life of fruits. They reported that importance should be given in selecting the right packaging material, storing the produce at the correct temperature and ensuring safety from microbial agents. They described a vacuum packaging system for fresh products in which the atmospheric pressure in a rigid storage container is reduced to approximately 400 millibar by evacuating air from the containers. The system can extend the shelf life of fresh products and prevent enzymatic browning of cut fruits.

Kucherer (1996) found that vacuum pack could replace the tin plate can. Advantages of the vacuum pack include improved freshness, safety of the product, lower pack weight, less packaging waste and more efficient utilization of storage capacity.

Mohamed *et al.* (1996) reported that the ascorbic acid content was high in vacuum-packed fruits. Geetha (1997) experimented on the vacuum packaging of fruits and revealed the fact that the shelf life of sapota fruits can be extended by three weeks and six weeks when the fruits were vacuum packed and stored at ambient and refrigeration temperature respectively.

Vacuum-packed mango slices showed higher SO_2 as compared to air packed material.

2.2.2 Storage

Good quality of fresh mission figs was maintained for four weeks when kept at 0, 2.2 or 5 ^{0}C in atmosphere enriched with 15 or 20 per cent CO_2. The visible benefits of exposure to high levels where a reduction of the incidence of decay and the maintenance of a bright external appearance. Ethylene production was lower and fruit softening was slower in CO_2 concentration than in those kept in air. Post harvest life of fresh mission fig can be extended by 2-3 weeks by holding them at 0-5^{0}C in atmosphere enriched with 15-20 per cent CO_2 but off flavours can be a problem by the fourth week of storage (Colleli *et al.*, 1991).

PVC wrapped fruits exhibited a slight off flavour and off odour. Cold storage was effective in reducing fruit rot (Piga *et al.*, 1995). Inclusion of a zeolite-based moisture absorbent prolonged the shelf life of fruits (Matteo *et al.*, 1999). Keeping the osmotic dehydrated mango slices above 64.8 per cent and below 75.7 per cent. Relative humidity would be conducive to the retention of colour, flavour, taste and texture of the produce (Amitabh and Tomar, 2000). Quality of wax apple packed in low-density polyethylene bag was better than stretch film wrapping (Parvathy *et al.*, 2003). The plastic film was very effective in maintaining freshness, delaying aging and reducing weight loss. Unwrapped fruits were not suitable for marketing after two days of storage.

During storage in air the rates of oxygen uptake and ethylene production declined substantially and fruit weight loss increased up to 2.1 per cent. Storage in two per cent oxygen resulted in further reduction of oxygen uptake and ethylene production rates. Fruits stored in air showed decreased firmness, ethylene production rate but no significant changes in respiratory quotient, oxygen uptake and CO_2 production rates, soluble solids content, titrable acidity. Two per cent O_2 is recommended for better firmness retention during storage for longer than eight days (Tsantilli *et al.*, 2003).

2.2.2.1 Modified atmospheric storage

Modified atmospheric storage is considered as a dynamic system, where respiration of product and gas permeation of film continues to take place simultaneously (Flores, 1990). MAP consists of enclosing the fruits in a plastic bag with reduction in oxygen levels. Under such conditions the respiration rate of the fruit is decreased and the ethylene climacteric rise was delayed there by retarding ripening and deterioration process.

Modified and controlled atmospheric storage can help to maintain quality and extend the storage life by inhibiting metabolic activity, decay and especially ethylene biosynthesis and action. It has been found to be successful in extending the storage life of some fruits and vegetables (O'Connor *et. al,* 1992).

Rosa *et al.,* (2001) reported that modified atmospheric storage dramatically reduced the percentage of weight loss in mango. MAP has been found to be successful in extending the storage life of some fruits and vegetables.

Emerald *et al.,* (2001) observed that sapota (cv cricket ball) fruits packed under two per cent O_2+ ten per cent CO_2 +88 per cent N_2 (MAP) recorded the minimum changes in physicochemical characteristics and thus helpful in extending the shelf life of sapota fruits by about four to five times compared to control.

The effects of high carbon dioxide concentrations (10 to 20 per cent) have been compared to those of low concentrations of oxygen (1 per cent). High CO_2 concentrations were more effective than low oxygen concentrations for storing grapes. A threshold concentration of around 15 per cent must not be exceeded due to phytotoxicity phenomena or flavour alteration, both of which may occur at higher carbon dioxide concentrations. However, Botrytis fungal disease can develop quickly upon the end of treatment and the return to ambient temperatures (Chapon, 2002).

2.2.2.2. Changes during storage

In early stages of drying much of the sugar present as sucrose, but as drying proceeds more and more reducing sugars are produced by acid inversion of non-reducing sugars and some of the free SO_2 forms complex with them, there by raising bound SO_2 in the product (Mc Bean, 1967). Irrespective of the packaging methods the moisture content, reducing and total sugar increased through out the storage period where as acidity decreased in the case of bael fruit (Roy and Singh, 1979). Free SO_2 is known to bind with sugars, pectin and amino acids (Bolin *et al.*, 1983).

Lerici *et al.* (1984) on conducting experiments in the dehydration of fruits such as plums, pears and peaches found that treated fruits were better in flavour, texture and colour than the untreated.

Sankat and Balkisson (1992) reported that TTS and TTA ratio of carambola fruits was not affected by packing during storage at 10, 15, 25 ^{0}c. Loss of free and total SO_2 during drying of puree followed first order kinetics and free SO_2 was lost more rapidly than total SO_2 (Mir and Nath, 1995). Rate of loss of free SO_2 was always greater than that of total SO_2 because some of free SO_2 escapes from product to the drying media.

Sagar *et al.* (1999) reported lower moisture in vacuum packed dehydrated ripe mango slices.

The highest score for overall acceptability recorded by nitrogen packs were due to the better retention of colour, flavour and texture. Sagar *et al.*(1999) also observed that nitrogen packed dehydrated ripe mango slices retained the colour and quality during storage under ambient conditions. Similar trend was reported by Kumar and Sreenarayanan (2000) in dehydrated onion flakes and Sagar and Khurdiya (2000) in ripe mango powder.

Tamarind pulp packed under vacuum sealing and stored under refrigerated temperature retained the brown colour up to 330 days of storage. Extended storage life without deterioration in colour and quality was observed when the pulp was vacuum packed and stored under refrigeration. The variation in total sugar content of pulp packed under vacuum and stored under refrigeration was 37.85 and 34.69. It was more in pulp packed under normal condition and stored under ambient conditions (30.47 and 30.43 per cent respectively). Acidity was high in vacuum-sealed pulp whereas reducing sugar was low (Nagalakshmi and Chezhiyan, 2004)

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on dehydration and storage studies in fig (*Ficus carica* L.) was carried out at the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala during 2004-2005. Vellanikkara enjoys a warm humid tropical climate throughout the year.

Fig, being a highly perishable commodity major chunk of the world production is sold in the form of dried product. Fig seen in Kerala is different from that of commercially cultivated ones; however fruits are comparable with that of commercial ones. Thousands of fruits are wasted every year because of the lack of knowledge regarding the post harvest operations in the state.

Therefore in the present study an attempt have been made to develop a suitable method for the dehydration and packaging of fig fruits, available in Kerala in comparison with that of commercial ones.

The whole programme was divided into two major experiments,

3.1 Dehydration studies
3.2 Packaging and storage studies

Procurement of fruits

F g fruits seen in Kerala were collected from the trees grown in the college orchard maintained by the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara and also from farmers' field (Plate1). Commercial fruits were obtained from Dharward in Karnataka state (Plate 2a & 2b). Fig seen in Kerala has a dark purple colour whereas commercial figs are green to light purple (Plate 3a & 3b).

Plate 1. View of a local fig tree

Plate 2a. Branch of local fig bearing fruits

Plate 2b. Local fig fruits and its longitudinal section

Plate 3a. View of a branch of commercial fig bearing fruits

Plate 3b. Commercial fruit and its longitudinal section

Harvesting of fruits was done based on the maturity standards suggested by Sadhu (1990).

3.1 DEHYDRATION STUDIES

Fully ripened fruits were washed, sorted, peeled and cut into smaller pieces and then subjected to the pretreatments.

3.1.1 Pretreatments

T_1 Dipping in plain boiling water for 30 seconds

T_2 Dipping in boiling lye water containing 2% $NaHCO_3$ for 30 seconds

T_3 Dipping in boiling 50% sugar solution for 15 minutes

T_4 Dipping in boiling 50% sugar solution containing Potassium metabisulphite (KMS) (375 ppm SO_2) for 15 minutes

T_5 Exposing the materials to sulphur fumes for half an hour

T_6 Control without any pretreatment

After the pretreatments drying was carried out employing three methods of drying viz,

1. Sun drying (SD)
2. Cabinet drying (50-60^{0}C) (CD)
3. Osmotic dehydration (OD)

3.1.2 Lay out

All the experiments were laid out in a Completely Randomised Design (CRD) with three replications each.

3.1.1.1 Blanching

Fruit pieces taken in a muslin cloth bag were dipped in plain boiling water for 30 sec. After that these bags were withdrawn and drained off excess water and fruit pieces were spread on a clean area.

3.1.1.2 Sulphuring

Fruit pieces were subjected to sulphur fumes for half an hour in a closed chamber fabricated for the purpose.

3.1.2 Sun drying (SD)

Fruit pieces after each pretreatment were subjected to sun drying by spreading uniformly on a mat. The temperature ranged from 25^0C to 35^0C during the period of sun drying.

3.1.3 Cabinet drying (CD)

Pieces after pretreatments, were spread uniformly in perforated trays and dried to constant weight by maintaining temperature between 50 and 60^0C in a cabinet dryer with inner dimensions 0.9 x 1 x 0.61 m^3 and 25KW heating capacity (Kilburn 0248,India).

3.1.2 Osmotic dehydration (OD)

In order to sandardise the fruit to sugar ratio, time suited for osmotic dehydration of fig preliminary study was carried out with three ratios for three different times. In the case of local fig, fruit pieces from all the pretreatments were immersed in dry sugar in the ratio 1:1 containing 375 ppm SO_2 and 0.3 percent citric acid as preservative for 20 hours. After 20 hours of contact time, the slices were taken out and given a quick hot water dip to wash off the excess syrup adhering to the pieces and subsequently wiped with a tissue paper to dryness. The osmosed fruit slices were further dried in a cabinet drier at 50-60^0 C for ten hours by spreading evenly on perforated aluminium trays.

3.1.3 Observations

Observations on both physical and chemical characteristics were taken immediately after drying.

3.1.3.1 Physical observations

3.1.3.1.1 Recovery percentage

Weight of samples after each drying over the initial weight was calculated and expressed as recovery percentage.

$$\text{Recovery percentage} = \frac{\text{Final weight after drying}}{\text{Initial weight}} \times 100$$

3.1.4.1.2 Residual moisture

Moisture content was estimated in each of the drying methods as suggested by Ranganna (1986). Known quantity of samples was dried in an oven at a higher temperature of 70 ± 2^0 C till a constant weight is achieved.

3.1.4.1.3 Colour change

Colour change due to various pretreatments were assessed visually and classified into light yellow, golden yellow, light brown and brown in case of commercial fig and dark purple, purple, light purple in case of local ones.

3.1.4.1.4 Dehydration ratio

Dehydration ratio was calculated as per the formula given by Pruthi *et al.* (1978).

$$\text{Dehydration ratio} = \frac{\text{Weight of fig fruit taken for dehydration}}{\text{Weight of dried fig fruit}}$$

3.1.4.1.5 Drying rate

Drying rate was found out using the method described by Narasimham and John (1995). Fig pieces kept for dehydration by various methods were taken at different intervals and their weight as percentage to original weight was worked out.

3.1.4.1.6 Shrinkage ratio

Shrinkage ratio was determined as per the formula given by Ocansey (1984).

$$\text{Shrinkage ratio} = \frac{\text{Final volume obtained after dehydration}}{\text{Initial volume}}$$

3.1.4.1.6 Reconstitution rate

Weighed samples of dried fig were reconstituted with water and at regular intervals weight pick up was assessed using electronic balance.

3.1.4.1.7 Reconstitution ratio

Calculated using the formula given by Pruthi *et al.* (1978).

$$\text{Reconstitution ratio} = \frac{\text{Weight of sample after maximum reconstitution}}{\text{Weight of original dried sample}}$$

3.1.4.2 Chemical analyses

Composite samples were withdrawn at random, from each treatment immediately after drying for estimation of total and reducing sugar, residual SO_2 and Ca.

3.1.4.2.1 Reducing sugars

Reducing sugar content was determined by Lane and Eynon method (Ranganna, 1986) and expressed as percentage.

Five g each of the samples were taken and soaked in water and further ground to a fine paste using mortar and pestle. To this added distilled water and neutralized with 1 N NaOH and boiled gently with occasional stirring and then clarified with neutral lead acetate. The excess lead was removed by adding potassium oxalate. The volume was then made up to 250 ml and filtered. Aliquot of this solution was titrated against a mixture of Fehling's solution A and B with methylene blue as indicator

3.1.4.2.2 Total sugars

Total sugars were also determined by Lane and Eynon method (Ranganna, 1986) and expressed as percentage.

From clarified solution used for estimation of reducing sugar, 50 ml was taken and boiled gently after adding citric acid and water. It was later neutralized with NaOH and the volume was made up to 250 ml. An aliquot of this solution was titrated against Fehling's solution A and B.

3.1.4.2.3 Residual SO_2

Residual SO_2 was analysed as per the modified Ripper titration method suggested by Ranganna (1986). Five g each of the samples were taken and soaked in water and further ground to a fine paste using mortar and pestle. Then it was filtered and 50 ml of the clear solution was taken and added 5N NaOH and ml 5N HCl. *Then it was titrated against 0.02 N Iodine solution using starch* as indicator. The titre value is A. Another 50 ml of the clear soluion was taken and added 5ml NaOH, 7ml HCl and 10 ml HCHO. Then it was titrated as explained above. The titre value is B. From these titre values residual SO_2 in the sample calculated in ppm.

3.1.4.2.4 Calcium

The calcium content was estimated by titration method using EDTA, as suggested by Page (1982).

Two g of dry powdered sample was predigested with 12 ml 9:4 mixture of nitric acid and perchloric acid. One ml of the diacid extract made upto 100 ml and added 50 ml water, 10 drops of hydroxylamine hydrochloride, 10 drops triethanloamine, 2.5 ml NaOH and 5 drops of calcone. Then it was titrated with EDTA till the appearance of permanent blue colour.

3.1.4.3 Sensory evaluation

Sensory evaluation was carried out with the help of 10-member semi trained panel on a five point hedonic scale. Panel members were asked to evaluate dehydrated samples for colour, flavour, texture and overall acceptability as given in the scorecard. Scorecard used in the evaluation is given in Appendix I

3.1.4.4 Economics of the product

Production cost for 100g-finished product was worked out based on the cost of inputs, overhead and utilities.

3.2 PACKAGING AND STORAGE STUDIES

Best drying technique developed through Experiment No: 1 was repeated in large quantities for packaging and storage studies. Osmotic dehydration was the best drying technique for both local and commercial types. However a pretreatment was needed in the case of local types, i.e. blanching the pieces in 50% sugar solution for ten minutes prior to osmotic dehydration, which was not needed for the commercial types.

Best-dehydrated samples were packed and kept for storage studies with the following packaging treatments.

3.2.1 **Treatments**

T_1 .Packaged in 100 gauge polyethylene with air as control (PE_A)

T_2 .Packaged in 100 gauge polyethylene with vacuum (PE_V)

T_3 .Packaged in 100 gauge polyethylene with nitrogen (PE_{N2})

T_4 .Packaged in 100 gauge polyethylene with carbon dioxide (PE_{CO2})

T_5 .Packaged in aluminium foil laminated pouch with air as control (Al_A)

T_6 .Packaged in aluminium foil laminated pouch with nitrogen (Al_{N2})

T_7 -Packaged in aluminium foil laminated pouch with carbon dioxide (Al_{CO2})

T_8-Packaged in aluminium foil laminated pouch with vacuum (Al_V)

3.2.2 Lay out

All the experiments were laid out in a completely randomised design (CRD) with three replications each.

3.2.3 Gas / Vacuum Packaging

Materials after dehydration were placed in both 100-gauge polyethylene (PE) and aluminium foil laminated pouches and placed in a Quick seal vacuum packaging machine with three pouches at a time (Sevana Electrical Appliances Pvt Ltd). The machine has a chamber capacity of 500 x 400 x 150 mm^3 with two sealing heads. (Plate 4)

For flushing the N_2 / CO_2 gas in to the pouches, pouches were first evacuated for vacuum and then the respective gases were flushed into such pouches till it attains the requisite gas pressure.

3.2.4 Observations

Observations at monthly intervals were taken for the following parameters.

3.2.4.1 Physical

3.2.4.1.1 Visual colour change

Colour change during storage was recorded by visual observation

3.2.4.1.2 Moisture pick up

By taking weight differences at bimonthly intervals and expressed the gain or loss in percentage.

3.2.4.1.3 Presence of any stored pest

Packed samples were examined visually for the presence of any insect or any of its stages.

Plate 4. Quick seal vacuum packaging machine

3.2.4.2 Chemical analyses

All chemical analyses were carried out as stated in 3.1.4.2.

3.2.4.2.1 Acidity

Titrable acidity was estimated as per A.O.A.C (1975) method and expressed as percentage citric acid.

Soaked the samples in 50 ml water and pulped to this 50 ml of water again added. Then it was boiled for 30 minutes; cooled and made upto 100 ml and filtered. Pipetted 25 ml of the clear solution and added 25 ml distilled water. Then it was titrated against 0.1 N NaOH using phenolphthalein as indicator.

3.2.4.3 Microbial load

The quantitative assay of micro flora was carried out by serial dilution plate count method as described by Agarwal and Hasija (1986). Ten g sample was added to 100 ml Ringers solution in 250 ml conical flask and shaken for 20 minutes in orbital shaker. This gives 10^{-1} dilution. Then ground in a sterile mortar and pestle and sieved through sterile muslin cloth. From the filtrate I ml was then transferred to test tube containing 9 ml Ringers solution to get 10^{-2} dilution. Later 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6} dilutions were prepared from this by serial dilutions.

Enumeration of total microflora was carried out using nutrient agar media for bacteria, potato dextrose agar media for fungi, malt dextrose media for yeast as suggested by Agarwal and Hasija (1986). The dilution used for bacteria was 10^{-6} and for fungi and yeast 10^{-3} dilution was used.

$$\text{Number of colony forming units (cfu) per gram of the sample} = \frac{\text{Mean number of cfu x dilution factor}}{\text{Quantity of the sample on weight basis}}$$

Composition for Ringers solution, PDA, NAM, Yeast media are given in Appendix II.

3.2.4.4 Tabulation and statistical analyses

Data were analysed using M-stat statistical software and subjected to analysis of variance at five percent level of significance following Factorial Completely Randomized Design (Panse and Sukhatme 1976). Significant differences between the means were estimated using Duncan's Multiple Range Test. Data pertaining to organoleptic evaluation were analysed using Kendall's coefficient of concordance.

Results

4. RESULTS

The results of the study "Dehydration and storage studies in fig" are presented under the following headings.

1. Dehydration studies
2. Packaging and storage studies

4.1 DEHYDRATION STUDIES

In order to standardize the best pretreatment suitable for each method of drying, in both local and commercial fig, various parameters needed for a dried product is compared and results are reported here. On standardizing the best pretreatment the drying methods were standardized further.

4.1.1 Physical parameters

Observations of the following parameters are taken immediately after drying.

4.1.1.1 Recovery percentage

Recovery percentage with respect to pretreatments under each method of drying for local and commercial figs are studied and presented in Table 1.

On comparing the recovery percentage in different methods of drying with respect to pretreatments showed that pretreatments in different methods of drying differ significantly.

Pretreatment T_3 (Dipping in boiling 50 per cent sugar solution for 15 minutes showed the highest value (23.00) in sun drying of local fig. While the higher values of cabinet drying were treating with sugar solution with and without KMS (19.5 and 19.00). In osmotic dehydration T_4 (Treating with 50 per cent sugar solution containing KMS (375 ppm SO_2) for 15 minutes) was the best (38.67).

Table 1. Recovery percentage of local and commercial fig dried under different techniques.

Treatments	Method of drying					
	SD		CD		OD	
	LF	CF	LF	CF	LF	CF
T_1	21.49 ^{hij}	22.48 ^{gh}	17.38 ^{mn}	22.33 ^{gh}	37 ^{b}	31.83 ^{de}
T_2	22.22 ^{gh}	22.33 ^{gh}	18.40 ^{lm}	22.5 ^{fgh}	38 ^{a}	33.17 ^{cd}
T_3	23 ^{fg}	22.50 ^{fgh}	19.50 ^{kl}	21.67 ^{ghi}	37.5 ^{ab}	33.5 ^{c}
T_4	22.50 ^{fgh}	22.50 ^{fgh}	19.00 ^{kl}	22.59 ^{fgh}	38.67 ^{a}	33 ^{cd}
T_5	21.80 ^{ghi}	21.17 ^{hij}	18.17 ^{lm}	21.5 ^{hij}	37 ^{b}	32 ^{de}
T_6	20 ^{k}	20.5 ^{ij}	16.67 ^{n}	20.17 ^{jk}	37 ^{b}	30.83 ^{e}

LF- Local fig   CF- Commercial fig
The values represent means of 3 replications
Values with different super scripts differ significantly at 5%level
OD-Osmotic dehydration   CD-Cabinet drying   SD-Sun drying

T_1 Dipping in plain boiling water for 30 sec

T_2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec

T_3 Dipping in boiling 50% sugar solution for 15 min

T_4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min

T_5 Exposing the materials to sulphur fumes for half an hour

T_6 Control without any pretreatment

The trend was slightly different in commercial fig where T_2 and T_4 gave highest values (treating with $NaHCO_3$ and 50 per cent sugar solution KMS (375 ppm SO_2) respectively), in cabinet drying. Whereas in sun drying T_3 and T_4 gave higher recovery percentage. While in osmotic dehydration treating with 50 per cent sugar solution (T_3) gave the highest value (33.5).

Irrespective of pretreatments both local and commercial type figs gave highest recovery percentage in osmotic dehydration.

4.1.1.2 Colour change due to drying

Purple colour of dried local fig and golden colour of commercial fig Are preferred. Sun drying and cabinet drying resulted in darkening of both types of fig. Only osmotic dehydration maintained desired colour in both types. Pretreating with KMS resulted in bleached appearance of the samples whereas $NaHCO_3$ treated samples turned dark brown.

4.1.1.3 Dehydration ratio, shrinkage ratio and reconstitution ratio

The effect of different combinations of drying methods and pretreatments on the dehydration ratio, shrinkage ratio and reconstitution ratio of local and commercial fig are presented in Table 2 and 3.

4.1.1.3.1 Dehydration ratio

Lower the dehydration ratio better is the method. Significant difference was observed in both between pretreatments and methods of drying ($P<0.05$) in both the types of figs with osmotic dehydration rated as the best.

Treating with 50 per cent sugar solution gave better dehydration ratio in osmotic dehydration of local fig. While in the case of commercial types, though no significant difference existed between pretreatments in sun drying, significant difference existed in the other methods of drying. Control without pretreatment-recorded higher values in cabinet drying and osmotic dehydration.

Table 2. Dehydration ratio, shrinkage ratio and reconstitution ratio of local fig dried under different techniques

Treatments	Method of drying								
	SD			CD			OD		
	DR	SR	RR	DR	SR	RR	DR	SR	RR
T_1	4.66 ^{efgh}	0.55 ^{gh}	3.53 *	5.76 ^{a}	0.48 ^{ijkl}	3.80 *	2.59 ^{mn}	0.71 ^{ab}	2 ^{jk}
T_2	4.50 ^{gh}	0.62 ^{def}	3.50 *	5.44 ^{abc}	0.49 ^{ijk}	3.74 *	2.63 ^{lmn}	0.65 ^{cd}	2.03 ^{jk}
T_3	4.45 ^{h}	0.57 ^{g}	3.54 *	5.27 ^{bcd}	0.51 ^{hi}	3.76 *	2.67 ^{klmn}	0.64 ^{cd}	2.06 ^{jk}
T_4	4.35 ^{h}	0.64 ^{cd}	3.71 *	5.13 ^{bcd}	0.49 ^{ijk}	4.02 *	2.70 ^{jklmn}	0.74 ^{a}	2.70 ^{i}
T_5	4.59 ^{fgh}	0.63 ^{de}	3.65 *	5.51 ^{ab}	0.45 ^{klm}	4.00 *	2.70 ^{jklmn}	0.68 ^{bc}	2.07 ^{jk}
T_6	5 ^{def}	0.59 ^{fg}	3.62 *	5.83 ^{a}	0.46 ^{jklm}	3.85 *	3.09 ^{ijk}	0.63 ^{de}	2.03 ^{jk}

LF- Local fig CF- Commercial fig
The values represent means of 3 replications
Values with different super scripts differ significantly at 5%level
* Non-significant
DR-Dehydration ratio RR-Reconstitution ratio SR-Shrinkage ratio

CD-Cabinet drying SD-Sun drying OD-Osmotic dehydration

T_1 Dipping in plain boiling water for 30 sec

T_2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec

T_3 Dipping in boiling 50% sugar solution for 15 min

T_4 Dipping in boiling 50% sugar solution containing potassium meta bisulphite (KMS) (375 ppm SO_2) for 15 min

T_5 Exposing the materials to sulphur fumes for half an hour

T_6 Control without any pretreatment

Table 3. Dehydration ratio, shrinkage ratio and reconstitution ratio of commercial fig dried under different techniques

Treatments	SD			CD			OD		
	DR	SR	RR	DR	SR	RR	DR	SR	RR
T_1	4.48 defg	0.48 ijkl	2.01*	4.88 defg	0.43 m	3.14 h	3.14 *	0.58 fg	1.9 jk
T_2	4.48 defg	0.5 ij	1.97*	4.46 h	0.44 lm	3.48 defgh	3.02 *	0.56 gh	1.73 k
T_3	4.45 h	0.45 klm	2.04*	4.2 h	0.45klm	3.26 gh	2.99 *	0.59 fg	2.14 j
T_4	4.45 h	0.47 ijklm	2.12*	4.42 h	0.44 lm	3.57 cdefg	3.02 *	0.62 def	1.96 jk
T_5	4.65 fgh	0.50 ij	1.97*	4.71 cfgh	0.45klm	3.41 efgh	3.13 *	0.59 fg	2.05 jk
T_6	4.97 def	0.49 ijk	2.05*	5.06 cde	0.44 lm	3.34 gh	3.24*	0.59 fg	2.10 j

The values represent means of 3 replications

Values with different super scripts differ significantly at 5%level * Non-significant
DR-Dehydration ratio; RR-Reconstitution ratio; SR-Shrinkage ratio;
CD-Cabinet drying; OD-Osmotic dehydration; SD-Sun drying
LF- Local fig CF- Commercial fig

T_1 Dipping in plain boiling water for 30 sec

T_2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec

T_3 Dipping in boiling 50% sugar solution for 15 min

T_4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min

T_5 Exposing the materials to sulphur fumes for half an hour

T_6 Control without any pretreatment

4.1.1.3.2 Shrinkage ratio

Higher the value, lower the shrinkage, and better is the product quality. Maximum value was noted for osmotic dehydration in both local and commercial fig. Dipping fruit pieces in boiling 50 per cent sugar solution with KMS (375 ppm SO_2) for 15 minutes was the best pretreatment with a value of 0.74 in osmotic dehydration and 0.64 in sun drying of local fig. While in cabinet drying T_3 (treating with boiling 50 per cent sugar solution) was found to be the best.

Dipping fruit pieces in 50 per cent sugar solution containing KMS (375 ppm SO_2) for 15 minutes was found to be the best pretreatment prior to osmotic dehydration in commercial fig which rated significantly different from all others. There was no significant difference among pretreatments in cabinet drying. While exposing the materials to sulphur fumes and treating with $NaHCO_3$ were found to be best in sun drying.

4.1.1.3.3 Reconstitution ratio

Higher reconstitution ratio was observed in cabinet drying for commercial figs whereas in sun drying no significant difference observed. There was no significant difference among the various pretreatments of the local fig subjected to cabinet drying and sun drying. Treating with sugar solution containing KMS gave highest value in osmotic dehydration (2.70).

Control without any pretreatment recorded the highest reconstitution ratio in commercial fig when subjected to sun drying while T_4 ranked first in cabinet drying of commercial fig. All the pretreatments in osmotic dehydration were homogenous (Table 3)

4.1.1.4 Drying rate and reconstitution rate

Drying rate with respect to pretreatments under each method of drying was studied separately for both figs and presented in Table 4 and 5.

Table 4. Drying rate of local fig dried under different techniques

Treatments	Method of drying								
	SD (hours)			CD (hours)			OD (hours)		
	3	6	9	0	4	8	0	4	8
T_1	50	38.31	20.45	100	31	18.95	100	81.2	65.76
T_2	57.3	40.45	21.28	100	33.2	20.23	100	84.65	68.32
T_3	48.85	34.48	18.31	100	29.85	17.9	100	75.68	59.82
T_4	51.54	35.71	19	100	32.5	17.43	100	76.35	60.32
T_5	50.48	33.71	17.51	100	31.65	16.23	100	71.95	57.58
T_6	48.77	33.71	17.2	100	29.21	16.12	100	70.86	55.44

Values denote the percentage of original weight
OD-Osmotic dehydration CD-Cabinet drying SD-Sun drying

T_1 Dipping in plain boiling water for 30 sec

T_2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec

T_3 Dipping in boiling 50% sugar solution for 15 min

T_4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min

T_5 Exposing the materials to sulphur fumes for half an hour

T_6 Control without any pretreatment

Table 5. **Drying rate of commercial fig dried under different techniques**

Treatments	SD			CD			OD		
	0	**6**	**12**	**0**	**4**	**8**	**0**	**4**	**8**
T_1	100	47.23	23.63	100	47.35	21.65	100	82.5	72.3
T_2	100	47.59	22.10	100	49.52	23.54	100	80.65	70.25
T_3	100	45.00	19.23	100	46.98	20.37	100	79.21	69.35
T_4	100	44.12	18.2	100	43.25	19.75	100	78.32	64.87
T_5	100	39	14.75	100	41	15.82	100	77.54	63.59
T_6	100	38.47	14.25	100	37.5	15.67	100	76.98	62.6

Values denote the percentage of original weight

OD-Osmotic dehydration ` CD-Cabinet drying SD-Sun drying

T_1 Dipping in plain boiling water for 30 sec

T_2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec

T_3 Dipping in boiling 50% sugar solution for 15 min

T_4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min

T_5 Exposing the materials to sulphur fumes for half an hour

T_6 Control without any pretreatme

Drying was faster in cabinet drying, followed by sun drying in both local and commercial figs where as it was slow in osmotic dehydration.

4.1.1.4.1 Drying rate

a) Sun drying

The pattern of drying rate of sun dried local and commercial fig after various pretreatments are shown in Figure 1(a & b) and 2(a & b) respectively.
On comparing the drying rate between various pretreatments followed by sun drying the reduction in weight was highest in control in both the figs.

b) Cabinet drying

Figures 3 (a & b) and 4 (a & b) respectively show the pattern of drying rate of cabinet dried local and commercial fig after various pretreatments. Rapid reduction in weight was observed in control for local and commercial type.

c) Osmotic dehydration

Though compared to sun drying or cabinet drying, osmotic dehydration was slow in drying rate however between pretreatments control showed little edge in drying rate over the pretreatments. (Fig 5 (a & b) and 6 (a & b)).

4.1.1.4.2 Reconstitution rate

Reconstitution rate with respect to pretreatments under each method of drying was studied separately for both the figs and presented in Table 6 and 7. Cabinet dried commercial fig reconstituted very fast compared to sun drying or osmotic dehydration. While in local fig sun dried and cabinet dried ones reconstituted almost at same rate. Reconstitution of osmotically dried samples was very slow. Fruit pieces treated with KMS reconstituted very fast irrespective of the type of fig or method of drying. Pattern of reconstitution of local and commercial fig under various methods of drying are given in figures 7(a&b), 8(a&b), 9(a&b), 10(a&b), 11(a&b) and12 (a&b).

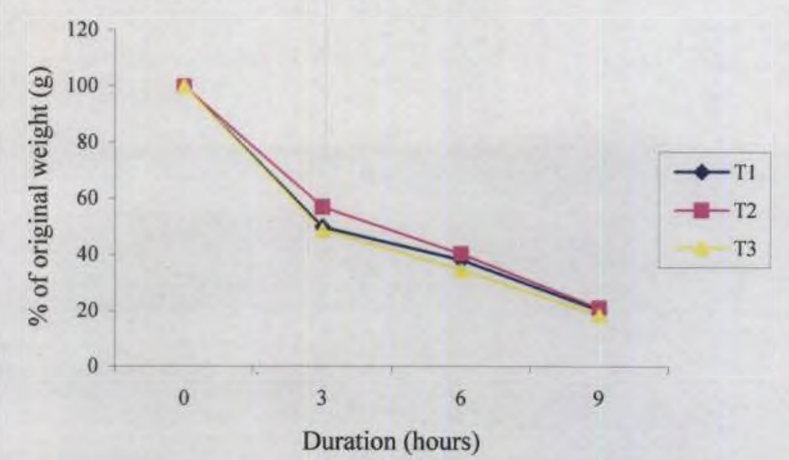


Fig. 1a.

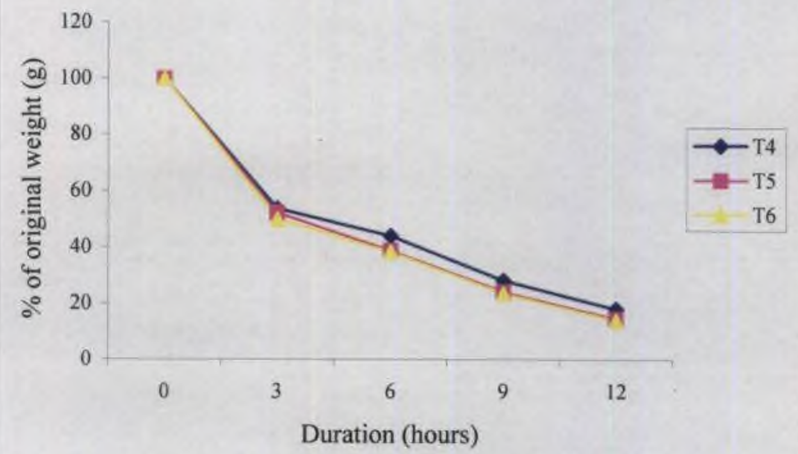


Fig. 1b.

Fig 1a & 1b. Drying curve of sun dried local fig under various pre-treatments

T1 Dipping in plain boiling water for 30 sec
T2 Dipping in boiling lye water containing 2% $NaHCO_3$ for 30 sec
T3 Dipping in boiling 50% sugar solution for 15 min
T4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min
T5 Exposing the materials to sulphur fumes for half an hour
T6 Control without any pretreatment

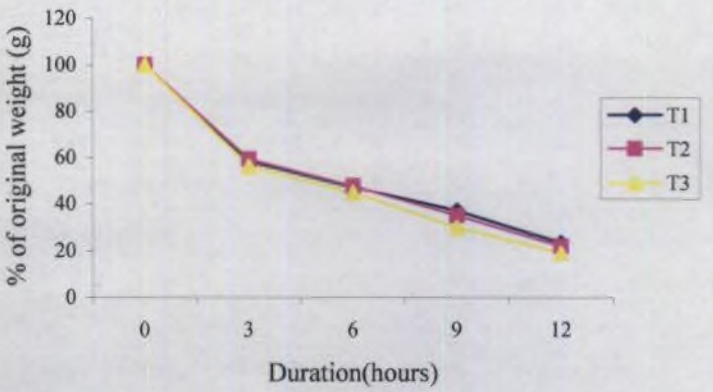


Fig. 2a.

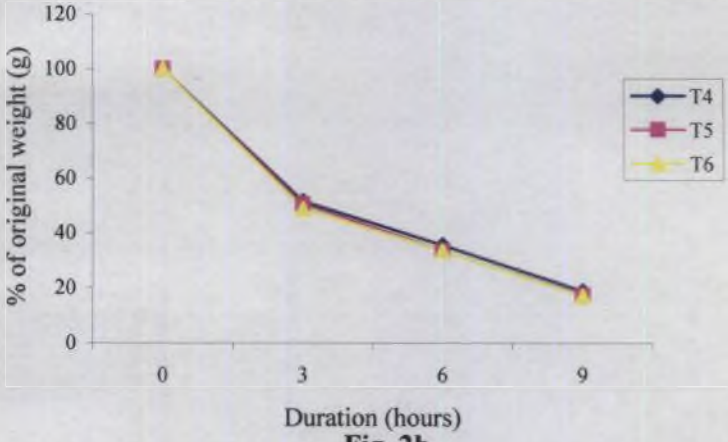


Fig. 2b.

Fig 2a & 2b. Drying curve of sun dried commercial fig under various pre-treatments

T1 Dipping in plain boiling water for 30 sec

T2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec

T3 Dipping in boiling 50% sugar solution for 15 min

T4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min

T5 Exposing the materials to sulphur fumes for half an hour

T6 Control without any pretreatment

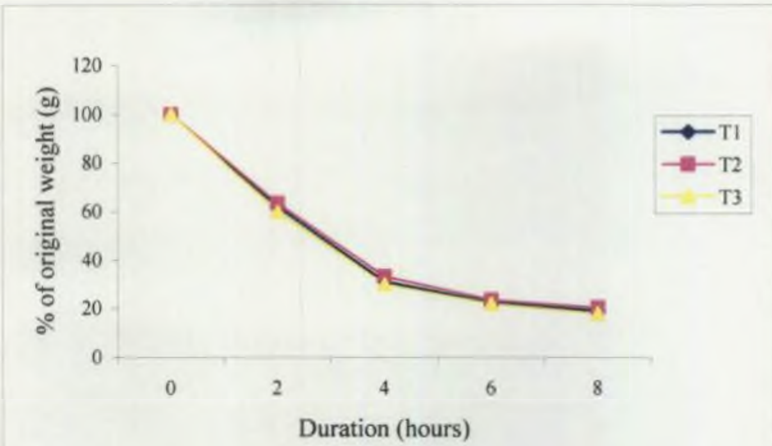


Fig. 3a.

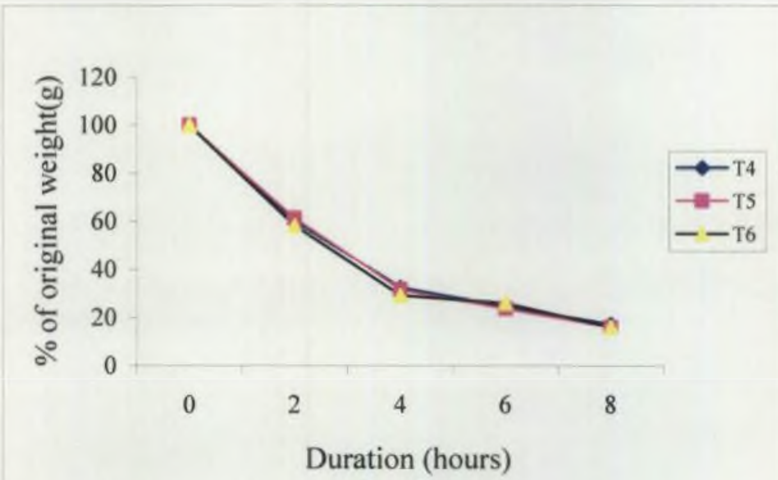


Fig. 3b.

Fig 3a & 3b. Drying curve of cabinet dried local fig under various pre-treatments

T1 Dipping in plain boiling water for 30 sec

T2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec

T3 Dipping in boiling 50% sugar solution for 15 min

T4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min

T5 Exposing the materials to sulphur fumes for half an hour

T6 Control without any pretreatment

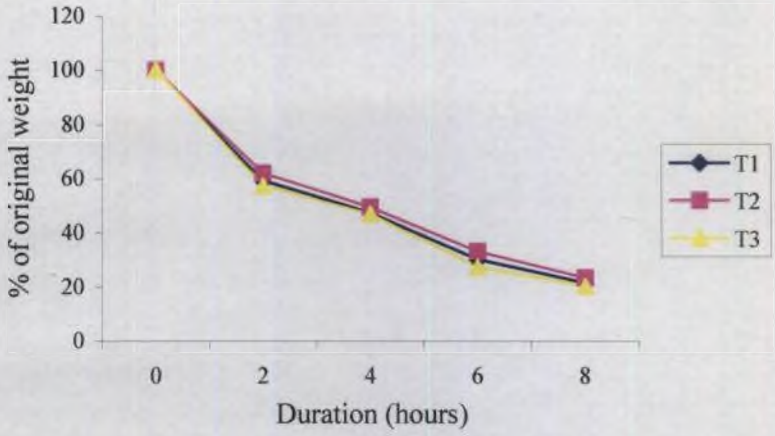


Fig. 4a.

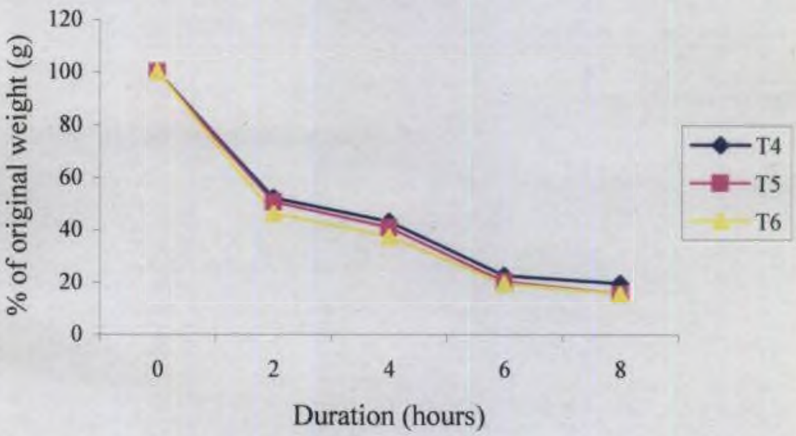


Fig. 4b.

Fig 4a & 4b. Drying curve of cabinet dried commercial fig under various pre-treatments

T1 Dipping in plain boiling water for 30 sec
T2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec
T3 Dipping in boiling 50% sugar solution for 15 min
T4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min
T5 Exposing the materials to sulphur fumes for half an hour
T6 Control without any pretreatment

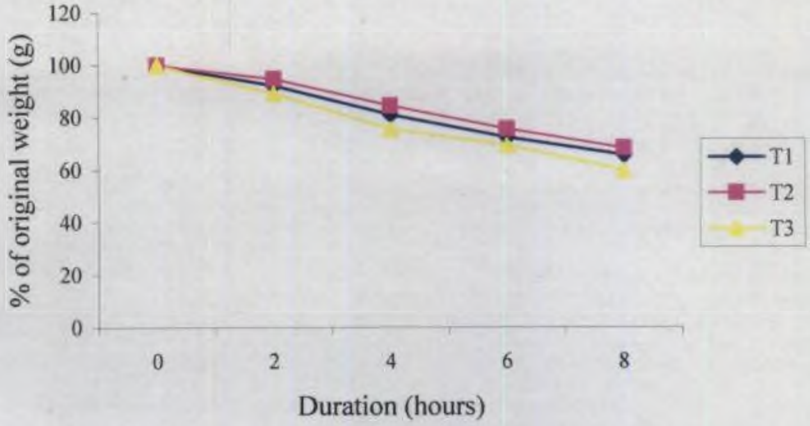


Fig. 5a.

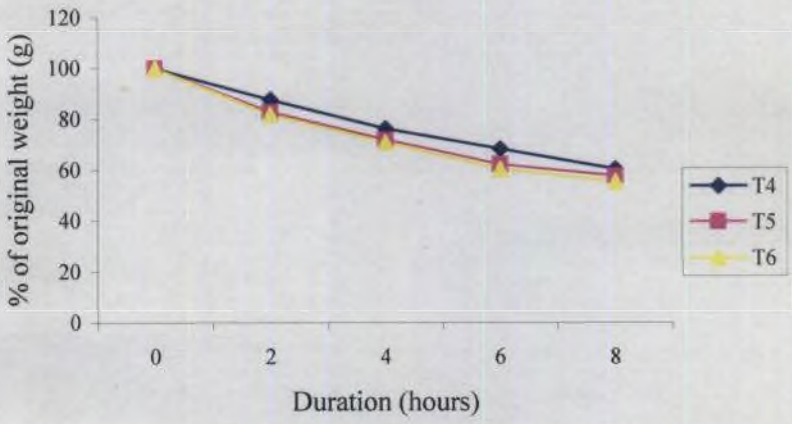


Fig. 5b.

Fig 5a & 5b. Drying curve of osmotically dried local fig under various pre-treatments

T1 Dipping in plain boiling water for 30 sec
T2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec
T3 Dipping in boiling 50% sugar solution for 15 min
T4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min
T5 Exposing the materials to sulphur fumes for half an hour
T6 Control without any pretreatment

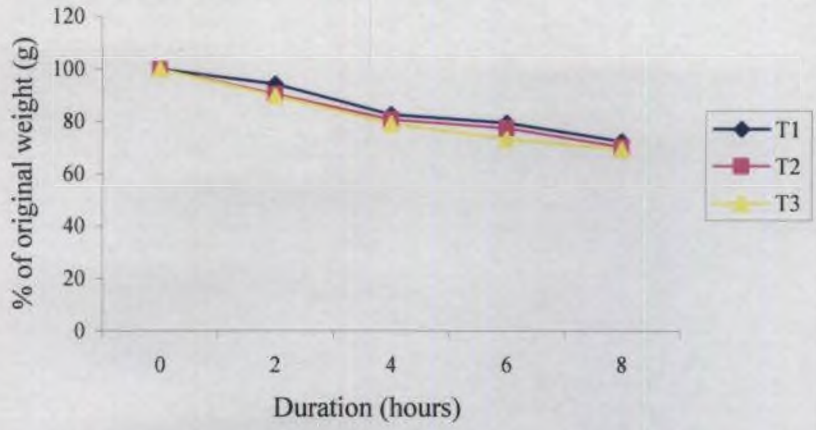


Fig. 6a.

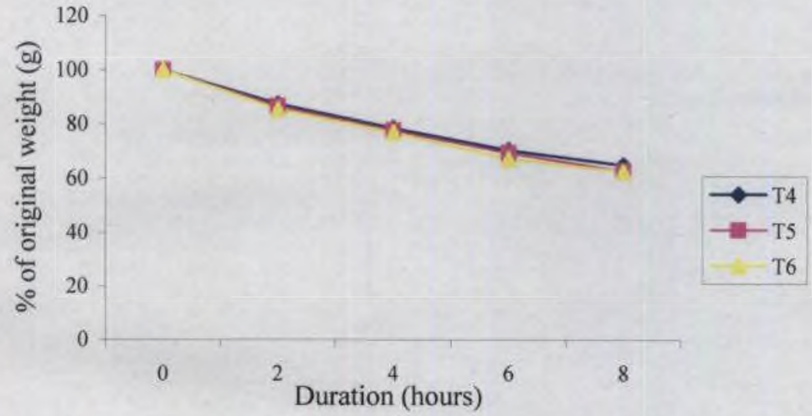


Fig. 6b.

Fig 6a & 6b. Drying curve of osmotically dried commerciall fig under various pre-treatments

T1 Dipping in plain boiling water for 30 sec
T2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec
T3 Dipping in boiling 50% sugar solution for 15 min
T4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min
T5 Exposing the materials to sulphur fumes for half an hour
T6 Control without any pretreatment

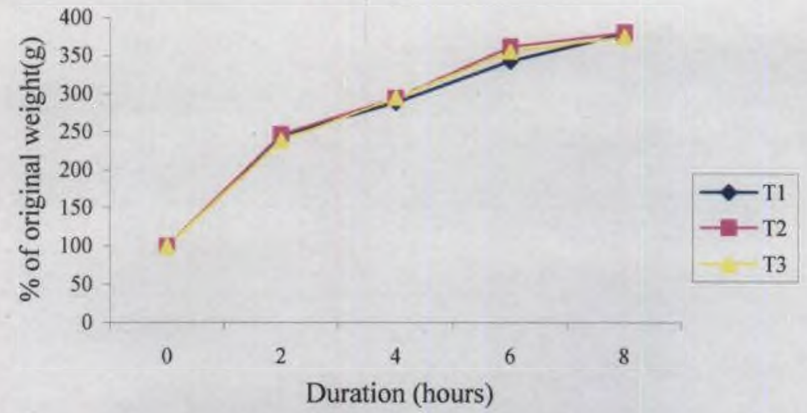


Fig. 7a.

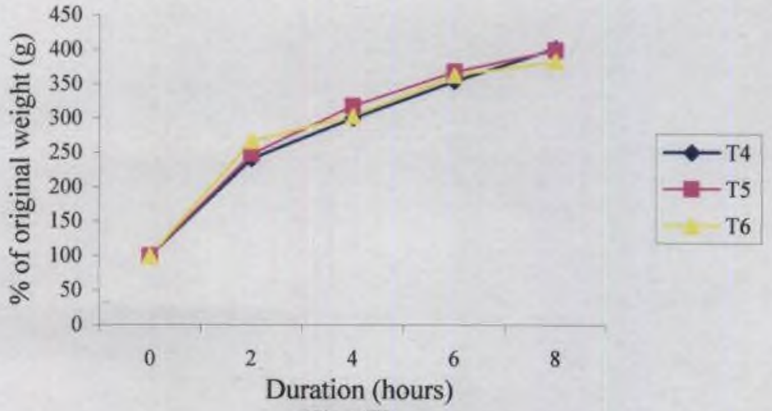


Fig. 7b.

Fig 7a & 7b. Reconstituition curve of sun dried local fig under various pre-treatments

T1 Dipping in plain boiling water for 30 sec
T2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec
T3 Dipping in boiling 50% sugar solution for 15 min
T4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min
T5 Exposing the materials to sulphur fumes for half an hour
T6 Control without any pretreatment

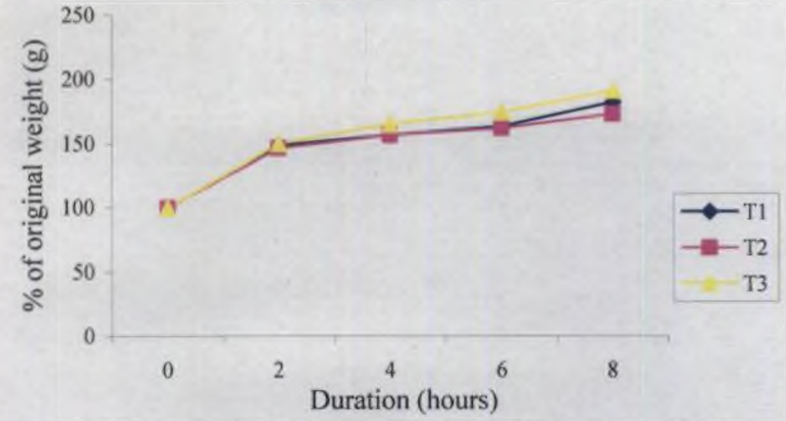


Fig. 8a.

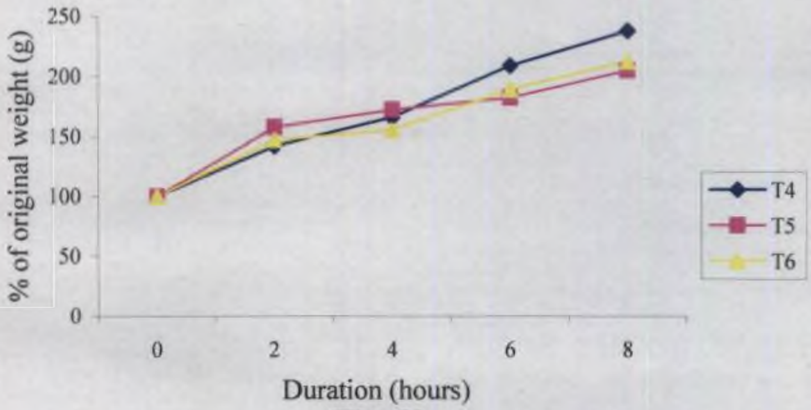


Fig. 8b

Fig 8a & 8b. Reconstituition curve of sun dried commercial fig under various pre-treatments

T1 Dipping in plain boiling water for 30 sec
T2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec
T3 Dipping in boiling 50% sugar solution for 15 min
T4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min
T5 Exposing the materials to sulphur fumes for half an hour
T6 Control without any pretreatment

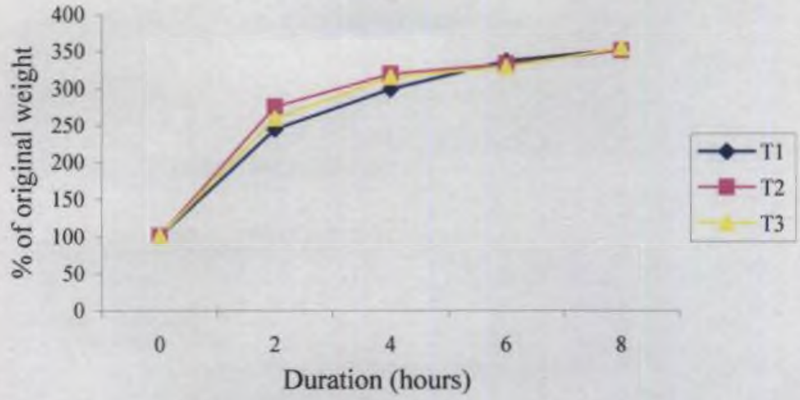


Fig. 9a.

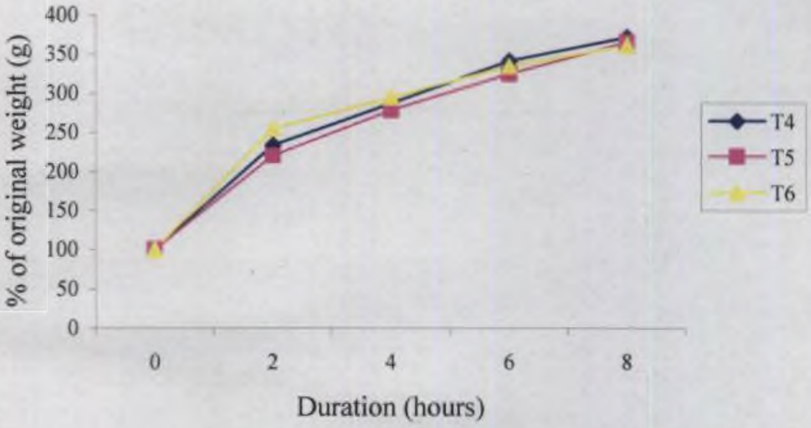


Fig. 9b.

Fig 9a & 9b. Reconstituition curve of cabinet dried local fig under various pre-treatments

T1 Dipping in plain boiling water for 30 sec

T2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec

T3 Dipping in boiling 50% sugar solution for 15 min

T4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min

T5 Exposing the materials to sulphur fumes for half an hour

T6 Control without any pretreatment

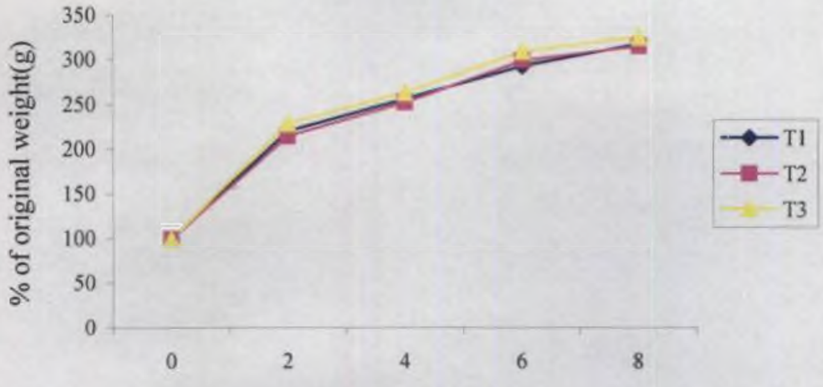


Fig. 10a.

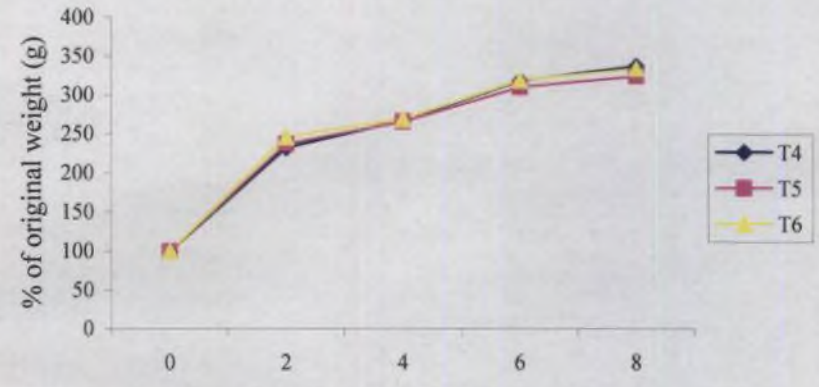


Fig. 10b.

Fig 10a & 10b. Reconstituition curve of cabinet dried commercial fig under various pre-treatments

T1 Dipping in plain boiling water for 30 sec
T2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec
T3 Dipping in boiling 50% sugar solution for 15 min
T4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min
T5 Exposing the materials to sulphur fumes for half an hour
T6 Control without any pretreatment

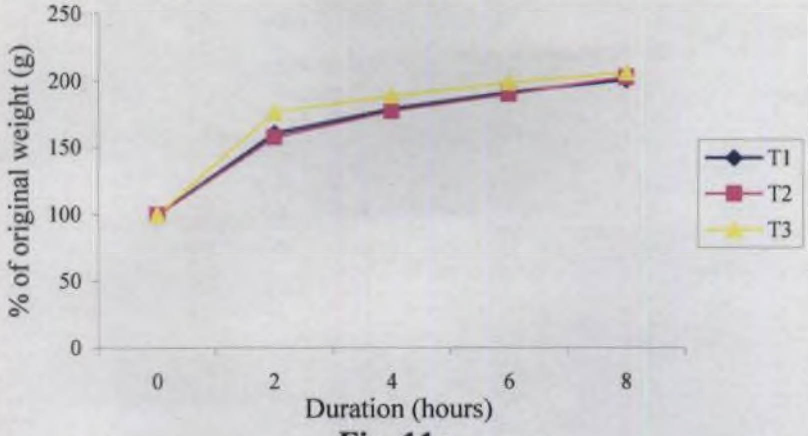


Fig. 11a.

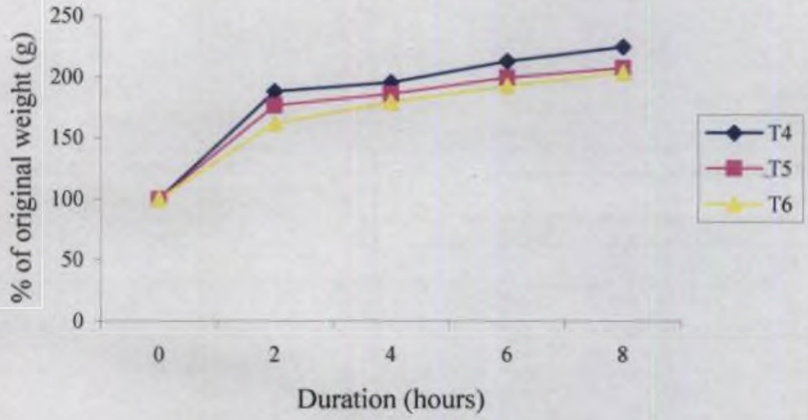


Figure. 11b.

Fig 11a & 11b. Reconstituition curve of osmotically dried local fig under various pre-treatments

T1 Dipping in plain boiling water for 30 sec
T2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec
T3 Dipping in boiling 50% sugar solution for 15 min
T4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min
T5 Exposing the materials to sulphur fumes for half an hour
T6 Control without any pretreatment

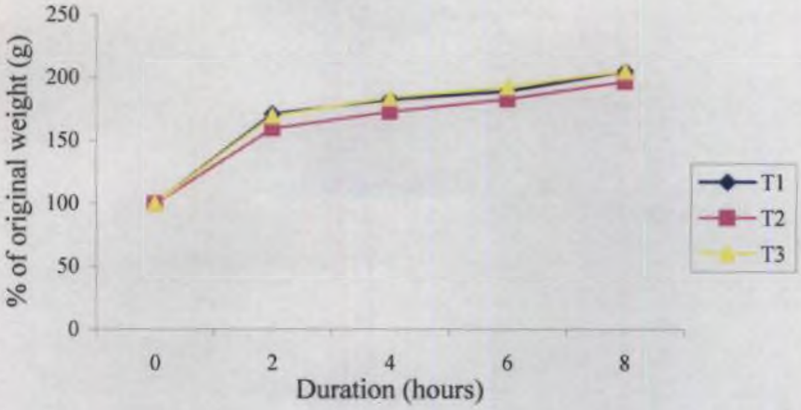


Fig. 12a.

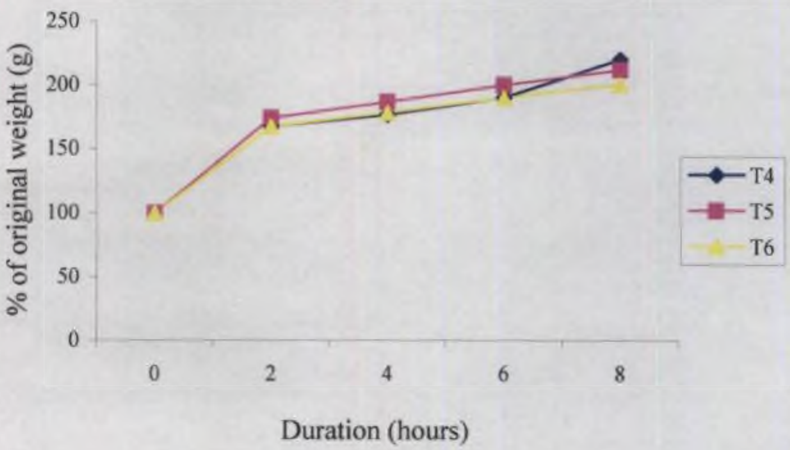


Fig. 12b.

Fig 12a & 12b. Reconstituition curve of osmotically dried commercial fig under various pre-treatments

T1 Dipping in plain boiling water for 30 sec
T2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec
T3 Dipping in boiling 50% sugar solution for 15 min
T4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min
T5 Exposing the materials to sulphur fumes for half an hour
T6 Control without any pretreatment

Table 6. Reconstitution rate of local fig dried under different techniques

Treatments	Method of drying								
	SD (hours)			CD (hours)			OD (hours)		
	0	4	8	0	4	8	0	4	8
T_1	100	289.4	379.6	100	298.6	352	100	178.67	200.67
T_2	100	295	380.8	100	318.4	350	100	177.33	202.67
T_3	100	295.2	376	100	314.4	353.8	100	188.7	206
T_4	100	300.6	402.2	100	286.8	371	100	195.33	224.66
T_5	100	318.4	399.6	100	278.2	364.4	100	186	207.33
T_6	100	303.2	384	100	294.6	360.6	100	179.33	203.3

Values denote the percentage of original weight

OD-Osmotic dehydration CD-Cabinet drying SD-Sun drying

T_1 Dipping in plain boiling water for 30 sec

T_2 Dipping in boiling lye water containing 2% $NaHCO_3$ for 30 sec

T_3 Dipping in boiling 50% sugar solution for 15 min

T_4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min

T_5 Exposing the materials to sulphur fumes for half an hour

T_6 Control without any pretreatment

Table 7. **Reconstitution rate of commercial fig dried under different techniques**

Treatments	Method of drying								
	SD			CD			OD		
	0	4	8	0	4	8	0	4	8
T_1	100	156.7	182	100	256.17	317.19	100	182	204.67
T_2	100	156.7	172.67	100	252.35	314.78	100	172.66	196.67
T_3	100	166	237.67	100	262.95	324.52	100	183.3	204.67
T_4	100	164.67	190.67	100	266.95	336.52	100	176.67	220
T_5	100	172	204.67	100	265.39	323.48	100	186.67	212
T_6	100	155.33	212	100	268.34	333.74	100	178	200.67

Values denote the percentage of original weight

OD-Osmotic dehydration CD-Cabinet drying SD-Sun drying

T_1 Dipping in plain boiling water for 30 sec
T_2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec
T_3 Dipping in boiling 50% sugar solution for 15 min
T_4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min
T_5 Exposing the materials to sulphur fumes for half an hour
T_6 Control without any pretreatment

4.1.2 Chemical parameters

4.1.2.1. Reducing sugar

Reducing sugar was found to be higher in osmotic dehydration for both local and commercial ones. Maximum reducing sugar observed in samples pretreated with 50 per cent sugar solution containing KMS in osmotically dried local fig. Whereas in commercial fig T_3 and T_4 were found to be on par (Table 8). Where as in sun drying and cabinet drying little hike in the reducing sugar content was observed in those pretreated with sugar solution with or without KMS.

4.1.2.1 Total sugar

It was found to be high in osmotically dehydrated figs of both types. Cabinet drying ranked second. Higher sugar content was in commercial figs compared to local type (Table 8).

a) Osmotic dehydration

In local fig all the pretreatments showed significant difference. Treating with 50 per cent sugar solution resulted in highest total sugar (64.13). In commercial fig T_3 and T_4 recorded higher values and these differed significantly from all others.

b) Sun drying

In sun drying both local and commercial types recorded the higher values in those pretreated with sugar solution without and with KMS (T_3 and T_4). Local fig recorded the values 12.8 and 12.93 in T_3 and T_4 respectively, whereas in commercial fig it was 14.63 and 14.64

c) Cabinet drying

Results are similar to that of sun drying.

4.1.2.2 Residual SO_2

Residual SO_2 of samples pretreated with KMS and dried under different methods were analysed. It was observed to be high in all those samples dried

Table 8. Total sugars (%) and reducing sugars (%) of local and commercial fig dried under different techniques

Treatments	Method of drying											
	SD				CD				OD			
	LF		CF		LF		CF		LF		CF	
	TS	RS	TS	RS	TS	RS	TS	RS	TS	RS	TS	RS
T_1	11.66^{pq}	5.39^{pqrst}	12.47^{no}	7.63^{lm}	11.71^{opq}	6.44^{mop}	14.07^{kl}	9.71^{hijk}	61.37^{ef}	39.05^{d}	61.75^{c}	37.15^{e}
T_2	9.75^{st}	4.74^{stu}	13.25^{mn}	8.78^{jkl}	10.57^{rs}	5.12^{qrstu}	15.49^{j}	10.62^{h}	60.08^{gh}	39.13^{d}	61.06^{c}	39.13^{d}
T_3	12.8^{n}	5.63^{opqrs}	14.63^{k}	9.57^{hijk}	14.43^{k}	6.78^{mno}	18.10^{i}	11.83^{g}	64.13^{c}	42.66^{c}	67.69^{a}	47.83^{a}
T_4	12.93^{mn}	5.45^{pqrst}	14.64^{k}	10.10^{hi}	14.46^{k}	6.50^{mnop}	18.19^{i}	12.48^{f}	62.65^{d}	44.7^{b}	67.90^{a}	46.80^{a}
T_5	8.64^{u}	3.98^{u}	11.52^{pq}	6.72^{mno}	10.94^{qr}	5.68^{opqr}	13.47^{lm}	8.46^{kl}	60.08^{gh}	38.76^{d}	59.30^{d}	38.76^{d}
T_6	9.68^{t}	4.30^{tu}	11.93^{op}	7.03^{mn}	11.38^{pq}	6.01^{nopq}	13.62^{lm}	9.06^{ijk}	60.93^{f}	38.76^{d}	66.22^{b}	47.67^{a}

LF- Local fig CF- Commercial fig TS- Total sugar RS- Reducing sugar

The values represent means of 3 replications

Values with different super scripts differ significantly at 5%level

T_1 Dipping in plain boiling water for 30 sec

T_2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec

T_3 Dipping in boiling 50% sugar solution for 15 min

T_4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min

T_5 Exposing the materials to sulphur fumes for half an hour

T_6 Control without any pretreatment

under osmotic dehydration especially with those pretreated with sugar solution containing KMS (77.83 in localand87.77 commercial fig). (Table 9)

4.1.2.3 Calcium

No significant difference existed between pretreatments in sundrying of both types of figs. Treating with sugar solution resulted in high calcium content in cabinet drying of both the types. Osmotically dehydrated samples have highest calcium content in both figs. There was no significant difference among the pretreatments in osmotic drying of local fig. However T_3 (treating with 50 per cent sugar solution) showed highest calcium content irrespective of the fig types (0.72 mg/g) (Table 9).

4.1.3 Sensory evaluation

The organoleptic evaluation was carried out on a five point hedonic scale-using score card for four attributes namely, colour, texture, flavour and overall acceptability. Each character was scored on the scale and the total scores calculated out of twenty.

Only in osmotically dried samples sensory evaluation was conducted to find out the best accepted pretreatment in both figs, because other methods of drying were not satisfactory enough to carry out sensory quality studies. Highest score for all characteristics were for T_3 (11.87) in local fig where as in commercial fig it was for control (14.36). Kendall's coefficients of concordance among the judges on all the characteristics were highly significant (Table 10 and11).

From the above results of all the parameters studied including sensory evaluation of the dried product osmotic dehydration was found to be the best method. Treating with 50 per cent sugar solution prior to drying was found to be best pretreatment for local fig, whereas in commercial fig samples dried without any pretreatment was found to be best.

Table 9. Calcium (mg/100g) and residual SO_2 (ppm) of local and commercial fig dried under different techniques

Treatments	METHOD OF DRYING											
	SD				CD				OD			
	LF		CF		LF		CF		LF		CF	
	Ca	Resi SO_2	Ca	Resi SO_2	Ca	Resi SO_2	Ca	Resi SO_2	Ca	Resi SO_2	Ca	Resi SO_2
T_1	0.65 *	-	0.61 *	-	0.63 ^{def}	-	0.58 ^{h}	-	0.67 *	69.60 ^{f}	0.62 ^{ef}	65.67 ^{h}
T_2	0.63 *	-	0.62 *	-	0.63 ^{def}	-	0.59 ^{gh}	-	0.69 *	69.63 ^{f}	0.62 ^{ef}	68.67 ^{fg}
T_3	0.68 *	-	0.64 *	-	0.70 ^{ab}	-	0.61 ^{f}	-	0.72 *	68.87 ^{fg}	0.72 ^{a}	74.5 ^{d}
T_4	0.65 *	65.73 ^{h}	0.63 *	67.9 ^{g}	0.69 ^{abc}	76.1 ^{c}	0.60 ^{f}	73.16 ^{de}	0.70 *	77.83 ^{b}	0.68 ^{abcd}	87.77 ^{a}
T_5	0.63 *	-	0.60 *	-	0.59 ^{gh}	-	0.58 ^{h}	-	0.65 *	69.70 ^{f}	0.63 ^{def}	72.13 ^{e}
T_6	0.65 8	-	0.60 *	-	0.67 ^{cde}	-	0.58 ^{h}	-	0.69 *	68.77 ^{fg}	0.63 ^{def}	70.03 ^{f}

- do not contain residual SO_2 OD-Osmotic dehydration CD-Cabinet drying SD-Sun drying LF- Local fig CF- Commercial fig

The values represent means of 3 replications
Values with different super scripts differ significantly at 5%level * Non significant

Table 10. Sensory evaluation of osmotically dried local fig after different pretreatments

Treatment	Colour	Texture	Flavour	Overall acceptability	Total score
T_1	1.3(3.82)	2.23(6.80)	1.9(6)	1.37(3.92)	6.8
T_2	1.37(3.92)	1.43(3.43)	1.5(4.20)	1.23(3.23)	5.53
T_3	2.6(8.5)	2.5(7.90)	3.5(10.80)	3.23(10.15)	11.83
T_4	3.2(10.15)	2.77(8.63)	2.23(10.37)	2.37(7.55)	10.57
T_5	2.57(8.1)	1.3(2.87)	1.6(4.87)	12.9(2)	6.47
T_6	1.8(5.72)	2(6.67)	1.33(3.58)	1.43(3.88)	6.53
Kendall's coefficient	0.518*	0.672*	0.792*	0.715*	

* Significant

Values in parantheses represent mean rank

T_1 Dipping in plain boiling water for 30 sec

T_2 Dipping in boiling lye water containing 2% $NaHCO_3$ for 30 sec

T_3 Dipping in boiling 50% sugar solution for 15 min

T_4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min

T_5 Exposing the materials to sulphur fumes for half an hour

T_6 Control without any pretreatment

Table 11. Sensory evaluation of osmotically dried commercial fig after different pretreatments

Treatment	Colour	Texture	Flavour	Overall acceptability	Total score
T_1	1.2(3.82)	1.67(4.35)	1.5(4.22)	2.37(7.85)	7.74
T_2	1.13(3.92)	1.70 (4.48)	1.73(5.22)	2.37(7.90)	7.83
T_3	2.33(7.85)	2.77(8.62)	2.2(8.35)	2.53(8.42)	9.83
T_4	2.37(7.90)	2.9(9.25)	2.07(6.53)	2.23(7.33)	9.57
T_5	1.3(3.65)	1.43(3.65)	1.1(2.55)	1.37(3.72)	9.10
T_6	3.23(5.72)	3.7(11.35)	3.73(11.32)	3.6(11.13)	14.36
Kendall's coefficient	0.518*	0. 672*	0.792*	0.715*	

Values in parenthesis represent mean rank

* Significant

T_1 Dipping in plain boiling water for 30 sec

T_2 Dipping in boiling lye water containing 2%$NaHCO_3$ for 30 sec

T_3 Dipping in boiling 50% sugar solution for 15 min

T_4 Dipping in boiling 50% sugar solution containing Potassiummetabisulphite (KMS) (375 ppm SO_2) for 15 min

T_5 Exposing the materials to sulphur fumes for half an hour

T_6 Control without any pretreatment

4.1.4 Economics of the product

Cost of production for 100 g dried sample was worked out to be Rs 24.00 for local and Rs 30.00 for commercial type.

4.2 PACKAGING AND STORAGE STUDIES

Osmotic dehydration standardized through the experiment I was employed in the storage studies (Plate 5). Larger quantities of both local and commercial type figs were dried osmotically and packed in two types of packaging materials, 100 gauge polyethylene and aluminium foil laminated pouch employing four methods of packaging viz, N_2, CO_2, vacuum and air (control) and kept under ambient temperature for storage studies and results are reported here (Plate 6 & 7).

4.2.1 Physical parameters

The dehydrated samples were evaluated monthly for changes in physical attributes for a period of three months.

4.2.1.1 Visual colour change

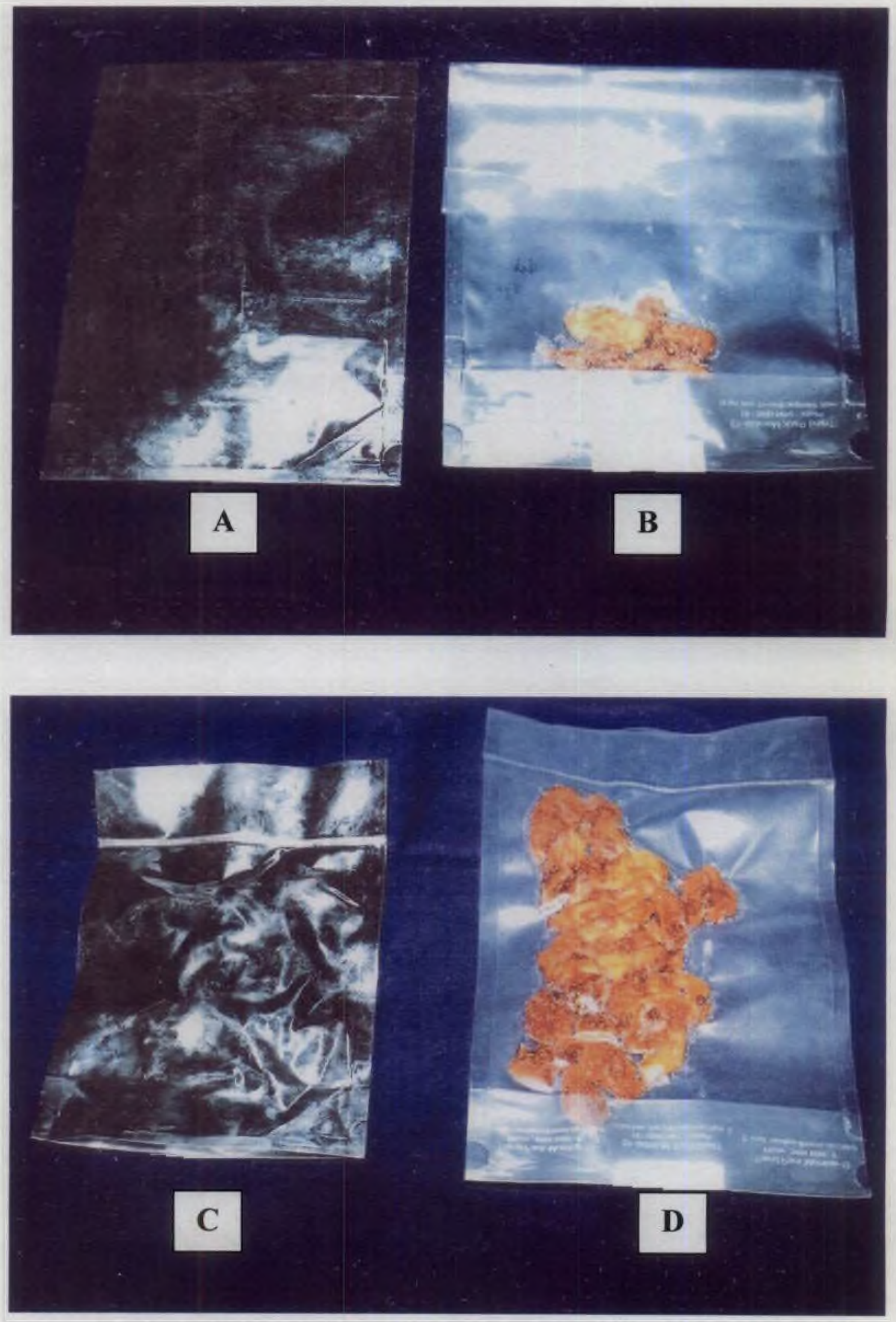
Irrespective of the methods of packaging, samples in 100 gauge polyethylene showed darkening as well as oozing of syrup. Samples in aluminium foil laminated pouches retained their attractive colours (golden in commercial and purple in local) throughout the storage period in both figs irrespective of the methods of packaging. However colour retention was maximum in vacuum-packed samples.

4.2.1.2 Moisture Pick up

Comparing the moisture pickup between the type of packaging materials and methods, significant difference observed throughout the storage period (Table 12). Highest moisture pick up was seen in samples packaged in 100-gauge polyethylene with air (control) during the storage period. Samples packaged in

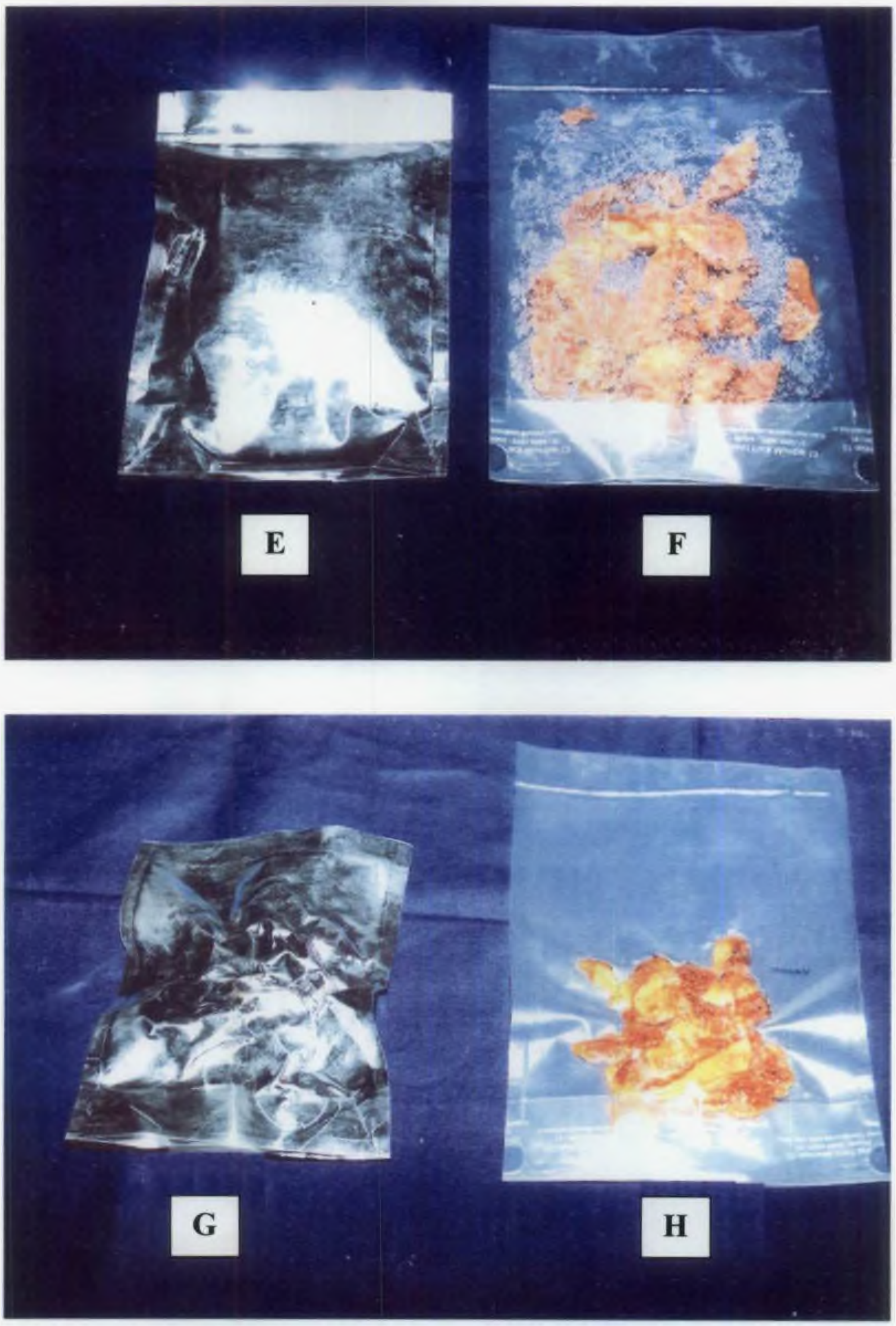
A - Local fig; B - Commercial fig

Plate 5. Osmotically dehydrated fig fruits



A - Aluminium foil laminated pouch with nitrogen; B - Polyethylene with nitrogen
C - Aluminium foil laminated pouch with CO_2; D - Polyethylene with CO_2

Plate 6. Packaged dehydrated commercial figs employing various packaging techniques



E - Aluminium foil laminated pouch with air; F - Polyethylene with air
G - Aluminium foil laminated pouch with vacuum; H - Polyethylene with vacuum

Plate 7. Packaged dehydrated commercial figs employing various packaging techniques

Table 12. Percentage moisture pick up osmoticlly dried local and commercial fig fruits during storage under ambient conditions with different packages

Treatments	I MAS		2 MAS		3 MAS	
	LF	CF	LF	CF	LF	CF
T_1	5.77 [a]	5.59 [a]	5.96 [a]	5.91 [ab]	6.22 [a]	6.04 [a]
T_2	2.99 [e]	2.25 [f]	3.37 [e]	2.59 [g]	3.47 [f]	2.88 [f]
T_3	3.18 [de]	2.46 [f]	3.49 [d]	2.86 [g]	3.58 [f]	3.03 [g]
T_4	4.41 [b]	4.51 [b]	4.83 [d]	5.32 [c]	4.96 [d]	5.41 [c]
T_5	4.65 [b]	4.67 [b]	4.8 [d]	5.62 [bc]	4.90 [d]	5.73 [b]
T_6	3.36 [d]	3.28 [de]	3.47[f]	3.54 [f]	3.53 [d]	3.65 [f]
T_7	3.13 [de]	3.01 [d]	3.44 [f]	4.65 [d]	3.47 [f]	4.81 [d]
T_8	4.03 [c]	3.39 [d]	4.27 [c]	4.67 [d]	4.33 [e]	4.83 [d]

MAS- months after storage LF- Local fig CF- Commercial fig

* Non-significant

The values represent means of 3 replications

Values with different super scripts differ significantly at 5%level

T_1 Packaged in 100 gauge polyethylene with air as control (PE_A)

T_2 Packaged in 100 gauge polyethylene with vacuum (PE_V)

T_3 Packaged in 100 gauge polyethylene with nitrogen (PE_{N2})

T_4 .Packaged in 100 gauge polyethylene with carbon dioxide (PE_{CO2})

T_5 Packaged in aluminium foil laminated pouch with air as control (Al_A)

T_6 Packaged in aluminium foil laminated pouch with nitrogen (Al_{N2})

T_7 Packaged in aluminium foil laminated pouch with carbon dioxide (Al_{CO2})

T_8 Packaged in aluminium foil laminated pouch with vacuum (Al_V)

polyethylene showed higher moisture pick up irrespective of the packaging methods. The trend of moisture pick up was observed to be increasing through out the storage period irrespective of packaging materials and methods and type of fig with the least values (3.47 in local fig, 2.88 in commercial fig) in vacuum packed samples. Though the moisture pick up was there in both the types, local showed higher values than that of commercial in all the periods of observation.

4.2.1.3 Presence of stored pest

Samples in all the packages are completely free from any stored pest even after four months of storage.

4.2.2 Chemical parameters

Changes in total sugar, reducing sugar, acidity, calcium and residual SO_2 of dehydrated samples stored up to three months are presented below. (Tables 13, 14 and 15)

4.2.2.1 Reducing sugar

With the advancement of time of storage reducing sugars in all the samples showed a slight increase irrespective of the packaging materials and methods. Packaging with nitrogen was found to be showing the least change in the in reducing sugar in both local and commercial fig. No change was observed till the end of the first month; but significant difference was observed in second and third month with least change noted in nitrogen packed samples.

Osmotically dried commercial fig had higher percentage of sugar compared to local type (Table 13).

4.2.2.2 Total sugar

Gradual decline in total sugar content was observed during the storage period. Nitrogen packed samples showed highest sugar content irrespective of packaging materials in both the figs. In local fig there was no significant difference among the samples during the first two months of storage however at

Table 13. **Total and reducing sugars (%) of osmoticlly dried local and commercial fig during storage under ambient conditions with different packages**

Treatments	1 MAS				2 MAS				3 MAS			
	LF		CF		LF		CF		LF		CF	
	TS	RS	TS	RS	TS	RS	TS	RS	TS	RS	TS	RS
T_1	63.73 *	46.13*	64.85 abcd	49.8 bcd	63.06 *	46.57 de	63. 42 abcde	52.15 ab	62.06 f	48.37 def	63.88 abc	52.57 b
T_2	62.99 *	45.77 *	63.79 cdef	46.58 ef	62.64 *	47.17 cd	64.32 abc	52.19 a	62.28 ef	47.47 g	62.67 cdef	52.74 b
T_3	63.89*	47.03 *	65.53 a	51.16 ab	63.31 *	47.37 c	64.48 ab	52.83 a	62.20 ef	48.5 de	63.86 ab	54.51 a
T_4	63.22 *	46.66 *	65.16 ab	50.40 bc	62.91 *	46.87 de	64.2 abcd	52.27 a	62.53 def	47.5 fg	63.43 abcde	53.97 a
T_5	63.32 *	46.07 *	64.34 abcde	49.9 bcd	62.74 *	47.27 cd	63.42 abcde	50.83 b	62.59 de	47.8 defg	62.74 bcdef	52.63 bc
T_6	63.08 *	45.53 *	63.55 def	48.77 d	62.53 *	46.7 cd	62.89 e	50.11 b	61.93 f	47.73 efg	62.41 ef	51.71 c
T_7	63.02*	47 *	65.14 ab	51.83 a	62.73 *	47.1 cd	64.54 a	52.1 a	62.80 bcdef	48.63 d	64.22 a	52.89 b
T_8	63.64 *	46.6*	64.99 abc	50.94 abc	63.21*	47.13 cd	64.33 abc	50.63 b	62.13 ef	47.4 g	63.80 abc	52.50 bc

MAS- months after storage The values represent means of 3 replications Values with different super scripts differ significantly at 5%level

* Non significant

T_1 Packaged in 100 gauge polyethylene with air as control (PE_A)
T_2 Packaged in 100 gauge polyethylene with vacuum (PE_V)
T_3 Packaged in 100 gauge polyethylene with nitrogen (PE_{N2})
T_4 .Packaged in 100 gauge polyethylene with carbon dioxide (PE_{CO2})
T_5 Packaged in aluminium foil laminated pouch with air as control (Al_A)
T_6 Packaged in aluminium foil laminated pouch with nitrogen (Al_{N2})
T_7 Packaged in aluminium foil laminated pouch with carbon dioxide (Al_{CO2})
T_8 Packaged in aluminium foil laminated pouch with vacuum (Al_V)

Table 14. Calcium (mg/100g) and acidity (%) of osmoticlly dried local and commercial fig during storage under ambient conditions with different packages

Treatments	1 MAS				2 MAS				3 MAS			
	LF		CF		LF		CF		LF		CF	
	Ca	Acidity	Ca	Acidity	Ca	Acidity	Ca	Acidity	Ca	Acidity	Ca	Acidity
T_1	0.64 *	0.77 ^{c}	0.66 *	0.77 ^{b}	0.60 ^{a}	0.77 ^{c}	0.56 *	0.77 ^{c}	0.59 *	0.77 ^{c}	0.52 *	0.77 ^{c}
T_2	0.63 *	1.11 ^{a}	0.66 *	1.04 ^{a}	0.60 ^{a}	1.04 ^{a}	0.55 *	0.96 ^{b}	0.59 *	0.96 ^{a}	0.52 *	0.83 ^{b}
T_3	0.63 *	0.75 ^{c}	0.67 *	0.77 ^{b}	0.60 ^{a}	0.61 ^{d}	0.55 *	0.77 ^{c}	0.59 *	0.51 ^{e}	0.51 *	0.77 ^{c}
T_4	0.63 *	0.77 ^{c}	0.64 *	0.51 ^{d}	0.60 ^{a}	0.61 ^{d}	0.56 *	0.61 ^{d}	0.59 *	0.51 ^{e}	0.53 *	0.61 ^{d}
T_5	0.63*	0.92 ^{b}	0.65 *	0.61 ^{d}	0.58 ^{bc}	0.77 ^{c}	0.55 *	0.61 ^{d}	0.58 *	0.77 ^{c}	0.51 *	0.51 ^{e}
T_6	0.62 *	1.08 ^{a}	0.65 *	0.77 ^{b}	0.60 ^{a}	0.77 ^{c}	0.55 *	0.77 ^{c}	0.58 *	0.61 ^{d}	0.52 *	0.77 ^{c}
T_7	0.63 *	0.73 ^{c}	0.65 *	0.77 ^{b}	0.59 ^{ab}	0.58 ^{e}	0.56 *	0.61 ^{d}	0.59 *	0.58 ^{d}	0.52 *	0.61 ^{d}
T_8	0.62 *	0.81 ^{c}	0.65 *	0.77 ^{b}	0.59 ^{ab}	0.77 ^{c}	0.53 *	0.51 ^{e}	0.58*	0.61 ^{d}	0.48 *	0.77 ^{c}

MAS- months after storage   The values represent means of 3 replications   Values with different super scripts differ significantly at 5%level

* Non significant

T_1 Packaged in 100 gauge polyethylene with air as control (PE_A)

T_2 Packaged in 100 gauge polyethylene with vacuum (PE_V)

T_3 Packaged in 100 gauge polyethylene with nitrogen (PE_{N2})

T_4 .Packaged in 100 gauge polyethylene with carbon dioxide (PE_{CO2})

T_5 Packaged in aluminium foil laminated pouch with air as control (Al_A)

T_6 Packaged in aluminium foil laminated pouch with nitrogen (Al_{N2})

T_7 Packaged in aluminium foil laminated pouch with carbon dioxide (Al_{CO2})

T_8 Packaged in aluminium foil laminated pouch with vacuum (Al_V)

Table 15. Residual SO_2 (ppm) of osmoticlly dried local and commercial fig during storage under ambient conditions with different packages

Treatments	I MAS		2 MAS		3 MAS	
	LF	CF	LF	CF	LF	CF
T_1	64.57 *	65.11 *	63.07 *	60.34 ^{abc}	59.6*	57.46 ^{ab}
T_2	66.05 *	66.10 *	63.63 *	63.15 ^{ab}	59.95 *	59.98 ^{a}
T_3	65.64 *	64.56 *	61.43 *	60.99 ^{abc}	57.97 *	58.78 ^{ab}
T_4	64.07 *	63.44 *	62.73 *	59.63 ^{bc}	58.41 *	56.87 ^{b}
T_5	65.07 *	64.11 *	62.43 *	59.36 ^{c}	58.35 *	57.35 ^{ab}
T_6	65.95 *	66.2 *	61.7 *	61.89 ^{abc}	57.54 *	59.90 ^{a}
T_7	65.41 *	65.64 *	62.81 *	61.5 ^{abc}	58 *	57.27 ^{ab}
T_8	64.21 *	64.85 *	61.73 *	60.89 ^{abc}	57.7 *	58.64 ^{ab}

MAS- months after storage LF- Local fig CF- Commercial fig
* Non-significant

The values represent means of 3 replications
Values with different super scripts differ significantly at 5%level
T_1 Packaged in 100 gauge polyethylene with air as control (PE_A)

T_2 Packaged in 100 gauge polyethylene with vacuum (PE_V)

T_3 Packaged in 100 gauge polyethylene with nitrogen (PE_{N2})

T_4 .Packaged in 100 gauge polyethylene with carbon dioxide (PE_{CO2})

T_5 Packaged in aluminium foil laminated pouch with air as control (Al_A)

T_6 Packaged in aluminium foil laminated pouch with nitrogen (Al_{N2})

T_7 Packaged in aluminium foil laminated pouch with carbon dioxide (Al_{CO2})

T_8 Packaged in aluminium foil laminated pouch with vacuum (Al_V)

at the end of the third month nitrogen packed samples in aluminium foil lkaminated pouches showed highest sugar content (62.80 in local 64.22 in commercialfig fig) and vacuum packed samples in aluminium foil laminated pouches showed the lowest sugar content in both the figs (61.93 in local fig and 62.41 in commercial fig (Table 13).

4.2.2.3 Calcium

No significant difference in calcium content among the packages in both figs was noted. Calcium content recorded decreasing trend throughout the storage period (Table 14)

4.2.2.4 Acidity

Acidity was highest in vacuum packed samples during the storage period irrespective of the packaging material and methods (Table 14)

Samples in 100 gauge polyethylene with air maintained same acidity through out the storage period. A gradual decline in acidity was observed in all other packages.

4.2.2.5 Residual SO_2

No significant difference in residual SO_2 was noted among the different packaging materials and methods in local fig. Significant difference was noted in commercial fig during second and third months of storage. Highest residual SO_2 observed was in vacuum packed samples in both cases. It goes on decreasing through out the storage period (Table 15)

4.2.3 Microbial load

The microbial population of the stored samples was assessed at bimonthly intervals for a period of four months and the results are presented in Table 16 and17. Increase in microbial population was observed through out the storage period irrespective of the packaging materials and methods.

Table 16. Microbial load in the dried local fig during storage

Treatments	Storage period					
	0MAS		2MAS		4MAS	
	Bacteria x 10^6 $cfug^{-1}$	Fungi x 10^4 $cfug^{-1}$	Bacteria x 10^6 $cfug^{-1}$	Fungi x 10^4 $cfug^{-1}$	Bacteria x 10^6 $cfug^{-1}$	Fungi x10^4 $cfug^{-1}$
T_1	0.87 (5.734) *	1 (2.824) *	4.33 (5.245) ^{a}	2.67 (2.440)*	6 (5.174) ^{a}	3.67 (2.33) ^{b}
T_2	,,	,,	1 (5.699) ^{d}	1 (2.824)*	1 (5.699) ^{d}	1.3 (2.638) ^{de}
T_3	,,	,,	1.77 (5.561) ^{cd}	1.2 (2.658)*	2 (5.523) ^{cd}	1.33 (6.32) ^{d}
T_4	,,	,,	2.33 (5.481) ^{bc}	1.4 (2.620)*	3 (5.398) ^{bc}	1.53 (2.596) ^{d}
T_5	,,	,,	3.3 (5.366) ^{ab}	2.33 (2.481)*	4.33 (5.245) ^{ab}	3 (2.398) ^{c}
T_6	,,	,,	1.23 (5.653) ^{cd}	1.03 (2.692)*	1.5 (5.602) ^{cd}	1.3 (2.638) ^{de}
T_7	,,	,,	1.47 (5.614) ^{cd}	1.1 (2.678)*	1.5 (5.602) ^{cd}	1.33 (2.632) ^{d}
T_8	,,	,,	2 (5.523) ^{bcd}	1.2 (2.658)*	3 (5.398) ^{bc}	1.37 (2.626) ^{d}

MAS- months after storage The values represent means of 3 replications Values with different super scripts differ significantly at 5%level
Cfu - colony forming units The values in parenthesis represent transformed values
* Non significant

T_1 Packaged in 100 gauge polyethylene with air as control (PE_A)

T_2 Packaged in 100 gauge polyethylene with vacuum (PE_V)

T_3 Packaged in 100 gauge polyethylene with nitrogen (PE_{N2})

T_4 .Packaged in 100 gauge polyethylene with carbon dioxide (PE_{CO2})

T_5 Packaged in aluminium foil laminated pouch with air as control (Al_A)

T_6 Packaged in aluminium foil laminated pouch with nitrogen (Al_{N2})

T_7 Packaged in aluminium foil laminated pouch with carbon dioxide (Al_{CO2})

T_8 Packaged in aluminium foil laminated pouch with vacuum (Al_V)

Table 17. **Microbial load in the dried commercial fig during storage**

Treatments	Storage period					
	0MAS		2MAS		4MAS	
	Bacteria x 10^6 cfug^{-1}	**Fungi x10^4 cfug^{-1}**	**Bacteria x 10^6 cfug^{-1}**	**Fungi x 10^4 cfug^{-1}**	**Bacteria x 10^6 cfug^{-1}**	**Fungi x 10^4 cfug^{-1}**
T_1	0.33 (5.9) *	1 (2.699) *	2.33 (5.508) ^{bc}	3 (2.398) *	3 (5.481) ^{bc}	4.33 (2.275) ^{a}
T_2	,,	,,	1.33 (5.699)^{d}	1 (2.699) *	2 (5.523) ^{cd}	1..1 (2.678) ^{e}
T_3	,,	,,	1.9 (5.540) ^{bcd}	1.3 (2.639) *	2.33 (5.640) ^{cd}	1.67 (2.582) ^{de}
T_4	,,	,,	2 (5.526) ^{bcd}	1.33 (2.632) *	2.33(5.523) ^{cd}	2 (2.523) ^{c}
T_5	,,	,,	2.33 (5.508) ^{bc}	3 (2.481) *	3 (5.398) ^{bc}	4 (2.301) ^{ab}
T_6	,,	,,	1.67 (5.545) ^{bcd}	1(2.699) *	2.33 (5.699) ^{d}	1.13 (2.672) ^{e}
T_7	,,	,,	1.47 (5.614) ^{cd}	1 (2.699) *	2.33 (5.699) ^{d}	1.23 (2.658) ^{de}
T_8	,,	,,	2.07 (5.523)^{bcd}	1.2(2.652) *	2.33(5.640) ^{cd}	1.67 (2.582) ^{de}

MAS- months after storage The values represent means of 3 replications Values with different super scripts differ significantly at 5%level
cfu - colony forming units The values in parenthesis represent transformed values
* Non-significant

T_1 Packaged in 100 gauge polyethylene with air as control (PE_A)

T_2 Packaged in 100 gauge polyethylene with vacuum (PE_V)

T_3 Packaged in 100 gauge polyethylene with nitrogen (PE_{N2})

T_4 .Packaged in 100 gauge polyethylene with carbon dioxide (PE_{CO2})

T_5 Packaged in aluminium foil laminated pouch with air as control (Al_A)

T_6 Packaged in aluminium foil laminated pouch with nitrogen (Al_{N2})

T_7 Packaged in aluminium foil laminated pouch with carbon dioxide (Al_{CO2})

T_8 Packaged in aluminium foil laminated pouch with vacuum (Al_V)

Initially the dried local fig recorded 0.87 x 10^6 $cfug^{-1}$ bacterial count that increased to 6 x 10^6 cfug-1 in control samples within four months and minimum increase was in vacuum packed samples (Fig.13 and 14). Fungal population also recorded similar trend (1 x 10^4 $cfug^{-1}$ to 3.67 x 10^4 $cfug^{-1}$). Commercial fig also showed the same trend but microbial load was comparatively less. Through out the storage period nitrogen packed samples was found to be on par with vacuum packed samples in the case of microbial load. (Fig.15 and 16)

There were no traces of yeast found throughout the storage period. Logarithmic transformation of the mean count was done and DMRT was applied.

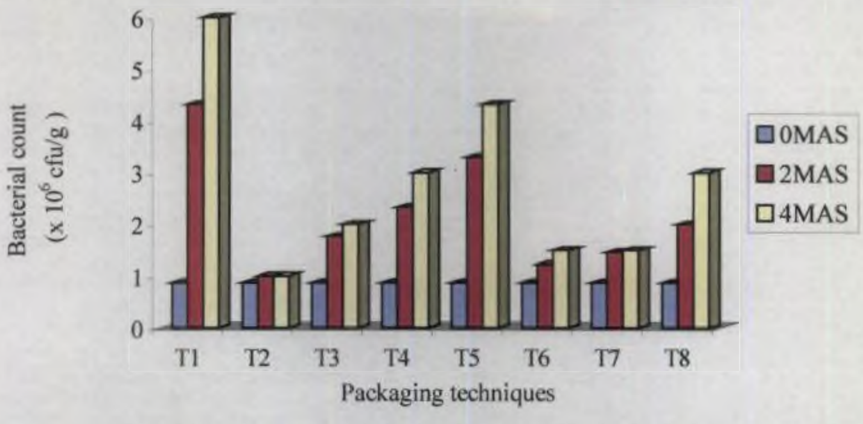


Fig. 13. Changes in the bacterial count of dried local fig during storage

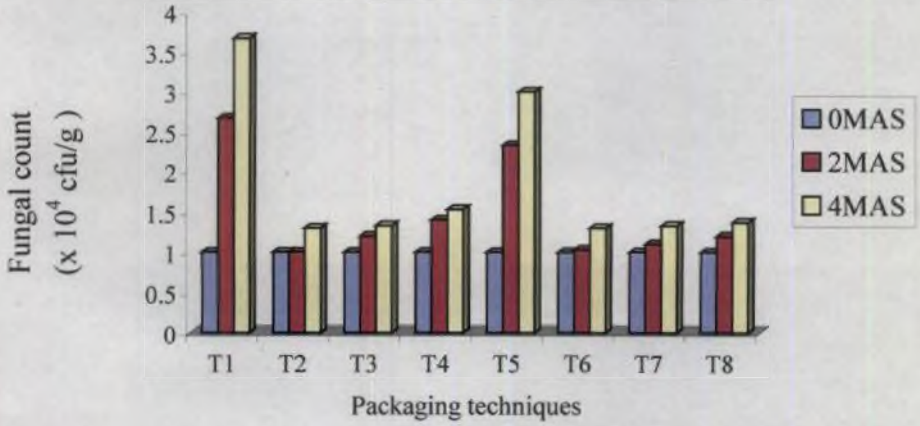


Fig. 14. Changes in the fungal count of dried local fig during storage

T_1 Packaged in 100 gauge polyethylene with air as control (PE_A)
T_2 Packaged in 100 gauge polyethylene with vacuum (PE_V)
T_3 Packaged in 100 gauge polyethylene with nitrogen (PE_{N2})
T_4 .Packaged in 100 gauge polyethylene with carbon dioxide (PE_{CO2})
T_5 Packaged in aluminium foil laminated pouch with air as control (Al_A)
T_6 Packaged in aluminium foil laminated pouch with nitrogen (Al_{N2})
T_7 Packaged in aluminium foil laminated pouch with carbon dioxide (Al_{CO2})
T_8 Packaged in aluminium foil laminated pouch with vacuum (Al_V)

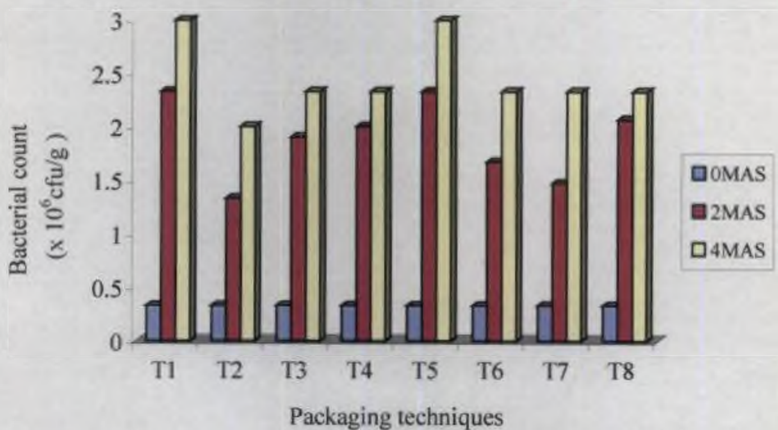


Fig. 15. Changes in bacterial count of dried commercial fig during storage

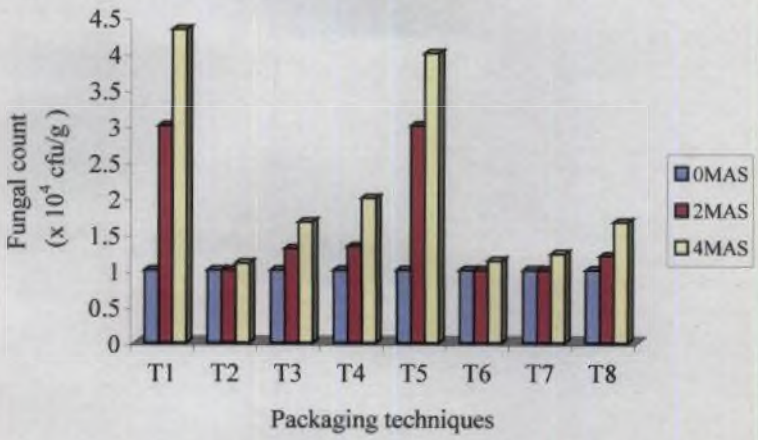


Fig. 16. Changes in fungal count of dried commercial fig during storage

T_1 Packaged in 100 gauge polyethylene with air as control (PE_A)
T_2 Packaged in 100 gauge polyethylene with vacuum (PE_V)
T_3 Packaged in 100 gauge polyethylene with nitrogen (PE_{N2})
T_4 .Packaged in 100 gauge polyethylene with carbon dioxide (PE_{CO2})
T_5 Packaged in aluminium foil laminated pouch with air as control (Al_A)
T_6 Packaged in aluminium foil laminated pouch with nitrogen (Al_{N2})
T_7 Packaged in aluminium foil laminated pouch with carbon dioxide (Al_{CO2})
T_8 Packaged in aluminium foil laminated pouch with vacuum (Al_V)

Discussion

5. DISCUSSION

Fig (*Ficus carica* L.) is mainly grown in subtropical countries and deciduous in growth habit. The nutritional value of fresh fig is comparable to that of many other fruits. Figs are consumed as fresh or dried, preserved candies or canned product. Though the fresh ripe fruit is very delicious, is highly perishable. The great bulk of the world production is dehydrated. Fig seen in Kerala is different from that of the commercial types. Thousands of fruits are wasted every year because of the lack in knowledge on the post harvest operations. Hence various pretreatments and drying techniques were employed to generate a suitable technique for dehydrating the local fig seen in Kerala; comparing it with the commercial one. An attempt has also been made to study the shelf life of dehydrated fig and changes during storage under ambient conditions after packaging with two types of material employing four methods of packaging. The results of the studies are discussed in this chapter.

5.1 DEHYDRATION STUDIES

Dehydration is a suitable method for long-term storage of the fruit and is comparatively cheaper method employed on a commercial scale. Drying refers to the removal of water by heat to such a level that biochemical and microbial activities are checked due to reduced water activity in the product. Maini *et al.* (1982) has reported that more fruits were preserved by drying than any other method as this had more advantages like greater concentration in dried form, cheaper to produce with minimal labour, processing equipment storage and distribution costs.

In the present study both local and commercial fig fruits were subjected to six pretreatments and three methods of drying. However osmotic dehydration was found to be the best method of drying for both local and commercial fig. Treating with sugar solution was found to be the best pretreatment for local fig while in commercial fig no pretreatment needed. Sugar content of local fig is less compared to commercial one. So treating with sugar prior to drying enhanced its acceptability on drying samples without pretreatment in commercial fig is preferred, because it is already having a delicate texture, so any heat treatment involved will destruct the texture further.

5.1.1 Physical parameters

5.1.1.1 Recovery percentage

Highest recovery percentage noted in the osmotic dehydration compared to other methods of drying was that in osmotic dehydration, dry sugar was used as the osmotic agent, which will get impregnated to fruit pieces and adding weight to the product. This is in agreement with the findings of Maya (1999) who reported higher recovery percentage in osmotically dried sapota.

Sun dried and cabinet dried samples were subjected to high temperature for long period of time and hence moisture removal will be very fast in those cases. Samples dried after blanching with hot water or sugar solution was more in recovery percentage because blanching increased the bound moisture content and there by resulting in higher weight of the dried product.

5.1.1.2 Colour change due to drying

The bleaching action of potassiummeta bisulphite is a time-tested factor therefore it is not used for coloured fruits. This was evident from the bleached appearance of the KMS treated fruit pieces. In addition to this blanching in hot water for more time will result in loss of pigments, this is evident from the colour of the dried samples after various pretreatments in the present study. Sulphuring or sulphiting is known to prevent the enzyme catalyzed oxidative changes, inhibit microbial deterioration and facilitate drying by plasmolysing the cells (Tanga, 1974). Involvement of heat or thermal energy in osmotic dehydration is less probably that may be the reason why they retained the respective colours. Sun drying and cabinet drying resulted in darkening of the samples because of longer exposure to heat or thermal energy. Similar results have been obtained by Pillai (2001) in breadfruit and Jayaraman *et al.* (1991) in sun dried peas.

5.1.1.3 Dehydration ratio, shrinkage ratio and reconstitution ratio

Dehydration ratio is an indicator of yield. While studying the drying of mushroom Kaushal and Sharma (1995) found that yield and quality of the dried product are influenced by factors such as initial moisture content, drying temperature and time, susceptibility of the material to heat damage, pre drying treatment and moisture content of the finished produce. Lower dehydration ratio means higher recovery of the dried product. Comparing the methods of drying better ratio (lowest value) observed was in osmotic dehydration. The reasons for these are similar to those explained in 5.1.1.2. Out of the different pretreatments in osmotic dehydration highest yield was recorded in blanching (sugar solution or sugar solution with KMS) and lowest yield in control. This may be due to the particles of citric acid and KMS might have entered intercellular spaces of fig fruit thus contributing to the higher weight. This is in agreement with the findings of Pillai (2001) in breadfruit. Similar results have been reported by Mulay *et al.* in cabbage in 1994.

Shrinkage ratio measures the extend of shrinkage after drying. Higher shrinkage ratio preferred for dried products. Lesser shrinkage (higher ratio) was shown by osmotically dried samples. This may be because of lesser loss of moisture during osmotic dehydration.

Highest reconstitution ratio was obtained by cabinet drying after blanching in 50% sugar solution. The elasticity of cell walls and swelling power of starch which are important for good rehydration are reduced when heat treatment is prolonged as suggested by Arsdel and Copley (1963). The lower rehydration ratio in sun-dried samples compared to cabinet drying may be explained by the above statement. The rehydration ratio of sulphited lots was higher than that for the non sulphited, probably due to better texture retention in the sulphited lots.

Reconstitution of osmotically dried samples was lower than those dried by other methods. Sagar (2001) reported that osmotically dehydrated onion flakes showed lesser ratio when they are less hygroscopic. Lower rehydration and moisture adsorption capacity of the sample was due to sugar impregnation in the fruit slices. The less hygroscopic nature of this sample as evident from reconstitution is an added advantage in handling and hence can be exposed for several hours without becoming sticky. The osmotically dried samples showed lower water activity at higher moisture content since the sugar infused into the fruit acted as water binding agent and increased resistance to moisture movement and gave lower diffusion coefficient. Thapa (1980) reported that to reconstitute osmo-oven dried sapota minimum six hours soaking in 20^0 brix syrup was necessary and reconstitution was only 1.89. The report of Ponting *et al* (1966) is that rehydration ratio of osmotically dried fruit is slightly less than that of untreated, both in rate and extent of reconstitution thus confirming the results.

5.1.1.4 Drying rate and reconstitution rate

Drying was fast in untreated samples compared to treated ones. Drying time is directly related to moisture content such that higher moisture level require more drying time and when the moisture content is less the time required is also less. The time taken for drying the blanched samples was 12 hours in sun drying, 8 hours in cabinet drying and 22 hours in osmotic dehydration. This difference in the drying time is due to the difference in the drying mechanism involved and the instruments used for drying (Suguna *et al.*, 1995).

5.1.2 Chemical parametres

Total sugar of the dried product was higher due to concentration in drying. Obviously total sugar recorded higher values in osmosed samples due to sugar impregnation during osmosis. The increased level of total sugars in dried fruits, which pretreated with sugar syrup, was also reported in banana, guava, papaya and mango (Unde *et al.*, 1998). Osmotically dehydrated products were sweeter, ensured a higher quality and got demand in the market (Lovino *et al.*, 1993). Reducing sugar is also high in osmotically dehydrated samples. In sun drying or cabinet drying sugar is added only in some pretreatments and which was not enough to use the sugar content similar to that of osmotically dehydrated samples.

All the osmotically dehydrated samples and only those sun dried or cabinet dried samples pretreated with KMS showed the presence of residual SO_2. Drying of mango puree followed a first order kinetics and free SO_2 was lost more rapidly than total SO_2 (Mir and Nath, 1995). On cooking the amount of residual SO_2 in the samples is found to get reduced to one fifth of the original quantity (Narasimham and John, 1995).

5.1.3 Sensory evaluation

Organoleptic evaluation rated osmotically dried samples as the best in both figs. Sugar treated products are usually considered to be "Fun foods". Their usage is normally very small in the daily consumption. Osmotically dehydrated fruits contain a large percentage of the fresh fruit flavour and are suitable for producing the foods with a lesser processing time as also found by Angela *et al.* (1991) in raisins. Treating with sugar before drying increased the sugar content and acceptability that may be the reason for selecting T_3 as the best pretreatment for local fig. Addition of KMS along with sugar solution resulted in bleached appearance of the product. Commercial fig had very soft delicate texture and pretreatments resulted in destruction of its texture and decreased its acceptability, therefore pretreatments can be avoided.

5.2 PACKAGING AND STORAGE STUDIES

Dehydrated products are highly hygroscopic, therefore unless stored properly will pickup moisture and invite microbial spoilage, thus deteriorating the products. So providing a suitable packaging to the dried product has become inevitable.

Packaging is a means of producing the correct environmental conditions for food during the length of its storage and/or distribution. The atmospheric oxygen can deteriorate the dried foods through the oxidative phenomena that it produces. The action of oxygen can be eliminated by packaging methods like vacuum packing, flushing with N_2 and CO_2.

Premalatha *et al.* (1999) reported that polypropylene packaging is the most suitable system for the long-term storage of fruit based products. Hameed (1981) also reported that banana chips packed in 100 gauge LDPE remained satisfactory up to two months.

Modified atmosphere packaging (MAP) is one of the methods for extending the shelf life of perishable and semi perishable food product by altering the relative proportions of atmospheric gases that surround the food (Barmor, 1987; Day, 1992, Wade, 1980). This differs from controlled atmosphere storage (CAS) where the storage atmosphere is differing from normal atmosphere by preface adjustment of the component gases to specific concentrations and maintaining it throughout the storage period (Debney *et al.*, 1980). In the present study packaging the osmotically dried fig fruit slices with vacuum was found to be superior to other packaging methods.

5.2.1 Physical parameters

5.2.1.1 Visual colour change

Samples in polyethylene showed darkening. Vacuum-packed samples retained the colour during the storage period. Oozing of syrup was highest in air packed samples. Better colour retention in vacuum-packed samples was due to lesser moisture and absence of air. Browning in dehydrated food may be produced by the interaction of nitrogenous constituents with the sugar and organic acids (Maillard reaction). Loss of colour reported in polyethylene packages may be due to the interaction with light. Similar results have been obtained by Kumari (1992) in bitter gourd. The rate of browning depends on factors like pH, moisture, and storage temperature and storage atmosphere. Nonenzymatic browning increases when the product moisture increases when the product is exposed to air.

Gvozdenovic *et al* (2000) reported that vacuum packing had the greatest protective effect against browning in powdered orange. Therefore browning will be comparatively higher in those packed without vacuum. The excellent barrier properties of aluminium foil laminated pouch protected the product against moisture ingress, discolouration and flavour loss as reported by Mary (2005) in banana powder.

5.2.1.2 Moisture pick up

By analyzing the moisture pickup of the sample during storage period, we can observe that it was lowest in vacuum packed samples especially in polyethylene packages. Similar results have been reported by Mary (2005) in banana powder. The lesser moisture in vacuum-packed samples was due to the elimination of air from the package while creation of vacuum. Sagar *et al.* (1999) also reported similar results in vacuum packed dehydrated dried mango slices.

5.2.2 Chemical parameters

Total sugar content of the samples decreased throughout the storage period. Maya (1999) also observed similar results in osmotically dried sapota. The decrease in total sugar content may be due to the moisture pick up by the samples. The reduced level of total sugar in vacuum packed fruit is due to the reduced respiration and other metabolic processes in the vaccum packed fruits.

In early stages of drying much of the sugars are present as sucrose. But as drying proceeds, more and more reducing sugars are produced by acid inversion of non-reducing sugars (Mc Bean, 1967). During storage the high levels of reducing sugar can be due to acid hydrolysis of sucrose, which was impregnated, in high amounts during osmotic dehydration. Similar results were reported in apricots, cherries and other processed fruits during storage (Dalal and Salunke, 1964 Desrosier, 1977). Similar results have also been obtained in sapota by Maya (1999) the accumulation of reducing sugars during storage is a consequence of starch hydrolysis.

The vacuum packed fruits had higher acidity due to the reduced oxygen concentration, slow rate of starch dehydration and accumulation of sugars. The reduction of acidity was less in vacuum packed samples and results were in agreement with earliest studies of Satyan *et al.* (1992) on banana. The decrease in acidity during storage could be due to the increase in reducing sugar and pick up of moisture by the fruit pieces. Similar trend was reported by Kumar and Sreenarayan (2000) in dehydrated onion flakes and Sagar and Khurdiya (2000) in ripe mango powder.

The gradual decrease in nutrient on storage might have also been due to the utilization of nutrients by microbes growing. Rangaswamy and Bagyaraj (2000) reported that microbes in foodstuffs utilize the nutrients from the food for their needs.

A gradual reduction in residual SO_2 was noted throughout the storage period. Pillai (2001) reported similar results in dried breadfruit. Sagar *et al.* (1999) also reported that vacuum-packed mango slices showed higher SO_2 as compared to air packed material.

5.2.3 Microbial load

In the present study, a gradual increase in the bacterial count and fungal count was observed. Similarly a gradual increase in the moisture content of the samples during storage was also observed. According to Bera *et al.* (2001), the growth of fungi and bacteria in the food samples are influenced by moisture content, high or low relative humidity, temperature of storage and type of samples. The increase in the bacterial count and fungal count can be correlated with the increase in moisture content on storage. Lesser microbial load in vacuum packed samples may be due to the reduced moisture content and absence of air. According to Bryan (1974) and Nanu *et al.* (1992), several factors such as quality of raw materials, storage temperature, storage containers, processing technique, the environment in which it is processed, etc. will have an effect on microbial quality of processed foods.

From the storage study we could observe that samples in aluminium foil laminated pouches with vacuum retained their colour. Microbial safety was also there in vacuum packed samples. Aluminium foil laminated pouches with vacuum was found to be the best packaging for dried local as well as commercial fig.

Summary

SUMMARY

The present investigation on "Dehydration and storage studies in fig (*Ficus carica* L.)" was undertaken at the Department of Processing Technology, College of horticulture, Vellanikkara during the period 2004-2005. Main objectives were to develop a suitable drying technique to dehydrate local fig seen in Kerala and compare it with commercial type and also to find out the best-suited packaging material and technique.

Various pretreatments and drying techniques were employed. Osmotic dehydration was found to be the best method of drying for both local and commercial types. Treating with 50 per cent sugar solution prior to drying enhanced the acceptability of local fig and rated as the best pretreatment. Where as in commercial type no pretreatment was needed.

Storage study conducted by packaging the best-dehydrated samples in two types of materials employing four methods of packaging. Changes during storage under ambient condition where also analysed. Irrespective of the packaging material, air packed samples showed higher moisture pickup. Which has resulted in the increased microbial load. Samples in polyethylene showed darkening. Vacuum-packed samples retained the colour through out the storage period of four months. There was no conspicuous variation in chemical constituents among he samples during storage. Aluminium foil laminated pouches with vacuum was found to be the best packaging method for dried product irrespective of the type of figs.

References

REFERENCES

*A.O.A.C. 1975. *Official and Tentative Methods of Analysis*. 12th ed. Association of Official Analytical Chemists, Washington D.C, 1018p.

Agarwal, G.P. and Hasija, S.K. 1986. *Microorganisms in the Laboratory*. Print House, Lucknow, 155p.

Ahmed, J. and Choudhary, D.R. 1995. Osmotic dehydration of papaya. *Indian Fd. Packer* 49: 5-11

Amitabh, Singh, R.D. and Tomar, M.C. 2000. Studies on osmotic dehydration of some varieties ripe mangoes grown in U. P. *Indian Fd. Packer* 54: 66-71

Amutha, S. and Krishnamurthy, P. 1999. Solar dehydration of moringa. *Indian Hort.* 44: 12-14

Angela, L., Arci and Humberto. 1991. Osmotic drying kinetics of pineapple and papaya. *J. Agric.* 75: 6-13

*Arie, B.R., Zuthki, Y., Sonego, L. and Klein, J. 1991. MAP for long-term storage of astringent persimmon. *Post Harvest Biol. Technol.* 2: 169-179

*Arsdel, V.W.B. and Copley, M.J. 1963. *Food Dehydration Vol.1*. The AVI Publishing Company, Inc. Westport, pp. 66-82

Balasubramanyam, N. 1995. *Profiles on Food Packaging*. Publication of Central Food Technological Research Institute, Mysore, pp. 24-37

Baloch, A.K., Buckle, K.A. and Edwards, R.A. 1997. Effect of processing variables on the quality of dehydrated carrot: leaching losses and carotenoid content. *J. Fd. Technol.* 12:285-293

Barmor, C.R. 1987. Packaging technology for fresh and minimally processed fruits and vegetables. *J. Fd. Qual.* 10:207-217

Bawa, A.S. and Gujral, H.S. 2000. Effect of osmotic agents on the drying behaviour and product quality in raisin processing. *J. Scient. Ind. Res.* 59: 63-66

Bera, M.B., Singh, C.J., Shrivastava, D.C., Kumar, K.S. and Sharma, Y.K. 2001. *J. Fd. Sci. Technol.* 38:8-11

Bhardwaj, J.C. and Kaushal, B.B. 1990. A study on drying behaviour of rings from different apple cultivars of Himachal Pradesh. *J. Fd. Sci. Technol.* 27: 144-149

Bhat, A. 2004. Effect of modified atmosphere, hot water and ethylene absorbent on storage behaviour of ber (*Zizyphus mauritiana* Lamk). *Indian J. Hort.* 61: 181-182

Bolin, H.R., Huxall, C.C., Jackson, R. and Ng, K.C. 1983. Effect of osmotic agents and concentration of fruit quality. *J. Fd. Sci.* 48: 202

Bolin, H.R., Stede, R.J and David, E.H. 1985. Head space SO_2 and storage of dried apples. *J. Fd. Sci.* 50: 1549-1651

Bongirwar, D.R. and Sreenivasan, A. 1977. Studies on osmotic dehydration of banana. *J. Fd. Sci. Technol.* 14: 104-112

*Brandao, M.C., Maia, G.A., Lima, D.P., Parente, E.J.de.S., Campello, C.C., Nassu, R.T., Feitosa, T.and Sousa, P.H.M.de. 2003. Physical and chemical, microbiological and sensorial analysis of cashew apples submitted to osmotic-solar dehydration. *Rev Cient Agron.* (Portuguese) 34: 139-145

Bryan, F.T. 1974. Microbiological food hazards of today based on epidemiological information. *Fd. Technol.* 28:52-66

*Canovas, B.G.V. and Vega, M.V. 1996. *Dehydration of Foods*. Chapmann and Hall, New York, 278 p.

*Chapon, J.F. 2002. Storage of table grapes. *Infos-Ctifl.* (French) 184:31-34

Choudhari, A.P., Kumbhar, B.K., Singh, B.P.N. and Narain M. 1993. Osmotic dehydration of fruits and vegetables - A Review. *Indian Fd. Ind.* 2:35-38

*Colleli, G., Mitchell, F.G. and Kader, A.A. 1991. Extension of post harvest life of 'Mission figs' by CO_2 enriched atmosphere. *Hort. Sci.* (Italian) 26: 1193-1195

Contreras, J.E. and Smyrl. T.G. 1981. An evaluation of osmotic concentration of apple rings using corn syrup solids solutions. *Can Inst. Food Sci. Technol. J.* 14: 310-314

Dalal, K.B. and Salunkhe, D.K. 1964. Thermal degradation of pigments and relative biochemical changes in canned apricot and cherries. *Fd. Technol.* 18:1198-1201

Day, B.P.F. 1992. An update on chilled atmosphere / modified atmosphere vacuum packaging developments in Europe. *In 9th Annual Food '92 conference*. The Plastics Institute of America, Fairfield, New Jersey, USA, pp. 1-21

Debney, H.G., Blacker, K.J., Reddins, B.J., Watkins, J.B. 1980. Handling and storage practices for fresh fruit and vegetables. Product Manual, Australian United Fresh fruit and vegetable association. 345p.

Desai, U.T. and Kumbhar, S.S. 1986. Influence of perforations of polyethylene on shelf life of sapota fruits. *Maharashtra J. Hort.* 41(3): 147-151

Desrosier, N.W. 1977. *Elements of Food Technology*. AVI Publishing Co. Inc. Westport, Connecticut,342p.

*El Razik, F.A.A., Farghal, S.A. and Kayati, S.M. 1997. Utilization of solar enegy in drying Kadota fig fruit. *Desert Institute Bulletin Egypt*. 47: 323-344

Emerald, F.M.E., Sreenarayanan, V.V. and Parvathy. R. 2001. Physico - chemical responses of sapota packed under modified atmosphere. *Madras Agri. J.* 88: 271-273

Fageria, M.S. and Choudhary, M.R. 2003. Effect of harvest stage, blanching and potassium metabisulphite on organoleptic quality of dried *Prosopis cineraria* fruit. *The J. Hort. Sci. and Biotechnol.* 78: 447 – 449

Flores, J.D. 1990. Controlled and modified atmospheres in food packaging and storage. *Chem. Engng. Progress* 26: 25-32

Gawade, M. H. and Waskar, D. P. 2003. Studies on processing and storage of fig fruits. *J. Maharashtra Agric. Universities* 28: 148-150

Gawade, M. H. and Waskar, D. P. 2004. Dried fig (*Ficus carica* L.) storage under various environments. *J. Fd. Sci. Technol.* 41:425-428

Geetha, P. 1997. Increasing the shelf-life of banana, guava, papaya and sapota by vacuum packaging. M.Sc. (Hort.) thesis, Tamil Nadu Agricultural University, Coimbatore. 121p.

Ghorai, K and Sethi, V. 1998. Effect of blanching on the nutritive value and pickling quality of Amla fruits. *J. Maharashtra agric.Universities.* 23: 69-70

Girabowski, S., Marcotte, M., Poiries, M. and Kudra, T. 2002. Drying characteristics of osmotically pretreated cranberries. Energy and quality aspects [online] available http://cetcvarennes.nrcan .gc.ca/eng/publication/ r.html [12 june 2004]

Gorini, F. 1985. Aspects of the use of plastic film in the packing of fruits and vegetable products. Atti dell Institute superimental perla valorizzazione technological dei prodotti Agri. coli, Milano. *Hort. Abst.* 57(12): 9144

Gorris, L.G.M and Peppelenbos. H.W. 1993. Modified atmosphere and vacuum packaging to extend shelf life respiration food products. *Post Harvest news and Information* 4: 129

Gowda, D.I.N. 2000. Evaluation of certain pre-treatments for raisin making. *J Fd. Sci.Technol.* 37(2) 121-125

*Gvozdenoviz, J., Ralfic, P.J. and Curakovic, M. 2000. Investigation of characteristic colour stability of powdered orange. *Fd. Chem.* 70:291-301

Hameed, R.S. 1981. Banana. Wilson publishing co Pvt. Ltd, Madras, 189p.

Heartwin, P., Dhas, A., Zachariah, J.T. and Shinoj, S. 2004. Effect of blanching and drying on quality of mace *(Myristica fragrans)*. *J. Fd. Sci. Technol.* 41: 306-308

Hymavathi, T.V. and Khader, V. 2004. Storage stability of vacuum dehydrated ripe mango mix powders. *J. Fd. Sci. Technol.* 41: 521-524

Icibal, N. and Altug, T. 1992. Degradation of aflatoxins in dried figs by sulphur dioxide alone or in combination with heat, ultraviolet energy and hydrogen peroxide. *Lebensm. Wiss. Technol*. 25: 294-296

Islam, M.N. and Flink, J.M. 1982. Dehydration of potato 11 Osmotic concentration and its effect on air-drying behaviour. *J. Fd. Technol.* 17:387

Jackson, T.H. and Mohammed, B.B. 1971. The shanbat process- New development arising from the osmotic dehydration of fruits and vegetables. *Sudan J. Fd. Sci. Technol.* 3: 18-23

Janowicz, M., Kowalska, H., Lazuka, W.P. and Lenart, A. 2002. Osmotic dehydration of fruits with different structure. *Inz Rolnicza* (Polish) 6-5: 449-454

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: 16-23

Jayaraman, K.S., Ramanuja, M.N., Govardhanan, T., Bhatia, B.S. and Nath, H. 1976. Technological aspects of use of ripe mangoes in the preparation of some convenience foods for defence services. *Indian Fd. Packer* 30:76-82

Kad, V.P., Unde, P.A., More, H.G. and Chobe, R.S. 2001. Preparation of quality products from potato. *Bev. Fd. Wld.* 28: 31-32

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

Kannan and Thirumaran, S. 2000. Effect of osmotic dehydration of guava. *South Indian Hort.* 50: 195-199

Kar, A., Chandra, P., Prasad, R., Samuel, D.V.K. and Khurdiya, D.S. 2003. Comparison of different methods of drying for Banana (Dwarf Cavendish) slices. *J. Fd. Sci. Technol.* 40: 378-381

Kaushal, B.B.L. and Sharma, K.D. 1995. Post harvest technology of mushroom. *Advances in Horticulture Vol.13* (eds. Chadha, K.L. and Sharma, S.R.). Malhotra Publishing House, New Delhi, pp.553-565

Kim, M.H. and Toledo, R.T. 1987. Effect of osmotic dehydration and high temperature fluidized bed drying on properties of rabbit eye blue berries. *J. Fd. Sci.* 52: 980

Krishnamoorthy, S. and Kushalappa, C.G. 1985. Studies on shelf life and quality of Robusta banana as affected by postharvest treatments. *J. Hort. Sci.* 60: 549-556

Kucherer, H. 1996. A vacuum pack replaces the Tin plate Can. *FSTA.* 28: 84

Kumar, P and Sreenarayan, V.V. 2000. Studies on storage of dehydrated onion flakes. *Indian Fd. Packer* 54: 73-74

Kumari, V.D. 1992. Pre and post harvest treatments on storage life and quality of fresh and dried bittergourd (*Momordica charantia* L.). M.Sc (Hort.) thesis, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala,136p.

*Le Maguer, M. 1988. Osmotic dehydration review and future directions. Proceedings of international symposium on progress in food preservation and processes. pp. 12 – 14

Lenart, A and Flink, J.M. 1984. Osmotic concentration of Potato 1 Criteria for the end point of the osmotic effect. *J. Fd. Technol.* 19: 65-67

Lerici, C.R. 1984. Influence of osmotic agent on drying behaviour and product quality. *J. Fd. Sci.* 50: 121-125

Levi, A., Martinez, J.R.R. and Padua, H. 1980. Influence of heat and sulphurdioxide treatments on some quality characteristics of intermediate moisture banana. *J. Fd. Technol.* 15: 557-566

*Lovino,R. Masignan,L. and Leo, P. 1993. Processing of seedless grapes. *Fd. Sci. and Technol. Abstr.* 25: 6-8

Maheswari, K.U. 2003. Effect of drying on physico-chemical and sensory characteristics of raisins prepared by a simple household method. *J. Fd. Sci. Technol.* 40: 515-517

Maini, S.B., Brijesh, Diwan., Gupta, S.K. and Anand. J.C. 1982. A solar drier for fruits and vegetables. *Indian Hort. Abstr.* 27:1

Mandhyan, B.L. 1999. Retention of freshness of guavas with respect to package material. *J. Fd. Sci. Technol.* 36(1): 46-48

Mary, E. A. 2005. Development of juice based beverage and ripe fruit powder from banana (*Musa spp.*). Ph.D. thesis, Kerala Agricultural University, Thrissur, 130p.

*Matteo-M-di, Rapacciuolo,M. and Cinquanta, L. 1999. Cold storage of figs using semipermeable plastic film. *Informatore Agrario.* (Italian) 55:35-36

Maya,T. 1999. Evalution of sapota (*Manilkara achras* (Mill.) Fosberg.) for post harvest qualities. M.Sc(Hort.) thesis. Kerala Agricultural University, Thrissur, 57p.

Mazza, G. 1983. Dehydration of carrots: effects of predrying treatments on moisture transport and product quality. *J. Fd. Technol.* 18: 113-123

Mc Bean. 1967. Levels of free and combined SO_2 in fruits during sulphuring and drying. *Fd. Technol.* 21: 1402-1406

Mehta, G.L., Tomar, M.C. and Gawar, B.S. 1982. Studies on dehydration of pineapple (*Ananas comosus* Limm / Merr). *Indian Fd. Packer* 36: 35-40

Mir, M. A. and Nath. N. 1995. Loss of moisture and SO_2 during air cabinet drying of mango puree. *J. Fd. Sci. Technol.* 32: 391-394

Mohamed, S., Taufik, B. and M. N. A. Karim. 1996. Effects of modified atmosphere package on physico-chemical characters of chiku at various storage temperature. *J. Fd. Sci. and Agric.* 70: 231-240

*Monsalve,G.A, Barbosa Canovas, Gustavo, V., Mcevily J Arthur and Iyengar R. 1985. Inhibition of enzymatic browning in apple products by 4-hexylresorcinol. *Fd. Technol.* 4:110-118

Mortenson, E and Bullard, E.T. 1968. *Handbook of Tropical and Subtropical Horticulture*, USDA, Agency for International Development, Washington, 576p.

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: 11-16

Nagalakshmi, S. and Chezhiyan, N. 2004. Influence of type of packaging and storage conditions on Tamarind (*Tamarindus indica*) pulp quality. *J. Fd. Sci. Technol.* 41: 586-590

Nanu, E., Narayanan, K.G. and Yadava,R. 1992. Bacteriological quality of pork kabab stored under marketing conditions. *J. Fd. Sci. Technol.* 29:309-310

Narasimham, P., and John, P.J. 1995. Controlled low temperature vacuum dehydration as alternative to freeze drying of diced breadfruit. *J. Fd. Sci. Technol.* 32: 305-309

*O'Conncr, R.E., Skarsheweshi, P. and Thowar, S.J. 1992. MAP of fruits, vegetables, seafood and meat:state of the art. *Asean Fd. J.* 7: 127-136

Ocansey, O.B. 1984. Effect of vacuum and atmospheric freeze drying on quality of shrimp, turkey flesh carrot samples. *J. Fd. Sci.* 49:1457-1461

Ozer, K.B. and Sen, F. 2003. Effects of some post harvest treatments on preserving quality of preserving quality of Yediveren' fig fruits. *Proceedings of the 2nd international symposium on fig, May 7-11, 2001* (eds. Corrales, L.M. and Garcia , B.M.J.). Caceres, Spain, pp 211-218

Page, A.L. 1982. Methods of soil analysis- part2. *Am. Soc. Agron.* p.334

Palodkar, D.M., Rodge, B.M. and Patil M.B. 2003. Studies on drying and dehydration of aonla fruits. *J. Maharashtra agric. Universities* 28: 81-83

Pandey, U.B., Singh,L.J.R., Bhonde, V.K., Singh. and Gupta. R. P. 1983. Studies on sorting, grading and packaging of onion. In: *Progressive National Workshop on onion.* 17-18. Dec., 1983; NHRDF, Nasik

Panse, V.G and Sukhatme, P.V. 1976. *Statistical Methods for Agricultural Workers.* Indian Council for Agricultural Research, New Delhi, 316 p.

Parvathy, S., Abdullah, H., Latifah. and Tarmizi, S. 2003. Effect of packaging system on the quality of wax apple (*Eugenia javanica* syn *samarangense*) stored at low temperature. *J. Fd. Sci. Technol.* 40: 177-182

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

Pawar,S.G. Kulkarni,D.N., Shere, D.M., Kulkarni, K.D. and Pail, V.K. 1992. Effect of pretreatments on chemical composition and drying rates of solar dried figs. *Indian Fd. Packer* 8:39-42

Piga, A., D-Aqciinos., Agabbio, M., and Pappoff, C. 1995. Keeping quality of fresh figs by post harvest film wrapping. *Italus Hortus* (Italian) 2:3-7

Pillai, K.C. 2001. Shelf life of bread fruit (*Artocarpus altilis* (Park) Fosberg) M.Sc(Hort.) thesis, Kerala agricultural university, Vellanikkara, Thrissur, 85p.

Ponting, J.D., Waters, G.G., Forrey,R.R., Jackson,R. and Stanley, W.L. 1966. Osmotic dehydration of fruits. *Fd. Technol.* 20:125

Premalatha,M.R., Sobana,R.M. and Thirumaran,A.S. 1999. Storage studies on papaya based fruit bars in flexible packaging. Fourth Agricultural Science Congress, 21-24, February 1999. Rajasthan Agricultural University, Jaipur. *Abstract*: 232

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

Raghupathy, P.R., Hussain, A.A., Reddy, P.N., Meger, V.K., Gaveli, K. and Narvani N.B. 1998. Evaluation of tray type bamboo basket solar driers for figs. *Karnataka. J. Agric. Sci.* 11: 268-269

Rahman, M.D.S. and Lamb, J. 1991. Air drying behaviour of fresh and osmotically dehydrated pineapple. *J. Fd. Proc Engng.* 14: 163-171

Ramamurthy, M.S., Bongirwar,D.R. and Bandopathyay. 1978. Osmotic dehydration of fruits possible alternative to freeze-drying. *Indian Fd. Packer* 32: 108-111

Ranganna, S. 1986. *Manual of Analysis of Fruit and Vegetable Products.* Tata McGraw Hill Publishing Co.Ltd., New Delhi p.2240

Rangaswamy,G. and Bagyaraj,D.J. (2000). *Agricultural microbiology* (2nd ed.). Prentice Hall of India Pvt Ltd., New Delhi, 422p.

*Raoult-Wack, A.L., Gilbert, S. and Lenart, A. 1992. Recent advances in drying through immersion in concentrated solutions. In: Majumdar, A. S. (ed.) *Drying of solids.* Ed International science publishers, Newyork, p. 21-51

*Roichev.V. and Botiyanski..P. 1998. Effect of preliminary treatment on grape drying and raisin quality of seedless and seeded grapevine varieties. *Bulgarian J. Agric. Sci.* 4;313-321

Rosa, B.A., Aharoni, D., Feyganberg, O., Aharoni, N., Keynanand, A. and Pesis. E. 2001. Effect of modified atmosphere packaging on mango ripening. Acta Hort. 553: 607-609

Roy, S.K. and Singh, R.N. 1979. Studies on utilization of bael fruit (*Aegle marmelos* cornea) for processing IV. Storage studies of bael fruit product. *Indian Fd. Packer* 31:9-14

Sadhu, M.K. 1990. Fig. *Fruits: Tropical and subtropical.* (eds Bose, T.K., and Mithra, S.K.) Naya Prokash, Calcutta. pp.650-655

Sadhu, K.S. and Pashwak. 2002. Studies on the preparation of dehydrated potato cubes. *J. Fd. Sci. Technol.* 39:594-602

Sagar, V.R., Khurdiya, D.S. and Balakrishnan, K.A. 1999. Quality of dehydrated ripe mango slices as affected by packaging material and mode of packaging. *J. Fd. Sci. Tecnol.* 36: 67-79

Sagar, V.R. and Khurdiya, D.S. 2000. Studies on dehydration of Dashehari mango slices. *Indian Fd. Packer* 53: 5-9

Sagar, V.R. 2001. Preparation of onion powder by means of osmotic dehydration and its packaging and storage. *J. Fd. Sci. Technol.* 38:525-52

*Samson, J.A. 1980. Tropical fruits. Longman, London

Sankat, C.K. and Balkission, F. 1992. The effect of packaging and refrigeration on the shelf life of carambola. *Asean Fd. J.* 72: 114-117

Satyan, S.H., Scott K. and Graham. D. 1992. Storage of banana bunches in sealed polythene tubes. *J. Hort. Sci.* 67: 283-287.

Setty, G.R., Reddy, K.B.S. M., Saroja, S., Chikkappaji, K.C. and Nanjundaswamy, A.M. 1978. Developments in dehydration techniques of fruits and vegetables. *Indian Fd. Packer* 32:115-122

Shahabuddin, N. and Hawladaar, M.N.A. 1990. Evaluation of drying characteristics of pineapple in the production of pineapple powder. *J. Fd. Processing and Preservation* 14: 375-391

Sharma, R.C., Joshi, V.K., Chouhan, S.K. and Lal ,B.B. 1991. Application of osmosis-osmo- canning of apple rings. *J. Fd. Sci. Technol.* 28: 86-88

Shi, X. Q., Maupoey, P. F. and Xian, Q. S. 1993. Vacuum osmotic dehydration of fruits. *Drying Technol.* 11: 1429-1442

Singhal, V. 1998. *Hand Book of Indian Agriculture.* Vikas Publishing House Pvt Ltd., NewDelhi, 1232p.

Singh, K.M. 1983. Dehydration, packing and storage studies of fruits (Banana, Jack and Mango. M.Sc. (Hort.) thesis, Kerala agricultural university.83 p.

*Sousa, P.H., deSouza Neto M-A-de, Maia, G.A., and Figueiredo,R. Wd. 2003. Osmotic dehydration of fruits. *Boletim-da-Sociedade-Brasilieira-de-Ciencia-e-Technologia-de-Alimentos*. (Portuguese) 37: 94-100

Suguna, S., Usha, M., Sreenarayanan, V.V., Raghupathy, R. and Gottandapani, L. 1995. Dehydration of mushroom by sundrying, thin layer drying; fluid bed drying and solar cabinet drying. *J. Fd. Sci. Technol.* 32: 284-288

Tanga, A.Q. 1974. Weight loss in mushroom during canning. *Indian Mushroom Sci.* 1:225-232

Teaotia, S.S., Mehta, G.L., Tomar, M.C. and Garg, R.C. 1976. Studies on dehydration of tropical fruits in Uttar Pradesh: 1 – Mango. *Indian Fd. Packer* 30: 15-18

Thapa, M.J. 1980. Some studies on the osmotic dehydration of sapota- an investigation, M.Sc dissertation, Central Food Technological Research Institute, Mysore, 106p.

Thonta,T.G. and Patil, V.K. 1988. Studies on drying of fig fruits. *Indian Fd. Packer* 8: 94-96

Tomar, M.C., Singh, O.B. and Surjeet, S. 1990. Studies on osmotic dehydration of pear (*Pyrus communis* L.). *Prog. Hort.* 4: 77-83

Tsantilli, E., Karaiskos, G. and Pontikis, C. 2003. Storage of fresh figs in low oxygen atmosphere. *J. hort. Sci. Biotechnol.* 78: 56-60

Unde, P.A., Kanawade, V.L. and Jadhav, S.B. 1998. Effect of syruping and drying methods on quality of Ber candy. *J. Fd. Sci. Technol.* 35:259-261

Veghani, S.N. and Chundawat, B.S. 1986. Sun drying of sapota (*Achras sapota* L.) fruits. *Indian Fd. Packer* 40: 23-28

Verma, R.C. and Gupta. A. 2004. Effect of pre-treatments on quality of solar dried amla. *J. Fd. Engng.* 65: 397-402

Wade, N.L. 1980. Atmosphere composition as an aid to refrigeration. *CSIRO Food Res. Qly.* 40:84-90

Waskar, D.P. and Nikam, S.K. 1995. Evaluation of packaging materials for shelf life and quality of sapota fruits. *South Indian Hort.* 46: 287-290

* Originals not seen

Appendices

APPENDIX I

Score card for organoleptic evaluation of dried fig

S. No.	Character	Description	Score	1	2	3	4	5
1	Colour	Excellent	5					
		Like very much	4					
		Neither like nor dislike	3					
		Dislike	2					
		Dislike very much	1					
2	Flavour	Excellent	5					
		Like very much	4					
		Neither like nor dislike	3					
		Dislike	2					
		Dislike very much	1					
3	Texture	Excellent	5					
		Like very much	4					
		Neither like nor dislike	3					
		Dislike	2					
		Dislike very much	1					
4	Overall acceptability	Excellent	5					
		Like very much	4					
		Neither like nor dislike	3					
		Dislike	2					
		Dislike very much	1					

Date:

Name:
Signature:

APPENDIX II

COMPOSITION OF MEDIA

1. Potato Dextrose Agar Media (for fungi)

Potato	:	200 g
Dextrose	:	20 g
Agar	:	20 g
Distilled water	:	1 litre
pH	:	7.0

2. Nutrient Agar Media (for bacteria)

Glucose	:	5 g
Peptone	:	5 g
Beef extract	:	3 g
Agar	:	20g
Sodium chloride	:	5 g
Distilled water	:	1 litre
pH	:	6.5-7.5

3. Modified Malt Extract Media (for yeast)

Malt extract	:	30 g
Peptone	:	5 g
Agar	:	18 g
Distilled water	:	1 litre
pH	:	5.5-5.6

DEHYDRATION AND STORAGE STUDIES IN FIG (*Ficus carica* L.)

By

HABEEBA. P. S.

ABSTRACT OF THE THESIS

submitted in partial fulfilment of the requirements for the degree of

Master of Science in Horticulture

Faculty of Agriculture
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2005

ABSTRACT

An experiment was conduced in the Department of processing technology, College of horticulture, Vellanikkara during 2004-05 to develop a suitable drying technique to dehydrate local fig seen in Kerala and to compare it with commercial type and to find out the best suited packaging technique.

Osmotic dehydration was found to be the best method of drying for both local and commercial types. Treating with 50 per cent sugar solution prior to drying enhanced the acceptability of local fig and rated as the best pretreatment. Where as in commercial type no pretreatment was needed.

Between the packaging materials tried aluminium foil laminated pouches was better than polyethylene and among the packaging methods, vacuum-packed samples in aluminium foil laminated pouches retained the maximum quality through out the storage period.

Thus the technique so developed could be effectively used for dehydrating the locally available fig to that of commercial ones, thus adding value to otherwise wasted local figs.