INFLUENCE OF PROCESSING METHODS ON THE BIOAVAILABILITY OF BETA-CAROTENE IN SELECTED FOODS

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DECLARATION

I hereby declare that this thesis entitled "**Influence of processing methods on the bioavailability of beta-carotene in selected foods**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Influence of processing methods on the bioavailability of beta-carotene in selected foods**" is a record of research work done independently by Ms. Benitha Augustine (2001-16-07) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Dedicated to

My Family

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INTRODUCTION

1. INTRODUCTION

Degenerative diseases are at their full swing to surrender the human kind and the trends indicate that unless controlled, it will become the leading cause of death in several countries during twenty first century. Free radicals are now pinpointed as the major cause. These are atoms or groups of atoms, which can disrupt the equilibrium of the biological systems by damaging their major constituent molecules leading eventually to cell death (Das, 1998). To fight against the detrimental effects of the free radicals, human body has several defense mechanisms and the most important is antioxidants.

Dietary antioxidants are nutrients that help to protect cells from a normal but damaging physiological process known as oxidative stress. It is established that β-carotene is an ideal day-to-day antioxidant. It can absorb the excited energy of singlet oxygen which may lead to its degradation at the same time preventing degradation of biomolecules (Kurashigae *et al.*, 1990). β-carotene is also reported to neutralize free radicals and it acts as chain breaking antioxidant (Boileau *et al.*, 1999).

β-carotene in the diet is reported to perform duel functions as an antioxidant and as a provitamin A carotenoid. β-carotene is the most abundant provitamin A found in foods, particularly in red, orange and green fruits and vegetables.

Though India has a wide range of inexpensive foods rich in carotenoids, the percapita availability of β-carotene in terms of retinol equivalents (400 mcg/d) is much below the recommended allowances (600 mcg/d) (Vijayaraghavan and Nayak, 1995). The frequency of consumption again varies widely depending on season, which in turn is related to availability and cost.

As vitamin A deficiency is a well recognized public health problem in India, food based strategies are recommended as a fundamental and long term measure to combat it. Consumption of 400-600g of carotene rich fruits and vegetables is recommended to combat the degenerative diseases (Herber, 2000).

Vegetables are often subjected to several processing methods, as a daily practice which would lead to the loss of vitamins, either due to oxidation or by dissolving into cooking oil. Onayem and Badifu (1987) opined that β-carotene is destroyed during processing and the loss is estimated to be high.

However pureeing and certain processing methods are considered to enhance the provitamin A carotenoid uptake from these foods considerably, thereby favouring its bioavailability. Parker (1996) has stated that bioavailability of carotenoids is influenced by factors such as characteristics of the source, interaction with other dietary factors and various subject characteristics. In addition, bioavailability of carotenoids from meals is influenced by a number of factors like carotenoid content, the manner in which foods are processed and cooked as well as the content of lipid and fiber in the meal (Rock *et al.* 1998).

Heat treatment promotes the isomerization of carotenoids from trans to cis form in vegetables and such treatments may improve the bioavailability of carotenoids from them. According to Zhou *et al.* (1996) processing vegetables with heat treatment results in small particle size and also mechanically disrupts the plant cells, so that carotenoids are more available for absorption.

Rock *et al.* (1998) reported that routine consumption of processed vegetables produced an increase in plasma β-carotene concentration than that associated with consumption of same amount of β-carotene from same vegetables in raw form. At present there is only limited information available on this aspect. There is also an added need to know about carotenoid bioavailability from vegetables due to the current interest on its antioxidant property. The present study is thus aimed at eliciting information on the existing consumption pattern of β-carotene rich foods and assessing the influence of processing methods on the bioavailability of β-carotene from selected plant foods.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The study entitled 'Influence of processing methods on the bioavailability of β-carotene content in selected foods' was reviewed under the following subtitles.

2.1 β-carotene – its importance in health and diseases

2.2 Food sources of carotene

2.3 Consumption pattern of carotene rich foods

2.4 Effect of processing on β-carotene content

2.5 Bioavailability of β-carotene

2.1 β-CAROTENE : ITS IMPORTANCE IN HEALTH AND DISEASES

2.1.1 Prevention of Vitamin A Deficiency

VAD was a serious problem of public health and nutrition and was probably the most important cause of preventable blindness in children of developing countries (Bender 1992). Summer and West (1996) stated that VAD has been known to be the underlying cause of xerophthalmia in many countries. The WHO (1998) has estimated that 2-8 million preschool children are at risk of blindness and the well being of 251 million people are affected due to vitamin A deficiency. The deficiency was caused by a dietary pattern providing too little bioavailable vitamin A to support physiological needs, can be aggravated by frequent infections, worm infestations and protein deficiency in the affected individuals (Underwood, 2000).

The paradox of epidemiology of VAD was that the countries where the problem was endemic was also endowed with various varieties of fruits, vegetables and green leafy vegetables which are rich sources of β-carotene, the vitamin A precursor (Olson, 1994). Bhaskarachary (2000) opined that provitamin A carotenoids especially β-carotene rich foods can replace vitamin A in the diet. Underwood (2000) opined that VAD can be corrected even when provitamin A carotenoids contributed to the bulk of the daily vitamin A needs, especially when dietary fat was adequate and aggravating factors such as infections and worm infestation have been attended to. The author also suggested that introduction of genetically new plant or crop strains which are micronutrient dense, as well the increased cultivation and consumption of environmentally suitable, culturally acceptable - provitamin A carotenoid rich foods (such as RPO) would be given emphasis in food based strategies to combat VAD.

Sivan (2001) reported that in a feeding trial, RPO regimen reduced the prevalence of bitot's spots from 8.8 per cent to 6.5 per cent compared with a rise from 8.6 per cent to 10.7 per cent in the control group. Olmedilla (2002) suggested that to achieve and maintain high serum levels of α-carotene, β-carotene and lycopene, regular consumption of plenty of green leafy vegetables and fruits and in the process, also benefit from other phytochemicals present in the food matrix. Dietary interventions of including β-carotene rich foods was the surest way of improving vitamin A nutrition, thereby preventing VAD (Chandrasekhar and Kowsalya, 2002).

2.1.2 β-carotene in Health

Oxygen that was essential for the functioning of brain, can also provoke harmful free radical formation in the nerve cells which in turn causes nerve cell membranes to scar and harden. Lohr and Browning (1995) suggested that antioxidants like β-carotene can be protective to brain cells by effective neutralization of free radicals. Perrig (1997) reported that people with high levels of β-carotene can memmorise better than those with low levels.

Daudu *et al.* (1994) reported that in healthy adults, consuming adequate vitamin A, β-carotene depiction had no adverse effect on the immune functions, nor was there any beneficial effect of modest β-carotene supplementation. A moderate increase in the dietary intake of β-carotene can enhance cell mediated immune response, with in a relatively short period, providing a potential mechanism for the anticarcinogenic properties attributed to β-carotene (Hughes *et al.*, 1997).

Chew *et al.* (1997) observed that conjugated dienoic derivatives of linoleic acid (CLA) along with β-carotene can suppress nitrogen induced lymphocyte proliferation. CLA and β-carotene alone or in concert, act to modulate different aspects of cellular host defence. Watzl *et al.* (1999) stated that in a low carotenoid diet, there was reduction in the T-lymphocyte functioning but if the carotene content in the diet was increased it can restore the T-lymphocyte functions. The antioxidant property of β-carotene will help to protect immune cells from oxidative damage thus enhancing their ability to detect and eliminating tumor cells (Hughes, 2001).

In early years, it was stated that β-carotene and vitamin C, hinder the absorption of iron (El- Hawary *et al.* 1976). But studies done by Garcia-Casal *et al.* (1998) revealed that the presence of vitamin A increase iron absorption upto two fold while β-carotene increased absorption more than three fold. They also reported that vitamin A and β-carotene may form a complex with iron, keep it soluble in the intestinal lumen and preventing the inhibitory effect of phytates and polyphenols on iron absorption.

Garcia-Casal *et al.* (2000) again reported that in the presence of phytates or tannic acid, β-carotene generally overcome the inhibitory effects of both compounds depending on their concentrations, thus increasing iron absorption. Layrisse *et al.* (2000) reported that vitamin A and β-carotene can increase iron absorption to three times in cereal diets, showing that both compounds were capable of preventing the inhibitory effect of phytates on iron absorption.

Plasma concentration of the antioxidant β-carotene have a relation to lung functioning. Antwerpen *et al.* (1995) reported that β-carotene status can also determine the susceptibility to oxidant mediated pulmonary dysfunction in smokers. Grievink (1999) stated that individuals with high plasma β-carotene tend to have higher forced vital capacity than individuals with low plasma β-carotene concentration. But for forced expiratory volume, the author did not find difference between high and low level of plasma β-carotene.

Roja (1999) reported that vitamins A and C play prominent roles in wound healing because of their involvement in the maintenance of normal epidermis and collagen synthesis, respectively. β-carotene may play supporting casts in the cascade of the healing process because of its ability to scavenge free radicals and reduce inflammation.

2.1.3 β-Carotene in Diseases

a) β-carotene in cancer prevention

In accordance with the role of β-carotene and vitamin A as a controller of epithelial differentiation, they can help to prevent conversion of normal cells to carcinogenic cells (Krinsky, 1993). Studies indicated that retinoids and carotenoids especially β-carotene can reverse precancerous oral lesions (Tanka, 1995; Scully, 1995).

Carotene rich diet significantly reduces the endogenous levels of strand breaks in DNA. Oxidative base damage was also significantly reduced which indicate that carotenoids can exert a cancer protection effect via oxidative and other damages to DNA in humans (Pool- Zobel *et al.*, 1997). Rock *et al.* (1997) opined that β-carotene in diet can improve the prognoswas even after diagnosis of breast cancer.

Rijken *et al.* (1999) opined that increased vegetable consumption especially rich in carotene reduces the risk of colorectal cancer mortality.

Diets that provide 400-600 g of fruits and vegetables daily are associated with the reduced risk of epithelial cancers (Herber, 2000). Michaud (2000) reported that, there was significant inverse association between carotenoid consumption and lung cancer. High consumption of α-carotene and lycopene, reduce the lung cancer risk by 20-25 per cent, while β-carotene reduce the risk by only 10-19 per cent.

Low intakes of vitamin A and β-carotene rich foods was associated with increased risk of cancers at several sites such as lungs, larynx, pancreas, urinary bladder, prostrate, ovary, endometrium, cervix and breast (Prema, 2001). β-carotene was capable of decreasing the rate of malignant growth of the cells, induces morphological changes in the cells concomitant with reduction in their proliferation (Prakash *et al.*, 2002).

b. β-Carotene and Other Diseases

Brockmans *et al.* (2000) suggested that high consumption of fruits and vegetables rich in carotenoids was associated with a decreased risk of heart disease. Andreeva-Grateva (2000) opined on the possible role of antioxidants in attenuating atherosclerotic mechanisms. High antioxidant status may help to prevent initiation and progression of early atherosclerotic lesions in men (Gale *et al.* 2001a). An inverse association was suggested by Liu, *et al.* (2001) between vegetables containing antioxidants and risk of CHD. Antioxidant vitamins can act as scavengers of free radicals, they protect LDL from oxidation.

Semba *et al.* (1993) observed that HIV infected adults with concomitant VAD has 6-3 fold higher risk of death than non deficient patients. Semba, *et al.* (1994) reported that the risk of mother to child transmission of HIV was more than four times lower in women with high retinol levels. Patients infected with HIV are at an increased risk of atheroscleroswas and have evidence of endothelium dysfunctioning β-carotene can protect the endothelium of these patients and thereby reducing the risk (Constans *et al.*, 1998).

Curran-Celentano *et al.* (2001) reported that macular pigments protect against age related macular degeneration in the eyes leading to irreversible blindness. Macular pigment optical density was associated with carotenoid content in the diet and in the serum, association being higher with lutein and zeaxanthin than for β-carotene. Gale *et al.* (2001b) reported that β-carotene can protect against cataract development.

Roob *et al.* (1996) stated that lung inflammation in cystic fibroswas was associated with an increased release of free radicals from activated neutrophils and proteinases. Free radicals thus generated was thought to be oxidatively inactivated to prevent this. The authors opined that in a high β-carotene diet, the plasma concentrations of both retinol and β-carotene increased, efficient enough to attenuate lung inflammation in cystic fibrosis. Supplementation of a maximum 50 mg β-carotene per day can minimize oxidative stress and can improve the quality of life of cystic fibroswas patients (Rust *et al.* 2000).

Schoenberg *et al.* (1995) observed that pancreatic insufficiency occurs when the pancreas does not secrete enough chemicals and digestive enzymes for normal digestion to occur. The authors suggested that free radical damage was linked with pancreatitis, so antioxidants might be beneficial for the disease. β-carotene was shown to have beneficial effect to both acute and chronic pancreatitis, by reducing pains, reduce free radical activity and can prevent acute reoccurrences of pancreatitwas (Mathew *et al.*, 1996). Morris-Stiff (1999) reported that patients with chronic hepatitis, had improved prognoswas following intake of antioxidant supplement.

People with active gastritwas have been reported to have low levels of β-carotene in their stomach. Palli *et al.* (1991) stated that β-carotene reduces free radical damage in the stomach, prevents the development of chronic gastritis. They also stated that, high intake of β-carotene lead to disappearance of gastric erosion and improves chronic gastritis.

Many asthmatic patients experience exercise- induced asthma, while practically all suffer some breathing discomfort upon exercise. Newman (1999) stated that the pathogeneswas of bronchial hyper-reactivity was complex, involving inflammatory mediations, production shift in eicosanoid species and the generation of a flux of damaging reactive oxygen species. The author further reported that antioxidants such as ascorbic acid and β-carotene provide some relieve in exercise induced asthma. Newman *et al.* (2000) reported that antioxidants like β-carotene can help to reduce symptoms of asthma caused by exercise.

2.2 FOOD SOURCES OF CAROTENE

2.2.1 Sources of Carotene

Over 80 per cent of the daily supply of vitamin A in the Indian diets was derived from its precursors of β-carotene, α-carotene, ϒ-carotene and β-cryptoxanthin which was present in many plant foods. Common dietary sources of provitamin A carotenoids are carrots, yellow squash, dark green leafy vegetables, corn, tomatoes, papaya and oranges (Olson, 1994).

Giri *et al.* (1980) reported that on ripening of papaya, the β-carotene content also increases significantly from half ripe to full ripe. Simon and Wolff (1987) studied different carrot varieties in US, showed variations in the total carotene content from 6300-58000 µg/100g depending on the depth of colour development. Holland *et al.* (1991) reported that foods such as sweet potato can vary in colour from white to deep orange depending on the variety and carotene content, which range from 100 µg to 16000 µg/100g. The β-carotene value reported for yellow variety of sweet potato in Philippines was 540mcg/100g (Almeida and Pentedo, 1992).

Work done by Granado *et al.* (1992) on β-carotene content of eighteen commonly and most frequently consumed fresh vegetables in Spain revealed that β-carotene and lutein were present in all vegetables except sweet red pepper which have zeaxanthin. The highest composition was found in spinach.

Red palm oil, was a very inexpensive but rich source of β-carotene. β-carotene forms 56 per cent of total carotene in the oil, which ranges from 500-1600 ppm Seshadri (1996). A wide variety of carotene containing foods have been identified by the author, 52 in all in a survey conducted all around India. Of these 60 per cent or more were green leafy vegetables, while others were roots and tubers and fruits. The β-carotene content of these foods indicates that about 30 per cent of them were rich in β-carotene with more than 5000 μg/g while 20 per cent were modest source with 1000-5000 μg/100g.

Reddy (1996) stated that other vegetables like carrots, pumpkin and sweet potato are good sources of provitamin A. Yellow fleshed yam and sweet potato contain about 2 mg of β-carotene and B-3 carrot contain β-carotene as high as 14 mg. On ripening, the edible part of mango, which was white turn to pale yellow, finally to orange yellow, due to the development of carotenoids and about 60 per cent of was β-carotene which was higher than in any other fruit (Anita and Abraham, 1997).

Plant sources of vitamin A include carrots, cantaloupe, apricots, mangoes and sweet potatoes, contain yellow orange pigments called carotenoids. β-carotene was plentiful in carrots, squash and other red and yellow vegetables and fruits as well as in leafy vegetables (Smolin and Grosvenor, 2000). Intact carotenoids are seen deposited in organs of animals such as in the yolk of eggs or in liver. β-carotene was also found in milk and milk products (Bhaskarachary, 2000). The author also reported that spirulina, a blue green algae was a rich source of β-carotene

(3000 μg/g). A small quantity of 2g spirulina was enough to meet the RDA of vitamin A.

Nagendran (2000) opined that characteristic red colour of RPO was due to multicarotenoids present in the oil, total of about 545 ppm with 90 per cent as the provitamin A carotenoids, β and α-carotenes, the RE of RPO was about 7000 mg/100g. Commonly consumed fruits of Indonesia was studied by Setiawan *et al.* (2001) and found that salak and guava were excellent sources of β-carotene (>140 μg RE per 100g), mango, red water melon and papaya as good sources (>70 μg RE per 100g).

2.2.2 Carotenoid Composition in Foods

Godoy and Amaya (1989) found the carotenoid composition of commercial mangoes from Brazil, as β-carotene was consistently the principle carotenoid accounting for 48-84 per cent of the total. The variety cultivar Extreme had the highest β-carotene (2545 μg/100g) and cultivar Hadan had the lowest (661 μg/100g). Mercadante and Amaya (1990) obtained the β-carotene composition of some native Brazilian GLVs. The results obtained was 110 μg/g for *Amaranthus viridis*, 84.6 for *Lepidium pseudodidymum*, 67.3 for *Xanthosoma* spp, 62.9 for *Sanchus oleraceus*, 29.8 for *Portulacia oleracea*.

Bhattacharjee *et al.*(1994) reported the provitamin A content of some selected Indian foods, pigeon pea leaves, mayalu leaves, spinach and carrot. The mean β-carotene values range between 488-7116 μg/100 g and constituted 41-63 per cent of total carotenoid. Reddy (1996) observed that β-carotene was the most predominant provitamin A in green leafy vegetables consisting 30-50 per cent of the total carotene except for fenugreek leaves which contain more than 80 per cent. Drumstick leaves and agathi had a highest β-carotene concentration, 15-20 mg/100g, hibiscus and colocasia 5 mg/100g. Yang *et al.* (1996) stated that several dark green leafy vegetables have very high β-carotene content ranging from 0.94 to 9.36 mg/100g. Wills and Ranga (1996) determined the β-carotene content of seven Chinese vegetables and found that lutein was the major carotenoid (20-36 per cent of total carotenes) followed by β-carotene (4-23 per cent).

Nambiar and Seshadri (1998) reported the β-carotene content of 16 GLVs. Of these, seven of them had β-carotene content more than 5000 μg/100g in fresh weight. The highest value was for *Trianthama monogyna* (Khatedo leaves), 14390 μg/100g, followed by fenugreek leaves, (*Trigonella foenum graecum*) 10226 μg/100g. Twelve out of 16 GLVs had β-carotene contents that varied from 40-90 per cent of total carotene. highest value was for bathua leaves (*Chenopodium album*, 83.9 per cent) and jharakhala (*Amaranthus* sp. 80.9 per cent).

The β-carotene content of four locally available green leafy vegetables of Palakkad District, Kerala was studied by Chandrasekhar *et al.* (2000). The green leafy vegetables were pumpkin leaves, ashgourd leaves, spreading hog weed and wild colocasia. The contents obtained were 34780, 20846, 24376 and 23845 respectively which were 88.7, 71.8, 93.6 and 86.0 percentage of the total carotene. Nambiar and Seshadri (2001) reported the β-carotene content of radish leaves fresh weight as 6540 μg/100g which forms 54.8 per cent of the total carotenes in it. Joshi and Kushrestha (2002) reported that fenugreek leaf powder have a β-carotene content of 40625 μg/100g on dry weight basis.

Chandrasekhar and Kowsalya (2002) obtained the provitamin A content of selected south Indian foods. The carotene contents of GLVs ranged from 14025 to 41984 μg/100g and β-carotene content ranged from 7130 to 28, 160 μg/100g of fresh leaves. Drumstick leaves showed the highest value in both total carotenes and β-carotene. The authors further studied on vegetables, among which carrots had the highest total carotenoid and β-carotene followed by pumpkin, green chillies, yam and sweet potato. Among the fruits, β-carotene value was maximum in mango (1866 mcg/100g), 73 per cent of total carotene.

In the rural pockets of India, there are a number of less familiar edible GLVs, available in plenty which are exceptionally rich in β-carotene (Bhaskarachary *et al.*, 1992). Promotion of intake of about 50 g GLV like amaranthus and agathi will provide adequate β-carotene to meet the vitamin A requirements of an adult (Chaddha 1992). In Kerala, the conventional and major sources of β-carotene include dark green leafy vegetables and yellow orange fruits (Prema, 2001).

2.3 CONSUMPTION PATTERN OF CAROTENE RICH FOODS

Gopalan *et al.* (1992) reported that the percapita availability of β-carotene from all carotene rich sources of vegetables and fruits produced in India was only 1,160 μg as against the daily requirement of 2400 μg. Thus the availability meets only about half of the daily requirement. Seshadri (1996) stated that consumption of β-carotene containing foods contributed to 60 per cent or more of the total vitamin A at the household level intake. The author also stated that carotene rich foods are the most important dietary sources of vitamin A to the poorer socio-economic rural and urban population in India. The frequency of consumption of carotene rich foods varied widely depending on seasons, which in turn was related to availability, cost and quality of vegetables and fruits.

Though India has a wide range of inexpensive foods rich in carotenoids the per capita availability of β-carotene in terms of retinol equivalent (400 mcg/d) was much below the recommended allowances of vitamin A for an individual (Vijayaraghavan and Nayak, 1995). Devadas *et al.* (1996) found that in Coimbatore the families have curry leaves, amaranth, agathi and ponnanganni all round the year, drumstick leaves and mint during south west monsoons, coriander leaves during winter and paruppukeeri, in summer as sources of β-carotene.

Reddy (1996) revealed that in villages of Andhra Pradesh, the rural communities consume a variety of green leafy vegetables either those traditionally known or which grow wild in the country side, but not on a regular basis. Though they know about the carotene rich foods available around them, they are consumed infrequently and in amounts inadequate to meet the nutritional needs. Bloem *et al.* (1996) reported that vitamin A intake of Bangladesh population was derived almost entirely from consumption of fruits and vegetables. The authors also found that cultivation and production of fruits and vegetables through homestead farming contributes valuably to the increased intake. Chandrasekhar *et al.* (1999) conducted a survey on the consumption pattern of β-carotene rich foods in Coimbatore district which revealed that amaranth, drumstick leaves, keerai and agathi were commonly consumed greens and fruits like papaya, tomato, mango and orange were relished most.

Decloitre and Volatier (2001) reported that in France the mean range of consumption of fruits and vegetables range between 400-500 g per day per individual. Hebert *et al.* (2000) studied food consumption pattern among adults in Gujarat and Kerala and found that there was relatively large interperson variability observed in the intake of different nutrients including β-carotene, which can contribute to improved resolution of diet outcome relationships in epidemiologic studies. Bhaskarachary (2000) stated that Indian pre-school children continue to consume less than 50 per cent of the RDI of vitamin A despite considerable socio-economic development.

NNMB (1997) surveys, over the years (1972-1997) in India revealed that the average intake of green leafy vegetables was found to be about a third of RDA. It was reported that a slight increase in consumption of fruits was observed through the years. The study also revealed that in Kerala, the intake of green leafy vegetables was less than one fourth of RDA, while for other vegetables, it was satisfactory. The repeat survey conducted by NNMB (2000) on 1998-1999 among the tribal population, revealed that in general the overall intake of various foods was less than RDA. Survey also revealed that the consumption of qualitative foods such as green leafy vegetables, fruits was grossly deficient. Prema (2001) reported that in a typical Kerala diet, fish, green leafy vegetables, yellow and orange coloured fruits and vegetables are considered as the major sources of either vitamin A or β-carotene. But in many rice eating populations especially carbohydrate dominating diet at or near subsistence level was found to be one reason for prevalence of VAD in Kerala.

Ogle *et al.* (2001) stated that in Vietnam, women consumed green leafy vegetables in mean daily quantities exceeding 50 g. Premavalli *et al.* (2001) reported that in India, the most commonly used β-carotene rich foods are the green leafy vegetables, which contribute to flavour, green colour, minor nutrients as well as medicinal properties. Agarwal *et al.* (2001) stated that children of urban areas consume more foods, vegetables, milk and flesh foods than rural children who consume more cereals and pulses in comparison to urban children. Singh and Kwatra (2001) reported that the tribes of Madhya Pradesh consume green leafy vegetables, amaranthus, raddish leaves and cabbage on a daily or atleast twice in a week basis. But the intake was dependent on the availability because they are collected from nearby.

Subratty and Jowaheer (2001) found that in Mauritian diet, fruits such as apples, pears, oranges, bananas, grapes, kiwi and papaya formed an important part. Kowsalya *et al.* (2001) stated that though the carotene rich foods are available largely in the country, their seasonal availability and high perishability makes their usage highly selective cumbersome and non available at all time. Deshpande *et al.* (2001) found that in Bhopal women consumed lower quantity of green leafy's, in the daily diet ranging from 44-72 g as against 100 g of RDA. Their diet consisted primarily cereal based, which have a low vitamin A activity caused poor availability of β-carotene. The authors also found that green leafy vegetables provided some β-carotene in the diet whereas vitamin A rich foods sources like milk, ghee, yellow fruits like papaya were lacking in the diets.

Rahman and Rao (2001) reported that in low income families, the consumption of qualitative foods such as pulses, legumes, green leafy vegetables and other vegetables were considerably low. Mehraj and Choudhary (2002) stated that in Udaipur, the limiting foods in the daily diet was green leafy vegetables, 25 per cent and fruits, 31 per cent. Kumari and Singh (2002) observed that among scheduled caste adults of rural areas of Bihar, consumption of both vegetables and green leafy vegetables was greater than RDA.

Vijayalakshmi (2002) stated that India has attained the position of being the first largest fruit producer and second largest producer of vegetables with the production of 49.5 and 85 million tonnes respectively during 98-99. But the percapita availability of fruits and vegetables was only 46 g and 140 g per day respectively, which was very less than RDA. The author also stated that the vitamin A intake in 1975 recorded 263 μg as against 288 μg during 1995, which shows that the nutrient intake was very grim.

2.4 EFFECT OF PROCESSING ON β-CAROTENE CONTENT

Most Indians, living either in rural or urban areas consume vegetables after cooking. Use of vegetables as salads was mostly confined to the households of urban elite (Rani *et al.*, 1995). Prema (2001) reported that several preliminary steps prior to cooking undertaken by families like peeling, trimming, washing and cutting as well as heating were found to be unscientific in most of the households. Also the atmospheric air, time of exposure and the presence of other food ingredients with which the carotene rich foods were cooked were also found to influence negatively the carotenoid content.

Household processing of vegetables involves several steps such as washing, peeling, trimming, cutting, grinding, boiling, frying and steaming during which they are often exposed to elevated temperature, high or low pH levels, oxygen and light which accelerate the oxidative destruction of carotenoids and decrease their vitamin A activity (Jonsson, 1990).

Processing at elevated temperature contribute to destruction of β-carotene by formation of compounds called ionenes (Sweeny and March, 1973). Cooking at elevated temperatures in the presence of oxygen was said to cause conversion of all trans carotene to cis isomers with decrease in vitamin A activity (Chandler and Schwartz, 1987; Speek *et al.*, 1988 ; Rock *et al.*, 1998; Rajalakshmi *et al.*, 2001).

Prolonged cooking was said to have deleterious effect on the retention of both total carotenoids and β-carotene (Madhavapeddi *et al.*, 1994). Their studies also revealed that washing of vegetables after cutting will cause a loss of 10-12 per cent, but no significant loss seen when vegetables are cut after washing.

In India, vegetables are cooked normally in a vessel either with or without lid. Covering with a lid, retains a higher percentage of β-carotene (Rani *et al.*, 1995). They also reported that retention of β-carotene was higher when cooked in the presence of small amounts of oil and retention rate ranges between 41 and 100 per cent.

During processing, losses of vitamins and minerals can occur either due to oxidation or by dissolving into oil (Vail *et al.* 1978). Edward and Lee (1986) reported that canned vegetables had a higher carotenoid content than fresh sample. The apparent increase in canned carrots was mainly due to loss of soluble solids into brine during processing. Dietz and Gould (1986) studied the retention of β-carotene after extraction, pasteurization canning and after seven months storage at 22°C.

A 20 per cent loss of β-carotene content was observed during extraction and another 20 per cent loss found after seven months storage.

According to Onayem and Badifu (1987) β-carotene was destroyed during processing and loss was estimated to be as high as 75 per cent. Park (1987) reported that dehydration of vegetables regardless of drying methods, significantly reduce the carotene content. Wu *et al.* (1992) found that β-carotene remained stable in both refrigerated and frozen broccoli during storage.

Gomez (1981) suggested that steam blanching result in little or no loss in β-carotene content. Bao and Chang (1994) opined that unblanched carrots produced highest amount of juice with high retention of total carotenes. Retorting, concentrating and freeze drying partly reduced the juice product carotenes and the loss was greater for β-carotene than for α-carotene.

Lane and Warthesen (1995) stated that light promoted pigment losses in raw spinach. Degradative losses at 8 days ranged from 60 per cent for violaxanthin to 22 per cent for lutein. Dark cold storage did not affect carotenoid levels except for all trans β-carotene which showed an 18 per cent loss at 8 days. Masrizal *et al.* (1997) compared the retention of β-carotene in five vegetables cooked by four household methods to equal degrees of over all acceptability. β-carotene retention in four of five vegetables cooked by different methods was similar. Overall, higher retention values were observed in vegetables cooked by microwave, steaming and stir frying with oil. Mosha *et al.* (1997) observed that blanching and cooking resulted in significant increase in concentration of carotenoids in cowpea, peanut and pumpkin leaves while amaranth and sweet potato greens showed a significant decrease in the amount of carotenoids. The study also revealed that traditional processing practices of sundrying and storage in ventilated containers resulted in a significant decrease in β-carotene content in all vegetables.

Ana *et al.* (1998) compared the methods of preparations, the retention ranged from 56.0 to 89.1 per cent for carotenoids with moist or dry cooking causing greatest losses in β and α-carotenes. They also suggested water cooking without pressure for reducing losses of carotenoids in carrots. Howard *et al.* (1999) reported that trans β-carotene content decreases slightly during freezer storage and significant decrease in canned carrots. Microwave cooking do not have significant effect on carotene content. Sharma *et al.* (2000) stated that total carotenoid content decreased by 9.9-10.86 per cent during blanching of carrots. Losses were higher in unblanched carrots as well as in fluidized bed dried samples as compared to blanched and cabinet dried ones.

Negi and Roy (2000) observed that β-carotene levels in fresh carrot samples decreases during storage. Blanching and drying of carrot slices resulted in a significant decrease of β-carotene, which decreased further during storage of dehydrated samples. Negi and Roy (2001) stated that blanched carrots contained higher β-carotene, than their unblanched counter parts, just after drying. But the values decreased on storage. Banga and Bawa (2002) reported that β-carotene content of both blanched and unblanched grated carrot samples dehydrated increased with increase in drying air temperature and thus retention of β-carotene also increased However retention was higher for unblanched grated carrot samples as compared to blanched counter parts.

Lakshmi and Vimala (2000) reported that after blanching and drying green leafy vegetable powders, retained only fair amounts of β-carotene and vitamin C. Premavalli *et al.* (2001) reported that in blanched and dehydrated green leafy vegetables there was a retention of 60 to 70 per cent of carotenoids, the provitamin A retained was better to the tune of 36 to 94 per cent. Kaur and Kapoor (2001) studied the qualities of vegetables blanched by mixed or microwave method and found mixed methods retain more carotenoids and that also more in high temperature short time method than low temperature long time method.

Nambiar and Seshadri (2001) reported that radish leaves subjected to shallow frying retained 82 per cent of β-carotene, steaming and sauteing 68 per cent and baking where there was prolonged heating retained only 36 per cent of β-carotene. Mziray *et al.* (2001) found the levels of β-carotene in amaranthus hybridus as 25-37 mg/100g dry weight. On boiling, the content remained uneffected. Rajyalakshmi *et al.* (2001) studied the effect of boiling on forest green leafy vegetables, and the percentage loss of β-carotene varies between 2.66 to 92.34 per cent.

Chavist *et al.* (2002) reported that during preservation there was loss of β-carotene. The loss in candied mango and papaya during processing was 17-18 per cent and the loss continued from 30-40 per cent during storage over 3 months. In contrast, β-carotene contents increased during fermentation of pickles, ranging from 30-40.

Hasan (1987) stated that in refined palm oil, all the components except carotenoids are present. The carotenoids are generally removed or destroyed while refining. Manorama (1992) reported that RPO was nutritionally superior to refined, bleached and deodorized palm oil, since it was rich in β-carotene. Manorama and Rukmini (1992) observed that 70-80 per cent of β-carotene was retained when RPO was cooked. On repeated heating, there was a steep fall in carotene content. Lietz *et al.* (1998) reported that degradation of all trans β-carotene in red palm oil can be reduced by putting a few curry leaf or chaya leaf. Nagendran (2000) found that carotenoid loss during shallow cooking was only 12-13 per cent. But on storage there was a decrease in β-carotene content of RPO (Sreekumar 2001).

Padmavathi and Udipi (1992) stated that the extent of β-carotene loss in the preparation was lower when processing or heating was kept to a minimum. Grinding, chopping plus cooking for long periods or prolonged cooking resulted in progressive loss of β-carotene. Simple procedure like cutting the vegetables after washing, covering the vessel while cooking, and adding small amounts of oil resulted in maximum retention of carotene. Addition of tamarind or lime juice results in higher retention of carotene (Seshadri, 1996; Reddy, 1996).

2.5 BIOAVAILABILITY OF β-CAROTENE

2.5.1 Absorption of β-Carotene

Brubacher and Weiser (1985) stated that as the amount of carotenoids in the diet increases, the absorption decreases. Olson (1990) stated that absorption efficiency of dietary vitamin A in healthy person who ingest significant amount of fats was 80 per cent, for dietary carotenoids 1-3 mg are absorbed approximately half as well as vitamin A. Bender (1992) reported that absorption of β-carotene was considerably lower than that of retinol, only about 20-50 of a test dose under normal conditions. Approximately 10-50 per cent of that total β-carotene consumed was absorbed in the GI tract and with in the intestinal wall was partially converted to vitamin A. The efficiency of β-carotene absorption decreases as the intake increases and conversion of vitamin was regulated by the vitamin A status of the individual (Wang, 1994).

Faulks *et al.* (1997) reported that 90 per cent of total β-carotene was absorbed without measurable perturbation of plasma total β-carotene or change in the all trans, 9- cis β-carotene ratio. Once in the mucosal cells, much of the β-carotene was converted into retinol upto 30 per cent of ingested will be absorbed unchanged (Smolin and Grosvenor, 2000). Chew *et al.* (2000) observed that domestic cats readily absorb β-carotene across the intestinal mucosa and transfer the β-carotene into peripheral blood leukocytes and their subcellular organelles.

2.5.2 Conversion of β-Carotene to Vitamin A

Wang *et al.* (1991) reported that the molecule of β-carotene was cleaved centrally into two molecules of retinal and then converted to retinyl esters before incorporation into chylomicron tissues. Wang (1994) stated that small intestinal mucosa contains β-carotene cleavage enzymes there by playing an important role in both the provitamin A activity and anticancer properties of β-carotene.

van Vliet *et al* (1995) observed that low β-carotene response was associated with a high ratio between retinyl palmitate and β-carotene responses. van Vliet *et al.* (1996) found that in rats intestinal β-carotene cleavage activity was higher in vitamin A deficient rats than in rats with a high intake of either vitamin A or β-carotene. van Vliet (1996) observed that absorbed β-carotene for most part was converted mainly into retinyl esters.

The β-carotene cleavage enzymes, retinal reductase and retinol esterifying enzymes are co-ordinately distributed along the villus crypt axwas with retinal reductase and lecithin: retinol acyl transferase, the two enzymes which require cellular retinol- binding protein, type II as the donor of the substrate (Tajima *et al.*, 1999).

Chen *et al.* (1999) stated that, uptake of β-carotene into intestinal mucosa was limited by saturation of an intestinal receptor or the conversion enzyme. Deming *et al.* (2000) observed that increasing dietary fat resulted in higher vitamin A and lower β-carotene stores in the liver, suggesting that consumption of high fat diets enhances conversion of β- carotene to vitamin A.

2.5.3 Bioavailability of β-Carotene

Sauberlich (1985) stated that bioavailability may be considered as the relative absorption of a nutrient from the diet. Bioavailability was defined as the fraction of an ingested nutrient, that was available to the body for the utilisation in normal physiological functions or for storage (Jackson, 1997).

Parker (1996) observed that bioavailability of carotenoids was influenced by several factors such as characteristics of food source, interaction with other dietary factors or various subject characteristics. Sies and Stahl (1998) observed that bioavailability of lycopene depends on various factors such as food processing or coingestion of fat. Grolier *et al.* (1998) observed that reduction in gut microflora results in a better utilization of α and β-carotene by rats although bacteria do not have a direct effect on the bioavailability of these pigment.

vanhet Hof *et al.* (1999a) stated that plasma concentration of carotenoids were significantly higher after high vegetable diet and the plasma responses of β-carotene and lutein were 14 per cent and 67 per cent respectively to those to pure carotene supplemented diet.

Each carotenoid seems to show an individual pattern of absorption. plasma transport and metabolic carotenoid bioavailability was influenced by a number of factors called SLAMENGHI factors (Castenmiller and West 1998). The factors are species of carotenoids, molecular linkage, amount of carotenoids consumed in a meal, matrix in which the carotenoid was incorporated, effectors of absorption and bioconversion, nutrient status of the host, genetic factors, host related factors, interactions.

The naturally occurring configuration of carotenoids in plant foods was usually all trans isomer. Cis isomeric composition increases with food, processing particularly heating and the quantity formed appears related to the severity and extend of heating (Chandler and Schwartz.

1987). The FAO/WHO Joint Expert Consultation (1988) on vitamin A requirements has assumed that the vitamin A activity of other provitamin A carotenoids including cis isomers of β-carotene was 50 per cent that of β-carotene.

Cis isomers of carotene have been reported to be less bioavailable than all trans isomers of β-carotene (Erdman *et al.*, 1993). Gaziano *et al.* (1995) stated that even in 50 :50 mixture of all trans and 9- cis β-carotene, the 9 cis concentration were only a small fraction of total plasma β- carotene.

You *et al.* (1996) reported that isomerization of ingested 9 cis β- carotene before its secretion into the blood stream limits the potential supply of 9-cis retinoids to tissues and increases the vitamin A value of 9 cis β-carotene. When multiple doses of mixtures of the two were ingested, the proportion of the 9 cis form found in serum was less than one sixth of the amount found in the carotenoid mixture (Amotz and Levy, 1996). Herbst *et al.* (1997) found that lutein diesters showed a trend toward greater bioavailability than free lutein did, which suggested that the human gut was efficient in cleaving esters of lutein and therefore, esterified lutein in food may be equally or better bioavailable than free lutein.

Nierenberg (1991) stated that in normal subjects, the efficiency of carotenoid absorption varies widely. Serum β-carotene concentrations rise quickly after a single oral dose and usually peak at 5 h and remain elevated for more than 24 h. Prince and Frisoli (1993) found that administering β-carotene daily in three divided doses with meals increased the serum β-carotene concentration three times more than when the same total dose was administered once daily. Carughi and Hooper (1994) suggested that the concentration of β-carotene in plasma and chylomicrons and the concentration of lycopene in plasma reflect the content of these carotenoids in the meal or supplement. Murray (1996) reported that vitamin A and carotene are absorbed from the small intestine into the lymph system, the maximum absorption reaches 3.5 h after consumption. The rate of absorption of vitamin A was more rapid than that of carotene.

Erdman *et al.* (1988) stated that in orange and yellow fruits and in pumpkin and sweet potato, carotenoids are dissolved in oil droplets in chromoplasts and can be readily extracted during digestion. The presence of dietary fiber in vegetables and fruits may explain in part the lower bioavailability of carotenoids from plant foods. It has been suggested that fiber interferes with micelle formation by partitioning bile salts and fat in the gel phase of dietary fiber (Rock and Swendseid, 1992). Bender (1992) opined that the absorption of carotene from vegetable foods may be lower depending on the integrity of plant cell walls, which will prevent absorption and also the fat content of the diet or test meal.

Zhou *et al.* (1996) observed that pureeing vegetables results in small particle size and also mechanically disrupts the plant cells, so that carotenoids are persumably more available in the intestinal lumen for absorption. They also suggested that the food matrix, probably pectin like fibers and the crystalline form of carotenoids in carrot chromoplast are the primary factors that reduce the relative bioavailability of carotenoids from carrot juice. Reddy (1996) stated that carotene absorption was higher with papaya than with green leafy vegetables, because of difference in fibre content.

West *et al.* (1998) found that β-carotene from fruits was 2.6-6 time as effective in increasing plasma concentrations of retinol and β-carotene than green leafy vegetables. The bioavailability from green leafy vegetables was low because of their entrapment and complexing to proteins in chloroplasts and within cell structures (Castenmiller and West 1998). vanhet Hof *et al.* (1999c) found that broccoli and green peas induced a larger β-carotene response in plasma than whole leaf and chopped spinach, despite a ten times lower β-carotene content in the former vegetables.

Hume and Krebs (1979) reported that bioavailability of β-carotene from vegetables and carrots was only a third of that of β-carotene in oil. The authors also found that β-carotene was more bioavailable in RPO, as it was fat in which β-carotene was naturally present.

Borel *et al.* (1996) observed that solubility of β-carotene and zeaxanthin decreases with increased chain length in triglyceride fatty acids. Jalal *et al.* (1998) indicated that the cut off point lies between 3 and 5 g of fat. vanhet Hof *et al.* (1998) suggest that addition of fat during processing increases the bioavailability of β-carotene. β-carotene added to soyabean oil used in the preparation of rice was absorbed heated or not and can be a practical source of provitamin A (Oliveira *et al.*, 1998). Takyi (1999) observed that consumption of dark green leafy vegetables with fat (10 g/100g) significantly enhanced serum retinol.

Hu *et al.* (2000) found that ingestion of β-carotene with a meal rich in sunflower oil as compared with a meal rich in beef tallow results in lower appearance of β-carotene. Roodenburg *et al.* (2000) stated that optimal uptake of α and β-carotenes requires a limited amount of fat where as the amount of fat required for optimal intestinal uptake of lutein esters was higher. The amount of dietary fat required to ensure carotenoid absorption seems low (approx-3-5 g/ meal) although it depends on the physicochemical characteristics of the carotenoids ingested (vanhet Hof *et al.*, 2000a). Lieshout (2001) stated that bioefficiency of β-carotene in oil was much higher than that from matrix of food. RPO ingested in small amounts promotes the relative bioavailability of β-carotene ten folds greater that what was available from whole uncooked carrots (Purushothaman and Paul, 2000).

Dietary protein, facilitates absorption of carotenoids by assuring sufficient precursors for the syntheswas of digestive enzymes and the mucosal carotene dioxygenase as well as for the maintenance of a healthy mucosal surface (Underwood, 1980). Wedzicha and Lamikanra (1983) stated that the presence of protein in the small intestine helps to stabilize fat emulsions and enhances micelle formation and carotenoid uptake. Tang *et al.* (1996) found that a single dose of β-carotene increased plasma concentrations of β-carotene at normal gastric pH to a level twice as high as that at a gastric pH of 6.4. Purushothaman and Paul (2000) stated that if provided with in the same meal, fat and proteins will improve the bioavailability of vitamin A and carotenoids where as dietary fiber will reduce the bioavailability.

Leo *et al.* (1992) reported a combination of an increase in plasma and liver β-carotene after ingesting ethanol and a relative lack of a corresponding rise in retinol suggested that alcohol interferes with the conversion of β-carotene to vitamin A. Lecomte *et al.* (1994) found that after withdrawal from alcohol consumption, the plasma carotenoid levels increased, whereas retinol concentration diminished. Albanes *et al* (1997) reported that drinkers compared with subjects with low or no alcohol intake had lower β-carotene levels, whereas plasma retinol levels were similar or higher.

Sklan *et al* (1989) showed that high vitamin A intake reduces carotenoid pigmentation in chickens, also, the vitamin A decreased the absorption not only of β-carotene but of canthaxanthin as well. The authors also stated that at lower levels of β-carotene intake, retinol levels in serum and liver are increased by ingestion of β-carotene. Castenmiller and West (1998) reported that feeding β-carotene rich foods to humans lead to an increase in serum retinol levels only when these are initially low. It was also assumed that a plasma level of β-carotene equal to or higher than 1.1 μmol/liter reflects a nutritional intake of provitamins sufficient to support homeostaswas of retinol. Kelly (2001) reported that men with persistent diarrhoea had lower baseline serum retinol concentration than control. The authors also stated that adults and children with diarrhoea had greater losses of retinol in urine over a 24h period than controls, persistent diarrhoea was also associated with reduced bioavailability of control.

Johnson *et al.* (1997) reported that ingestion of a combined dose of β-carotene and lycopene resulted in a significant increase in serum concentration of both β-carotene and lycopene at 24 h, where as the absorption of lycopene when ingested with β-carotene was higher than when ingested alone.

Kostic *et al* (1995) stated that carotenoids interact with each other during intestinal absorption, metabolism and serum clearance although individual responses can differ markedly, also lutein can reduce the β-carotene absorption significantly. vanden Berg (1998) observed that inhibitory effect of lutein was found to be most marked when lutein was the predominant carotene. However the presence of α-carotene do not affect the absorption of β-carotene (vanhet Hof *et al.*, 1999b). Tyssandier *et al.* (2002) found that adding a second carotenoid to a meal will cause diminished chylomicron response to the first carotenoid. However co-supplementation with a second carotenoid of a diet supplemented with a first carotenoid did not diminish the medium term plasma response to the first carotenoid.

2.5.4 Effect of Processing on Bioavailability of β-Carotene

Grimme and Brown (1984) observed that heat treatment such as cooking and steaming help to release protein bound carotenoids and enables them to be more readily extracted.

Homogenization and heat treatment disrupt cell membranes where as heat treatment has been suggested to disrupt further the protein carotenoid complexes (Erdman *et al.*, 1988)

Dietz and Erdman (1989) found that during steaming because of denaturation of carotene binding proteins, released the carotenoids so that they can be extracted more easily. Micozzi *et al.* (1992) opined that mild heating improve the extract ability of β-carotene from vegetables and thus its bioavailability.

Khachick *et al* (1992) reported that cooking enhances the carotenoid content measured in vegetables, possibly due to increased extractability of carotenoids from the vegetable matrix.

Erdman *et al.* (1993) stated that β-carotene absorption can be as low as 1-2 per cent from raw vegetables such as carrot. Mild heating appears to improve the extractability of β-carotene from vegetable and also its bioavailability. Poor *et al.* (1993) reported that heat treatment may improve the bioavailability of carotenoids from vegetables.

Hart and Scott (1995) stated that cooking increase chemical extractability of carotenoids and thwas may be a factor in reported that cooking increases bioavailability of carrots in humans.

Torronen *et al.* (1996) showed a 70 per cent difference in bioavailability of β-carotene from raw carrots versus carrot juice consumed by well nourished adult females for 6 week although the difference was not significant. Parker (1996) reported that heating and conservative cooking increases the bioavailability of β-carotene in carrots. The lycopene response in plasma or triglyceride rich lipoproteins was 22-380 per cent greater after consumption of tomato paste than that for the same amount of lycopene consumed as fresh tomatoes (Gartner *et al.*, 1997).

vanhet Hof *et al.* (1998) stated that processing of vegetables by mechanical homogenization or heat treatment has the potential of increasing the bioavailability of carotenoids. Rock *et al.* (1998) reported that daily consumption of processed carrots and spinach over a four week period produced an increase in plasma β-carotene concentration that averaged three times that associated with consumption of the same amount of β-carotene from same vegetables in raw form.

Eligot *et al.* (1999) reported that bioavailability of β-carotene was more in juice form than in raw or cooked vegetables. vanhet Hof *et al.* (1999c) reported that bioavailability of β-carotene from spinach can be improved by the disruption of the vegetable matrix. Huang *et al.* (2000) stated that the relative bioavailability of β-carotene from stir fried and deep fried vegetables was about one third to one fourth of the purified β-carotene beadlets. Purushothaman and Paul (2000) found that mild cooking can enhance the bioavailability by releasing the free carotenoids from carotenoid protein complexes of green leafy vegetables.

Intactness of cellular matrix determines the bioavailability of carotenoids and matrix disruption by mechanical homogenization and heating can enhance the bioavailability (vanhet Hof *et al.*, 2000b). Richella *et al.* (2002) stated that absorption of lycopene was higher from processed foods such as tomato paste and tomato juice heated in oil. Processing can significantly improve the bioavailability of carrot carotenes and some cases influence the carotene value more than the intrinsic vitamin A value (Edwards *et al.*, 2002).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study entitled 'Influence of processing methods on the bioavailability of β-carotene content in selected foods' is carried out with the objective to determine the influence of different household processing methods on the bioavailability of β-carotene from selected fruits and vegetables.

The study comprised of the following aspects:

3.1 Selection of area

3.2 Selection of subjects

3.3 Socio economic survey

3.4 Assessing the dietary habits of the respondents

3.5 Selection of foods for the study

3.6 Selection and standardization of processing techniques

3.7 Estimation of β- carotene bioavailability

3.8 Analysis of data

3.1 SELECTION OF AREA

Socio economic differences have an influence on the diet and nutrient intake of pre school children, school going and adolescent children and adults of urban and rural population (Thimmayamma *et al.*, 1982). Arokiasamy and Rao (1988) found that dietary quality and quantity are better in rural and urban rich households. It was also noted that. rich urban households consumed more amount of protective nutrient rich foods as against poor households.

Based on the above facts it was decided to conduct the study among rural as well as urban households. An urban and a rural area, adjacent to

College of Agriculture, Vellayani was selected the locale of the study based on the convenience to approach subjects. Thus Kalliyoor Gramapanchayat was selected as the rural area for survey while Thiruvananthapuram corporation was selected as the urban locale. The urban population particularly consisted of working as well as non-working homemakers.

3.2 SELECTION OF SUBJECTS

Rothenberg *et al.* (1994) found that food choices and intake were related to socio economic status and activity of daily living status in a homogenous population. As the study aims to investigate the relationship between food habits, cooking pattern and adequacy of β-carotene consumption homemakers were considered to be the appropriate samples for survey. Fifty housewives from rural area and 50 housewives from urban area formed the respondents of the study. The homemakers were thoughtfully selected because of their involvement in different aspects like purchase of foodstuffs, preparation of meals by making best use of available resources and serving food to members of the family (Moorthy, 1998).

3.3 SOCIO ECONOMIC SURVEY

The socio economic level of the respondents such as social, economic, religious and the family background in general have a very distinct part to play in determining the attitudes and food behavioural pattern of the individual (Arora, 1991). Nayga (1994) analysed the relation of socio economic and demographic factors and urbanization, religion, race, ethnicity, sex, employment status, household size, weight, height, age and income with consumption of different nutrients. The author found that several of these factors significantly affect consumption of certain nutrients. Rahman and Rao (2001) stated that socio economic and demographic factors play a vital role on the variations in consumption of food and nutrients.

In this study, a schedule was developed to elicit information on socio economic characteristics such as age, religion, type of the family, size of the family, number of independent and dependent members and total monthly income. Monthly expenditure on food was also assessed through the questionnaire. The schedule developed was pretested before collecting data and is given in Appendix I.

Interview method was used for collection of data. Bass *et al.* (1979) reported that interview method is most suitable since it proceeds systematically and records the collected information quickly. Gupta (1987) remarked that interview is a two way method which permits an exchange of ideas and information and explains that information received from the interview schedule is more reliable as the accuracy of statement can be checked by supplementary questions whenever necessary. Interviewing is also an established research technique (Britten, 1995).

3.4 ASSESSING THE DIETARY HABITS OF RESPONDENTS

Avinash *et al.* (2001) stated that analysis of consumption pattern is a pre requisite of a planned economy to match supply with changed pattern of demand consumption depending upon the income level. The authors also suggested that an analysis of income and consumption pattern of household become an important tool for the planners and policy makers for evolving suitable research measures for improving economic lot of rural people. Thus the food use frequency, consumption pattern of β-carotene rich foods and cooking pattern of the study group were assessed.

3.4.1 Food Use Frequency

Deshpande *et al.* (2001) stated that food consumption is one of the important determinants of nutritional status, hence dietary assessment forms an integral part of nutrition surveys. The authors have also stated that diet surveys constitute an essential part of any complete study of nutritional status of individual or households, providing necessary information on food and nutrient intake level, frequency of use, food habits and so on. Diet surveys also yield data regarding the extent of dietary deficiencies and the quantity and type of foods required for overcoming them.

The frequency of use of different food groups would give an indication to the adequacy of daily diet pattern (Nelson, 1995). Thus in this study, the food use frequency of different β-carotene rich food items was measured using a food use frequency score sheet. A four point scale was used for measuring the food use frequency as shown below.

Frequency of use	Score
Never	0
Occasionally	1
More than twice in a week	2
Daily	3

Information regarding the source of purchase of β-carotene rich food stuffs was also collected as part of the survey. The schedule developed is given in Appendix II.

3.4.2 Food Consumption Pattern

Swaminathan (1999) stated that recall method will give an approximate picture of the dietary habits of a large section of the population within a short period in a particular area, information regarding the food items commonly consumed, approximate quantities of food and dietary trends.

Food consumption pattern of the respondents were assessed through 24 hour recall method. The respondents were asked to list out the actual foods consumed by them during the previous day. Kumari and Singh (2002) stated that 24 hour recall method can be carried out to determine the food and nutrient intake of the respondents. In this method of diet survey, the individuals were asked a series of questions to ensure recollection and description of all foods before the interview with emphasis on foods consumed meal by meal. The schedule used for recall survey is presented in Appendix III.

Adequacy of β-carotene content of the daily diet of the family was assessed using the method given by Thimmayamma and Rao (1998). The raw quantity of the foodstuffs used in each preparation was enquired and β-carotene content of the daily diet of the family was then calculated using nutritive value table given by ICMR (1999). The household adequacy of β-carotene was ascertained by dividing total β-carotene content of daily diet with total number of persons and the intake per person per day was calculated and compared with RDA for β-carotene.

Adequacy of carotene content in the daily diet of the respondents individually was also assessed by following the same method. Standard measuring cups and spoons were shown to the respondents to help in estimating the amount of food consumed. Food intake was recorded in terms of standard cups and information about method of cooking was also collected. Calculations were done to get values of raw equivalents consumed by them. The β-carotene content of foods consumed were then calculated.

3.4.3 Cooking Pattern

Most Indians, living either in rural or urban areas consume vegetables after cooking. Prema (2001) reported that several preliminary steps prior to cooking undertaken by families like peeling, trimming, washing and cutting as well as heating were found to be unscientific in most of the households. The author also stated that the processing techniques employed, the atmosphere, air, time of exposure and presence of other ingredients with which carotene rich foods were cooked etc. were found to influence negatively on the carotene content. The carotene content of unprocessed foods may not necessarily be indicative of how much carotene is consumed. Thus the question of how much β-carotene is retained at the point of consumption after processing needs to be established (Nambiar and Seshadri, 2001).

In order to find out the processing techniques followed by the families, details pertaining to the different cooking methods employed with regard to each β-carotene rich food item was ascertained. The use of modern cooking equipments was also specifically enquired here.

3.5 SELECTION OF FOODS FOR THE STUDY

Bhaskarachary (2000) reported that over 80 per cent of the daily supply of vitamin A in the dietaries is derived from its precursors *viz.*, β-carotene, α-carotene, Υ-carotene and β-cryptoxanthin which is present mostly in plant foods.

A survey conducted by Seshadri (1996) all through India found the use of 52 different β-carotene rich foods out of which 60 per cent or more were green leafy vegetables while others were roots, tubers and fruits. Reddy (1996) stated that other vegetables like carrot, pumpkin and sweet potato are good sources of β- carotene.

In the present study ten most commonly used β-carotene rich foods by the families under study as revealed through the survey was selected for further experiments.

3.6 SELECTION AND STANDARDIZATION OF PROCESSING TECHNIQUES

Household level processing of vegetables involve several steps which accelerate the oxidative destruction of carotenoids and decrease the vitamin A activity (Jonsson, 1990). Madhavapeddi *et al.* (1994) reported that there is rapid loss of β- carotene on processing and storage of vegetables. Conventional cooking of green leafy vegetables results in loss of water solubles, minerals and change in colour (Olufemi *et al.* 1996).

Even though, some amount of β-carotene is destroyed during processing mild heating is said to improve the extractability of β-carotene from vegetables and thus its bioavailability (Micozzi *et al.* 1992).

Processing techniques followed by the respondents with respect to the selected foods were standardized in the laboratory. The study was also extended to analyse the impact of modern appliance in the β-carotene bioavailability on selected foods. The penetration of domestic market by microwave ovens is rising day by day because of the convenience it offers in terms of speed and cleanliness (Hajela *et al.*, 1998). Therefore microwave cooking was also included.

The selected foods were subjected to five cooking methods namely boiling, stewing, sautéing, pressure cooking and microwave cooking. The cooking methods were standardized for all the ten selected vegetables/fruits. The standardization was performed with regard to three parameters *i.e.*, cooking medium, cooking time and cooking temperature.

Conking media : For each processing technique, a specific medium was needed. The media thus required (water or oil) was first measured and then used for cooking. This was replicated to standardise the quantity of media required.

Cooking time : Each foodstuff was allowed to be cooked until done and the time taken was noted. This was repeated till the standard time taken for cooking was identified.

Cooking temperature : The temperature at the stage of optimum doneness of each food was recorded as its standardised cooking temperature.

3.7 ESTIMATION OF β-CAROTENE BIOAVAILABILITY

Bioavailability is defined as the fraction of an ingested nutrient, that is available to the body for the utilization in normal physiological functions or for storage (Jackson, 1997). Not only the intracellular location, but also the intactness of the cellular matrix may be the determinant of carotenoid availability of vegetables and fruits.

Carotenoid bioavailability has been generally assessed by monitoring the appearance of plasma carotenoids following the ingestion of either purified carotenoid or a carotenoid rich meal (Oshima *et al.*, 1997). This approach is useful although it fails to indicate the actual amounts of the ingested carotenoids that have been absorbed and metabolized. Such information can also be obtained by use of experimental animals. However specialized needs of these animals limits its wide spread use. Thus the use of *in vitro* models for assessing carotenoid bioavailability from foods appears to provide a cost effective alternative (Parker, 1996).

In vitro bioavailability of β-carotene of the selected raw as well as processed foods was estimated in this study. This was carried out in two phases.

First Phase : *In vitro* digestion was carried out using the method suggested by Garrett *et al.* (1999) (modified). This method is based on the release of carotenoids from samples after digestion with pepsin-HCl and subsequent treatment with pancreatin-bile extract mixture at physiologic conditions and observing thorough protection from oxidation.

Second Phase : Extraction of β-carotene and analysis of β-carotene content. It was performed using the standardised procedure given by Srivastava and Kumar (1994).

3.8 ANALYSIS OF DATA

The data collected was subjected to statistical analysis and interpreted in terms of percentage analysis, chi square test of significance, correlation analysis and ANOVA.

RESULTS

4. RESULTS

The present study entitled "Influence of processing methods on the bioavailability of β-carotene in selected foods" was undertaken to assess the current consumption pattern of β-carotene rich foods and to study the impact of different processing methods on the bioavailability of β-carotene. The results of the study are presented under the following heads.

4.1 Socio-economic status of the respondents

4.2 Frequency of use of β-carotene rich foods

4.3 Adequacy of β-carotene content of the diet

4.4 Source of purchase of β-carotene rich foods

4.5 Processing practices followed by the respondents

4.6 β-carotene rich foods identified for bioavailability study

4.7 Processing techniques selected

4.8 Standardisation of cooking methods for selected vegetables

4.9 Bioavailability of β-carotene

4.1 SOCIO-ECONOMIC STATUS OF THE RESPONDENTS

Socio-economic status of the homemakers (50 rural and 50 urban) were studied with reference to their personal characteristics, family profile and economic status.

Details on personal characteristics of the subjects *viz*., age and religion are presented in Table 1.

Table 1. Personal characteristics of the subjects

Sl. No.	Variable	Category	Percentage of respondents	
			Rural N = 50	Urban N = 50
1.	Age (years)	Young <30	2.00	12.00
		Middle aged 31-55	94.00	74.00
		Old >55	4.00	14.00
2.	Religion	Hindu	64.00	76.00
		Muslim	-	12.00
		Christian	36.00	12.00

Data showed that majority of the respondents, both in urban (74 per cent) and rural (94 per cent) belonged to the middle aged category. Out of the remaining respondents in the rural area, four per cent of homemakers belonged to the elderly group and two per cent were young women, while in the urban 12 per cent of the women belonged to young group and 14 per cent belonged to the aged category.

Table 1 also revealed that majority of the respondents were Hindus (64 per cent rural and 76 per cent urban subjects), 36 per cent rural and 12 per cent urban respondents were Christians. The remaining 12 per cent of the urban respondents were Muslims.

As summarized in Table 2, the distribution of the subjects in relation to the type of family revealed that majority of the respondents (86 per cent of rural and 90 per cent of urban) were having nuclear families. Only 14 per cent rural and 10 per cent urban respondents belonged to joint families.

The family size of the subjects indicated that 86 per cent of rural and 92 per cent of urban respondents have small sized families with members upto five. Twelve per cent rural families and four per cent urban families were medium sized having five to eight members, while two per cent rural families and four per cent urban families were large sized having more than eight members.

Table 2. Family characteristics of the respondents

Sl. No.	Characteristics	Category	Percentage of respondents	
			Rural N = 50	Urban N = 50
1.	Type of family	Joint	14.00	10.00
		Nuclear	86.00	90.00
2.	Family size	Small 1-5	86.00	92.00
		Medium 6-8	12.00	4.00
		Large >8	2.00	4.00
3.	Independent members	One earning member	24.00	46.00
		Two earning members	34.00	46.00
		Three earning members	30.00	6.00
		More than three	12.00	2.00
4.	Dependent members	None	16.00	4.00
		1-2	44.00	62.00
		3-4	36.00	30.00
		>4	4.00	4.00

Details pertaining to the employment status of the family, the number of employed persons were more in rural families than the urban counterparts. Twenty four per cent of rural families and 46 per cent of urban families had one earning member each. It was noted that 34 per cent of rural families and 46 per cent of urban families had two employed persons. 30 per cent of rural and six per cent of urban families were comprised of three earning members. It was also noted that 12 per cent of rural families and two per cent of urban families were having more than three earning members.

Table 2 also revealed that 44 per cent of the rural households had 1-2 dependent members. Thirty six per cent had 3-4 dependent members and four per cent had more than four dependent members. Sixteen per cent of the rural families had no dependent members.

Among the urban families studied 62 per cent had 1-2 dependent members, 30 per cent had 3-4 dependents and four per cent had more than four dependent members in the family. Four per cent of the urban families do not have dependent members.

Table 3. Distribution of families based on monthly income

Monthly income of the family	Income range	Percentage of respondents	
		Rural N = 50	Urban N = 50
Low	Rs. <5000	28.00	2.00
Medium	Rs. 5001-15000	70.00	64.00
High	Rs. >15001	2.00	34.00

Distribution of the families based on monthly income as presented in Table 3 revealed that 28 per cent of rural families and two per cent of urban families were earning less than Rs. 5000 per month. Majority (70 per cent of rural and 64 per cent of urban) of families belonged to the monthly income group ranging from Rs. 5001 to Rs. 15000. Two per cent and 37 per cent of the families in the rural and urban area respectively were acquiring a monthly income above Rs. 15001.

Table 4. Distribution of families based on monthly food expenditure pattern

Expenditure on food / month	Percentage of respondents	
	Rural N = 50	Urban N = 50
Rs. 1000 – Rs. 2000	58.00	20.00
Rs. 2001 – Rs. 3000	40.00	68.00
Rs. >3001	2.00	12.00

It is noted from Table 4, that the monthly food expenditure of 58 per cent rural and 20 per cent of urban families ranged from Rs. 1000 to Rs. 2000. Forty per cent of rural families and 68 per cent of urban families had a monthly food expenditure ranging from Rs. 2001 to Rs. 3000. Only two per cent of rural and 12 per cent of urban families were found spending more than Rs. 3001 for food every month.

4.2 FREQUENCY OF USE OF β-CAROTENE RICH FOODS

India is fortunately blessed with a wide range of inexpensive foods rich in provitamin A, carotenoids. However the percapita availability of carotene rich foods in India is much less when compared with the RDA.

Data pertaining to the frequency of use of β-carotene rich foods is presented in Table 5. As revealed in the table, the green leafy vegetable agathi was consumed more frequently by the rural families than the urban. Twenty four per cent and 18 per cent families respectively in the rural and urban sector were found to use agathi more than twice in a week. Occasional users of this vegetable comprised of 56 per cent families in rural and 38 per cent families in the urban group. However 44 per cent urban families and 20 per cent rural families never used agathi in their diet.

Regarding the frequency of use of amaranthus – a popular green leafy vegetable, majority of the rural and urban families (66 per cent and 56 per cent respectively) were found to use it more than twice a week, while 32 per cent of rural and 42 per cent urban families used amaranthus occasionally.

Data revealed that drumstick leaves was used more than twice in a week by 42 per cent of rural families and 12 per cent urban families. Meanwhile majority (50 per cent rural and 66 per cent urban) were found to include drumstick leaves occasionally in their diet. Remaining eight per cent and 22 per cent families in the rural and urban never used drumstick leaves in their diet.

It was evident from the results that chekkurmanis was used occasionally by majority of the rural families (56 per cent). Twenty six per cent used it more than twice in a week and the rest (18 per cent) were not users of this vegetable. But among the urban families, majority (56 per cent) were not users of this vegetable. Meanwhile 18 per cent used it more than twice a week and 26 per cent used chekkurmanis in their dietaries occasionally.

The results emphasized the fact that amaranth (green and red) was reported to be the most commonly used leafy vegetable followed by drumstick leaves. Data also showed that that use of locally available drumstick leaves, chekkurmanis and agathi was more frequent in rural families when compared to the urban. Statistical analysis showed that there was significant difference observed between the frequency of consumption among rural and urban families with regard to all green leafy vegetables under study except amaranth.

Observations on the frequency of consumption of β-carotene rich roots and tubers indicated that, the urban families used carrots more frequently than rural families and the variation was statistically significant. Majority of families in both the groups (62 per cent and 68 per cent) used it more than twice a week, while 10 per cent rural families and 26 per cent urban families used carrots daily. This vegetable was included in the diet occasionally by 28 per cent of rural and six per cent of urban homemakers.

Discussing the frequency of use of yam, urban families were reported to use better than rural families, though statistically no difference was noted. Forty eight per cent rural and 62 per cent urban families included yam more than twice a week in their meal, while 20 per cent and 24 per cent among the rural and urban groups respectively were only occasional uses. Twenty six per cent of rural families and 12 per cent of urban families never use yam in their diets.

Data on consumption pattern of other vegetables rich in β-carotene as shown in the table revealed that majority of families were occasional users of bitter gourd (38 per cent rural and 44 per cent urban families). While 30 per cent and 32 per cent of rural and urban families respectively included bittergourd more than twice in week in their diet, four per cent each among the groups used this vegetable daily. Remaining 28 per cent of rural and 20 per cent of urban families were not in the habit of using bitter gourd.

Table 5 Frequency of use of β-carotene rich foods

Food item	Group	Daily	More than twice a week	Occasionally	Never	Variation χ^2
Green leafy vegetables						
Agathi	Rural Urban	- -	12 (24.00) 9 (18.00)	28 (56.00) 19 (38.00)	10 (20.00) 22 (44.00)	χ^2_2=6.65*
Amaranth	Rural Urban	- 1 (2.00)	33 (66.00) 28 (56.00)	16 (32.00) 21 (42.00)	1 (2.00) -	χ^2=0.679^{NS}
Drumstick leaves	Rural Urban	- -	21 (42.00) 6 (12.00)	25 (50.00) 33 (66.00)	4 (8.00) 11 (22.00)	χ^2=11.41**
Chekkurmanis	Rural Urban	- -	13 (26.00) 9 (18.00)	28 (56.00) 13 (26.00)	9 (18.00) 28 (56.00)	χ^2_2=15.94**
Roots & tubers						
Carrot	Rural Urban	5 (10.00) 13 (26.00)	31 (62.00) 34 (68.00)	14 (28.00) 3 (6.00)	- -	χ^2=4.33*
Yam	Rural Urban	3 (6.00) 1 (2.00)	24 (48.00) 31 (62.00)	10 (20.00) 12 (24.00)	13 (26.00) 6 (12.00)	χ^2_2=3.17^{NS}
Other vegetables						
Bittergourd	Rural Urban	2(4.00) 2(4.00)	15 (30.00) 16 (32.00)	19 (38.00) 22 (44.00)	14 (28.00) 10 (20.00)	χ^2_2=0.24^{NS}
Cluster beans	Rural Urban	18 (36.00) 3 (6.00)	20 (40.00) 22 (44.00)	8 (16.00) 10 (20.00)	4 (8.00) 15 (30.00)	χ^2_2=7.250**
Drumstick	Rural Urban	12 (24.00) 15 (30.00)	32 (64.00) 27 (54.00)	4 (8.00) 8 (16.00)	2 (4.00) -	$\chi^2_2$1.038^{NS}
French beans	Rural Urban	2 (4.00) 1 (2.00)	29 (58.00) 36 (72.00)	12 (24.00) 13 (26.00)	7 (14.00) -	χ^2=1.65^{NS}
Onion stalk	Rural Urban	1 (2.00) 2 (4.00)	22 (44.00) 17 (34.00)	18 (36.00) 23 (46.00)	9 (18.00) 8 (16.00)	χ^2_2=1.046^{NS}
Pumpkin	Rural Urban	1 (2.00) 2 (4.00)	13 (26.00) 25 (50.00)	26 (52.00) 18 (36.00)	10 (20.00) 5 (10.00)	$\chi 2_2$=7.24*
Fruits						
Dates	Rural Urban	- -	9 (18.00) 15 (30.00)	29 (58.00) 29 (58.00)	12 (24.00) 6 (12.00)	χ^2_2=3.5^{NS}
Jack fruit	Rural Urban	3 (6.00) -	29 (58.00) 23 (46.00)	18 (36.00) 26 (52.00)	- 1 (2.00)	χ^2=3.27^{NS}
Mango ripe	Rural Urban	4 (8.00) 2 (4.00)	37 (74.00) 33 (66.00)	9 (18.00) 15 (30.00)	- -	χ_2=1.97^{NS}
Orange	Rural Urban	- 1 (2.00)	14 (28.00) 11 (22.00)	36 (72.00) 38 (76.00)	- -	χ^2_2=0.207^{NS}
Papaya	Rural Urban	- -	9 (18.00) 7 (14.00)	41 (82.00) 20 (40.00)	- 23 (46.00)	χ^2−0.297^{NS}
Tomato	Rural Urban	26 (52.00) 22 (44.00)	23 (46.00) 27 (54.00)	1 (2.00) 1 (2.00)	- -	χ^2=0.641^{NS}

Figures in parenthesis denotes percentage
*Significant at 5 per cent level, **significant at 1 per cent level, NS - not significant

Data revealed that cluster beans was preferred and more frequently used by the rural families compared to the urban, the variation in use was statistically significant. It was noticed that cluster beans was used daily by 36 per cent rural families while only six per cent urban families used it daily. Forty per cent from rural and 44 per cent from urban sector used cluster beans more than twice in a week. Sixteen per cent rural and 20 per cent of urban families included it occasionally. However eight per cent of rural and 30 per cent of urban homemakers never included cluster beans in their diet.

Drumstick was used frequently by the urban and rural families alike. It was observed that majority (64 per cent rural and 54 per cent urban) used drumstick more than twice a week and 24 per cent rural families and 30 per cent urban families used this vegetable daily. Remaining eight per cent and 16 per cent families in the rural and urban areas respectively were occasional users and four per cent of rural families never used drumstick in their diet.

Regarding the frequency of use of french beans, it was revealed that majority (58 per cent and 72 per cent in rural and urban families) used it more than twice in a week. Twenty four per cent rural families and 26 per cent urban families used beans occasionally while 14 per cent of rural subjects never included this vegetable in their diet.

Onion stalk, a seasonal vegetable and a good source of β-carotene was used more than twice a week by majority of rural families (44 per cent), while a good number of urban families (46 per cent) were occasional users. Among rural families, two per cent used it daily when available, 36 per cent used occasionally and 18 per cent never used it. At the same time four per cent of urban families included onion stalk daily in their diet, 34 per cent used it more than twice a week, while 16 per cent never used this vegetable.

It was found that pumpkin was more frequently used by urban families as 50 per cent of them used it more than twice in a week while only 26 per cent of rural families reported the same frequency of use. The daily users of pumpkin was two per cent and four per cent respectively. Fifty two per cent rural families and 36 per cent of urban families used pumpkin occasionally. However 20 per cent of the families in rural and 10 per cent in the urban area were not in the habit of using pumpkin in their diet. Statistically, there existed a significant difference between rural and urban families, regarding the frequency of consumption of pumpkin.

Data pertaining to the frequency of use of β-carotene rich fruits revealed that fruits like dates was used more than twice in a week by 30 per cent of urban families and 18 per cent of rural families. Fifty eight per cent each in both groups used dates occasionally. Remaining 24 per cent and 12 per cent of rural and urban families respectively never used dates in their diet.

The seasonally available jackfruit was found to be used more frequently by rural families, though no significant difference in its use was observed between the two groups. It was observed that 58 per cent of rural families and 46 per cent of urban families included jack fruit more than twice in a week. Thirty six per cent and 52 per cent of rural and urban subjects used it occasionally and six per cent of rural families used jack fruit daily in their diet during times of availability.

Ripe mango, yet another β-carotene rich seasonal fruit was preferred equally by all the rural and urban population. Mango was used more than twice in a week by 74 per cent of rural and 66 per cent of urban families. Eighteen per cent of rural and 30 per cent of urban families used it occasionally while eight per cent and four per cent rural and urban families respectively used mango daily in their diet, during mango season.

Orange a conventional fruit was used more than twice in a week by 28 per cent of rural families and 22 per cent of urban families. Majority of rural and urban families (72 per cent and 76 per cent) included this fruit occasionally, while two per cent urban used it daily.

It was noticed that papaya was consumed by all the rural families more frequently than urban counterparts though statistically no significant variation was observed. Papaya (ripe) was included more than twice in a week by 18 per cent of rural families and 14 per cent of urban families. Eighty two per cent and 40 per cent rural and urban families respectively used it occasionally and 46 per cent families in the urban sector never used papaya in their diet.

The frequency of using tomato was observed to be high among both the groups. Tomato (ripe) was included daily by 52 per cent and 44 per cent of rural and urban families respectively. Meanwhile 46 per cent rural families and 54 per cent urban families use tomato more than twice in a week, only two per cent each of both group used it occasionally.

The above results revealed the fact that carrot and yam, were the more frequently used roots and tubers by the selected families. Among the 'other vegetable', bittergourd was observed to be an occasionally used vegetable by majority of families, while rest of the vegetables in this group were included more than twice in a week by most of the families. Considering the β-carotene rich fruits, jack fruit, mango, tomato and papaya were the commonly consumed items.

4.3 ADEQUACY OF β-CAROTENE CONTENT OF THE DIET

Actual quantity of food consumed by the selected families was assessed by conducting twenty four hour recall survey among the selected families. From the data collected by recall method the percapita consumption of β-carotene containing foods through diet was assessed. The β-carotene content of foods was calculated using the food composition tables of ICMR (1999).

4.3.1 Average Dietary β-carotene Intake of Families

Table 6 represents the mean of β-carotene consumption per person in the daily diet of urban and rural families.

Data thus collected revealed that the percapita consumption of 22 per cent rural and 16 per cent of urban families were found to be grossly deficient in β-carotene as their daily diet could meet only less than twenty five per cent of RDA. It was also observed average availability of β-carotene in the daily diets of 20 per cent and 22 per cent families of rural and urban sectors respectively were deficient in β-carotene as only 25 to 50 per cent of the RDA was met. Meanwhile diets of 24 per cent rural and eight per cent urban families provided 50 – 75 per cent of the RDA of β-carotene.

Table 6. Average dietary β-carotene intake of families

Average β-carotene intake (per cent of RDA met)	Number of families	
	Rural n = 50	Urban n = 50
<25	11 (22.00)	8 (16.00)
25 – 50	10 (20.00)	11 (22.00)
50 – 75	12 (24.00)	4 (8.00)
75 – 100	9 (18.00)	17 (34.00)
>100	8 (16.00)	10 (20.00)

RDA for adult 2400 μg/d (ICMR, 1999)
Figures in parenthesis denotes percentage

Average β-carotene composition sufficient to meet above 75 per cent of the RDA was observed among 18 per cent rural and 34 per cent urban families. It was also recorded that among 16 per cent of rural families and 20 per cent of urban families the average dietary contribution of this nutrient remained above the level required as per recommended dietary allowances.

4.3.2 Adequacy of β-carotene in the diet of respondents

Parallel to assessing the adequacy of the β-carotene content of the diet of the family the respondent's individual data on these lines was also collected by following the same method. Moreover there are reports that women consume diets that are significantly inadequate even when family diets were observed to be satisfactory (Seshadrinath, 1993).

Data revealed that β-carotene intake in the daily diets of 22 per cent rural and 18 per cent urban homemakers were significantly deficient in β-carotene as it was found to supply less than 16 per cent of RDA. So also diets of 28 per cent respondents belonging to both groups consumed diets which provided β-carotene in the range of 16 – 33 per cent of RDA. The β-carotene adequacy of the diet was met to a level of 50 per cent of the RDA by 10 per cent and 12 per cent rural and urban homemakers respectively.

Table 7 β-carotene content of daily diet of the respondents

β-carotene content (μg)	Number of respondents		Adequacy of β-carotene (percentage)
	Rural n = 50	Urban n = 50	
< 400	11 (22.00)	9 (18.00)	< 16
400 – 800	14 (28.00)	14 (28.00)	16 – 33
800 – 1200	5 (10.00)	6 (12.00)	33 – 50
1200 – 1600	11 (22.00)	4 (8.00)	50 – 66
1600 – 2000	5 (10.00)	6 (12.00)	66 – 83
2000 – 2400	1 (2.00)	6 (12.00)	83 – 100
>2400	3 (6.00)	5 (10.00)	> 100

RDA for adult women 2400 μg/d (ICMR, 1999)
Figures in parenthesis denotes percentage

Data further revealed that 50 – 66 per cent of daily requirement of β-carotene was met by 22 per cent of the rural and eight per cent of the urban women. Ten per cent of the rural women and 12 per cent of the urban women consumed diets having a β-carotene allowance of 66 – 83 per cent of RDA. Further it was found that only two per cent rural women and 12 per cent urban women consumed diets having just satisfactory level of β-carotene *i.e.*, between 83-100 per cent of RDA. This investigation also revealed the fact that the diets of a small group of respondents *i.e.*, six per cent rural and ten per cent urban women were supplied with higher quantity of this nutrient than the recommended daily allowance of 2400 µg.

4.4 SOURCE OF PURCHASE OF β-CAROTENE RICH FOODS

The sources of procuring β-carotene rich foods for the household use were ascertained and the details are given in Table 8.

The data as per Table 8 revealed that majority of the households, both rural and urban procured agathi from their homestead itself (54 and 36 per cent respectively). A small percentage (six per cent of rural households) purchased it from the local shops and 20 per cent from local market. Twenty eight per cent of urban respondents purchased agathi from local market and 12 per cent purchased it from the main market.

While looking into the purchasing pattern of amaranthus it could be seen that majority of rural respondents (44 per cent), procured it from local market; 36 per cent from local shops and 18 per cent grew them in their homestead garden. Similarly the urban respondents also purchased it from the local shops (40 per cent) or local market (28 per cent) and 30 per cent obtained it from the main market. Only two per cent of them grew amaranthus in their homestead.

Regarding procurement of drumstick leaves, data revealed that cent per cent of the rural respondents who used drumstick leaves took it from their home garden. However only 50 per cent of urban respondents were able to pick it from their homesteads. Among the rest 14 per cent purchased drumstick leaves from local shops, four per cent from local market and 10 per cent procured it from the main market.

Table 8. Source of purchase of β-carotene rich foods

Food item	Group	Local shop	Local market	Main market	Homestead
Agathi	Rural	3 (6.00)	10 (20.00)	-	27 (54.00)
	Urban	-	14 (28.00)	6 (12.00)	18 (36.00)
Amaranth	Rural	18 (36.00)	22 (44.00)	-	9 (18.00)
	Urban	20 (40.00)	14 (28.00)	15 (30.00)	1 (2.00)
Drumstick leaves	Rural	-	-	-	46 (92.00)
	Urban	7 (14.00)	2 (4.00)	5 (10.00)	25 (50.00)
Chekkurmanis	Rural	-	-	-	41 (82.00)
	Urban	-	-	-	22 (44.00)
Carrot	Rural	23 (46.00)	25 (50.00)	2 (4.00)	-
	Urban	12 (24.00)	18 (36.00)	20 (40.00)	-
Yam	Rural	14 (28.00)	17 (34.00)	1 (2.00)	4 (8.00)
	Urban	15 (30.00)	12 (24.00)	17 (34.00)	-
Bittergourd	Rural	15 (30.00)	15 (30.00)	-	6 (12.00)
	Urban	18 (36.00)	12 (24.00)	10 (20.00)	-
Cluster beans	Rural	24 (48.00)	22 (44.00)	-	-
	Urban	15 (30.00)	11 (22.00)	9 (18.00)	-
Drumstick	Rural	8 (16.00)	21 (42.00)	-	19 (38.00)
	Urban	9 (18.00)	10 (20.00)	11 (22.00)	20 (40.00)
French beans	Rural	21 (42.00)	22 (44.00)	-	-
	Urban	17 (34.00)	18 (36.00)	15 (30.00)	-
Onion stalk	Rural	20 (40.00)	21 (42.00)	-	-
	Urban	20 (40.00)	10 (20.00)	12 (24.00)	-
Pumpkin	Rural	15 (30.00)	21 (42.00)	2 (4.00)	2 (4.00)
	Urban	14 (28.00)	12 (24.00)	19 (38.00)	-
Dates	Rural	18 (36.00)	20 (40.00)	-	-
	Urban	10 (20.00)	19 (38.00)	15 (30.00)	-
Jack fruit	Rural	-	-	-	50 (100.00)
	Urban	8 (16.00)	17 (34.00)	10 (20.00)	14 (28.00)
Mango (ripe)	Rural	2 (4.00)	20 (40.00)	-	28 (56.00)
	Urban	5 (10.00)	20 (40.00)	20 (40.00)	5 (10.00)
Orange	Rural	11 (22.00)	37 (74.00)	2 (4.00)	-
	Urban	10 (20.00)	26 (52.00)	14 (28.00)	-
Papaya	Rural	-	-	-	50 (100.00)
	Urban	7 (14.00)	5 (10.00)	5 (10.00)	10 (20.00)
Tomato	Rural	24 (48.00)	26 (52.00)	-	-
	Urban	17 (34.00)	17 (34.00)	16 (32.00)	-

Figures in parenthesis denotes percentage

Considering chekkurmanis, another green leafy vegetable it was procured solely from homestead, both by urban and rural homemakers.

From the data, it was also found that urbans depend more on the markets and shops for procurement of β-carotene rich green leafy vegetables except chekkurmanis whereas rural households mostly have it in their homesteads itself.

Carrot, the β-carotene rich root is widely consumed by the respondents. Majority of rural families (50 per cent) procured it from local market, while another 46 per cent purchased it from local shops and four per cent bought it from the main market. Carrots were purchased by the urban households from local shops (24 per cent), local markets (36 per cent) and 40 per cent from the main market.

Regarding the availability of yam, it was noticed that 34 per cent of rural women procured it from the local market, while 28 per cent got it from local shops, two per cent from the main market and eight per cent cultivated yam for their use. Among the urban respondents 34 per cent purchased it from main market, 30 per cent procured it from local shops and 24 per cent from local markets.

Data on availability of β-carotene rich roots and tubers for the households revealed that for carrots both urban and rural families depended on markets and shops. While for purchase of yam few of the rural families (eight per cent) cultivated it while the rest depended on shops. The urban households depended solely on shops for buying yam.

For the purchase of bittergourd, most of the rural families depended local shops and local markets (30 per cent each). However, 12 per cent of the rural houses used this vegetables grown in their homesteads itself. Availability of this vegetable among urban respondents also showed that

36 per cent of them bought bittergourd from local shops 24 per cent from local market and 20 per cent from the main market.

It was observed that 48 per cent of rural families procured cluster beans from local shops, while 44 per cent purchased it from the local market. Among the urban subjects, 30 per cent bought cluster beans from local shops, 22 per cent from local market and 18 per cent from the main market.

With regard to the procurement of drumstick it was noticed that 38 per cent of rural homemakers and 40 per cent of urban homemakers reported that they consumed drumstick harvested from their homestead itself. Further details indicated that 42 per cent of rural households purchased it from local market and 16 per cent from the local shop. Details on availability of the vegetable to the urban homes revealed that 18 per cent procured drumstick from local shops, 20 per cent from local markets and 22 per cent from the main market.

French beans was purchased by a majority (44 per cent) of rural respondents from local market while 42 per cent procured it from local shop. Data also explained that 34 per cent of urban respondents purchased french beans from local shops, 36 per cent from local market and 30 per cent from the main market.

Onion stalk another β-carotene rich seasonal vegetable was found to be regularly used by both urban and rural families whenever available. In rural families procurement details showed that 42 per cent and 40 per cent purchased onion stalk from local market and local shops respectively. Coming to the urban families 40 per cent procured onion stalk from local shops, 20 per cent from local market and 24 per cent from the main market.

Regarding the purchase of pumpkin, it was found that majority of rural families (42 per cent) depended on local market, 30 per cent local shops and four per cent main market for procuring it. Another four per cent could get pumpkin from their own field. While in urban families 28 per cent bought pumpkin from local shops, 24 per cent obtained it from local market and 38 per cent from the main market.

Thus considering the procurement of different vegetables it was noticed that both rural and urban families depended heavily on shops, either a local one or in the main market. The cultivation of vegetables in the homestead is restricted to a small number of households, in the rural areas.

Focusing on source of procurement of fruits it was observed that fruits like dates was purchased mainly from local shops (36 per cent) and local market (40 per cent) by the rural families. Data also revealed that 20 per cent of urban families procured dates from local shops, 38 per cent from local market and 30 per cent from the main market.

The seasonally available jackfruit was procured solely from the homesteads in rural families. However 16 per cent of urban families bought jackfruit from the local shops, 34 per cent from local market and 20 per cent from the main market. At the same time 28 per cent of urban households also were able to use jackfruit grown in their homestead itself.

Mango was widely used by the respondents and for majority of rural respondents (56 per cent) this item was available from their homestead gardens. However, four per cent and 40 per cent of rural respondents purchased mango from local shops and local market respectively. Among the urban subjects 10 per cent bought it from local shops, 40 per cent each from local market and main market and 10 per cent procured mango from the homestead.

Orange, the conventional fruit was purchased from market by all families. Among the rural households 22 per cent procured it from local shops, 74 per cent from local market and four per cent from main market.

Among the urban respondents, 20 per cent procured orange from local shops. 52 per cent from local market and 28 per cent from the main market.

Regarding the availability of papaya it was found that cent per cent of rural homemakers used papaya grown at the home yards, while the same facility was availed by urban subjects was only 20 per cent. Among the rest 14 per cent bought papaya fruit from local shops, 10 per cent each from local market and main market.

Tomato, the fruit commonly used as a vegetable was purchased either from local shops (48 per cent) or from local market (52 per cent) by the rural homemakers. Same trend was followed by the urban counterparts where 34 per cent each purchased from local shops and local market, remaining 32 per cent from the main market.

4.5 PROCESSING PRACTICES FOLLOWED BY THE RESPONDENTS

The commonly adopted cooking methods by the homemakers with respect to the vegetables and fruits under study were enquired and details are presented in Table 9.

The respondents were not able to distinguish between boiling and stewing as its difference lies only in the amount of water used. Thus in the presentation of results the data on cooking by boiling and stewing were consolidated.

Regarding the processing practice for green leafy vegetables, sauteing was identified as the most commonly followed method both among rural and urban households. For cooking agathi sauteing was the only method employed by rural (80 per cent) and urban (56 per cent) households. However for amaranthus, boiling and microwave processing were also employed by a minority of respondents.

Table 9. Processing practices followed by the respondents

Food item	Group	Sauteing	Boiling	Deep frying	Pressure cooking	Microwave
Agathi	Rural	40 (80.00)	-	-	-	-
	Urban	28 (56.00)	-	-	-	-
Amaranth	Rural	49 (98.00)	2 (4.00)	-	-	-
	Urban	50 (100.00)	1 (2.00)	-	-	2 (4.00)
Drumstick leaves	Rural	46 (92.00)	-	-	-	-
	Urban	39 (78.00)	-	-	-	-
Chekkurmanis	Rural	41 (82.00)	-	-	-	-
	Urban	22 (44.00)	-	-	-	-
Carrot	Rural	50 (100.00)	50 (100.00)	-	2 (4.00)	-
	Urban	50 (100.00)	50 (100.00)	1 (2.00)	42 (84.00)	5 (10.00)
Yam	Rural	34 (68.00)	37 (74.00)	-	2 (4.00)	-
	Urban	40 (80.00)	44 (88.00)	-	42 (84.00)	-
Bittergourd	Rural	36 (72.00)	-	13 (26.00)	-	-
	Urban	40 (80.00)	-	14 (28.00)	-	1 (2.00)
Cluster beans	Rural	46 (92.00)	41 (82.00)	-	2 (4.00)	-
	Urban	33 (66.00)	32 (64.00)	-	30 (60.00)	2 (4.00)
Drumstick	Rural	34 (68.00)	16 (32.00)	-	2 (4.00)	-
	Urban	50 (100.00)	50 (100.00)	-	48 (96.00)	-
French beans	Rural	43 (86.00)	41 (82.00)	-	2 (4.00)	-
	Urban	45 (90.00)	45 (90.00)	-	43 (86.00)	5 (10.00)
Onion stalk	Rural	41 (82.00)	-	-	-	-
	Urban	42 (84.00)	-	-	-	-
Pumpkin	Rural	-	40 (80.00)	-	2 (4.00)	-
	Urban	-	45 (90.00)	-	44 (88.00)	-
Tomato	Rural	-	50 (100.00)	-	-	-
	Urban	-	50 (100.00)	-	47 (94.00)	-

Figures in parenthesis denotes percentage

For the culinary preparation of drumstick leaves and chekkurmanis, the only practice adopted was sauteing. Ninety two per cent rural and 78 per cent urban respondents cooked drumstick leaves by sauteing while considering chekkurmanis 82 per cent of rural respondents and 44 per cent of urban respondents practiced sauteing.

Regarding the processing practices adopted for carrot it was found that all the respondents were accustomed to the methods both sauteing and boiling. Along with the above methods two per cent of urban subjects practiced deep frying, while 10 per cent of them practiced microwave cooking. Eighty four per cent of urban respondents adopted pressure cooking also as the processing technique. But only four per cent of rural respondents practiced pressure cooking.

Data revealed that for cooking yam, sauteing and boiling were the most commonly practiced procedure by both the rural and urban households. Sixty eight per cent of the rural respondents used sauteing while 74 per cent followed boiling also as processing technique for the vegetable. While among urban respondents 80 per cent followed sauteing and 88 per cent followed boiling as well as sauteing. Eighty four per cent practiced pressure cooking also along with other methods.

Discussing on the processing practices for bittergourd, 72 per cent followed sauteing and 26 per cent practiced deep frying along with sauteing, in the rural sector. In urban families 80 per cent followed sauteing, in addition to 28 per cent practiced deep frying along with sauteing and two per cent used microwave cooking with respect to bittergourd.

Cluster beans was processed by sauteing method by 92 per cent rural and 66 per cent of urban respondents. For this vegetable 82 per cent of rural women practiced boiling and four per cent practiced pressure cooking along with sauteing. Sixty four per cent of urban women cooked cluster beans by boiling and 60 per cent performed boiling as well as pressure cooking.

Along with these methods four per cent urban women practiced microwave processing also.

Among the urban group all the subjects used sauteing as well as boiling methods to process drumstick. Above this 96 per cent of urban subjects followed pressure cooking also. Data revealed that among the rural respondents, 68 per cent used sauteing, 32 per cent used boiling and four per cent used pressure cooking as the processing practice with drumstick.

Regarding the processing practices adopted for french beans it was found that 86 per cent of rural women performed sauteing and 82 per cent used boiling along with the above method. Four per cent applied pressure cooking to french beans. In the urban category, 90 per cent performed sauteing as well as boiling as the processing method. In addition to the above practice 86 per cent used pressure cooking and 10 per cent used microwave cooking also.

Considering the processing of onion stalk, 82 per cent of rural households and 84 per cent of urban households performed sauteing.

Data on processing pumpkin revealed that 80 per cent of rural subjects and 90 per cent of urban subjects were practicing boiling method, while 88 per cent of urban and four per cent of rural homemakers followed pressure cooking along with boiling.

Tomato, the fruit used commonly in culinary preparations was processed in all the households by boiling while 94 per cent of urban respondents practiced pressure cooking method also.

4.6 β-CAROTENE RICH FOODS IDENTIFIED FOR BIOAVAILABILITY STUDY

Results of the survey carried out indicated the frequency pattern of various β-carotene rich fruits and vegetables by selected rural and urban households. From the list of commonly consumed items, ten most frequently used vegetables or fruits were identified and chosen for further study.

The vegetables and fruits thus selected for bioavailability analysis are presented in Table 10.

Table 10 β-carotene rich foods selected for bioavailability study

Food group	Selected vegetable/fruit
Green leafy vegetables	Agathi Amaranth red Amaranth green Drumstick leaves Chekkurmanis
Roots and tubers	Carrot Yam
Other vegetables	Cluster beans Pumpkin
Fruit	Tomato

The most commonly used green leafy vegetables included agathi. amaranth red, amaranth green, drumstick leaves and chekkurmanis, a locally available leafy vegetable. Carrot and yam were identified as the β-carotene rich root and tuber, commonly consumed by the study group. Among the 'other vegetables', cluster beans and pumpkin were observed as the frequently used ones. Tomato (ripe) a fruit often used in culinary by the subjects was also chosen for analysis of β-carotene bioavailability.

4.7 PROCESSSING TECHNIQUES SELECTED

Processing practices followed by the families both in urban and rural sector with respect to the β-carotene rich plant foods were enumerated through a survey among the families. From the results the most common processing techniques as well as modern technique on which much studies have not been undertaken in these lines were selected for further experiments.

The results obtained showed that for green leafy vegetables sauteing was the commonest method of processing (100 per cent urban and 98 per cent rural families). A small percentage (four per cent rural and two per cent urban) had practiced boiling also for cooking green leafy vegetables, while four per cent urban families adopted microwave cooking in addition to the above techniques.

For processing rest of the vegetables, sauteing, boiling / stewing and pressure cooking were identified as the common methods. Among few urban families (10 per cent) microwave cooking was also found to be used to process certain vegetables.

Thus for selecting processing methods to carry out the study on influence of processing methods on bioavailability of β-carotene, the commonly employed methods of processing *viz.*, sauteing, boiling, stewing and pressure cooking were identified along with the most advanced microwave processing – a technique that takes least preparation time and offers most convenience in operation were selected in this study.

4.8 STANDARDISATION OF COOKING METHODS FOR SELECTED VEGETABLES

Standardisation as it applies to food preparation requires a uniform set of criteria for each operation. Twenty five gram each of selected vegetables were subjected to processing methods *viz.*, boiling, stewing sauteing, pressure cooking and microwave processing and each procedure adopted was standardised.

The details on procedure for standardisation of selected vegetables and fruits with respect to boiling method is given in Table 11.

Table 11 Standardisation of cooking method – boiling

Vegetables (25 g)	Parameters for standardisation		
	Cooking medium water (ml)	Cooking time (minute)	Cooking temperature (°C)
Agathi	50	4	70
Amaranth red	50	4	80
Amaranth green	50	4	82
Drumstick leaves	50	4	77
Chekkurmanis	50	4	77
Carrot	25	3	82
Yam	35	3	68
Cluster beans	35	4	84
Pumpkin	25	3	80
Tomato ripe	20	3	83

Data presented in Table 11 indicated that quantity of water used as medium required for adequate doneness of all of the selected green leafy vegetables were found to be similar (50 ml). For rest of the vegetables, the amount of water needed to cook them to the correct doneness ranged from 20 ml to 35 ml. Tomato was cooked with the least amount of water (20 ml) followed by pumpkin and carrot (25 ml). Cluster beans and yam were well done with 35 ml water.

Regarding the cooking time, the green leafy vegetables were done in four minutes and other vegetables including roots, this was generally found to be three except for cluster beans, which took four minutes to get properly done.

The cooking temperature however varied from 70°C to 82°C. Agathi required the least, followed by drumstick leaves and chekkurmanis (77°C), while the temperature required for amaranth red and green was 80°C and 82°C respectively. Among vegetables, yam required the least of 68°C and cluster beans (84°C) required the highest temperature when compared to other vegetables and fruits.

Table 12 presents the details on procedure for standardisation of selected vegetables and fruits for cooking by stewing method.

Table 12 Standardisation of cooking method – stewing

Vegetables (25 g)	Parameters for standardisation		
	Cooking medium water (ml)	Cooking time (minute)	Cooking temperature (°C)
Agathi	30	4	70
Amaranth red	30	4	80
Amaranth green	30	4	80
Drumstick leaves	30	4	77
Chekkurmanis	30	4	77
Carrot	15	3	80
Yam	15	3	66
Cluster beans	15	4	82
Pumpkin	15	3	80
Tomato ripe	10	3	82

The table shows that all the green leafy vegetables were adequately cooked by stewing in 30 ml water. For other vegetables, the quantity of media used was found to be 15 ml water except for tomato, which required only 10 ml.

Considering the cooking time, all green leafy vegetables needed four minutes to be done, while other vegetables, excluding cluster beans, the standard cooking time was recorded as three minutes and for cluster beans, four minutes.

The cooking temperature, varied for green leafy vegetables from 70°C to 80°C, the lowest for agathi and highest for amaranth (red and green). Among other vegetables, the highest value was observed for cluster beans and tomato (ripe) (82°C) followed by carrot and pumpkin (80°C), the least being for yam (66°C).

Data regarding the procedure for standardisation of selected vegetables and fruits with respect to sauteing method is given in Table 13.

Table 13 Standardisation of cooking method – sauteing

Vegetables (25 g)	Parameters for standardisation		
	Cooking medium oil (ml)	Cooking time (minute)	Cooking temperature (°C)
Agathi	3	3	72
Amaranth red	3	3	77
Amaranth green	3	3	85
Drumstick leaves	2	3	80
Chekkurmanis	3	3	80
Carrot	2	3	80
Yam	3	3	63
Cluster beans	3	3	82
Pumpkin	2	3	82
Tomato ripe	2	3	84

All green leafy vegetables except drumstick leaves required 3 ml oil to be well done by sauteing. The amount of oil required for cooking by sauteing vegetables *viz.*, carrot, pumpkin and tomato was 2 ml each, while yam and cluster beans needed 3 ml. It was confirmed from the observations that the cooking time required for sauteing vegetables was only three minutes.

The temperature range at which different green leafy vegetables were well done was 72°C to 85°C (the lowest for agathi and highest for amaranth green). Yam was cooked at a temperature of 63°C while all other vegetables required more than 80°C.

Table 14 elucidate the data on procedure for standardisation of cooking vegetables with regard to the processing technique pressure cooking.

Table 14 Standardisation of cooking method – pressure cooking

Vegetables (25 g)	Parameters for standardisation		
	Cooking medium water (ml)	Cooking time (minute)	Cooking temperature (°C)
Agathi	25	3	>100
Amaranth red	25	3	>100
Amaranth green	25	4	>100
Drumstick leaves	40	4	>100
Chekkurmanis	35	3	>100
Carrot	15	2	>100
Yam	15	3	>100
Cluster beans	20	4	>100
Pumpkin	15	2	>100
Tomato ripe	15	2	>100

The data revealed that water uptake while pressure cooking for agathi and both varieties of amaranth was 25 ml. Drumstick leaves and chekkurmanis were cooked using 40 ml and 35 ml water respectively. Adequate cooking media for carrot and yam among roots and tubers, pumpkin among other vegetables and tomato were recorded as 15 ml of water. At the same time cluster beans needed 20 ml water for pressure cooking.

On standardisation of time for pressure cooking, the selected vegetables were found to be cooked by 2 to 4 minutes. Amaranth green, drumstick leaves and cluster beans took four minutes each, while rest of the green leafy vegetables and yam were cooked within three minutes. The optimum cooking time for carrot, pumpkin and tomato were lesser recording two minutes.

It was also noted that the standard temperature for pressure cooking vegetables under study was more than 100°C, as pressure cooker works with the principle of raising the boiling point of water above 100°C.

The data obtained on procedure standardisation for processing fruits and vegetables with respect to microwave cooking is depicted in Table 15.

Table 15 Standardisation of cooking method – microwave cooking

Vegetables (25 g)	Parameters for standardisation		
	Cooking medium water (ml)	Cooking time (minute)	Cooking temperature
Agathi	35	2.30	High
Amaranth red	20	2.00	High
Amaranth green	25	2.00	High
Drumstick leaves	10	2.00	High
Chekkurmanis	10	1.30	High
Carrot	10	1.00	High
Yam	15	1.00	High
Cluster beans	10	2.00	High
Pumpkin	10	1.00	High
Tomato ripe	5	1.00	High

The cooking media required for microwave cooking of green leafy vegetables, varied from 10 ml for drumstick leaves and chekkurmanis, to 35 ml for agathi. Water uptake in microwave cooking for amaranth red and green was 20 and 25 ml respectively. Among other vegetables, tomato required the least (5 ml) amount of water, while the highest water requirement was recorded (15 ml) for yam to get the required doneness.

It was observed that the cooking time requirement in microwave oven was highest for agathi, which was 2.30 minutes. Rest of the green leafy vegetables and cluster beans took two minutes each followed by chekkurmanis (1.30 minutes), while all the remaining vegetables were properly cooked within one minute when microwave oven was used.

Regarding standardisation of temperature all the vegetables under study were cooked under temperature grade marked as 'high' in the microwave oven to cook them to a well done state.

4.9 BIOAVAILABILITY OF β-CAROTENE

4.9.1 Bioavailability of β-carotene Raw and Processed Vegetables

Bioavailability is the availability of a nutrient for absorption and metabolism with in the body. Bioavailability of carotenoids is influenced by several factors such as characteristics of source, interaction with other dietary factors and various subject characteristics (Parker, 1996). Processing of vegetables do have a specific effect on the bioavailability of β-carotene, as processing can disrupt the cell matrix which can influence the release of carotenoids in the intestinal lumen.

In the current study the selected vegetables were subjected to different processing methods and their effect on β-carotene bioavailability was assessed.

Table 16 Bioavailability of β-carotene from agathi (percent)

Sl. No.	Treatments	Percentage bioavailability	Mean
1	Raw	6.45	7.23
2	Sauteing	8.90	
3	Boiling	6.55	
4	Stewing	8.25	
5	Pressure cooking	7.15	
6	Microwave cooking	6.05	

Table 16 depicts the percentage bioavailability of β-carotene from raw and processed agathi leaves. The bioavailability percentages ranged from 6.05 to 8.90, the lowest being microwave processed and highest being from sauted agathi leaves. Sauteing (8.90), stewing (8.25) and pressure cooking (7.15) were observed to induce higher bioavailability than the raw sample (6.45) and the bioavailability percentage of β-carotene when the vegetable was boiled remained similar to the unprocessed one.

Table 17 Bioavailability of β-carotene from amaranth-red variety (percent)

Sl. No.	Treatments	Percentage bioavailability	Mean
1	Raw	15.85	
2	Sauteing	18.15	
3	Boiling	17.55	16.32
4	Stewing	15.95	
5	Pressure cooking	15.35	
6	Microwave cooking	15.05	

The results given in Table 17 indicates the bioavailability of β-carotene from amaranthus (red variety) where the bioavailability was highest for sauted leaves (18.15 per cent), followed by boiled (17.55 per cent) and stewed (15.95 per cent) where all the above values found higher than the bioavailability value for raw red amaranthus (15.85 per cent). The percentage bioavailability of β-carotene from pressure cooked (15.35) and microwave processed (15.05) samples was however lower than that of raw red amaranthus.

Table 18 Bioavailability of β-carotene from amaranth-green variety (percent)

Sl. No.	Treatments	Percentage bioavailability	Mean
1	Raw	13.60	
2	Sauteing	14.95	
3	Boiling	15.95	14.67
4	Stewing	14.60	
5	Pressure cooking	14.25	
6	Microwave cooking	14.75	

Data pertaining to bioavailability of β-carotene from raw amaranth green was 13.60 per cent, while after subjecting it to different processing treatments, the bioavailability values were found to range from 14.25 per cent to 15.95 per cent, the maximum being for boiled and minimum for pressure cooked samples. Thus a significant increase in bioavailability of β-carotene was observed in all the processed of amaranth green samples compared to the raw one.

Table 19 Bioavailability of β-carotene from drumstick leaves (percent)

Sl. No.	Treatments	Percentage bioavailability	Mean
1	Raw	14.65	13.73
2	Sauteing	15.35	
3	Boiling	13.55	
4	Stewing	14.60	
5	Pressure cooking	12.80	
6	Microwave cooking	11.45	

The results of *in vitro* bioavailability of β-carotene from drumstick leaves is depicted in Table 19. Sauteing obtained the highest bioavailability value of 15.35 per cent as against 14.65 per cent for raw drumstick leaves followed by stewing (14.60 per cent). Boiling, pressure cooking and microwave cooking of drumstick leaves recorded bioavailability values ranging from 13.55 per cent to 11.45 lowest being that for microwave processing.

Table 20 Bioavailability of β-carotene from chekkurmanis (percent)

Sl. No.	Treatments	Percentage bioavailability	Mean
1	Raw	10.25	9.19
2	Sauteing	10.70	
3	Boiling	9.95	
4	Stewing	7.40	
5	Pressure cooking	8.20	
6	Microwave cooking	8.65	

The percentage bioavailability of β-carotene from raw as well as processed chekkurmanis were analysed (Table 20) and sauteing was proven as the best processing practice that can be adopted for the improved bioavailability of β-carotene (10.70 per cent). Raw chekkurmanis showed a percentage bioavailability of 10.25 which was higher than rest of the processed samples other than sauteing. Among the other processing methods studied on chekkurmanis, boiling gave a value of 9.95 per cent, microwave cooking 8.65 per cent, pressure cooking 8.20 per cent and lowest bioavailability was recorded in stewing (7.40 per cent).

Table 21 Bioavailability of β-carotene from carrot (percent)

Sl. No.	Treatments	Percentage bioavailability	Mean
1	Raw	19.95	24.45
2	Sauteing	28.50	
3	Boiling	32.20	
4	Stewing	27.60	
5	Pressure cooking	18.85	
6	Microwave cooking	19.60	

Table 21 elucidates the bioavailability of β-carotene from carrot. The result indicated that bioavailability of β-carotene from carrot was observed to range from 18.85 per cent to 32.20 per cent, the highest being for boiling. Stewing and sauteing were also proven to be better methods indicating bioavailability of 27.60 per cent and 28.50 per cent respectively Raw carrots gave a higher percentage bioavailability (19.95) compared to pressure cooked (18.85) and microwave cooked (19.60) carrot.

Table 22 Bioavailability of β-carotene from yam (percent)

Sl. No.	Treatments	Percentage bioavailability	Mean
1	Raw	17.95	24.77
2	Sauteing	29.40	
3	Boiling	23.80	
4	Stewing	29.40	
5	Pressure cooking	23.55	
6	Microwave cooking	24.55	

On analysing the β-carotene bioavailability from yam (Table 22) the highest bioavailability percentage was found when processed by sauteing and stewing (29.40 each). This was followed by microwave processed yam (24.55), boiled (23.80) and pressure cooked (23.55) samples. Raw yam recorded the lowest bioavailability value of 17.95 per cent compared to all the treatments applied in this study.

Table 23 Bioavailability of β-carotene from cluster beans (percent)

Sl. No.	Treatments	Percentage bioavailability	Mean
1	Raw	25.35	24.47
2	Sauteing	27.00	
3	Boiling	25.70	
4	Stewing	25.60	
5	Pressure cooking	22.00	
6	Microwave cooking	21.20	

The percentage bioavailability of β-carotene from cluster beans is given in Table 23. Bioavailability was maximum with the treatment sauteing (27.00 per cent) followed by boiling (25.70 per cent) and stewing (25.60 per cent), which gave higher values than raw cluster beans (25.35). At the same time, the values recorded for other processing treatments, such as pressure cooking and microwave cooking were 22.00 and 21.20 which remained lower than the bioavailability value from raw cluster beans.

Table 24 Bioavailability of β-carotene from pumpkin (percent)

Sl. No.	Treatments	Percentage bioavailability	Mean
1	Raw	43.20	41.24
2	Sauteing	43.75	
3	Boiling	44.40	
4	Stewing	41.65	
5	Pressure cooking	37.20	
6	Microwave cooking	37.25	

Regarding the bioavailability of β-carotene from pumpkin (Table 24), it was observed that maximum bioavailability was recorded when processed by boiling (44.40 per cent) followed by sauteing (43.75 per cent) of pumpkin. Raw pumpkin, however obtained a value of 43.20 per cent which was higher than that for stewed (41.65 per cent), microwave processed (37.25 per cent) and pressure cooked (37.20 per cent) pumpkin.

Table 25 Bioavailability of β-carotene from tomato (percent)

Sl. No.	Treatments	Percentage bioavailability	Mean
1	Raw	44.25	45.35
2	Sauteing	47.50	
3	Boiling	45.95	
4	Stewing	49.25	
5	Pressure cooking	40.25	
6	Microwave cooking	44.90	

Table 25 describes the bioavailability of β-carotene from tomato, the fruit commonly used in culinary. The data indicates that the percentage bioavailability of β-carotene after all the processing treatments under study except pressure cooking was higher than that of raw tomato. Stewing was identified as the best method of processing of tomato with respect to β-carotene bioavailability as it recorded the highest value of 49.25 per cent followed by sauteing (47.50 per cent), boiling (45.95 per cent) and microwave cooking (44.90 per cent). Raw tomato, measured bioavailability to the extent of 44.25 per cent, while pressure cooking, gave the lowest value of 40.25 per cent.

The pooled data on the mean percentage bioavailability of β-carotene from the selected vegetables is given in Table 26. As indicated in table the mean percentage bioavailability of ten vegetables studied was found to be maximum with treatment sauteing (24.42 per cent) followed by boiling (23.56 per cent) and stewing 23.43 per cent. Raw vegetables served the next position in the bioavailability status (21.14) which was apparently higher than pressure cooking (19.96 per cent) and microwave cooking (20.34 per cent). Statistically also significant variation was observed between different treatments adopted in the study.

Thus to summarize, the study highlights that certain processing techniques applied in vegetables were found to be beneficial in the release of carotene during digestion than its release from the unprocessed vegetables. Sauteing was observed to be the best method that can be adopted for obtaining the benefit of higher bioavailability of β-carotene followed by boiling and stewing. Pressure cooking as well as microwave processing of vegetables however recorded lower bioavailability compared to rest of the processing methods, experimented.

4.9.2 Variation in Bioavailability between Selected Vegetables

The bioavailability of carotenoids is influenced by a number of factors such as the carotenoid species ingested, the amount of carotenoid in the diet, the matrix of the food source, the presence of absorption

Table 26 β-carotene bioavailability of selected vegetables subjected to processing methods (Per cent)

Treatments	Vegetables										Mean
	Agathi	Amaranth red	Amaranth green	Drumstick leaves	Chekkurmanis	Carrot	Yam	Cluster beans	Pumpkin	Tomato	
Raw	6.45	15.85	13.50	14.65	10.25	19.95	17.95	25.35	43.20	44.25	21.14
Sauteing	8.90	18.15	14.95	15.35	10.70	28.50	29.40	27.00	43.75	47.50	24.42
Boiling	6.55	17.55	15.95	13.55	9.95	32.20	23.80	25.70	44.40	45.95	23.56
Stewing	8.25	15.95	14.60	14.60	7.40	27.60	29.40	25.60	41.65	49.25	23.43
Pressure cooking	7.15	15.35	14.25	12.80	8.20	18.85	23.55	22.00	37.20	40.25	19.96
Microwave cooking	6.05	15.05	14.75	11.45	8.65	19.60	24.55	21.20	37.25	44.90	20.34
Mean	7.23	16.32	14.67	13.73	9.19	24.45	24.77	24.47	41.24	45.35	

CD

Method : 0.631
Foodstuffs : 0.814
Method on food : 1.994

Standard error

Method : 0.223
Foodstuffs : 0.288
Method on food : 0.704

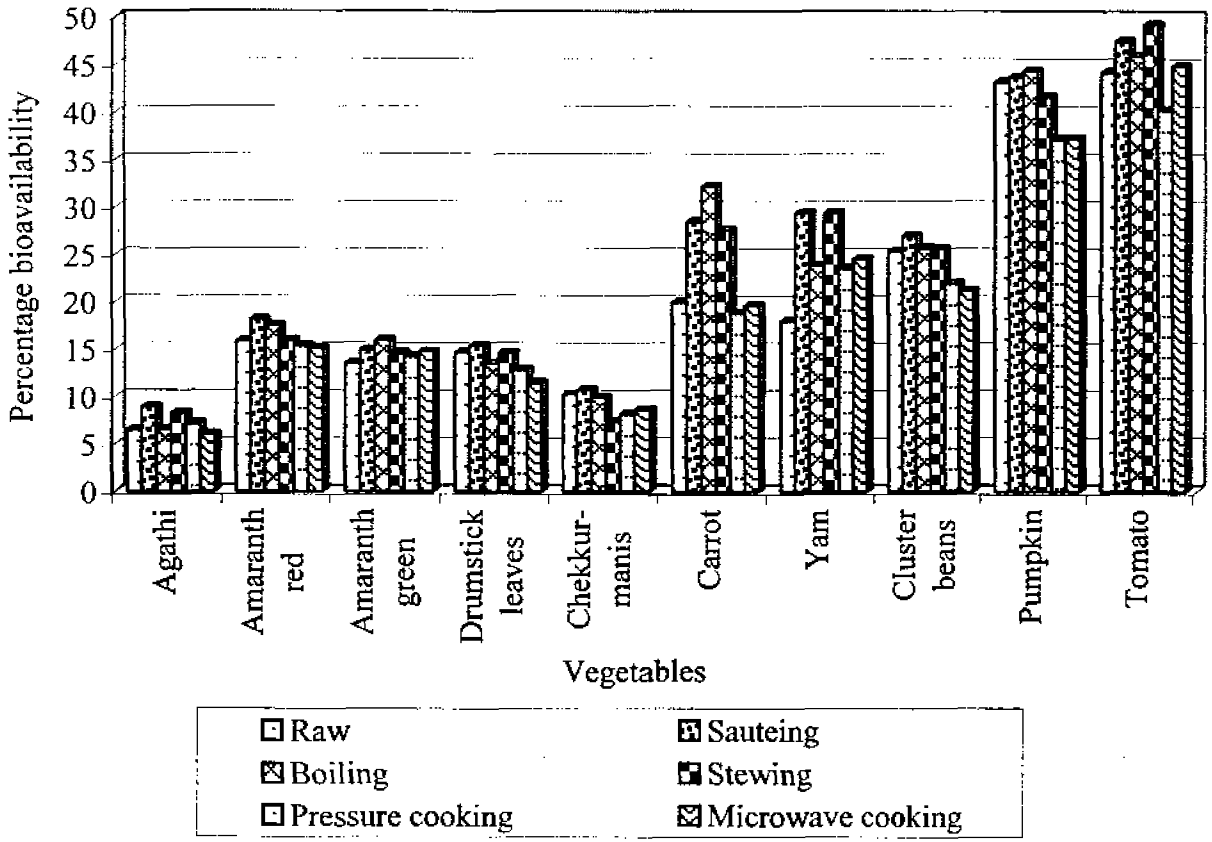

Fig. 1 β-carotene bioavailability of selected vegetables subjected to processing methods

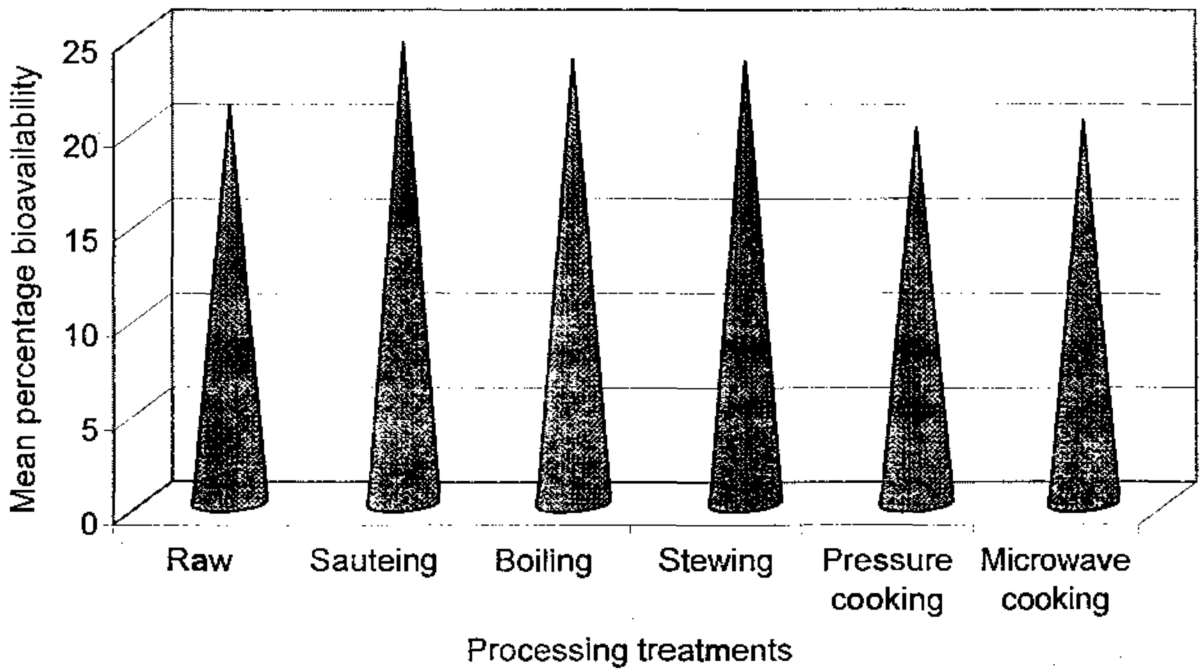

Fig. 2 Percentage bioavailability of β-carotene as influenced by processing methods

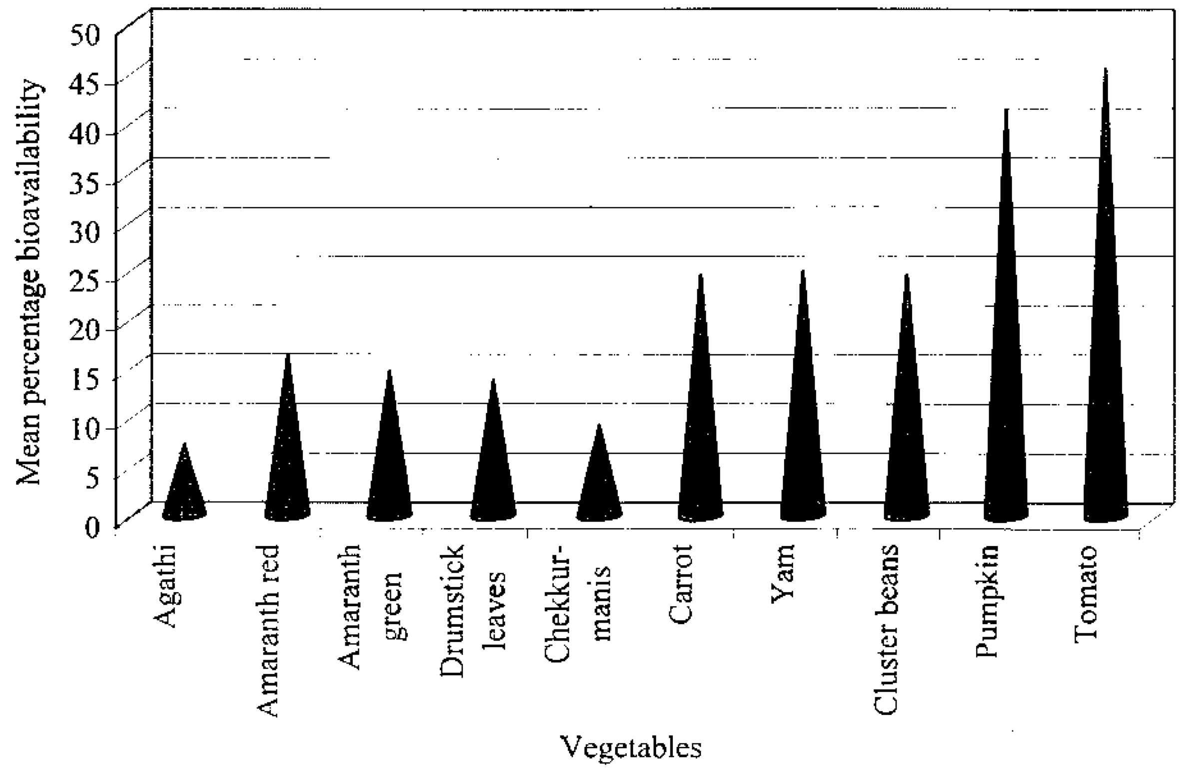

Fig. 3 Bioavailability of b-carotene from selected vegetables

enhancers or inhibitors, other host related factors and interactions among these factors. In the current study, a comparison was elucidated between the selected vegetables in terms of their mean percentage bioavailability as influenced by the different treatments applied (Table 26).

On comparing the vegetables on the basis of the mean bioavailability figures obtained for various treatments, the maximum value on β- carotene bioavailability was recorded for tomato (45.35 per cent) closely followed by pumpkin (41.24 per cent). Green leafy vegetables were proved to be similar and inferior compared to the other vegetables studied.

The bioavailability mean for roots and tubers studied revealed that yam had a higher amount of bioavailable β-carotene 24.77, than carrots (24.45). Cluster beans was observed to have mean percentage bioavailability of 24.47, which again was higher than carrots.

Among the vegetables studied, green leafy vegetables were observed to have lower bioavailability percentages, of which the lowest value was recorded for agathi (7.23) and chekkurmanis (9.19). Among the leafy vegetables, amaranth red variety obtained the maximum value 16.32, followed by amaranth green (14.67) and drumstick leaves (13.73).

Statistically there was significant difference among all the selected vegetables with respect to bioavailability of β-carotene.

The results on bioavailability analysis of ten selected vegetables revealed the fact that tomato and pumpkin have higher bioavailable β-carotene compared to rest of the vegetables. Green leafy vegetables, though have a higher carotene content, the bioavailable percentage remained low. Roots and tubers and other vegetables were proved to have higher per cent of bioavailable carotenoids than green leafy vegetables.

DISCUSSION

5. DISCUSSION

Carotenoids have many functions in the human body including being the precursors of retinol and retinoids and acting as antioxidants (Krinsky, 1993). They are found in dark green, leafy vegetables, in yellow and orange coloured fruits and vegetables. The bioavailability of carotenes from these foods however are influenced by several factors, one important factor being the cell matrix. Processing of vegetables have found to increase the bioavailability of carotenoids, possibly due to destruction of cell matrix. The current study "Influence of processing methods on the bioavailability of β-carotene in selected foods" focuses on the effect processing on the bioavailability of β- carotene in vegetables and fruits.

The results of the study are discussed under the following titles.

5.1 Socio-economic status of the subjects

5.2 Frequency of use of β-carotene rich foods

5.3 Adequacy of β- carotene content in the diet

5.4 Source of purchase of β- carotene rich foods

5.5 Processing practices followed by the respondents

5.6 Standardisation of cooking methods

5.7 Bioavailability of β- carotene

5.1 SOCIO-ECONOMIC STATUS OF THE RESPONDENTS

Socio-economic factors have a definite bearing on the dietary habits of the people and thereby are related to the dietary intake and nutritional status. Food consumption is influenced by many factors such as socio-economic status, culture, religion, education, ignorance, food beliefs and habits (Mulimani *et al.*, 2001). Among the various factors affecting the nutritional status of an individual, diet with its close association with socio-economic factors emerge as an important force of influence.

5.1.1 Personal Characteristics of the Respondents

The present study revealed that majority of the urban and rural homemakers belonged to the middle aged group (74 per cent urban and 94 per cent rural). Park (1997) reported that the demographic profile of India is fast changing and is characterised by adult population forming 60 per cent and young population (below the age of 15 years) forming 40 per cent. The percentage of young homemakers were found to be low (two per cent and 12 per cent of rural and urban homemakers respectively). Also, the number of respondents who come under old aged category was four per cent and 14 per cent in rural and urban respectively. The present results are in the tune with the findings of Rekha (2001) and Thara (2002), who conducted studies in Thiruvananthapuram district.

Rahman and Rao (2002) stated that religion can play a significant role in the dietary pattern and nutrients consumed. On assessing the religion of the respondents, it was found that majority of them were Hindus.

Reports published by Kerala Statistical Institute (1992), revealed that among the population in Thiruvananthapuram district majority follow Hindu religion and probably this may be the reason for higher representation of Hindu families.

5.1.2 Family Characteristics of the Respondents

FAO (1996) reported that family characteristics are well correlated with the variations in nutrient intake. Smaller the family size better were the intake of nutrients and nutrient adequacy. The study revealed that an overwhelming majority of the urban (90 per cent) and rural (86 per cent) respondents belonged to nuclear families. Joint families were found less in number [rural (14 per cent) and urban (10 per cent)].

Saxena (1986) reported that nuclear type families are more popular in the state of Kerala and these families are considered to be generally better than joint type families for the healthy development of children. Studies done by Rekha (2001) and Bulliya *et al.* (2002) also indicated similar results.

Present data observed that majority of the respondents, both rural (86 per cent) and urban (92 per cent) were members of small families. The subjects having medium sized and large sized families were very few. The average family size among the rural respondents was 4.58. Paul (1999) had reported that the average size of the family in Thiruvananthapuram district was 4.5. Average family size of the urban respondents was recorded as four. This again is in corroboration with the reports of Park (1997) who stated that the average family size in India is four.

According to Reddy *et al.* (1993) the employment status of the population is an important determining factor with respect to health and nutritional status. The present data evidenced that most of the families consisted of more than one earning member. In few families, there were even more than three earning members. Seshadrinath (1993) reported that among agricultural labourer families of Thiruvananthapuram, 40 per cent families had one earning member whereas 36 per cent had two wage earners and remaining 23 per cent had three or more earning members in the family.

Data further revealed that number of dependentmumbers in majority of the families were one to two and in very few families, the presence of more than four dependent members was also found.

5.1.3 Economic Status

Family income is considered as an important determinant since the income determine family status and the socio-economic position in the society to which they belong. It was observed in the study that majority of the rural and urban families were having a monthly income in the range of Rs. 5001 to Rs. 15000. However 34 per cent of the urban families were earning a high monthly income of more than Rs.15,001. These results are in tune with the results obtained by Rekha (2001) and Thara (2002).

Mehar (1995) reported that the income is considered to be one of the important factors determining the level of nutrition. The economic status directly or indirectly influences the purchasing power, standard of living and quality of life.

Regarding the monthly food expenditure pattern, majority of rural households spend Rs. 1000-2000 per month on food. While among urban households majority were spending an amount between Rs. 2001 and Rs. 3000. Study by Paul (1999) also revealed similar trend with regard to expenditure pattern.

Park (1997) states that Keralites are enjoying high standard of living inspite of low percapita income. Lisa (1996) stated that factors like food preferences, availability of food items in the locality, knowledge of nutritional values of certain food items, relative prices of food articles and urgency of non-food expenses were found to determine the priorities in the food expenditure pattern.

In a nutshell, the current data revealed that most of the respondents both rural and urban belonged to nuclear, middle income families. The number of earning members varied from family to family, but most families had more than one earning member. Most of the rural families spend lesser amount on food compared to urban households. The reason behind this can be, the urbans had to depend on markets for all the food stuffs, including the locally available ones, but for rural they obtain many food articles like vegetables from their home gardens itself.

5.2 FREQUENCY OF USE OF β- CAROTENE RICH FOODS

Vegetables occupy an important place especially in the vegetarian diet in India. Provitamin A carotenoids predominantly, β-carotene and α-carotene present in plant foods are important sources of vitamin A particularly in countries where vitamin A deficiency is prevalent and sources of preformed vitamin A are consumed infrequently (Underwood, 1984). The frequency of consumption of β-carotene rich vegetables varied greatly depending on season, availability, cost and quality.

Results obtained in the consumption pattern of β-carotene rich vegetables revealed that among the green leafy vegetables, agathi, amaranth and drumstick leaves were commonly consumed. And the consumption of agathi more common among rural families. Seshadri (1996) reported that in Southern region of India, drumstick leaves were consumed by a large number of households. Study done by Chandrasekhar *et al.* (1999) revealed that in Coimbatore district, amaranth, drumstick, keerai and agathi were the commonly consumed greens.

Apart from the well known conventional greens, leaves of large number of plants growing countryside could also prove to be good sources of β-carotene. It was observed in the study that chekkurmanis, a locally available green leafy vegetable was also relished by many families. However a higher percentage of urban respondents (56 per cent) never consumed this green leafy vegetable. Paul (1999) reported that foods such as amaranth, cabbage, chekkurmanis, coriander leaves, drumstick leaves, drumstick, bitter gourd, cluster beans, gooseberry, guava, orange and many other vegetables are commonly used in Kerala.

Regarding the use of roots and tubers, it was observed that all the respondents (50 rural and 50 urban) consumed carrots much frequently. Yam was also consumed by most of the respondents. But a small percentage (26 per cent rural and 12 per cent urban) never used this vegetable in their diet. Seshadri (1996) stated that carrots are consumed in all regions of India invaridly. Reddy (1996) reported that yam, especially different new varieties are very good sources of β-carotene.

Considering the frequency of consumption of several vegetables, it was observed in the study that bitter gourd, cluster beans, drumstick, french beans, onion stalk and pumpkin are the commonly consumed other vegetables rich in β-carotene. Some of these vegetables were also consumed daily by some respondents. Similar results were observed by Paul (1999).

Deshpande *et al.* (2001) reported that items from the 'other vegetable' group which are rich in β-carotene were also consumed widely by women of Bhopal. Kumari and Singh (2002) stated that the consumption of other vegetables in daily diet was higher and more adequate than of green leafy vegetables and fruits.

Fruits like dates and tomato ripe were consumed almost all through out the year by the respondents. The consumption of jack fruit, mango (ripe) and orange is depended on the seasonal availability and cost. Papaya, is consumed invariably by all the respondents of rural area. But majority of urban respondents (46 per cent) were not using it in their diet. Chandrasekhar *et al.* (1999) observed that in Coimbatore district fruits like papaya, tomato, mango and orange are relished most. Lisa (1996) reported that fruits are mostly included in the diet depending on the seasonal availability.

The study thus revealed that β-carotene rich food items which are available, in and around their homes like agathi, drumstick, chekkurmanis and papaya were more frequently consumed by the rural families. On the contrary, urban families depended upon such food items, that are available in the market or shops like carrot, yam, french beans, pumpkin etc.

Seasonal fruits like jackfruit, mango and orange were consumed more or less similarly by both the groups. The families therefore were found depend primarily on plant sources rich in provitamin A carotenoids (dark green leafy vegetables, yellow or orange fruits and vegetables) for their vitamin A supply.

5.2.1 Variation in Consumption of β-carotene Rich Foods

Consumption pattern of foodstuffs may differ among societies depending on the area of residence, society, education, income and availability. Analysis on variation in consumption of β-carotene rich foods by the homemakers in the present survey revealed that significant variation was noted in the consumption pattern of six vegetables among rural and urban families. On verifying the consumption pattern of each vegetable among rural and urban households, it was revealed that a significant difference at one per cent level existed with regard to drumstick leaves, chekkurmanis and cluster beans. Consumption pattern of agathi, carrot and pumpkin varied significantly at five per cent level between urban and rural households.

It could be observed from the study that leafy vegetables like agathi, drumstick leaves and chekkurmanis were consumed more frequently by the rural population than the urban families. The reason could be traced as the availability of these vegetables in the rural homesteads itself. Chandrasekhar and Kowsalya (2002) reported that drumstick leaves are rich in β-carotene and is more popular in Southern India.

Carrots are more frequently consumed by the urban families than the rural. Similar results was observed for yam, though the difference was not statistically significant. Cluster beans, β-carotene rich vegetable however was more frequently consumed by rural families.

Regarding the consumption of dates the urban population were better consumers compared to rural families, though statistically no variation was observed. Arokiasamy and Rao (1988) reported that rich households especially of the urban consumed more amounts of protective foods, protein and energy rich foods as against the rural households. Agarwal *et al.* (2001) stated that rural population consumed more cereals and less amount of protective foods in comparison with urban population, who consumed more quantities of fruits, vegetables milk and fleshy foods.

In case of papaya, frequency of consumption was more by the rural families. This may be associated with the fact that papaya is widely grown in rural homesteads than urban holdings.

5.3 ADEQUACY OF β-CAROTENE CONTENT OF THE FAMILY DIET

Actual quantity of β-carotene containing food consumed per day by selected families was assessed and the percapita consumption of β-carotene was calculated as suggested by Thimmayamma and Rao (1998). Results emphasized that 42 per cent of rural families and 38 per cent urban families were consuming diets inadequate in β- carotene as it could meet only less than 50 per cent of RDA. Diets of 24 per cent rural families and eight per cent urban families provided 50-75 per cent of RDA from daily diet. This can be associated with the observation made during the study that inclusion of β-carotene rich green leafy vegetables in the daily diet was very less and restricted to few families. NNMB (1997) observed that the intake of green leafy vegetables in Kerala was less than one fourth of RDA, while for other vegetables the RDA was more or less satisfactory. The report further observed that the intake of vitamin A from all sources including the plant sources was about a third of the RDA.

More than 75 per cent of the daily average family requirement of β-carotene was met in the diets of 18 per cent rural and 34 per cent urban families. Further it was a welcome observation that 16 per cent and 20 per cent of rural and urban families attained an average dietary contribution of β-carotene above 100 per cent. These observations also pointed out that urban families do consume diets that enable them to meet the β-carotene requirements better than that of the rural families. ICMR (1999) reported that diets of middle income groups in urban areas were fairly satisfactory, in β- carotene content, while the diets of rural people were inadequate in many respects. It was also reported that the intake of protective foods like pulses, leafy and other vegetables, milk, fruits, fats and oils were quite low in the diets of the rural especially the poor.

Rahman and Rao (2001) observed that in low income families, the consumption of qualitative foods such as pulses and legumes, green leafy vegetables were considerably low. The authors opined that higher the income better was the quality of the diet and the quantity of nutrients consumed. However no such relation was elucidated from the current study.

5.3.1 Adequacy of β-carotene in the Diets of Respondents

Food recall survey among selected urban and rural families revealed that the percapita requirement of β-carotene in many families was met satisfactorily. However when adequacy of β-carotene content of daily diet of the homemakers were studied individually, there observed a relatively wider gap in intake and RDA. The reason could be narrated as even though female head of the family cook and distribute the food, more priority was given to other members of the family (Devadas and Easwaran, 1986). Here also the respondents being the homemakers might be consuming only limited quantity of carotene rich foods as well like her share of other foods, which restricted the β-carotene supply. Present study revealed that both in rural and urban sector, majority of respondents (60 per cent rural and 58 per cent urban) had a diet containing β-carotene less than 50 per cent of RDA.

Gittelson (1989) revealed that women were less likely to meet the nutrient requirement for energy, β-carotene, riboflavin and vitamin C than men of the same age. Women's late position in household serving order, channeling of special food to males and children and lower total intake of food were the major reasons appeared to account for this inadequacy.

It was noted that diets of 32 per cent rural and 20 per cent urban subjects supplied β-carotene only sufficient to meet 50 to 83 per cent of RDA. Seshadrinath (1993) reported that among agricultural labourers of Thiruvananthapuram district, diets were deficient in many foods and diets of female group were more deficient in this respect. The author also reported that often male members, employed members, head of the family and children were given priority while serving food and vegetables are preferentially given to adult males.

At the same time a group of two per cent rural subjects and 12 per cent urban subjects were able to meet more than 83 per cent of the recommended allowance of β-carotene from their daily diet. Moreover, six per cent and 10 per cent of rural and urban homemakers respectively had a satisfactory intake and were able to meet hundred per cent of their RDA.

5.4 SOURCE OF PURCAHSE OF β-CAROTENE RICH FOODS

Kerala is considered as a consumer state. It was observed that all the food items, including cereals, pulses, vegetables and fruits are procured from neighboring states. Information pertaining to the mode of procurement of vegetables in the present study also indicates similar results.

Data on the source of purchase of β-carotene rich vegetables, revealed that among green leafy vegetables, only agathi, drumstick leaves and chekkurmanis were obtained from the homesteads of the respondent families. However in the case of amaranth, homemakers purchased the item from local shops or from the market. According to ICMR (1999), a major crop grown in abundance in Kerala is green leafy vegetables which are the inexpensive sources of many nutrients essential for health and maintenance of normal health. Chandrasekhar *et al.* (2000) stated that green leafy vegetables are the cheapest and locally available foods rich in provitamin A carotenoids.

Considering the purchase of roots and tubers, vegetables and fruits, it was noticed that the families obtained them from local shops, local market or from the main market. This phenomenon is highly visible among the urban families. It was revealed from the study that 50 per cent of the urban families purchased drumstick leaves from the shops. The other vegetables like bitter gourd, cluster beans, french beans, onion stalk and pumpkin were solely purchased from the markets.

Facility to procure vegetables from the homestead was restricted to drumstick, where 38 per cent of the rural and 40 per cent of the urban families got it from their home gardens.

Considering the availability of fruits from homesteads, it was seen that jack fruit and papaya were available from home gardens of all rural families. Mango was available from home garden only to a limited number of respondents (56 per cent). Meanwhile among the urban families jack fruit, mango and papaya were available at the homesteads of only to a few families. Many of the families were found to depend on markets for its purchase.

Laisamma (1992) reported that only a small number of families were engaged in production of foodstuffs. The author found in her study conducted among rural agricultural labourers of Thiruvananthapuram district that many vegetables, cereals, pulses, roots and tubers were purchased from market.

Thus the study observed that household production of carotene rich vegetables was very less, restricted to few green leafy vegetables and fruits. Majority of families depended heavily on markets or shops for procuring these vegetables. This phenomenon was however more prominent among urban families who depended on markets even for locally available vegetables.

5.5 PROCESSING PRACTICES FOLLOWED BY THE RESPONDENTS

In India, vegetables are commonly consumed after cooking. Vegetables from the time of harvest till they are served in the form of cooked food, undergo several steps of processing and all these can interfere with their nutrient composition.

An assessment of common processing practices employed by the homemakers had primarily revealed lack of variety in the cooking pattern. The most common methods practiced in general, for cooking vegetables by the families of both urban and rural area were sauteing and boiling. Pressure cooking was also used particularly by the urban respondents.

Sankhala (2003) stated that consumption of monotonous diets supplying less than adequate amounts of nutrients is a picture emerging from the Indian scenario. This phenomenon is not restricted to any geographical boundaries particularly in the case of rural masses belonging to low socio-economic status.

Sauteing was observed as the commonest method adopted for processing green leafy vegetables, both in rural as well as urban area. Boiling and microwave cooking were performed for amaranthus but by only a limited number of families (four per cent rural and two per cent urban and four per cent urban respectively). Seshadri (1996) reported that in rural and urban households of Gujarat, the most frequent methods of processing green leafy vegetables were sauteing, boiling, steaming, shallow frying and pressure cooking. Chandrasekhar *et al.* (2000) observed that in Palakkad, the common cooking methods followed for green leafy vegetables were boiling, sauteing and pressure cooking.

In this study as far as the culinary practice for roots and tubers like carrot and yam are counted, the commonly performed method by rural families were sauteing and boiling / stewing. Pressure cooking, boiling/stewing and sauteing were the practices adopted by the urban families.

Considering the processing practices employed for other β-carotene rich vegetables, it was observed that boiling / stewing and sauteing were followed invariably by both urban and rural families. Pressure cooking was also widely employed by the urban homes.

Laisamma (1992) reported that among the agricultural labourers of Thiruvananthapuram district, the major culinary practice followed for vegetables are boiling, boiling and seasoning. Lisa (1996) observed that in Thiruvananthapuram, boiling and sauteing or shallow frying are the commonest methods adopted for cooking green leafy vegetables, other vegetables and roots and tubers.

Among fruits, tomato was widely and commonly used by both rural and urban households. Boiling was performed as the most common processing practice, by rural homemakers. Among the urban families along with boiling, most of them adopted pressure cooking also as a processing method for tomato.

Present result points out that for cooking vegetables sauteing, boiling/ stewing are basic processing practices very commonly applied to various preparations. The regular use of these methods may be due to the easiness in operation and non requirement of specific equipments as needed in the case of pressure cooking, baking or microwave cooking. Practice of processing with the help of modern gadgets, like pressure cooker was restricted to urban families and working mothers.

5.6 STANDARDISATION OF COOKING METHODS

Vegetables are cooked to improve the colour, flavour and texture by which overall palatability and digestibility are improved. The fibre becomes softened, starch gets gelatinized and protein gets coagulated by cooking while processing also adds variety to the diet. Standardisation is a yardstick which when imposed on preparation procedures can produce uniformity and harmony in each processing method. Thus the selected processing techniques when subjected to standardisation procedures could help to obtain the standard values on the use of cooking media, cooking time and cooking temperature. The techniques standardised were boiling, stewing, sauteing, pressure cooking and microwave processing.

5.6.1 Quantity of Cooking Media

Cooking media, in a major sense is used to transfer that heat energy during processing. When boiling method was standardised, the quantity of cooking media required was uniform in the case of all green leafy vegetables i.e., 50 ml/25 g. Rajyalakshmi *et al.* (2001) reported that green leafy vegetables can be cooked by boiling adding water generally in the ratio of 1 : 2. Rest of the vegetables under study required lesser amount of water to obtain adequate doneness and the quantity ranged between 20 ml for tomato to 35 ml for yam and cluster beans.

Beegum (1991) had stated that stewing is a gentle method of cooking in a pan with a tight fitting lid, using small quantities of liquid to cover only half the food and the media used will be kept at simmering temperature (98°C). When the quantity of cooking medium for the processing method stewing was standardised, water requirement for adequate doneness of green leafy vegetables were found to be more (30 ml) compared to the rest of the vegetables under study and for tomato it was only 10 ml. This difference may be explained to the greater volume of cell matrix to be cooked with green leafy vegetables in comparison to the same weight of root/fleshy vegetables included in the study. Hence a variation in the quantity of medium was observed in stewing where water is used just to cover the entire cell matter.

Sauteing is a method, which involves cooking in just enough of oil to cover the base of the pan. The food is tossed occasionally to enable all the pieces to come in contact with oil and get cooked evenly (Srilakshmi, 1997). As revealed in Table 12 the optimum quantity of cooking medium used was 3 ml for most of the vegetables, while for drumstick leaves, carrot, pumpkin and tomato the optimum quantity of oil required was only 2 ml.

When standardisation was performed for the cooking method, 'pressure cooking', the quantity of water needed for cooking different green leafy vegetables varied and was found to be more when compared to that needed for rest of the vegetables selected. The reason could be the same as explained for the higher water uptake by green leafy vegetables on stewing. Drumstick leaves recorded the highest water requirement (40 ml) followed by chekkurmanis (35 ml). The optimum amount of water needed for cooking other vegetables selected in the study was 15 ml in all cases except for cluster beans.

The penetration of the domestic market by microwave ovens is rising day by day because of the convenience it offers in terms of speed and cleanliness (Rao *et al.*, 1995). The standardised volume of water needed for microwave processing varied greatly from 5 ml to 35 ml. Vegetables like amaranth red and green and agathi needed more amount of water while for rest of the vegetables the optimum water requirement was lesser.

5.6.2 Cooking Time

Cooking time for the selected processing techniques was standardised as the time taken for processing also have an effect on the bioavailability of carotenes. A uniform cooking time was observed when boiling and stewing methods were applied on green leafy vegetables and cluster beans (four minutes). Time required was lesser in the case of remaining vegetables. The fibre content of green leafy vegetables could be mentioned as the reason for this increase in cooking time requirement.

Cooking time for sauteing was also three minutes and was same for all vegetables studied. Nambiar and Seshadri (2001) reported that sauteing and shallow frying takes the shortest cooking time (approximately three minutes), thereby helping in maximum nutrient retention.

Different time span were observed for pressure cooking the selected vegetables and it varied from four minutes and two minutes. Amaranthus green, drumstick leaves and cluster beans required more time while carrot, pumpkin and tomato needed lesser time. One of the major reasons for processing vegetables is to soften the fibre. Roots and tubers and fruits being soft and less fibrous is liable to get cooked easily than fibrous leafy vegetables.

Optimum cooking time was minimal in the case of microwave cooking compared to other processing techniques applied in this study. Carrot, yam, pumpkin and tomato ripe needed only one minute to be done and the maximum time required was 2.30 minutes *i.e.,* for agathi. Electromagnetic waves from power source of oven are absorbed by the food directly and at once heat is generated inside the food and therefore food gets cooked very fast. Microwave oven thus stands as a boon to the homemakers who are able to spare only lesser time on their cooking chores. According to Rao *et al.* (1995) the principle advantage of using microwave oven is saving time.

5.6.3 Cooking Temperature

Standardisation of cooking temperature with respect to the five selected processing techniques were also essential, as temperature at which vegetables are cooked can influence their nutrient content especially carotenes which are highly heat liable. For boiling technique, the optimum temperature ranged between 68°C to 84 °C. Yam was done at the lowest temperature while cluster beans required the highest. Observations made by Chandrasekhar *et al.* (1999) also revealed that standardised cooking temperature for green leafy vegetables when boiling method was performed was in a range of 80-84 °C.

Standardised data on cooking temperature for stewing of vegetables existed in the range of 66°C to 82°C, as stewing is a gentle method where cooking is performed at lower temperature.

Similarly for sauteing the standardised temperature range for different vegetables were recorded within 63 °C to 85 °C.

In pressure cooking, the escaping steam is trapped and kept under pressure, so that the temperature of the boiling water and steam can be raised above 100°C so as to reduce cooking time (Moorthy, 1998). Accordingly in the current study, the cooking temperature observed while standardizing pressure cooking method on selected vegetables stood above 100 °C for all the vegetables alike.

When microwave energy was used, heat is generated within the food by the oscillation of mainly water molecules. Thus the rate of increase in temperature is extremely rapid in microwave heating, as compared to traditional heating process (Hajela *et al.*, 1998). Therefore in the effort to standardise temperature for microwave processing in the present study, all the vegetables attained 'well done' stage at the temperature grade marked as 'high' in the equipment.

Therefore, by standardisation of different processing methods under study, it was observed that boiling method required the highest amount of medium as cooking was performed with water covering the food lavishly. The cooking time was found to be higher for green leafy vegetables compared to rest of the vegetables under study and microwave processing was observed to be the quickest method. The optimum temperature for cooking varied more widely between the different vegetables than that of the variation observed between different processing methods. Here as heat is generated within the food in microwave cooking the temperature grade observed in this method was at the grade 'high', which stands above 100 °C.

5.7 BIOAVAILABILITY OF β-CAROTENE

Jackson (1997) defined bioavailability as that fraction of the nutrient that is available for absorption, utilization or for storage in the body. The absorption of carotenoids includes several steps. Factors that may interfere with the rate of each of these steps will affect the overall bioavailability of carotenoids ingested. The mnemonic 'SLAMENGHI' mentioned by Castenmiller and West (1998) best describes this.

5.7.1 Bioavailability from Raw Vegetables Versus Processed Vegetables

The current study focuses on the influence of processing methods on the bioavailability of β-carotene from selected plant foods. It was reported that isomerization of β-carotene produced by heat treatment does not negate the enhanced β-carotene uptake associated with consuming cooked and pureed vegetables versus raw vegetables (Rock *et al.*, 1998). Intactness of the cellular matrix of vegetables determines the bioavailability of carotenoids and that matrix disruption by mechanical homogenization or heat treatment enhance bioavailability (vanhet Hof *et al.*, 2000a).

Solomons (1996) stated that when compared to carotene supplements, providing carotenoid rich foods that have mild heat treatment has been observed to promote an increased serum β-carotene concentration.

The data on assessment of β-carotene bioavailability highlights that processing treatments of vegetables *viz.*, sauteing, boiling and stewing resulted in the release of more bioavailable form of β-carotene than the raw samples of most of the vegetables studied.

With respect to all green leafy vegetables studied, the bioavailability percentage was maximum when cooked by sauteing except in amaranth green for which the reason is not clear. Nambiar and Seshadri (2001) have reported that for green leafy vegetables sauteing retains a good amount of β-carotene.

The percentage bioavailability of β-carotene was enhanced in all the processing practices with agathi, except in microwave cooking. Sauteing, boiling and stewing were proved to be superior methods to process red variety amaranth. Castenmiller *et al.* (1999) stated that heat can improve the bioavailability of β-carotene from green leafy vegetables.

For amaranth green, processing improved the percentage bioavailability of β-carotene as the values obtained with all processing methods studied were higher as against raw amaranth. Observations also pointed out that the most effective method was boiling, which could be corroborated with the views of Mziray *et al.* (2001) that the β-carotene retention for amaranthus was maximum during boiling.

Sauteing was proven to be beneficial for both drumstick leaves and chekkurmanis in enhancing β-carotene bioavailability. The fat concentration in processing by sauteing improves the β-carotene bioavailability as carotenoids being fat soluble could be more efficiently absorbed in a fat diet, than in a no fat diet. Data showed that all the other processing techniques applied were negatively influencing the β-carotene bioavailability in these two vegetables and the lowest being microwave processing with drumstick leaves and stewing with chekkurmanis.

Influence of processing on bioavailability of carrot emphasized that processing by means of sauteing, boiling and stewing can increase the bioavailable β-carotene content. Boiling was superior among these and boiling without pressure was reported to reduce loss of carotenoids from carrots (Ana *et al.*, 1998). Boiling could increase the bioavailability of carotenes by softening of plant cell walls and disrupting carotenoid protein complexes and helping the carotenes to be easily extracted. This finding is supported by the study conducted by Rock *et al.* (1998) that heat treatment can improve the bioavailability of β-carotene from carrots.

Processing carrots increases the ratio of soluble to insoluble fibre (Penner and Kim, 1991), promotes solubilization of cell wall pectins and subsequent softening of the tissue (Greve *et al.*, 1994) and affects the microstructure of cell walls (Kidmose and Martens, 1999), thereby improving the bioavailability of β-carotene. However results indicated that processing by using very high temperature even for shorter duration were found to destroy carotenes heavily, thus affecting the bioavailability as observed for pressure cooking (18.85 per cent) and microwave cooking (19.60 per cent).

While analysing the bioavailability of β-carotene from yam, raw yam exhibited the least value (17.95 per cent) in providing bioavailable β-carotene and processing treatments proved to improve bioavailability. All cooking methods studied were found to enhance the bioavailable carotenoid content, measured in the vegetable possibly due to increased extractability of carotenoids from vegetable matrix (Khachik *et al.*, 1992). Among the different processed samples sauteing and stewing (29.40 per cent) recorded the highest followed by microwave processing (24.55).

Similar to the results obtained for green leafy vegetables, carrots and yam processed by sauteing, boiling and stewing indicated slight improvement in bioavailability of β-carotene from cluster beans than that from raw. However bioavailability of this nutrient was less compared to raw cluster beans with processing treatments like pressure cooking and microwave cooking, Sauteing recorded the top percentage values as processing by sautéing is found to elevate the bioavailability of β-carotene because of the presence of fat (Takyi, 1999).

Considering the bioavailability of β-carotene from pumpkin, processing by boiling method surpassed even sauteing which also presented a higher β-carotene bioavailability percentage than raw. Boiling being a vigorous method helps in bioavailability of β-carotene as it dissolves the food matrix well (disruption of cell wall structure resulting in loss of integrity) thus boosting bioavailability (Castenmiller *et al.*, 1999), while the processing techniques, stewing, pressure cooking and microwave cooking were not found to impart a positive influence on β-carotene bioavailability from pumpkin.

While studying the bioavailability of β-carotene with tomato, again the method 'stewing' was clearly observed to be the best among processing techniques under study focus higher β-carotene bioavailability. It is to be mentioned that among the different processing methods applied only pressure cooking gave a lower percentage bioavailability value than that of raw tomato. vanhet Hof *et al.* (2000a) reported that heat treatment or homogenization of tomatoes was found to improve the bioavailability of carotenes from tomato.

Hussein and El-Tohamy (1990) found that cooking or fine grinding of foods could increase the bioavailability of carotenes by disrupting or softening plant cells and disrupting carotenoid protein complexes. It was also reported that β-carotene from raw vegetables is less available than that from cooked or processed vegetables (Torronen *et al.*, 1996).

In general, for most of the vegetables studied sauteing was observed as the best method for improving bioavailability of β-carotene. Boiling was distinguished as the best for amaranth green, carrot and pumpkin whereas stewing was found superior for yam and tomato. Pressure cooking and microwave processing however were found to be inferior for bioavailability of β-carotene from most of the vegetables studied.

5.7.2 Influence of Different Processing Methods on Bioavailability

The overall influence of different processing methods was worked out to arrive at the techniques that are more feasible. The mean bioavailability values of different processing methods revealed that the technique 'sauteing' was the best method for improving the bioavailability of β-carotene. While considering the five processing techniques together, the mean bioavailability value recorded for sauteing was the highest (24.42) followed by boiling (23.56) as against raw (21.14). However the mean value variation between boiling and stewing (23.56 and 23.43 respectively) was only meager. However, values for pressure cooking and microwave cooking were significantly lower than that for the raw.

β-carotene being a fat soluble vitamin may be well extracted in the intestinal lumen into the micelles from the plant cells if sufficient dietary fat is present. So sauteing being a processing technique using oil, may improve the extractability of carotenes and thereby its bioavailability. Onayem and Badifu (1987) observed that higher retention of β-carotene in cooking using oil can be due to the release of carotenoids or due to the release, consequent to the break up of fibrous cells. Findings of Rani *et al.* (1995) and Reddy (1996) were in the same line, reporting that retention of β-carotene was higher when foods are cooked in the presence of small amount of oil.

The absorption and bioconversion of β-carotene is markedly reduced when the intake of fat is low (Prince and Frisoli, 1993). Addition of small quantity of fat to the diet greatly improves the absorption of vegetable carotenoids (Shiau *et al.*, 1994). Svanberg (1999) reported that β-carotene released from processed carrots was more than double the amount released from raw. Addition of oil further increased the bioavailability from processed to about 30 per cent. Thus sauteing, a processing practice involving addition of fat, can improve the bioavailability of β-carotene from plant foods.

Boiling and stewing were also proven to be good treatments for improving the bioavailability of β-carotene, as the mean value obtained remained higher than that of raw in almost all vegetables. Only in the case of chekkurmanis, stewing was found to have a lower percentage bioavailability value than raw.

The mean bioavailability of β-carotene from pressure cooked vegetables and microwave processed samples were found to be less than raw vegetables. This can be associated with the increased loss of β-carotene by oxidation due to the high temperature employed while processing. The rate of disruption of cell structures may also be called for the difference in the bioavailability of β-carotene from the processing methods. Chandrasekhar *et al.* (2000) had reported that microwave cooking retains only about 65 per cent of β-carotene and pressure cooking only upto 73 per cent.

Bhaskarachary *et al.* (1995) reported that microwave cooking is no way superior than other cooking methods for carotene retention. However there are also reports that indicate minimal loss of carotenes by microwave processing which could not be correlated with the present results. Chen and Han (1990) and Howard *et al.* (1999) observed that microwave cooking do not have any significant effect on carotene content.

The bioavailability of β-carotene increased significantly when processed using the techniques, sauteing, boiling and stewing in the case of most vegetables studied. Among these methods sauteing proved to be the outstanding and superior method enhancing β-carotene bioavailability.

5.7.3 Variation in β-carotene Bioavailability between Selected Vegetables

Traditionally, public health strategies to improve vitamin A status have focused on increased consumption of carotene rich fruits and vegetables as the most appropriate and sustainable solution for populations in low income countries (Solomons and Bulux, 1993). However the bioavailability of β-carotene from plant sources particularly from green leafy vegetables is generally lower than that from pure compound (Bulux *et al.*, 1994). The relative bioavailability of β-carotene from food stuffs are dependent on the type of food, the fiber content as well as the cellular structure.

West *et al.* (1998) observed that β-carotene from fruits was found to be 2.6 to 6 times as effective in increasing plasma concentrations of retinol and β-carotene than green leafy vegetables. The difference may result from difference in intracellular location of carotenoids. The authors also suggested that in leaves they are present in chloroplasts where as in fruits, carotenoids are located in chromoplasts; chloroplasts may be less efficiently disrupted in the intestinal tract than chromoplast.

The current study also revealed similar results as the mean bioavailability of β-carotene from pumpkin (41.24) and tomato ripe (45.35) were higher than that for green leafy vegetables and other vegetables studied. Erdman *et al.* (1988) reported that in yellow fruits, pumpkin and sweet potato, carotenoids are dissolved in oil droplets in the chromoplasts and can be readily extracted during digestion.

Carotene absorption is superior from fruits than from green leafy vegetables because of difference in fibre content (Reddy, 1996). de Pee *et al.* (1998) demonstrated that β-carotene is less available from dark green leafy vegetables than from fruits.

The mean bioavailability of rest of the vegetables, carrot, yam and cluster beans were also observed to be higher than that from green leafy vegetables. Among them yam was superior in containing more bioavailable β-carotene (mean 24.78) followed by cluster beans (24.48) and carrot (24.45). Carotene in carrots are encased in a thick membraneous sheet comprised of large proteins making their transfer to oil droplet less likely than that of lutein (Erdman *et al.*, 1993). Zhou *et al.* (1996) reported that food matrix, probably pectin like fibers and the crystalline form of carotenoids in carrot chromoplast are the primary factors that reduce the relative bioavailability of carotenoids from carrot. It was also observed that the relative bioavailability of β-carotene from carrot is in the range of 19 to 34 per cent (Castenmiller *et al.*, 1999). The above factors can be attributed to the finding that bioavailability of β-carotene from carrots hold only the next position to yam and cluster beans.

The bioavailability of β-carotene from dark green leafy vegetables was reported to be as low as seven per cent (de Pee *et al.*, 1995) and 5 – 6 per cent (Castenmiller *et al.*, 1999). Green leafy vegetables in general present a lower bioavailability of carotenoids among plant foods. This is due to the higher dietary fibre present in these vegetables (Rock and Swendseid, 1992) which interfere with the release and absorption of carotenoids.

The results of the current study also stood in agreement to this view, as the mean bioavailability of β-carotene from all the green leafy vegetables studied were comparatively lower to other vegetables, the minimum was observed from agathi leaves (7.23) followed by chekkurmanis (9.19). The mean bioavailability from amaranthus varieties were higher than other leafy vegetables. The variability in fibre content among leafy vegetables can be accounted for this difference.

Other reasons, that can be attributed to the lower bioavailability of β-carotene from green leafy vegetables are, the entrapment and complexing of carotene to protein chloroplasts within cell structures, which make it difficult to free β-carotene from its matrix. In addition plant components such as other carotenoids, fibre, phytic acid and polyphenols may have inhibitory effect on β-carotene absorption (de Pee *et al.*, 1995).

The presence of pectin in the plant foods, increases the viscosity of gastro intestinal contents which disrupts mixing of the contents and proper micelle formation and thus interferes with carotenoid uptake (Schneeman and Tietyen, 1994).

Thus when the β-carotene bioavailability of different foodstuffs were compared, fruits, tomato and pumpkin attained the highest value, followed by root vegetables and cluster beans. Green leafy vegetables, eventhough the richest source of β-carotene, showed lower values and this is due to their high fibre and pectin content which interferes with its release and absorption.

SUMMARY

6. SUMMARY

The study entitled 'Influence of processing methods on the bioavailability of β-carotene in selected foods' was undertaken with an objective to assess the current consumption pattern of β-carotene rich foods and to assess the impact of processing on bioavailability of β-carotene.

The consumption pattern of β-carotene rich foods was ascertained through survey conducted among 50 rural and 50 urban homemakers of Thiruvananthapuram district.

The socio-economic and dietary profile of the families were enumerated. The personal profile of the subjects indicated that majority (94 per cent rural and 74 per cent urban) belonged to middle aged group and most of them (64 per cent rural and 76 per cent urban) were Hindus.

The family background of the respondents revealed that majority of them lived in nuclear families with numbers less than five. The number of dependent members varied from family to family. Most of the families had more than one earning member, and many families had 1-2 dependent members.

Economic status of the study group indicated that majority (70 per cent rural and 64 per cent urban) families had a monthly income that ranging between Rs. 5001 -15000. The amount spent on food by most of the rural families was between Rs. 1000 to 2000, while the expenditure on food by urban families ranged between Rs. 2001 to 3000.

Data on frequency of use of β-carotene rich foods revealed that green leafy vegetables like agathi, drumstick leaves and chekkurmanis were occasionally used by many families, while amaranth (red and green) was consumed more than twice in a week by most of the families. Carrot and yam were used more frequently by the urban families than rural.

Among the β-carotene rich 'other vegetables' cluster beans was preferred by rural population at the same time pumpkin was frequently used by urban population. Frequency of use regarding rest of the vegetables under study was found similar by both the groups. The locally available β-carotene rich fruits, jack fruit and papaya were used more frequently by rural families than urban families. Tomato (ripe) was also observed to be regularly used by the respondent families for culinary purposes.

The adequacy of β-carotene in diets consumed by the families were assessed by 24 hour recall method. The data obtained revealed eventhough the frequency of use was found to be rather satisfactory, the percapita consumption of β-carotene rich foods were inadequate for majority of families both in rural (66 per cent) and urban (46 per cent) areas as their diets provided only less than 75 per cent of RDA with respect to β-carotene. Few families however were found to consume diets with the percapita β-carotene availability more than 100 per cent (16 per cent rural and 20 per cent urban).

Parallel to assessing the adequacy of β-carotene content of the diet of the family, the respondent's individual data on these line was also collected. The β-carotene content of daily diet of most of the respondents studied were less than 83 per cent of RDA. An ideal status of dietary β-carotene was observed only among two per cent rural and 12 per cent urban women who were obtaining 83-100 per cent RDA of this nutrient. Investigation also revealed that diets of a small group of respondents, (six per cent rural and 10 per cent urban women) were supplied with slightly higher quantity of this nutrient than the recommended daily allowance of 2400 μg.

Data collected on the processing practices adopted for cooking β-carotene rich vegetables revealed that sauteing, boiling / stewing and pressure cooking were the practices employed usually for cooking vegetables by them. The use of pressure cooker was however more common among urban families. Similarly the use of the modern gadget microwave oven was found only among very few urban households.

Enquiry on the availability of β-carotene rich foods revealed that most of the respondents depend on markets or shops to procure vegetables. Household production of β-carotene rich food items was restricted to few vegetables like agathi, drumstick leaves, chekkurmanis and drumstick and fruits like jack fruit and papaya and was observed mainly in the rural area.

As the main objective of the study was to assess the effect of processing on bioavailability of β-carotene, ten commonly consumed vegetables and common processing practices employed by the respondents were identified for further proceedings. The vegetables identified were agathi, amaranth red and green, drumstick leaves, chekkurmanis, carrot, yam, cluster beans, pumpkin and tomato.

The common cooking practices employed were sautéing, boiling, stewing and pressure cooking. The above processing techniques along with the modern technique- microwave processing were standardised in terms of quantity of cooking media, cooking time and cooking temperature with respect to the ten commonly consumed β-carotene rich vegetables. The cooking media requirement varied widely between food groups and cooking methods. With regard to cooking time, slight variation was observed between food groups, the highest time recorded was for cooking green leafy vegetables. Among processing methods, microwave cooking required comparatively lesser time. The temperature at which proper cooking was effected varied widely between foodstuffs than between methods.

Results on the effect of processing on β-carotene bioavailability highlighted that processing treatments of vegetables *viz.*, sauteing, boiling and stewing resulted in the release of more bioavailable form of β-carotene than from the raw samples in most of the vegetables studied.

With respect to all green leafy vegetables under focus the bioavailability percentage was maximum when cooked by sauteing except in amaranth green, where boiling proved to offer the best effect.

Sauteing was the only method proven to be beneficial for both drumstick leaves and chekkurmanis with respect to β-carotene bioavailability. Data showed that all the other processing techniques applied were negatively influencing the β-carotene absorption in these two vegetables the lowest being microwave processing with drumstick leaves and stewing with chekkurmanis.

Influence of processing on all the other vegetable studied revealed that sauteing, boiling and stewing were established as better methods for effective bioavailability of β-carotene compared to their raw counterparts. Boiling, a rather vigorous cooking method was demonstrated to be the best for an improvement in bioavailability of β-carotene from carrot and pumpkin.

Processing of yam, increased the bioavailable form of β-carotene from it as raw yam exhibited the least value against other treatments. Among the different processed samples, sauteing and stewing recorded the highest per cent β- carotene bioavailability followed by microwave processing. Sauteing was found to be the ideal method for cluster beans on the basis of β-carotene bioavailability and similarly stewing for tomato.

While comparing the different processing methods, sauteing remained to be the outstanding and superior method in enhancing β-carotene bioavailability followed by boiling and stewing. The study also revealed that the processing methods in which temperature level to be applied was high as in the case of pressure cooking and microwave cooking, the bioavailability percentage was lower.

When the β-carotene bioavailability of different foodstuffs studied were compared, fruits like tomato and pumpkin attained the highest value followed by carrot, yam and cluster beans. Green leafy vegetables, eventhough are known to be the richest source of β-carotene showed lower values in bioavailability and this is due to their high fibre and pectin content which interferes with release and absorption of this nutrient.

Thus the salient findings of the study are :

1) Though the frequency of use of β-carotene rich vegetables was rather satisfactory, the percapita consumption was inadequate to meet the RDA.

2) Processing techniques *viz.*, sauteing, boiling and stewing enhanced the bioavailability of β-carotene from vegetables

3) Sauteing was identified to be the superior processing method positively influencing β-carotene bioavailability in all the vegetables since this nutrient is effectively absorbed in fat used for cooking.

4) β-carotene from fruits like tomato and pumpkin, where this nutrient is present in chromoplast are more readily bioavailable compared to foods like green leafy vegetables, where carotene is present in chroloplasts and have high fiber content.

In conclusion methods of processing such as sautéing, stewing and boiling appeared to be beneficial in offering more bioavailable β-carotene from carotenoid rich plant foods. Therefore processing β-carotene rich vegetables applying those methods can be established as a feasible approach to enhance dietary β-carotene composition and this would have more applicability for populations who relay on plant foods to meet their vitamin A requirements.

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7. REFERENCES

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*Original not seen

INFLUENCE OF PROCESSING METHODS ON THE BIOAVAILABILITY OF BETA-CAROTENE IN SELECTED FOODS

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Abstract of the
thesis submitted in partial fulfilment of the requirement
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8. ABSTRACT

The study entitled "Influence of processing methods on the bioavailability of β-carotene in selected foods" was carried out with the objective to envisage the current consumption pattern of β-carotene rich foods and to assess the influence of selected processing techniques on the bioavailability of β-carotene.

The consumption pattern of carotene rich foods was elucidated by a dietary survey conducted among fifty urban and fifty rural homemakers from Thiruvananthapuram district.

Personal profile of the respondents indicated that majority were middle aged Hindu women belonging to nuclear middle income families. Most of the families were small sized, with less than five members. The monthly food expenditure pattern indicated that urban families spent more amount on food compared to rural households.

With regard to frequency of use of β-carotene rich foods, locally available green leafy vegetables like agathi, drumstick leaves and chekkurmanis were consumed more by rural families than urban as these items were available from their homesteads. Amaranth (red and green) though purchased mostly from markets and shops was preferred equally by households of both areas. Moreover, urban families were found to prefer conventional vegetables like carrot, yam, pumpkin and fruits like dates which are readily accessible from the markets. Cluster beans a low cost β-carotene rich vegetable was preferred by rural families. Seasonally available jack fruit and locally available papaya were observed to be more frequently consumed by rural households, while mango, orange and tomato were used in a similar frequency rate by both the groups.

The ten commonly consumed β-carotene rich vegetables identified through survey included green leafy vegetables like agathi, amaranth (red

and green), drumstick leaves and chekkurmanis, other vegetables and fruits like carrot, yam, cluster beans, pumpkin and tomato (ripe).

Daily meal pattern of the selected rural and urban families assessed by recall method revealed that the β-carotene content of the diets of most of the families were inadequate, as it could meet only less than 75 per cent of their RDA. Meanwhile a small group were able to obtain β-carotene even above 100 per cent of RDA.

The dietary adequacy of β-carotene of the daily diet of homemakers were specifically studied as women are more susceptible to poor nutrition for several reasons. It was found that majority of women (both urban and rural) had diets deficient in β-carotene and only a small group had satisfactory intake of this nutrient meeting 83-100 per cent of RDA. Also very few homemakers were observed to meet adequate levels of carotene from their diets.

Enquiry on the processing practices adopted for cooking β-carotene rich vegetables revealed that sauteing, boiling / stewing and pressure cooking were the commonly employed methods. The use of pressure cooker was however more common among urban families. Similarly the use of modern gadget microwave was also found only among very fewurban households.

Following the standardised procedures of cooking, the ten β-carotene rich vegetables were processed and subjected to bioavailability study.

Bioavailability analysis of selected β-carotene rich foods highlighted that processing treatments of vegetables namely sauteing, boiling and stewing released more bioavailable form of β-carotene. At the same time processing techniques in which a high temperature was employed as in the case of pressure cooking and microwave cooking, the bioavailability of β-carotene was found to be lower than the same unprocessed vegetables.

With respect to all green leafy vegetables studied, the bioavailability percentage was maximum when cooked by sauteing. Processing influence on the remaining vegetables revealed that sauteing, boiling and stewing were better methods for enhanced bioavailability of β-carotene compared to their other processed forms and raw samples experimented in this study. Boiling was observed for carrots, pumpkin and green amaranth. Similarly for yam both sauteing and stewing was found to be the ideal methods, while for tomato stewing was the best method since these treatments improved β-carotene bioavailability; even for cluster beans, sauteing was recorded as the best cooking practice.

To bring the observations to a nut shell, it was concluded that certain processing treatments such as sautéing, stewing and boiling were found to be positively influencing β-carotene bioavailability from vegetables and fruits. Sauteing was proved to be an outstanding and superior processing method enhancing β-carotene bioavailability, followed by boiling and stewing. Study also highlighted the variations in bioavailability status of β-carotene from different plant foods. It was observed that the percentage bioavailability of β-carotene from fruits like tomato and pumpkin was high followed by carrot, yam and cluster beans. Green leafy vegetables eventhough labeled as the richest source of β-carotene, bioavailability of this nutrient was comparatively low.

APPENDICES

APPENDIX-I

Kerala Agricultural University
College of Agriculture, Vellayani
Department of Home Science

Name of the investigator :

Interview Schedule to elicit information on the socio-economic pattern of respondents

Name of the respondent :

Full Address :

Age :

Religion : 1) Hindu 2) Muslim 3) Christian

Place of residence : 1) Rural 2) Urban

Type of family : 1) Joint 2) Nuclear

Family size

Number of independent members:
Number of dependent members:
Total income of the family

Monthly Expenditure pattern on food :-

Sl. No.	Items	Amount spent/ month
1	Cereals	
2	Pulses and legumes	
3	Green leafy vegetables	
4	Other vegetables	
5	Roots and tubers	
6	Fruits	
7	Nuts and oil seed	
8	Milk and Milk products	
9	Fish	
10	Meat	
11	Egg	
12	Fats and oils	
13	Sugar and jaggery	
14	Miscellaneous	

APPENDIX II

Kerala Agricultural University
College of Agriculture, Vellayani
Department of Home science

Name of Investigator

Name of respondent

Schedule to elicit information on the processing practices and consumption pattern of β-carotene rich foods

Sl. No.	Food stuff	Frequency of use	Source	Methods employed for cooking
1	Agathi	1.1	1.2	1.3
2	Amaranth	2.1	2.2	2.3
3	Colocasia leaves	3.1	3.2	3.3
4	Drumstick leaves	4.1	4.2	4.3
5	Chekkurmanis	5.1	5.2	5.3
6	Carrot	6.1	6.2	6.3
7	Yam	7.1	7.2	7.3
8	Bittergourd	8.1	8.2	8.3
9	Cluster beans	9.1	9.2	9.3
10	Drumstick	10.1	10.2	10.3
11	French beans	11.1	11.2	11.3
12	Onion stalk	12.1	12.2	12.3
13	Pumpkin	13.1	13.2	13.3
14	Dates	14.1	14.2	14.3
15	Jackfruit	15.1	15.2	15.3
16	Mango ripe	16.1	16.2	16.3
17	Orange	17.1	17.2	17.3
18	Papaya ripe	18.1	18.2	18.3
19	Tomato ripe	19.1	19.2	19.3

Frequency Scores

0 Never

1 Occasionally

2 More than twice in a week

3 Daily

Sources of availability

1 Local shop

2 Local market

3 Main market

4 Homestead

5 Others (specify)

Methods of cooking

1 Sauteing

2 Boiling

3 Stewing

4 Deep frying

5 Pressure cooking

6 Microwave cooking

7 Others (specify)

APPENDIX III

Kerala Agricultural University
College of Agriculture, Vellayani
Department of Home Science

Schedule used to ascertain the individual food consumption pattern (24 hour recall method)

Name of the respondent

Meal	Type of food preparation	Raw quantity of each ingredient (g)	Total cooked amt (g)	Individual intake cooked volume (g)

$$\text{Individual intake in terms of raw equivalents (g)} = \frac{\text{Total raw amount of each ingredient (g)}}{\text{Total cooked amount (g)}} \times \text{Individual intake of cooked amount (g)}$$