Dedicated to the

Food Engineering Profession

CONTENTS

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SYMBOLS AND ABBREVIATIONS

%	percentage
/	per
˚C	degree celsius
=	equal to
±	plus or minus
cm	centimeter
C A	citric acid
et al.,	and others
etc.	etcetera
Fig.	figure
g	gram(s)
GLVs	green leafy vegetables
H	hour(s)
i.e.	that is
j	journal
KCAET	Kelappaji College of Agricultural Engineering and Technology
KAU	Kerala Agricultural University
Kg	kilogram
$Kgcm^{-2}$	kilogram per square centimetre
KMS	potassium metabisulphite
m	meter
µm	micrometer
mg	milligram
mm	millimeter
Min	minute(s)
Ml	millilitre
RH	relative humidity
Sec	second(s)
viz.	namely
w.b	wet basis
wt	weight
AOAC	Associates of Official Analytical

	Chemists
MSG	Monosodium glutarate
m/s	Metre per second
Kg	Kilogram
Kg Div	Kilogram division
MHz	Mega hedz
µm	Micro metre
Mm	milli metre
Mg	Milligram
Na	Sodium
HDPE	High density polyethylene
W	Watt
PE	Polyethylene
PP	Polypropylene

CHAPTER I

INTRODUCTION

India is blessed with an array of leafy vegetables, some are cultivated many are gathered. Green Leafy Vegetables (GLVs) represent an excellent component of habitual diet in the tropical and temperate countries. Numerous types of GLVs are consumed, to mention a few methi, mint, coriander, curry leaves, amaranthus and drumstick leaves. Green leafy vegetables add variety to a monotonous diet, have an alternative taste, attractive in appearance and contribute a pleasing aroma. Besides, they are known to be the most inexpensive sources of several vital nutrients. This group of foods are rich sources of vitamins like vitamin-A in the form of β-carotene, ascorbic acid, riboflavin, folic acid; minerals like calcium, iron, potassium, sodium and phosphorous.

Micronutrient deficiencies especially Vitamin A (VAD) and iron (IDA) are the major nutritional problems of India. As Gopalan (1996) rightly puts it, food approach is excellent strategy to combat nutritional deficiencies and is superior to pharmacological approach as the former provides a package of nutrients and health promoting components like fiber, unlike sole nutrients in the latter. In this context, GLVs being inexpensive, affordable, sustainable and culturally acceptable, fit very well into the routine diet and can serve as a means to address these micronutrient deficiencies.

GLVs provide several other components that function as antioxidants, primary among them are fiber, carotene, ascorbic acid, vitamin E, selenium and flavonoids. These offer protection against many life style related chronic diseases *viz.*, heart diseases, obesity, diabetes, hypertension and certain type of cancers. Green leafy vegetables also provide a variety of phytonutrients - leutin and zeaxanthin which protect our cells from damage and age-related problems. Since many degenerative human diseases have been recognized as being a consequence of free radical damage, there have been many studies undertaken to realize how to delay or prevent the onset of these diseases. Zhang *et al. (*2001) and Alia *et al. (2003)* reported the most likely and practical way to fight these degenerative diseases are to improve antioxidant status, which could be achieved by higher consumption of vegetables and fruits. Foods from plant origin usually contain natural antioxidants that can scavenge free radical. Epidemiological evidence has clearly shown that diets based on fruits and vegetables, with high content of natural antioxidants, contribute to reduced mortality from cardiovascular and cerebrovascular diseases, although their protective effect on cancer risk is less conclusive. The high fiber, magnesium and low glycemic index of green leafy vegetables are valued for persons with type II diabetes.

Green leafy vegetables are highly perishable with shelf-life of only a few days owing to higher amount of moisture. Around 30 % of the produce gets rotten and spoilt, becomes inedible, rendering wastage of a huge amount of nutritious products. This calls for preservation and processing to prevent losses and as well as make them available in the lean season at remunerative price.

Amaranthus is a common a green leafy vegetable seen throughout the tropics and in many warm temperate regions. It is cultivated and consumed as a leaf vegetable in many parts of the world. Amaranth leaves are nutritionally similar to beets, swiss chard and spinach, but are much superior. For example amaranth leaves contain three times more calcium and three times more niacin (vitamin B3) than spinach leaves. Amaranth is much closer genetically to its wild ancestors than our over developed and nutritionally depleted typical vegetables. Amaranth leaves are an excellent source of carotene, iron, calcium, protein, vitamin C and trace elements. Their high moisture content renders them perishable and seasonal availability limits their utilization all around the year. Hence, there is a need to preserve this nature‘s store house of nutrients through proper processing techniques for safe storage with efficient nutrient retention. Drying is the commonly used technique for preservation.

Drying is one of the traditional methods of preservation, which converts the leafy vegetables into light weight, easily transportable and storable product. Advantage of this method is that the vegetable can be easily converted into fresh like form by rehydrating it and can be used throughout the year. Chauhan and Sharma (1993) revealed that in addition to increasing the variety in menu, reducing losses, labor and storage space, dehydrated leafy vegetables are simple to use and have longer shelf-life than fresh vegetables along with concentration of nutrients.

The quality of the dehydrated product in terms of rehydration ratio, colour and flavour retention depends on the pretreatments and method of drying. Vacuum drying is ideal for materials that would be damaged or changed if exposed to high temperatures. The vacuum removes moisture while preventing the oxidation or explosions that can occur when certain materials combine with air. Vacuum drying is also ideal in situations where a solvent must be recovered or where materials must be dried to very low levels of moisture.

Unlike atmospheric drying, drying under reduced pressure lowers the boiling point and provides a greater temperature difference between the heating medium and product. This results in faster drying and more efficient heat recovery. Drying at lower temperatures reduces energy consumption. Vacuum drying has some distinctive characteristics such as higher drying rate, lower drying temperature and oxygen deficient processing environment etc., these characteristics may help to improve the quality and nutritive value of the dried products.

Jha and Prasad (1996) claimed that pre-treatment is common in most processing operation to improve product quality or process efficiency. The main drying pre-treatments are blanching, dipping and sulphiting. In recent years an improvement in quality retention of dried products by altering processing strategy pre-treatment has gained much attention.

With these backgrounds a study has been carried out with the following objectives:

a. To study the effect of pre-treatments to retain the drying quality of amaranthus leaves.
b. To compare the drying characteristics of vacuum, cabinet and sun drying on amaranthus leaves.
c. To study the effect of packing material on the shelf life of dried amaranth leaves.

CHAPTER II

REVIEW OF LITERATURE

This chapter gives general information on amaranthus leaves, its chemical composition, various method of drying and its effects on the quality of end products and packaging studies of amaranthus. Research done on these aspects are also reviewed and discussed in detail.

2.1 Amaranthus leaves

Amaranthus, collectively known as amaranth, is a cosmopolitan genus of annual or short-lived perennial plants. Some amaranth species are cultivated as leaf vegetables, cereals, and ornamental plants. *Amaranthus viridis* include in the family *Amaranthaceae* .Amaranthus contain about 90% moisture content. Reddy et al. (1999) claimed that the leaf is a good source of proteins and the dry matter of leaves contained as much as proteins as legumes.

Component	**Amaranthus leaves**
Dry matter, g	13.1
Protein, g	3.5
Fat, g	0.5
Carbohydrates	
Total, g	6.5
Fiber, g	1.3
Ash, g	2.6
Calcium, mg	267
Phosphorous, mg	67
Iron, mg	3.9
Sodium, mg	3.5
Potassium, mg	411
Vitamin A, IU	6,100
Thiamin, mg	.08
Riboflavin, mg	0.16
Niacin C, mg	1.4
Vitamin C, mg	80

Table 2. 1. Chemical composition of amaranthus leaves, source: Saunders and Becker (1983)

2.2. Pretreatment methods of leafy vegetables

Pretreatments and methods employed prior to drying influence the physicochemical and enzymatic changes that occur during drying and helps to enhance the keeping quality of dried products. Drying conditions including time, temperature and relative humidity influence the final quality of dehydrated product.

Singh *et al*. (1997) studied the dehydration characteristics of four commonly consumed green leafy vegetables. The vegetables were cut into shreds and blanched in hot water at 90°C for two minutes and immersed in 0.2 per cent potassium metabisulphate solution. The blanched leaves when dried at 60 ± 2°C with 55-60 per cent relative humidity, required four hours for complete dehydration in cabinet drier and two days for drying under sun 25°C, to reach desired moisture level 9-10%. Drying rate was fast in spinach and lower in fenugreek leaves.

An experiment on dehydration of drumstick leaves was carried out by Seshadri *et al*. (1997). Drumstick leaves were subjected to steam blanching for three minutes and blanching followed by sulphitation for three minutes at room temperature and all the pretreated leaves were shade dried. Results indicated that, time taken for drying to a constant weight was 20 hours for blanching.

Negi and Roy (2001) reported that blanching of amaranth in hot water at 95 ±3˚C for one minute followed by cooling in running tap water and dipping in 0.5 per cent solution of potassium meta bisulphite for one minute prior to drying in cabinet drier showed higher retention of chlorophyll, s-carotene and lowered non-enzymatic browning.

Gupta *et al*. (1990) carried out a study on improvement in rehydration and shelf life stability of hot air dried and sun dried cabbage by pre drying treatment. Both treated (soaking in solutions containing 3% salt, 6% sugar and a combination of both at 0-4 °C for 12- 16 hours) and untreated (only blanched) cabbage was soaked at room temperature in 0.2 percent KMS solution for 10 minutes and dried in hot air oven, solar cabinet drier and under direct sun. The results showed that incorporation of sugar increased the drying time of cabbage by one hour in hot air oven 8 hours , four hours in direct sun 13 hours and three hours in solar cabinet drier 12 hours apparently due to the humectants effect of sugar.

Bajaj *et al*. (1993) evaluated culinary quality of blanched and dehydrated fenugreek leaves. Colour, texture, aroma and overall quality of blanched leaves received significantly higher scores than unblanched. Among the blanching treatments, plain water, magnesium oxide (0.1%) and sodium bicarbonate (0.1%) were found to be better blanching solutions in terms of quality.

Sukanya *et al*.(1995) revealed blanching as a pre-treatment prior to drying in sun and shade resulted in organoleptically acceptable product from fenugreek. On comparison with untreated fenugreek, blanched fenugreek leaves obtained better scores for all sensory parameters even up to three months of storage. It was also concluded that drying of vegetables under sun is effective method.

Seven types of green leafy vegetables viz., *dhantu, khirkhire, honagone, chakota, palak, kanchi* and fenugreek were chopped, and in to small pieces, blanched in boiling water containing sodium bicarbonate(0.1%), magnesium oxide (0.1%) and sodium metabisulphite (0.2%) for two minutes and dried in cross air flow drier at 60°C all leaves could be dried to a moisture content of four to five per cent within three and half hours except *kachi* which took four hours as reported by Premavalli *et al.(* 2001).

2.3 Drying Studies

Drying is one of the oldest methods of food preservation. Drying preserves foods by removing enough moisture from food to prevent decay and spoilage. Water content of properly dried food varies from 5 to 25 % depending on the food. Successful drying depends on: enough heat to draw out moisture, without cooking the food; dry air to absorb the released moisture; and adequate air circulation to carry off the moisture.

Drying is the oldest method of preserving food. Krokida and Marinos-Kouris (2003) reported that main aim in drying agricultural products is to decrease water content to certain level, at which, microbial spoilage and deterioration chemical reaction are greatly minimized.

Okos *et al*. (1992) claimed that dried foods are tasty, lightweight, easy to prepare, store and use. Microorganisms that cause food spoilage and decay cannot grow and multiply in the absence of water. When water content is reduced below 10 percent, the microorganisms are not active. Drying involves two basic phenomena, vaporization of moisture from the surface of material and moisture from internal part of material to its surface. Movement of moisture takes place due to diffusion, cell concentration and vapour pressure gradient.

2.3.1 Methods of drying

Sahay and Singh (1994) reported that when drying foods, the key is to remove moisture as quickly as possible at a temperature that does not seriously affect the flavour, texture and colour of the food. If the temperature is too low in the beginning, micro organisms may survive and even grow before the food is adequately dried. If the temperature is too high and the humidity too low, the food may harden on the surface. This makes it more difficult for moisture to escape and the food does not dry properly.

Coriander and fenugreek leaves were dried in solar drier by Pande *et al.* (2000). A forced circulation solar hot-air-dryer was used, where the leaves were loaded at the rate of 3.3 kg/m^2 tray area and 3.7 kg/m^2 respectively in perforated trays. The results indicated that, coriander could be dried within 3.5, 3.0, 2.5 hours at 40, 45 and 50°C respectively, while fenugreek required 4.5, 3.5, 3.0 and 2.5 hours at 40, 45, 50 and 60°C, respectively. The drying rate was higher in the first 30 minutes where temperature had a significant influence on moisture reduction.

Microwave drying characteristics of parsely leaves were assessed by Soysal (2004). At seven different microwave output powers ranging from 360-900W were used for drying parsley. The Results indicated that, as the microwave output power increased to 900W from 360W, the drying time decreased significantly (64%). Microwave drying at 900 W output power instead of 30, 40, 50 and 65°C in hot air oven, the drying time can be shortened by 111, 92, 37 and 31 fold respectively. Drying rates of parsely leaves ranged from 0.48 to 1.33 kg water/kg DW/ minute for the output power between 360 and 900W respectively.

Singh *et al*.(2006) investigated the effect of drying conditions on the drying rate of five leafy vegetables. The leaves were dried under cabinet drier at 58-60˚C, low temperature drier at 40 ± 2°C and 25-40% RH and solar drier at 40-50°C, 60-80% RH to a moisture content of four to five per cent. The drying rate was faster in cabinet drier followed by low-temperature drier and solar drier. Drumstick leaves took seven hours for drying in cabinet drier whereas amaranth, curry leaves, and fenugreek required six hours in the same drying condition.

Kaur and associates (2006) studied the time taken for drying of coriander leaves as affected by pretreatments and method of drying. Coriander leaves were pretreated by dipping in potassium metabisulphite solution for 15 minutes at room temperature; blanching in boiling water for 30s followed by dipping for 15 minutes in solutions either of magnesium chloride (0.1%), sodium bicarbonate (0.1%) or potassium metabisulphite (2.0%) in water at room temperature; dipping for 15 minutes in solutions of magnesium chloride (0.1%) + sodium bicarbonate (0.1%) + potassium metabisulphite (2.0%) at 60°C all the pretreated samples were dried in cabinet at 55°C, open sun, forced convection air, domestic solar dryer with covered and uncovered trays, minimulti-rack solar dryer at 45°C and portable farm type solar dryer. The results indicated that, the pretreatments did not influence the time taken for drying. Coriander pretreated with different solutions and untreated took five hours to dry to constant weight. Minimum time of 5 hours was taken by cabinet drier while drying under open sun, domestic solar drier with uncovered trays and minimulti-rack solar drier took nine hours.

An investigation was carried out by Manchekar and associates (2008) to dry the curry leaves under shade at 24-28°C , sun at 29.7°C and conventional method 40 100, 140 and 180°C. Time taken for drying and physiological loss in weight (PLW) was recorded. The results depicted that, conventional drying method was faster compared to sun drying and ambient drying . Higher the temperature in conventional drying lower was the time taken for drying to a constant weight.

Agasimani *et al.* (2008) studied value addition to the coriander through drying and dehydration. The cleaned coriander leaves were dried under three different drying methods viz., shade drying at 28°C, 32.5% RH, sun drying of 7 hours and conventional drying at 40, 100 and 140°C. The results indicated that, coriander leaves dried by conventional method of drying showed a uniform physiological loss in weight and colour at lower levels of air temperature. In case of sun drying physiological loss in weight was more rapid at initial period of drying followed by gradual decrease in moisture content in the later part of drying. The weight of leaves dried at 40°C reduced from 25g to 6g at the end of drying period. Similarly, the weight was reduced to 4.2g at the conventional drying temperature of 140°C .

Karva (2008) evaluated the effect of pretreatments and methods of drying on yield and drying time of green leafy vegetables. Fenugreek, spinach, rajagira, shepu and kiraksali leaves were subjected to different pretreatments viz., blanching (1min), sulphitation (1min), blanching + sulphitation (blanching followed by sulphitation) which were compared with control (without any treatment). The pretreated leaves were dried under microwave oven (2250 mHz frequency at 100% power), hot air oven at 60°C, sun at 38-42°C and shade drying at 24.5-25°C. The results indicated that irrespective of the treatments, microwave drying took less time while more under shade drying. Shepu could be dried in shorter time of 1.10 hours (sun), 33.82 hours (shade), 1.48 hours (hot air oven) and 2.24 minutes (microwave) irrespective of pretreatment compared to other greens. Yield was found to be higher in shade dried greens (12.75%) while least in sun dried leaves (4.41%).

Influence of different drying techniques on the quality of spearmint (*Mentha spicaata)* was assessed by Kaur and associates (2009). Spearmint was dried using conventional drying like sun, room air, solar drying (using polythene tent dryer) and compared with convective drier, which was carried out at air temperature of 45, 50, 55, 60 and 65°C and velocities of 0.5, 1.0, 1.5, 2.0, 2.5 m/s. Both leaves and leaves with stalks were chemically pretreated by dipping in solution containing 0.1 per cent magnesium oxide, 0.1 per cent sodium bicarbonate and two per cent potassium metabisulphate for 15 minutes and dried. The results indicated that, in leaves drying ratio increased with increase in temperature up to The dry ash was converted in to solution and used for mineral estimations as out lined in AOAC (1990) followed by decrease, while in leaves with stalk, it increased up to the temperature of 55°C and further decreased at 60°C and finally increased at 65°C.

Characterization of microwave vacuum drying and hot air drying of mint leaves was carried out by Therdthai *et al.* (2009). For microwave vacuum drying, pressure controlled at 13.33 K Pa and for hot air drying, drying temperatures of 60 and 70°C were adopted. The result revealed that, microwave vacuum drying could reduce drying time of mint leaves by 85-90 per cent, compared with the hot air drying. Hot air drying required 90 and 60 minutes respectively, where as microwave vacuum drying at 1600W, 1920W and 2240W required 13, 12 and 10 minutes respectively.

Esturk and Soysal (2010) studied drying properties and quality parameters of dill dried with intermittent and continuous microwave-convective air treatments in a custom designed and fabricated air drying system. The cleaned leaves were subjected to continuous or intermittent microwaving with convective air drying at 30, 40 and 50°C. The results indicated that, the drying time in continuous microwave convective air drying to reach the moisture content of 0.10 Kg^{-1} was 9-10 minutes, while microwaving for 30 seconds followed by discontinuing for 30, 60 and 90 seconds and further convective air drying took 17-84 minutes. Drying rate increased with decrease in pulse ratio. The drying rates for 30, 40 and 50°C air temperature were found to be 0.21, 0.21 and 0.23 Kg^{-1} respectively. The studies indicated that higher the temperature lower will be the time taken for drying which again depends on with the drying method. Ideal drying temperature was reported to be 60°C.

Lakshmi and vimala (2000) studied drying characteristics of green leafy vegetables. Amaranth, curry leaves, gogu and mint leaves were dried under sun and cabinet drier at 30-45°C and 60-70°C respectively. Sun drying required 5 to 10 folds longer time compared to cabinet drying to bring down the moisture to 9-11 per cent. Amaranth, curry leaves, gogu and mint respectively required 2.5, 1.0, 3.0, and 2.5 hours for drying in cabinet drier.

The effect of drying five green leafy vegetables in microwave oven on yield, and time taken for drying was investigated by Fathima *et al.* (2001). Mint, coriander, amaranth, fenugreek and shepu leaves were blanched at 98°C for two minutes and immersed in cold water 24°C. The blanched greens were subjected to microwave drying at 100 per cent power and a frequency of 2450 mHz. The results revealed that, mint required 16 minutes for complete removal of moisture yielding 10.3 per cent product while, fenugreek and shepu could be dried in 11 minutes exhibiting an yield of 15.9 and 32 per cent, respectively.

Sriyana Abdulla *et al*. (1983) conducted studies on the drying characteristics and relationship between drying temperature and marker compounds constituent of *misai kucing* (Orthosiphon staminiues Benth.) leaves were investigated. The leaves of misai kucing herbal plant were dried by oven method at different temperatures: 400C, 550C and 700C. Drying at higher temperature shortened the drying time and increased the drying rate. Initial moisture content of the leaves was 77.00% (w.b). The drying process was done until the equilibrium moisture content was achieved. The total antioxidant activity of the dried leaves extract increased with the oven temperatures.

2.3.2 Vacuum drying

The main aim of creating vacuum during drying is to enable the removal of moisture at lower temperature than the boiling point under ambient condition. Water boils at 100ºC under standard atmospheric pressure (1.013 bar), but if the pressure is reduced or the vacuum is created to 40 mbar, the boiling temperature will be reduced to 29ºC as reported by Moran and Shapiro (1996).

Many scientists have contributed in the vacuum application to food drying and combining with other systems like microwave and freeze drying. Among them, Fernando and Thangavel (1987) reported that the quality of vacuum dried coconut was superior to the conventionally dried products.

Drouzas *et al*. (1999) Combination of microwave heating and vacuum drying resulted in the accelerated drying rate of model fruit gels. Further, they reported that the experimental pectin gel with 38.4% moisture content was dried to less than 3% moisture in four minutes and the colour of the dried gel was better compared to air drying. Similarly, the vacuum dried celery was better in quality compared to hot air dried ones by Madamba *et al*. (2001).

Similar combination method was used by Mousa (2002) for drying banana slices with microwave under vacuum. They concluded that thermal and drying efficiencies were almost 100% at the beginning of the drying process, but decreased with reduction in the moisture content and the effect of vacuum was particularly important to attain low moisture values in food products.

Long Wu *et al*.(2007) reported that important feature of vacuum drying is the exclusion of air during drying, which makes this process more attractive for drying food materials that may deteriorate or chemically modified due to air or exposure to high temperature. The lower pressure (vacuum) in the system allows the use of lower drying temperature in order to achieve similar moisture content of the end product with other drying methods. The drying system that has vacuum application consists of four main components such as vacuum chamber, vacuum pump, heat supply and a device to collect condensed water vapour. Vacuum treatment is useful in combination with other processes to get a good final end product. Obvious advantages of combining vacuum with other drying processes have guided many scientists to work on food drying experiments. Since, the product temperature is lower compared to other drying methods; drying time will be reduced as a result the final quality of the product will be better.

2.4 Effect of dehydration on nutrient composition

Dehydration is a simple and economical method of preservation of green leafy vegetables. While it is of great importance to produce dehydrated vegetables without marked loss of vitamins during preparation and dehydration, it is equally important to prevent considerable losses during the period between dehydration and consumption.

Yadav *et al.* (1995) carried out an experiment to study the effect of home processing on ascorbic acid and β-carotene of spinach and amaranth leaves. The leaves were divided into batches and processed, which includes drying in oven at 65°C and sun for 10 hours , after blanching for 5, 10 and 15 minutes. All the samples were analyzed for ascorbic acid and β-carotene content. The results indicated that, loss of ascorbic acid was 83.4 and 82.5 per cent (amaranth leaves) and 90.5 and 90.0 per cent (spinach) on sun and oven drying respectively. On the other hand, loss of β-carotene was higher (49%) in both the leaves on sun drying compared to oven drying (14%). Blanching for 15 minutes exhibited 93.2 (spinach) and 92.6 per cent (amaranth leaves) loss of ascorbic acid, while five minutes blanching lead to approximately 52 per cent loss in both the leaves. About 26 and 24.2 per cent loss was registered on blanching for

15 minutes in spinach and amaranth leaves respectively and approximately 8.3 per cent loss was observed in both the leaves on five minutes blanching

Maharaj *et al*. (1996) studied the quality changes in pretreated dehydrated dasheen leaves. The results revealed that, drying at 40-70°C and under natural convection resulted in complete loss of vitamin-C (91.6 to 93.0 %). Under forced convection, it ranged from 81.8 to 72.6 per cent. Ascorbic acid losses increased by blanching in steam, water and magnesium carbonate infusion prior to dehydration. This was reduced under forced convection drying and was particularly evident for the steam, water and unblanched dehydrated vegetables.

Singh *et al.* (1997) studied the effect on compositional quality of commonly consumed green leafy vegetables. The result revealed that, unblanched leaves showed lowered retention of chlorophyll as compared to blanched leaves. The maximum retention was observed for blanched bathu , while spinach had minimum. The blanched fenugreek, mustard leaves, bathu and spinach showed higher ascorbic acid content than the unblanched samples. The dietary fiber content (natural detergent and acid detergent fiber) was maximum in mustard leaves.

Seshadri *et al*. (1997) reported that the retention of β-carotene on dehydration of drumstick leaves total and beta carotene retention in blanched + sulphited leaves was 73 and 72 per cent respectively compared to 62 and 59 per cent in blanched leaves. Similarly, blanching + sulphitation resulted in a much higher retention of ascorbic acid (87%) as against 27 per cent in blanched leaves.

Effect of dehydration of green leafy vegetables on β-carotene content was studied by Seema (1997). Irrespective of pretreatment and drying, harvi recorded highest amount of β-carotene (6832.97µg/100g) while hakarki registered lower values (1545.34 µg/100g). Among pretreatments blanched harvi retained 88 per cent and hakarki had lower retention of 61 per cent. Sulphited harvi and hakarki retained 92.41 and 65.36 per cent respectively. Sulphited leaves recorded significantly higher β-carotene values than blanched samples.

A study conducted by Lakshmi and vimala (2000) on effect of blanching prior to drying on the composition of amaranth, curry leaves, gogu and mint revealed that, amaranth and mint leaves blanched in 0.1 per cent magnesium oxide solution showed higher retention of chlorophyll and ascorbic acid. Curry leaves blanched in two per cent sodium chloride showed greater retention of chlorophyll while that blanched in two per cent sodium chloride and 0.5 per cent magnesium oxide retained higher amounts of ascorbic acid. Two per cent sodium chloride and 0.5 per cent sodium metabisulphite were effective in retaining greater amounts of chlorophyll in gogu leaves. Ascorbic acid retention was better in plain water blanching of gogu leaves.

The effect of drying methods of composition revealed the moisture content of sun dried gogu to be higher (11.3 % dw) and cabinet dried curry leaves to be minimum (2.5 %). Protein content increased by three to eight fold compared to fresh, with maximum in sun and cabinet dried amaranth leaves (29.47 and 27.3 g/100g respectively). Curry leaves had higher fiber (14-16 g/100g) and β-carotene (79-125µg/g); while sun and cabinet dried amaranth leaves (6.17-8.82 & 60-86 µg/g respectively) exhibited lower values. Ascorbic acid was found to be low (44 mg/100g) in mint and higher in cabinet dried curry leaves (346.86 mg/100g). Sun and cabinet dried amaranth leaves were found to be rich in calcium (2990.44- 2605.17 mg/100g), iron (65.56 and 65.75 mg/100g), magnesium (1196.01 and 1226.62 mg/100g) and zinc (8.32 and 8.67 mg/100g) respectively as Lakshmi and Vimala, (2000).

Ahmed *et al.* (2001) studied the chlorophyll retention in dried coriander leaves. The leaves were blanched at 80°C for three minutes in hot water prior to drying under cabinet drier at 45, 50, 55, 60 and 65°C. The result revealed that, hot water blanching significantly increased the chlorophyll retention. The retention in the dried product decreased with the increase in temperature of drying and was at a maximum when leaves were dried at 45°C (3.47 mg/ -1 in blanched and 3.20 mg/ -1 in unblanched leaves.

Premavalli *et al*. (2001) studied processing effect on color and vitamins of green leafy vegetables. The leaves were chopped and subjected to blanching (solution containing 0.1% Na_2CO_3, 0.1% MgO and 0.2% SMS) for two minutes and dried at 60°C in air flow drier . Moisture content of dehydrated leaves ranged from 4-5 per cent. In general, total chlorophylls decreased during blanching and dehydration. However, it was found to be increased in chakota , palak and fenugreek. Highest retention of total chlorophyll was found in fenugreek (95.6%) compared to palak (89.33%), chakota (87.30%), dhantu (70.32%), kachi (59.80%) and honagone (51.35%). Retention of total carotenoids was highest in chakota (94%) followed by palak (82.70%), kachi (79.30%), dhantu (71.42%), fenugreek (71.20%), khirkhire (66.0%) and honagone (36.15%). The loss of ascorbic acid was less in fenugreek having (74.7 % retention) while higher losses were recorded in dhantu (28.64%), khirkhire (37.05%), honagone (39.87%), kachi (48.60%), palak (63.54%) and chakota (67.27%). The retention of vitamin A in terms of β-carotene was highest in chakota , fenugreek and palak recording 93.75, 92.91 and 82.70 per cent respectively compared to other vegetables.

Negi and Roy (2001, a) carried out an investigation on the effect of blanching on quality of dehydrated carrots. The results revealed that, the carotene content of carrots was higher (29.16 mg/100g) in blanched samples compared to unblanched (23.38 mg/100g). The retention of ascorbic acid was found to be higher (35.7 mg/100g) in unblanched leaves than blanched (27.5 mg/100g) samples.

Negi and Roy (2001,b) examined the effect of blanching on quality characteristics of dehydrated green leafy vegetables. The results reported that, on dehydration the retention of β-carotene in savoy beet and fenugreek leaves on drying was 40.9 and 38.1 mg/100g respectively while the ascorbic acid retention was found to be higher (350.78 mg/100g) in fenugreek compared to savoy beet (31.46 mg/100g). Chlorophyll content was higher (9.25 mg/g) in savoy beet than fenugreek leaves (7.15 mg/g) on drying.

Singh *et al*. (2003) investigated the effect of dehydration on nutritional composition of green leafy vegetables, herbs and carrot. The leaves and carrot were blanched for 10-15 s and one minute respectively, followed by drying in hot air oven at 40 ± 5°C for four to six hours and 50 ± 5°C for 16-18h respectively. The results revealed that, dried mint and cauliflower leaves possessed higher amounts of protein (30.99 and 29.98% respectively) compared to coriander (22.34%), bengal gram leaves (26.17%) and carrot (9.82%).

Effect of traditional open sun drying and solar cabinet drying on carotene content of eight green leafy vegetables was studied by Mulokozi (2003). The green leafy vegetables were dried under sun and in cabinet after blanching in water for two to three minutes. The results indicated that, the content of β-carotene, α-carotene, 9-cis- β-carotene and 13-cis- β-carotene ranged from 526-917, 12-39, 80-136 and 16-40µg/g (dw) respectively in fresh blanched leaves, all significantly differed from each other. Corresponding values for solar and open sun dried vegetables ranged from 338-776 and 264-484 µg/g; 8-30 and 4-12 µg/g; 54-132 and 43-103µg/g;

respectively. However, 13-cis- β-carotene was not identified in solar dried and open sun dried samples.

The effect of microwave drying on quality of parsely leaves was investigated by Soysal (2004). The leaves were dried at seven different microwave output powers ranging from 360-900 W. Microwave drying did not significantly influence the color of fresh and microwave dried leafy vegetables, a brilliant green color close to that of the original fresh parsely leaves was maintained.

Singh *et al.* (2006) assessed the effects of drying conditions on the quality of dehydrated leafy vegetables. The leaves were blanched and dried under cabinet (58-60°C), solar (40-50°C, 60-80% RH) and low temperature drier (40 ± 2°C and 25-40% RH). The moisture content was found to be higher in dried drumstick leaves dried in cabinet (5.5%), solar (6.1%) and low temperature (6.7% driers). Ascorbic acid and chlorophyll contents were maximum in curry leaves (212.4 & 130.3 mg/100g respectively) and minimum in palak (14.2 and 70mg/100g). Quality of dried coriander leaves as affected by pretreatments and methods of drying was evaluated by. Dipping for 15 minutes in solution of magnesium chloride (0.1%), sodium bicarbonate (0.1%) and potassium metabisulphite (2.0%) water at room temperature was best for maintaining quality of dried coriander leaves. Irrespective of cost, solar drying in minimulti-rack dryer was the best method for coriander leaves, as closest to fresh.

Karva (2008) studied the effect of dehydration on composition of green leafy vegetables. Fenugreek, shepu, spinach, rajagira and kiraksali leaves were subjected to pretreatments viz., blanching (1 min), sulphitation (1 min), blanching and sulphitation, all treated leaves were compared with control. The leaves were then dried under microwave oven (2250 mHz frequency, at 100% power), hot air oven (60°C), sun (38-42°C) and shade (24.5-25°C) drying. The results revealed that, rehydration ratio was found to be higher in microwave dried leaves (6.29) while sun dried samples exhibited lowest (4.10) irrespective of pre-drying treatments. Microwave drying of rajagira resulted in highest chlorophyll content (12.40 mg/g) irrespective of the treatments followed by drying in hot air oven (12.38 mg/g), and sun drying resulted in minimum chlorophyll content (6.85 mg/g). Among pretreatments sulphitation without blanching resulted in minimum chlorophyll (10.32 mg/g) but blanching before sulphitation had maximum retention (11.48 mg/g). Iron content was found to be highest in rajagira (222.57 mg/100g) while fenugreek had lowest amount (26.19 mg/100g).

2.4. Packaging and Storage quality of dehydrated GLVs

The main purpose of dehydration of vegetables is to preserve for a longer duration with the retention of good quality, in terms of nutrients availability and sensory attributes. The related literature is reviewed here.

Seshadri *et al*. (1997) studied retention and storage stability of β-carotene in dehydrated drumstick leaves. Dehydrated leaves were packed in polyethylene containers and stored at room temperature. The results indicated that, up to 90 days of storage losses occurred in blanched and blanched+sulphited samples. The retention of total carotene and ascorbic acid was significantly higher in blanched + sulphited samples compared to blanched leaves at 30, 60 and 90 days of storage. Rehydration ratio showed deterioration with increasing duration of storage in both the pretreated samples but superior with the blanching + sulphiting compared to only blanched leaves.

The effect of processing and storage on β-carotene content of green leafy vegetables was evaluated by Seema (1997). Honagone, harvi, pundi, hakarki and dodagooni leaves were blanched, sulphited, packed in LDPE and stored in air tight aluminum container. The results revealed that, moisture content ranged from 7.78 to 9.06 per cent and in all the greens it increased significantly at every point of storage. The rehydration ratio of samples ranged from 4.05 to 6.59 per cent during storage where honagone recorded highest (5.75 %) on zero day of storage while hakarki recorded highest (4.36%) at the end of storage. Honagone registered highest (72.4%) retention of β carotene followed by harvi (69.62%), dodagoon i (67.98%), pundi (58.27%) and hakarki (54.18%). Shade dried leaves exhibited significantly higher β- carotene than oven and sun dried.

Ramalakshmi *et al.* (2001), worked on storage stability of dehydrated curry leaf, rosemary and marjoram in different packaging materials. The results depicted that, absorption of moisture was more in the samples stored in PET jars at 38°C and 27°C compared to other packaging materials. Retention of chlorophyll was maximum (90%) in rosemary leaves stored in aluminum foil laminate pouches at ambient condition while those stored in other packaging material showed 40-80 per cent retention. The loss of green color was more in the samples stored in glass and PET jars than the others and also the loss was more in elevated temperature than in ambient. Curry leaves had minimum color loss compared to other leaves.

Fathima *et al*. (2001) studied microwave drying of selected greens and their sensory characteristics during storage. The dried greens were packed and sealed in polythene pouches and stored under refrigeration at 5°C for 60 days. The results revealed that, the scores for appearance of the fresh greens were significantly different from dried greens. During storage (60 days) of the dried greens, a decline in the rating for appearance, odor and color was observed. The reduction was found to be proportional to the increase in storage time.

Retention of quality characteristics of dehydrated greens during storage was studied by Negi and Roy (2001,a). The dried savoy beets and fenugreek leaves were packed in 200 gauge HDPE bags in a single or double layers and stored at ambient at 15.0-37.5°C ,35- 90% RH and cold storage at 7.5-8.5°C ,75-80% RH and condition for nine months. The results indicated that, chlorophyll content of samples continuously declined during storage with samples packed in double layers retaining higher amounts throughout the nine months in both crops compared to single packed samples. At the end of storage, leaves of savoy beets and fenugreek retained 57 and 67 per cent of β-carotene in double packed samples when stored at 7.5-8.5°C. Ascorbic acid content was retained only to an extent of 10.62 mg/100g in single packed savoy beets at the end of storage. The double packed cold stored samples retained 17.08 mg/100g. On the contrary, a drastic reduction was recorded in fenugreek leaves during storage.

Negi and Roy (2001,b) studied the effect of blanching on quality attributes of dehydrated carrots during long term storage. The dried carrot slices were packed in single or double layers of 50µm thick HDPE films and stored at ambient condition at 15.0- 37.5°C, 40-85% RH and cold storage at 7.5-8.5°C, 70-75% RH for nine months. The results revealed that, a spontaneous loss of β-carotene was observed in both unblanched and blanched carrots during storage. Higher carotene retention was observed under cold storage conditions and the samples packed in double layer of HDPE film. Ascorbic acid retention was found to be higher in blanched samples throughout the storage. Invariably, cold stored samples retained higher ascorbic acid and double packaging reduced the losses.

Singh *et al.* (2003) assessed the effect of storage on nutritional composition of dehydrated green leafy vegetables and carrot after packing in polythene bags and stored for two months at room temperature. The moisture content of samples increased gradually with increase in storage period ranging from 2.20 to 3.90 per cent. After 60 days of storage, it varied from 2.74 to 4.55 per cent. Protein, β-carotene and ascorbic acid contents of all the dried vegetables decreased significantly during storage. Minimum loss of β-carotene was observed in spinach (12.26%) and maximum in amaranthus (31.20%). Total iron content ranged between 7.1 mg/100g in carrots to 84.4mg/100g in Bengal gram leaves and it remained similar throughout the storage period.

Negi and Roy (2001, a) showed that the degradation of quality parameters was faster at ambient conditions and packaging of leaves in low density polyethylene bags was beneficial in improving shelf life and nutritive value.

2.5 Effect of dehydration of vegetables on sensory quality

In general, processing alters the sensory quality of the foods while dehydration in particular, affects organoleptic quality in terms of color, appearance, texture and flavor.

The quality of dasheen leaves dried at 40 and 70°C and under both natural and forced convection conditions and the effects of pretreatments viz., blanching in steam, water and in 0.5 per cent magnesium oxide at near boiling point prior to immersion in a mixed chemical bath consisting of sucrose was evaluated. The results indicated that, preliminary tests showed good re-constitutional properties for all the products of dehydration particularly for leaves subjected to alkali blanching followed by infusion in a mixed chemical bath prior to dehydration by Maharaj and Sankat (1996).

Singh *et al*. (1997) studied the sensory evaluation of rehydrated green leafy vegetables on a four point scale. A desirable color was obtained in cabinet drying while that of sun dried products was unacceptable. Flavor of sun dried vegetables were scored higher compared to cabinet dried. The overall acceptability of cabinet dried fenugreek and spinach was better than sundried. But in case of bathu and mustard leaves method of drying did not influence the sensory quality.

Lakshmi and vimala (2000) showed that, the acceptability of rehydrated green leafy vegetables ranged from average to excellent. It was found that blanching prior to dehydration, retained bright green color of the leaves. However, the original flavor could be retained in gogu and amaranth compared to curry leaves and mint.

Microwave drying of selected green leafy vegetables and their sensory characteristics were studied by Fathima *et al.* (2001). It was reported that, dehydration resulted in significant decrease in the scores for appearance, color and odor compared to the fresh greens. During storage (0-60 days) of the dried greens there was a decline in the ratings for appearance was found to be proportional duration of storage. However, the green pigment was appreciably retained even after drying.

Dried coriander was analyzed for sensory parameters by Kaur *et al.* (2006). The results indicated that, dipping for 15 minutes in solution of magnesium chloride (0.1%), sodium bicarbonate (0.1%) and potassium metabisulphite (2.0%) at room temperature received the score of nine out of ten for over all acceptability. Color of rehydrated coriander obtained from drying in mini multi-rack solar dryer was nearest to fresh followed by cabinet dryer and forced convection air dried leaves. Rehydration ratio was highest for leaves dried under portable farm-type solar drier followed by open sun dried leaves.

Effect of drying conditions on the sensory quality of dehydrated leafy vegetables was studied by Singh *et al*. (2006). Amaranth, fenugreek, spinach and curry leaves were blanched, dried under cabinet drier, solar drier and further evaluated for overall acceptability. The results revealed that, all the green leafy vegetables dried under cabinet drier received excellent scores for sensory quality. Amaranth was excellent in color, flavor and good in texture. Curry leaves and palak scored alike as excellent in flavor and texture while good in color.

Manchekar *et al*. (2008) studied the effect of processing on sensory quality of curry leaves. The leaves dried at ambient condition retained maximum green color and aroma followed by convectional drying at 40°C and sun drying. Drying at 100, 140 and 180°C exhibited better flavor but leaves turned brown.

Agasimani *et al*. (2008), studied the effect of drying on sensory quality of coriander leaves. The results indicated that, the leaves dried at ambient condition retained better organoleptic qualities compared to shade drying. The sun dried samples showed had retained olive green color while shade dried samples had bright green color. The leaves dried at 100 and 140°C turned brown to reddish brown and gave burnt appearance and flavor, while those dried at 40°C recorded better color and organoleptic attributes.

Esturk and soysal (2010) reported that the dill leaves dried in continuous or intermittent microwaving in comparison with convective air drying were evaluated for sensory attributes The results revealed a significant influence of drying air temperature on the visual appearance. Microwave-convective air dried dill leaves were acceptable with scores of five out of nine, in terms of visual appearance, color, texture and flavor at all drying applications. Although continuous microwave convective air drying at 40°C received the highest scores, no significant difference was found among treatments. Flavor of sun dried vegetables were scored higher compared to cabinet dried. Blanching prior to dehydration retained bright green color of the leaves.

CHAPTER III
MATERIALS AND METHODS

This chapter deals with the details of the materials and the methodology followed during the course of the present investigation.

3.1 Test sample

Amaranthus viridis of the family *Amaranthaceae* was used for the study which was collected from the instructional farm of KCAET college. The collected leaves were separated from the stalks and it was cleaned and washed under running water. After draining the additional water, the initial moisture content, crude fibre and ascorbic acid content were estimated by the standard methods as described in section 3.6.1 to 3.6.3.

3.2 Pre-treatments

To maintain the quality of dried leaves various pre-treatments like blanching, sulphitation, citric acid treatment etc. were carried out.

3.2.1 Hot water blanching (T1)

A batch type hot water blancher (Plate 3.1(a)) with dimension 600 × 300 × 300 mm made of stainless steel was used for the study. A thermostat arrangement was incorporated to automatically regulate the temperature from 60˚C to 110^{o}C.

The samples were kept in a tray which was fixed inside the compartment. For this study leaves were kept in blancher at 60˚C for 2 minutes. Afterwards the leaves were spread for few minutes for cooling.

3.2.2 Steam blanching (T2)

In this treatment batch type steam blancher (plate 3.1(b)) made of stainless steel was used. Separate trays are specifically provided inside the blanching compartment for keeping

samples during blanching. The leaves were kept for 1 minute. Afterwards the leaves were spread for few minutes for cooling.

plate 3.1 (a) Hot water blancher (b) Steam blancher

3.2.3 Citric acid dipping (T3)

The process of treating leaves in citric acid solution before drying prevents browning and oxidation. So a set of leaves were treated with citric acid. The leaves were dipped in 0.1% citric acid for 2 minutes.

3.2.4 Sulphitation (T4)

Sulphitation is the process of treating leaves in potassium metabisulphite solution for preventing browning and oxidative reaction during further processing. It may also reduce microbial spoilage. Amaranthus leaves were dipped in 0.05% KMS solution for 2 minutes.

3.2.5 Hot water blanching + Citric acid dipping (T5)

Combination treatments such as hot water blanching followed by citric acid treatment was carried out inorder to improve the quality of dried leaves. Leaves were blanched for 1 minute and followed by citric acid (0.1%) treatment was conducted.

3.2.6 Hot water blanching + Sulphitation (T6)

Combination treatments such as hot water blanching and sulphitation was carried out inorder to improve the quality of dried leaves. Leaves were blanched for 1 minute and followed by sulphitation(0.05%) was carried out.

3.2.7 Steam blanching + Citric acid dipping (T7)

Steam blanching followed by citric acid treatment was used as a pre- treatment. Leaves were steam blanched for 30 seconds and followed by citric acid(0.1%) treatment was used.

3.2.8 Steam blanching + Sulphitation (T8)

Amaranthus leaves were steam blanched for 30 seconds and followed by sulphitation(0.05%) was done.

3.2.9 Control (T9)

In addition to all these pre-treatments, for assessing the quality characteristics of pre-treated dried leaves a sample without any pre- treatment was kept as control.

3.3. Drying

Inorder to assess the drying quality of different drying techniques methods such as sun drying, cabinet drying and vacuum drying of amaranthus leaves were conducted.

3.3.1 Sun drying

It is the traditional and inexpensive method. Leaves after pre-treatment were spread evenly over a perforated tray. The trays were kept under full sunshine throughout the day(plate 3.3). The trays were kept raised from the ground using bricks to proper aeration. The temperature in sun drying was measured using an ordinary thermometer. Drying process was continued till the moisture content reaches a safe level of 4-10%.

3.3.2 Cabinet drying

A cabinet dryer (605 x 605 x 910mm) made of stainless steel, with digital display cum controller and air circulating fan was used for study (plate 3.4). The leaves were spread on stainless steel tray and were kept inside the cabinet dryer at 60±1˚C which is an agreement with Loesecke (2005).

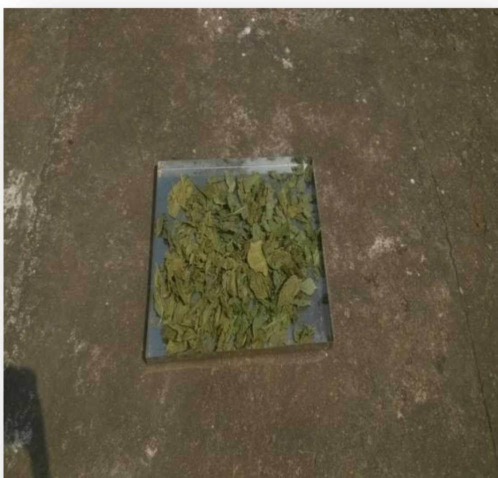

Plate 3.2 (a) Sun drying **(b) Cabinet drying**

3.3.3 Vacuum drying

A vacuum tray drier with digital display cum controller was used for the study. Amaranthus leaves were spread on stainless steel tray (plate 3.4, b) and were kept inside the vacuum drier for various time, temperature and vacuum. Commercial type of tray dryer essentially consist of a drying chamber fitted with stainless steel hollow flat trays, vacuum system consisting of water ring vacuum pump and hot water system to provide heating medium which circulates through the hollow trays inside the drying chamber.

Degree of vacuum in the drying chamber was adjusted by varying the flow of water through vacuum pump. The chamber temperature was controlled by temperature of heating medium flowing through the hollow trays. The desired temperature of hot water was set by switching on the required number of electrical heaters. The samples were allowed to dry on the hollow trays inside the vacuum chamber at predetermined vacuum and temperature levels.

Drying trials were conducted at different time temperature combination. Practical limitations in the equipment restricted to these temperature limits for functioning and operation of the system. Drying carried out at 40˚C, 50˚C and 60˚C at 680 mm of Hg.

Plate 3.3 (a) Vacuum dryer (b) Leaves kept in dryer

3.5. Packaging of vacuum dried amaranthus leaves

Vacuum dried leaves with optimum parameters were selected for packaging studies. They were packed in three different types of packaging materials such as polypropylene (PP), poly ethylene (PE) and areacanut sheet trays. The packets were sealed by using a hot bar sealing machine (PP and PE). Before packing quantitative analysis of leaves were found. After every 30 days these test were repeated. The tests were conducted for a storage period of 60 days.

Plate 3.4 (a) Poly ethylene **(b) Poly propylene**

(c) Shrink packaging

3.6. Quantitative Analysis of Green and Dried leaves

The major constituents of amaranthus leaves such as water, ascorbic acid, fibre, rehydration ratio etc. were estimated as per the procedure mentioned as described by Ranganna *et al*. (1977).

3.6.1. Moisture content

Moisture content was determined by using vacuum drying according to the method of Diamante *et al.* (2009). Samples were kept in the vacuum at 60˚C for 2 hours. The moisture content of the samples was calculated on a per cent wet basis, and the average value of the triplicate measurements was used.

$$Moisture\ conten\ wet\ basis = \frac{\text{M initial } - \text{M dried}}{\text{M initial}} \times 100$$

3.6.2. Crude fibre of food

Crude fibre dehydrated GLVs was estimated as per Ranganna *et al*. (1977). Crude fiber consists of cellulose, variable proportion of hemicellulose and highly variable proportion of lignin along with some minerals. Estimation is based on treating the moisture and fat free sample successively with dilute alkali. During these steps, oxidative hydrolytic degradation of the native cellulose and considerable degradation of lignin occur. The residue obtained after final filtration is weighed, incinerated, cooled and weighed again. The reagents were: 0.255 N (±0.005) H_2SO_4 - Mix 6.79ml of H_2SO_4 in water and make up to 1 litre (1.25%), 0.313 N (±0.005) NaOH - Dissolve 12.5g NaOH in water and make up to 1 litre (1.25%). The loss in weight gives crude fibre content.

2g of the dried sample was ground and boiled with 200ml of H_2SO4 for 30 minutes. The mass was then filtered through muslin cloth and washed with boiling water until washings are no longer acidic. This was then boiled with 200ml NaOH for 30 minutes. Filter through muslin cloth again and washed with 25ml of boiling 1.25% H_2SO4, 350ml portion of water and 26ml alcohol. Remove the residue. Transfer to ashing dish (W1). Dry the residue for 2hour at 130±2°C. Cool the dish in the desiccators and weigh (W2). Ignite for 30 minutes at 600±15°C. Cool in a desiccator and reweigh (W3).

Calculation

$$\text{crude fibre} = \frac{(W2 - W1) - (W3 - W1)}{\text{Weight of the sample}}$$

3.6.3. Ascorbic acid

Ascorbic acid of dehydrated GLVs was estimated as per Ranganna *et al*., (1977). The reduction of dye 2, 6 dichloro phenol indophenol by an acid solution of ascorbic acid forms the basis of the estimation. In the absence of interfering agent, the capacity of an extract of the sample to reduce a standard solution of the dye is directly proportional to ascorbic contents. The reagents used were 4% oxalic acid, standard ascorbic acid, 2, 6 dichlorophenol indophenol dye. The standardization of the dye was carried out by taking 5ml of standard ascorbic acid to which 5ml of oxalic acid was added. This was titrated with dye solution taken in burette to a pink colour which should persist at least for 15 seconds.

$$\text{Dye factor} = \frac{0.5}{Titre\ value}$$

Ascorbic acid content of leaf juice was estimated by making up 10 ml of leaf juice to 100 ml with 4 % oxalic acid. Pipette 10 ml of the made up solution into a conical flask. This was titrated against the dye taken in a burette to a pink end point, which should persist for at least 15 seconds. The titration was repeated to obtain concordant values (d).

$$Ascorbic\ acid\ (mg) present\ in\ 100\ ml\ of\ leaf\ juice = \frac{\text{Dye factor} * \text{d} * \text{volume made up} * 100}{\text{volume taken} * \text{weight of sample}}$$

3.6.4. Rehydration ratio

Rehydration ratio of dehydrated GLVs was estimated as per Patil *et al.*, 1978. Five grams of dehydrated sample was weighed accurately and placed in 500 ml beaker and 50 ml of distilled water was added and covered with watch glass. The water was brought to boil and continued for two minutes and switched off. After half an hour the sample was filtered with Whatman No.1 filter paper. Gentle suction was applied and drained with careful stirring for 30 to 60 sec. until the drop from the funnel stopped and then the weight was recorded.

$$Rehydration = \frac{\text{Weight of rehydrated material}}{\text{Weight of dehydrated material}}$$


Plate 3.5 Rehydrated vacuum dried amaranthus leaves

3.6.5. Sensory evaluation

The amaranthus leaves obtained after drying employing different treatments as described were used for the preparation of ‘cheera thoran’ with the traditional ingredients whose quantities were fixed in all the samples prepared. The main ingredients of the thoran were amaranthus leaves, coconut oil, salt, masala powder, desicated coconut , curry leaves and onion etc. Six samples were choosen which comprises of fresh, and vacuum dried with different pre-treatments. A heterogeneous population consisting of eleven people with different age group and sex were selected for sensory evaluation. They ranked the samples according to over all flavour, taste, texture and acceptability of the prepared cheera thoran. The specimen score card is shown in figure 3.1.

(a)

(b)

(c)

(d)

(e)

(f)

Plate 3.6 sensory evaluation

a - Sulphitation

b - hot water blanched

c - fresh vacuum dried

d - steam blanched

e - citric acid treated

f - fresh

SENSORY EVALUATION CARD

Name of the panelist: Date:

SAMPLE NO	COLOUR	TASTE	TEXTURE	OVERALL ACCEPTABILITY

5-Like very much

4-Like

3-Nither like nor dislike

2-Dislike

1-Dislike very much Signature of the panelist

Fig. 3.7 score card for sensory analysis

CHAPTER IV

RESULTS AND DISCUSSION

Amaranthus leaves were subjected to different pre-treatments and then dried by various drying methods. The influences of these on the quality of amaranthus leaves were studied.
This chapter highlights the results of various methods of drying of amaranthus leaves and the quality evaluation of dried samples.

4.1. Test sample

Amaranthus leaves stored after treated with different pre- treatment and drying method were analysed for its shelf life studies. The initial moisture content , crude fibre content and ascorbic acid content were estimated by the standard methods explained in chapter III and the results were tabulated.

1.	Initial moisture content	81.86%
2.	Ascorbic acid content	57.34 mg / 100 ml
3.	Crude fibre content	1.3 g/ 100 g

Table 4.1: Composition of fresh amaranthus leaves

4.2 Effect of different methods of drying and pretreatments on quality

An investigation on the effect of various drying methods on the quality of the dried amaranthus leaves was done. Amaranthus leaves are rich source of ascorbic acid, crude fibre and minerals. In this study moisture content ,ascorbic acid content, rehydration ratio ,crude fibre content and sensory quality were considered as basic parameters of quality analysis. The details are discussed below:

4.2.1 Vacuum drying

For prolonged shelf life of amaranthus leaves the recommended moisture content of amaranthus leaves be 4-10% .In order to reach this ideal moisture content the temperature and period of drying was determined by trial and error basis. Vacuum drying for two hours at 60˚C at 680 mm of Hg was sufficient to reach the ideal moisture content .Hence the temperature and time of drying was fixed as 60˚C for 2 hours, for further studies.

Temperature	Time(minutes)	Moisture content(%)
40˚C	120	16.45
50˚C	120	12.34
60˚C	120	4.43
70˚C	120	4.1

Table 4.2 Effect of moisture content on different drying temperature

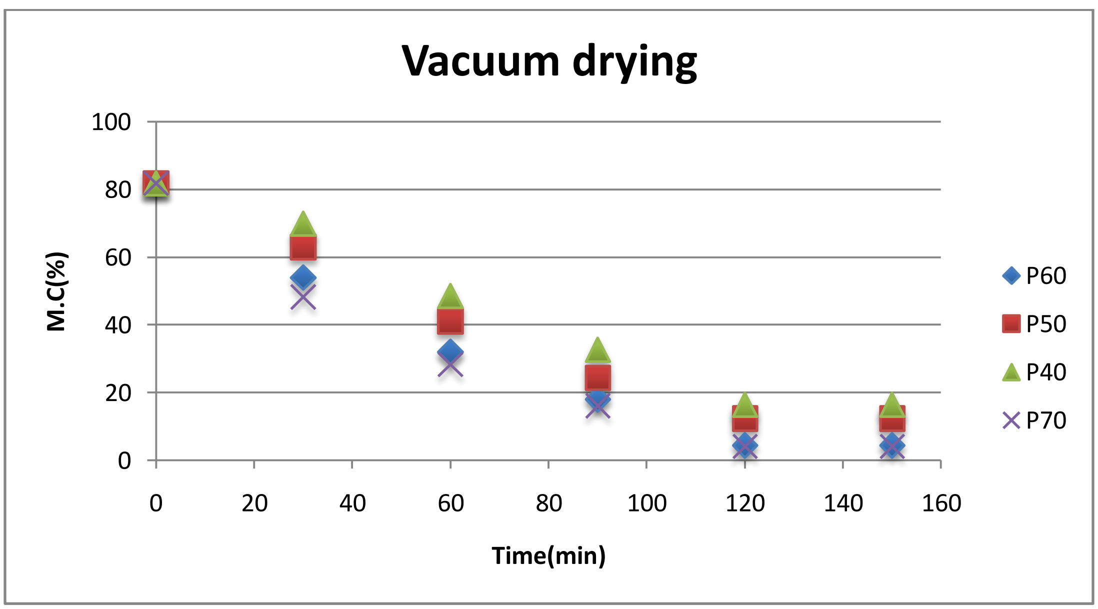

Fig.4.1 Drying curve for vacuum drying at different temperatures

All the pre-treated samples are vacuum dried at 60˚C, 680 mm of Hg for two hours in a vacuum dryer.

Sample	**Time(min)**	**Moisture content (%)**
T_1	120	4.25
T_2	120	4.25
T_3	120	4.24
T_4	120	4.24
T_5	120	4.23
T_6	120	4.23
T_7	120	4.23
T_8	120	4.23
T_9	120	4.28

Table 4.3 Effect of vacuum drying on moisture content

From the above table ,it was found that the control sample had moisture content of 4.28% whereas the pretreatments reduced the moisture content to a range of 4.23% to 4.25%.This reduction in moisture content of pre-treated sample is due to relaxation of the tissues that enabled the easy removal of water by Anonymous(1999).

4.2.2 Cabinet drying

A cabinet dryer maintained at 60˚C was used for drying. The dried samples gave higher browning values due to longer drying time and exposure to hot air.

Sample	**Time(min)**	**Moisture content (%)**
T_1	180	4.75
T_2	180	4.75
T_3	180	4.74

T_4	180	4.73
T_5	180	4.72
T_6	180	4.72
T_7	180	4.72
T_8	180	4.72
T_9	180	4.78

Table 4.4 Effect of vacuum drying on moisture content

From the above table it is inferred that the cabinet drying of control sample for 3 hours reduced the moisture content only up to 4.78% whereas in pre-treated samples the moisture content was brought to 4.75 – 4.72%.Inspite of shrinkage and browning during drying ,quality of convective dried amaranthus leaves was better than sun dried leaves.

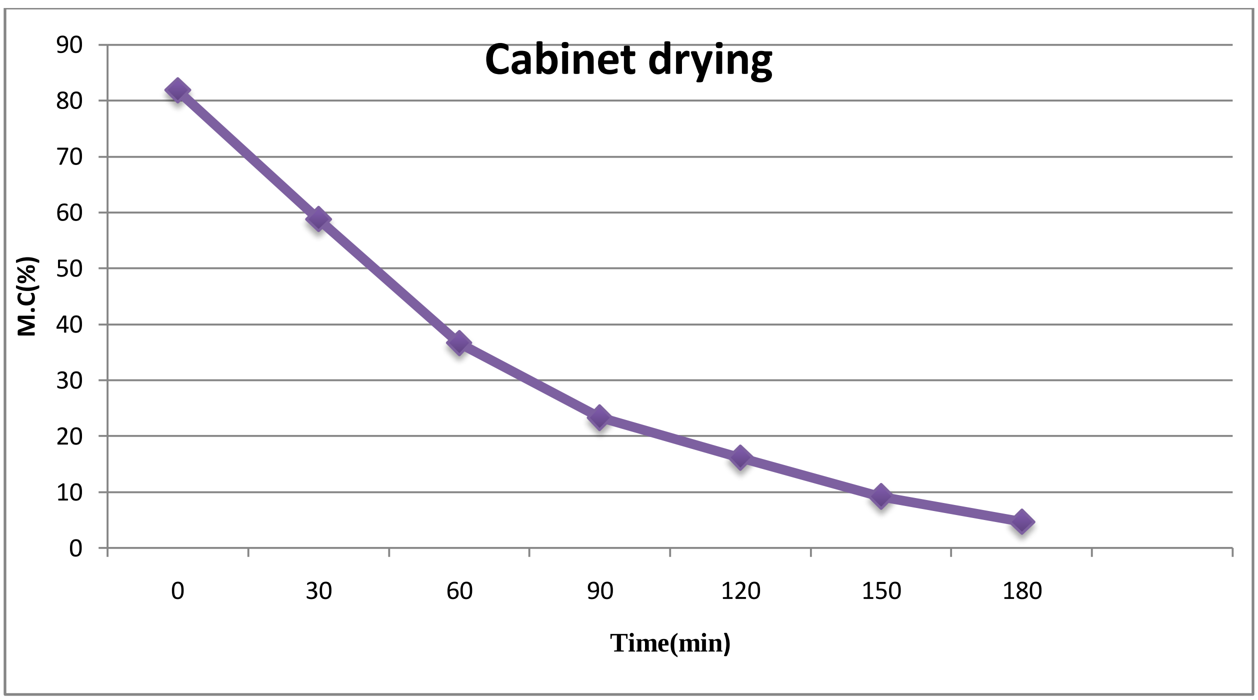

Fig 4.2 Drying curve for cabinet drying

From the above figure, it is clear that there is gradual decrease in the moisture content of the sample. This is because of the slow diffusion of water molecules from the interior to the surface implying that drying process is in the falling rate period. The drying rate was maximum during the first 30 minutes of exposure in cabinet drier, confirming that in initial stages, wet plant tissues behave like surfaces saturated with water which is in agreement with Brennan *et al.*
(1990) and later stagger. Constant drying rate was obtained after 3 hours in case of cabinet drying.

4.2.3 Sun drying

The samples were dried in open air under an ambient temperature of 23˚C to 31˚C at a relative humidity of 70-82%. It is a slow process and it is not possible to dry below 8%.The entire process is unhygienic and requires large floor area.

Sample	**Time(in min)**	**Moisture content(%)**
T_1	360	9.7
T_2	360	9.7
T_3	360	9.7
T_4	360	9.7
T_5	360	9.7
T_6	360	9.7
T_7	360	9.7
T_8	360	9.7
T_9	360	9.2

Table 4.5 Effect of sun drying on moisture content

From the above table ,it was noted that in sun drying of fresh samples weight of the sample became constant after 6 hours of drying .Hence sun drying could not lower the moisture content below 9.2%.Pre-treatments relaxed the tissues and thus reduced the moisture content to 9.2% in 6 hours. The dried product was of poor quality and hard due to structural changes.

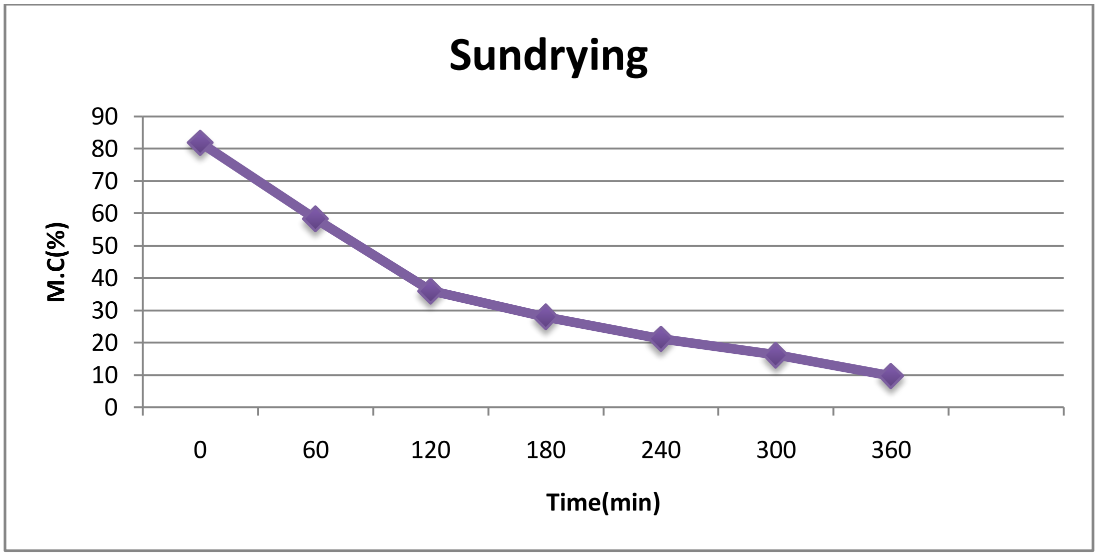

Fig 4.3 Drying curve for sun drying

From the above figure it is inferred that there is gradual removal of moisture content up to 6 hours.

4.3. Quality characteristics of dried amaranthus leaves

Quantitative analysis of quality characteristics of dried amaranthus leaves are depicted below;

4.3.1 Crude fibre content

From the various results obtained, it was found that the various methods does not have any effect on fiber content. Drying amaranthus leaves in vacuum after both steam and hot water blanching resulted in similar amount of fibre content as that of fresh leaves at the same time chemically treated samples showed the reduction in the fiber content.

Fresh	**Vacuum dried**				
	HB	**SB**	**KMS**	**CA**	**FV**
6.7	1.3	1.3	0.9	0.9	1.3

Table 4.6 Crude fiber content in gram/100g

4.3.2. Ascorbic acid

Vacuum drying retained the vitamin C without significant losses where as conventional method resulted in high losses of vitamin. The hot air and sun dried sample showed vitamin C content of 42.4 and 38.3 mg per 100 g whereas vacuum dried samples without blanching has 54.34 mg per 100 g. It may be due to drying without air in vacuum condition.

Ascorbic acid, the most liable of all vitamins found in foods, is very sensitive to heat and is rapidly destroyed during dehydration. It is in agreement with Desrosier & Desrosier (1977). Kincal and Giray (1987) reported inactivation of oxidative enzymes (eg: ascorbic acid oxidase and polyphenol oxidase) in potato at higher air drying temperatures of 85-95˚C.

4.3.3. Rehydration ratio

Effect of storage on rehydration ratio of vacuum dried amaranthus leaves is presented in the table 4.7 with the progress of storage rehydration ratio was decreased in all the treatments of vacuum dried amaranthus leaves. The rehydration ratio was reported to range from 3.87 percent which decrease further to 3.71 percent at the end of storage period.

Days of storage	**Rehydration ratio**		
	Vacuum drying	**Cabinet drying**	**Sun drying**
0	3.87	4.8	5.2
15	3.82	4.67	5.01
30	3.79	3.87	4.67
45	3.74	3.8	4.2
60	3.71	3.81	3.8

Table: 4.7 Rehydration ratio of dried amaranthus leaves

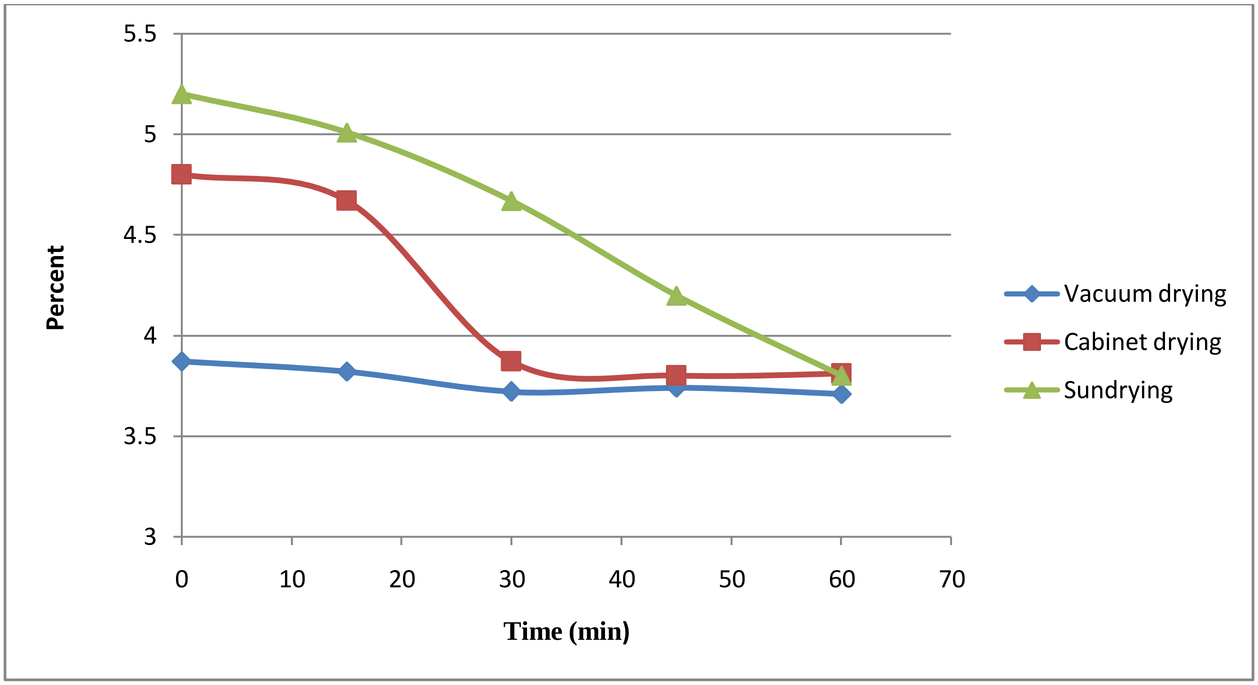

Fig: 4.4 Rehydration ratio of vacuum dried, sundried and cabinet dried amaranth leaves

Rehydration ratio indicates the capacity of dehydrated leafy vegetables to absorb the moisture. In the present study, the samples dried in vacuum drier exhibited higher absorption of water while, those dried in cabinet and sun dried samples indicated significantly lower rehydration or water pick up . The slight difference in moisture uptake can be attributed to variation in the drying conditions, initial moisture content, moisture removal and interactions between the components during dehydration.

4.3.4. Sensory evaluation

As mentioned in section, the sensory evaluation of cheera thoran prepared using amaranthus leaves dried by vacuum drying with different pre-treatment where carried out and they were compare with that of cheera thoran prepared by fresh amaranthus leaves.

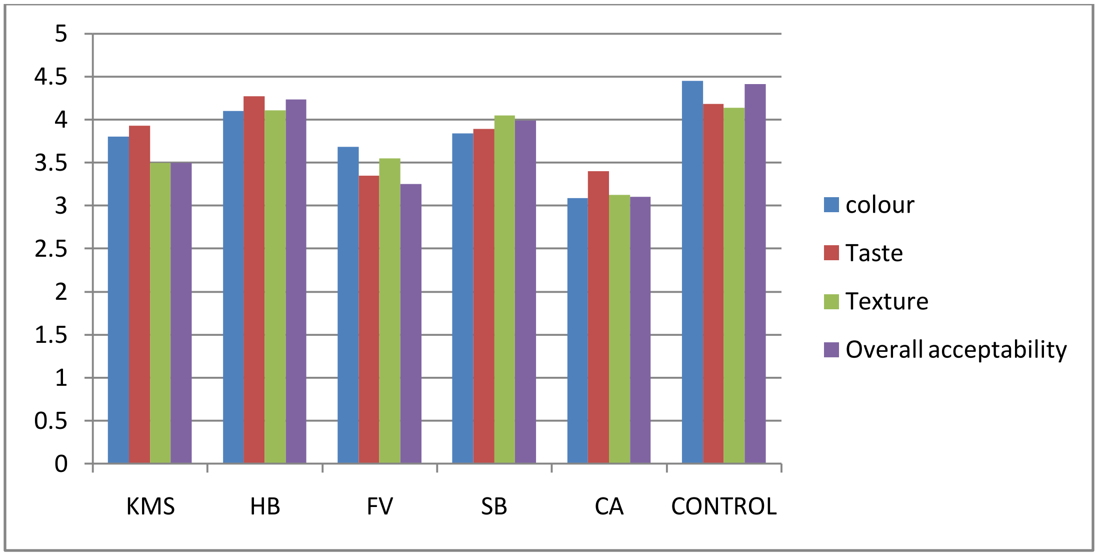

Fig : 4.5 Sensory evaluation

The figure shows that hot water blanched amaranthus leaves has more similar characters as that of fresh in all the parameters. The cooking time taken for the dried leaves are lesser compared to the fresh leaves. Texture of KMS and citric acid treated samples were hard and the colour was different from the fresh. The colour change may be due to the reaction of components with the chemicals.

4.4 Packaging of vacuum dried leaves

The vacuum dried amaranthus leaves were filled and sealed in the packaging materials such as Polypropylene(PP), polyethylene (PE) and shrink package. Quantitative analysis of the quality characteristics were carried out the samples before packaging and at intervals of 30 and 60days.

It may be revealed that there is no change in the vitamin, fibre and moisture content during storage in different packaging materials. But, during drying the leaves become crisp and the chance of damage is higher. So as to avoid breakage the leaves are shrink wrapped in areacanut sheet trays which reduced the chance of damage.

CHAPTER V

SUMMARY AND CONCLUSION

Green leafy vegetables are highly perishable with shelf-life of only few days owing to higher amount of moisture due to which around 30 per cent of the produce gets rotten and spoilt, becomes inedible, rendering wastage of a huge amount of nutritious products. This calls for preservation and processing to prevent losses as well as make them available in the lean season at remunerative prices. Amaranthus are a common leaf vegetable throughout the tropics and in many warm temperate regions. Drying is one of the traditional methods of preservation, which converts the vegetables into light weight, easily transportable and storable product. Advantage of this method is that the vegetable can be easily converted into fresh like form by rehydrating it and can be used throughout the year. Based on the above facts, an investigation was undertaken to study the effect of microwave drying of amaranthus leaves and also to study its packaging.

In this study we used three drying methods viz., sun drying, cabinet drying and vacuum drying with different pretreatments such as blanching, steam blanching, citric acid and sulphitation. The quality of the dried amaranthus leaves were was expressed in terms of moisture content, ascorbic acid and fibre content and also cooking quality through sensory evaluation.

In the light of above literature, results obtained in present study are summarized below:

- Pre-treatment such as hot water blanching gives better colour retention to amarathus leaves during drying.
- In this study vacuum drying of amaranthus leaves were analysed under various variable levels of vacuum and temperature , based on the preliminary studies the time of drying was fixed at 120 min. Moisture content in wet basis was found to decreased upto after 4.23% vacuum drying at power level of 60.
- It was found that vacuum dried samples were close to that of the fresh samples leading to the conclusion that vacuum drying retain the fresh like flavour and aroma.

- It was also found that fibre content of the amaranthus leaves were not affected by drying process, whatever the method be.
- The vacuum drying retain the vitamin c without significant losses was not significantly affected by drying process.
- It may be revealed from the results that the scores of the cheera thoran prepared by different pre-treatments at p-60are superior and close to the scores of those prepared by fresh amaranthus leaves.
- The vacuum dried amaranthus leaves were filled and sealed in the packaging materials such as Polypropylene(PP),polyethylene(PE) and shrink packaging. Quantitative analysis of the quality characteristics were carried out. It showed the amaranthus leaves stored in different packaging showed minimum physiological loss and shrink packaging is found to be better in reducing damage.

APPENDIX I

Variation of moisture content at different temperature during vacuum drying

TIME(MIN)	P60	P50	P40	P70
0	81.86	81.86	81.86	81.86
30	54	63	69.89	48.3
60	32	41.14	48.56	28.33
90	18	24.39	32.66	16.16
120	4.43	12.34	16.45	4.1
150	4.43	12.34	16.45	4.1

APPENDIX II

Variation of moisture content at temperature during cabinet drying

TIME(MIN)	MOISTURE CONTENT (%)
0	81.87
30	58.82
60	36.66
90	24.34
120	16.18
150	9.23
180	4.72

APPENDIX III

Variation of moisture content at temperature sun drying

TIME(MIN)	MOISTURE CONTENT
0	81.87
60	58.33
120	35.98
180	28.01
240	21.22
300	16.18
360	9.2

APPENDIX IV

Variation in rehydration ratio of vacuum dried, sundried and cabinet dried amaranth leaves

DAYS	VD	CD	SD
0	3.87	4.8	5.2
15	3.82	4.67	5.01
30	3.72	3.87	4.67
45	3.74	3.8	4.2
60	3.71	3.81	3.8

APPENDIX V

Sensory evaluation of cheera thoran prepared using vacuum dried amaranthus

SAMPLE	COLOUR	TASTE	TEXTURE	OVERALL ACCEPTABILITY
1	3.9	3.925	3.5	3.5
2	4.025	3.7	4.05	4.1
3	3.375	3.35	3.35	3.25
4	3.625	3.42	3.975	3.85
5	3.05	3.4	3.125	3.1
6	4.3	4.1	4.075	4.675

THE EFFECT OF DRYING ON THE SHELFLIFE AMARANTHUS LEAVES

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ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfillment of the requirement for the degree

Bachelor of Technology

In

Food Engineering

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Food and Agricultural Process Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR - 679 573, MALAPPURAM

2015

ABSTRACT

Amaranthus is a common green leafy vegetable rich in vitamin A,vitamin C, micronutrients and minerals .Though the leaves are not available during rainy season it is important to preserve them for the off season. It is highly perishable and can be stored for 5 days in ambient temperature.

Amaranthus leaves were subjected to three different drying methods namely ; sun drying , cabinet drying and vacuum drying.The study involves pre-treaments such as hot water blanching,steam blanching,sulphitation,citric acid treatment and combination treatments. The quality parameters were analyzed after of 30 and 60 days. Vacuum dried products at a temperature of 60˚C at 680 mm of Hg exhibit good rehydration ratio ,better colour ,texture and overall acceptability. The drying time was lesser than other methods . Hot water blanched vacuum dried amaranthus leaves were reported to be the best among the vacuum dried products. Longer shelf life of 60 days was noted with all the packaging materials. Though a longer shelf life was observed for shrink packaging in areacanut sheet trays avoiding breakage of leaves.