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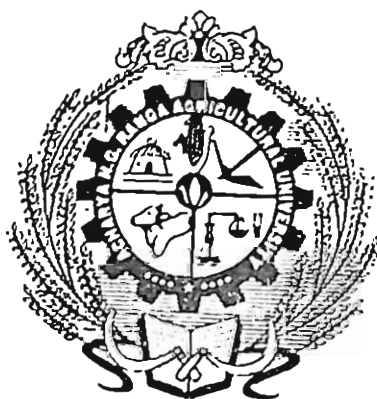
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# PRODUCT DEVELOPMENT WITH DEHYDRATED CARROTS

By  
M. SUMAN

THESIS SUBMITTED TO THE  
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY  
IN PARTIAL FULFILMENT OF THE REQUIREMENTS  
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN HOME SCIENCE  
FOODS AND NUTRITION



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December, 1999

## CERTIFICATE

Ms. M. SUMAN has satisfactorily prosecuted the course of research and that the thesis entitled "**PRODUCT DEVELOPMENT WITH DEHYDRATED CARROTS**" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by her for a degree of any other university.

Date : 10/12/99  
Place : Hyderabad

  
(Dr. (Mrs.) K. KRISHNA KUMARI)  
Major Advisor

## CERTIFICATE

This is to certify that the thesis entitled "**PRODUCT DEVELOPMENT WITH DEHYDRATED CARROTS**" submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN HOME SCIENCE** of the **Acharya N.G. Ranga Agricultural University, Hyderabad**, is a record of the bonafide research work carried out by **Ms. M. SUMAN** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of investigation have been duly acknowledged by the author of the thesis.

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## DECLARATION

I, Ms. M. SUMAN hereby declare that the thesis entitled "PRODUCT DEVELOPMENT WITH DEHYDRATED CARROTS" submitted to the ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY for the degree of MASTER OF SCIENCE IN HOME SCIENCE is the result of original research work done by me. I further declare that the thesis or any part thereof has not been published earlier in any manner.

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(M. SUMAN)

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## LIST OF ABBREVIATIONS

cm	: Centimeter
g	: gram
hr	: hour
kg	: kilogram
KMS	: Potassium Metabisulphite
lt	: litre
meq	: milli equivalents
mg	: milligram
ml	: milli litre
ppm	: parts per million
Rs	: Rupees
tsp	: tea spoon
TSS	: Total Soluble Solids
°C	: degrees centigrade
°F	: degrees Fahrenheit
α	: alpha
β	: Beta
'	: Foot
"	: inch
%	: per cent
μg	: microgram

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## ABSTRACT

Carotenes are precursors of vitamin A, an essential nutrient, for maintaining health. Over 80 per cent of the daily supply of vitamin A among the Indian population is derived from its precursor  $\beta$ -carotene which is present in plant foods. Among roots and other vegetables carrot is the best source of  $\beta$ -carotene. Carrot finds wide application in the day-to-day use for making curries, sweet meats, soups, carrot juice etc. Because of its multifaceted applications various processing methods have been developed for making different products or to extend its shelf-life.

In the present study fresh carrots were dried under direct sunlight, in a solar cabinet drier and in hot air cabinet drier. The drying method which had maximum retention of  $\beta$ -carotene was adopted for further development of dehydrated products. Hot air cabinet drying (58 %) followed by solar drying (48 %) had better retention of  $\beta$ -carotene compared to sundrying (29 %). Hence dehydrated carrot products namely carrot chops, carrot shreds and carrot powder were developed using hot air cabinet-drier.

Among the dehydrated carrot products carrot chops (63 %) had better retention of  $\beta$ -carotene. Rehydration ratio of carrot shreds (10.1) was more when compared to carrot chops (8.1). Three recipes were prepared namely curry, *halwa* and biscuit with dehydrated carrot chops, shreds and powder respectively. The sensory evaluation trials, indicated

that carrot *halwa* and biscuit with 10 per cent carrot powder were more acceptable than carrot curry. Among the recipes carrot curry (963  $\mu\text{g}/100\text{g}$ ) had more amount of  $\beta$ -carotene followed by *halwa* (617  $\mu\text{g}/100\text{ g}$ ) and biscuit (240  $\mu\text{g}/100\text{ g}$ ).

The shelf life of dehydrated carrot products was studied for a period of 90 days by analysing moisture, peroxide value, microbial load and  $\beta$ -carotene content at monthly intervals. The percentage increase in moisture was more in carrot powder than shreds and chops. Peroxide value reported after 60 days of storage and the microbial load during storage were very less indicating better shelf life. The  $\beta$ -carotene content of the products gradually decreased during storage, the higher loss being observed in carrot powder.

The dehydrated products especially freshly prepared carrot powder when used in the preparation of laddus, rotis, infant mixes, milk beverages etc. not only adds to the variety but also contributes  $\beta$ -carotene, a precursor of vitamin A. Similarly shreds and chops could be incorporated in coconut *burfi*, vegetable pulav respectively.

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*INTRODUCTION*

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## CHAPTER I

### INTRODUCTION

In India Vitamin A deficiency has long been recognised as one of the major preventable public health problems. Surveys conducted in different parts of the nation have shown that 1-5 per cent of children under 5 years have clinical signs of Vitamin A deficiency (Empowering Vitamin A Foods, 1996). Over 80 per cent of the daily supply of Vitamin A among the Indian population is derived from its precursor  $\beta$ -carotene which is present in many different plant foods. It is commonly observed that many of the households do not use available green leafy vegetables in their daily diet and efforts are being made to develop a wider variety of recipes to encourage the consumption of green leafy vegetables and other carotene rich foods. Several programmes like Vitamin A prophylaxis programme and horticultural intervention programmes are being implemented to reduce the incidence of Vitamin A deficiency. Carotenes are precursors of Vitamin A, an essential nutrient, for maintaining human health. Recently anti-cancer role of  $\beta$ -carotene has been emphasised where, the epidemiological studies of fruits and vegetables with above average carotenoids have been associated with 30-50 per cent lower incidence of several types of cancer including, lung, stomach and skin (Mayne *et al.*, 1994, Menkes *et al.*, 1986, Zeigler, 1989). A multicentric study by Nutrition Foundation of India (1995) on household consumption patterns, revealed that preformed Vitamin A from animal foods was low and contributed no more than 20-25 per cent of the total vitamin A intake. On the contrary,

the consumption of  $\beta$ -carotene containing foods contributed to 60 per cent or more of the total vitamin A at the household level intake. Thus, it was evident that carotene rich foods are the most important dietary sources of vitamin A to the poorer socio-economic rural and urban population in India and the promotion of consumption of  $\beta$ -carotene through fresh fruits and vegetables is quite significant.

Among the roots and other vegetables, carrot is the best source of carotene. In sanskrit, it is called 'garjaru' and 'shikamula'. It is cultivated throughout the world for its fleshy edible roots. It is a cool season crop and is cultivated largely in the hills in southern and central India. Carrot is highly nutritious when taken as such. It finds wide application in the day-to-day use for making curries, sweet meats and soups, and the processed carrots are used for making carrot juice, carrot powder, carrot flakes etc. It occupies an important place in the root vegetables for its multifaceted applications which has in turn resulted in the development of various processing operations for making different products or to extend shelflife.

The discovery that the drying of foods as a suitable method for preservation, until needed is lost in antiquity. Drying of fruits and vegetables has been a common household method of preservation in many a culture and civilization. Dried products weigh only 1/4th to 1/9th of the fresh weight and have advantages like reduction in bulk, unlimited shelflife, ease in handling, transportation and above all low capital investment.

Dehydrated vegetables have been an important food supply in U.S and other parts of the world for military operations especially during war times.

Conventional drying is carried out using sun and various ways of dehydration techniques such as solar drying, tunnel drying, drum drying, spray drying etc are widely in use. Methods used for food preservation by drying should produce maximum drying rate with minimum product damage and economic drying costs. The nutrient losses in dehydration depends on the type of food, length of drying time etc. and varies from nutrient to nutrient.

Dehydrated vegetables in addition to increasing variety in the menu, have a much longer shelf life than fresh vegetables (Chauhan and Sharma, 1993). Moreover, the demand for dehydrated products may also increase in future with the increasing trend in the use of processed and ready-to-eat foods (Shaw *et al.*, 1993a). Quality and preservation of the nutritive value of the product have to be given attention during the manufacture of dehydrated products.

Because of the seasonal nature of the vegetable, efforts were made in the past to extend the shelf life of carrots by dehydration either in the form of cubes/dices or by fermenting, pickling, canning or cold storage. Dehydration is one of the commonly employed method for preserving carrots and methods like hot air drying, solar drying, freeze drying, fluidized bed drying are practiced (Walde *et al.*, 1992).

In view of the increasing demand for natural  $\beta$ -carotene in foods, as a source of vitamin A, the present study was taken up to see the feasibility of dehydration of carrots by three dehydration methods and to see the extent of retention of  $\beta$ -carotene in the products and recipes developed with dehydrated carrots.

Thus, the present study is designed with the following objectives.

### **General objective**

To develop products with dehydrated carrots.

### **Specific objectives**

1. To dehydrate carrots in solar drier, cabinet drier and under direct sunlight and analyse the  $\beta$ -carotene content.
2. To develop the product by adopting the method of drying which has the maximum retention of  $\beta$ -carotene.
3. To analyse the  $\beta$ -carotene content and to assess the acceptability of dehydrated carrot products.
4. To standardize the recipes with dehydrated carrot products and evaluate the acceptability.
5. To study the storage characteristics of dehydrated carrot products.

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*REVIEW OF LITERATURE*

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## CHAPTER II

## REVIEW OF LITERATURE

Sundrying of fruits and vegetables is an ancient simple method of preservation, that has been practiced world over. Dried fruits and more particularly dried vegetables like potatoes, carrots, cabbage, cauliflower and peas became important during World war II, when armies had to be fed with nutritious foods in regions far removed from centres of production of fresh materials. Carrot (*Daucus carota* L.) a popular root vegetable, available almost throughout the world is rich in carotene, vitamins and minerals, finds extensive use in the preparation of various food products.

A review of literature on nutrient composition, utilisation of carrots, preservation of carrot by various dehydration techniques and the effect of dehydration on nutrient quality is discussed under the following heads.

- 2.1 Production of vegetables
- 2.2 Composition and nutritive value of carrots
- 2.3 Utilisation of carrots
- 2.4 Preservation of vegetables by various methods of dehydration.
- 2.5 Dehydration of carrots
- 2.6 Effect of pre-treatment on quality characteristics of dried products.
- 2.7 Effect of drying process on physical characteristics and nutrient quality of dehydrated products.

- 2.8 Rehydration characteristics of dehydrated carrots.
- 2.9 Effect of cooking on the  $\beta$ -carotene content of carrots.
- 2.10 Shelf life of dehydrated products.

## 2.1 PRODUCTION OF VEGETABLES

India has diverse agro-climatic zones which makes it possible to grow a variety of fruits and vegetables. In the world horticultural scenario, India ranks first in the production of fruits and second only to China in the production of vegetables. In recent years, on an average, there is an increased production of fruits and vegetables. The data shows an increase in the production of fruits from 38.6 million tonnes during 1994-95 to 46.97 million tonnes during 1996-97. The production of vegetables during 1995- 96 (Bansal, 1998) is as follows :

**Table 1 : Production of vegetables during 1995-96**

Vegetables	Production (in million tonnes)
Potato	18.8
Brinjal	6.4
Tomato	5.5
Onion	4.1
Okra	4.0
Cabbage	3.9
Cauliflower	2.5
Peas	2.3
Others	24.1
<b>Total</b>	<b>71.6</b>

Bansal, 1998.

The production of vegetables was further increased to 80.80 million tonnes in 1996-97 (Food Digest, 1998).

## 2.2 COMPOSITION AND NUTRITIVE VALUE OF CARROTS

The chemical composition of carrots in respect of dry matter, sugars, protein, amino acids, fat, vitamins, crude fibre, flavours, enzymes and mineral contents has been reported by Choudary (1991), Kaur (1976) and Pruthi (1980). The carrot roots contain 88.82 to 92.43 per cent moisture. They are reported to contain 1.67 to 3.35 per cent reducing sugars, 1.02 to 1.18 per cent non-reducing sugars and 2.71 to 4.53 per cent total water soluble sugars.

Otasuka and Take (1969) found sucrose, maltose and glucose to be responsible for sweetness of carrots. The protein content of carrots is reported to vary with the variety and size of the root from 0.77 to 1.26 per cent on fresh weight basis. Otasuka and Take (1969) suggested that the taste of carrot is mainly due to the presence of glutamic acid and the buffer action of amino acids.

Krachanov and Kirtschev (1980) reported that carrot roots contain pectin which is similar to citrus pectin in respect of chemical properties.

Carrot roots are reported to contain very little oil, about 0.2 per cent on fresh weight basis. The main fatty acids reported are palmitic, oleic, linoleic and linolenic acid.

Bajaj *et al.* (1980) reported that carrots contain 8.2 to 11.4 mg/100 g of carotene and that  $\beta$ -carotene content in carrots varied from 0.85 to 8.5 mg/100 g.

Several carotenoid fractions in raw carrot have been reported by Baloch *et al.* (1977) and Ogunlesi *et al.* (1979), the major being  $\alpha$ - and  $\beta$ -carotene accounting for about 83 per cent.

Harris *et al.* (1950) reported that the tocopherol content of carrot was almost 100 per cent in the  $\alpha$  form which varies from 0.11 to 0.5 mg per 100 g.

Kaur *et al.* (1976) and Pruthi *et al.* (1980) reported that the total ash of carrot ranged from 0.48 to 1.1 per cent on fresh weight basis.

The flavour of fresh carrots has been attributed to high sugar levels, predominant terpenoid volatiles such as terpinolene and caryophyllene (Howard *et al.*, 1995).

### 2.3 UTILISATION OF CARROTS

Carrot is universally accepted vegetable and can be consumed in raw or cooked form.

Preparation of carrot flakes was suggested by Stephens *et al.* (1960) where in fresh unpeeled carrots were cooked, commuted made into puree and dried for 35 sec in a drum drier, which retained good typical carrot flavour and might be stored for 24 months at 0°F and 68°F when packed in an atmosphere of nitrogen.

Maur *et al.* (1979) suggested the preparation of carrot puree by cooking carrots in water in 4 : 1 weight ratio till soft, made into pulp and Sterilized at 121°C for 50 min.

Saldana *et al.* (1980) developed an acceptable carrot pie filing of equal or better nutritional value when compared with pumpkin.

Hess (1980) suggested the preparation of fried carrot chips by frying the slices in oil with constant agitation, which contained 35.40 per cent oil and had a typical flavour not resembling the traditionally cooked carrots.

Carrot *halwa*, a popular sweetmeat of North India is prepared by cooking shredded carrot with sugar and moderately frying in hydrogenated oil (or) pure ghee with dehydrated milk (Khoa) and cashewnuts, almonds, grated coconut, raisins as topping and cardamom as flavouring agent, which can be stored well for about 3-4 days.

Sampathu *et al.* (1981) developed a suitable recipe and the process of canning carrot *halwa*, without affecting the quality.

Grewal and Jain (1982) reported that carrot juice beverage may be prepared by incorporation of 0.6 per cent common salt, 8 per cent sugar and 0.3 per cent citric acid. Further, a milk based carrot juice beverage may also be prepared by blending 20 per cent carrot juice into skim milk and the product may be sterilized at 116°C for half an hour.

Carrot preserve (conserve) is prepared in North India, which contains about 68-70 per cent sugars. The popularity of carrots in the form of its preserve may be due to its nutritive role for supply of  $\beta$ -carotene. There is a general complaint of its getting sour during storage. Beerh *et al.* (1984) found that second cooking given to the product after 4 to 6 days of first cooking resulted in product having required TSS and free from spoilage.

Koryachkina *et al.* (1984) investigated the possibility of use of carrot puree in dough for improving the quality of bakery products and found that carrot puree had a physical and chemical effect on the components of flour, changing the structural and mechanical properties of the dough gluten and starch and capable of improving the quality of finished product.

Preparation of carrot nectar, carrot apple cocktail by Szilagyi-Toth *et al.* (1985) have also been reported.

Walde *et al.* (1992) suggested drying of carrot gratings for which the drying rates would be faster, the dried product could find direct application for making carrot powder and rehydrated gratings for making *halwa* and other products.

Bhavani and Kamini Devi (1996) developed maize puff using curry leaf powder and carrot powder at levels ranging from 5 to 40g per cent of product, where the carrot powder and curry leaf powder incorporated products were reported to be more acceptable than control.

**Table 2 : Dehydration techniques used for fruits and vegetables in large scale processing units**

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<b>I Cross flow drying</b>		
a.	Cabinet drying	Fruits and vegetables
b.	Tunnel drying	Fruits and vegetables
c.	Pneumatic drying	Cooked potatoes
d.	Continuous conveyer drying	Fruits and vegetables
<b>II Thorough flow drying</b>		
a.	Kiln drying	Apples
b.	Tower drying	Fruits and vegetables
c.	Belt trough drying	Vegetables
d.	Bin drying	Vegetables
e.	Fluidized bed drying	Vegetables
III	Drum drying	Fruit and vegetables, Purees, Paste, Sludge
IV	Spray drying	Fruits and vegetable juices
<b>V Puff drying</b>		
a.	Explosive puff drying	Fruits and vegetables
b.	Vacuum puff drying	Fruits and vegetable juices
VI	Freeze drying	Fruits and vegetables
VII	Accelerated freeze drying	Fruits and vegetables
VIII	Foam-mat drying	Fruit juices
IX	Microwave drying	Fruits and vegetables
X	Dehydrofreezing	Fruits and vegetables
XI	Osmotic drying	Fruits and vegetables

---

Sources : Cruess (1958); Debrosier (1970); Van Arsdel *et al.* (1973)

## 2.4 PRESERVATION OF VEGETABLES BY VARIOUS METHODS OF DEHYDRATION

The terms drying and dehydration tend to be used synonymously but the former is used more often when the drying is done by natural agents such as the Sun (or) the atmosphere, whereas the latter is used when mechanical methods are employed.

Utilisation of solar energy for drying foods has been in practice since ancient times. Advantages of using solar energy for drying are that, the energy is free, non-polluting, in- exhausting and readily available in tropical and sub-tropical countries. Sundrying has not been used for drying vegetables except on a very limited scale for home use, due to the poor quality of the products obtained especially with regard to colour and flavour by direct exposure to sun as often practiced and the material is also susceptible to contamination because of open yard drying. This disadvantage is overcome in solar drying, where the materials are covered under glass covers and solar radiation is concentrated on the surface. Thus, the materials are not subjected to outside contamination.

Normally vegetables are dried in hot air driers where the heat transfer mechanism is by way of convection either with natural air circulation or forced air circulation. Hence the hot air driers are considered under the terminology of convective driers, cabinet driers or tunnel driers. Cabinet driers are suitable for drying fruits and vegetables in batch operation while tunnel driers are used for continuous operation.

Freeze drying of food materials is another classical technique of preservation by drying where there is no shrinkage of food materials.

Fluidized bed drying technique is also one of the most common drying techniques employed in food processing, which results in the production of less expensive dried food sample.

Several new techniques of dehydration have been successfully established and applied in commercial practice to meet the ever increasing demands of space age as well as the general consumers demand.

The dehydration techniques used for fruits and vegetables in large scale processing units is given in Table 2.

## 2.5 Dehydration of carrots

Efforts were made in the past to extend the shelf-life of carrots by dehydration either in the form of cubes/dices (or) by fermenting, pickling, canning or cold storage. Dehydration is one of the commonly employed method of preserving carrots and methods like hot air drying/cabinet drying, solar drying, freeze drying, fluidized bed drying and microwave drying are practiced.

Sullivan *et al.* (1981) studied the dehydration of carrot by a continuous explosion puffing system (CEPS) and reported that carrots dried by this process dry three times faster than those by conventional hot air drying.

Carbonell *et al.* (1985) studied the effect of various operating parameters on carrot drying and reported that the final moisture content of solar dehydrated carrots to be of the order of 10 per cent (wet basis) which however could be brought down to 6.3 per cent if the carrots were subjected to drying with ambient air before solar drying.

Mandhyan *et al.* (1988) compared the drying times of peas, spinach, carrot and cabbage dehydrated in sun and solar cabinet drier and observed that drying time was 15 to 20 per cent lower in solar drier than by direct sundrying.

Berna *et al.* (1988) conducted a study to assess the sensory quality characteristics of carrots dried in a pilot scale solar drier with a chamber of  $8.6 \text{ m}^2$  evaporation surface and compared with open drying in sun. It was found that the carrots dried in pilot scale drier possessed good sensory quality characteristics.

Jayaraman *et al.* (1991) studied the drying behaviour and quality characteristics of green peas and carrots by three modes of drying viz., solar cabinet, direct and hot air drying and reported that sundrying was faster than drying inside solar cabinet and in hot air drier. They also found that  $\beta$ -carotene loss was more in sundried and solar dried carrots compared to hot air cabinet dried carrots.

## 2.6 EFFECT OF PRE-TREATMENT ON QUALITY CHARACTERISTICS OF DRIED PRODUCTS

Dehydration is normally preceded by pretreatment operations like blanching, sulphiting, freezing, starching and sucrose and sodium chloride dipping.

Mazza (1983) reported that pre-treatments like blanching, sulphiting, freezing, starching, sucrose and sodium chloride dipping before air drying would effect the moisture transport and quality.

### 2.6.1 Effect of blanching

Blanching, defined as partial cooking is used in the preparation of vegetables before processing. Blanching brings about number of changes.

#### a) Change in enzyme activity

Blanching has been successfully employed to control the enzyme activity in vegetables.

Giebriel *et al.* (1977) reported about the heat resistance parameters of peroxidase of carrots and the activation energy of peroxidase from carrots to be 16060 Kcal/mol.

Glossock *et al.* (1982) reported considerable reduction in peroxidase activity in carrots after blanching.

Baruffaldi *et al.* (1983) found that 99.4 per cent of peroxidase activity may be destroyed during blanching at 92°C for 4 min.

## b) Changes in carotenoids

Carotenoid pigments present in plants provide attractive colours to the foods and are nutritionally important as precursors of vitamin A. Carotene is not generally affected as it is not water-soluble and blanching appears to protect against carotene losses during frozen storage in comparison to unblanched vegetables.

Carotenoids are mainly responsible for the colour of carrots. On boiling, the colour of carrot changes. Borchgrevink *et al.* (1966), suggested that the colour of cooked carrots is related to carotene content.

Baloch *et al.* (1977) studied the effect of blanching on carrots and concluded that loss of soluble solids by leaching during blanching resulted in increased carotenoid destruction but resulted in reducing the non-enzymatic browning.

Mirza and Morton (1977) found that the colour change during blanching, in carrots was not due to formation of browning compounds but due to change in cellular structure of carrots. It was reported that some loss of carotene occurred from sliced carrots through damaged cell walls in the blanching media when hot water blanching was used.

Schaller and Vamos Vigyazo (1980) reported that blanching did not improve or stabilize significantly the colour of the prepared product.

### c) Texture

Texture is one of the most important quality attributes of processed vegetables. Pectin, a polysaccharide is widely believed to contribute to the texture of fruits and vegetables (Jarvis, 1982).

Heatherbell *et al.* (1971) reported that blanching treatment leads to initial decline in carrot aroma and textural loss and additional thermal processing such as canning results in more severe effects.

Lee *et al.* (1979) reported that low temperature blanching gives a firmer texture than high temperature treatment.

Kalra *et al.* (1987) reported losses in soluble sugars, minerals and pectic substances and other solutes from carrots during processing.

Bourne (1989) reported that blanching vegetables at 60-65°C before canning resulted in significantly firmer products.

Aguilera and Stanley (1990) reported that heating produces structural alterations in plant tissue that influence texture. The general result being softening brought about by loss of turgor pressure and occluded air, thermal degradation of middle lamella pectins and other cell wall polysaccharides and starch gelatinization.

### 2.6.2 Effect of sulphiting, sodium chloride and sucrose dipping

Sterling (1968) reported that firmness of carrots during processing increase in sucrose solution and solutions with divalent cations and decreases with monovalent cations.

Barbosa (1981) studied the effect of thickness of carrot slices and solute treatment (20 % NaCl, 10 % sucrose, 20 % glycerol) on the quality of dehydrated carrots and found that solute treatment improved the sensory properties of dehydrated product.

Baloch *et al.* (1981) reported that gaseous sulphite treatment (0.6% sodium metabisulphite) for 6 minutes retarded carotenoid breakdown and decreased discolouration of dehydrated carrots.

Carbonell *et al.* (1984) studied the effect of salt treatment of carrots before convective drying and concluded that the salt dip treatment affects the moisture transport and product quality. The drying rates were lowered because of decrease in water diffusibility in salted carrots, inspite of the activation energy for water diffusion during drying being same in both salted and unsalted carrots.

Carbonell *et al.* (1987) studied the effect of storage temperature on some quality factors of salted carrots dehydrated with ambient air and found that after drying, agar plate counts of salted carrots (0.112 kg of NaCl/kg of dry matter) dehydrated with air at 23°C were 70-80 per cent lower than those of the same dehydrated product with no salt added.

Kalra *et al.* (1987) suggested that for dehydration, blanching of carrot shreds in 50 per cent sugar solution not only imparts an attractive colour but also improves its organoleptic and keeping quality.

Mohammed and Hussein (1994) treated carrots with sodium metabisulphite before drying and obtained a  $\beta$ -carotene retention twice as good when compared with no metabisulphite and also suggested that air drying at 40°C will have a better retention of  $\beta$ -carotene than any higher temperature.

Zhao and Chang (1995) showed that 2.5 per cent concentration corn starch led to better retention of  $\beta$ -carotene, in dehydrated carrots.

### 2.6.3 Freezing

Arya *et al.* (1982) reported that freezing before conventional hot air drying considerably improved the stability of carotenoids and lipids in dehydrated carrots.

## 2.7 EFFECT OF DRYING PROCESS ON PHYSICAL CHARACTERISTICS AND NUTRIENT QUALITY OF DEHYDRATED PRODUCTS

### 2.7.1 Physical characteristics

Method of dehydration greatly affects the quality of the dehydrated product. Quality refers to the degree of perfection present and involves characteristics such as aroma, flavour, colour, texture and shape/size of foods.

Falconer *et al.* (1964) reported development of unpleasant off-flavour in carrots, dehydrated by tunnel method during storage in the presence of oxygen. This was due to the formation of  $\beta$ -ionone formed by the oxidation of  $\beta$ -carotene.

Andrreotti *et al.* (1981) found that carrot pre-dried in air lost 50 per cent of their weight followed by freeze drying (air freeze drying) which had half the volume of the production obtained by freeze drying alone and concluded that air freeze dried carrots had deeper colour.

Welder *et al.* (1981) studied the effect of physical preservation methods and storage on the quality of carrots and found that freeze drying gave a better product with improved taste and texture.

Bolin and Salunke (1982) reported that drying conditions that involve exposure of the material to direct solar radiation result in loss of quality and vitamin content and also reported that papaya and jack fruit dried under solar tents rated higher in appearance, odour, colour, flavour, texture and general acceptability than conventional sun-dried products.

Camacho (1983) studied the effect of air drying of carrots under various conditions and found that freeze drying resulted in a better quality product in respect of colour than air drying.

Darman *et al.* (1983) studied the effect of thermal dehydration on cellulose structure of carrot cell wall and reported that thermal dehydration

causes partial destruction of cellulose macromolecules. The structural changes affect the quality of the dried carrot.

Eichner and Wolf (1983) found that the quality retention may be improved by lowering air temperature. It was also suggested that initial drying at high temperature and final drying at low temperature leads to better quality retention.

Boeh-Ocansey (1984) reported that freeze drying of carrots in vacuum gave a better quality product than atmospheric freeze drying in terms of colour and aroma.

### 2.7.2 Nutrient quality

Processing of foods leads to destruction of nutrients as they are sensitive to the pH of the solvent, to oxygen, light and heat or a combination of these. Nutrient deterioration in foods is gradual and depends on method of process employed.

Sundrying is the oldest and easiest method of preservation based on reducing moisture content of vegetables to a very low level and the concentration of soluble solids becomes so high, making the product chemically stable (Encyclopaedia of Food Science, Food Technology and Nutrition, 1991).

Apgar *et al.* (1959) explained that greater loss of moisture in microwave heated products was due to a greater rise in post oven temperature causing more dehydration and greater shrinkage.

Labuza (1972) reported that carotene is degraded by free radical oxidation mechanism with the degree of oxidation depending on the drying temperature.

Salem and Hegazi (1973) analysed  $\beta$ -carotene in sundried apricots and reported that a large part of carotenes were lost during processing and drying.

The results of the study conducted by Mc Dowel (1973) revealed that drying of vegetables under shade promoted high carotene retentions when compared to direct sundrying.

Bolin and Stafford (1974) found that  $\beta$ -carotene loss was highest (30 %) in sundried apricot as compared to dehydrated and shade dried products (about 10 %).

Arya *et al.* (1979) observed rapid degradation of  $\beta$ -carotene during air-drying of carrots.

Maeda and Salunke (1981) reported minimum retention of carotene in leafy vegetables dried in open sunshine.

In another study by Camacho (1983) on air drying and freeze drying of carrot under various conditions found that freeze dried carrots had better retention of  $\beta$ -carotene.

Rukmini *et al.* (1985) dried slices of fresh carrots in hot air at 60°C to 70°C then milled and sieved to produce carrot powder, and estimated

the  $\alpha$ - and  $\beta$ -carotene content of the carrot powder. The final  $\alpha$ - and  $\beta$ -carotene contents of carrot powder were found to be 18 per cent and 28 per cent respectively of the original amount.

Park (1987) studied the retention of  $\beta$ -carotene in carrots, broccoli and spinach by subjecting them to various drying methods i.e vacuum, freeze drying or microwave drying. Among carrots, broccoli and spinach, on an average, spinach retained a higher percentage (80 %) of its carotenes than carrots (41.5 %) and broccoli (29.6 %) independent of the drying methods.

Bao and Chang (1994) observed between 45 per cent to 55 per cent of carotene loss during the freeze drying process of carrots.

## 2.8 REHYDRATION CHARACTERISTICS OF DEHYDRATED CARROTS

Removal of water from foods inevitably leads to the precipitation of solutes and aggregation of insoluble structural components with consequent effects on texture and rehydratability. Adequate rehydration is essential in order for the food stuff to have satisfactory eating quality.

Sterling (1955) stated that individual cell walls lose rigidity upon heating and separation of cells might take place when intercellular pectic materials were softened.

Wager (1958) found in vegetable tissue that the elasticity of cells and the swelling power are important for good rehydration. Both are reduced by substantial heat treatment and drying.

Van Arsdel and Copley (1963) observed that drying can diminish the osmotic properties of cell walls.

Rahman (1972) suggested that increased cooking times before freeze drying could improved rehydration via textural and composition changes in cell walls.

Curry *et al.* (1976) incorporated sodium chloride into freeze-dried carrot slices and found to have marketed effect on rehydration and highest rehydration ratios were obtained at the 0.2 M sodium chloride treatment.

Eusebio *et al.* (1980) reported that carrots pretreated with sulphite (0.2 % KMS for 2-3 min.) starch (2.5 % for 1 min.) or blanched in boiling water resulted in rehydration ratios of 6.2 to 5.7, 8.2 to 8.5 and 4.2 to 4.3 respectively.

Mudahar (1989) concluded that lower rehydration ratio of starch treated carrots might be due to the penetration of starch into the carrot tissue when boiled in starch solution causing changes in the texture and rehydration.

Seow (1992) reported that blanching treatment given prior to dehydration affects the texture of the rehydrated products. Greater rehydration ratio and firmer texture of the rehydrated products were

reported in case of carrots, celery and green beans when low temperature, long time blanching is used instead of conventional single stage, high temperature short time method.

Zhao and Chang (1995) reported that diced carrots (1 cm cubes) treated with 2.5 per cent corn starch had a lower rehydration ratio than carrots soaked in distilled water at 65°C for 8 min or 0.05 per cent sulfite treated or 0.2 per cent sulfite treated carrots after dehydration. It was opined that polysaccharide gel absorbed on the cell walls probably caused the low rehydration ratio.

Zhao and Chang (1995) also suggested that dehydrated carrots with higher rehydration ratio have a higher yield product and also have softer texture than dehydrated carrots with low rehydration ratio. These are preferred for cake and muffin mixes because a high moisture holding increases final product tenderness. And dehydrated carrots with low rehydration ratio are preferred for stew mixes because their texture can hold up better after cooking.

## 2.9 EFFECT OF COOKING ON $\beta$ -CAROTENE CONTENT OF CARROTS

Methods of cooking also influence the nutrient content of vegetables, in particular leaching losses and oxidative changes are considered as deteriorative processes.

Borchgrevink and Helen Charley (1966) conducted a study on colour of cooked carrots related to  $\beta$ -carotene content and reported that carrots cooked in a sauce pan had more crude carotene (53.8  $\mu\text{g/g}$ ) than did those cooked in a pressure sauce pan. And also those cooked for 2 min in a pressure sauce pan had less (40.3  $\mu\text{g/g}$ ) than those cooked for 50 sec (48.1  $\mu\text{g/g}$ ). It was suggested that differences in the carotene content of cooked carrots were due to destruction of all-trans  $\beta$ -carotene and some isomerization of the cis-form.

Dikshit *et al.* (1988) estimated the losses in carotene content due to cooking for some Indian recipes by HPLC method and reported that 25 g of carrot *halwa* prepared from fresh carrots contained 181  $\mu\text{g}$  of  $\beta$ -carotene and resulted 78 per cent loss of  $\beta$ -carotene.

Vinodini Reddy *et al.* (1995) estimated the carotene content in common Indian recipes and found that grating and prolonged heating as in carrot *halwa* resulted in only 48 per cent loss of  $\beta$ -carotene. The percentage retention of  $\beta$ -carotene in carrot without lid, with lid, steaming and sauteing was found to be 67, 65, 72 and 74 respectively.

## 2.10 SHELF LIFE OF DEHYDRATED PRODUCTS

Dehydration brings component molecules into closer proximity, thereby increasing the likelihood that they will interact. The most susceptible nutrients to dehydration and dried storage conditions are unsaturated lipids, proteins, vitamin C and  $\beta$ -carotene. The most likely reason for the loss of fat soluble vitamins in dehydration and dried food storage is the

interaction between them and the free-radicals generated during oxidation of lipids. Deterioration of chemical and physical properties of dehydrated carrots causes major changes in their quality and stability during storage.

Safe microbiological quality of foods refers to the state of food and food products, which are free from pathogenic bacteria and have lower threshold number of those bacteria which are unlikely to cause spoilage of food at given storage temperature (Elliott and Michener, 1961). The detection of pathogenic bacteria in foods help in controlling food borne infections, the estimation of level of bacterial contamination in food allows assessing the shelf-life of food and mode of storage.

Unlike most enzymes, lipases and lipoxygenases remain active even in very dry foods with water activities less than 0.3. Lipoxygenases are present in spices, wheat flour and vegetables and will catalyse the oxidation of unsaturated fats in dried and drying produce, more rapidly generating peroxides and volatile breakdown products.

Chace, Noel and Pease (1941) found that when young carrots were blanched and then dehydrated in a tunnel drier, the starch which had been gelled by blanching seals the tissues together where completely dried samples were hard and brittle and showed less carotene loss and the off odours also less pronounced than in older dehydrated carrots.

Reeve (1943) suggested the denaturation of the cytoplasm, which contains the carotene and oils results from heating, drying or freezing treatments. Some of the off odours of dehydrated carrot are related to oil

and carotene oxidation. Preservation of carotene in the blanched, dehydrated carrot is partially effective according to the amount of carotene dissolved in and coated by the oil and also according to the rate at which the oils oxidize.

Reeve (1943) quoted that the problems arising from 'Off odours' apparently cannot be solved by blanching alone. Since carrot oil contain atleast one unsaturated fatty acid, it is reasonable to regard the freed oils in the root (after dehydration) as a source of future off odours. At the same time, it is also evident that even in blanched, dried carrots, carotene loss occurs over a period of time.

Niranjan Singh Sekhon (1943) studied the effect of storage on the carotene content of dehydrated vegetables and reported that dehydrated vegetables on storage showed a progressive loss in their carotene content. Dehydrated carrots stored at 37°C in sealed containers had 36, 41.5, 62.9 percentage loss of carotene at 27, 83 and 143 days of storage respectively. He also observed that losses in carotene content on storage are quite considerable, being rapidly during the first 4 weeks.

Tomkins *et al.* (1944) reported that the proportion of  $\beta$ -carotene oxidized during storage was higher at 8.2 per cent moisture level than at 5.4 per cent moisture level.

Reese H. Vaughn (1951) reported a marked reduction in number of microorganisms if the vegetable were treated before dehydration or partially dehydrated (25-30 % moisture) with epoxides (ethylene oxide).

Falconer *et al.* (1964) observed that loss of carotene by oxidation is closely related with development of off-flavour in accelerated freeze dried carrots.

Crivelli and Polesello (1973) stored carrot slices at  $-20^{\circ}\text{C}$  for a long time (12 months) and observed 60 per cent loss of carotenes.

Welder *et al.* (1981) obtained a higher retention of carotene in carrots by freeze drying than by heat drying and in such a way the carrots remained acceptable for nine months.

Baloch *et al.* (1981) reported that sulphite treatment, using 0.6 per cent sodium metabisulphite for 6 min. retarded carotenoid breakdown, inhibited lipid oxidation and decreased discoloration of dehydrated carrots.

Arya *et al.* (1982) reported that carotenoids were relatively stable when water activity ranged from 0.32 to 0.57, equivalent to moisture contents from 8 to 12 per cent in freeze dried carrots.

Goldman *et al.* (1983) showed that the oxygen content in the medium is the crucial factor acting the carotene decoloration and a small percentage of oxygen in contact with carotene has a dramatic effect on its shelf-life.

Simpson (1985) also found oxidation was the major cause of  $\beta$ -carotene destruction. Exclusion of oxygen during storage of powders would extend their shelf-life.

Taylor *et al.* (1986) suggested that reaction of sulphite with carbonyl groups, reducing sugars, and disulphide bonds in proteins and enzymes may be responsible for the better retention of carotenoids in dehydrated carrots treated with sodium metabisulphite.

Baloch *et al.* (1987) reported that the storage life of dehydrated unblanched carrots during storage at 37°C was only 31 days which increased to 56, 106 and 176 days on blanching for 5 min and sulphiting unblanched carrot to 1723 µg/g SO<sub>2</sub> and by both blanching for 1 min. and sulphiting to 2325 µg/g SO<sub>2</sub> prior to dehydration respectively. It was also suggested that combination of sulphiting and blanching to a level sufficient to just inactivate peroxidase systems to be the most effective method for extending the storage life of the product.

Baloch *et al.* (1987) also reported that carrots with a sulfite concentration of 1584 to 9621 ppm and carrots blanched for 3 to 5 min had 129 to 138 mg/100 g of carotenoids. After 4 months storage, carotenoid levels were 67.4 to 85 per cent of initial values and 50-62 per cent after 14 months storage.

Zhao and Chang (1995) reported that low concentration of sulphite (0.05 % 222 ppm) residual sulphite) can reduce loss of redness in dehydrated products during storage, however did not improve retention of β-carotene during storage.

Wagner and Warthesen (1995) reported that encapsulation with various dextrose equivalent (DE) hydrolysed starches affected stability of  $\alpha$ - and  $\beta$ -carotene in spray-dried carrot powders. Degradation of  $\alpha$ - and  $\beta$ -carotene during storage of the powders at temperatures ranging from 37°C to 65°C followed first order kinetics and both degraded at the same rate.

Desobry *et al.* (1998) suggested that during storage of carrots, spoilage occurs due to high relative humidity, which ultimately results in enzymatic degradation of the structure allowing carotenoid to oxidize.

Lakshmi (1998) stored green leafy vegetable powders in cast polypropylene and metallized polypropylene pouches. It was observed that the packaging materials were permeable to oxygen and watervapour transmission, which resulted in the oxidation of  $\beta$ -carotene during storage.

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*MATERIALS AND METHODS*

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## CHAPTER III

### MATERIALS AND METHODS

Carrots are consumed as fresh or in cooked form along with other vegetables. Attempts have been made by several workers to process this vegetable as canned, dehydrated, pickled, juice, preserve, puree, flakes or as a frozen product.

Since dehydration is an easy and inexpensive method of preservation, this work has been taken up to develop dehydrated carrot products and standardizing the recipes with dehydrated carrot products. In view of the present day focus on utilisation of solar energy based equipments, it was also proposed to screen the method of drying which retains maximum  $\beta$ -carotene content in dried carrots. The methodology adopted in this work is being described in the following heads.

- 3.1 Dehydration of carrots by using solar drier, hot air cabinet drier and direct sunlight, screening the drying method with maximum retention of  $\beta$ -carotene and evaluating the acceptability of dehydrated carrots.
- 3.2 Development of dehydrated carrot products, assessing their acceptability and  $\beta$ -carotene content.
- 3.3 Assessment of the rehydratability of dried carrot products.
- 3.4 Standardisation of recipes with dehydrated carrot products, their organoleptic evaluation and analysis of  $\beta$ -carotene content.
- 3.5 Suitability of biscuits as supplementary food.

3.6 Assessment of shelf life of dehydrated carrot products.

3.7 Statistical analysis

### 3.1 DEHYDRATION OF CARROTS BY USING SOLAR DRIER, CABINET DRIER AND DIRECT SUNLIGHT

Carrots were made into small pieces and subjected to three methods of drying i.e. in solar drier, cabinet drier and under direct sunlight in order to assess the best method of drying which has less loss of  $\beta$ -carotene from carrots.

#### 3.1.1 Procurement of raw materials

Carrots were purchased in bulk from local market at Hyderabad. Care was taken to select fresh carrots with bright orange colour.

#### 3.1.2 Pretreatment of carrot

The carrots were first washed in water, trimmed and lightly peeled to remove outer skin. Carrot gratings of uniform size (0.5 cm length) were prepared using a household grater, and were then blanched in boiling water (92°C) for 3 minutes containing 0.2 per cent potassium metabisulphite and 5 per cent sucrose. The blanched carrot gratings were dried in solar drier, cabinet drier and direct sunlight to obtain uniform moisture content of 10 to 11 per cent.

### 3.1.3 Drying/dehydration of carrot gratings

The blanched carrot gratings were divided into 3 equal parts and spread uniformly in a single layer on aluminium trays (2' x 4") for drying in solar drier (SDM - 8 kgs, manufactured by Rao Associates, Jublee Hills), Cabinet drier (SDM - 8 kgs manufactured by Rao Associates. Jublee Hills) and under direct sunlight. During the drying process the maximum atmospheric temperature ranged from 37°C to 41°C. The material was turned periodically for every 2 hrs to ensure uniform drying. The temperature and time taken for dehydrating carrot gratings by different methods is given in Table 3.

**Table 1 : Time and temperature followed for the preparation of dehydrated carrot gratings by three methods of drying**

	Drying method	Time Hrs & Min.	Temperature °C
1.	Solar drier	4 hr 30 min.	35 - 53
2.	Cabinet drier	3 hr 30 min.	45 - 55
3.	Direct sunlight	5 hr 30 min.	32 - 42

### 3.1.4 Screening the drying method with maximum retention of $\beta$ -carotene in carrots

The dehydrated carrot gratings were analysed for  $\beta$ -carotene to screen the method of drying which retains maximum  $\beta$ -carotene content.

#### Analysis of moisture

Moisture content of fresh and dried carrot gratings was determined by standard AOAC method (AOAC, 1984).

## Analysis of $\beta$ -carotene

Fresh carrots and the carrot gratings dried by three methods of drying viz. by direct sunlight, solar and cabinet driers were analysed for  $\beta$ -carotene content.  $\beta$ -carotene was determined by using reverse phase High Performance Liquid Chromatography (HPLC) by method of Zakaria and Simpson (1979). The carotenoids were extracted using acetone and hexane and the filtrates were used for analysing the  $\beta$ -carotene content. The detailed procedure is given in Appendix A. The amount of  $\beta$ -carotene in carrot gratings was determined as follows:

$$\beta\text{-carotene (mg/100 g)} = \text{PA} \times \frac{\text{ARF} \times 100}{0.02} \times \frac{100}{\text{wt. of the sample}}$$

Where

PA = Peak area of the sample

ARF = Area resolution factor of standard  $\beta$ -carotene as obtained from the standard graph.

### 3.1.5 Evaluation of the acceptability of dehydrated carrots obtained by three methods of drying

The dehydrated carrot gratings were subjected to sensory evaluation trials (Jellinek, 1964) by trained panel of judges consisting of 10 members from Post Graduate and Research Centre (PGRC), Rajendranagar. A score card was developed for sensory evaluation to assess the various quality attributes like appearance, colour, texture, flavour and overall acceptability

and numerical scores were assigned to each attribute.. The score card used for sensory evaluation is given in Appendix B.

### 3.2 DEVELOPMENT OF DEHYDRATED CARROT PRODUCTS, ASSESSING THEIR ACCEPTABILITY AND ANALYSIS OF $\beta$ -CAROTENE CONTENT

Dehydrated products viz., carrot chops, carrot shreds, carrot chips and carrot powder were prepared by dehydrating carrots in Cabinet drier. For this purpose the carrots were first subjected to pre-treatment operations like washing, trimming, chopping, slicing or grating which were then blanched and dried. The processing conditions followed for preparing dehydrated carrot chops, shreds and powder are given in Table 4.

**Table 4 : Processing conditions followed for drying carrots in cabinet drier**

Name of the product	Blanching								Drying	
	Size	Water (lt)	Sucrose (g)	KMS (g)	Starch (g)	Salt (g)	Time (min)	Temp (°C)	Time (hr)	Temp (°C)
Carrot chops	1/4 inch	1	-	2	20	10	3	92	11-12	45°-55°
Carrot shreds	0.5 cm length	1	50	2	-	-	3	92	7-8	45°-55°
Carrot chips	1.5 mm thick slices	1	-	2	20	10	3	92	5-6	45°-55°
Carrot powder	0.3 cm cubes	1	-	2	20	10	3	92	10-11	45°-55°

The blanched carrot products were spreaded uniformly in a single layer on aluminium trays (2' x 4") and the position of the trays inside the cabinet was shifted in rotation from bottom upwards periodically to

ensure uniform drying. The temperature ranged from 45°C to 55°C during the drying process and time taken for drying ranged from 6 hrs to 11 hrs. The carrot powder is made by grinding 0.3 cm dried carrot pieces in an electric grinder and sieved through 100 mesh sieve.

### 3.2.1 Analysis of moisture and $\beta$ -carotene content

Moisture and  $\beta$ -carotene content of dehydrated carrot products were estimated by standard AOAC method and reverse phase high performance liquid chromatography respectively as mentioned above.

### 3.2.2 Evaluation of the acceptability

The three dehydrated carrot products viz., carrot chops, carrot shreds and carrot powder were subjected to sensory evaluation to evaluate their acceptability as given in 3.15 (Appendix B).

## 3.3 ASSESSMENT OF REHYDRATABILITY OF DRIED CARROT PRODUCTS

The rehydratability of dehydrated carrot chops and carrot shreds was assessed by soaking 5 g of the product in 200 ml of distilled water. The weight of the product and its rehydration ratio were estimated at 1, 2, 3, 4, 5, 6, 8 and 24 hrs intervals. Rehydration ratio was calculated as follows :

$$\text{Rehydration ratio} = \frac{\text{Weight of the soaked product}}{\text{Weight of the dehydrated product}}$$

### 3.4 STANDARDIZATION OF RECIPES WITH DEHYDRATED CARROT PRODUCTS, THEIR ORGANOLEPTIC EVALUATION AND ANALYSIS OF $\beta$ -CAROTENE CONTENT

Three recipes were standardized by using one dehydrated carrot product in each recipe. Thus, carrot curry, *halwa* and biscuits were prepared with dehydrated carrot products viz., chops, shreds and powder respectively. The ratio of ingredients used and processing methods are given in Table 5.

**Table 5 : Ratio of ingredients used and processing conditions of recipes standardized with dehydrated carrots**

Recipe	Ingredient	Amount (g)	Processing time and temperature
1. Carrot curry	Carrot chops	350	Shallow frying at 70-75°C for 20 min.
	Onions	75	
	Green chillies	2	
	Seasonings	15	
	Coconut gratings	10	
	Oil	20	
	Salt	to taste	
2. Carrot halwa	Carrot shreds	500	Pressure cooking for 10 min and sauteing for 20 min. at 60-75°C.
	Ghee	25	
	Milk	250 ml	
	Sugar	175	
	Cardomom	2-3 (1/4 tsp)	
3. Carrot biscuits	Refined flour	150	Baking at 175°C for 20 min.
	Carrot powder	15	
	Sugar	85	
	Fat	85	
	Milk	125 ml	
	Baking powder	1/4 tsp	
	Vanilla essence	few drops	

The method of preparation of recipes is given in Appendix B.

#### **3.4.1 Organoleptic evaluation of recipes**

The standardized recipes were tested for their organoleptic quality through sensory evaluation trials (Jellinek, 1964) by a trained panel of judges consisting of 10 members from PGRC. A score card for evaluation of quality attributes like appearance, colour, flavour, taste, texture and overall acceptability was developed and given in Appendix C. The recipes were coded and were evaluated for their sensory characteristics on a five point scale. Each recipe was evaluated twice with an interval of four days and the mean scores were obtained for determining the acceptability of the recipes.

#### **3.4.2 Analysis of $\beta$ -carotene in recipes**

The  $\beta$ -carotene content of recipes were analysed by reverse phase high performance liquid chromatography (Zakaria and Simpson, 1979).

### **3.5 SUITABILITY OF BISCUITS AS SUPPLEMENTARY FOOD**

The energy and protein content of the biscuits per 100 g and per serving were calculated from the nutritive value of Indian foods NIN, ICMR (1989), apart from estimation of  $\beta$ -carotene in biscuits with 10 per cent carrot powder to see the suitability as supplementary food for children.

### 3.6 ASSESSMENT OF SHELF-LIFE OF DEHYDRATED CARROT PRODUCTS

Shelf life of the dehydrated products viz. carrot chops, carrot shreds and carrot powder was assessed by storing them in polythene covers for a period of 90 days. The moisture,  $\beta$ -carotene were estimated as per the procedures mentioned earlier in 3.14. Peroxide value by AOAC 1980 and total bacterial count by Pour- plate method (Cruickshank *et al.*, 1975) (Appendix E).

### 3.7 STATISTICAL ANALYSIS

The results obtained from the sensory evaluation trials of dehydrated products and recipes were subjected to analysis of variance and independent t-test, the significant difference between their scores was tested by critical difference and t-table value respectively (Snedecor and Cochran, 1968).

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## *RESULTS*

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## CHAPTER IV

### RESULTS

The results related to the study are arranged sequentially and presented under the following heads.

- 4.1 Dehydration of carrots by three methods of drying and evaluation of the acceptability of dehydrated carrots.
- 4.2 Effect of three drying methods on the  $\beta$ -carotene content of carrots.
- 4.3 Development and evaluation of the acceptability of dehydrated carrot products.
- 4.4 Evaluation of the acceptability of the recipes prepared with dehydrated carrots and their  $\beta$ -carotene content
- 4.5 Suitability of biscuits as supplementary food
- 4.6 Shelf life of the dehydrated carrot products.

#### 4.1 DEHYDRATION OF CARROTS BY THREE METHODS OF DRYING AND EVALUATION OF THE ACCEPTABILITY OF DEHYDRATED CARROTS

Carrots were subjected to three methods of drying i.e., under direct sunlight, in solar drier and in cabinet drier. The preparatory techniques have been already dealt in Chapter III.

The dehydrated carrots thus obtained were evaluated by a trained panel of 10 members for their sensory characteristics. The mean scores of

the sensory characteristics of carrots dried by three methods of drying are presented in Table 6.

**Table 6 : Mean scores of sensory characteristics of carrots dried by three methods of drying**

Sensory characteristics	SD	SOD	CD
Appearance	2.4 <sup>a</sup>	2.7 <sup>a</sup>	3.6 <sup>c</sup>
Colour	1.6 <sup>d</sup>	2.2 <sup>b</sup>	3.7 <sup>c</sup>
Flavour	2.8 <sup>a</sup>	3.1 <sup>a</sup>	3.4 <sup>a</sup>
Texture	2.3 <sup>a</sup>	3.2 <sup>b</sup>	3.1 <sup>b</sup>
Overall acceptability	2.3 <sup>a</sup>	2.9 <sup>b</sup>	3.4 <sup>b</sup>

SD : Sun dried; SOD : Solar dried; CD : Cabinet dried

Figures with same superscripts do not differ significantly at  $P < 0.05$

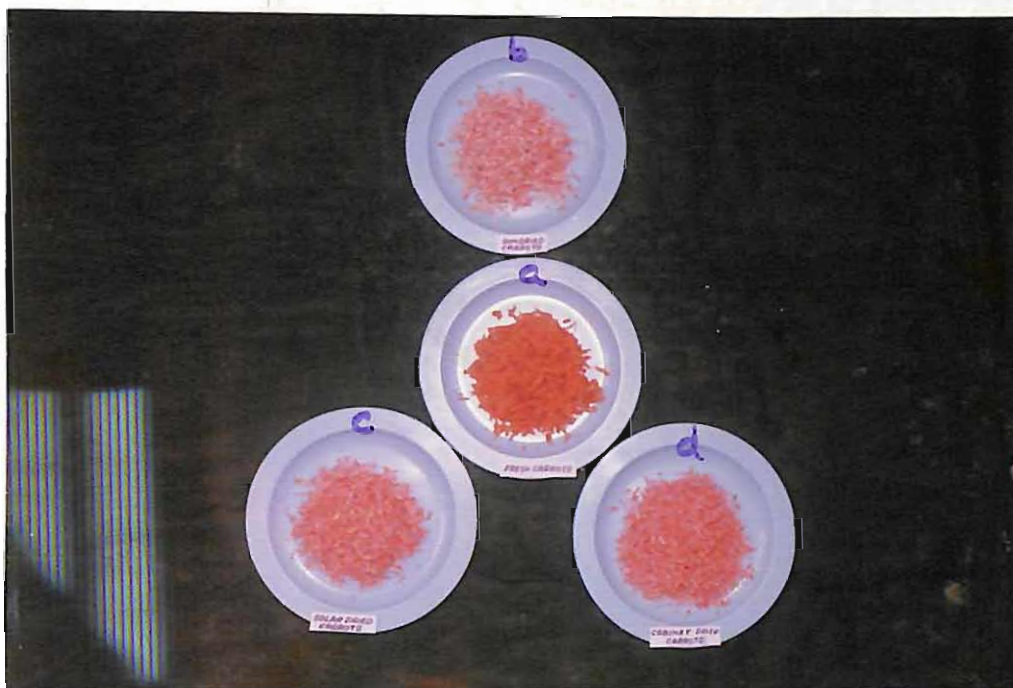
Note : Scores 5 are maximum and 1 is minimum

The data in the table shows that there is no significant difference in the flavour of carrots dried by three methods. The appearance of carrots dried by cabinet drier differed significantly from sun and solar dried carrots. The texture and over all acceptability of sun dried carrots differed significantly from solar and cabinet dried carrots. Among the sensory characteristics colour and appearance scored maximum for carrots dried by cabinet drier.

#### 4.2 EFFECT OF THREE DRYING METHODS ON THE $\beta$ -CAROTENE OF CARROTS

The effect of sun drying, solar drying and cabinet drying on  $\beta$ -carotene content of carrots are presented in the Table 7.

Plate 1 : Drying of carrots by three methods



a - Fresh carrots

c - Solar dried carrots

b - Sun dried carrots

d - Cabinet dried carrots

**Table 7 :  $\beta$ -carotene content of carrots dried by three methods of drying**

Samples	$\beta$ -carotene mg/100 g	* Percentage loss of $\beta$ -carotene
Fresh	25.31 $\pm$ 0.17	-
Sun dried	7.29 $\pm$ 0.19	71
Solar dried	11.94 $\pm$ 0.70	52
Cabinet dried	14.49 $\pm$ 0.14	42

Values are expressed as mg/100 g mean  $\pm$  SD of 3 determinations

\*Percentage loss calculated with reference to  $\beta$ -carotene content of fresh carrots on moisture free basis.

The  $\beta$ -carotene content of fresh and dehydrated carrots varied greatly when subjected to three methods of drying. The percentage loss of  $\beta$ -carotene ranged from 42 to 71 per cent and sundrying of carrots showed maximum loss of  $\beta$ -carotene.

#### 4.3 DEVELOPMENT AND EVALUATION OF ACCEPTABILITY OF DEHYDRATED CARROT PRODUCTS

Three dehydrated carrot products namely carrot chops, carrot shreds and carrot powder were developed by using cabinet drier, the preparatory techniques of which are dealt in detail in Chapter III.

The mean scores of sensory evaluation of dehydrated carrot products are presented in Table 8.

**Table 8 : Mean sensory scores of the dehydrated carrot products**

Products	Appearance	Colour	Flavour	Texture	Overall acceptability
Carrot chops	3.8 <sup>a</sup>	3.8 <sup>a</sup>	2.7 <sup>ab</sup>	3.2 <sup>a</sup>	2.5 <sup>a</sup>
Carrot shreds	3.6 <sup>a</sup>	3.7 <sup>ab</sup>	3.1 <sup>a</sup>	3.6 <sup>a</sup>	2.9 <sup>a</sup>
Carrot powder	3.6 <sup>a</sup>	3.3 <sup>bc</sup>	2.5 <sup>cb</sup>	2.7 <sup>bc</sup>	2.8 <sup>a</sup>

Values with same superscripts donot differ significantly at P < 0.05

The mean scores of the dehydrated carrot products from the table shows that the three products donot differ significantly with regard to appearance and overall acceptability. But carrot chops and carrot powder had significant differences in colour and texture, while carrot shreds and carrot powder differed significantly with regard to flavour.

The moisture and  $\beta$ -carotene content of dehydrated carrot chops, carrot shreds and carrot powder are presented in Table 9.

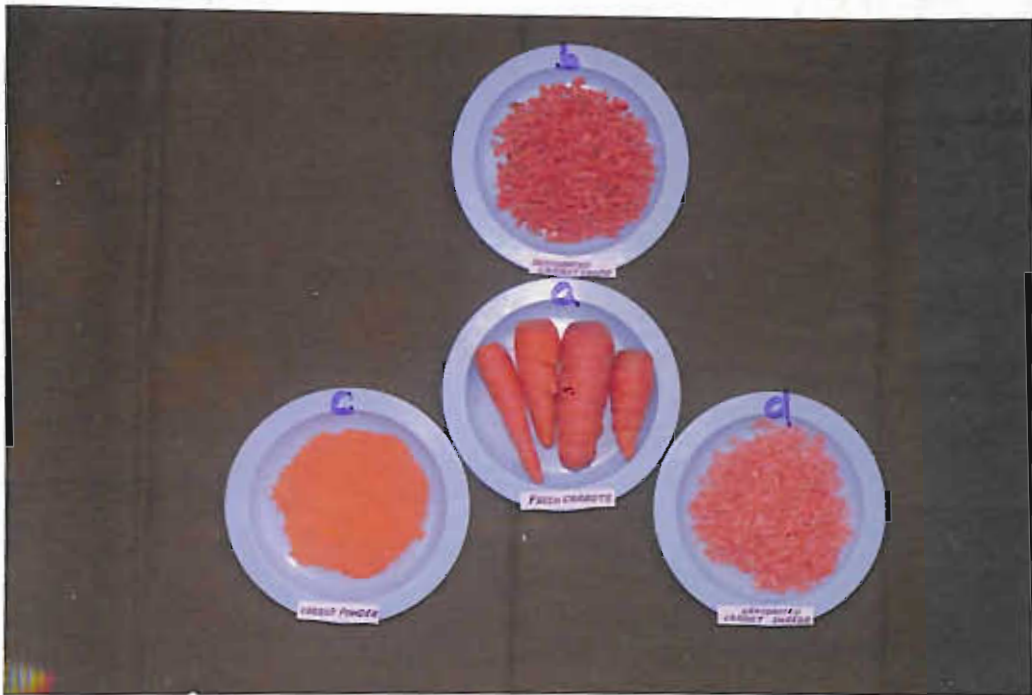
**Table 9 : Moisture and  $\beta$ -carotene content of dehydrated products**

Products	Moisture (%)	$\beta$ -carotene (mg/100 g)	Percentage loss of $\beta$ -carotene
Fresh carrots	90.09	39.58 $\pm$ 0.81	-
Dehydrated carrot chops	7.02	24.70 $\pm$ 0.73	37
Dehydrated carrot shreds	7.64	22.48 $\pm$ 0.68	43
Carrot powder	7.81	23.86 $\pm$ 0.24	40

Values are expressed as mean  $\pm$  S.D of 2 deterninations

\* Percentage loss calculated with reference of  $\beta$ -carotene content of fresh carrots on moisture free basis.

Plate 2 : Dehydrated carrot products



a - Fresh carrots

c - Carrot powder

b - Carrot chops

d - Carrot shreds

The moisture content of the dehydrated products ranged from 7.02 to 7.81 per cent and the  $\beta$ -carotene content ranged from 22.48 to 24.70 mg per 100 g of the product. The loss of  $\beta$ -carotene ranged from 37 to 43 per cent among the products.

The rehydration characteristics of dehydrated carrot chops and carrot shreds are given in Table 10.

**Table 10 : Rehydration characteristics of dried carrot products**

Characteristic	Carrot chops	Carrot shreds
Drying time (hr)	11-12	7-8
Moisture (%)	7.02	7.64
Time taken for rehydration (hr)	8	6
Rehydration ratio	8.1	10.1

The table shows that the time taken for rehydration of carrot chops was more compared to carrot shreds. The greater rehydration ratio was observed for carrot shreds.

#### 4.4 EVALUATION OF THE ACCEPTABILITY OF RECIPES PREPARED WITH DEHYDRATED CARROTS AND THEIR $\beta$ -CAROTENE CONTENT

Three recipes namely carrot curry, carrot *halwa* and biscuit (at 10 % level of incorporation of carrot powder) were prepared with carrot chops, carrot shreds and carrot powder respectively. The proportion of ingredients in the preparation of recipes is given in chapter III and the method of preparation of recipes is given in Appendix D.

**Plate 3 : Recipes with carrot chops**

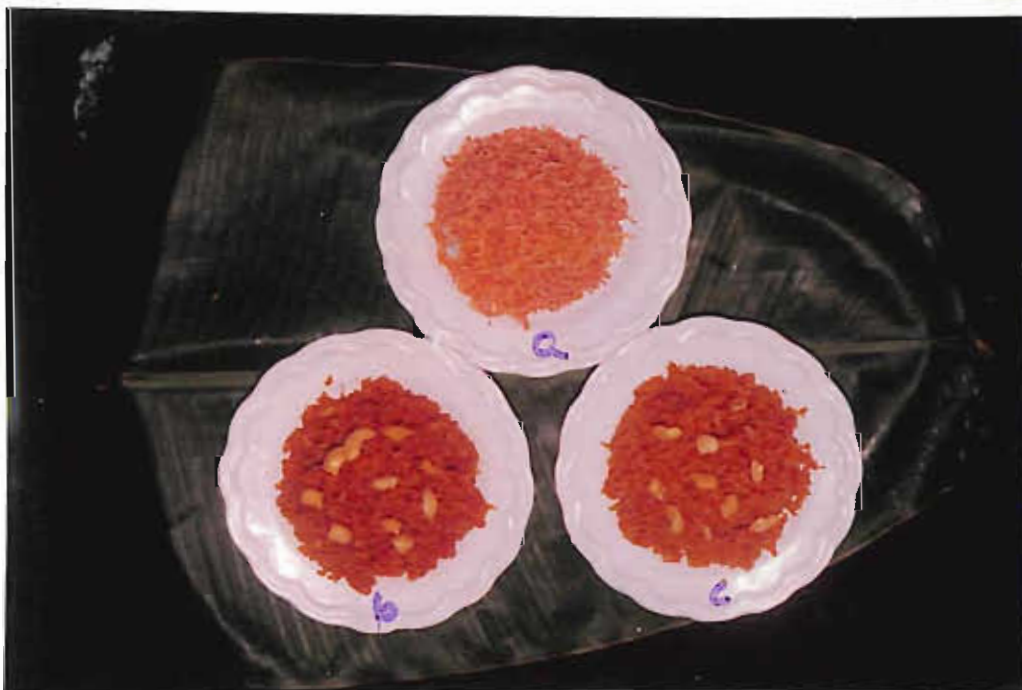


**a - Dehydrated carrot chops**

**b - Carrot curry with Fresh chops**

**c - Carrot curry with rehydrated chops**

Plate 4 : Recipes with carrot shreds



a - Dehydrated carrot shreds

b - *Halwa* with fresh shreds

c - *Halwa* with rehydrated shreds

Plate 5 : Biscuits with and without carrot powder



a - Carrot powder

b - Maida biscuits

c - Maida biscuits with 10 % carrot powder

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#### 4.4.1 Acceptability of the recipes

The acceptability of the recipes was assessed with regard to appearance, colour, flavour, taste, texture and overall acceptability and the results are given in Table 11.

**Table 11 : Mean sensory scores of recipes prepared with fresh and dehydrated carrot products**

Sensory characteristics	Recipes					
	Curry with		Halwa with		Biscuit	
	FCC	RCC	FCS	RCS	MB	MBC
Appearance	3.80± 0.61 <sup>a</sup>	3.65± 0.67 <sup>a</sup>	4.35± 0.67 <sup>a</sup>	4.25± 0.63 <sup>a</sup>	4.10± 0.71 <sup>a</sup>	3.85± 0.74 <sup>a</sup>
Colour	3.80± 0.61 <sup>a</sup>	3.75± 0.55 <sup>a</sup>	4.40± 0.75 <sup>a</sup>	4.15± 0.74 <sup>a</sup>	3.90± 0.64 <sup>a</sup>	3.90± 0.64 <sup>a</sup>
Flavour	4.05± 0.60 <sup>b</sup>	2.90± 0.67 <sup>c</sup>	4.15± 0.81 <sup>a</sup>	3.90± 0.85 <sup>a</sup>	4.10± 0.78 <sup>a</sup>	3.85± 0.73 <sup>a</sup>
Taste	3.95± 0.51 <sup>b</sup>	3.20± 0.52 <sup>c</sup>	3.95± 0.51 <sup>a</sup>	3.65± 0.74 <sup>a</sup>	4.15± 0.81 <sup>a</sup>	3.65± 0.98 <sup>a</sup>
Texture	4.15± 0.48 <sup>b</sup>	2.90± 0.55 <sup>c</sup>	4.50± 0.51 <sup>a</sup>	3.80± 0.83 <sup>b</sup>	4.05± 0.75 <sup>a</sup>	3.85± 0.81 <sup>a</sup>
Overall acceptability	3.95± 0.55 <sup>b</sup>	3.15± 0.76 <sup>c</sup>	4.10± 0.71 <sup>a</sup>	3.85± 0.74 <sup>a</sup>	4.05± 0.01 <sup>a</sup>	3.85± 0.74 <sup>a</sup>

Figures with same superscripts do not differ significantly at  $P < 0.05$

FCC - Fresh carrot chops

RCC - Rehydrated carrot chops

FCS - Fresh carrot shreds

RCS - Rehydrated carrot shreds

MB - Maida biscuit

MBC - Maida biscuit with 10 % carrot powder

The results indicated that there is no significant difference in appearance and colour of the curry prepared with fresh and rehydrated carrot chops, while the other parameters like flavour, taste, texture and acceptability differed significantly.

There is no difference in sensory scores obtained for *halwa* prepared with fresh and rehydrated carrot shreds except in the texture of the recipe.

In case of biscuits, there is absolutely no significant difference in sensory characteristics of maida biscuits and biscuits made with 10 per cent carrot powder.

#### 4.4.2 $\beta$ -carotene content of recipes

$\beta$ -carotene content of the recipes was analysed and given as  $\mu\text{g}/100$  g of the product (Table 12).

**Table 12 :  $\beta$ -carotene content of recipes prepared with dehydrated carrot products**

Recipes	$\beta$ -carotene ( $\mu\text{g}/100$ g)
Carrot curry	963 $\pm$ 0.61
Carrot <i>halwa</i>	617 $\pm$ 0.78
Carrot biscuit	240 $\pm$ 0.48

The values are expressed as mean  $\pm$  S.D of 2 determinations

The  $\beta$ -carotene content of recipes ranged from 240  $\mu\text{g}$  to 963  $\mu\text{g}$  per 100 g of the product. Among the recipes, carrot curry had more amount of  $\beta$ -carotene.

#### 4.5 SUITABILITY OF BISCUITS AS SUPPLEMENTARY FOOD

As the biscuits are ideally suited products for any supplementary feeding programme, the usual sweet biscuit which supplies calories largely can be supplemented with  $\beta$ -carotene by the incorporation of carrot powder. The energy and protein content of maida biscuit and biscuit with 10 per cent carrot powder was calculated from nutritive value of Indian foods per 100 g and their cost is given in Table 13.

**Table 13 : Energy and protein content of biscuits and their cost**

Nutrients	Maida biscuit (100 g)	Maida biscuit with 10 % carrot powder
Energy (Kcal)	475	475
Protein (g)	5.9	5.9
Cost (Rs.)	2.60	3.00

As any supplementary food should provide 300 kcal energy and 8 to 9 g protein, the nutritive value of carrot biscuit per serving was calculated and presented in Table 14.

**Table 14 : Nutritive value and cost of carrot biscuit per serving**

No. of biscuits	6
Weight (gm)	70
Energy (kcal)	332
Protein (g)	4.1
$\beta$ -carotene ( $\mu$ g)	168
Cost (Rs.)	2.00

#### 4.6 SHELF LIFE OF THE DEHYDRATED PRODUCTS

The shelf life of the dehydrated carrot chops, carrot shreds and carrot powder was studied for a period of 90 days. Moisture, peroxide value and total bacterial count at 30 days interval were analysed. The  $\beta$ -carotene content of the products during subsequent storage was also analysed, and the results are presented in the following tables.

Table 15 :  $\beta$ -carotene content of dehydrated carrots during storage

Products	Storage period (days)	$\beta$ -carotene mg/100 g	* Percentage loss of $\beta$ -carotene
Carrot chops	0	24.70 $\pm$ 0.73	-
	30	22.53 $\pm$ 0.61	9
	60	19.98 $\pm$ 0.83	19
	90	15.48 $\pm$ 0.74	37
Carrot shreds	0	22.48 $\pm$ 0.68	-
	30	19.84 $\pm$ 0.64	11
	60	17.48 $\pm$ 0.69	22
	90	13.84 $\pm$ 0.81	38
Carrot powder	0	23.86 $\pm$ 0.24	-
	30	19.34 $\pm$ 0.73	18
	60	11.19 $\pm$ 0.80	53
	90	7.48 $\pm$ 0.65	68

Values are expressed as mean  $\pm$  S.D of 2 determinations

\* Percentage loss calculated with reference to  $\beta$ -carotene content of dehydrated carrots before storage on moisture free basis.

The table shows decrease in the  $\beta$ -carotene content of dehydrated carrot products with increase in storage period. The loss of B- carotene in carrot chops ranged from 9 to 37 per cent and carrot shreds from 11

to 38 per cent and carrot powder from 19 to 68 per cent over a period of 90 days.

The total loss of  $\beta$ -carotene during storage period when compared to fresh carrots is given in Table 16.

Table 16 : Loss of  $\beta$ -carotene before and after storage

Samples	Before storage		After storage	
	$\beta$ -carotene mg/100 g (0 days) storage	Percentage loss of $\beta$ -carotene	$\beta$ -carotene mg/100 (90 days)	Percentage loss of $\beta$ -carotene
Fresh carrots	39.58 $\pm$ 0.81	-	-	-
Dehydrated carrot chops	24.70 $\pm$ 0.81	37	15.48 $\pm$ 6.74	60
Dehydrated carrot shreds	22.48 $\pm$ 0.73	43	13.84 $\pm$ 0.81	67
Carrot powder	23.86 $\pm$ 0.21	40	7.48 $\pm$ 0.65	81

\* Percentage loss calculated with reference to  $\beta$ -carotene content of fresh carrots on moisture free basis.

The table shows that there was loss of  $\beta$ -carotene in the dehydrated products before storage ranging from 37 to 43 per cent, which further degraded during storage for 90 days, with the loss ranging from 60 to 81 per cent. Storage of carrot powder reported greater loss compared to carrot chops and carrot shreds.

The moisture and peroxide value of carrot products during storage is given in Table 17.

Table 17 : Moisture and peroxide value of dehydrated carrot products during storage

Products	Storage period (days)	Moisture (%)	Peroxide value (mew/kg/fat)
Carrot chops	0	7.02	0.00
	30	6.23	0.00
	60	6.34	0.005
	90	6.42	0.08
Carrot shreds	0	7.64	0.00
	30	6.41	0.00
	60	6.44	0.01
	90	6.75	0.10
Carrot powder	0	7.81	0.00
	30	7.93	0.00
	60	8.09	0.05
	90	8.42	0.15

The moisture content of the dehydrated carrot chops, carrot shreds and carrot powder ranged from 7.02 to 8.42 per cent. The peroxide value was nil at 0 and 30 days storage in all the products and it ranged from 0.005 to 0.15 (meq/kg fat) among the products during storage.

The results obtained for total plate count of bacteria in dehydrated carrots are presented in Table 18.

**Table 18 : Total bacterial count in dehydrated carrots during storage**

Dehydrated products	Storage period (days)	Total plate (count x 10 <sup>7</sup> per g)
Carrot chops	0	2.2 x 10 <sup>7</sup>
	30	3.4 x 10 <sup>7</sup>
	60	4.2 x 10 <sup>7</sup>
	90	5.5 x 10 <sup>7</sup>
Carrot shreds	0	2.8 x 10 <sup>7</sup>
	30	4.2 x 10 <sup>7</sup>
	60	5.4 x 10 <sup>7</sup>
	90	6.5 x 10 <sup>7</sup>
Carrot powder	0	3.6 x 10 <sup>7</sup>
	30	5.5 x 10 <sup>7</sup>
	60	6.8 x 10 <sup>7</sup>
	90	8.2 x 10 <sup>7</sup>

The total bacterial count in dehydrated carrot products namely carrot chops, carrot shreds and carrot powder increased during the storage period ranging from 2.2 x 10<sup>7</sup> per g to 8.2 x 10<sup>7</sup> per g.

CHAPTER V

DISCUSSION

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*DISCUSSION*

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## CHAPTER V

### DISCUSSION

The results obtained from the study were analysed and discussed under following heads.

- 5.1 Sensory evaluation of dehydrated carrots subjected to three methods of drying.
- 5.2 Effect of drying methods on  $\beta$ -carotene content of carrots.
- 5.3 Development and evaluation of dehydrated carrot products.
- 5.4 Evaluation of the recipes prepared with dehydrated carrot products and suitability of carrot biscuit as supplementary food.
- 5.5 Shelf life of the dehydrated carrot products.

#### 5.1 SENSORY EVALUATION OF DEHYDRATED CARROTS SUBJECTED TO THREE METHODS OF DRYING

It is a common practice followed by several housewives to purchase the vegetables in bulk in some seasons and preserve them by sun drying. In this context, carrot has no exception and it was interesting to study the method of drying which retains not only the appearance but also the nutrient retention in carrots.

Sundrying is an age old practice followed since many centuries, as it is the cheapest source of heat for the removal of water from foods especially fruits and vegetables. During sundrying, the food material

becomes susceptible to contamination because of drying in open yard and also direct sundrying results in significant loss of pigments and this disadvantage could be overcome by solar drying where the materials are covered by glass and solar radiation is concentrated on the surface. Dehydration of fruits and vegetables can be performed in various ways (Table.2) among which hot air cabinet drier is one. Any drying procedure will be successful only if it produces a good quality product. Selection of drying process depends on the type of vegetable as well as the quality of the end product desired. In the present study carrots were dried by sundrying, solar cabinet drying and hot air cabinet drying. Feasibility of the above methods for the production of dehydrated carrot products was tested based on the product quality and the retention of  $\beta$ -carotene content.

During sundrying, carrots were subjected to 32 to 42°C while the temperature maintained in solar cabinet and hot air cabinet driers were 35°C to 53°C and 45-55°C respectively. Drying of the carrot gratings in cabinet drier took lesser time i.e. 3 1/2 hrs compared to sundrying 5 1/2 hours and solar drying (4 1/2 hrs), to obtain a moisture level of 10 to 11 per cent. This might have been due to the intensity of heat and a limited air circulation inside the cabinet.

Drying leads to shrinkage in foods and brings about a range of chemical changes which contribute to the quality of the final product in terms of colour, flavour, texture, nutritive value and storage stability. The carrots dehydrated by three methods of drying, were subjected to the

sensory evaluation tests (Plate 1). The results revealed that cabinet dried carrots had maximum score for colour (3.7) and appearance (3.6) which might be related to more retention of  $\beta$ -carotene and less carotene oxidation compared to sundrying and solar drying. Though there is difference in the scores obtained for flavour of carrots dried by three methods statistically significant difference was not observed. The texture of sundried carrots scored less. This might be due to the uncontrolled conditions of drying which led to unevenness in the texture. There is no difference in the overall acceptability of carrots dried in solar drier and cabinet drier while the acceptability was less in sundried carrots. Jayaraman *et al.* (1991) also reported that although indirect sundrying using solar cabinet with plate collector took more time to dry and consequently resulted in slightly more shrinkage, the appearance, colour, flavour and organoleptic characteristics of vegetables dried in solar drier were much better than those of direct sundried vegetables and were comparable to those of hot air dried vegetables.

## 5.2 EFFECT OF DRYING METHODS ON $\beta$ -CAROTENE CONTENT OF CARROTS

Carotene is an unstable compound being highly oxidizable. Its preservation in foods is necessary to ensure a stable amount of vitamin A during storage. In the present study the  $\beta$ -carotene content of fresh carrots was 25.31 mg/100 g on moisture free basis, while considerable loss was observed during drying (Fig. 1). Among the different methods of drying the maximum amount of loss i.e. 71 per cent was observed in

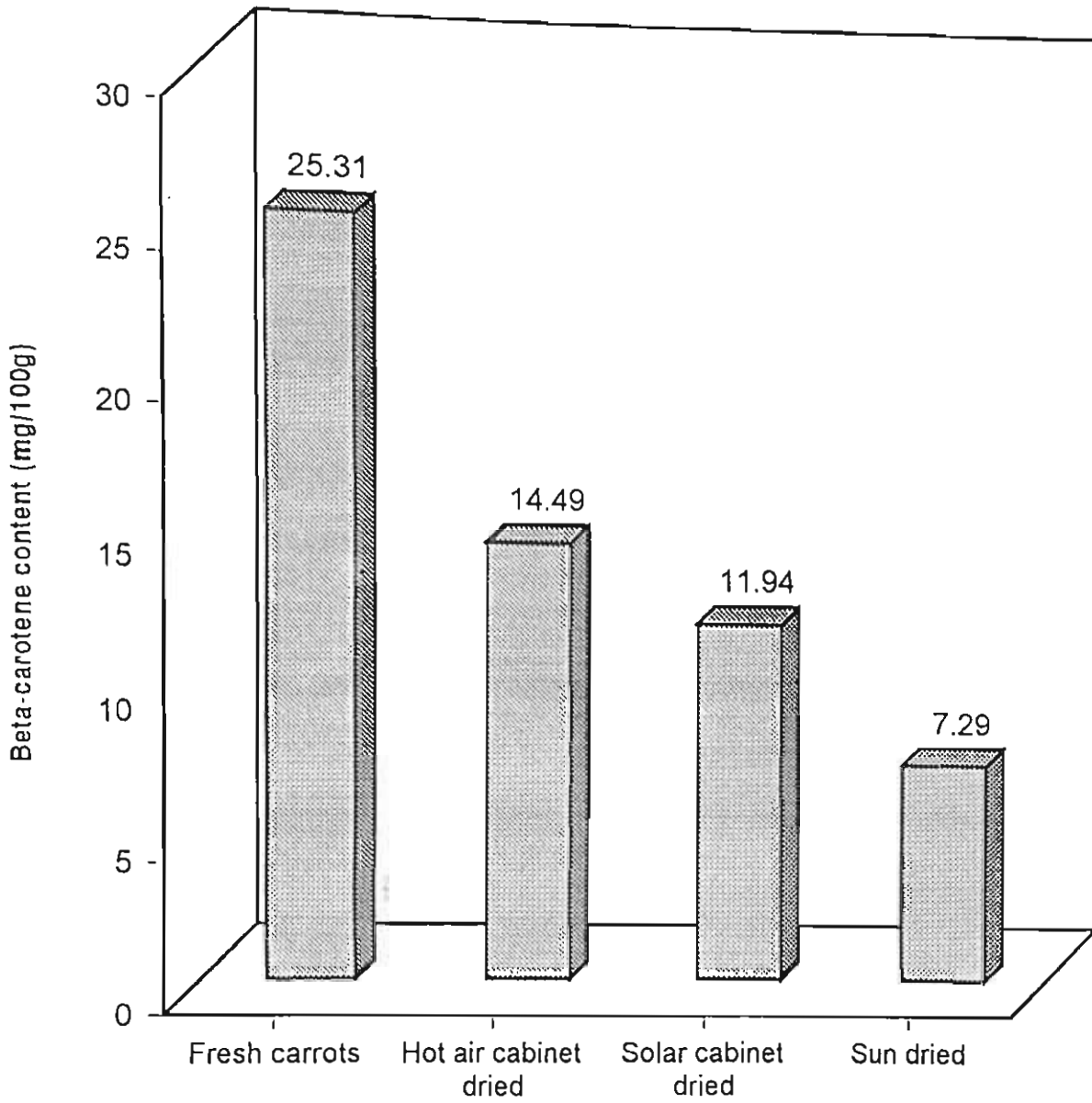


Fig. 1 : Effect of drying methods on  $\beta$ -carotene content of carrots

carrots dried by direct sunlight and 52 per cent loss was observed in solar cabinet drying followed by 42 per cent loss in hot air cabinet drier. Among the three methods of drying higher carotene loss observed in carrots dried by sun and solar drier might be due to the longer time taken for drying leading to higher degree of oxidation of carotene. Similar results were reported by Jayaraman *et al.* (1991) when carrot dices were dried by direct sun, solar cabinet and hot air cabinet driers where loss of  $\beta$ -carotene was more in sundried carrots (49 %) followed by Solar dried carrots (37 %) and hot air cabinet dried carrots (16 %). Maeda and Salunke (1981) also reported minimum retention of carotenes in leafy vegetables dried in open sunshine. Bolin and Stafford (1974) found highest  $\beta$ -carotene loss in sundried apricot as compared to dehydrated and shade dried products. This could be because of the conditions encountered during sundrying such as exposure to light, temperature, oxygen (air) and loss of moisture leading to significant loss of colour and further destruction of carotenes.

Based on the higher retention of  $\beta$ -carotene in carrots dried in hot air cabinet drier, when compared to other two methods of drying, the study was proceeded to develop dehydrated products with carrots using hot air cabinet drier.

### 5.3 DEVELOPMENT AND EVALUATION OF DEHYDRATED CARROT PRODUCTS

Dehydrated carrot products were developed namely carrot chops, carrot shreds, carrot chips and carrot powder by drying fresh carrots in cabinet drier at 45°C - 55°C. The pretreatment methods followed for the development of dehydrated carrot products were given in Table 4.

Carrot chips after drying had a shrivelled appearance and did not retain the shape. When fried in oil become pale in colour due to the leaching of carotenes into the oil. The fried chips became soggy and lost crispiness with in 10 to 15 minutes of exposure to atmosphere. Hence the further analysis of chips was not carried out.

The time taken for drying of carrot shreds (7-8 hrs) was less compared to carrot chops (11-12 hrs) and carrot powder (10-11 hrs) because of smaller size and hence greater rate of evaporation of moisture. The final moisture content of the carrot chops, carrot shreds and carrot powder obtained were 7.02, 7.64 and 7.81 respectively. The  $\beta$ -carotene content of carrot chops, shreds and powder were 24.7 mg/100 g, 22.48 mg/100 g and 23.86 mg/100 g respectively and the loss of  $\beta$ -carotene observed were 37, 43 and 40 per cent respectively. Among the products carrot chops showed less loss of  $\beta$ -carotene due to lesser surface area exposed to drying. The duration of processing method was also less when compared to shreds and powder. The carrot powder had less loss of  $\beta$ -carotene when compared

to shreds and the loss was more when compared to carrot chops. This might be due to the difference in the size of the pieces exposed to drying.

Rukmini *et al.* (1985) milled dried carrot slices and obtained carrot powder, which had only 28 per cent retention of  $\beta$ -carotene. However in the present study the retention was greater (60 per cent) in carrot powder. This might be due to the pre-treatments used before drying like blanching in 0.2 per cent potassium metabisulphite and dipping in 2 per cent starch solutions which were reported to reduce carotenoid destruction during processing. Mohammed and Hussein (1994) treated carrots with sodium meta-bisulphite and obtained a retention twice as good when compared with no metabisulphite. Starch coating gave a surface coverage and hence, protected carotene effectively by isolating oxygen from carrots (Baloch *et al.*, 1986).

### 5.3.1 Sensory characteristics

The three products viz., chops, shreds and powder (Plate 2) when subjected to sensory evaluation trials showed better acceptability. The colour of the carrot chops was good compared to carrot shreds and carrot powder, which is related to  $\beta$ -carotene content as discussed above. The carrot shreds had higher mean score for flavour when compared with carrot chops and carrot powder. This could be because of sucrose treatment during blanching. Kalra *et al.* (1987) suggested that for dehydration, blanching of carrot shreds in 5 per cent sugar solution not only imparts

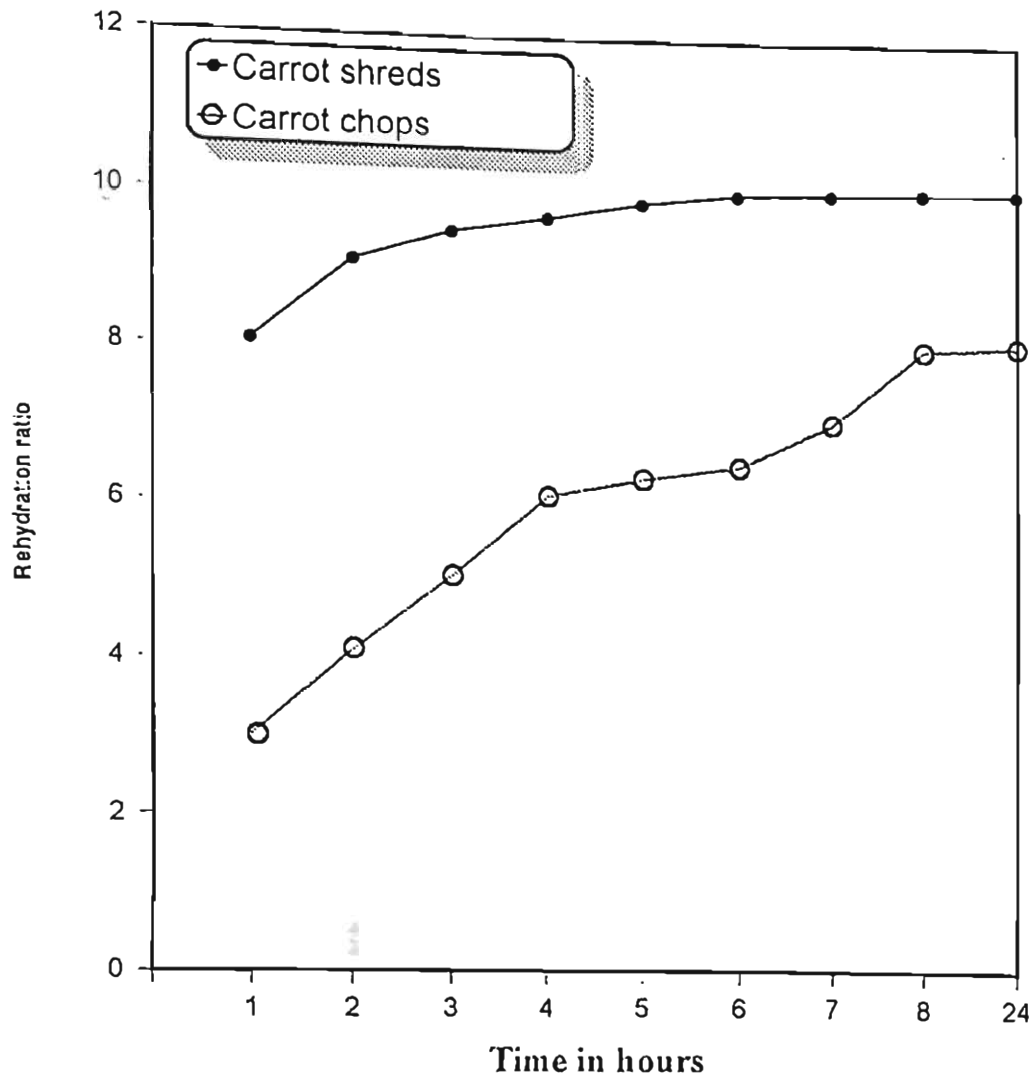


Fig. 2 : Rehydration characteristics of dehydrated carrots

an attractive colour but also improves its organoleptic and keeping quality. The appearance of three products was rated to be good by the panelists.

### 5.3.2 Rehydration characteristics

Any dried food product has to be rehydrated before its usage in food preparation. Adequate rehydration is essential in order to have satisfactory eating quality. The rehydration of carrot shreds was faster when compared to carrot chops with time and had a maximum rehydration ratio in 6 hrs compared to 8 hr for carrot chops (Fig. 2). Rehydration ratio was found higher (10.1) for carrot shreds and the rehydration ratio obtained for carrot chops was 8.1. Eusebio *et al.* (1990) reported almost similar values for carrot dices which ranged from 8.2 to 8.5. The lower rehydration ratio of carrot chops was opined due to the polysaccharide (corn starch) gel absorbed on the cell walls causing changes in texture and rehydration (Mudahar, 1989). Wager (1958) found that the substantial heat treatment and drying reduced the elasticity of cells and the swelling power which are important for rehydration.

## 5.4 EVALUATION OF THE RECIPES PREPARED WITH DEHYDRATED CARROT PRODUCTS AND SUITABILITY OF CARROT BISCUIT AS SUPPLEMENTARY FOOD

### 5.4.1 Acceptability of the recipes

In order to assess the acceptability of a product, carrying out acceptability tests becomes the most important requirement. The role of sensory evaluation studies to assess the acceptability of a food product is

well known. Sensory evaluation provides the first opportunity for feedback on a new product (Rao *et al.*, 1997). The ultimate use of a food item lies in food product preparation. Hence the acceptability of rehydrated carrot chops, shreds and carrot powder in food preparation was tested by sensory evaluation and compared with the recipes made with fresh carrot chops, carrot shreds and maida biscuits (Plates 3, 4 and 5). Food products were assessed in terms of their individual characteristics which include appearance, texture, colour, flavour and overall acceptability.

The mean scores (3.65, 4.25, 3.85) for appearance of the recipes carrot curry, carrot *halwa* and biscuit with 10 per cent carrot powder did not show significant difference when compared with the mean scores of control recipes (3.80, 4.35 and 4.10). This shows that appearance of the recipes was on par with controls.

The mean scores for texture (2.90, 3.80) were low for carrot curry and carrot *halwa* prepared with rehydrated carrot chops and carrot shreds respectively when compared with the mean scores (4.15, 4.50) obtained for recipes prepared with fresh chops and shreds. This might be due to loss of soluble sugars, minerals and pectic substances and other solutes from carrots during processing (Kalra *et al.*, 1987). Aguilera and Stanley (1990) reported that heating produces structural alterations in plant tissue that influence texture and the general result being softening brought about by loss of turgor pressure and occluded air, thermal degradation of middle lamella pectins and other cell wall polysaccharides. In the present study also similar changes might have taken place during processing. The mean

scores (4.05, 3.85) obtained for biscuits prepared with maida and maida with 10 per cent carrot powder did not show significant difference in texture. However, the other ingredients like fat used in biscuit might have contributed to the better texture.

The mean scores for colour (3.75, 4.15 and 3.90) obtained for carrot curry, carrot *halwa* and biscuit with 10 per cent carrot powder respectively were not significant when compared with the mean scores (3.80, 4.40 and 3.90) of control recipes. Hence the rehydrated products were on par with controls recipes with regard to colour.

The flavour or aroma emitted by a food is an indication of its quality and wholesomeness. The sensation of flavour contributes pleasure to eating. The mean scores for the flavour of carrot curry prepared with fresh carrot chops (4.05) and with rehydrated carrot chops (2.90) differed significantly and this difference in aroma might be due to loss of soluble sugars during blanching (Heatherbell *et al.*, 1971). The mean scores for the flavour of carrot *halwa* prepared with fresh and rehydrated carrot shreds did not differ significantly. This might be due to the addition of sugar during blanching of carrot shreds before drying and also the milk and sugar added during the preparation which could have made up the flavour component of the recipe. The mean scores for the flavour of maida biscuits and biscuits with 10 per cent carrot powder did not differ significantly which shows that the addition of carrot powder at 10 per cent level did not alter the flavour of biscuit.

The mean scores for the taste of carrot curry prepared with fresh (3.93) and rehydrated carrot chops (3.20) differed significantly and this might be due to loss of flavour and texture as discussed above. However, the taste of carrot *halwa* and biscuit with 10 per cent carrot powder did not differ significantly with control recipes. This might be due to camouflaging effect of other ingredients during preparation.

The overall acceptability of a product is the sum total of the attributes. This was reflected in the case of acceptability of carrot curry which had significant difference when compared with control recipe. While the acceptability of carrot *halwa* and biscuit with 10 per cent carrot powder were good.

#### 5.4.2 $\beta$ -carotene content of recipes

The  $\beta$ -carotene content of recipes prepared with rehydrated carrot chops, carrot shreds and with 10 per cent incorporation of carrot powder in maida biscuit was estimated. Loss of  $\beta$ -carotene was observed in the recipes and this might be due to the oxidation of  $\beta$ -carotene during various methods of cooking. The  $\beta$ -carotene content of carrot curry, carrot *halwa* and biscuit with 10 per cent carrot powder were 963  $\mu\text{g}/100$ , 617  $\mu\text{g}/100$  g and 240  $\mu\text{g}/100$  g respectively. Dikshit and Udipi (1998) estimated the losses in carotene content due to cooking and reported that carrot *halwa* prepared from fresh carrots resulted in 78 per cent loss of  $\beta$ -carotene. Vinodini Reddy (1995) also reported that grating and prolonged heating as in carrot *halwa* resulted in 48 per cent retention of  $\beta$ -carotene.

In spite of higher losses in  $\beta$ -carotene during processing, the incorporation of carrot powder contributes certain amount of  $\beta$ -carotene in recipes like biscuits. 100 g of biscuits with 10 per cent incorporation of carrot powder supplies 475 kcal energy, 5.9 g protein and 240  $\mu$ g of  $\beta$ -carotene. The incorporation of carrot powder may be justified in view of the existing vitamin A deficiency in pre-school children. The calculated cost of 100 g biscuits with carrot powder is Rs. 3.00 which can be reduced by reducing the fat percentage in the biscuit. The carrot powder can also be easily incorporated in the recipes like laddu, milk beverage, roti and mixes which are suitable for supplementary feeding programmes.

#### 5.5 SHELF-LIFE OF THE DEHYDRATED CARROT PRODUCTS

The shelf life of the dehydrated carrot products was assessed by analysing  $\beta$ -carotene content, moisture, peroxide value and total bacterial count at 30 days intervals. The extent to which deterioration occurs depends upon the physical factors, storage environment and biological factors. In the present study the dehydrated carrot products were stored in air tight polythene covers, for a period of 90 days at room temperature.

The results showed that there is gradual loss of  $\beta$ -carotene during storage in all the three dehydrated carrots products viz., carrot chops, carrot shreds and carrot powder (Table 15 and Fig. 3). Niranjana Singh Sekhon (1943) studied the effect of storage on the carotene content of dehydrated vegetables and reported that dehydrated vegetables on storage showed a progressive loss in their carotene content. Zhao and Chang

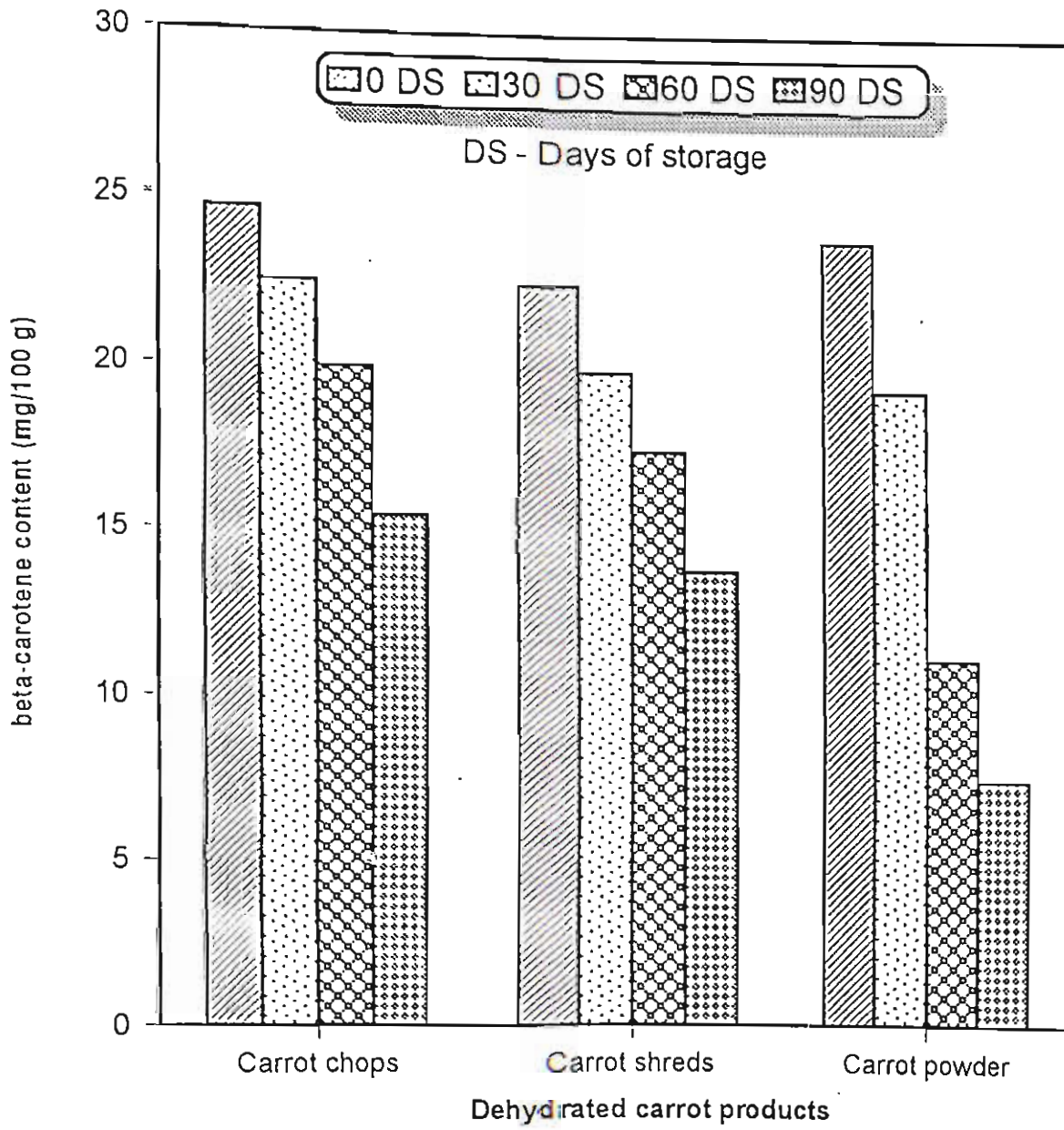
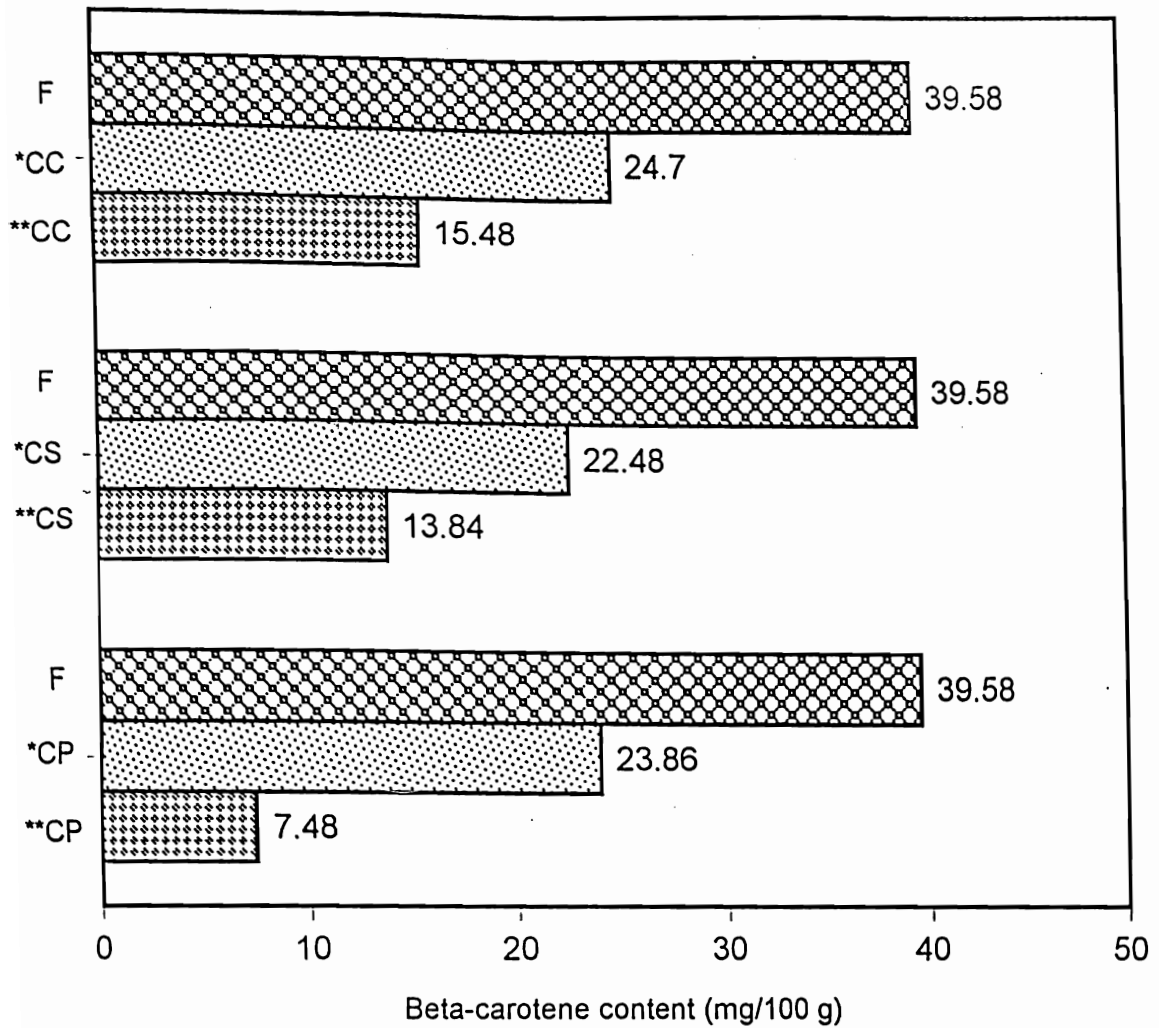


Fig. 3 : Loss of  $\beta$ -carotene during storage



F : Fresh carrots  
 CC : Carrot chops  
 CS : Carrot shreds  
 CP : Carrot powder

\* Dehydrated carrot products before storage  
 \*\* Dehydrated carrot products after storage

**Fig. 4 : Total loss of  $\beta$ -carotene content in carrots**

(1991) reported that metabisulphite treatment reduced the loss of redness in dehydrated products during storage but did not improve retention of  $\beta$ -carotene. Carrot powder has higher rate of  $\beta$ -carotene loss (68 %) during storage than carrot chops (37 %) and shreds (38 %) (Table 16 and Fig. 4). This might be due to the more oxidation of  $\beta$ -carotene during storage. Tomkins *et al.* (1994) reported that proportion of  $\beta$ -carotene oxidized during storage was higher at 8.2 per cent moisture level than at 5.4 per cent level as in case of carrot powder. Lakshmi (1998) reported that packaging materials (Cast polypropylene and low density polyethene) were permeable to oxygen and water vapour transmission. Thus the  $\beta$ -carotene loss in the present study may also be attributed to the presence of oxygen content in contact with the stored product resulting in the oxidation of  $\beta$ -carotene. Goldman *et al.* (1983) showed that the oxygen content in the medium is the crucial factor acting on carotene decolouration and a small percentage of oxygen in contact with carotene has a dramatic effect on its shelf-life. Similarly Simpson (1985) also found oxidation to be the major cause of  $\beta$ -carotene destruction and exclusion of oxygen during storage of powders would extend their shelf life.

$\beta$ -carotene content of the products was also found to be affected on the method of drying and temperature of storage. Welder *et al.* (1981) obtained a higher retention of carotene in carrots by freeze drying than by heat drying. Storage at lower temperatures had comparatively slower degradation of  $\beta$ -carotene. Crivelli and Polesello (1973) stored carrot slice at  $-20^{\circ}\text{C}$  for a long time (12 months) and observed 60 per cent loss. Thus,

storage of dehydrated carrot products, in the present study, at room temperature might also be another cause for  $\beta$ -carotene deterioration.

Under storage, the moisture content of any substance increases or decreases until it comes into equilibrium with the surrounding air. Moisture content is known to fluctuate depending upon relative humidity and temperature during storage which in turn contributes to deterioration (Saio *et al.*, 1980). The moisture content of the dehydrated products decreased during first 30 days of storage period, later increased gradually. This decrease and increase in the moisture content might be due to evaporation, absorption and changes in the relative humidity during storage.

Another parameter studied is the peroxide value. Peroxide value is a very sensitive indicator of early stages of oxidative deterioration. The dehydrated carrot products after 30 days storage were found to have zero peroxide value while the peroxide values were found to be less, ranging from 0.005 to 0.15 milliequivalents per kg fat after 60 and 90 days of storage respectively. Carrot powder after 90 days of storage showed peroxide value of 0.15 milliequivalents which might be due to the oxidation of freed oils. Reeve (1942) quoted that since carrot oils contain at least one unsaturated fatty acid, it is reasonable to regard to freed oils as a source of future off odours.

Microbiological examination is another parameter to assess the quality of a food item during storage. The total bacterial count varied between  $2.2 \times 10^7$  to  $8.2 \times 10^7$  per gram in stored, dehydrated carrot

products (Table 18). There is an increase in plate count with the increase in storage period which might be correlated to the moisture content. With the increase in moisture content, the water activity increases and under favourable conditions of temperature bacterial multiplication occurs. There are no specifications established for bacteriological standards of dehydrated vegetables. Considering an upper limit of 50,000 for milk powder, the total count obtained per gram of dehydrated products in the study which ranged from 34 to 82 is negligible. Hence they can be considered safe for consumption.

Thus, the dehydrated products could be stored without deterioration till 90 days with negligible microbial load and peroxide value. But, the  $\beta$ -carotene content in the dehydrated products diminished gradually during storage.

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## SUMMARY

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... employed method for preserving carrots and methods like sun-drying, solar drying, freeze drying, fluidized bed drying are practiced (et al., 1992). In view of the increasing demand for  $\beta$ -carotene rich

the present study has been planned to develop products with tolerable  $\beta$ -carotene retention by dehydration technology and assess shelf life

Fresh carrots in the form of slices (0.5 cm length) were blanched at 100°C for 3 min in water containing 0.2 per cent KMS and 2 per cent rose, and subjected to three methods of drying viz. sun-drying, solar met drying and hot air subject to tunnel drying for

## CHAPTER VI

### SUMMARY

Vitamin A deficiency has long been recognised as one of the major preventable public health problems in India. Several programmes like vitamin A prophylaxis programme and horticultural intervention programmes are being implemented to reduce the incidence of vitamin A deficiency. Over 80 per cent of the daily supply of vitamin A among the Indian population is derived from its precursor  $\beta$ -carotene which is present in different plant foods. Among the roots and other vegetables, carrot is the best source of carotene. It occupies an important place in root vegetables for its multifaceted applications in day-to-day use which has led to the development of various processing operations for making different products or to extend its shelf life. Dehydration is one of the commonly employed method for preserving carrots and methods like hot air drying, solar drying, freeze drying, fluidized bed drying are practiced (Walde *et al.*, 1992). In view of the increasing demand for  $\beta$ -carotene rich foods, the present study has been planned to develop products with considerable  $\beta$ -carotene retention by dehydration technology and assess their shelf life.

Fresh carrots in the form of shreds (0.5 cm length) were blanched at 92°C for 3 min. in water containing 0.2 per cent KMS and 2 per cent sucrose, and subjected to three methods of drying viz sundrying, solar cabinet drying and hot air cabinet drying. Cabinet drying took lesser time

for drying compared to sun and solar drying. The sensory characteristics and  $\beta$ -carotene content (14.49 mg/100 g) of cabinet dried carrots was good followed by solar (11.94 mg/100 g) and sundried carrots (7.29 mg/100 g). Based on this observation, the study was proceeded to develop dehydrated carrots products namely carrot chops, carrot shreds and carrot powder by drying the carrots in cabinet driers.

Before dehydration, fresh carrots were subjected to pretreatment operations like washing, topping off the roots, cutting for carrot chops and carrot powder and grating for preparing carrot shreds. Then blanched at 92°C for 3 min in water containing 0.2 per cent KMS, 1 per cent salt and dipped in 2 per cent starch for 15 min for preparing carrot chops and carrot powder. Carrot shreds were blanched in boiling water at 92°C, containing 0.2 per cent KMS, 5 per cent sucrose for 3 min. Then they were dried in a cabinet drier at 45° - 55°C. Carrot shreds look less time for drying compared to carrot chops and carrot powder.

The moisture content of dehydrated products ranged from 7.0 to 8.5 per cent. The  $\beta$ -carotene content of dehydrated carrot chops, carrot shreds and carrot powder were 24.70 mg/100 g, 22.48 mg/100 g and 23.86 mg/100 g respectively. The loss of  $\beta$ -carotene ranged from 37 to 43 per cent. The three dehydrated products were quite acceptable, when subjected to sensory evaluation. Carrot chops and carrot shreds were rehydrated in distilled water. The time taken for rehydration of carrot

chops and carrot shreds was 8 hr and 6 hr respectively. Carrot shreds had a higher rehydration ratio (10.1) compared to carrot chops (8.1).

Sensory evaluation studies were carried out to test the suitability of dehydrated carrot products in the preparation of recipes. Rehydrated carrot chops and carrot shreds were used in the preparation of carrot curry and carrot *halwa* respectively. Carrot curry had a lower level of acceptance compared to fresh carrot curry, but carrot *halwa* was at par with control recipe except for texture. Maida biscuit with 10 per cent carrot powder was equally good when compared with biscuit without carrot powder.

The  $\beta$ -carotene content of the carrot curry, *halwa* and biscuit prepared with dehydrated carrot products were 963  $\mu\text{g}/100\text{ g}$ , 617  $\mu\text{g}/100$  and 246  $\mu\text{g}/100\text{ g}$ , respectively. The calculated energy and protein values for 100 g maida biscuit with carrot powder were 475 kcal and 9 g respectively. Thus, maida biscuit with 10 per cent carrot powder contributed  $\beta$ -carotene apart from energy and protein when compared to maida biscuit without carrot powder and this may be considered in the recipes formulated for supplementary feeding programmes of children.

Shelf life of the dehydrated carrot products during storage was also studied with reference to changes in moisture, peroxide value, microbial load and  $\beta$ -carotene content, by storing them in polythene covers. The products were tested periodically at an interval of 30 days during 90 days of storage period. The moisture content of the products decreased during

first 30 days storage and then gradually increased. The peroxide value was nil in all the products during first 30 days and negligible amounts were reported during later storage. The bacterial multiplication was also slow. The  $\beta$ -carotene content of all the products reduced gradually, during storage, the higher loss being observed in carrot powder.

The present study clearly shows that  $\beta$ -carotene is sensitive to any drying method and cabinet drying was found to retain considerable amount of  $\beta$ -carotene. In the dehydrated carrot products though  $\beta$ -carotene loss was reported, they could be used in the preparation of recipes during off-seasons. Freshly prepared carrot powder could be incorporated into several recipes like laddu, roti, milk beverage and feeding mixes of infants etc.

## CONCLUSION

It could be concluded from this study that  $\beta$ -carotene loss is inevitable on dehydration of carrots, independent of the drying/dehydration method. The results showed that cabinet drying (42 %) followed by solar drying (52 %) had considerably less loss of  $\beta$ -carotene, compared to sundrying (71 %). The use of equipment like cabinet drier is linked mostly to the laboratory and commercial level. Although sundrying is an economical method, the loss of nutrients particularly the vitamins and minerals is extensive. Hence there is a need to follow other methods of drying which could preserve the nutrients. Several low cost equipments, designed to work with solar energy are available in the market. Solar drier (3 kg

capacity) is one such equipment available with a price range of Rs. 2000/- to Rs. 3000/-. The use of solar driers with U.V. filters could also be recommended for dehydration of carrots and other vegetables at household level or at community level, keeping in view the energy restrictions in near future and also the advantage of retention of certain vitamins like  $\beta$ -carotene.

Dehydrated products have good shelf life, easily transportable and are better utilized during emergency periods and during off-seasons when vegetables become expensive. The dehydrated carrots have an additional advantage of having  $\beta$ -carotene content when compared to the other dehydrated vegetables like gourds.

The recipes prepared with dehydrated carrots had good acceptability. The freshly prepared carrot powder had considerable amount of  $\beta$ -carotene (23.86 mg/100 g) which could be used in preparations like laddu, roti, milk beverages, feeding mixes for infants etc which not only adds to the variety but also enhances the nutritive value. Addition of antioxidant could reduce the loss to some extent. Further research is needed to develop carrot powder with low cost technology, with minimum loss of  $\beta$ -carotene for greater utilisation of carrots as a source of  $\beta$ -carotene.



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*LITERATURE CITED*

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## LITERATURE CITED

- Aguilera J.M and Stanley D W 1990 Microstructural principles of food processing and engineering. Elsevier Applied Science, London.
- Andreotti R, Tomasicchio M and Macchiavelli L 1981 Studies on the freeze drying of carrots and onions after an initial partial air drying (Air freeze dried products). *Ind. Conserve.* 56(2) : 89-91 (FSTA abstracts computer search).
- AOAC 1980 Official methods of analysis of the Association of Official Analytical Chemists, 13th edition, Arlington, VA, USA.
- AOAC 1984 Official methods of analysis of the Association of Official Analytical Chemists. 14th edition Arlington, VA, USA.
- Apgar J, Cox N, Downay J and Fenton F 1959 Cooking pork electronically. *Journal of American Dietetic Association* 35 : 1260.
- Arya S S, Nateson V, Parihar D B and Vijayaraghavan P K 1979 Stability of carotenoids in dehydrated carrots. *Journal of Food Technology* 14 : 579-586.
- Arya S S, Natesan V, Premavalli K S and Vijayaraghavan P K 1982 Effect of prefreezing on the stability of carotenoids in imbalanced air dried carrots. *Journal of Food Technology* 17(1) : 109- 113.
- \* Bajaj K L, Kaur G and Sukhija B S 1980 *Qualitas plantarum* 30(2) : 97-107.
- Baloch A K, Buckle K A and Edward R A 1977 Effect of processing variables on the quality of dehydrated carrots (a) leaching losses and carotenoid content. *Journal of Food Technology* 12(3) : 285-293. (b) Leaching losses and stability of carrots during dehydration and storage. *Journal of Food Technology* 12(3) : 295- 307.
- Baloch A K, Buckle K A and Edwards R A 1981 Effect of chemical treatment on stability of dehydrated carrot. *Pakistan Journal of Science of Industrial Research* 24 : 203-211.

- Baloch A K, Buckle K A and Edwards R A 1987 Effect of sulphurdioxide and blanching on the stability of carotenoid in dehydrated carrot. *Journal of Science and Food Agriculture* 40 : 179-187.
- Bansal R K 1998 Fruit and vegetable processing industry in India. *Indian Food Packer* 52(5) : 33-36.
- Bao B and Chang K C 1994 Carrot juice color, carotenoids and nonstarchy polysaccharides as affected by processing conditions. *Journal of Food Science* 59 : 1155-1158.
- \* Barbosa W C 1981 Unicamp informativo, Anualda Faculdede de Engenharia dc Alimentos Agricola 9 : 3-4.
- \* Baruffaldi R, Vessoni Penna T C, Colombo A J, Pitombo R N 1983 *1984 Dehydration*  
Ciencia C Tecnologia de Alimentos 3(27) : 155-160.
- Beerh O P, Saxena A K, Manar J K 1984 Improvement of the traditional method of manufacture of carrot murabba. *Indian Food Packer* 36(4) : 59-63. (1) : 87-94
- Berna A, Rosello C, Mullet A and Catale P 1988 Food dehydration with solar energy description of a pilot dryer and exploratory tests with carrots. *Revista de Agraquinica Y. Tecnologia da Alimentos* 28(2) : 241-250.
- Bhavani K N and Kamini Devi 1996 Suitability of curry leaves and carrot powder in snack preparation. *Indian Journal of Nutrition Dietetics* 33 : 255-257.
- Boeh-Ocansey O 1984 Effects of vacuum and atmospheric freeze drying on quality of shrimp, turkey flesh and carrot samples. *Journal of Food Science* 49(6) : 1457-1461.
- Bolin H R and Stafford A E 1974 Effect of processing and storage on provitamin A and vitamin C in Apricots. *Journal of Food Science* 39 : 1035.
- Bolin H R and Salunke D K 1982 Food dehydration by solar energy *CRC Crit. Rev. Fd. Sci. Nutr.* 16(4) : 327-354.

- Borchgrevink and Helen Charley 1966 Colour of cooked carrots related to carotene content. *Journal of the American Dietetic Association* 49(2) : 116.
- Bourne M C 1989 How kinetic studies of detergency with water Jennings led to firmer textured processed vegetables and fruits. 198th American Chemical Society National Meeting, Miami, September 12. Division of Agriculture and Food Chemistry Abstract No. 28.
- Camacho N L 1983 Air drying and freeze-drying of carrots under various conditions. *Alimentos* 8 : 15-21.
- Carbonell J V, Madarro A, Pinaga F, Pena J L 1984 Dehydration of fruits and vegetables with ambient air. iv. Kinetics of Water absorption and desorption in carrots. *Rev. Agroquim. Technol. Aliment* 24(1): 94-104.
- Carbonell J V, Pinaga F and Pena J L 1985 Solar drying of food products IV carrots. *Rev. Agroquim Technology Aliment* 25(1) : 87-94.
- Carbonell J V, Madarro A, Pinaga F, Pena J L and Izquicrodo L 1987 Dehydration of fruit and vegetables with ambient air. VI storage study of dried carrots. *Revista de Agroquimica Y. Tecnologia da Alimentos* 27(1) : 96-106.
- \* Chace E M, Noel W A and Pease V A 1941 Preservation of fruits and vegetables by commercial dehydration. U.S Department Agricultural Circ 619.
- Chauhan S K and Sharma R C 1993 Development of instant dehydrated saag. *Beverage and Food World* 20(4) : 25-26.
- Choudhury B 1991 *Vegetables*. National Book Trust, India, New Delhi 19, 87-91.
- Crivelli G and Polesello A 1973 Research on quick freezing of vegetables. III. Suitability of carrot varieties. *Freddo* 27 : 29-30.
- Cruess W V 1958 *Commercial fruit and vegetable products*. 4th Edn. McGraw Hill Book Co. Inc., New York.

- Cruick Shank R, Duguid J P, Marmion B P and Swain R H A 1975 Medical microbiology. The practice of medical microbiology. Churchill Livingstone, Edinburgh, London and New York : 306.
- Curry J C, Burns E E and Heidelbaugh N D 1976 Effect of sodium chloride on rehydration of freeze-dried carrots. *Journal of Food Science* 41 : 176-179.
- \* Darman Yan, Drukkin E B, Prikladnaya M S 1983. *Biokomiya Mikrobiologia* 18(3) : 423-430.
- Debrosier N W 1970 The technology of food preservation. The AVI publishing co. Inc. Westport, Connecticut.
- Desobry S A, Netto F M and Labuza T P 1998 Preservation of beta-carotene from carrots. *Critical Reviews in Food Science and Nutrition* 38(5) : 381-396.
- Dikshit S N, Udipi S A, Rao A, Manohar V 1988 Separation of carotenoids and estimation of beta-carotene content of selected Indian Food and Food Preparations by HPLC. *Journal of Food Science and Technology* 25(1) : 39-41.
- \* Eichner K, Wolf W 1983 ACS Symposium Series 215 : 317-333.
- Elliott H P, Michener H D 1961 Microbiological standards and handling codes for chilled and frozen foods. A review *Appl Microbiol* 9 : 452-468.
- Empowering vitamin A foods - Food based approach for Asia and Pacific Region, 1996.
- Encyclopaedia of Food Science, Food Technology and Nutrition 1993 vol. 2.
- Eusebio E C, Gonzales J G, Tobias J R, Soriano L B, Peralta E L and Marcelo E S 1980 Studies on the dehydration of pearsay leaves. Kamote tops and carrots. *NSDB Technology Journal* 5(1) : 48-53.
- Falconer M E, Fish Wick M J, Land D G and Sayer E R 1964 Carotene oxidation and off-flavour development in dehydrated carrot. *Journal of Science in Food Agriculture* 15 : 897.

- Giebriel A Y, El-Sahrigi A F, El-Mansy H A H, Kandil S H 1977  
Egyptian Journal of Food Science 5(1/2) : 31-39.
- Glossock S J, Arelson J M, Palmer J K, Phillips J A, Taper L J 1982  
Home Economics Research Journal 11(2) : 149-158.
- Goldman M, Horev B and Saguy I 1983 Decoloration of beta-carotene  
in model systems simulating dehydrated foods. Mechanism and  
Kinetic principles. Journal of Food Science 48 : 751-754.
- Grewal K S, Jain S C 1982 Physico-chemical characteristics of carrot  
juice beverages. Indian Food Packer 36(5) : 44-47.
- \* Harris P L, Qualif M L and Swanson W J 1950 Journal of Nutrition  
40 : 368.
- Heatherbell D A, Wrolstad R E and Libbey L M 1971 Carrot volatiles.  
1. Characterization and effects of canning and freeze drying. Journal  
of Food Science 36 : 219-224.
- \* Hess 1980 Journal of Snack Food 70(1) : 58-60.
- Howard L R, Braswell D, Heymann H, Lee Y, Pike L M and Aselage  
1995 Sensory attributes and instrumental analysis relationships for  
strained processed carrot flavour. Journal of Food Science 60 :  
145-148.
- Jarvis M C 1982 The proportion of calcium-bound pectin in the plant  
cell wall. Planta 154 : 344-346.
- Jayaraman K S, Dasgupta K S and Babu Rao N 1991 Quality characteristics  
of some vegetable dried by direct and indirect sundrying. Indian  
Food Packer, Jan - Feb 1 : 16-21.
- Jellinek G 1964 Introduction of critical review of modern methods of  
sensory analysis (odour, taste and flavour evaluation) with special  
emphasis on descriptive sensory analysis (Flavour profile method).  
The Indian Journal of Nutrition Dietetics 1 : 219-226.
- Kalra C L, Kulkarni S G and Berry S K 1987 The carrot (*Daucus carota*  
L.). A most popular root vegetable. Indian Food Packer 41(6) :  
46-73.

- Kaur (Gurdeep), Jaiswal S P, Brar J S, Nandpuri K S 1976 Physico-chemical characteristics of some important varieties of carrot (*Daucus carota* L.) Indian Food Packer 30(2) : 5-8.
- \* Kirtschev N A and Krachanov C (chor. G) Z. Lebensmittel - Unters. Forsch 1980, 170(1) : 31-33.
- \* Koryachkina S Y A, Baranov V S, Shakirova V S 1984 Izvestiya Vysshikh Uchebny K H, Zavedenii Pischevaya Technologia 4 : 31-34.
- Labuza T P 1972 Nutrient losses during drying and storage of dehydrated foods. CRC Critical Reviews in Food Technology 3 : 217.
- Lakshmi 1998 Development of nutritious dehydrated green leafy vegetable powders and blends. Ph.D Thesis Submitted to A.N.G.R. Agricultural University.
- Lee C Y, Bourne M C and Vanburen J P 1979 Effect of blanching treatments on firmness of canned carrots. Journal of Food Science 44(2) : 615.
- Maeda E E and Salunke D K 1981 Retention of ascorbic acid and total carotene in solar dried vegetables. Journal of Food Science 46 : 1288.
- Mandhyan B L, Abroal C M and Tyagi H R 1988 Dehydration characteristics of winter vegetables. Journal of Food Science and Technology 25(1) : 20-22.
- Mayne S T, Janerich D T, Greenwald P, Chorost S, Tucci C, Zaman M B, Melamed R, Kiely M and Mc Kncally M F 1994 Dietary beta- carotene and lung cancer risk in U.S. non-smokers. Journal of National Cancer Institute 86(1) : 33.
- Mazza G 1983 Dehydration of carrots. Effect of predrying treatments on moisture transport and product quality. Journal of Food Technology 18(1) : 113-123.

- Mc Dowell J 1973 Solar drying of crops and foods in humid tropical climates. A practical working manual on construction and use of enclosed convection ventilated solar driers. Carribean Food and Nutrition Institute, Jamaica and Trinicolad Centre.
- Menkes M S, Comstock G W, Vuilleumier J P, Kelsing K J, Rider A A and Brookmeyer R 1986 Serum beta-carotene, vitamins A and E, selenium and the risk of lung cancer. *New England Journal of Medicine* 315 : 1250.
- Mirza S, Morton I D 1977 Studies of dehydration of vegetables. *Journal of Food Science and Agriculture* 28(1) : 1035-1039.
- Mohammed S and Hussain R 1994 Effect of low temperature blanching, cysteine-Hcl, N-acetyl-L-cysteine, Na-meta sulfite and drying temperature on the firmness and nutrient content of dried carrots. *Journal of Food Process Preservation* 18 : 343-348.
- Mudahar G S 1989 Process optimisation and physico chemical investigation of high quality processing vegetables. Ph.D Dissertation, University of Georgia, Athens, G.A.
- Narasinga Rao B S, Deosthale Y G and Panth K C 1989 Nutritive value of Indian Foods. National Institute of Nutrition. Indian Council of Medical Research, Hyderabad, India.
- Niranjan Singh Sekhon 1943 The effect of storage on the carotene content of dehydrated vegetables. *Indian Journal of Medical Research* 31 : 141-144.
- Ogunlesi A T and Lee C Y 1979 Effect of thermal processing on the Sterisisomerization of major carotenoids and vitamin A value of carrots. *Food Chemistry* 4(4) : 311-318.
- Otasuka H and Take T 1969 Sapid components in carrot. *Journal of Food Science* 34(5) : 392.
- Park Y W 1987 Effect of freezing, thawing, drying and cooking on carotene retention in carrots, broccoli and spinach. *Journal of Food Science* 52 : 1022-1025.

- Pruthi J S, Saxena A K and Manan J K 1980 Studies on the determination of optimum conditions of preservation of fresh vegetables in acidified sulphited brine for subsequent use in Indian style curries etc. *Indian Food Packer* 34(6) : 9-16.
- Rahman A R 1972 Increased density for military foods. Technical Report No. AD-750-368, U.S. Army Natick Labs. Natick Mass. CAB abstracts computer search.
- Rao K V S S, Thompkinson D K and Mathur B N 1997 Role of sensory analysis in product development. *Indian Food Industry* 16(1&2) : 53-57.
- Reese H Vaughn 1951 The microbiology of dehydrated vegetables. *Food Research* 17 : 429-438.
- Reev R M 1943 Microscopy of the oils and carotene bodies in dehydrated carrots. *Food Research* 8 : 137-145.
- Rukmini H S, Soekato S T, Fardiaz D, Jenis B S L and Tomomatsu A 1985 The stability of pro vitamin A in preparation of carrot powder. *Forum Pascasarjana* 8 : 13-24.
- Saldana G, Meyer R, Lime B J 1980 Carrots, Potential processed product. *Journal of Food Science* 45(5) : 1444-45, 1448.
- Salem S A and Hagazi S M 1973 Chemical changes occurring during the processing of sundried apricot juice. *Journal of Science and Food Agriculture* 24 : 123.
- Sampathu S R, Chakraborty S, Karan Prakash, Bisht H C, Agarwal M D, Saha N K 1981. Standardisation and Preservation of carrot 'Halwa' an Indian Sweet. *Indian Food Packer* 35(6) : 60-67.
- \* Schaller A, Vamos- Vignyazo L 1980 *Confructa* 25(3/4) : 87-106.
- Seow C C N G K B and Bourne M C 1992 Effect of blanching treatment on physico-chemical properties of dehydrated carrots, Celery and green beans. *ASEAN Food Journal* 74(4) : 184-188.
- Shaw A, Mathur P and Mehrotra N N 1993a A study of consumer's attitude towards processed foods. *Indian Food Packer* 47(2) : 29-41.

- Simpson K L 1985 Chemical changes in natural food pigments. In chemical changes in food during processing (eds. Richardson T and Finley J N), AVI West Port, CT p. 411.
- Snedecor G W and Cochran W G 1967 Statistical methods 6th edition, Oxford and IBH Publishing Company, New Delhi.
- \* Stephens T S and Mchemore T A 1960 Food Technology Campaign 23(12) : 1600.
- Sterling C 1955 Effect of moisture and high temperatures on cell walls in plant tissue. Food Research 20 : 474.
- \* Sterling C 1968 Journal of Food Technology 3(4) : 367.
- Subhadra Seshadri 1995 Use of carotene rich foods to combat vitamin A deficiency in India - A multicentric study. Nutrition Foundation of India. Scientific Report.
- Sullivan J F, Knostance R P, DellaMonica F S, Heiland W K and Craig J C Jr. 1981 Carrot dehydration-optimization process studies on explosion puffing process. Journal of Food Science 46(5) : 1537-1542.
- \* Szilagyi-Toth E, Reichart O, Zetelaki Horvath K 1985 Acta Alimentaria 14(1) : 15-28.
- Taylor S L, Higley N A and Bush R K 1986 Sulfites in foods, uses, analytical methods, residues, fate, exposure assessment, metabolism, toxicity and hypersensitivity. Advance Food Research 30 : 1-76.
- \*Tomkins R G, Mapson H W, Allen R J L, Wager H G and Barker J 1944 Jr. of Soc. Chem. Ind.. 63, 225 T.
- Van Arsdel W B, Copley M J, Morgan A I 1973 Food dehydration, 2nd edn. The AVI Publishing Company, Inc. West Port, Connecticut.
- Vinodini Reddy K, Vijayaraghavan 1995 Carotene rich foods for combating vitamin A deficiency. NIN Report.
- Wager H C 1958 Plant structure and dehydration. Fundamental aspects of the dehydration of food stuffs. Chem. and Ind. 6 : 821.

- Wagner L A and Warthesen J J 1995 Stability of spray dried encapsulated carrot carotene. *Journal of Food Science* 60 : 1048- 1053.
- Walde S G, Math R G, Chakkaravarthi A and Rao D G 1992 Preservation of carrots (*Daucus carota* L.) by dehydration techniques - A review. *Indian Food Packer* 46(6) : 37-42.
- Welder A, Wolf W, Paulus K 1981 Effects of physical preservation methods and storage on the quality of carrots. *Zeitschrift fur Lebensmittel Technologie and Verfahren Stehchnik* 32(16) : 25-30.
- Zakaria M, Simpson K, Brown R P, Krurtulovic A 1979 Use of reversed phase high performance liquid chromatography for the determination of provitamin carotenoids in tomatoes. *Journal of Chromatography* 176 : 109.
- Zeigler R 1989 A review of the epidemiological evidence that carotenoids reduce the risk of cancer. *Journal of Nutrition* 119 : 116.
- Zhao Y P and Chang K C 1995 Sulfite and starch affect colour and carotenoids of dehydrated carrots during storage. *Journal of Food Science* 60 : 324-326.

\* Original not seen



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APPENDICES

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Sample	...	...	...
...	...	...	...

## APPENDIX A

## HPLC DETERMINATION OF BETA-CAROTENE

## Procedure

For analysis of the  $\beta$ -carotene content in carrots, 5 gm each of the weighed sample (fresh and dried) was placed in a mortar and stirred slowly by adding 40 ml acetone, 60 ml hexane and 0.1 g  $MgCO_3$  for about 5 min. The liquid was decanted into a separating funnel. The residue was washed with two 25 ml portions of acetone and 25 ml hexane. Then washed with five 100 ml portions water. Finally the upper layer was transferred to 100 ml volumetric flask containing 9 ml acetone and diluted to volume with hexane. The filtrates were filtered using a micropore membrane filter and exactly 20  $\mu$ l of the sample extract was injected on the HPLC column. The separation of carotenoids was accomplished with the mobile phase consisting of acetonitrile/methanol/chloroform in the proportion of 70 : 15 : 15, pumped at a flow rate of 2 ml/min.  $\beta$ -carotene was monitored with Shimadzu SPD 10 A. UV detector set at wave length of 450 nm. The chromatographic system consisted of a reverse phase; ODS C18 column and the column length was 25 cm. The pressure was maintained at 130 to 180 kg/cm<sup>2</sup> and the retention time was 12.5 min.

## Quantitation

20  $\mu$ l of standard  $\beta$ -carotene was injected into a HPLC and the peak area was noted. The peak area of the sample was obtained by injecting 20  $\mu$ l of extract. The amount of  $\beta$ -carotene in the sample was determined as follows.

$$\beta\text{-carotene (mg/100 g)} = PA \times ARF \times \frac{100}{0.02} \times \frac{100}{\text{Wt. of the sample}}$$

Where,

PA = Peak area of the sample

ARF = Area resolution factor of standard  $\beta$ -carotene obtained from the standard graph.

## APPENDIX B

**SCHEDULE FOR SENSORY REVALUATION OF  
DEHYDRATED PRODUCTS**

Name of the Judge :

VALUATI

Date :

Instructions :

You are being given 3 dehydrated carrot products. Please evaluate the products based on the characteristics tested.

Sensory attributes	Scores	Products		
		1	2	3
<b>Appearance</b>				
Very good	5			
Good	4			
Fair	3			
Average	2			
Poor	1			
<b>Colour</b>				
Very good	5			
Good	4			
Fair	3			
Average	2			
Poor	1			
<b>Flavour</b>				
Very good	5			
Good	4			
Fair	3			
Average	2			
Poor	1			
<b>Texture</b>				
Very good	5			
Good	4			
Fair	3			
Average	2			
Poor	1			
<b>Overall acceptability</b>				
Very good	5			
Good	4			
Fair	3			
Average	2			
Poor	1			

## Appendix C

## SCHEDULE FOR SENSORY EVALUATION OF RECIPES

Name of the Judge :

Date :

Instructions :

You are being given 2 samples each of curry, *halwa* and biscuits.

Please evaluate the products based on the five point scale given below.

5 - Very good

4 - Good

3 - Fair

2 - Average

1 - Poor

Sensory attributes	Recipes					
	1	1a	2	2a	3	3a
Appearance						
Colour						
Flavour						
Taste						
Texture						
Overall						
Acceptability						
Suggestions or comments, if any :						

## APPENDIX D

## RECIPES

**CARROT CURRY****Ingredients**

Carrot chops	350 g
Green chillies	2
Onions	75
Seasonings	10 g
Oil	20 g
Salt	to taste
Coconut gratings	10 g

**Method**

- Heat oil and add the seasonings
- Add chopped onions and green chilli paste and fry till onions become soft.
- To it add carrot chops, salt and cook till done
- Sprinkle coconut gratings and serve.

**CARROT HALWA****Ingredients**

Carrot shreds	500
Ghee	25 g
Milk	250 ml
Sugar	175 g
Cardomom powder	1/4 tsp
Cashewnuts	few

**Method**

- Put ghee in a pan, add carrot shreds and shallow fry for 5-6 min.
- Add milk and pressure cook for 10 min.
- To this add sugar and cardomom powder and keep on fire with occasional stirring till the product becomes dry x garnish with cashewnuts and serve.

## BISCUIT WITH 10 PER CENT CARROT POWDER

### Ingredients

Refined flour	150 g
Carrot powder	15 g
Sugar	85 g
Fat	85 g
Milk	125 ml
Baking powder	1/4 tsp
Vanilla essence	few drops

### Method

- Cream fat and sugar till light and fluffy.
- Sieve flour with baking powder and carrot powder, ensuring proper mixing of the ingredients.
- Add vanilla essence to milk
- Add flour to the creamed mixer and make, soft pliable dough using milk.
- Roll out into 1/2 inch thickness and cut into desired shape with a biscuit cutter.
- \*Bake at 175°C/350°F from 15-20 min.

## APPENDIX E

**DETERMINATION OF TOTAL BACTERIAL COUNT****Reagents**

Normal saline - 0.8 %

Standard plate count agar

**Principle**

The number of living bacteria or groups of bacteria in a liquid culture or suspension is counted by a cultural method such as the pour plate method. A measured amount of suspension is mixed with molten agar medium in petridish. After setting and incubation, the number of colonies are counted. As a compromise between sampling and overcrowding errors, counts of pure cultures should be made on plates inoculated to yield between 30 and 300 colonies.

**Procedure**

Serial ten fold dilution of the bacterial suspension was prepared over a range ensuring that one dilution contained between 30 and 300 viable bacterial per ml. Normal saline was used as a diluent for the organism. 9 ml of the diluent was pipetted out into several sterile test tubes. The bacterial suspension was uniformly mixed. Using a sterile 1 ml pipette, 1 ml of suspension was transferred into the first tube of diluent by touching the tip of the pipette to the wall of the tube. The first dilution was mixed thoroughly using another sterile pipette by filling and emptying the contents several times. From this mixed dilution,

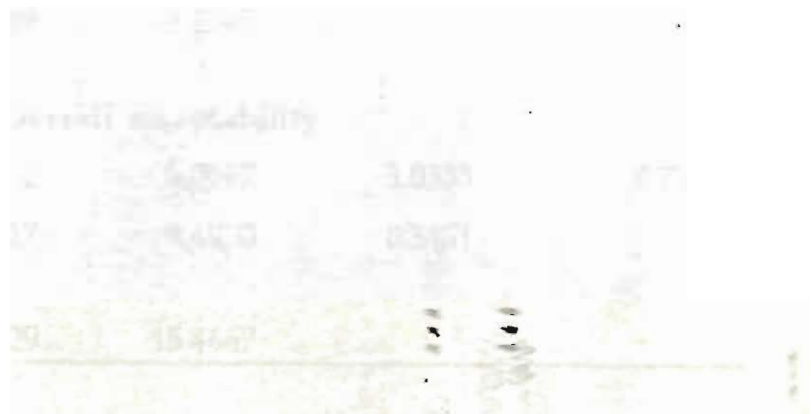
1 ml was transferred to the next diluent. Similar dilutions were made in the same way using fresh pipettes.

1 ml of each dilution (from the greatest dilution) was pipetted into three, 4 inch petridishes. Into each dish, 10 ml standard plate count agar was poured which was melted earlier and cooled to 45 to 50°C. The agar was immediately distributed by gently swirling the petridishes in circular movements while flat on the bench for 10 sec. The agar was allowed to set evenly and the inverted petridishes were incubated for 2 days at 37°C.

### Calculations

The colonies which were inoculated under different dilutions were counted for 30 to 300 colonies per plate and the average number per plate was multiplied by the dilution factor to obtain the viable count per ml in the original suspension.

No. of colonies  $\times$  dilution factor = count per gm of the sample



## APPENDIX F

ANOVA tables for each sensory characteristic of carrots dried in solar drier, hot air cabinet drier and direct sunlight

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F value
<b>Appearance</b>				
Treatments	2	7.80	3.90	15.26
Error	27	6.90	0.25	
Total	29	14.70		
<b>Colour</b>				
Treatments	2	23.4000	11.7000	39.00
Error	27	8.1000	0.3000	
Total	29	31.5000		
<b>Flavour</b>				
Treatments	2	1.8000	0.9000	4.96
Error	27	4.9000	0.1815	
Total	29	6.7000		
<b>Texture</b>				
Treatments	2	4.8667	2.4333	4.50
Error	27	14.6000	0.5407	
Total	29	19.4667		
<b>Overall acceptability</b>				
Treatments	2	6.0667	3.0333	8.71
Error	27	9.4000	0.3481	
Total	29	15.4667		

Acc: No:

D5929

99

Date:

2-5-2000

## APPENDIX G

## ANOVA Tables for each sensory characteristics of carrot products dried in Hot air cabinet drier

Source of variation	Degrees of Freedom	Sum of squares	Mean sum of squares	F Value
<b>Appearance</b>				
Treatments	2	0.2667	0.1333	0.56
Error	27	6.4000	0.2370	-
Total	29	6.6667		
<b>Texture</b>				
Treatments	2	4.0667	2.0333	9.00
Error	27	6.1000	0.2259	
Total	29	10.1667		
<b>Colour</b>				
Treatments	2	1.4000	0.7000	3.26
Error	27	5.8000	0.2148	
Total	29	7.2000		
<b>Flavour</b>				
Treatments	2	1.8667	0.9333	2.65
Error	27	9.5000	0.3519	
Total	29	11.3667		
<b>Overall acceptability</b>				
Treatments	2	0.8667	0.4333	1.67
Error	27	7.000	0.2593	
Total	29	7.8667		