ORGANOLEPTIC AND NUTRITIONAL QUALITY OF SELECTED FROZEN SUMMER VEGETABLES

Dissertation

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FOOD AND NUTRITION
(Minor Subject : Food Science & Technology)

By

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CERTTIFICATTE – I

This is to certify that the dissertation entitled **"Organoleptic and nutritional quality of selected frozen summer vegetables"** submitted for the degree of **Ph.D.** in the subject of **Food and Nutrition** (Minor subject : Food Science and Technology) of the Punjab Agricultural University, Ludhiana is a bonafide research work carried out by **Ms Jaswinder Kaur (L-99-H.Sc.-46-D)** under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during course of investigation have been fully acknowledged.

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CERTIFICATE – II

This is to certify that the dissertation entitled **"Organoleptic and nutritional quality of selected frozen summer vegetables"** submitted by **Ms Jaswinder Kaur (L-99-H.Sc.-46-D)** to the Punjab Agricultural University, Ludhiana in partial fulfilment of requirement for the degree of **Ph.D.** in the subject of **Food and Nutrition** (Minor subject : Food Science and Technology) has been approved by the Student's Advisory Committee after oral examination on the same in collaboration with External Examiner.

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ABSTRACT

Three summer vegetables namely okra rings and trimmed of variety-Shagun, French beans 1.0 and 6.0 cm cuts and capsicum halves of local varieties were water blanched, frozen by IQF method and stored at PAGRO Foods Ltd., Fatehgarh Sahib at –20 to –25°C. Organoleptic, nutritional and quality characteristics were evaluated for fresh, processed and frozen stored vegetables every second month for six months. The results revealed that processing and frozen storage changes in pH, acidity, protein, fat, fibre, ash, total sugars and pectin of all the vegetables were non-significant. The reduction was highly significant ($P \leq 0.01$) after blanching and frozen storage in the microbial count of all the five types of the vegetables; β-carotene and ascorbic acid in French beans (1.0 cm), okra rings, okra trimmed and capsicum but in French beans (6.0 cm) the decrease was significant ($P \leq 0.05$). However, the total solids and available carbohydrates in French beans (1.0 cm), okra rings and okra trimmed decreased significantly ($P \leq 0.01$) whereas neutral detergent fibre in French beans (1.0 cm) and okra rings; and acid detergent fibre in okra rings decreased significantly ($P \leq 0.05$) after processing and frozen storage. Inspite of 27.0 to 30.5 per cent losses in β-carotene and 19.6 to 32.2 per cent losses in ascorbic acid, on fresh weight basis, vegetables retained 35.2 to 302.4 μg/100g and 11.8 to 98.3 mg/100g of respective nutrients. The organaoleptic evaluation scores of frozen vegetables varied from good to very good, indicating that the frozen vegetables were acceptable in the cooked form in traditional Punjabi recipes. Keeping in view, all the processing and frozen storage expenses, the retail market prices of the frozen vegetables were 25-42 per cent lower than the off-season market fresh vegetables. Thus frozen stored vegetables in addition to their improved quality, economics, nutritive value and consumer acceptability, can help farmers and processors in overcoming seasonal gluts.

Key words: Vegetables, blanching, IQF, β-carotene, ascorbic acid, organoleptic acceptability.

Signature of Major Advisor

Signature of Student

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LIST OF ABBREVIATIONS

Alpha	-	α
Beta	-	β
Degree centigrade	-	^{o}C
Degree Fahrenheit	-	^{o}F
Gram	-	g
Milligram	-	mg
Microgram	-	μg
Milliliter	-	ml
Minutes	-	min
Seconds	-	Sec
Optical Density	-	OD
Nanometer	-	nm
Parts per million	-	ppm
Colony forming unit	-	cfu
Most probable number	-	MPN
Table spoon	-	Tbsp
Tea spoon	-	tsp
Low temperature long time	-	LTLT
High temperature short time	-	HTST
Lipoxygenase	-	LPO
Peroxidase	-	POD
Cystine lyase	-	CL
Individual Quick Freezing	-	IQF
Neutral detergent fibre	-	NDF
Acid detergent fibre	-	ADF
World Trade Organisation	-	WTO

CHAPTER-I

INTRODUCTION

CHAPTER – I

INTRODUCTION

The health benefits of vegetables are well recognised by nutritional and medical communities, but the per capita intake of vegetables in the country is 135g against the recommendation of Indian Council of Medical Research for the minimum per capita consumption of 280 g/day, which needs urgent attention. Research reports link increased consumption of fruits and vegetables with reduced risk of chronic degenerative diseases like cardio-vascular disease, cancer, obesity and diabetes (Sies and Stahl 1995; Steinmetz and Potter 1996; Franceschi *et al* 1998). Important features of vegetables include micronutrients, fibre, antioxidants and their low caloric value. Antioxidant compounds namely ascorbic acid and β-carotene are present in abundance in vegetables. β-carotene, a vitamin A precursor, has been identified as a potential anticarcinogen as well as an antioxidant (Sies and Stahl 1995).

India is the second largest producer of the vegetables after China. The production of vegetables in India rose from 58.33 MT in 1991-92 to about 95 MT in 1999-2000. In Punjab, the production of vegetables was 2.28 MT during 1999-2000. Despite such high levels of production, the annual per capita consumption of vegetables in India is only about 63 kg as against 220 kg in South Korea, 115 kg in China and 105 kg in Japan (Anon, 1999). As vegetables are highly perishable, around 30-35 per cent of fruits and vegetables worth about Rs. 23,000 crores are lost every year. The main reasons being improper post-harvest handling, lack of proper processing and storage facilities and absence of linkages between the processors and marketeers of fruits and vegetables. As a result, there is a considerable gap between gross production and net availability. Further, during the glut season, prices of fresh vegetables crash thus depriving the farmer the fruit of his hard labour while the major benefit is harvested by the middlemen. Each intermediary in the chain is being benefitted 2.5 times more than the actual price realised by a small farmer. So, to achieve the target of a hidden hunger free India, only increasing the productivity is not enough. A lot more emphasis needs to be given to post-harvest management and food processing sector.

In India, most of the vegetables are still consumed fresh and only 1.8 percent of the total production is processed as against 83 per cent in Malaysia, 80 per cent in South Africa, 78 per cent in Philippines, 70 per cent in Brazil and 65 per cent in U.S.A. The production of processed fruits and vegetables in India rose from 2.13 lakh tonnes in 1988 to 3.60 lakh tonnes in 1991 and 9.74 lakh tonnes in 1996. The utilization capacity of the industry rose from about 35 percent in 1988 to 50 per cent in 1996 (Anon, 1999). Recently, the production of frozen vegetables has also been taken up in the country both for the domestic and export markets. Freeze dried and quick frozen vegetables are being produced in the country mostly for export purpose. Thus judicious storage of fresh vegetables during the peak season can prevent the crash in prices to a large extent and can also extend the shelf-life of vegetables in order to stretch their supply to a larger section of population.

At present, the National Dairy Development Board (NDDB) is marketing frozen peas under its brand 'Safal' for direct consumption in households. In India, the frozen food industry is of recent origin and is still in its infancy. The recent trends reveal that the production of frozen fruits is rather small but frozen vegetable products dominate comprising 47.50 per cent of the total frozen fruit and vegetable products manufactured in India. The recent export of frozen vegetables was of the order of 330 tonnes while the domestic consumption of frozen vegetables was 541 tonnes. However, total frozen fruit and vegetable products constitute about 1.5 per cent of the total processed fruit and vegetable products (Pruthi, 1999). So, there is considerable scope for further augmenting the production of frozen fruits and vegetable products in India.

Until recently, the inadequate development of food processing sector in the country was mostly due to poor domestic demand. Traditionally, the Indians prefer fresh home cooked food as they always have doubts about the quality of fruits and vegetables that go into the production of processed foods and also find such foods very expensive. This was because the government levied very heavy duties and taxes on the processed products including packing material as it always considered that these products were meant for the consumption of rich. But in foreign countries, with the development of mechanical refrigeration and quick freezing techniques, the frozen food industry is expanding rapidly. Even in homes, the freezing of vegetables has now become a common practice because spacious deep freezers are readily available.

There is a demand for high quality convenient, fresh, shelf-stable and ready-to-use vegetables for dual income group families as well as for retail fast food outlets and restaurants. Further, changing life styles and nuclear family structures have resulted in an increased demand of processed foods. There is a tremendous scope for frozen vegetables in India both for export and domestic consumption. At present, frozen vegetables have a market of Rs. 100 crores in India. During 1981, the installed capacity of processed fruits and vegetables was only 2.7 lakh tonnes which rose to 19.10 lakh tonnes in 1996 (Anon, 1999). Freezing provides an environment which inhibits microbial growth, retards chemical reaction rate and the action of food enzymes which are responsible for spoilage at ordinary temperature. However, frozen vegetables actually retain more nutrients than the unprocessed form as vegetables are picked and frozen within hours of harvest, whereas 'fresh' vegetables may have been stored for several days before use.

The frozen foods had better nutritive value, flavour, colour and appearance than the corresponding food preserved by any other processing technique like canning, bottling or dehydration. This conclusion has been drawn from the comparative quality data based on their sensory evaluation by the experts (Pruthi, 1989).

Most vegetables freeze well and the shelf-life of frozen vegetables at 0^{o}F (-18^{o}C) is one year. Frozen foods including fruits and vegetables are not inert. The type of quality changes that occur in frozen storage include chemical, physical and some microbial (all of which affect the quality of vegetables).

During frozen storage, microbial population gradually decreases. This decrease is lower at higher storage temperature and at higher initial microbial populations.

Colour of frozen fruits and vegetables is affected during frozen storage by chemical degradation of chlorophyll and anthocyanin but blanching stabilizes it. Frozen peas after blanching are dark green in colour while carrots become bright red in colour. Ascorbic acid is the only vitamin that undergoes serious destruction i.e. 6-18 per cent during frozen storage of 12 months. Other chemical reactions during frozen storage include denaturation of proteins and oxidation of lipids. This leads to flavour changes. A gradual but significant decline in the quality always occur during normal commercial storage. The rate of quality deterioration depends mainly on two factors; storage temperature and type of product. The storage temperature should be below $0^{o}F$ ($-18^{o}C$) and it should be held as constant as possible (Breene, 1985).

It is important to blanch vegetables before freezing in order to halt the enzymic activity which would otherwise result in development of off-flavours, poor texture of vegetables and low ascorbic acid content after only a few weeks in the freezer. Water blanching is the easiest and most economical technique.

Various methods of freezing have been used. The most recent one used for the vegetables is Individual Quick Freezing (IQF) using fluidized bed freezing. The freezing of unpacked fruit and vegetable products is known as IQF. Product units do not freeze together into a mass but on the contrary individual pieces are retained. In this method, a shallow layer of product is conveyed on a mesh belt through a chamber where it is subjected to blast of cold air at approximately $-40^{o}C$.

A number of advantages are claimed for IQF. Freezing rate is rapid; approximately 3-5 minutes are required for freezing peas and there is less damage to texture than slow freezing. The product is pourable i.e. it doesn't come out of the container as one large block. Containers can be opened and any amount of product can be readily poured. Since individual product units are separate, these are easier to thaw than those frozen together in a single mass. The frozen vegetables require less time for cooking. Moreover, there is no peeling or preparatory loss. In each package, 100 per cent edible portion of food is available as there is no syrup, no brine or gravy.

Food supply has to keep pace with the needs of population. Vegetables are highly seasonal and available for a short duration. In order to stretch the supply of vegetables for longer duration, to make vegetables available throughout the year for healthy balanced diet, to add variety to the diet, to economise on cooking, to stabilize prices of vegetables and above all, to make the vegetable growing profitable to the farmer and promoting crop diversification, suitable post-harvest processing is essential. Further, for value addition to perishable produce by primary processing at the village level such as removal of inedible parts, washing, sorting, trimming, slicing or chopping, shelling, packing, etc. would make the transportation easier, minimise the losses, will generate employment for women in rural areas, enhance the income of the farmers and minimise migration from villages to towns alongwith increasing exports thus adding to the inflow of foreign exchange earnings. Further, secondary processing such as refrigeration, freezing etc. would give added advantage. Above all, it will provide nutritional security to the people and improve the nutritional status of Indian population. Keeping in view all the above, the present study has been planned with the following objectives:

1. To determine the optimum shelf life of selected frozen vegetables.
2. To study the loss of labile nutrients in vegetables during frozen storage.
3. To evaluate the organoleptic acceptability of frozen vegetables in commonly used recipes.

CHAPTER-II

REVIEW
OF
LITERATURE

CHAPTER – II

REVIEW OF LITERATURE

Vegetables are essential component of our daily diet. Therefore, these are required throughout the year. On the other hand the production of vegetables is seasonal and these are perishable. Their demand, however, is throughout the year. Thus the processed vegetables could fill the gap between demand and supply. Among the processing methods, freezing can preserve many vegetables in a form acceptable to the consumer. An attempt has been made to review the available literature to comprehend the work done so far in India and abroad, as per the objectives of the present investigation. The review has been discussed under the following headings:

2.1 Selection, blanching and freezing of vegetables-specifications/ standardization

2.2 Effect of blanching on frozen vegetables

2.3 Effect of enzymic action on quality of frozen vegetables

2.4 Effect of freezing on quality of frozen vegetables

2.5 Effect of processing and frozen storage on quality characteristics

2.5.1. Total solids

2.5.2. pH

2.5.3. Titrable acidity

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2.6 Effect of processing and frozen storage on nutritional characteristics

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2.7 Effect of frozen storage on organoleptic characteristics

2.1. Selection, blanching and freezing of vegetables-specifications/standardization.

The suitability of vegetables for freezing varies greatly with the type and variety. It is essential that vegetables for freezing are of the best quality.

Tressler *et al* (1957) suggested that okra of proper maturity produced an excellent frozen product suitable for use as a cooked vegetable. Woody and fibrous pods should be discarded, stems removed, blanched preferably in steam for 2 min and larger pods for 3 min followed by immediate cooling prior to freezing. Sistrunk *et al* (1960) evaluated a short pod okra of dark green colour to meet the trade requirements. By comparisons with different vegetables, okra has been found to be well adopted to freezing preservation.

Simpson (1962) postulated that the best stage of maturity for freezing is reached when fruits and vegetables are at their best for eating. If they are immature, they lack their full characteristic flavour. On the other hand, over-ripe vegetables may be too firm and fibrous and on thawing may taste bitter. Some of them may lose their shape on thawing and become less attractive. Mature bell peppers contained higher ascorbic acid levels than those harvested green (immature). It was further reported that vitamin A generally increased with maturity (Matthews *et al*., 1975).

Clarice Sackett (1975) reported that the okra pods should be harvested while still tender and immature. They should attain the length of 6 to 8 inches and upto 1 inch or more in diameter. Okra can be preserved by drying, quick freezing and canning.

Sikora and Wanger (1988) reported that cauliflower varieties: White Rock, Lawyna, Jura Andes, Atos and Bejo-1149 grown in three different regions of Poland were harvested at technological ripeness in successive years. Samples were blanched at 98^0 for 3.5 min, frozen and stored at -18^0C for three months. Evaluation of morphological, chemical and organoleptic characteristics showed that White Rock and Jura varieties had the best morphological features and sensory quality after freezing and storage. The chemical composition of all the cauliflower varieties under examination did not change significantly during freezing and storage.

Mallet (1993) informed that the cultivars of snap beans required for freezing should be young, tender, stringless which snap when broken. Capsicum for freezing should be deep green, crisp and thick walled. Okra cultivars must be young and tender with green pods.

Barrett and Theerakulkait (1995) noted that two cultivars of green beans had significantly different initial enzyme activities. Therefore, target blanch times varied with cultivars. They found that Lipoxygenase (LPO) inactivation in supersweet corn at

93°C was accomplished in 6 to 9 min while Peroxidase (POD) inactivation under the same conditions required 18 to 20 min. Inactivation of LPO and POD at 93°C in green beans required times of 2.0 and 0.5 min, respectively.

For freezing purpose, snap beans or French beans should be long, straight, tender, stringless pods of medium size, bright green in colour and resistant to mosaic. Indian Agricultural Research Institute has recommended Bush type varieties - Contender, Giant stringless and Pusa Parvati. Okra pods should be tender, soft, immature, small to medium (5-8 cm in length), velvety to touch, bright green in colour and free from fibre. Suitable okra varieties are Pusa Makhmali, Pusa Sawni and Perkins Long Green. The desirable characteristics of capsicum included uniform green colour, glossy skin, thick flesh, tender texture and high characteristic flavour of capsicum. Varieties recommended are California Wonder, Yolo Wonder and King North (Pruthi, 1999).

Barrett *et al* (2000) reported that three cultivars of Sweet Corn-on-the-cob designated as Sugary A, Sugary B and Supersweet-C; and two cultivars of broccoli designated A and B were steam blanched for various times and frozen in a blast freezer (-44°C). The blanched samples were then stored for nine months at -18°C and then analysed. There were significant differences among the three corn cultivars. Cultivar C, requiring the shortest blanch, was the firmest and showed the least number of undesirable attributes. The two broccoli cultivars also behaved differently as a function of blanching time which resulted primarily in textural changes.

2.2. Effect of blanching on frozen vegetables

It is important to blanch vegetables before freezing in order to inactivate endogenous enzymes which would otherwise cause changes in colour, flavour, texture and nutritional value (loss of vitamins A, B_1, B_2 and C) during subsequent freezing, storage and thawing. Blanching has no detrimental effect on most of the vegetables since nearly all vegetables are cooked before consumption.

Dietrick *et al* (1970) compared microwave, steam and water blanching techniques and found better ascorbic acid retention in Brussels sprouts using microwave. However, from an overall quality point, the best product was achieved with a combination of microwave and water blanching process.

Eheart and Odland (1973) studied quality of frozen peas, green beans, lima beans, broccoli and Brussels sprouts blanched in four concentrations of ammonium bicarbonate. It was recommended that 0.2 per cent NH_4HCO_3 was the optimum concentration for peas and lima beans. Colour improvement was noted at this concentration with no adverse effect on ascorbic acid retention, flavour, texture or acceptability.

Effect of different concentrations of chemicals in the cooling medium was investigated by Hudson *et al*. (1974). The different samples of Runner beans, peas, perpetual spinach and brussels sprouts after blanching were cooled in 1.2 and 2.0 per cent NaCl, 1.2 per cent sucrose and 0.25 per cent Na_2SO_3 followed by storage at -18^oC. The appearance of sprouts was slightly improved by 1.2 per cent NaCl and 1.2 per cent sucrose blanching liquids. Flavour of runner beans was significantly increased by the use of 1.2 per cent NaCl but the 2 per cent level significantly lowered scores for appearance and texture. Sugar significantly lowered texture scores for beans but improved those for peas.

Adams (1981) reported variations in loss of vitamin C, total sugars and proteins due to water/steam blanching of peas and green beans.

Drake *et al* (1981) observed that the microwave blanched vegetables were poor in colour and ascorbic acid than water or steam blanched vegetables. Sensory preference scores for colour and flavour were very low for the microwave blanched vegetables. Little or no difference in quality was found between water and steam blanched vegetables. Similar observations were made by Gullett *et al* (1984) also. Microwave treated samples of green beans were firmer and less green than water blanched samples. Microwave treated samples had less typical bean flavour, more off-flavour and off-odour as well as lower overall acceptability than the water blanched vegetables.

Baardseth and Naesset (1989) studied three varieties of cauliflower. The florets were blanched, frozen and stored at –20°C for eight months. Unblanched florets were used as reference. Blanching completely inactivated peroxidase, palmitoyl-CoA hydrolase and α-oxidase, while residual activity was found for acylhydrolase, lipoxygenase and catalase. Protein content was reduced with increased blanching time. Unblanched florets were inedible and organoleptically unacceptable after four weeks of storage at –20°C. The heat treated samples also developed off-flavour and off-odours but to a lesser extent. Significant correlations were obtained between sensory and colour analysis.

Effects of blanching on physico-chemical properties of frozen green beans were studied by Hugo *et al* (1989). Blanching was carried out immediately after harvest by immersing the beans in 100°C boiling water for 1, 2, 3, 4 and 5 min followed by cooling. Samples were frozen at –18°C. Results showed no significant change in moisture, ash, soluble solids, reducing sugars and starch due to difference in blanching time but significant losses occurred in ascorbic acid and carbohydrate contents (27.3 and 21.4 per cent, respectively) at 5 min blanching time.

Ramaswamy and Ranganna (1989) evaluated the influence of blanching time and post-blanching sulfite treatment on the sensory quality and texture of frozen cauliflower after storage at –18°C upto one year. Samples were blanched (before freezing) for 3 min and dipped in a solution containing 1000 ppm of SO_2 for 5 min and were stored for one year. Cauliflower texture was influenced by blanching time but the textural differences in blanched samples diminished following freezing and storage. After 3 min cooking, the texture of all defrosted samples was comparable to that of fresh cauliflower cooked for 10-12 min.

Klein (1992) reported that colour stability could be improved by blanching. The heating medium and processing conditions significantly affected sensory properties of blanched broccoli.

Mallet (1993) found that due to blanching, the loss of half of the total vitamin C from vegetables such as peas, sliced beans and diced carrots occurred due to large surface to volume ratio, with smaller losses (about one-third of vitamin C) from whole beans, potatoes and sprouts where the surface-to-volume ratio was small. Time appeared to be of less importance as compared to the surface area.

Ramaswamy and Fakhouri (1998) blanched carrot slices and French fry style sweet potatoes for selected duration of time (30-180 sec) in microwave oven and a boiling water bath. Both blanched and unblanched samples were packed and frozen stored at –20°C. Microwave blanched samples were comparable to individually quick water blanched samples when the quality of the frozen stored samples was evaluated.

The carotene retention in carrots was better when blanching was done by microwaves as compared to steam blanching (Kidmose and Martens, 1999).

According to Pruthi (1999), blanching reduced the microbial load and provided thermal inactivation of peroxidase to some extent and thus helped to preserve quality of vegetables. Blanching was also helpful in fixation and stabilization of natural green colour.

Barrett *et al* (2000) studied the effect of steam blanch time on quality of frozen stored corn and broccoli. The corn was blanched at 100°C for 0, 2, 4, 6 and 8 min and broccoli for 0, 45, 90, 135 and 180 secs. All samples were frozen in blast freezer (-44°C) and stored at –18°C. The results showed that reducing blanch time is desirable from a sensory standpoint, because longer blanch treatments generally reduced firmness and freshness but increased cooked flavours. Short blanch treatments positively affected both broccoli and corn colour which would result in a more desirable product. It would also benefit the industry by decreasing energy costs, water and clean up cost.

Czapski and Szudyga (2000) reported that blanching is undesirable because of weight loss and toughness increase during storage of blanched frozen mushrooms. It was concluded that the blanching process could be omitted by washing mushrooms in water containing sodium metabisulfite (3g L^{-1}). Appearance and whiteness of frozen mushrooms were most affected positively. The residue of SO_2 changed from 52 mg kg^{-1} after one day to 27 mg kg^{-1} after 90 days of storage.

Sapers *et al* (2001) studied the shelf life extension of fresh mushrooms by application of H_2O_2 and browning inhibitors. It was reported that mushrooms can be washed in 3 to 5 per cent H_2O_2 concentration and 4 per cent sodium erythorbate + 0.1 per cent NaCl can be substituted for the more complex browning inhibitor. The product thus obtained was free of adhering soil, less subject to brown blotch than conventionally washed mushrooms. It was also resistant to enzymatic browning like unwashed mushrooms during storage at 4°C.

The impact of blanching on firmness retention and ultrastructural changes in the cell wall and middle lamella of carrot tissues were studied by Roy *et al* (2001). HTST blanching (100°C, 0.58 min, 90°C, 2.12 min) retained firmer texture than LTLT blanching (80°C, 11.64 min, 70°C, 71.1 min). Softening was further enhanced in blanched carrots on freezing.

Another study indicated the potential application of microwave processing in reducing the loss of volatile nutrients (Ramesh *et al*, 2002). In this method, the leaching losses occurring during conventional processing using steam or water blanching and subsequent ice water cooling were avoided.

2.3 Effect of enzymic action on quality of frozen vegetables

The loss of quality in inadequately blanched vegetables is due to polyphenol oxidase activity which causes browning and lipoxygenases activity which produce off-flavour and off-odour from lipids. The degradation of carotene and oxidation of lipids takes place slowly at low temperature.

The enzyme lipoxidase has been postulated by Wagenknecht and Lee (1956) as a causative agent for chlorophyll breakdown during frozen storage of raw peas. The primary action of lipoxidase results in peroxidation of the double bonds of certain unsaturated fatty acids. A concurrent action involves the oxidation of certain unsaturated plant pigments such as chlorophyll and carotenes.

Baardseth (1977) found that five percent residual activity of peroxidase in frozen French beans, carrots and cauliflower, stored at –20°C to –30°C for upto 15 months, did not affect the quality during storage.

Adams (1981) reported that some activity of peroxidase may be left in many vegetables after blanching and a long shelf life in frozen storage could still be achieved. This observation leads to the interpretation that the peroxidase alone did not give rise to quality deterioration during frozen storage.

Baardseth and Slinde (1983) studied the effect of storage at –20°C on carrot cubes, which had been blanched at 50, 60, 70 and 80°C for 20, 10, 5 and 2 min, respectively. Results showed that good quality product was obtained when Palmitoyl-CoA hydrolase enzyme was no longer present, while some activity of catalase (9%) and peroxidase (6%) enzyme remained.

Muftugil (1985) determined the peroxidase activity in some fresh vegetables. The vegetables were blanched in hot water at 75, 85 and 95°C. Peroxidase inactivation was faster at higher temperature. Blanching of vegetables at 75°C for 30 min was not sufficient for complete inactivation of peroxidase enzyme. Williams *et al* (1986) indicated that lipoxygenase was the key enzyme in the development of undesirable aroma in English green peas and beans. The individual isolated enzymes were added to completely blanched purees of these vegetables. Lipoxygenase in English green peas was inactivated more rapidly by heating than peroxidase and all of the lipoxygenase activity was lost in about half the time of heating required for complete loss of peroxidase activity.

Halpin and Lee (1987) blanched fresh green peas for various times/temperatures and stored at –23°C. After three months, peroxidase and polyphenoloxidase activity decreased while Lipoxygenase activity increased during storage, more noticeably in the long time/low temperature blanch treatment.

Aparicio-Cuesta *et al* (1992) studied the total soluble and bound peroxidase activities in frozen green beans stored under proper conditions (-18 to –22°C and in a display freezer) and under adverse conditions (temperature fluctuation). Blanching inactivated the enzyme and there was no regeneration after 12 months of storage at –22°C, but a slight regeneration was noticed at –18°C. Sensory quality of the properly stored product was acceptable after one year of storage. Temperature fluctuations were deleterious for sensory quality and peroxidase activity was only slightly regenerated.

Gunes and Bayindirh (1993) reported that because of its thermal resistance, peroxidase is generally used as an indicator enzyme to evaluate the adequacy of blanching. Mallet (1993) observed that in peas, complete or nearly complete inactivation of peroxidase correlated well with achievement of best quality product. Best sensory quality in green beans was achieved prior to complete inactivation of peroxidase while complete inactivation led to loss of flavour, quality and colour was also adversely affected.

Barrett and Theerakulkait (1995) found that LPO inactivation in super sweet corn at 93°C was accomplished in 6 to 9 min while POD inactivation under the same conditions required 18 to 20 min. Inactivation of POD and LPO at 93°C in green beans required 2.0 and 0.5 min, respectively. In another study Theerakulkait and Barrett (1995) found that in sweet corn lipoxygenase catalysed off-odour formation and blanch treatments targeting inactivation of this enzyme enhanced desirable characteristics, such as sweetness and corn flavour. Addition of peroxidase extracts to corn homogenates did not result in a significant difference in sensory quality.

Ramirez and Whitaker (1998) proposed the use of cystine lyase (CL) as a blanching indicator in broccoli since it was the main enzyme responsible for off-flavour production. Different research groups found that Cl was more heat labile than POD and LPO (Barrett *et al* 2000; Kawaguchi *et al* 2000).

2.4 Effect of freezing on quality of frozen vegetables

As a preservation method, freezing takes over where refrigeration and cold storage leave off. Freezing causes negligible changes to pigments, flavour or nutritionally important components although these may be lost in preparation procedures or deteriorate later during frozen storage. The main effect of freezing on food quality is damage caused to cells by ice-crystal growth.

Chen (1986) found that quality parameters such as water, vitamin B complex, vitamin C, soluble solids and acidity remained constant after freezing.

Kalia and Sood (1996) described that during freezing, the formation of ice-crystals affected the texture of many frozen foods. When water froze rapidly it formed minute ice-crystals and clusters of crystals. In slow freezing, the water crystals resulted in physical rupture and separation of cells. If freezing was rapid, the minute crystals were formed only within the cells and physical damage of the cells was less severe. So, quick freezing was desirable for better product quality.

Fellows (2000) described the influence of freezing rate on plant tissues. During slow freezing ice-crystals grew in intercellular spaces which deformed and ruptured adjacent cell walls. On thawing, cells did not regain their original shape and turgidity. The food became soft and cellular material leaked out from ruptured cells (drip loss). In fast freezing, smaller ice-crystals formed within both cells and inter-cellular spaces and there was little physical damage to cells and the texture of the food was retained to a greater extent.

2.5 Effect of frozen storage on quality characteristics

The lower the temperature of frozen storage, the lower is the rate of microbiological and biochemical changes. The types of quality changes that occur on frozen storage include chemical, physical and microbiological changes, all of which affect the quality attributes of texture, flavour, colour and nutritive value. Frozen foods including fruits and vegetables are not inert. A gradual but significant decline in quality always occurs during normal commercial storage. The nature of the several changes has been the subject of research which has been reviewed below:

2.5.1 Total solids : Bomben *et al* (1975) reported that most of the vegetables lost weight during blanching. Peas had the maximum weight loss (11.3%) while Brussels sprouts gained weight (1-8%). Apparently in most vegetables, the cell damage resulting from heating reduced the amount of liquid within the tissue. During freezing, the structure of organic molecules gets transformed which may result in increased bonding with water for stability and this bonded water may result in increased weight of the vegetables.

Brown (1977) observed the changes on the ultrastructural level in frozen and stored green peas and green beans. He reported that in green beans large intercellular cavities that were rich in air, could be found in the parenchyma. During blanching, the air is replaced by liquid. The starch granules picked up water and the volume of the cells showed a relative increase in weight whereas no difference in dry matter contents in fresh, blanched and frozen samples of various varieties of carrots were observed (Michalik and Hallas, 1991).

Lisiewska and Kmiecik (1996) found that blanching reduced the dry matter by 18-20 per cent in broccoli and 9-10 per cent in cauliflower, corresponding to a dry matter content of 9.1-9.5 per cent in broccoli and 7.6-7.9 per cent in cauliflower. Freezing and storage period of six months increased dry matter by 1-4 per cent as compared to that in blanched material. However, no effect of 12 months frozen storage at –20°C on soluble solids has been reported by Lisiewska and Kmiecik (2000).

2.5.2 pH : Hugo *et al* (1989) observed that the pH of 5 minutes blanched sample decreased from 6.3 (fresh beans) to 5.6 after 15 days of frozen storage before increasing and finally stabilizing at the initial pH. In case of peas, beans, broccoli and sprouts the pH decreased during the storage period of six months at –18°C. Increase in total acidity was significant only in case of beans and sprouts (Eheart and Odland, 1973). No effect of duration and temperature of storage on the pH of frozen tomato cubes was observed by Lisiewska and Kmiecik (2000).

2.5.3. Titrable acidity : Eheart and Odland (1973) observed significant increase in total acidity of beans and sprouts during the storage period of six months at –18°C.

Chen (1986) found that quality parameter i.e. acidity remained constant after freezing in frozen fruits and vegetables.

2.5.4 Total microbial count : The count of microorganisms in the vegetables is likely to reflect the sanitary quality of the processing steps and the microbiological condition of the raw product at the time of processing.

Vegetables should not contain more than 50,000 microbes per gram of peas, 60,000 in case of corn and 100,000 in case of string beans at the time of freezing. Frozen vegetables should not contain more than 100,000 microbes per gram and fruits fewer than vegetables (Frazier, 1967).

According to Adams (1981), blanching was essential to reduce microbial count of the vegetables. The numbers were reduced, usually to less than 1000 per gram. Without such reduction, there was a possibility of introduction of high level of microbial enzymes leading to the loss of quality during storage of the frozen product.

Baardseth and Slinde (1983) observed that unblanched sample of carrot had a total count of 3.5 x 10^3 cfu/g. Further, the total count was reduced in the heat-treated samples to 50 per cent of the initial value.

Microbiological analysis was carried out by Gola *et al* (1990) on 102 samples of frozen vegetables obtained from an Italian market. About 94 per cent of the sampless had total count of less than 10^6 cfu/g.

Aguado *et al* (1997) used three different methods to isolate Listeria monocytogens from 110 food samples (89 frozen vegetables, 54 cooked meat products and 27 smoked salman samples) obtained from retail outlets. The incidence of L. monocytogens in smoked salman was 44.4 per cent whereas in frozen vegetables and cooked products, it was much lower (2.2 and 5.5 per cent, respectively).

Microbiological quality of samples of frozen broccoli, artichokes and spinach was assessed by Senturk (1997). Data were taken for counts of total aerobic mesophiles, total and faecal coliforms, staphylococcus aurens, faecal streptococci, salmonella, psychrotropic bacteria, clostridium perfringens, *E.coli*, yeasts and filamentous fungi. None of the samples contained salmonellae or *C. perfringens*. Excessive counts of yeasts were found in frozen spinach and artichoke.

Chang and Chen (1999) blanched samples of broccoli, mustard, spinach green, cabbage and water spinach at various optimized conditions i.e. at 100°C in water for 20, 30, 40, 50 and 60 seconds, respectively. The conditions resulted in a total aerobic microbial count of less than 10^3 cfu/g in all frozen vegetable prepared from blanched samples.

Gomez *et al* (2002) studied the effect of primary processing on microbial load of cauliflower and fenugreek. The results showed that washing of vegetables reduced the microbial load. Shrink-wrapping and storage at low temperatures resulted in further lowering of microbial growth as compared to unwrapped samples stored at ambient temperature.

Khalilur *et al* (2002) studied the microbiological quality of milk, vegetables and fruit juices. The scientists found that total viable count in vegetables was in the range of 1690×10^6 to 16000×10^6 cfu/100g. The mean staphylococcal count was 138×10^6 cfu/100g. Total coliforms detected in all the food samples were in the range of 1600 to $\geq$ 2400 MPN/100 ml. Salmonella and Shigella were not detected in any of the food samples.

2.6 Effect of frozen storage on nutritional characteristics

2.6.1 Proximate composition : Adams (1981) reported a loss of three and 12 per cent in the protein content during three minutes water blanch process in whole green beans and peas, respectively whereas no significant change in protein content during the commercial blanching operation of peas was observed (Lee *et al* 1982a).

Amaro *et al* (1988) investigated the effects of frozen storage (at -18°C for 45 and 90 days) on mineral contents (Ca, Cu, Fe, K, Mg, Mn, Na, P and Zn) of white asparagus (*Asparagus officinalis*). Statistically significant differences were observed during frozen storage in Cu, Fe, K and Mn concentrations but Zn, Ca, Mg, Na and P levels did not show any significant change.

Eskin (1989) on the other hand observed that steam blanching under ideal conditions caused a loss of about five per cent of the total solids which is likely to be reflected in the concentration of total ash content also.

Hugo *et al* (1989) observed no change in ash content when green beans were blanched in boiling water.

Latunde (1990) analysed 12 Nigerian local vegetables for iron content. It was reported that blanching resulted in the loss of total iron ranging from 14.1 to 45.4 per cent while squeeze-washing resulted in 15.3 to 64.4 per cent losses.

Polo *et al* (1991) studied the effect of freezing on the mineral (Ca, Mg, Cu, Mn, Ni, Zn etc.) composition of green beans and peas. Minerals were measured in fresh and frozen stored (-18°C for 7 week) samples. Statistical analysis of the data revealed that the copper losses due to freezing were significant ($P \leq 0.01$) in green beans and peas. However, there was no significant loss in the mineral content of vegetables during frozen storage. Total fibre content also decreased after milder processing, such as blanching due to loss of soluble dietary fibre, such as pectic polymers (Svanberg *et al.,* 1997).

Bognar *et al* (1998) observed that boiling and steaming of vegetables reduced the mineral content by 25-50 per cent whereas frozen storage of 12 months at –20°C had no effect on total nitrogen, dietary fibre and ash content of frozen tomato cubes (Lisiewska and Kmiecik, 2000).

2.6.2 Total Sugars : Adams (1981) reported a loss of three and 20 per cent in the total sugars during three minutes water blanch process in whole green beans and peas, respectively.

Skrede (1983) demonstrated that changes in sugar content of defrosted strawberries were a consequence of invertase enzymes rather than sucrose synthase or acid hydrolysis. These results indicated the presence of active enzymes in frozen and defrosted fruits (that had not been blanched, such as strawberry), which can cause chemical degradation during frozen storage and even more while thawing.

Hugo *et al* (1989) observed that reducing sugars and starch levels of frozen green beans were slightly reduced during storage period of 60 days.

Michalik and Hallas (1991) studied the freezing quality of different varieties of carrots and found that there was no difference in the content of sugars in fresh, blanched and frozen samples of various varieties. Oruna-Concha *et al* (1996) reported that the sugar content was unaffected by frozen storage at $-22^{o}C$ upto 12 months. Similar results have been repoted by Lisiewska and Kmiecik (2000).

2.6.3 Pectin : Texture of frozen vegetables is considered to be an important factor in product quality. Pectic polysaccharides, which are abundantly found in the primary wall and the middle-lamella between cells are primarily responsible for the texture of vegetables (Jarvis, 1984).

The effect of tunnel steam blanching followed by freezing and frozen storage was examined by Carr (1984). He reported that the amount of water-soluble pectin in cell wall increased with increased blanching time. A possible entrapment of pectin by gelatinised starch was suggested.

Sajjaanantakul (1986) observed that total pectin in frozen peaches decreased with increase in frozen storage time. The major change was found in alkaline soluble pectin fraction, which was the main component of the peach pectin.

Fuchigami *et al* (1995) reported that quick freezing was effective in improving texture of frozen carrots. Loss in texture was accompanied by release of pectin. Slow freezing accelerated release of pectin as compared to quick freezing.

Pectin content in green beans and pepper was unaffected by blanching and frozen storage at $-22^{o}C$ for 12 months (Oruna-Concha *et al.,* 1996). On the other hand, a higher pectin content in the frozen and blanched frozen carrots than in the raw and blanched carrots has been reported by Prestamo *et al.* (1998).

Statistically significant reduction was detected by Lisiewska and Kmiecik (2000) in concentration of pectin during storage of frozen tomato cubes. Following 12 months of storage at $-30^{o}C$, the pectin content was 28 per cent of the initial level.

Roy *et al* (2001) studied the impact of blanching and freezing conditions on firmness retention and ultra structural changes in the cell wall and middle lamella of carrot tissues. Extensive degradation of cell wall pectins was reported. High-temperature short time (HTST) blanching resulted in firmer texture than LTLT blanching. Further, freezing at rapid rates showed less softening than slow rates

2.6.4 Fibre fractions : Herranz *et al* (1981) analysed 22 raw and 19 cooked spanish vegetables for different fibre fractions. The results indicated that with the exception of carrots and potatoes, all the vegetables showed an increase in the NDF, ADF and hemicellulose values after boiling. In 1983, Herranz *et al* again reported that the frozen vegetables, on boiling resulted in an increase in the NDF, ADF and cellulose contents of spinach, green beans and peas. Similar results have been reported by Sadana (1984) and Mann *et al.* (1992).

Chen (1986) studied the impact of freezing time on quality improvement of frozen fruits and vegetables. He reported that the fibre content increased during frozen storage for five months.

The influence of microwave blanching on dietary fibre in green beans was investigated by Svanberg *et al* (1997). It was found that total fibre content decreased only after the most severe microwave treatment primarily due to the loss of soluble dietary fibre (pectic polymers).

2.6.5 β-Carotene : Park (1987) evaluated the effects of freezing, thawing, cooking and drying on carotene retention of carrots, broccoli and spinach. Fresh and microwave dried samples of carrots, broccoli and spinach had carotene content as 989, 459, 368 and 455, 325, 315 μg/g, respectively. Microwave cooking retained slightly more carotene than the conventional cooking. Even blanching at 95°C resulted in markedly more retention of carotenoid than blanching at 70°C or absence of blanching in case of frozen French beans (Bubicz *et al.,* 1990).

Effects of processing on α and β-carotene content in carrot juice products were investigated by Bao and Chang (1994). Fresh carrot juice from unblanched carrots had better β-carotene retention of 59 per cent whereas juice from blanched carrots had 42-50 per cent retention. Steam blanching reduced β-carotene content in carrots and broccoli by about 15 per cent (Howard *et al.,* 1996). However, the carotene retention in carrots was better when blanching was done by microwave as compared to steam blanching (Kidmose and Martens, 1999).

Sungpuag *et al* (1999) analysed various recipes consumed in North-east Thailand and found that blanching resulted in 7 to 11 per cent losses of β-carotene in vegetables. Statistically significant reduction was detected in the concentration of carotenoids, β-carotene and lycopenes during storage of frozen tomato by Lisiewska and Kmiecik (2000).

Kaur and Kapoor (2001) also repoted higher retention of total carotenoids on microwave blanching, 88 per cent being in carrots and 76 to 79 per cent in French beans, while HTST and LTLT showed 34 and 42 per cent retention, respectively in French beans.

2.6.6. Ascorbic acid : Changes in ascorbic acid (AA) content during post harvest handling, processing and storage have been reported by many workers. As early as 1945, Van Duyne and Co-workers (1945) established that 15 to 20 per cent of AA was lost during blanching and AA content gradually decreased during nine months of frozen storage. Because of its lability, AA is routinely used as an index to measure processing effects on nutrient retention (Erdman and Klein, 1982; Klein and Perry, 1982; Vanderslice *et al*, 1990).

Hudson *et al* (1974) analysed AA of defrosted sprouts blanched in 1.2 per cent NaCl/sucrose separately and showed that the treatments did not lower the ascorbic acid content.

Quick frozen peas retained about 80 per cent of the original AA content. Cooking caused a further loss of AA, so that at the point of consumption, the frozen peas retained approximately 55 per cent of this nutrient found in the fresh vegetables (Morrison, 1974).

Desrosier and Tresseler (1977) found that cauliflower retained 80 per cent of its ascorbic acid when it was frozen and 60 per cent after six months of frozen storage. In case of peas blanching caused a loss of 33 per cent AA. Selman (1978) also reported 9.6-27.7 per cent loss of AA in different varieties of peas after blanching for one minute at 97°C in water. On the other hand, there was no loss of AA in green beans. The analysis of beans showed that the ascorbic acid was concentrated in the seeds which were protected by the pod (Cumming *et al.*, 1981).

Quenzer and Burns (1981) demonstrated that microwave blanching was superior to water and steam blanching regarding the retention of AA in spinach. Microwave blanching induced coagulation of protoplasmic material surrounding the cell walls, thus keeping the cell structure intact and thereby yielding a superior product.

Lee *et al* (1982a) have also reported that blanching significantly reduced the AA content of peas, the extent depending upon the blanching method. Further, Burger (1982) reported that the frozen storage of green beans and peas at –18°C for 12 months resulted in 52 and 11 per cent loss of AA, respectively.

Muftugil (1985) compared microwave blanching of green beans with conventional method of blanching and found that retention of ascorbic acid was highest with microwaves (14.2 mg/100g), followed by water (13.44 mg/100g) and steam (12.92 mg/100g), the losses being 9.3, 14.2 and 17.5 per cent, respectively.

Chen (1986) found that vitamin B-complex and ascorbic acid decreased while the fibre content increased during frozen storage (5 months) of fruits and vegetables.

Halpin and Lee (1987) reported that ascorbic acid content of fresh green peas (blanched at various times/temperatures and stored at –23°C) decreased gradually during three months of storage period.

Another study was conducted by Aparicio-cuesta and Garcia-Moreno (1988) on changes occurring in AA content in frozen cauliflower stored under different conditions. During storage at –22°C, 25 per cent ascorbic acid was lost after 13 months and 62.2 per cent after 30 months.

Changes in vitamin C content were studied in frozen cauliflower by Aparicio *et al* (1989). During storage at –22°C, AA was retained for a long duration, the loss being 32.6 per cent after 30 months whereas storage at –18°C resulted in only 24 per cent loss of AA after 60 days.

Mallet (1993) illustrated that there was little loss of ascorbic acid in peas at the usual storage temperature of –18°C and presumably less at lower temperatures but a much more rapid loss at –12°C.

Microwave energy alone or in combination with steam in the blanching process improved the ascorbic acid retention and gave better sensory characteristics in spinach (Ponne *et al* 1994).

Selman (1994) observed vitamins in frozen vegetables. During frozen storage, AA was fairly stable over a period of one year at temperature below –20 and –25°C and a loss of 10 per cent was expected. At temperatures of –25 to –30°C and below, practically no losses were expected. However, at elevated temperature of around –10°C loss of 80-90 per cent of AA occured after storage for one year.

Howard *et al* (1996) reported that ascorbic acid level decreased linearly by about 10 per cent per week during storage of carrot, broccoli and corn at 4°C for 3-12 weeks. Ascorbic acid losses fell by about 30, 50 and 10 per cent, respectively after steam blanching.

Katsaboxakis and Papanicolaou (1996) studied changes in L-ascorbic acid during quick freezing of raw and blanched okra, beans and raw cut red pepper. The results revealed that vitamin B-complex and AA decreased while fibre content increased during frozen storage of five months.

Lisiewska and Kmiecik (1996) studied the effects of processing conditions and period of storage on AA retention in frozen broccoli and cauliflower. During blanching, AA was reduced by 41-42 per cent and 28-32 per cent, respectively. Freezing resulted in little change of the AA content which was 15-18 per cent in broccoli and 6-13 per cent in cauliflower during frozen storage. After 12 months of storage, the level of AA was

4.9 – 57.4 mg in broccoli and 38.5 – 41.9 mg per 100 g in cauliflower, being slightly igher at storage temperature of –30°C than at –20°C.

Favell (1997) compared the AA content of fresh and frozen vegetables. The utrient status of frozen whole green beans and carrots with no loss on freezing (stored leep frozen for upto 12 months) was similar to the fresh vegetables at harvest.

Howard *et al* (1999) reported that steam blanching resulted in AA loss, but etention remained stable after freezing broccoli and green beans. Linear decrease in AA vas found in most frozen vegetables stored at –20°C upto one year.

Loss of AA during blanching of different vegetables ranged from 10-20 per cent nd some times even more depending upon the nature, maturity time, temperature and nethod of blanching. No loss of AA was observed in 41 weeks storage at –40°F (Pruthi, 999).

Kaur and Kapoor (2001) reported that microwave blanching of French beans ccounted for maximum AA retention (76 per cent) as compared to mixed blanching LTLT/HTST both i.e. at 70°C for 30 minutes followed by a second blanch in boiling vater for three minutes) LTLT and HTST showed 69, 42 and 34 per cent retention espectively. Similar trend was observed in carrots. Higher losses in HTST method night be attributed to leaching losses due to high temperature.

Premavalli *et al* (2001) also observed 24.5 and 9.48 per cent losses of AA, espectively when spinach and fenugreek were blanched.

Nursal and Yucecan (2001) examined commercially cooked frozen spinach, peas, green beans and okra with or without initial thawing and evaluated AA losses. Frozen peas were least affected and frozen beans the most after thawing (3.5 and 19.6 per cent AA losses, respectively). In order to minimise AA loss, it was recommended that frozen vegetables should be cooked without thawing, with the minimum amount of water.

2.7 Effect of frozen storage on Organoleptic characteristics

Lee (1970) assessed the freezing effects on the texture of peas. It was found that quick frozen peas had firmer texture than conventional frozen peas, but cooking reduced the differences to insignificance.

Colour, flavour, texture, odour and overall acceptability of microwave blanched and 2 minute water blanched green beans after 3 and 6 months of frozen storage were assessed by Gullet *et al* (1984). All microwave treated samples had less typical bean flavour and more off-flavour or odour along with lower overall acceptability than the water blanched samples.

Halpin and Lee (1987) blanched fresh green peas for various times/temperatures and stored at $-23^{o}C$. Their sensory evaluation indicated a gradual loss of quality due to poor flavour in the long time/low temperature blanched samples.

Eskin (1989) estimated the time required at various temperatures to reach a perceptible change in flavour and colour of frozen peas. He reported that samples stored at $0^{o}F$ changed colour after 7 months and flavour after 10 months. However, frozen peas stored at $10^{o}F$ ($-12^{o}C$) changed colour after only 1.5 months and flavour after 2 months.

Pruthi (1989) concluded that the frozen foods had better nutritive value, flavour, colour and appearance than the corresponding food preserved by any other processing technique like canning, bottling or dehydration. This has been visualized from the comparative quality data based on sensory evaluation by the experts.

Hung and Thompson (1989) examined the effect of freezing and frozen storage on texture of cooked frozen vegetables. They found that peas frozen by a Freon-12 Immersion method with no appreciable damage to cell structure had firmer and more chewy sensory textural quality compared to those frozen by a slow freezing method.

Blanching and freezing effects were focused on the microscopic structure of carrots by Prestamo *et al* (1998). The firmness of the frozen samples decreased by about 50 per cent as compared to the raw samples. However, in the blanched samples, the firmness was reduced by only 21.5 per cent as a result of gel formation due to the impact of heat on the pectic substances. Both the treatments together reduced the firmness slightly but freezing process caused the maximum softness in the tissue.

Collins *et al* (1995) evaluated the sweet potato samples stored at–17^{o}C after 2 and 6 months. They found that the sensory attributes of formed and frozen baked sweet potato products were acceptable to the sensory panel.

From the review cited above, it was seen that a large number of studies have been conducted on preparation, blanching, freezing and frozen storage of vegetables like peas, beans and carrots in the developed countries. On the other hand, very little work has been done on preservation of vegetables by freezing in India. The freezing of okra, capsicum and French beans in India has not received adequate attention although okra is a vegetable of considerable economic and culinary importance. Now a days capsicum and French beans are used in *Pulaos*, soups, mixed vegetables, *samber* etc. throughout the year. But these vegetables become costly in off-season. Punjab state has the necessary potential for development of processing of vegetables by frozen storage. Keeping this in view, the present study has been planned.

CHAPTER-III

MATERIALS AND METHODS

CHAPTER – III

MATERIALS AND METHODS

The study was undertaken to evaluate the organoleptic and nutritional quality of three popular summer vegetables i.e. Lady's finger/okra (*Abelmoschus esculentus* L.), French beans (*Phaseolus vulgaris* L.) and capsicum/peppers sweet (*Capsicum annum* L.). The vegetables were frozen at PAGRO FOODS LTD., Fatehgarh Sahib, Punjab and the nutritional and organoleptic evaluation of the frozen vegetables were carried out in the Department of Food & Nutrition, Punjab Agricultural University, Ludhiana. To put this planned study into action, the following material and methods were used:

3.1 Procurement of vegetables

3.2 Preparation of vegetables

3.2.1. French beans

3.2.2. Okra

3.2.3. Capsicum

3.3 Blanching

3.4 Freezing

3.5 Packing and storage

3.6 Transportation of frozen samples

3.7 Sampling

3.8 Quality characteristics

3.8.1. Total solids

3.8.2. pH

3.8.3. Titrable acidity

3.8.4. Total microbial count

3.8.5. Peroxidase enzyme test

3.9 Nutritional characteristics

3.9.1. Proximate composition

3.9.2. Total sugars

3.9.3. Pectin

3.9.4. Fibre fractions

3.9.5. β-carotene

3.9.6. Ascorbic acid

3.10 Recipes using frozen vegetables

3.10.1. French beans-potato

3.10.2. French bean – potato fry

3.10.3. Okra-onion

3.10.4. Okra fry

3.10.5. Stuffed capsicum

3.11 Organoleptic evaluation

3.12 Statistical analysis

3.1. Procurement of vegetables

Two vegetables i.e. French beans and capsicum were purchased from the local market at their peak maturity stage, packed in gunny bags and immediately transported to the processing unit. Okra was procured directly from the farm packed in plastic crates and transported in a truck to the processing plant in the month of July, 2002.

3.2. Preparation of vegetable

Prior to freezing, vegetables were washed and prepared as under:

3.2.1. French beans : Long, straight, tender and stringless pods of green colour were selected. Diseased and insect bitten beans and other foreign materials were removed. The beans were washed while stems and ends from the pods were snipped off. The beans were cut into 1.0 cm and 6.0 cm long pieces.

3.2.2. Okra : Small and large (6-8 inches long) sized tender green pods were selected and washed. Their stems and ends were cut off. The large pods were cut into rings and the smaller pods were slitted length wise in the centre.

3.2.3. Capsicum (sweet pepper) : The dark green medium sized, with glossy skin and thick flesh, firm pieces of capsicum were selected, washed thoroughly and then were cut into halves. The seeds and stems were removed.

3.3 Blanching

Different combinations of temperature and time were tried for determining the optimum combination for the blanching process for the selected vegetables (Table 3.1).

Table 3.1 Effect of water blanching on peroxidase activity and texture of vegetables

Time/ Temp	French bean (1.0 cm)		French bean (6.0 cm)		Okra rings		Okra trimmed		Capsicum halves	
	PA	Texture	PA	Texture	PA	Texture	PA	Texture	PA	Texture
2 min										
85 °C	+ve	Retained	+ve	Retained	+ve	Retained	+ve	Retained	+ve	Retained
90 °C	+ve	Retained	+ve	Retained	+ve	Retained	+ve	Retained	-ve	Lost
95 °C	+ve	Retained	+ve	Retained	+ve	Retained	+ve	Retained	-ve	Lost
100 °C	-ve	Lost	-ve	Lost	-ve	Lost	-ve	Lost	-	-
At 95°C										
1.0 min	+ve	Retained	+ve	Retained	+ve	Retained	+ve	Retained	+ve	Retained
2.0 min	+ve	Retained	+ve	Retained	+ve	Retained	+ve	Retained	-ve	Lost
3.0 min	-ve	Lost	+ve	Retained	-ve	Lost	+ve	Retained	-	-
4.0 min	-	-	-ve	Lost	-	-	-ve	Lost	-	-

PA : Peroxidase activity

It was found that there was no activity of peroxidase enzyme after blanching at 95°C for 2 min in capsicum and 100°C for 2 min in French beans and okra. However, the texture of blanched vegetables was adversely affected. It was further observed that there was no effect on the texture of the blanched vegetables at 85°C for capsicum and 95°C for French beans and okra for 2 min time but there was a little activity of peroxidase enzyme. Therefore, this optimum combination was selected at which there was a balance between texture and peroxidase activity. Hence capsicum was blanched at 85°C for 2 min, and French beans and okra at 95°C for 2 min. A number of studies have shown that a little activity of peroxidase enzyme did not have any adverse effect on quality of frozen vegetables. Baardseth (1977) found that 5 per cent residual activity of peroxidase in frozen french beans, carrots and cauliflower did not affect the quality during frozen storage. According to Adams (1981), some activity of peroxidase may be left in many vegetables after blanching and a long shelf life in frozen storage could still be achieved. Williams *et al* (1986) indicated that lipoxygenase rather than peroxidase was responsible for off-flavour development in the frozen vegetables and that lipoxygenase was lost in about half of the heating time required for complete loss of peroxidase activity. The lipoxygenase has very low measurable activity in fresh products which makes this enzyme less suitable as a blanching indicator. So, peroxidase activity has been used as an index of blanching (Muftugil, 1985).

3.4 Freezing

Freezing of vegetables was done in a fluidized bed freezer. The vegetables from the blancher were transferred to a moving stainless steel wire mesh belt conveyer. The

French beans, okra and capsicum were subjected to an upward cold air stream (approximately at –40°C) of high velocity. The pieces of vegetable were floated in air, separated from each other and were free to move upwards and the mass of vegetable pieces behaved like a fluid. The freezing process was completed in 3-6 minutes. The freezing of vegetables was done in the month of July, 2002.

3.5. Packing and storing

The vegetables were packed and sealed in polythene bags of one kg capacity and then in polythene coated cartons and kept in the cold storage room whose temperature was maintained at –20 to -25°C.

3.6. Transportation of frozen samples

The frozen stored samples were transported from the PAGRO LTD, Fatehgarh Sahib to the department of Food & Nutrition, Punjab Agricultural University, Ludhiana, also early in the morning, in an insulated ice-box that was cooled with dry ice.

3.7. Sampling

The samples were taken fresh, immediately after blanching, immediately after freezing and after two, four and six months of frozen storage (i.e. September, November and January) for organoleptic, quality characteristics and nutritional evaluation. For organoleptic evaluation, fresh vegetables available in the market at that time were compared with the frozen ones. The fresh samples of vegetables for comparison with blanched and frozen (0 month) samples were of the same variety but in the months of September, November and January, the fresh samples available in the local market irrespective of the variety were used. The coding of samples was as follows:

Market fresh, I, II and III were market fresh samples available in the month of September, November and January, respectively. Frozen stored 0, I, II, III are frozen stored samples after 0, 2, 4 and 6 months of storage period, respectively.

3.8. Quality characteristics

3.8.1. Total solids : These were determined as per method given by AOAC (1985).

3.8.2. pH : It was determined as per method given by AOAC (1985).

3.8.3. Titrable acidity (AOAC, 1985)

Principle: Titrable acidity was measured as anhydrous citric acid by titration against standard NaOH solution using phenolphthalein as an indicator.

Reagents 1. 0.1N NaOH

2. 1% Phenolphthalein in absolute alcohol.

Preparation of sample : The sample was pulped in mortar and mixed thoroughly. The pulped material was weighed, glass-distilled water was added and boiled for one hour. The water lost by evaporation was replaced. It was cooled and transferred to a volumetric flask and made up to volume with glass-distilled water. Filtered if necessary.

Procedure : Diluted an aliquot of the sample prepared above with glass-distilled water. Titrated with 0.1N NaOH solution using a few drops of 1% phenolphthalein solution as indicator. Titre value was noted and calculated as per cent anhydrous citric acid using the following formula:

$$\% \text{ Total acid} = \frac{\text{Titre x Normality of alkali x Total vol. made x Eq.wt. of acid}}{\text{Volume of sample x Wt of sample taken}} \times 100$$

3.8.4. Total microbial count : The total microbial count of the vegetable samples was measured by 'Pour plate' method as given by Cruickshank (1969). Three replications were taken for total bacterial count for each of the fresh and frozen vegetable samples. Four to five fold dilutions of vegetable samples were made in normal saline to facilitate colony counting. One gram of sample was taken at regular intervals at room temperature and was transferred to a 9 ml sterile saline blank near the burner flame and was shaken well and further dilutions upto 10^{-5} were prepared. One ml of the desired dilution was then plated in a petri plate to which 20 ml of molten nutrient agar was added and closed immediately with lid. These petri dishes were rotated gently to mix the samples thoroughly in the nutrient agar. Then these plates were allowed to solidify, after which the plates were inverted and incubated at 37°C for 24-48 hours. The colonies obtained on the nutrient agar media were counted manually. The average counts of the three plates were expressed as colony forming units (cfu).

3.8.5. Peroxidase enzyme test (Ranganna, 1995)

Principle: Peroxidase oxidize dihydroxyphenols in the presence of H_2O_2 forming quinines which are coloured compounds.

Reagents: 1. 0.08% H_2O_2 : Diluted 2.8 ml of 30% H_2O_2 with water and stored in a dark bottle in a refrigerator prepared fresh every week.

2. 0.5% Guaiacol in 50% ethyl alcohol.

Procedure : The sample (10 g) was ground in a mortar with 30ml glass-distilled water added in small portions. The mixture was filtered through cotton gauze. To 2.0 ml of the filterate, 20 ml of distilled water was added in a test tube and mixed. Then 1.0 ml of 0.5 per cent guaiacol solution was added followed by 1.0 ml of 0.08 per cent H_2O_2 solution and mixed thoroughly. If no colour appeared in 3.5 minutes, the test was considered to be negative and the product was adequately blanched. In case, the test was positive, the colour appeared within 3.5 minutes. If the colour was developed after 3.5 minutes, the test was still considered negative. A blank was prepared without the addition of guaiacol and H_2O_2.

3.9 Nutritional characteristics

3.9.1. Proximate composition : Moisture, crude protein, total ash, crude fat and crude fibre were determined as per methods given by AOAC (1985). Available carbohydrates were calculated by adding the above mentioned proximate principles and subtracting the total from 100.

3.9.2. Total sugars : The total sugars were estimated by the phenol-sulphuric acid method of Dubois *et al* (1956).

Principle : The sulphuric acid reacts with sugars to produce hydroxy methyl furfural and furfural further reacts with phenol to yield coloured, condensed product that can be read at 490 nm.

Reagents

1. 95.5% sulphuric acid
2. 5% phenol in glass-distilled water
3. Standard glucose solution
4. Saturated solution of lead acetate in water
5. 80% ethanol
6. 70% ethanol
7. Sodium oxalate

Preparation of sample : One gram of the dried ground sample was taken in a 100 ml conical flask. The sugars were extracted twice with 50 ml of 80% ethanol followed by complete extraction (four times) with 70% ethanol by refluxing on a boiling water bath for 30 min each time. The contents in the flasks were stirred occasionally. The combined alcoholic extract of each sample was concentrated to aquous syrup on a boiling water bath. The last traces of concentrated sugar solution was quantitatively transferred to a 100 ml volumetric flask and the volume raised to about 98 ml with distilled water. One ml of saturated water solution of lead acetate was added to remove proteins and the volume made to 100 ml. The contents were filtered through Whatman No.1 filter paper and the excess of lead ions were eliminated from the filterate by the addition of sodium oxalate crystals followed by filtration. The clear extract so obtained was then used for the estimation of free sugars.

Procedure : For the determination of total sugars, 0.2 ml of the test extract was taken in each test tube and volume made to 1 ml. Glucose standards (10-60 μg) and blank were taken simultaneously. After adding 1 ml of 5% phenol to each test tube, the tubes were placed in ice-cold water and 5 ml of 95.5% sulphuric acid was added swiftly, the stream of acid being directed against the liquid surface rather than against the side of the test tube to obtain good mixing. The contents were mixed and brought to room temperature. The absorbance of pink colour developed was read at 490 nm in a Bausch and Lomb spectrophotometer-20. The concentration of total sugars from the test extract was then calculated in terms of glucose from the standard glucose curve (Figure I).

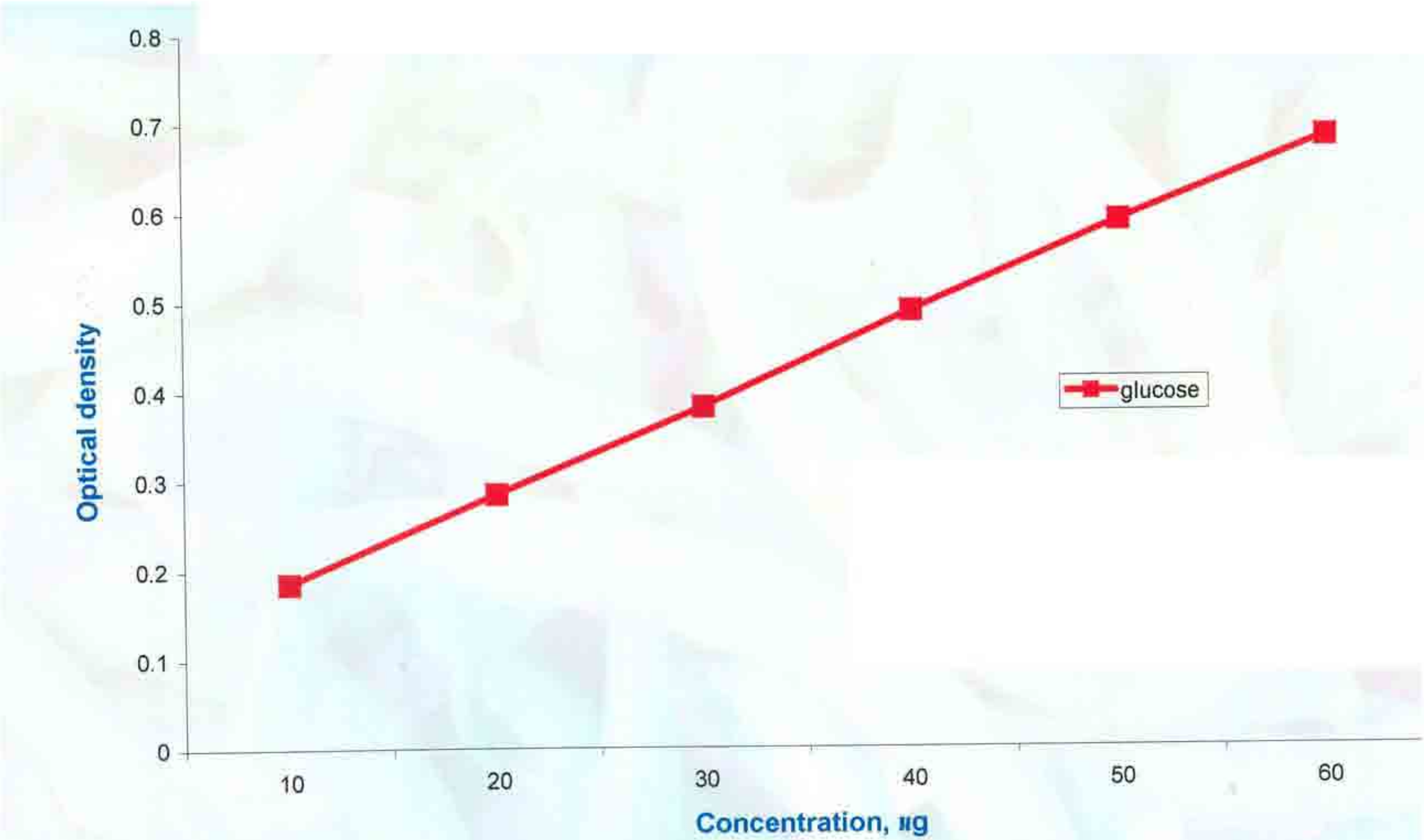

Fig 1 Standard curve of glucose

3.9.3. Pectin (Ranganna, 1995)

Principle: Pectin extracted from plant material is saponified with alkali and precipitated as calcium pectate from an acid solution by the addition of calcium chloride. The calcium pectate precipitate is washed until free from chloride, dried and weighed.

Reagents

1. 1 N Acetic acid (approximate) : Diluted 30 ml of glacial acetic acid to 500 ml with water.
2. 1 N calcium chloride (approximate) : Dissolved 27.5 g of anhydrous $CaCl_2$ in water and diluted to 500 ml.
3. 1% silver nitrate: Dissolved 1 g of $AgNO_3$ in 100 ml of water.
4. 0.05N HCl
5. 1N NaOH

Procedure : Fifty gram of blended fresh sample was extracted with 400 ml of 0.05N HCl for 2 hours at 80-90°C. The water lost by evaporation was replaced. The contents were transferred into a 500 ml volumetric flask and made up to the mark with water. The contents were shaken and filtered through No.4 Whatman paper into a 500 ml conical flask.

Aliquots of about 100 ml were pipetted into each of the three 1000 ml beakers and 250 ml of water were added. The acid was neutralized with 1N NaOH using phenolphthalein as indicator. Now added 100 ml of 1N NaOH with constant stirring. The solution was allowed to stand overnight. Then, 50ml of 1N acetic acid were added and after 5 minutes, 25 ml of 1N $CaCl_2$ solution were added with constant stirring. After one hour, it was boiled for 2 minutes. It was filtered through a previously treated filter paper (filter paper was made wet in hot water, dried in oven at 102°C for 2 hours, cooled in a desiccator and weighed in a cover dish). The precipitate was washed with water that was almost boiling until free from chloride. It was tested using silver nitrate. The filter paper containing the calcium pectate was transferred to the original weighing dish, dried overnight at 100°C, cooled in a desiccator and weighed.

Calculations

$$\text{Calcium pectate (\%)} = \frac{\text{Wt. of calcium pectate x 500 x 100}}{\text{ml of filterate taken for estimation x wt. of sample}}$$

3.9.4. Fibre fractions : Neutral detergent fibre was determined by the method of Goering and VanSoest (1970).

Principle : Neutral detergent solution (NDS) solublizes all the components except neutral detergent fibre (NDF) of food. Acid detergent fibre (ADF) is treated with acid detergent solution (ADS) in which hemicellulose is solubilized. The residue (ADF) consists of cellulose and lignin.

3.9.4.1. Neutral Detergent Fibre (NDF)

Reagents 1. Neutral Detergent Solution (NDS): 18.61g ethylene diamine tetra-acetic acid dihydrate and 6.81g disodium borate decahydrate ($NaB_4O_7.10H_{20}$) were dissolved in distilled water and heated to dissolve the reagents. To this solution 30g sodium lauryl sulphate and 10ml of 2-ethoxy ethanol were added. Then 4.51g of disodium hydrogen orthophosphate (anhydrous) was dissolved in distilled water and mixed with above solution. The pH of the solution was adjusted to 7.0 ± 0.1. Volume was made to one litre with distilled water.

2. Acetone

3. Sodium sulphite (Na_2SO_3)

Procedure : Moisture and fat free ground sample (0.5 g) was taken in refluxing beaker having 100 ml NDS and 0.5g of sodium sulphite (Na_2SO_3). The contents were boiled under controlled conditions to an even level of liquid for 60 minutes. The contents were filtered through sintered glass crucible-Grade 0 under low suction. Finally, the contents of the beaker were rinsed into the crucible with minimum of hot water to clear soapiness. The washing with hot water was repeated. The residue was finally washed with acetone twice in the same way.

The crucible was dried in hot air oven at 100 ± 2°C for 8 hours. It was then transferred to a desiccator, cooled and weighed. Then, it was ignited in a muffle furnace at 500-550°C for 3 hours and cooled to room temperature in a desiccator and reweighed.

$$\text{NDF, \%} = \frac{\text{Loss in weight of crucible after ignition (g)}}{\text{Weight of the sample}} \times 100$$

3.9.4.2. Acid Detergent Fibre (ADF)

Reagents 1. Acid detergent solution (ADS): Dissssoslved 20g of cetyl trimethyl ammonium bromide in one litre of 1N sulphuric acid.

2. Decalin

3. Acetone

Procedure : Moisture and fat free ground sample (0.5g) was taken in a spoutless beaker of 600 ml capacity to which 100 ml of ADS and 2 ml of decalin were added. The contents were refluxed for 60 minutes. Foaming on boiling was avoided by adjusting heat to an even level. This was filtered through sintered glass crucible-grade 0 under light suction.

The residue as well as sides of the crucible were washed twice with hot water to clear soapiness (90-100°C). The residue was then washed with acetone until clear filterate was obtained.

The crucible was dried in hot air oven at 100 ± 2°C for 8 hours. Then it was cooled in the desiccator and weighed. The sample was ignited in a muffle furnace at 500-550°C for three hours. The crucible was transferred to the desiccator, cooled and reweighed.

$$\text{ADF, \%} = \frac{\text{Loss in weight of crucible after ignition (g)}}{\text{Weight of sample (g)}} \times 100$$

3.9.5. β-carotene (Rao, 1967)

Reagents and materials

1. 12 per cent potassium hydroxide: Prepared 60% KOH in distilled water and combined with ethanol/distilled alcohol in the ratio of 1:5 and used immediately.
2. Ethanol
3. Calcium carbonate
4. Petroleum ether (60-80°C)
5. Three per cent acetone in petroleum ether
6. Aluminium oxide (active)

7. Anhydrous sodium sulphate

8. Glass wool

9. Glass pieces

Preparation of sample : The fresh sample (5g) was finely ground using glass pieces. Mixed with 25 ml of KOH solution and allowed to stand overnight for sponification. Added a spatula of calcium carbonate and vortexed. Then added 30 ml petroleum ether and again vortexed for 5 minutes. Allowed the separation of two layers and removed the top layer into a separating funnel. This was repeated till the solvent layer was colourless. All the extracts were pooled into separating funnels. Added 50 ml water, shook and discarded the water layer. This was repeated till solvent was free of KOH. This was tested with a litmus paper. Petroleum ether extract was filtered through a funnel plugged with glass wool and followed by adding anhydrous sodium sulphate into a conical flask and finally washed with 20-25 ml of petroleum ether. Combined all the extracts and measured the volume. It was kept overnight and concentrated by evaporation.

Packing of the column : The glass column was packed with aluminium oxide (active) by making a slurry with petroleum ether. Added 1-2 g anhydrous sodium sulphate on the top of the packed column.

Separation of β-carotene : The column was charged with 5-10 ml of the concentrated carotene extract which resulted in the development of coloured band. The coloured band was eluted with 3 per cent acetone in petroleum ether and collected as 5 ml fractions in test tubes and read the optical density (OD) in spectrophotometer at 450 nm.

Calculations : β-carotene (μg/100g) = Total volume charged in the column x Av.ODx4

$$= y\ \mu g$$

$$= \frac{\text{Total volume made x y x 100}}{\text{weight of sample}}$$

Note : 1 OD = 4 μg/ml of β-carotene.

3.9.6. Ascorbic acid (AA): Ascorbic acid was estimated colorimetrically as given by AOVC (1966).

Principle : The dye, which is blue in alkaline solution and red in acid solution, is reduced by ascorbic acid to a colourless form. The reduction is quantitative and practically specific for ascorbic acid in solution in the pH range of 1-3.5.

Reagents
1. Acetate buffer, pH – 4.0: Dissolved 300 g of anhydrous sodium acetate in 700 ml of water and added 1000 ml of glacial acetic acid.
2. 2,6-dichlorophenol indophenol dye solution: Dissolved 25 mg of sodium salt of 2,6-dichlorophenol indophenol in distilled water and finally made up the volume to 200 ml.
3. 6% HPO_3: Dissolved 60g of HPO_3 in distilled water and diluted to one litre.
4. Ascorbic acid standard – (1mg/ml): Dissolved 100 mg of pure ascorbic acid in 100 ml 6% metaphosphoric acid.
5. Xylene

Procedure : Weighed 5 g of fresh vegetable sample and placed in a mortar. Added 20 ml 6% HPO_3 and slowly ground to a slurry. Filtered through Whatman No.1 filter paper.

Added 30 ml HPO_3 to the residue and filtered again. Five separatory funnels (50 ml) were set and labelled as A, B, C, D and E wherein B was for blank and C for standard. Pippetted 5 ml of filterate into separatory funnels A, D and E. Pippetted 0.1 ml of standard ascorbic acid solution into funnel C and added 4.9 ml of 6% HPO_3. Pipetted 5 ml of 6% HPO_3 into separatory funnel B. Added 5 ml acetate buffer to all five funnels followed by 2 ml of dye solution and 10 ml of xylene solution quickly and shaken the contents for 5-10 sec. Allowed to stabilize into two layers. Discarded the water layer, transferred xylene layer into a test tube and read the optical density in a spectrophotometer at 500 nm.

Calculations

$$\text{Ascorbic acid content (X) mg} = \frac{0.1\,(b-a)}{(b-c)}$$

OD of blank = b

OD of sample = a

OD of standard = c

5 ml of filterate contain X mg

$$\text{50 ml of filterate contain } \frac{50 \times X}{5} = Y \text{ mg}$$

5 g sample contain Y mg

$$\text{100 g sample contain} = \frac{Y \times 100}{5} = \text{-------} \text{ mg/100g}$$

3.10 Recipes from frozen vegetables

Five different recipes standardized from the frozen vegetables were French beans-potato, French beans-potato fry, okra onion, okra fry, and stuffed capsicum vegetable. The ingredients used for the preparation of these dishes are given in Table 3.2. The methods of preparation of these vegetables are given below:

3.10.1 French beans-potato : Heated oil in a non-stick pan. Added omum, when it started splittering, added chopped onions and cooked till light golden brown. Added frozen beans along with salt, red chilli powder and turmeric powder and cooked till the vegetable was done.

3.10.2. French beans-potato fry : Frozen beans were kept in a plate at room temperature for 15 minutes. Then slitted lengthwise in the centre. Mixed griddle fry spice mixture with salt, red chillies and turmeric thoroughly. Filled a little spice mixture in each bean and closed it. Peeled potatoes and cut into fingers. Heated refined oil in a non-stick pan and added beans and potatoes. Stirred from time to time. Cooked on slow fire till done.

3.10.3 Okra-onion : Heated mustard oil in a non-stick pan. Added onions and cooked till light golden brown. Added okra rings, salt, turmeric powder and red chilli powder and cooked till the vegetable was done.

Table 3.2. Recipes for different frozen vegetables

Ingredients	**Amount(g)** French beans-potato	French beans-potato fry	Okra-onion	Okra fry	Stuffed capsicum
French beans, g	500 g[b]	500 g[a]	-	-	-
Okra/Lady's finger, g	-	-	500 g[d] cut	500 g[c]	-
Capsicum half, g	-	-	-	-	300[e]
Onions, g	75[g]	-	200[f]	200[f]	75[g]
Potatoes, g	100[i]	150[g]	-	-	300[j]
Cheese, g	-	-	-	-	75[k]
Omum, tsp	¼	-	-	-	-
Turmeric powder, tsp	½	½	½	½	¼
Salt, red chillies	--------------------------to taste	--------------------	--------------------	--------------------	--------------------
Griddle fry spice mixture,Tbsp	-	1	-	1	-
Mustard oil, ml	-	-	50	50	-
Refined ground nut oil , ml	25	25	-	-	10

a – cut into 1.0 cm pieces
b – cut into 6.0 cm long pieces
c – Trimmed and slitted lengthwise in the centre
d – cut into rings
e – cut into halves
f - chopped lengthwise
g - chopped
h - finger-cut
i - sliced
j - boiled and mashed
k - grated

3.10.4 Okra fry : Frozen okras were kept in a plate at room temperature for 15 minutes. Mixed griddle fry masala with salt, red chillies and turmeric thoroughly. Filled a little masala in each okra and closed it. Peeled onions and cut lengthwise. Heated mustard oil in a non-stick pan, added onions and cooked to light brown. Then added the okras. Stirred from time to time. Cooked on slow fire till done.

3.10.5 Stuffed capsicum : Boiled potatoes were peeled and mashed. Peeled onions were chopped and cheese was grated. Heated one tsp refined oil in a non-stick pan, added onions and cooked till light golden brown. Then added turmeric powder, salt, red chilli powder and mashed potatoes. Stirred for a while. Then added grated cheese and mixed thoroughly. Now filled this mixture into halves of frozen capsicum and decorated with black pepper and cloves. Brushed with refined oil and grilled in microwave for fifteen minutes.

3.11 Organoleptic evaluation

The dishes prepared from frozen vegetables were compared with the corresponding dishes from fresh vegetables available in the market at that time. Organoleptic evaluation was carried out using 'Ranking method' proposed by Larmond (1982). This is a five point scale where the scores of 5, 4, 3, 2 and 1 are given to the recipes which are excellent, very good, good, fair and poor, respectively. The recipes were tested every second month for a period of six months. A panel of ten trained judges was formed for the evaluation of recipes. The evaluation was carried out in triplicates and average scores were taken. The proforma used for evaluation is given in Appendix-1.

3.12 Statistical analysis

3.12.1 The Friedman two-way analysis of variance by ranks (Siegel and Castellan, 1989) : This test was used to determine whether the organoleptic scores given by the judges to the vegetables at different processing stages were uniform or not. For the Friedman test, the data was casted in a two-way table, which had N rows and k columns. The scores in each row were ranked separately. The lowest score in each row was given the ranks of 1 and so on. Then set of ranks in each column was summed down. The Friedman test determined whether the rank totals denoted (Rj) for each condition differed significantly or not. The computed value of the statistics was denoted as Fr.

$$Fr = \left[\frac{12}{Nk\,(k+1)} \; {}^{k}\Sigma_{j} = 1\; Rj^{2} \right] - 3N\,(k+1)$$

Where

N = Number of judges

k = Number of conditions

Rj = Sum of ranks in the jth column

And ${}^{k}\Sigma_{j} = 1$ directs one to sum the squares of the sums of ranks overall conditions.

3.12.2 The Wilcoxan Mann Whitney test (Siegel and Castellan, 1989) : This test was used to test whether two independent groups had been drawn from the same population. The scores from both groups were combined and ranked in order of increasing size. The value of Wx was calculated by taking the sum of ranks for the scores coming from any one of the groups. Then from the table, the probability of Wx taking value equal to the calculated value or more, was noted. If the probability of Wx value was greater than 0.05, then the scores of both the groups were not significantly different from each other.

3.12.3. One way analysis of variance, student's t-test, mean and standard error : The well known one way analysis of variance and student's t-test were used to test the equality of several mean values and two mean values, respectively, as per the procedure given by Gupta and Saini (1995). The mean and standard error were also calculated using the procedures given by Gupta and Saini (1995).

CHAPTER-IV

RESULTS AND DISCUSSION

CHAPTER – IV

RESULTS AND DISCUSSION

Three summer vegetables i.e. French beans, okra and capsicum were selected for the present study. The French beans and capsicum of local variety were purchased from the local market (60 kg each). One variety of okra i.e. Shagun was purchased from the Namdhari farm. The beans were washed, ends were snipped off and cut into 1.0 cm and 6.0 cm pieces. The okra was trimmed i.e. stems and ends were removed after washing. Half of the produce was cut into rings and the other half of okra was slited lengthwise. The capsicum was washed, cut into halves, and the stems as well as seeds were removed. The cut vegetables were washed in fresh water. The capsicum was blanched at 85°C for 2 minutes whereas French beans (1.0 cm) and okra rings were blanched at 95°C for 2 minutes. The French beans (6.0 cm) and okra trimmed were blanched for 3.0 minutes and subsequently cooled in water. The vegetables were then frozen by IQF method at –40°C and packed in polythene bags (HDPE, 200 gauge) of one kg capacity followed by polythene-coated cartons. These vegetables were stored at –20 to –25°C for a period of six months. The evaluation for quality, nutritional and organoleptic characteristics was carried out in case of fresh samples, after blanching, after freezing and after every second month to determine the effect of frozen storage period on these characteristics. The results of the present study have been discussed under the following headings:

4.1 Quality characteristics of the fresh vegetables

4.2 Nutritional characteristics of the fresh vegetables

4.2.1 Proximate composition of fresh vegetables

4.2.2 Nutrient content of the fresh vegetables

4.3 Effect of processing and frozen storage on quality characteristics of the vegetables

4.3.1 Total solids

4.3.2 pH

4.3.3 Titrable acidity

4.3.4 Total microbial count

4.3.5 Peroxidase activity

4.4 Effect of processing and frozen storage on nutritional characteristics of the vegetables

4.4.1 Proximate composition

4.4.2 Total sugars

4.4.3 Pectin

4.4.4 Fibre fractions

4.4.5 β-carotene

4.4.6 Ascorbic acid

4.5 Organoleptic evaluation of frozen vegetables

4.6 Economics of frozen vegetables

4.1 Quality characteristics of the fresh vegetables

The data on quality characteristics of the fresh vegetables have been presented in Table 4.1. The data revealed that the total solids were highest in okra rings followed by okra trimmed, French beans (1.0 and 6.0 cm) and lowest in capsicum halves, the corresponding values being 11.55, 11.26, 9.48, 9.22 and 7.40 per cent, respectively. The pH was highest of okra rings followed by okra trimmed, French beans (6.0 and 1.0 cm) and lowest in capsicum halves, the corresponding values being 6.87, 6.65, 6.31, 6.21 and 5.50, respectively. The acidity of capsicum halves was maximum followed by French beans (1.0 and 6.0 cm) and minimum of okra (rings and trimmed), the corresponding values being 0.0179, 0.0096 and 0.0064 per cent, respectively. The data depicted the maximum total microbial count in fresh okra rings followed by French beans (1.0 cm), okra trimmed, French beans (6.0 cm) and minimum in capsicum halves, the corresponding values being 5.50 x 10^4, 5.30 x 10^4, 5.00 x 10^4, 4.90 x 10^4 and 4.20 x 10^4, cfu/ml, respectively.

The data indicated higher amount of total solids and total microbial count in French beans having 1.0 cm cut, the values being 9.48 per cent and 5.30 x 10^4 cfu/ml, respectively, whereas the pH value was higher in French beans (6.0) i.e. 6.31. Statistically, these differences were non-significant between the two cuts in all the characteristics. The titrable acidity, however, was same in both the cuts of French beans, the value being 0.0096 per cent.

Table 4.1.Quality characteristics of the fresh vegetables

Vegetable	Total solids (%)	pH	Titrable acidity (%)	Total microbial count (cfu/ml) X 10^4
French bean (1.0 cm)	9.48	6.21	0.0096	5.30
French bean (6.0 cm)	9.22	6.31	0.0096	4.90
t value	0.53^{NS}	1.65^{NS}	-	1.79^{NS}
Okra rings	11.55	6.87	0.0064	5.50
Okra trimmed	11.26	6.65	0.0064	5.00
t value	0.001^{NS}	1.69^{NS}	-	2.24^{NS}
Capsicum halves	7.40	5.50	0.0179	4.20

NS – Non-significant, * - Significant at 5% level, Values are on fresh weight basis

The total solids, pH and total microbial count were higher in okra rings, the corresponding values being 11.55 per cent, 6.87 and 5.50 x 10^4, cfu/ml, respectively. The differences were statistically non-significant between the two cuts of okra, in all the characteristics. The titrable acidity also was same in both the cuts i.e. 0.0064 per cent.

According to Baardseth (1977), the total solids of carrots and cauliflower were 15.0 and 9.0 per cent, respectively, whereas according to Gopalan *et al* (1997), the dry matter content of French beans, okra and capsicum was 8.6, 10.4 and 7.6 per cent, respectively. According to Ramaswamy and Ranganna (1981), the pH of fresh cauliflower was in the range of 5.51 and 6.15. Hugo *et al* (1989) observed that the pH of fresh beans was 6.3. Dhaliwal (2002) also reported that the total solids, pH, titrable acidity and total microbial count of two varieties of peas and cauliflower each and of carrots were in the ranges of 25.6 to 25.8, 7.4 to 8.3 and 11.9 per cent; 5.8 to 5.9, 5.7 to 5.8 and 6.9; 0.0192; 0.0192 and 0.0064 per cent; and 2.1 to 2.7 x 10^4, 6.8 to 7.2 x 10^4 and 4.0 x 10^4 cfu/ml, respectively. The results of the present study were in line with the results of the studies reported above.

4.2 Nutritional characteristics of the fresh vegetables

4.2.1. Proximate composition of fresh vegetables

The data on proximate composition of fresh vegetables have been shown in Table 4.2 on fresh weight basis. The data depicted that the capsicum halves contained highest moisture content, followed by French beans (6.0 cm), French beans (1.0 cm), okra trimmed (6.0 cm) and lowest in okra rings, the corresponding values being 92.60, 90.78 90.52, 88.74 and 88.45 per cent, respectively.

Table 4.2 Proximate composition of the fresh vegetables (g/100g)

Vegetable	**Moisture**	**Crude protein Nx6.25**	**Crude fat**	**Crude fibre**	**Total ash**	**Available Carbohy-drates (By difference)**
French bean 1.0cm	90.52	1.90	0.68	1.70	0.50	4.70
French bean 6.0cm	90.78	1.90	0.67	1.80	0.49	4.36
t-value	0.52^{NS}	0^{NS}	0.32^{NS}	0.45^{NS}	0.83^{NS}	2.29^{NS}
Okra ring	88.45	2.20	0.43	1.30	0.62	7.00
Okra trimmed	88.74	2.20	0.43	1.40	0.61	6.62
t-value	1.33^{NS}	-	-	0.24^{NS}	0.45^{NS}	1.17^{NS}
Capsicum halves	92.60	1.40	0.25	1.10	0.57	4.08

NS – Non-significant; values are on fresh weight basis

The protein content was highest in okra (rings and trimmed), followed by French beans (1.0 and 6.0 cm) and lowest in capsicum halves, the corresponding values being 2.20, 1.90 and 1.40 per cent, respectively. The fat content was highest in French beans (1.0 cm) followed by French beans (6.0 cm), okra (rings and trimmed) and lowest in capsicum halves, the corresponding values being 0.68, 0.67, 0.43 in both cuts and 0.25 per cent, respectively. The crude fibre content was lowest in French beans (6.0 cm) followed by French beans (1.0 cm), okra trimmed as well as rings and lowest in capsicum halves, the corresponding values being 1.80, 1.70, 1.40, 1.30 and 1.10 per cent, respectively. The total ash content was highest in okra rings followed by okra trimmed, capsicum halves, French beans (1.0 and 6.0 cm), the corresponding values being 0.62, 0.61, 0.57, 0.50 and 0.49 per cent, respectively. The available carbohydrate contents were highest in okra rings followed by okra trimmed, French beans (1.0 and 6.0 cm) and lowest in capsicum halves, the corresponding values being 7.00, 6.62, 4.70, 4.36 and 4.08 per cent, respectively.

The data indicated higher crude fat, total ash and available carbohydrates in French beans having 1.0 cm cut, the levels being 0.68, 0.50 and 4.70 per cent, respectively. On the other hand, moisture content and crude fibre were slightly more in French beans having 6.0 cm long cut, the levels being 90.78 and 1.80 per cent, respectively. However, statistically, the differences in all the proximate principles of the two types of cuts were non-significant.

The total ash and available carbohydrate contents were more in okra rings, the corresponding values being 0.62 and 7.00 per cent, respectively. On the contrary, the moisture content and crude fibre was higher in okra trimmed, the values being 88.74 and 1.40 per cent, respectively. However, the differences were statistically non-significant between the two types of cuts of okra with respect to all the proximate principles. Wills *et al* (1984) reported 89.5 to 96.8 per cent moisture, 0.3 to 3.3 per cent protein, 0.0 to 0.5 per cent fat, 1.1 to 4.6 per cent fibre and 0.3 to 1.9 per cent ash in vegetables on fresh weight basis. Gopalan *et al* (1997) also reported the proximate composition of French beans, okra and capsicum on fresh weight basis. The moisture content ranged from 89.6 to 92.4 per cent, protein from 1.3 to 1.9 per cent, fat content from 0.1 to 0.3 per cent, fibre content from 1.0 to 1.80 per cent, minerals (total ash) from 0.5 to 0.7 per cent and available carbohydrates from 4.3 to 6.4 per cent in these vegetables. The corresponding ranges in the present study were 88.45 to 92.60 per cent, 1.40 to 2.20 per cent, 0.25 to 0.68 per cent, 1.10 to 1.80 per cent, 0.49 to 0.62 per cent and 4.08 to 7.00 per cent on fresh weight basis, which were slightly higher than those reported by Gopalan *et al* (1997). The variation might be due to varietal and environmental differences.

4.2.2 Nutrient content of the fresh vegetables

The data on nutrient content of the fresh vegetables have been presented in Table 4.3 on fresh weight basis. The data revealed that the sugar content was highest in okra trimmed, followed by okra rings, French beans (6.0 and 1.0 cm) and lowest in capsicum halves, the corresponding values being 51.5, 51.0, 40.3, 40.2 and 38.0 mg/g, respectively. The NDF content was highest in French beans (1.0 cm) followed by okra rings, okra trimmed, French beans (6.0 cm), and lowest in capsicum halves, the corresponding values being 1.92, 1.91, 1.90, 1.89 and 1.20 per cent, respectively. The ADF content was

Table 4.3 Nutrient content of the fresh vegetables.

Vegetable	Total sugars mg/g	NDF, %	ADF, %	Pectin, %	Total dietary fibre, %	Ascorbic acid mg/100g	β-carotene μg/100g
French bean 1.0cm	40.2	1.92	1.41	0.70	2.62	25.2	123
French bean 6.0cm	40.3	1.89	1.38	0.70	2.59	26.0	125
t-value	0.10^{NS}	1.32^{NS}	0.55^{NS}	-	1.30^{NS}	0.39^{NS}	0.47^{NS}
Okra rings	51.0	1.91	1.46	1.00	2.91	15.0	49
Okra trimmed	51.5	1.90	1.45	1.00	2.90	15.3	50
t-value	0.37^{NS}	1.01^{NS}	0.82^{NS}	-	1.00^{NS}	0.59^{NS}	0.36^{NS}
Capsicum halves	38.0	1.20	0.50	0.40	1.70	145.0	435

NS – non-significant; values are on fresh weight basis maximum in okra rings followed by okra trimmed, French beans (1.0 cm), French beans (6.0 cm) and minimum in capsicum halves, the corresponding values being 1.46, 1.45, 1.41, 1.38 and 0.50 per cent, respectively. The pectin content was maximum in okra rings and trimmed, followed by French beans (1.0 and 6.0 cm) and minimum in capsicum halves, the corresponding values being 1.0 in both cuts, 0.70 in both cuts and 0.40 per cent, respectively. The total dietary fibre was highest in okra rings followed by okra trimmed, French beans (1.0 and 6.0 cm) and lowest in capsicum halves, the corresponding values being 2.91, 2.90, 2.62, 2.59 and 1.70 per cent, respectively. The ascorbic acid content was highest in capsicum halves, followed by French beans (6.0 and 1.0 cm), okra trimmed and minimum in okra rings, the corresponding values being 145.0, 26.0, 25.2, 15.3 and 15.0 mg/100g, respectively. The β-carotene content was maximum in capsicum halves, followed by French beans (6.0 and 1.0 cm) and okra (trimmed and rings), the corresponding values being 435, 125, 123, 50 and 49 μg/100g, respectively.

The data indicated higher amount of total sugars, NDF, ADF, ascorbic acid and β-carotene in French beans (6.0 cm), the values being 40.3 mg/g, 20.5 per cent, 15.0 per cent, 26.0 mg/100g and 125.0 μg/100g, respectively. The pectin content, however was same in both the cuts of French beans, the level being 0.70 per cent. However, statistically, the differences were non-significant between the two cuts in all the nutrients.

The total sugars, NDF, ADF, ascorbic acid and β-carotene were higher in okra trimmed, the corresponding values being 51.5 mg/g, 16.9 per cent, 12.0 per cent, 15.3 mg/100g and 50 μg/100g, respectively. The differences were statistically non-significant between the two cuts of okra, in all the nutrients. The pectin content, however, was same in both the cuts i.e. 1.00 per cent. Kaur (1984) reported the NDF, ADF and ascorbic acid content of small and large pods of okra (Punjab Padmani variety) as 16.0 and 21.0 per cent, 12.2 and 17.5 per cent; and 17.8 and 15.0 mg/100g, respectively. The ascorbic acid content as reported in Anon (1992) was 14 mg in French beans, 30 mg in okra and 137 mg/100g in capsicum. The β-carotene content was 427 μg/100g in capsicum. According to Gopalan *et al* (1997), the ascorbic acid and β-carotene of French beans, okra and capsicum were 24.0, 13.0 and 137.0 mg/100g; and 132, 52 and 427 μg/100g, respectively. Kaur and Kapoor (2001) reported that the ascorbic acid and carotenoid content of fresh French beans were 26.0 ± 0.34 mg/100g and 145 ± 6.0 μg/100g, respectively. The findings of the present study for fresh vegetables were in good agreement with the results reported in the above mentioned studies. The differences in ascorbic acid and β-carotene content could be due to varietal differences in addition to the agro-climatic variations.

4.3 Effect of processing and frozen storage on quality characteristics of the vegetables.

4.3.1. Total solids. The total solids of fresh, processed and frozen stored vegetables have been presented in Table 4.4. The data indicated that the total solids of fresh French beans (1.0 cm) were 9.48 per cent which after blanching decreased to 7.66 per cent but after freezing, there was slight increase in the contents, the corresponding value being 7.70 per cent. Statistically, the blanching process had highly significant ($P \leq 0.01$) effect on total solids of French beans (1.0 cm). On the other hand, frozen storage period of two, four and six months had non-significant effect on total solids and the values varied from 7.69

Table 4.4 Effect of processing and frozen storage on total solids (%) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	9.48	7.66	7.70	7.70	7.69	7.70	19.79* (0.997)	0.03^{NS}	19.16** (0.5456)
French bean 6.0cm	9.22	9.12	9.18	9.18	9.20	9.20	0.50^{NS}	0.60^{NS}	0.45^{NS}
t-value	0.53^{NS}	32.66*	66.98*	29.59*	67.29*	67.88*			
Okra rings	11.55	7.84	7.90	7.94	8.00	8.00	441.20** (0.456)	0.19^{NS}	161.42** (0.402)
Okra trimmed	11.26	8.96	9.00	9.00	9.00	9.00	175.11** (0.449)	-	63.86** (0.401)
t-value	0.001^{NS}	11.38*	21.53*	29.43*	7.07*	7.14*			
Capsicum halves	7.40	7.20	7.30	7.30	7.30	7.40	0.17^{NS}	0.17^{NS}	0.15^{NS}

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant
* - significant at 5% level; ** - significant at 1% level
Figures in parenthesis indicate C.D. values

to 7.70 per cent. From the overall analysis of variance, it was inferred that the processing and frozen storage period of six months had significant ($P \leq 0.05$) effect on the total solids of the French beans (1.0 cm).

The total solids of fresh French beans (6.0 cm) were 9.22 per cent, which after blanching decreased to 9.12 per cent and increased slightly after freezing to 9.18 per cent. However, statistically, the blanching and freezing processes had no significant effect on the total solids of French beans (6.0 cm). The total solids of frozen French beans remained between 9.18 to 9.20 per cent during the frozen storage period of six months. Statistically, the frozen storage period of six months had no significant effect on the total solids of French beans (6.0 cm). The overall analysis of variance revealed that the processing and frozen storage period of six months had non-significant effect on the total solids of the French beans (6.0 cm).

The total solids of fresh French beans having 1.0 cm cut were 9.48 per cent which were higher than that of the fresh French beans having 6.0 cm cut but the differences were not statistically significant. The total solids of French beans (6.0 cm) were higher than the French beans (1.0 cm) throughout the processing and frozen storage period of six months. The corresponding range was 7.66 to 9.20 per cent and the differences were statistically significant ($P \leq 0.05$). The overall range of total solids in all stages of two types of French beans was 7.66 to 9.48 per cent. Further, the statistical analysis revealed that the total solids of the two types of cuts of French beans were significantly ($P \leq 0.05$) different from each other after blanching, freezing and during frozen storage period of six months.

The total solids of fresh okra rings were 11.55 per cent but after blanching decreased to 7.84 per cent and after freezing, increased slightly to 7.90 per cent. Statistically, these differences were significant ($P \leq 0.01$). The total solids in okra rings after two months of frozen storage were 7.94 per cent while after four and six months, the values were constant at 8.0 per cent. The difference was statistically non-significant. However, the overall analysis of variance, indicated that the processing and frozen storage period of six months had significant ($P \leq 0.01$) effect on the total solids of the okra rings.

The total solids of fresh okra trimmed were 11.26 per cent, which decreased to 8.96 per cent after blanching but increased slightly to 9.00 per cent after freezing. These differences in total solids were statistically significant ($P \leq 0.01$). The total solids of frozen okra trimmed remained constant at 9.00 per cent during the frozen storage period of six months. But the overall analysis of variance revealed that the processing and frozen storage period of six months had significant ($P \leq 0.01$) effect on the total solids of the okra trimmed.

The total solids of fresh okra rings were 11.55 per cent which were higher than that of the fresh okra trimmed. The difference was statistically non-significant. The total solids of okra trimmed were higher than that of the okra rings during processing and frozen storage of six months. The corresponding range was 7.84 to 9.00 per cent and the differences were statistically significant ($P \leq 0.05$). The overall range of total solids in all the stages of two types of okra was 7.84 to 11.55 per cent. Further, the statistical analysis revealed that the total solids of the two types of cuts of okra were statistically $(P \leq 0.05)$ different from each other throughout the processing and frozen storage period of six months.

The total solids in fresh, blanched and frozen capsicum halves were 7.40, 7.20 and 7.30 per cent, respectively, the differences being statistically non-significant. The total solids of frozen stored capsicum halves remained almost constant i.e. 7.30 to 7.40 per cent during the six months of frozen storage period. Statistically, the frozen storage period of six months had no significant effect on the total solids of the capsicum. Further, the overall analysis of variance indicated that the processing and frozen storage period of six months had non-significant effect on the total solids of the capsicum halves.

The capsicum was cut into halves only and the minimum losses took place after processing and frozen storage period of six months, followed by French beans (6.0 cm) and okra trimmed; and maximum losses took place in French beans (1.0 cm) and okra rings. The main reason was larger size of the cuts and smaller surface area was exposed during blanching, hence minimum losses and vice-versa.

It has been observed that the total solids of the vegetables decreased after blanching and then increased after freezing, but the change was not significant in all cases. During blanching in water, the larger surface area of French beans (1.0 cm) and okra rings coupled with porous structure resulted in higher water absorption. Blanching also caused leaching of some soluble solids resulting in loss of total solids. During freezing, the structure of organic molecules get transformed which may result in increased bonding with water for stability and this bonded water might have resulted in increased weight of the vegetables (Bomben *et al,* 1975). Hence the total solids increased after freezing. Brown (1977) observed the changes on the ultrastructural level in frozen and stored green peas and green beans. He reported that in green beans large intercellular cavities that were rich in air, could be found in parenchyma. During blanching, the air is replaced by liquid. The starch granules picked up water and the volume of the cells showed a relative increase in weight. Michalik and Hallas (1991) reported that there was no difference in dry matter content in fresh, blanched and frozen carrots of various varieties. Lisiewska and Kmiecik (2000) reported no effect of storage (12 months at –20 or –30°C) on soluble solids. In 1996, they further observed that blanching reduced the dry matter by 18-20 per cent in broccoli and 9-10 per cent in cauliflower but on the other hand, during freezing and storage period of 12 months, the dry matter increased by 1-4 per cent as compared to that found in blanched material. The results of present study are in accordance with the above reports.

4.3.2. pH : The pH of the fresh , processed and frozen stored vegetables is presented in Table 4.5. The data depicted that the pH of fresh French beans (1.0 cm) was 6.21 which after blanching changed to 6.11 and after freezing to 6.10. Statistically, the processing had non-significant effect on the pH of the French beans (1.0 cm). The pH of the frozen French beans (1.0 cm) varied between 6.08 and 6.10 during the six months of frozen storage period. Statistically, the frozen storage period had no significant effect on the pH of the French beans (1.0 cm). The overall analysis of variance also revealed that processing and frozen storage period of six months had non-significant effect on the pH of the French beans (1.0 cm).

Table 4.5 Effect of processing and frozen storage on pH of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	6.21	6.11	6.10	6.08	6.10	6.10	1.06^{NS}	0.02^{NS}	0.59^{NS}
French bean 6.0cm	6.31	6.20	6.18	6.18	6.20	6.20	3.58^{NS}	0.26^{NS}	2.50^{NS}
t-value	1.65^{NS}	4.01^{NS}	0.78^{NS}	2.24^{NS}	0.98^{NS}	3.33^{NS}			
Okra rings	6.87	6.69	6.69	6.77	6.77	6.78	0.63^{NS}	0.19^{NS}	0.51^{NS}
Okra trimmed	6.65	6.45	6.46	6.55	6.55	6.55	5.77^{NS}	1.52^{NS}	3.18^{NS}
t-value	1.69^{NS}	4.11^{NS}	1.18^{NS}	4.09^{NS}	4.00^{NS}	4.09^{NS}			
Capsicum halves	5.50	5.41	5.41	5.37	5.38	5.37	0.77^{NS}	0.97^{NS}	1.22^{NS}

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio

NS – Non-significant

The pH of the fresh French beans (6.0 cm) was 6.31 which after blanching changed to 6.20 and after freezing further changed to 6.18. Statistically, the blanching and freezing processes had non-significant effect on the pH of the French beans (6.0 cm). The pH of the frozen French beans remained between 6.18 and 6.20 per cent during the frozen storage period of six months. Statistically, the frozen storage period of six months had non-significant effect on the pH of the French beans (6.0 cm). The overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the pH of the French beans (6.0 cm).

The pH of the French beans having 6.0 cm cut was higher than that of the French beans having 1.0 cm cut throughout in fresh form during processing and frozen storage period of six months, the corresponding overall range being 6.08 to 6.31. However, the pH of the two types of cuts of French beans was statistically not different from each other in fresh form, during processing and frozen storage period of six months.

The pH of fresh okra rings was 6.87 which after blanching decreased to 6.69 but remained same after freezing. Statistically, these differences were not significant. The pH of the okra rings remained in the narrow range of 6.69 to 6.78 during the six months of frozen storage period. Statistically, the frozen storage period had no significant effect on the pH of the okra rings. The overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the pH of the okra rings.

The pH of fresh okra trimmed was 6.65 which decreased to 6.45 after blanching and changed to 6.46 after freezing. Statistically, there was no significant effect of processing on the pH of the okra trimmed. The pH of the frozen okra trimmed remained 6.46 to 6.55, throughout the frozen storage period of six months. Statistically, the frozen storage period of six months had non-significant effect on the pH of the okra trimmed. From the overall analysis of variance, it was derived that the processing and frozen storage period of six months had non-significant effect on the pH of the okra trimmed.

The pH of the okra rings was higher than that of the okra trimmed throughout in fresh stage, during processing and frozen storage period of six months, the corresponding overall range being 6.45 to 6.87. The pH of the two types of cuts of okra was, however, statistically not different from each other in fresh stage during processing and frozen storage period of six months.

The pH of fresh, blanched and frozen capsicum halves was 5.50, 5.41 and 5.41, respectively. These differences were statistically not significant. The pH of frozen stored capsicum halves remained in the narrow limits of 5.37 to 5.41 during the six months of frozen storage period. Statistically, the frozen storage period of six months had no significant effect on the pH of the capsicum halves. The overall analysis of variance indicated that the processing and frozen storage period of six months had non-significant effect on the pH of the capsicum halves.

It has been observed that the type of cut of French beans and okra had no effect on the pH of these vegetables. It was also observed that the pH decreased after blanching of the vegetables. Hugo *et al* (1989) observed that the pH of the five minutes blanched samples of French beans decreased from 6.3 (fresh beans) to 5.6 after 15 days of frozen storage and finally stabilized at the initial pH. Eheart and Odland (1973) noted that the pH of beans, broccoli and peas decreased during the storage period of six months at –18°C. On the other hand, Lisiewska and Kmiecik (2000) reported that there was no change in pH during the frozen storage (-20°C) of frozen tomato cubes for 12 months. In the present study, the non-significant change in pH was observed after blanching but no change was observed during frozen storage period of six months. It may be due to very fast freezing rate and low storage temperature i.e. –20 to –25°C.

4.3.3. Titrable acidity: The data on acidity of fresh, processed and frozen stored vegetables have been shown in Table 4.6. The results indicated that the acidity of both types of fresh French beans (1.0 and 6.0 cm) was 0.0096 per cent which after blanching increased slightly to 0.0102 per cent. Thereafter, no change was observed after freezing as well as throughout the frozen storage period of six months. The overall statistical analysis revealed that processing and the frozen storage period of six months had no effect on the acidity of the vegetables.

The acidity of fresh okra rings and okra trimmed was 0.0064 per cent but increased slightly to 0.0076 per cent after blanching and remained same after freezing. Statistically, the processing had non-significant effect on the acidity of the okra rings and trimmed. The acidity of the frozen okra rings and trimmed remained constant at 0.0076 per cent throughout the frozen storage period of six months. The overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the acidity of the okra rings and okra trimmed.

Table 4.6 Effect of processing and frozen storage on titrable acidity (%) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	0.0096	0.0102	0.0102	0.0102	0.0102	0.0102	1.29^{NS}	0	0.62^{NS}
French bean 6.0cm	0.0096	0.0102	0.0102	0.0102	0.0102	0.0102	1.91^{NS}	0	0.74^{NS}
t-value	-	-	-	-	-	-			
Okra rings	0.0064	0.0076	0.0076	0.0076	0.0076	0.0076	2.39^{NS}	0	1.53^{NS}
Okra trimmed	0.0064	0.0076	0.0076	0.0076	0.0076	0.0076	3.44^{NS}	0	2.99^{NS}
t-value	-	-	-	-	-	-			
Capsicum halves	0.0179	0.0192	0.0192	0.0192	0.0192	0.0192	0.61^{NS}	0	0.40^{NS}

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio

NS – Non-significant

The acidity of the two types of cuts of French beans and okra were same and statistically, these were not different from each other throughout the processing and frozen storage period of six months.

The acidity of fresh, blanched and frozen capsicum halves was 0.0179, 0.0192 and 0.0192 per cent, respectively. These differences were statistically non-significant. The acidity of the frozen stored capsicum halves remained same throughout the frozen storage period of six months, the value being 0.0192 per cent. Statistically, the frozen storage period had no effect on the acidity of the capsicum halves. The overall analysis of variance also indicated that the processing and frozen storage period of six months had non-significant effect on the acidity of the capsicum halves.

It has been observed that the type of cut of French beans and okra had no effect on the acidity of these vegetables. It has been seen that there was slight increase in acidity after blanching and remained constant after freezing and during frozen storage. Eheart and Odland (1973) observed increase in total acidity in case of beans and sprouts during the storage period of six months at –18°C. On the other hand, Chen (1986) found that quality parameters such as soluble solids and acidity remained constant after freezing. However, the results of the present study also revealed no significant change in pH of vegetables during frozen storage period of six months at –20 to –25°C.

4.3.4. Total microbial count : The data in Table 4.7 shows the microbial count in fresh, processed and frozen stored vegetables. The data revealed that the total microbial count of fresh French beans (1.0 cm) was 5.30×10^4 cfu/ml. After blanching, the corresponding count was reduced to 3.40×10^3 cfu/ml which after freezing decreased to 2.10×10^2 cfu/ml

Table 4.7 Effect of processing and frozen storage on total microbial count (cfu/ml) in the vegetables

Vegetable	Fresh $x10^4$	Blanched $X10^3$	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0 $x10^2$	2 $x10^2$	4 $x10^2$	6 $x10^2$			
French bean 1.0cm	5.30	3.40	2.10	2.00	2.00	1.99	97.13** (0.737)	0.19^{NS}	78.52** (0.525)
French bean 6.0cm	4.90	5.50	4.30	4.20	4.10	4.10	18.00* (0.638)	0.61^{NS}	24.12** (0.399)
t-value	1.79^{NS}	9.39**	11.00**	9.84**	21.00**	15.68**			
Okra rings	5.50	4.30	3.00	2.88	2.87	2.87	33.5** (0.975)	0.17^{NS}	49.37** (0.541)
Okra trimmed	5.00	4.10	2.80	2.60	2.50	2.60	61.16** (0.638)	1.95^{NS}	78.44** (0.405)
t-value	2.24^{NS}	0.89^{NS}	0.63^{NS}	2.19^{NS}	3.36^{NS}	5.40*			
Capsicum halves	4.20	4.50	3.30	3.20	3.10	3.20	39.00** (0.451)	0.27^{NS}	18.28** (0.489)

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant
* - significant at 5% level; ** - significant at 1% level
Figures in parenthesis indicate C.D. values

Statistically, the blanching and freezing processes had significant ($P \leq 0.01$) effect on total microbial count of French beans (1.0 cm). On the other hand, frozen storage period of six months had non-significant effect on total microbial count and the corresponding values ranged between 1.99×10^2 and 2.10×10^2 cfu/ml. The overall analysis of variance revealed that the processing and frozen storage period of six months had significant ($P \leq 0.01$) effect on the total microbial count of the French beans (1.0 cm).

The total microbial count of fresh French beans (6.0 cm) was 4.90×10^4 cfu/ml which decreased to 5.50×10^3 cfu/ml after blanching and further reduced to 4.30×10^2 cfu/ml after freezing. Statistically, the processing had significant ($P \leq 0.05$) effect on total microbial count of French beans (6.0 cm). On the other hand, frozen storage period of six months had non-significant effect on total microbial count and the corresponding values ranged between 4.10×10^2 and 4.30×10^2 cfu/ml. However, the overall analysis of variance indicated that the processing and frozen storage period of six months had significant ($P \leq 0.01$) effect on the total microbial count of French beans (6.0 cm).

The total microbial count of fresh French beans having 1.0 cm cut was 5.30×10^4 which was higher than that of the fresh French beans having 6.0 cm cut. The difference was statistically non-significant. The microbial count of French beans (6.0 cm) was higher than that of the French beans (1.0 cm) after blanching, freezing and during frozen storage period of six months. The corresponding range was 1.99×10^2 to 5.50×10^3 cfu/ml. The differences were statistically significant ($P \leq 0.01$). The overall range of microbial count in all stages of two types of French beans was 1.99×10^2 to 5.30×10^4 cfu/ml. Further the statistical analysis confirmed that the microbial count of two types of cuts of French beans was significantly different ($P \leq 0.01$) from each other throughout the processing and frozen storage period of six months.

The total microbial count of fresh okra rings was 5.50×10^4 cfu/ml. After blanching, the corresponding count was reduced to 4.30×10^3 cfu/ml which after freezing further decreased to 3.00×10^2 cfu/ml. Statistically, the processing had significant ($P \leq 0.01$) effect on total microbial count of okra rings. On the other hand, frozen storage period of six months had non-significant effect on total microbial count of okra rings, the corresponding range being 2.87×10^2 to 3.00×10^2 cfu/ml. However, the overall analysis of variance revealed that the processing and frozen storage period of six months had significant ($P \leq 0.01$) effect on the total microbial count of okra rings.

The total microbial count of okra trimmed was 5.00×10^4 cfu/ml which decreased to 4.10×10^3 cfu/ml after blanching and further decreased to 2.80×10^2 cfu/ml after freezing. Statistically, the blanching and freezing had significant ($P \leq 0.01$) effect on total microbial count of okra trimmed. On the other hand, frozen storage period of six months had non-significant effect on total microbial count of okra trimmed and the corresponding numbers ranged between 2.50×10^2 to 2.80×10^2 cfu/ml. The overall analysis of variance also revealed that the processing and frozen storage period of six months had statistically significant ($P \leq 0.01$) effect on the total microbial count of okra trimmed.

The total microbial count of okra rings was higher than that of the okra trimmed in fresh form, during processing and frozen storage period of six months. The corresponding overall range was 2.50×10^2 to 5.50×10^4 cfu/ml. However, the statistical analysis confirmed that the microbial count of two types of cuts of okra was statistically not different from each other, in fresh form, after processing and during frozen storage period of two and four month, but was significantly ($P \leq 0.05$) different during frozen storage period of six months.

The total microbial count of fresh, blanched and frozen capsicum halves was 4.20 x 10^4, 4.50 x 10^3 and 3.30 x 10^2 cfu/ml, respectively. The reduction was statistically significant ($P \leq 0.01$) indicating that the blanching and freezing had marked effect on the total microbial count of capsicum halves. The total microbial count of frozen stored capsicum halves remained almost constant between 3.10 x 10^2 and 3.30 x 10^2 cfu/ml during the six months of frozen storage period. Statistically, the frozen storage had non-significant effect on the total microbial count of the capsicum halves. On the contrary, the overall analysis of variance, indicated that the processing and frozen storage period of six months had statistically significant ($P \leq 0.01$) effect on the total microbial count of capsicum halves.

It has been observed that the microbial count dropped significantly ($P \leq 0.01$) after blanching and freezing, but the frozen storage period of six months had no further significant effect on the microbial count (Figure 2) as the microbes do not grow at the very low temperature. It was observed from the above results that despite preliminary washing in cold water before blanching, the vegetables carried thousands of microbes. The count was significantly reduced after blanching because at such a high temperature (85-95^o) most of the microbes were killed. This reduction was lowest in French beans (6.0 cm) followed by capsicum halves, okra trimmed, okra rings and highest in French

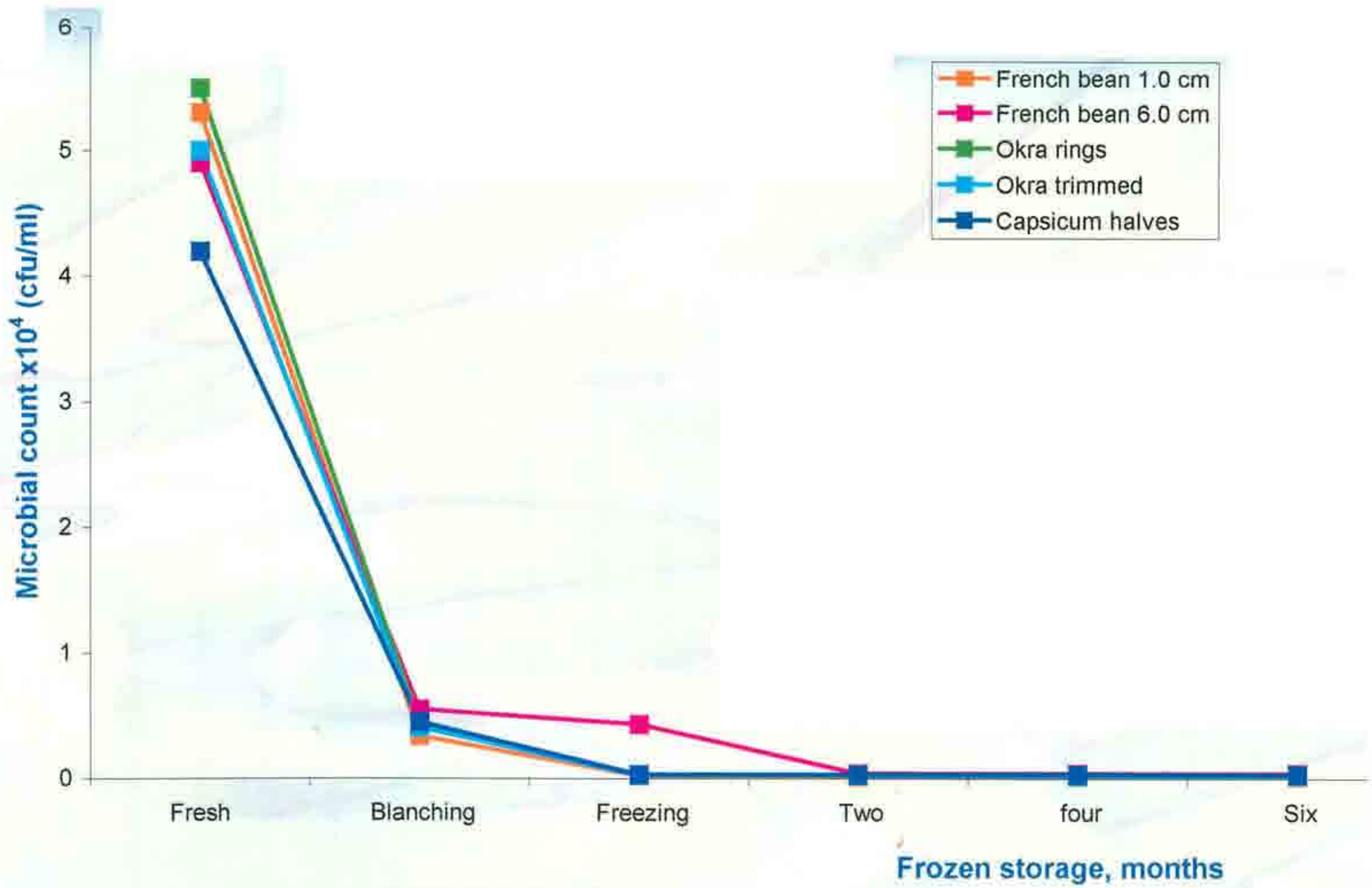

Fig 2 Microbial count of vegetables during processing and frozen storage

beans (1.0 cm), the corresponding lowest and highest values being 88.7 and 93.5 per cent, respectively (Table 4.8). The freezing process also resulted in the further reduction of the microbial count. The reduction was 92.1 to 93.8 per cent, of the count in the blanched vegetables, because at very low temperature (-40°C) most of bacteria do not survive. Further, during the frozen storage period of six months, the microbial count was reduced only by 3.0 to 7.1 per cent of the count in the immediately frozen vegetables, because the storage at low temperature (-20 to –25°C) does not kill bacteria but merely suspend their growth. The overall reduction in the total microbial count ranged from 99.1 to 99.6 per cent in all the three vegetables starting from fresh to frozen storage period of six months. The remaining microbes did not show any adverse effect on quality during the frozen storage of vegetables, as the microbes were inactive at such a low (-20 to –25°C) temperature.

A number of microbiological studies have been conducted on frozen foods. According to Frazier (1967), the frozen vegetables should not contain more than 1.0×10^5 bacteria per gram. In the present investigation, the bacterial count was much lower than the recommended standards. Desrosier and Tressler (1977) suggested that it was possible to keep the number of bacteria on frozen vegetables below 100,000 per gram. Total counts in excess of 200,000 organisms per gram were common on frozen green beans. Baardseth and Slinde (1983) reported that the unblanched sample of carrot had a total count of 3.50×10^3 cfu/g but was reduced in the heat-treated samples to 50 per cent of the original value. The results of microbiological analysis performed by Gomez *et al* (2002) showed that washing reduced the microbial load as compared to unwashed samples and

Table 4.8 Reduction (%) of total microbial count during processing and frozen storage of the vegetables

Vegetable	Blanching	Freezing	Six months frozen storage	Overall reduction
French bean 1.0cm	93.5	93.8	5.2	99.6
French bean 6.0cm	88.7	92.1	4.6	99.1
Okra ring	92.2	93.0	4.3	99.4
Okra trimmed	91.8	93.1	7.1	99.5
Capsicum halves	89.2	92.6	3.0	99.2

the samples stored at low temperatures resulted in lower microbial proliferation. Further, the wrapped samples had low microbial counts than the unwrapped samples. In the present study, vegetables were blanched, at 85-95°C, frozen at –40°C, packed in polythene bags and stored at –20 to –25°C and overall reduction of microbial count ranged from 99.1 to 99.6 per cent. So the findings were in good agreement with other studies reported in the literature.

4.3.5. Peroxidase activity : It has been said that a significant, though not well defined, proportion of active peroxidase may be left in the vegetables after blanching and long shelf life in the frozen storage may still be achieved. In the present study also, the blanching did not completely inactivate the peroxidase enzyme in French beans (1.0 and 6.0 cm), okra (rings and trimmed) and capsicum halves. The data in Table 3.1 revealed that there was no activity of peroxidase enzyme after blanching at 95°C for 2 min in capsicum halves and at 100°C for 2 min in French beans and okra. However, the texture of blanched vegetables was adversely affected. It was further observed that there was no effect on the texture of the blanched vegetables at 85°C for capsicum halves, at 95°C for French beans (1.0 cm) and okra rings for 2 min time and at 95°C for French beans (6.0 cm) and okra trimmed for 3 min time, but there was a little activity of peroxidase enzyme left. Therefore, this optimum combination was selected at which there was a balance between texture and peroxidase activity. Hence capsicum was blanched at 85°C for 2 min, French beans (1.0 cm) and okra rings at 95°C for 2 min and French beans (6.0 cm) and okra trimmed at 95°C for 3 min. During freezing and frozen storage of six months, some enzyme activity remained in the vegetables. The results have shown that this activity had no detrimental effect on the quality of frozen vegetables. Williams *et al* (1986) indicated that lipoxygenase was the key enzyme in the development of undesirable aroma in English green peas and beans. Baardseth (1977) found that five per cent residual activity of peroxidase in frozen French beans, carrots and cauliflower (stored at –20°C to –30°C for upto 15 months) did not affect the quality during storage. Baardseth and Slinde (1983) showed that good sensory quality in carrots was obtained when palmitoyl CoA hydrolase enzyme was no longer present, but some activity of catalase (9%) and peroxidase (6%) enzyme remained. Keeping in view the literature reports, the enzyme peroxidase was used as an indicator being most heat sensitive.

4.4 Effect of processing and frozen storage on nutritional characteristics of the vegetables

4.4.1 Proximate composition

4.4.1.1. Crude protein : The data in Tables 4.9 and 4.10 represent the crude protein content of fresh, processed and frozen stored vegetables on fresh and dry weight basis, respectively.

The protein content of fresh French beans (1.0 cm) was 1.90 g/100g which after blanching decreased to 1.70 g/100g and further decreased to 1.65 g/100g after freezing, on fresh weight basis. Statistically, the blanching and freezing processes had non-significant effect on the protein content. Similarly frozen storage period of six months had non-significant effect on the protein content and the values remained almost constant i.e. between 1.60 and 1.65 g/100g. The protein content of fresh French beans (1.0 cm), on dry weight basis, was 20.4 g/100g, which increased to 22.1 g/100g after blanching but

Table 4.9 Effect of processing and frozen storage on crude protein (g/100g, fresh weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	1.90	1.70	1.65	1.65	1.60	1.65	3.50^{NS}	0.30^{NS}	3.28^{NS}
French bean 6.0cm	1.90	1.85	1.82	1.80	1.80	1.82	1.44^{NS}	0.03^{NS}	0.47^{NS}
t-value	-	2.12^{NS}	2.92^{NS}	1.44^{NS}	3.71^{NS}	1.98^{NS}			
Okra rings	2.20	2.05	2.00	1.95	1.95	1.95	1.50^{NS}	0.17^{NS}	1.84^{NS}
Okra trimmed	2.20	2.13	2.00	1.97	1.97	1.97	0.80^{NS}	1.72^{NS}	1.58^{NS}
t-value	-	-	-	0.39^{NS}	0.28^{NS}	0.20^{NS}			
Capsicum halves	1.40	1.20	1.15	1.16	1.16	1.16	1.00^{NS}	0.02^{NS}	0.57^{NS}

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant

Table 4.10 Effect of processing and frozen storage on crude protein (g/100g, dry weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	20.4	22.1	21.4	21.4	20.8	21.4	2.80^{NS}	0.03^{NS}	3.10^{NS}
French bean 6.0cm	20.6	20.2	19.8	19.6	19.5	19.7	0.80^{NS}	0.05^{NS}	1.00^{NS}
t-value	0.50^{NS}	1.35^{NS}	1.25^{NS}	1.33^{NS}	1.10^{NS}	1.30^{NS}			
Okra rings	19.0	26.1	25.3	24.5	24.3	24.3	21.74* (4.0165)	0.69^{NS}	5.24* (4.029)
Okra trimmed	19.5	23.7	22.2	21.8	21.8	21.8	9.75* (6.127)	0.07^{NS}	4.81* (1.9781)
t-value	0.56^{NS}	2.49^{NS}	2.82^{NS}	4.28^{NS}	0.59^{NS}	1.93^{NS}			
Capsicum halves	18.9	16.6	15.7	15.8	15.8	15.6	1.00^{NS}	0.01^{NS}	1.20^{NS}

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3-ratio overall F-ratio

NS – Non-significant

* - significant at 5% level

decreased slightly after freezing to 21.4 g/100g and remained between 20.8 to 21.4 g/100g, during the frozen storage period of six months. Statistically, these changes were non-significant. The overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the protein content of French beans (1.0 cm) on fresh as well as dry weight basis.

The protein content of fresh French beans (6.0 cm) was 1.90 g/100g which after blanching decreased to 1.85 g/100g and after freezing to 1.92 g/100g on fresh weight basis. Statistically, the blanching and freezing processes had non-significant effect on the protein content. The frozen storage period of six months also had non-significant effect on the protein content, the corresponding range being 1.80 to 1.82 g/100g. On dry weight basis, the protein content was 20.6 g/100g in fresh French beans (6.0 cm) which decreased to 20.2 g/100g after blanching and further after freezing to 19.8 g/100g but remained almost constant between 19.5 and 19.8 g/100g during the frozen storage period of six months. Statistically, these changes were non-significant. The overall analysis of variance also indicated that the processing and frozen storage period of six months had non-significant effect on the protein content of French beans (6.0 cm) on fresh as well as dry weight basis.

The protein content of both cuts of fresh French beans was same i.e. 1.90 g/100g whereas the protein content of French beans having 6.0 cm cut was higher than that of the French beans having 1.0 cm cut throughout the processing and frozen storage period of six months. The corresponding range was 1.60 to 1.85 g/100g on fresh weight basis. The differences were statistically non-significant. The overall range of protein in all stages of two types of French beans was 1.60 to 1.90 g/100g. On dry weight basis, the protein content of fresh French beans (6.0 cm) was 20.6 g /100g which was higher than that of the French beans (1.0 cm). The difference was not statistically significant. But the protein content of French beans (1.0 cm) was higher after blanching, freezing and throughout frozen storage period of six months. The corresponding as well the overall range was 19.5 to 22.1 g/100g for protein content. The statistical analysis revealed that the protein content of the two types of cuts of French beans was statistically not different from each other throughout the processing and frozen storage period of six months on fresh as well as dry weight basis.

The protein content of fresh okra rings was 2.20 g/100g which after blanching was reduced to 2.05 g/100g and further reduced after freezing to 2.00 g/100g, on fresh weight basis. Statistically, this reduction was non-significant. The protein content remained 2.00 to 1.95 g/100g throughout the frozen storage period of six months. The overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the protein content. On dry weight basis, the protein content of fresh okra rings was 19.0 g/100g which increased to 26.1 g/100g after blanching and then deceased to 25.3 g/100g after freezing. Statistically, this change was significant ($P \leq 0.05$). The protein content remained in the narrow range of 24.3 to 25.3 g/100g during the frozen storage period of six months. Statistically, the frozen storage period had non-significant effect on the protein content. However, the overall analysis of variance revealed that the processing and frozen storage period of six months had significant ($P \leq 0.05$) effect on the protein content of okra rings on dry weight basis.

The protein content of fresh okra trimmed was 2.20 g/100g which after blanching decreased to 2.13 g/100g and further decreased after freezing to 2.00 g/100g, on fresh weight basis. Statistically, the processing had non-significant effect on the protein content. Even during the frozen storage period of six months, the protein content remained 2.00 to 1.97 g/100g. The overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the protein content of okra trimmed. On dry weight basis, the protein content of fresh okra trimmed was 19.5 g/100g which increased to 23.7 g/100g after blanching and decreased after freezing to 22.2 g/100g. Statistically, these changes were significant ($P \leq 0.05$). On the contrary, the protein content remained 22.2 to 21.8 g/100g throughout the frozen storage period of six months. However, the overall analysis of variance indicated that the processing and frozen storage period of six months had significant ($P \leq 0.05$) effect on the protein content of okra trimmed on dry weight basis.

The protein content of both cuts of fresh okra was same i.e. 2.20 g/100g whereas the protein content of okra trimmed was higher than that of the okra rings throughout the processing and frozen storage period of six months. The corresponding range was 1.95 to 2.13 g/100g on fresh weight basis. The differences were statistically non-significant. The overall range of protein in all stages of two types of okra was 1.95 to 2.20 g/100g. But on dry weight basis, the protein content of fresh okra trimmed was 19.5 g/100g which was slightly higher than that of the okra rings. The difference was statistically non-significant. But the protein content of okra rings was higher than that of the okra trimmed after blanching, freezing and throughout frozen storage period of six months.

The corresponding and overall range was 21.8 to 26.1 g/100g. The differences were statistically non-significant. However, the statistically analysis revealed that the protein content of the two types of cuts of okra was not statistically different from each other throughout the processing and frozen storage period of six months on fresh as well as dry weight basis.

Capsicum halves had 1.40 g/100g of protein on fresh weight basis, which was reduced to 1.20 g/100g after blanching and further reduced after freezing to 1.15 g/100g. The analysis of variance revealed that the reduction was non-significant. The protein content remained 1.15-1.16 g/100g during the frozen storage period of six months. On dry weight basis, the fresh capsicum halves had 18.9 g/100g of protein, which after blanching decreased to 16.6 g/100g and further decreased after freezing to 15.7 g/100g. Statistically, the protein changes were non-significant. The protein content during the frozen storage period of six months remained in a very narrow range of 15.6 to 15.8 g/100g. Statistically, the frozen storage period had non-significant effect on the protein content. The overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the protein content of capsicum halves on fresh and dry weight basis.

From the overall analysis of variance, it was observed that processing and frozen storage period of six months had no effect on the protein content of all the vegetables, on fresh weight basis. A slight reduction was observed which might be due to the leaching losses. However, on dry weight basis, after blanching, there appeared to be some gain in protein content of okra rings and trimmed. This can be attributed to absorption of water during blanching and loss of some soluble components. As a matter of fact, the protein content was slightly reduced on fresh weight basis. Adams (1981) also reported that there was no change in protein content when green beans were blanched in water for one minute but it became three per cent less when blanching time was increased to three minutes. Even the loss was three per cent during three minutes of steam blanching. These losses may be due to denaturation and solubilisation of proteins. Lee *et al* (1982a) did not observe any significant decrease in protein content during the commercial blanching operation. Lisiewska and Kmiecik (2000) also observed that there was no effect of storage of two months at –20°C on total nitrogen in tomato cubes. The findings of present study are in reasonable agreement with the literature reports.

4.4.1.2. Crude fat : The data in Tables 4.11 and 4.12 represent the crude fat content of fresh, processed and frozen stored vegetables on fresh and dry weight basis, respectively. The data indicated that the fat content of fresh French beans (1.0 cm) was 0.68 g/100g which remained in the very narrow range of 0.67 to 0.68 g/100g after blanching, freezing and frozen storage period of six months, on fresh weight basis. Statistically, these changes were non-significant. On dry weight basis, the fat content of fresh French beans (1.0 cm) was 7.1 g/100g which increased to 8.8 g/100g after blanching and remained in the narrow limits of 8.7 to 8.8 g/100g after freezing as well as during frozen storage period of six months. Statistically, these changes were non-significant. The overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the fat content of French beans (1.0 cm) on fresh and dry weight basis.

Table 4.11 Effect of processing and frozen storage on crude fat (g/100g, fresh weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	0.68	0.68	0.67	0.67	0.68	0.68	0.07^{NS}	0.02^{NS}	0.02^{NS}
French bean 6.0cm	0.67	0.67	0.67	0.67	0.67	0.67	-	-	-
t-value	0.32^{NS}	0.36^{NS}	-	-	0.35^{NS}	0.32^{NS}			
Okra rings	0.43	0.42	0.43	0.42	0.42	0.42	0.20^{NS}	0.09^{NS}	0.11^{NS}
Okra trimmed	0.43	0.43	0.43	0.42	0.42	0.43	-	0.08^{NS}	0.08^{NS}
t-value	-	0.36^{NS}	-	-	-	0.28^{NS}			
Capsicum halves	0.25	0.25	0.24	0.25	0.25	0.25	1.00^{NS}	0.17^{NS}	0.14^{NS}

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3-ratio overall F-ratio
NS – Non-significant

Table 4.12 Effect of processing and frozen storage on crude fat (g/100g, dry weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	7.1	8.8	8.7	8.7	8.8	8.8	3.20^{NS}	0.33^{NS}	3.25^{NS}
French bean 6.0cm	7.2	7.3	7.2	7.2	7.2	7.2	0.05^{NS}	-	0.05^{NS}
t-value	0.40^{NS}	3.30^{NS}	3.15^{NS}	3.10^{NS}	3.25^{NS}	3.20^{NS}			
Okra rings	3.7	5.3	5.4	5.3	5.2	5.2	5.25^{NS}	0.45^{NS}	5.35^{NS}
Okra trimmed	3.8	4.8	4.7	4.6	4.6	4.7	2.85^{NS}	0.07^{NS}	2.70^{NS}
t-value	0.35^{NS}	1.05^{NS}	1.10^{NS}	1.15^{NS}	1.10^{NS}	1.05^{NS}			
Capsicum halves	3.4	3.4	3.3	3.4	3.4	3.3	0.10^{NS}	0.09^{NS}	0.10^{NS}

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant

The fat content of fresh French beans (6.0 cm) was 0.67 g/100g which remained same after blanching, freezing and during frozen storage period of six months, on fresh weight basis. On dry weight basis the fat content of fresh French beans (6.0 cm) was 7.2 g/100g which increased slightly to 7.3 g/100g after blanching and remained static at 7.2 g/100g after freezing as well as during frozen storage period of six months. Statistically, these changes were not significant. The overall analysis of variance also revealed that the processing and frozen storage period had no effect on the fat content of French beans (6.0 cm) on fresh and dry weight basis..

The fat content of French beans having 1.0 cm cut was slightly higher than that of the French beans having 6.0 cm cut throughout the processing and frozen storage period of six months, the corresponding range was 0.67 to 0.68 g/100g on fresh weight basis. Statistically, the differences were non-significant. On dry weight basis, the fat content of fresh French beans (6.0 cm) was 7.2 g/100g which was slightly higher than that of the fresh French beans (1.0 cm). The difference was statistically non-significant. But it was slightly higher in French beans (1.0 cm) after processing and throughout the frozen storage period of six months. The corresponding range was 7.2 to 8.8 g/100g. Statistical analysis also revealed that fat content of the two types of cuts of French beans was not significantly different from each other throughout the processing and frozen storage period of six months on fresh as well as dry weight basis.

The fat content of both types of fresh okra was 0.43 g/100g and remained in the narrow limits of 0.42 to 0.43 g/100g, after blanching, freezing and frozen storage period of six months, on fresh weight basis. Statistically, these changes were non-significant.

On dry weight basis, the fat content of fresh okra rings was 3.7 g/100g which increased to 5.3 g/100g after blanching and further to 5.4 g/100g after freezing. The corresponding value remained almost static i.e. between 5.2 and 5.4 g/100g, during the frozen storage period of six months. Statistically, these changes were non-significant.

The fat content of okra trimmed, on dry weight basis, was 3.8 g/100g which increased to 4.8 g/100g after blanching and decreased to 4.7 g/100g after freezing. The corresponding value remained between 4.6 to 4.7 g/100g, during the frozen storage period of six months. These changes were statistically non-significant. However, the overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the fat content of okra rings and okra trimmed on fresh as well as dry weight basis.

The fat content of okra rings and trimmed was almost same i.e. 0.42 and 0.43 g/100g on fresh weight basis, after blanching, freezing and during frozen storage period of six months. On dry weight basis, the fat content of fresh okra trimmed was 3.8 g/100g which was higher than that of the fresh okra rings. But the fat content of okra rings was higher than that of the okra trimmed after processing and frozen storage period of six months. The values ranged from 4.6 to 5.4 g/100g. However, the differences were statistically non-significant.

The fat content of fresh, blanched, frozen and frozen stored capsicum halves was almost same, the range being 0.24 to 0.25 g/100g, on fresh weight basis, 3.3 to 3.4 g/100g, on dry weight basis and hence no significant change was evident. The overall analysis of variance also confirmed that the processing and frozen storage period of six months had non-significant effect on the fat content of capsicum halves on fresh as well as dry weight basis.

It was observed that on fresh weight basis, the processing and frozen storage period had no effect on fat content of all the vegetables. On dry weight basis, after blanching, there appeared to be a gain in fat content of French beans (1.0 cm) and okra (rings and trimmed), which remained at high level after freezing and during frozen storage period of six months. This can be attributed to absorption of water during blanching and loss of soluble components. As a matter of fact, the fat content was static on fresh weight basis. Similar results have been reported by Pruthi (1999) that even after nine months of storage at –23°C. There was no change in fat content of vegetables.

4.4.1.3. Crude fibre : The data in Tables 4.13 and 4.14 represent the crude fibre content of fresh, processed and frozen stored vegetables on fresh and dry weight basis. The data indicated that the fibre content of fresh French beans (1.00 cm) was 1.70 g/100g which after blanching decreased to 1.50 g/100g and further decreased to 1.49 g/100g after freezing, on fresh weight basis. The reduction was statistically non-significant. The fibre content remained constant i.e. 1.48 to 1.49 g/100g, throughout the frozen storage period of six months. On dry weight basis, the fibre content of French beans having 1.0 cm cut was 17.9 g/100g which after blanching increased to 19.5 g/100g and then decreased to 19.3 g/100g after freezing. The fibre content remained static between 19.2 to 19.3 g/100g during the frozen storage period. These changes were statistically non-significant. The overall analysis of variance also revealed that the processing and frozen storage period of

Table 4.13 Effect of processing and frozen storage on crude fibre (g/100g, fresh weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	1.70	1.50	1.49	1.49	1.48	1.49	1.95^{NS}	0.04^{NS}	1.95^{NS}
French bean 6.0cm	1.80	1.65	1.63	1.63	1.64	1.64	0.57^{NS}	0.04^{NS}	0.55^{NS}
t-value	0.45^{NS}	1.23^{NS}	2.80^{NS}	4.26^{NS}	3.4^{NS}	3.69^{NS}			
Okra rings	1.30	1.00	0.98	0.98	0.98	0.98	1.04^{NS}	-	1.07^{NS}
Okra trimmed	1.40	1.05	1.02	1.03	1.03	1.03	1.44^{NS}	0.06^{NS}	1.44^{NS}
t-value	0.24^{NS}	0.71^{NS}	1.79^{NS}	1.77^{NS}	1.82^{NS}	1.39^{NS}			
Capsicum halves	1.10	1.00	0.98	0.98	0.98	0.98	1.14^{NS}	-	1.15^{NS}

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3-ratio overall F-ratio
NS – Non-significant

Table 4.14 Effect of processing and frozen storage on crude fibre (g/100g, dry weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	17.9	19.5	19.3	19.3	19.2	19.3	2.87^{NS}	0.04^{NS}	3.19^{NS}
French bean 6.0cm	19.5	18.0	17.7	17.7	17.8	17.8	0.96^{NS}	0.06^{NS}	1.09^{NS}
t-value	0.45^{NS}	1.24^{NS}	2.80^{NS}	6.27^{NS}	4.44^{NS}	3.36^{NS}			
Okra rings	11.2	12.7	12.4	12.3	12.2	12.2	1.20^{NS}	1.05^{NS}	1.30^{NS}
Okra trimmed	12.4	11.7	11.3	11.4	11.4	11.4	1.66^{NS}	1.00^{NS}	1.00^{NS}
t-value	0.24^{NS}	0.74^{NS}	1.79^{NS}	1.77^{NS}	5.00^{NS}	1.39^{NS}			
Capsicum halves	14.8	13.6	13.4	13.4	13.4	13.2	1.81^{NS}	0.84^{NS}	1.91^{NS}

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant

six months had non-significant effect on the fibre content of French bean (1.0 cm) on fresh and dry weight basis.

The fibre content of fresh French beans having 6.0 cm cut was 1.80 g/100g which after blanching decreased to 1.65 g/100g and after freezing to 1.63 g/100g, on fresh weight basis. The reduction was statistically non-significant. The fibre content remained in the narrow range of 1.63 to 1.64 g/100g during the frozen storage period of six months and hence the change was statistically non-significant. On dry weight basis, the fibre content was 19.5 g/100g in fresh French beans (6.0 cm) which decreased to 18.0 g/100g after blanching, further after freezing to 17.7 g/100g and remained between 17.7 and 17.8 g/100g during the frozen storage period of six months. Statistically, these changes were non-significant. The overall analysis of variance also indicated that the processing and frozen storage period of six months had non-significant effect on the fibre content of French beans (6.0 cm) on fresh as well as dry weight basis.

The fibre content of French beans having 6.0 cm cut was higher than that of the French beans having 1.0 cm cut throughout in fresh form, during processing and frozen storage period of six months, on fresh weight basis. The corresponding overall range was 1.48 to 1.80 g/100g. Statistically, the difference was non-significant. On dry weight basis, the fibre content of the fresh French beans having 6.0 cm cut was 19.5 g/100g which was higher than that of the fresh French beans having 1.0 cm cut, but it was higher in French beans (1.0 cm) after blanching, freezing and during frozen storage period of six months. The corresponding as well as overall range was 17.7 to 19.5 g/100g and the differences were statistically non-significant. From the statistical analysis, it was observed that the fibre content of the two types of cuts of French beans was not statistically different from each other in fresh form, during processing and frozen storage period of six months on fresh as well as dry weight basis.

The fibre content of fresh okra rings was 1.30 g/100g but after blanching decreased to 1.00 g/100g and after freezing further decreased to 0.98 g/100g. The fibre content remained static at 0.98 g/100g, throughout the frozen storage period of six months on fresh weight basis. The decrease was statistically non-significant.

On dry weight basis, the fibre content of the fresh okra rings was 11.2 g/100g which after blanching increased to 12.7 g/100g and then decreased to 12.4 g/100g after freezing. The fibre content remained between 12.2 and 12.4 g/100g during the frozen storage period of six months. These changes were statistically non-significant. The overall analysis of variance also indicated that the processing and frozen storage period of six months had non-significant effect on the fibre content of okra rings on fresh and dry weight basis.

The fibre content of fresh okra trimmed was 1.40 g/100g which decreased to 1.05 g/100g after blanching and further decreased to 1.02 g/100g after freezing, on fresh weight basis. The corresponding value remained 1.02 to 1.03 g/100g during the frozen storage period of six months. On dry weight basis the fibre content was 12.4 g/100g in fresh okra trimmed which decreased to 11.7 g/100g after blanching and further decreased to 11.3 g/100g after freezing, but remained static at 11.4 g/100g during the frozen storage period of six months. Statistically, these changes were non-significant. From the overall analysis of variance, it was also observed that the processing and frozen storage period had non-significant effect on the fibre content of okra trimmed on fresh and dry weight basis.

The fibre content of okra trimmed was higher than that of the okra rings in fresh form after processing and during frozen storage period of six months, on fresh weight basis. The corresponding overall range was 0.98 to 1.40 g/100g. The differences were statistically not significant. On dry weight basis, the fibre content of the fresh okra trimmed was 12.4 g/100g which was higher than that of the okra rings, but it was higher in okra rings after blanching, freezing and during frozen storage period of six months. The corresponding overall range was 11.2 to 12.7 g/100g and the differences were statistically non-significant. The statistical analysis revealed that the fibre content of the two types of cuts of okra was not statistically different from each other throughout the processing and frozen storage period of six months on fresh as well as dry weight basis.

The fibre content of fresh, blanched and frozen capsicum halves was 1.10, 1.00 and 0.98 g/100g, respectively, on fresh weight basis. The corresponding value remained at 0.98 g/100g during the frozen storage period of six months. These changes were statistically non-significant. On dry weight basis, the fibre content of fresh, blanched and frozen capsicum halves was 14.8, 13.6 and 13.4 g/100g, respectively. The corresponding value remained between 13.2 and 13.4 g/100g during the frozen storage period of six months. Statistically, these changes were non-significant. The overall analysis of variance also indicated that the processing and frozen storage period of six months had non-significant effect on the fibre content of capsicum halves on fresh as well as dry weight basis.

It was observed that on fresh weight basis, the processing and frozen storage period had non-significant effect on fibre content of all the vegetables. However, on dry weight basis, after blanching, there appeared to be a gain in fibre content of French beans having 1.0 cm cut and okra rings which remained so after freezing and during frozen storage period of six months. This can be attributed to absorption of water during blanching and loss of soluble components. As a matter of fact, the fibre content was reduced on fresh weight basis.

According to Svanberg *et al* (1997), the total fibre content decreased after milder processing, such as blanching due to loss of soluble dietary fibre, such as pectic polymers. Lisiewska and Kmiecik (2000), on the other hand, reported that there was no effect of storage of 12 months at –20 or –30°C on dietary fiber, soluble solids and sugars. The results of the present study are in agreement with the above reports. In view of the above, it can be concluded that processed vegetables like fresh vegetables are important sources of dietary fibre.

4.4.1.4. Total ash content : The ash content is an indication of mineral content in the vegetables. The ash content of the fresh, processed and frozen stored vegetables is given in Tables 4.15 and 4.16 on fresh and dry weight basis, respectively. The data revealed that the ash content of fresh French beans (1.0 cm) was 0.50 g/100g which was reduced to 0.48 g/100g after blanching but remained constant after freezing and during frozen storage period of six months, on fresh weight basis. Statistically, the variation was non-significant. On dry weight basis, the ash content of fresh French beans (1.0 cm) was 5.2 g/100g which increased to 6.2 g/100g after blanching and remained same after freezing as

Table 4.15 Effect of processing and frozen storage on ash content (g/100g, fresh weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	0.50	0.48	0.48	0.48	0.48	0.48	0.67^{NS}	-	0.50^{NS}
French bean 6.0cm	0.49	0.48	0.49	0.49	0.49	0.49	0.50^{NS}	-	0.08^{NS}
t-value	0.83^{NS}	-	0.45^{NS}	1.00^{NS}	1.00^{NS}	1.00^{NS}			
Okra rings	0.62	0.59	0.59	0.61	0.61	0.61	1.50^{NS}	0.57^{NS}	0.75^{NS}
Okra trimmed	0.61	0.59	0.60	0.60	0.59	0.59	0.60^{NS}	0.45^{NS}	0.50^{NS}
t-value	0.45^{NS}	-	1.00^{NS}	0.45^{NS}	1.41^{NS}	1.41^{NS}			
Capsicum halves	0.57	0.55	0.56	0.55	0.54	0.55	1.00^{NS}	1.30^{NS}	1.62^{NS}

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant

Table 4.16 Effect of processing and frozen storage on ash content (g/100g, dry weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	5.2	6.2	6.2	6.2	6.2	6.2	4.65^{NS}	0.03^{NS}	3.61^{NS}
French bean 6.0cm	5.3	5.2	5.3	5.3	5.3	5.3	0.50^{NS}	-	0.08^{NS}
t-value	0.71^{NS}	2.69^{NS}	3.16^{NS}	3.00^{NS}	8.00^{NS}	2.85^{NS}			
Okra rings	5.3	7.5	7.4	7.6	7.6	7.6	54.75** (0.749)	0.60^{NS}	32.13** (0.556)
Okra trimmed	5.4	6.5	6.6	6.6	6.5	6.5	44.54** (0.4701)	0.44^{NS}	22.89** (0.363)
t-value	0.28^{NS}	3.53^{NS}	4.00^{NS}	3.90^{NS}	3.95^{NS}	4.02^{NS}			
Capsicum halves	7.7	7.6	7.6	7.5	7.4	7.5	0.05^{NS}	2.46^{NS}	2.43^{NS}

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3-ratio overall F-ratio
NS – Non-significant
** - significant at 1% level
Figures in parenthesis indicate C.D. values

well as during frozen storage period of six months. Statistically these changes were non-significant. The overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the ash content of French beans (1.0 cm) on fresh as well as dry weight basis.

The ash content of fresh French beans (6.0 cm) was 0.49 g/100g which decreased slightly to 0.48 g/100g after blanching and remained 0.49 g/100g after freezing and during frozen storage period of six months, on fresh weight basis. Statistically, the reduction was non-significant. On dry weight basis, the ash content of fresh French beans (6.0 cm) was 5.3 g/100g which decreased slightly to 5.2 g/100g after blanching and remained at 5.3 g/100g after freezing and during frozen storage period of six months and hence no statistical change. The overall analysis of variance also revealed that the processing and frozen storage period had non-significant effect on the ash content of French beans (6.0 cm) on fresh and dry weight basis.

The ash content of fresh French beans having 1.0 cm cut was 0.50 g/100g which was slightly higher than that of the fresh French beans having 6.0 cm cut, but was same in both the cuts after blanching i.e. 0.48 g/100g. The ash content was higher in French beans (6.0 cm) than that of French beans (1.0 cm) after freezing and during frozen storage period of six months, on fresh weight basis. The corresponding range was 0.48 to 0.49 g/100g. The overall range was 0.48 to 0.50 /100g. On dry weight basis, the ash content of fresh French beans (6.0 cm) was 5.3 g/100g which was slightly higher than that of the French beans (1.0 cm). On the other hand, the ash content after blanching and during frozen storage period was higher in French beans (1.0 cm) than that of the French beans (6.0 cm), the corresponding range being 5.2 to 6.2 g/100g. The statistical analysis revealed that the ash content of the two types of cuts of French beans was not statistically different from each other throughout the processing and frozen storage period of six months on fresh as well as dry weight basis.

The ash content of fresh okra rings was 0.62 g/100g which after blanching and freezing was reduced to 0.59 g/100g and remained 0.61 g/100g during the frozen storage period of six months, on fresh weight basis. The reduction in ash content was statistically non-significant. On dry weight basis, the ash content of fresh okra rings was 5.3 g/100g which increased to 7.5 g/100g after blanching and then decreased to 7.4 g/100g after freezing. Statistically, this change was significant ($P \leq 0.01$). The ash content remained 7.4 to 7.6 g/100g during the frozen storage period of six months and hence no statistical change was noticed. However, the overall analysis of variance revealed that the processing and frozen storage period of six months had significant ($P \leq 0.01$) effect on the ash content of okra rings.

The ash content of fresh okra trimmed was 0.61 g/100g which after blanching decreased to 0.59 g/100g and changed to 0.60 g/100g after freezing, on fresh weight basis. Even during the frozen storage period of six months, the ash content remained within the narrow range of 0.59 to 0.60 g/100g. These changes were statistically non-significant. The overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the ash content of okra trimmed. On dry weight basis, the ash content of fresh okra trimmed was 5.4 g/100g which increased to 6.5 g/100g after blanching and further increased slightly to 6.6 g/100g after freezing. Statistically, these changes were significant ($P \leq 0.01$). But on the contrary, the ash content remained almost constant throughout the frozen storage period of six months, the overall range being 6.5 to 6.6 g/100g and hence no significant change had occurred. However, the overall analysis of variance indicated that the processing and frozen storage period of six months had significant ($P \leq 0.01$) effect on the ash content of okra trimmed.

The ash content of fresh okra rings was 0.62 g/100g which was slightly higher than that of the fresh okra trimmed but was same in both the cuts after blanching i.e. 0.59 g/100g and then became higher in okra trimmed after freezing i.e. 0.60 g/100g, on fresh weight basis. Again the ash content of okra rings was higher i.e. 0.61 g/100g, than that of the okra trimmed throughout the frozen storage period of six months. The differences were statistically non-significant. The overall range of ash content in all stages of two types of okra was 0.59 to 0.62 g/100g. On dry weight basis, the ash content of fresh okra trimmed was 5.4 g/100g which was slightly higher than that of the okra rings. But it was slightly higher in okra rings after blanching, freezing and during frozen storage period of six months, the corresponding range being 6.5 to 7.6 g/100g. The overall range was 5.3 to 7.6 g/100g for ash content but statistical analysis revealed that the ash content of the two types of cuts of okra was not statistically different from each other throughout the processing and frozen storage period of six months on fresh as well as dry weight basis.

Capsicum halves had 0.57 g/100g of ash content on fresh weight basis, which was reduced to 0.55 g/100g after blanching and slightly increased after freezing to 0.56 g/100g. These changes were statistically non-significant. The ash content remained almost constant during the frozen storage period of six months, the range being 0.54 to 0.56 g/100g and hence no significant change was evident. On dry weight basis, the fresh capsicum halves had 7.7 g/100g of the ash content, which after blanching and freezing decreased to 7.6 g/100g. Statistically, this change was non-significant. The ash content remained nearly same during the frozen storage period of six months, the range being 7.4 to 7.6 g/100g and hence no significant change occurred. The overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the ash content of capsicum halves on fresh as well as dry weight basis.

From the overall analysis, it was concluded that on fresh weight basis, the processing and frozen storage period had non-significant effect on ash content of all the vegetables. A slight decrease after blanching may be due to loss of the soluble minerals. However, on dry weight basis, there appeared to be some gain in ash content of French beans (1.0 cm), okra (rings and trimmed) after blanching. This can be attributed to absorption of water during blanching and loss of some soluble components. As a matter of fact, the ash content was reduced on fresh weight basis. The results are in conformity with those of Lisiewska and Kmiecik (2000) who observed that there was no change in ash content of frozen tomato cubes stored for a period of six months. Hugo *et al* (1989) also observed no change in ash content when green beans were blanched in boiling water. Eskin (1989) on the other hand observed that steam blanching under ideal conditions caused a loss of about 5 per cent of the total solids which is likely to be reflected in the concentration of total ash content also.

4.4.1.5. Available carbohydrates : The Tables 4.17 and 4.18 show the available carbohydrates after blanching, freezing and frozen storage period of six months, on fresh and dry weight basis, respectively. The data revealed that the carbohydrate content of fresh French beans having 1.0 cm cut was 4.70 g/100g which after blanching decreased to 3.30 g/100g but increased to 3.41 g/100g after freezing, on fresh weight basis. These changes were statistically significant ($P \leq 0.05$). The carbohydrate content remained nearly constant i.e. 3.40 to 3.46 g/100g, throughout the frozen storage period of six months and hence no statistical change occurred. On the other hand, the overall statistical analysis of variance revealed that the processing and frozen storage period had significant ($P \leq 0.01$) effect on the carbohydrate content of French beans (1.0 cm). The carbohydrate content of fresh French beans (1.0 cm), on dry weight basis, was 40.0 g/100g which after blanching decreased to 35.8 g/100g and then increased to 36.7 g/100g after freezing. Statistically, these changes were non-significant. The carbohydrate content remained almost static during frozen storage period of six months, the overall range being 36.6 to 37.3 g/100g. The overall statistical analysis also revealed that processing and frozen storage period had non-significant effect on the carbohydrate content of French beans (1.0 cm) on dry weight basis.

The carbohydrate content of fresh French beans (6.0 cm) was 4.36 g/100g which after blanching increased to 4.47 g/100g and further increased to 4.57 g/100g after freezing on fresh weight basis. The increase was statistically non-significant. The corresponding value remained between the narrow range of 4.57 and 4.60 g/100g, throughout the frozen storage period of six months and the variance was not statistically

Table 4.17 Effect of processing and frozen storage on available carbohydrate content (g/100g, fresh weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	4.70	3.30	3.41	3.41	3.46	3.40	29.28* (0.649)	0.09^{NS}	21.17** (0.402)
French bean 6.0cm	4.36	4.47	4.57	4.59	4.60	4.58	0.70^{NS}	0.001^{NS}	0.45^{NS}
t-value	2.29^{NS}	4.46*	8.53^{NS}	0.92^{NS}	8.47**	9.67**			
Okra rings	7.00	3.78	3.90	3.98	4.04	4.04	76.36** (0.943)	0.18^{NS}	49.59** (0.614)
Okra trimmed	6.62	4.76	4.95	4.98	4.99	4.98	81.61** (0.511)	0.02^{NS}	37.73** (0.391)
t-value	1.17^{NS}	19.61**	4.20^{NS}	4.27^{NS}	8.11**	5.71**			
Capsicum halves	4.08	4.20	4.37	4.36	4.37	4.49	2.33^{NS}	0.38^{NS}	2.52^{NS}

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3-ratio overall F-ratio
NS – Non-significant
* - significant at 5% level; ** - significant at 1% level
Figures in parenthesis indicate CD values

Table 4.18 Effect of processing and frozen storage on available carbohydrate content (g/100g, dry weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	40.0	35.8	36.7	36.7	37.3	36.6	3.82^{NS}	0.11^{NS}	2.53^{NS}
French bean 6.0cm	38.2	40.2	40.8	41.0	41.0	40.8	0.91^{NS}	0.001^{NS}	0.49^{NS}
t-value	*1.47^{NS}*	*1.87^{NS}*	*3.27^{NS}*	*2.14^{NS}*	*3.21^{NS}*	*3.76^{NS}*			
Okra rings	49.2	40.5	41.6	42.3	42.7	42.7	10.81* (9.450)	0.08^{NS}	5.55* (6.668)
Okra trimmed	47.6	44.3	46.2	46.6	46.7	46.6	6.27^{NS}	0.02^{NS}	2.30^{NS}
t-value	0.66^{NS}	8.60**	2.55^{NS}	1.81^{NS}	3.77^{NS}	2.51^{NS}			
Capsicum halves	47.8	51.5	52.7	52.6	52.7	53.0	3.13^{NS}	0.10^{NS}	2.64^{NS}

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant
* - significant at 5% level; ** - significant at 1% level
Figures in parenthesis indicate C.D. values

significant. The overall analysis of variance also indicated that the processing and frozen storage period of six months had non-significant effect on the carbohydrate content of French beans (6.0 cm). On dry weight basis, the carbohydrate content was 38.2 g/100g in fresh French beans (6.0 cm) which increased to 40.2 g/100g after blanching and further to 40.8 g/100g after freezing. However, these changes were statistically non-significant. The carbohydrate content remained almost static during the frozen storage period of six months, the overall range being 40.8 to 41.0 g/100g and hence no statistical change took place. From overall analysis of variance, it was inferred that the processing and frozen storage period had non-significant effect on the carbohydrate content of French beans (6.0 cm).

The carbohydrate content of fresh French beans having 1.0 cm cut was 4.70 g/100g which was higher than that of the French beans having 6.0 cm cut on fresh weight basis. But it was higher in French beans (6.0 cm) after blanching, freezing and during frozen storage period of six months, the corresponding range being 3.30 to 4.60 g/100g on fresh weight basis. The overall range was 3.30 to 4.70 g/100g. The differences were statistically significant after blanching ($P \leq 0.05$) and after four and six months of frozen storage period ($P \leq 0.01$). Similar results were obtained on dry weight basis. The carbohydrate content of French beans (1.0 cm) was 40.0 g/100g which was higher than that of the French beans (6.0 cm). But it was higher in French beans (6.0 cm) after blanching, freezing and during frozen storage period of six months. The corresponding overall range was 35.8 to 40.8 g/100g and the differences were statistically non-significant. The statistical analysis also revealed that the carbohydrate content of the two types of cuts of French beans was statistically different from each other after blanching ($P \leq 0.05$) and during four and six months of frozen storage period ($P \leq 0.01$), on fresh weight basis, but was statistically not different from each other at various stages of processing and frozen storage on dry weight basis.

The carbohydrate content of fresh okra rings was 7.00 g/100g but after blanching decreased to 3.78 g/100g and then increased to 3.90 g/100g after freezing, on fresh weight basis. These changes were statistically significant ($P \leq 0.01$). The carbohydrate content remained between 3.90 and 4.04 g/100g during frozen storage period of six months and the changes were statistically non-significant. The overall statistical analysis, on the other hand revealed that processing and frozen storage period had significant ($P \leq 0.01$) effect on the carbohydrate content of okra rings. On dry weight basis, the carbohydrate content of the fresh okra rings was 49.2 g/100g which after blanching decreased to 40.5 g/100g and then increased to 41.6 g/100g after freezing. Statistically, these changes were significant ($P \leq 0.05$). However, the corresponding levels remained between 41.6 and 42.7 g/100g during the frozen storage period of six months and hence the differences were statistically non-significant. However, the overall analysis of variance revealed that processing and frozen storage period had significant ($P \leq 0.05$) effect on the carbohydrate content of okra rings.

The carbohydrate content of fresh okra trimmed was 6.62 g/100g which decreased to 4.76 g/100g after blanching and then increased to 4.95 g/100g after freezing on fresh weight basis. These changes were statistically significant ($P \leq 0.01$). The corresponding value remained between the narrow range of 4.95 and 4.99 g/100g during frozen storage period of six months and the variations were statistically non-significant. The overall statistical analysis, on the contrary, confirmed that the processing and frozen storage period had significant ($P \leq 0.01$) effect on the carbohydrate content of okra trimmed. On dry weight basis, the carbohydrate content of fresh okra trimmed was 47.6 g/100g which decreased to 44.3 g/100g after blanching but increased to 46.2 g/100g after freezing. Statistically, these changes were non-significant. The corresponding levels remained nearly static i.e. 46.2 to 46.7 g/100g during frozen storage period of six months, the differences being statistically non-significant. From the overall analysis of variance, it was also observed that the processing and frozen storage period had non-significant effect on the carbohydrate content of okra trimmed on dry weight basis.

The carbohydrate content of fresh okra rings was 7.00 g/100g which was higher than that of the okra trimmed on fresh weight basis. But it was higher in okra trimmed after blanching, freezing and during frozen storage period of six months, the corresponding range being 3.78 to 4.99 g/100g. The differences were statistically significant ($P \leq 0.01$) after blanching and after four and six months of frozen storage period. The overall range of carbohydrates in all stages of two types of okra was 3.78 to 7.00 g/100g. On dry weight basis again, the carbohydrate content of fresh okra rings was 49.2 g/100g which was higher than that of the okra trimmed. But it was higher in okra trimmed after blanching, freezing and during frozen period of six months, the corresponding range being 40.5 to 46.7 g/100g. The differences were statistically significant ($P \leq 0.01$) after blanching only. The overall range of carbohydrate in all stages of two types of okra, on dry weight basis, was 40.5 to 49.2 g/100g. The statistical analysis confirmed that the carbohydrate content of the two types of cuts of okra, on fresh weight basis, was statistically different ($P \leq 0.01$) from each other after blanching and after four and six months of frozen storage period whereas on dry weight basis was significantly different ($P \leq 0.01$) after blanching only.

The carbohydrate content of fresh, blanched and frozen capsicum halves was 4.08, 4.20 and 4.37 g/100g, respectively, on fresh weight basis. The corresponding value remained between 4.36 and 4.49 g/100g during the frozen storage period of six months. On dry weight basis, the carbohydrate content of fresh, blanched and frozen capsicum halves was 47.8, 51.5 and 52.7 g/100g, respectively. The corresponding level remained between a very narrow range of 52.6 and 53.0 g/100g during frozen storage period of six months. Statistically, the changes were non-significant. The overall analysis of variance also depicted that the processing and frozen storage period of six months had non-significant effect on the carbohydrate content of capsicum halves, on fresh as well as dry weight basis.

From the overall analysis of variance, it was observed that the carbohydrate content of French beans having 1.0 cm cut and okra (rings and trimmed) on fresh weight basis was significantly ($P \leq 0.01$) affected by the processing and frozen storage period of six months.

The carbohydrate content was calculated by difference i.e. by adding up the values of all the other proximate principles (moisture, crude protein, crude fibre, crude fat and total ash content) and subtracting from 100. The increase or decrease in the above mentioned principles inversely affected the available carbohydrate content. The data revealed that the total solids decreased due to increase in moisture content or leaching losses after blanching and the corresponding change in the available carbohydrates was observed after blanching, freezing and frozen storage period of six months.

4.4.2 Total sugars : The sugar content of fresh, processed and frozen stored vegetables is given in Tables 4.19 and 4.20 on fresh and dry weight basis, respectively. The sugar content of fresh French beans having 1.0 cm cut was 40.2 mg/g which decreased to 38.6 mg/g after blanching and further decreased to 38.3 mg/g after freezing, on fresh weight basis. These changes were statistically non-significant. The sugar content remained almost static throughout the frozen storage period, the value being between 38.2 and 38.3 mg/g and hence no significant change occurred. The overall analysis of variance also confirmed that processing and frozen storage period had non-significant effect on the sugar content.

On dry weight basis, the sugar content of French beans having 1.0 cm cut was 424.0 mg/g which after blanching increased to 503.9 mg/g and then decreased to 497.4 mg/g after freezing. Statistically, these changes were significant ($P \leq 0.05$). The sugar content remained almost constant i.e. between 496.1 and 497.4 mg/g during the frozen storage period of six months and hence no significant change was evident. However, the overall statistical analysis revealed that processing and frozen storage period had significant ($P \leq 0.05$) effect on the sugar content of French beans (1.0 cm) on dry weight basis.

The sugar content of fresh French beans having 6.0 cm cut was 40.3 mg/g which after blanching decreased to 39.1 mg/g and to 39.0 mg/g after freezing, on fresh weight

Table 4.19 Effect of processing and frozen storage on total sugars (mg/g, fresh weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	40.2	38.6	38.3	38.2	38.2	38.3	1.68^{NS}	0.001^{NS}	0.68^{NS}
French bean 6.0cm	40.3	39.1	39.0	39.0	39.0	39.0	2.24^{NS}	-	0.25^{NS}
t-value	0.10^{NS}	1.00^{NS}	0.58^{NS}	0.74^{NS}	0.30^{NS}	0.67^{NS}			
Okra rings	51.0	49.3	49.1	49.1	49.0	49.1	1.56^{NS}	0.02^{NS}	1.39^{NS}
Okra trimmed	51.5	50.2	50.1	50.0	50.0	50.0	1.22^{NS}	0.001^{NS}	0.31^{NS}
t-value	0.37^{NS}	1.00^{NS}	1.64^{NS}	0.86^{NS}	0.49^{NS}	0.81^{NS}			
Capsicum halves	38.0	36.5	36.3	36.3	36.2	36.3	0.67^{NS}	0.001^{NS}	0.50^{NS}

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant

Table 4.20 Effect of processing and frozen storage on total sugars (mg/g, dry weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	424.0	503.9	497.4	496.1	496.7	497.4	20.67* (44.0517)	0.002^{NS}	6.36* (41.786)
French bean 6.0cm	437.0	428.	424.8	424.8	423.9	423.9	1.42^{NS}	0.002^{NS}	0.20^{NS}
t-value	1.32^{NS}	12.12**	4.76*	3.91^{NS}	2.28^{NS}	2.38^{NS}			
Okra rings	441.5	628.8	621.5	618.3	612.5	613.7	157.98** (38.1192)	0.86^{NS}	108.57** (24.1459)
Okra trimmed	457.3	560.2	556.6	555.5	555.5	555.5	62.87** (32.98)	0.002^{NS}	10.81** (42.3763)
t-value	1.17^{NS}	6.16**	9.58**	5.36^{NS}	2.50^{NS}	2.57^{NS}			
Capsicum halves	513.5	500.0	497.2	497.2	495.8	490.5	0.32^{NS}	0.09^{NS}	0.34^{NS}

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant
* - significant at 5% level; ** - significant at 1% level
Figures in parenthesis indicate C.D. values

basis. The reduction was statistically non-significant. The corresponding value remained same throughout the frozen storage period of six months. On dry weight basis, the sugar content was 437.0 mg/g, which decreased to 428.7 mg/g after blanching and further decreased to 424.8 mg/g after freezing. This decrease was statistically non-significant. The sugar content remained within a very narrow range of 423.9 to 424.8 mg/g during frozen storage period and hence no statistical change was observed. The overall statistical analysis also indicated that the processing and frozen storage period had non-significant effect on the sugar content of French beans (6.0 cm) on fresh as well as dry weight basis.

The sugar content of French beans having 6.0 cm cut was 40.3 mg/g which was slightly higher than that of the French beans having 1.0 cm cut, throughout the processing and frozen storage period of six months on fresh weight basis. The corresponding overall range was between 38.2 and 40.3 mg/g. The differences were statistically non-significant. On dry weight basis, the sugar content of the fresh French beans (6.0 cm) was 437.0 mg/g which was higher than that of the French beans (1.0 cm). But it was higher in French beans (1.0 cm) after blanching, freezing and during frozen storage period of six months. The corresponding overall range was 423.9 to 503.9 mg/g. The statistical analysis revealed that the sugar content of the two types of cuts of French beans was statistically non-significant on fresh weight basis whereas significantly different after blanching ($P \leq 0.01$) and after freezing ($P \leq 0.05$) were observed on dry weight basis.

The sugar content of fresh okra rings was 51.0 mg/g but after blanching decreased to 49.3 mg/g and after freezing further to 49.1 mg/g, on fresh weight basis. The decrease was statistically non-significant. The sugar content remained almost same i.e. 49.0 to 49.1 mg/g, throughout the frozen storage period of six months and hence no statistical change was evident. The overall statistical analysis also confirmed that processing and frozen storage period had non-significant effect on the sugar content of okra rings. On dry weight basis, the sugar content of fresh okra rings was 441.5 mg/g, which after blanching increased to 628.8 mg/g and then decreased to 621.5 mg/g after freezing. Statistically, these changes were significant ($P \leq 0.01$). The sugar content remained between 612.5 and 621.5 mg/g during the frozen storage period of six months and differences were not statistically significant. The overall analysis of variance, on the other hand, indicated that the processing and frozen storage period of six months resulted in significant ($P \leq 0.01$) increase in the sugar content of okra rings on dry weight basis.

The sugar content of fresh okra trimmed was 51.5 mg/g which decreased to 50.2 mg/g after blanching and further decreased slightly to 50.1 mg/g after freezing, on fresh weight basis. These changes were statistically non-significant. The corresponding value remained 50.1 to 50.0 mg/g during the frozen storage period of six months and so no statistical change was evident. The overall analysis of variance also depicted that the processing and frozen storage period had non-significant effect on the sugar content of okra trimmed. On dry weight basis, the sugar content was 457.3 mg/g in fresh okra trimmed which increased to 560.2 mg/g after blanching and then decreased to 556.6 mg/g after freezing. Statistically, these changes were significant ($P \leq 0.01$). The sugar content remained 556.6 to555.5 mg/g during the frozen storage period of six months and so no statistical change was visible. From the overall analysis of variance, it was observed that the processing and frozen storage period had significant ($P \leq 0.01$) effect on the sugar content of okra trimmed, on dry weight basis.

The sugar content of okra trimmed was higher than that of the okra rings throughout the processing and frozen storage period of six months on fresh weight basis. The corresponding overall range was between 49.0 and 51.5 mg/g. The differences were statistically non-significant. On the other hand, on dry weight basis, the sugar content of only fresh okra trimmed was 457.3 mg/g which was higher than that of the okra rings. But it was higher in okra rings after blanching, freezing and during frozen storage period of six months. The corresponding overall range was between 441.5 and 628.8 mg/g. The differences were significant ($P \leq 0.01$) after blanching and freezing. The statistical analysis revealed that the sugar content of the two types of cuts of okra was not statistically different from each other, on fresh weight basis. On the other hand, on dry weight basis, the sugar content of the two types of cuts was significantly different ($P \leq 0.01$) from each other after blanching and freezing processes.

The sugar content of fresh, blanched and frozen capsicum halves was 38.0, 36.5 and 36.3 mg/g, respectively, on fresh weight basis. These changes were statistically non-significant. The corresponding value remained between the narrow range of 36.2 and 36.3 mg/g throughout the frozen storage period of six months and so no statistical change. On dry weight basis, the sugar content of fresh, blanched and frozen capsicum halves was 513.5, 500.0 and 497.2 mg/g. The corresponding value remained between

490.5 and 497.2 mg/g during the frozen storage period of six months. Statistically, these changes were non-significant. The overall analysis of variance also depicted that the processing and frozen storage period of six months had non-significant effect on the sugar content of capsicum halves on fresh as well as dry weight basis.

It was observed that processing and frozen storage period had non-significant effect on total sugars of all the vegetables. A slight reduction was observed which might be due to the leaching losses. However, on dry weight basis, there appeared to be a gain in sugar content of French beans (1.0 cm), okra rings and okra trimmed after blanching, which remained so after freezing and during frozen storage period of six months. This can be attributed to absorption of water during blanching and loss of soluble components. As a matter of fact, the sugar content was reduced on fresh weight basis. According to Adams (1981), the total sugars of green beans reduced by three per cent during water blanching in three minutes while steam blanching for three minutes caused no loss. Eskin (1989) reported that short periods of blanching in water resulted in dissolution of appreciable quantities of sugars and other soluble components from peas, but not in case of steam blanching. Oruna-Concha *et al* (1996) reported that sugar content of vegetables was unaffected by frozen storage at –22°C upto 12 months. Lisiewska and Kmiecik (2000) observed that in case of tomato cubes, there was no effect of storage of 12 months at –20°C on the sugar content. Dhaliwal (2002) also reported that blanching, freezing and frozen storage period of six months (-20 to –25°C) had non-significant reduction in total sugars. The results obtained in the present study are in good agreement with the literature reports.

4.4.3. Pectin content : The pectin content of fresh, blanched, frozen and frozen stored vegetables is presented in Tables 4.21 and 4.22 on fresh and dry weight basis respectively. The data revealed that the pectin content of fresh French beans having 1.0 cm cut was 0.70 per cent which after blanching decreased to 0.63 per cent and remained same after freezing i.e. 0.63 per cent on fresh weight basis. Statistically, these changes were non-significant. The corresponding value remained between the narrow range of 0.63 to 0.64 per cent during the frozen storage period of six months and hence no statistical change. On dry weight basis, the pectin content was 7.3 per cent, which after blanching increased to 8.2 per cent and then decreased slightly to 8.1 per cent after freezing. However, these changes were statistically non-significant. The corresponding level remained between 8.1 and 8.3 per cent during six months of frozen storage period and hence no significant change occurred. From the overall analysis of variance, it was concluded that the processing and frozen storage period of six months had non-significant effect on the pectin content of French beans (1.0 cm) on fresh as well as dry weight basis.

The pectin content of French beans (6.0 cm) was 0.70 per cent which decreased to 0.66 per cent after blanching but remained stable after freezing on fresh weight basis. Statistically, these changes were non-significant. The corresponding level remained in the narrow range of 0.65 to 0.66 per cent throughout the frozen storage period of six months. Hence, no statistical change was observed. On dry weight basis, the pectin content was 7.6 per cent which decreased to 7.2 per cent after blanching and further to 7.1 per cent after freezing. Statistically, these changes were non-significant. The pectin content remained almost static during the frozen storage period of six months, the value

Table 4.21 Effect of processing and frozen storage on pectin content (%, fresh weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	0.70	0.63	0.63	0.64	0.64	0.63	2.23^{NS}	0.22^{NS}	1.90^{NS}
French bean 6.0cm	0.70	0.66	0.66	0.65	0.66	0.66	3.20^{NS}	0.04^{NS}	0.69^{NS}
t-value	-	1.34^{NS}	1.34^{NS}	0.32^{NS}	0.66^{NS}	1.34^{NS}			
Okra rings	1.00	0.96	0.96	0.95	0.95	0.95	0.32^{NS}	0.57^{NS}	0.73^{NS}
Okra trimmed	1.00	0.99	0.98	0.98	0.97	0.97	0.18^{NS}	0.04^{NS}	0.18^{NS}
t-value	-	0.83^{NS}	0.45^{NS}	0.83^{NS}	0.49^{NS}	2.50^{NS}			
Capsicum halves	0.40	0.38	0.38	0.37	0.38	0.37	0.36^{NS}	0.13^{NS}	0.36^{NS}

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant

Table 4.22 Effect of processing and frozen storage on pectin content (%, dry weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	7.3	8.2	8.1	8.3	8.3	8.1	1.60^{NS}	0.21^{NS}	1.68^{NS}
French bean 6.0cm	7.6	7.2	7.1	7.0	7.1	7.1	2.60^{NS}	0.02^{NS}	0.48^{NS}
t-value	0.39^{NS}	3.80^{NS}	3.90^{NS}	3.15^{NS}	3.29^{NS}	4.20^{NS}			
Okra rings	8.6	12.2	12.1	11.9	11.8	11.8	22.12* (1.967)	0.12^{NS}	14.93** (1.245)
Okra trimmed	8.8	11.0	10.8	10.8	10.7	10.7	26.20* (1.059)	0.03^{NS}	7.26* (1.050)
t-value	0.53^{NS}	2.68^{NS}	2.24^{NS}	2.56^{NS}	2.32^{NS}	2.56^{NS}			
Capsicum halves	5.4	5.2	5.2	5.0	5.2	5.0	0.95^{NS}	0.22^{NS}	0.86^{NS}

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant
* - significant at 5% level, ** - significant at 1% level
Figures in parenthesis indicate C.D. values

being between 7.0 and 7.1 per cent and hence no statistically significant change was observed. The overall statistical analysis also revealed that the processing and frozen storage period of six months had non-significant effect on the pectin content of French beans (6.0 cm) on fresh and dry weight basis.

The pectin content of both cuts of fresh French beans was same i.e. 0.70 per cent whereas the pectin content of French beans having 6.0 cm cut was higher than that of the French beans having 1.0 cm cut throughout the processing and frozen storage period of six months. The corresponding range was 0.63 to 0.66 per cent on fresh weight basis and the differences were statistically non-significant. The overall range was 0.63 to 0.70 per cent. On dry weight basis, the pectin content of fresh French beans (6.0 cm) was 7.6 per cent which was higher than that of the fresh French beans (1.0 cm), but the differences were not statistically significant. However, the pectin content of French beans (1.0 cm) was higher than that of the French beans (6.0 cm) after blanching, freezing and throughout the frozen storage period of six months. The corresponding as well as overall range was 7.0 to 8.2 per cent and the differences were statistically non-significant. However, the difference in the pectin content of two types of cuts of French beans was statistically non-significant in fresh stage, after blanching, freezing and during frozen storage period of six months on fresh as well as dry weight basis.

The pectin content of fresh okra rings was 1.00 per cent which decreased to 0.96 per cent after blanching and freezing, on fresh weight basis. Statistically, the decrease was non-significant. The corresponding level remained same throughout the frozen storage period, the value being 0.95 per cent and hence no significant change was observed. The overall analysis of variance also indicated that the processing and frozen storage period had non-significant effect on the pectin content of okra rings. On dry weight basis, the pectin content was 8.6 per cent in fresh okra rings, which increased to 12.2 per cent after blanching but then decreased to 12.1 per cent after freezing. Statistically, the changes were significant ($P \leq 0.05$), indicating that the processing had significant effect on the pectin content. However, the pectin content remained in the narrow range of 11.8 to 11.9 per cent, during the frozen storage period of six months and hence no significant change was observed. The overall analysis of variance revealed that the processing and frozen storage period of six months had significant ($P \leq 0.01$) effect on the pectin content of okra rings on dry weight basis.

The pectin content of fresh okra trimmed was 1.00 per cent which decreased to 0.99 per cent after blanching and further decreased to 0.98 per cent after freezing, on fresh weight basis. Statistically, these changes were non-significant. The corresponding value remained between 0.97 to 0.98 per cent during the frozen storage period of six months and hence no significant change occurred. The overall analysis of variance also indicated that the processing and frozen storage period had non-significant effect on the pectin content on fresh weight basis. On dry weight basis, the pectin content was 8.8 per cent in fresh okra trimmed, which increased to 11.0 per cent after blanching and then decreased to 10.8 per cent after freezing. Statistically, these changes were significant ($P \leq 0.05$), indicating that the processing had significant effect on the pectin content of okra trimmed. The corresponding level remained between 10.7 and 10.8 per cent during the six months of frozen storage period and hence no significant change was observed. The overall analysis of variance also revealed that the processing and frozen storage period had significant ($P \leq 0.05$) effect on the pectin content of the okra trimmed on dry weight basis.

The pectin content of two cuts of fresh okra was same i.e. 1.00 per cent. But the pectin content of okra trimmed was higher than that of the okra rings throughout the processing and frozen storage period of six months, the corresponding range being 0.95 to 0.99 per cent on fresh weight basis. The differences were statistically non-significant as the overall range was 0.95 to 1.00 per cent. On dry weight basis, the pectin content of fresh okra trimmed was 8.8 per cent which was higher than that of the fresh okra rings. Statistically, the differences were non-significant. On the other hand, the pectin content of okra rings was higher than the okra trimmed after blanching, freezing and during frozen storage period. The corresponding range as well as overall range was 10.7 to 12.2 per cent but the differences were statistically non-significant. The statistical analysis confirmed that the pectin content of the two types of cuts of okra was statistically not different from each other in fresh stage, after processing and during frozen storage period on fresh as well as dry weight basis.

The pectin content of fresh capsicum halves was 0.40 per cent which was reduced to 0.38 per cent after blanching and freezing on fresh weight basis. This reduction was statistically non-significant. The pectin content remained between the narrow range of 0.37 to 0.38 per cent throughout the frozen storage period of six months. The variation was statistically non-significant. Similar results were obtained on dry weight basis and the pectin content in fresh, blanched and frozen capsicum halves was 5.4, 5.2 and 5.2 per cent, respectively. The value remained between 5.0 to 5.2 per cent during the frozen storage period of six months. These changes were statistically non-significant. The overall analysis of variance also revealed that the processing and frozen storage period of six months had non-significant effect on the pectin content of the capsicum halves on fresh as well as dry weight basis.

The results of the study revealed that a slight decrease after blanching may be due to losses of soluble pectic polymers. However, on dry weight basis, after blanching, there appeared to be some gain in pectin content of French beans (1.0 cm) and okra (rings and trimmed). This can be attributed to absorption of water during blanching and loss of some soluble components. As a matter of fact, the pectin content was reduced slightly on fresh weight basis. The results are in agreement with those of Zyren *et al* (1983) who reported that the pectin content in frozen vegetables ranged from 0.5 to 1.0 per cent and there appears to be no great loss of pectin during commercial processing. Oruna-Concha *et al* (1996) reported that the content of pectin in green beans and pepper was not affected by blanching and frozen storage. According to Roy *et al* (2001) a substantial loss of pectic material was seen at slower freezing rates and low temperature for long time blanching. The results of the present study are quite similar as the blanching was done at HTST and the vegetables were frozen by IQF method at a very rapid freezing rate.

4.4.4. Fibre fractions

4.4.4.1. Neutral detergent fibre (NDF) : The NDF content of the fresh, blanched, frozen and frozen stored vegetables is given in Tables 4.23 and 4.24 on fresh and dry weight basis, respectively. The data showed that the NDF content of fresh French beans

Table 4.23 Effect of processing and frozen storage on NDF content (%, fresh weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	1.92	1.64	1.65	1.65	1.66	1.66	11.54* (10.5018)	1.09^{NS}	7.58* (8.1456)
French bean 6.0cm	1.89	1.94	1.95	1.94	1.95	1.95	2.77^{NS}	0.002^{NS}	0.29^{NS}
t-value	1.32^{NS}	4.40^{NS}	3.63^{NS}	3.81^{NS}	3.10^{NS}	3.16^{NS}			
Okra rings	1.91	1.53	1.54	1.55	1.56	1.56	11.19* (9.3610)	0.12^{NS}	7.15* (9.7160)
Okra trimmed	1.90	1.70	1.71	1.71	1.72	1.72	3.00^{NS}	0.01^{NS}	2.50^{NS}
t-value	1.01^{NS}	3.99^{NS}	3.31^{NS}	3.10^{NS}	2.76^{NS}	2.75^{NS}			
Capsicum halves	1.20	1.28	1.29	1.29	1.30	1.31	3.28^{NS}	0.19^{NS}	3.99^{NS}

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant
* - significant at 5% level
Figures in parenthesis indicate C.D. values

Table 4.24 Effect of processing and frozen storage on NDF content (%, dry weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	20.3	21.5	21.5	21.5	21.6	21.6	1.07^{NS}	0.001^{NS}	0.80^{NS}
French bean 6.0cm	20.5	21.3	21.3	21.2	21.3	21.3	1.80^{NS}	0.001^{NS}	0.22^{NS}
t-value	0.35^{NS}	0.35^{NS}	0.20^{NS}	0.26^{NS}	0.42^{NS}	0.26^{NS}			
Okra rings	16.6	19.6	19.6	19.6	19.5	19.6	16.98* (1.898)	0.01^{NS}	6.84* (1.611)
Okra trimmed	16.9	19.0	19.0	19.0	19.1	19.1	3.13^{NS}	0.01^{NS}	2.98^{NS}
t-value	0.41^{NS}	0.94^{NS}	0.60^{NS}	1.50^{NS}	0.74^{NS}	0.75^{NS}			
Capsicum halves	16.2	17.7	17.7	17.6	17.8	17.7	8.83^{NS}	0.08^{NS}	4.30^{NS}

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant
* - *significant at 5% level*
Figures in parenthesis indicate C.D. values

(1.0 cm) was 1.92 per cent which was reduced to 1.64 per cent after blanching and changed to 1.65 per cent after freezing on fresh weight basis. Statistically, the NDF content deceased significantly ($P \leq 0.05$) during processing. The corresponding level remained in the narrow range of 1.65 to 1.66 per cent during the frozen storage period of six months and hence no significant change occurred. The overall analysis of variance indicated that the processing and frozen storage period had significant ($P \leq 0.05$) effect on the NDF content of French beans (1.0 cm). On the other hand, on dry weight basis, the NDF content of fresh French beans (1.0 cm) was 20.3 per cent which was increased to 21.5 per cent after blanching and freezing but then remained between 21.5 and 21.6 per cent during the frozen storage period of six months. Statistically, the processing and frozen storage period had non-significant effect on the NDF content of French beans (1.0 cm).

The NDF content of fresh French beans (6.0 cm) was 1.89 per cent which increased to 1.94 per cent after blanching but remained almost stable after freezing and during frozen storage period of six months, the value being between 1.94 and 1.95 per cent on fresh weight basis. Hence statistically, these changes were non-significant. On dry weight basis, the NDF content of fresh French beans (6.0 cm) was 20.5 per cent which increased to 21.3 per cent after blanching but remained stable after freezing on fresh weight basis. Statistically, this decrease was non-significant. The NDF content remained in the narrow range of 21.2 to 21.3 per cent during the frozen storage period of six months and hence no significant change occurred. From the overall analysis of variance, it was concluded that processing and frozen storage period of six months had non-significant effect on the NDF content of French beans (6.0 cm) on fresh as well as dry weight basis.

The NDF content of fresh French beans having 1.0 cm cut was 1.92 per cent which was higher than that of the fresh French beans having 6.0 cm cut. The NDF content of French beans (6.0 cm) was higher than the French beans (1.0 cm) after blanching, freezing and during frozen storage period of six months, the corresponding as well as overall range being 1.64 to 1.95 per cent on fresh weight basis. On dry weight basis, the NDF content of fresh French beans having 6.0 cm cut was 20.5 per cent which was higher than that of the French beans having 1.0 cm cut. On the other hand, the NDF content was higher in French beans (1.0 cm) than that of the French beans (6.0 cm) after processing and throughout frozen storage period of six months, the corresponding range being 21.2 to 21.6 per cent. The overall range of NDF in all stages of two types of cuts was 20.3 to 21.6 per cent on dry weight basis. The statistical analysis revealed that the NDF content of the two types of cuts of French beans was not significantly different from each other throughout the processing and frozen storage period of six months on fresh as well as dry weight basis.

The NDF content of fresh okra rings was 1.91 per cent which decreased to 1.53 per cent after blanching and slightly increased to 1.54 per cent after freezing, on fresh weight basis. Statistically, the decrease was significant ($P \leq 0.05$). The NDF content remained almost stable i.e. 1.54 to 1.56 per cent throughout the frozen storage period of six months and hence no significant change was observed. The overall analysis of variance also indicated that the processing and frozen storage period had significant

($P \leq 0.05$) effect on the NDF content of okra rings. On dry weight basis, the NDF content of fresh okra rings was 16.6 per cent which increased to 19.6 per cent after blanching but remained stable after freezing on dry weight basis. Statistically, these changes were significant ($P \leq 0.05$). The NDF content remained almost constant i.e. 19.5 to 19.6 per cent throughout the frozen storage period of six months and hence no significant change was observed. The overall analysis of variance also confirmed that the processing and frozen storage period had significant ($P \leq 0.05$) effect on the NDF content of okra rings on dry weight basis.

The NDF content of fresh okra trimmed was 1.90 per cent which decreased to 1.70 per cent after blanching and then increased to 1.71 per cent after freezing on fresh weight basis. Statistically, these changes were non-significant. The NDF content remained between the narrow range of 1.71 to 1.72 per cent throughout the frozen storage period of six months and hence no significant change was evident. On dry weight basis, the NDF content of fresh okra trimmed was 16.9 per cent which increased to 19.0 per cent after blanching but remained stable after freezing. Statistically, these changes were non-significant. The NDF content remained in the narrow range of 19.0 to 19.1 per cent during the frozen storage period of six months. Hence the variation was statistically non-significant. The overall analysis of variance also confirmed that the processing and frozen storage period had non-significant effect on the NDF content of okra trimmed on fresh as well as dry weight basis.

The NDF content of fresh okra rings was 1.91 per cent, which was slightly higher than that of the fresh okra trimmed. But the NDF content was higher in okra trimmed after blanching, freezing and during frozen storage period of six months, the corresponding range being 1.53 to 1.72 per cent on fresh weight basis. The overall range of NDF in all stages of two types of okra was 1.53 to 1.91 per cent. On the other hand, the NDF content of fresh okra trimmed was 16.9 per cent which was higher than that of the okra rings on dry weight basis. But the NDF content was higher in okra rings after blanching, freezing and during frozen storage period of six months, the corresponding range being 19.0 to 19.6 per cent. The overall range of NDF in all stages of two types of okra was 16.6 to 19.6 per cent. However, the statistical analysis revealed that the NDF content of the two types of cuts of okra was not statistically different from each other throughout the processing and frozen storage period of six months on fresh as well as dry weight basis.

The NDF content of fresh capsicum halves was 1.20 per cent which increased to 1.28 per cent after blanching and slightly increased to 1.29 per cent after freezing on fresh weight basis. These changes were statistically non-significant. The NDF content remained between the narrow range of 1.29 to 1.31 per cent during the frozen storage period of six months and hence no significant change was evident. On dry weight basis, the NDF content of fresh capsicum halves was 16.2 per cent, which increased to 17.7 per cent after blanching but remained same after freezing. These changes were statistically non-significant. The corresponding level remained in the very narrow range of 17.6 to 17.8 per cent throughout the frozen storage period of six months and hence no statistical change was observed. The overall statistical analysis also revealed that the processing and frozen storage period of six months had non-significant effect on the NDF content of capsicum halves on fresh as well as dry weight basis.

From the overall analysis of variance, it was observed that statistically the processing and frozen storage period of six months had significant ($P \leq 0.05$) effect on the NDF content of French beans having 1.0 cm cut on fresh weight basis and in case of okra rings, both on fresh as well as dry weight basis. The findings of the present study are in agreement with those of Herranz *et al* (1983). They also reported that boiling resulted in an increase in the NDF, ADF and cellulose contents in case of spinach, green beans and peas on dry weight basis but a decrease in NDF content on fresh weight basis. The scientists analysed 22 raw vegetables for different fibre fractions and reported that with the exception of carrots and potatoes, all the vegetables showed an increase in the NDF, ADF and hemicellulose values after boiling on dry weight basis. The authors suggested that this might be the result of liberation of cellulose. Zyren *et al* (1983) reported that the NDF content of frozen green beans was 1.8 ± 0.1 per cent on fresh weight basis. The scientists further observed that the loss of NDF during cooking was due to loosening or physical breaking up of the insoluble fibre into smaller particles which were washed away during the draining of water. In the present study also, the NDF content decreased after blanching in case of French beans (1.0 cm), okra (rings and trimmed) on fresh weight basis, which might be due to leaching losses. On the other hand, an increase after blanching was observed on dry weight basis. Chen (1986) also reported that the fibre content increased during frozen storage of vegetables for five months. From the findings, it could be concluded that frozen vegetables like fresh vegetables are important source of dietary fibre.

4.4.4.2. Acid detergent fiber (ADF) : The ADF content of processed and frozen stored vegetables is shown in Tables 4.25 and 4.26 on fresh and dry weight basis, respectively. The results revealed that the ADF content of fresh French beans having 1.0 cm cut was 1.41 per cent which was reduced to 1.22 per cent after blanching and increased slightly to 1.23 per cent after freezing, on fresh weight basis. Statistically, the ADF content decreased non-significantly during processing. The corresponding level remained in the narrow range of 1.23 to 1.24 per cent during the frozen storage period of six months and hence the change was statistically non-significant. On dry weight basis, the ADF content of fresh French beans (1.0 cm) was 14.9 per cent which increased to 16.0 per cent after blanching and remained same after freezing. Statistically, the increase was non-significant. The ADF content of French beans (1.0 cm) remained nearly constant i.e. 16.0 to 16.1 per cent during the frozen storage period of six months and hence no significant change occurred. From the overall analysis of variance, it was concluded that the processing and frozen storage period had non-significant effect on the ADF content of French beans (1.0 cm) on fresh as well as dry weight basis.

The ADF content of fresh French beans having 6.0 cm cut was 1.38 per cent which increased to 1.44 per cent after blanching followed by a further slight increase to 1.45 per cent after freezing on fresh weight basis. This increase was statistically non-significant. The ADF content remained between 1.45 and 1.46 per cent during the frozen storage period of six months and hence the change was statistically non-significant. On

Table 4.25 Effect of processing and frozen storage on ADF content (%, fresh weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	1.41	1.22	1.23	1.23	1.24	1.24	2.00^{NS}	0.06^{NS}	1.81^{NS}
French bean 6.0cm	1.38	1.44	1.45	1.45	1.46	1.46	0.75^{NS}	0.02^{NS}	0.68^{NS}
t-value	0.55^{NS}	3.02^{NS}	3.20^{NS}	4.20^{NS}	4.12^{NS}	4.12^{NS}			
Okra rings	1.46	1.09	1.10	1.13	1.13	1.13	12.44* (14.40)	0.10^{NS}	8.50* (10.65)
Okra trimmed	1.45	1.25	1.26	1.27	1.27	1.27	2.15^{NS}	0.002^{NS}	2.01^{NS}
t-value	0.82^{NS}	1.75^{NS}	1.69^{NS}	4.13^{NS}	4.00^{NS}	3.95^{NS}			
Capsicum halves	0.50	0.57	0.57	0.57	0.58	0.58	2.34^{NS}	0.41^{NS}	2.15^{NS}

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant
* - Significant at 5% level
Figures in parenthesis indicate C.D. values

Table 4.26 Effect of processing and frozen storage on ADF content (%, dry weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	14.9	16.0	16.0	16.0	16.1	16.1	1.06^{NS}	0.04^{NS}	1.10^{NS}
French bean 6.0cm	15.0	15.8	15.8	15.8	15.9	15.9	0.56^{NS}	0.04^{NS}	0.58^{NS}
t-value	0.10^{NS}	0.20^{NS}	0.28^{NS}	0.67^{NS}	0.89^{NS}	1.42^{NS}			
Okra rings	12.7	14.0	14.0	14.2	14.1	14.2	1.56^{NS}	0.12^{NS}	1.75^{NS}
Okra trimmed	12.9	14.0	14.0	14.1	14.1	14.1	0.89^{NS}	-	0.98^{NS}
t-value	0.32^{NS}	-	-	0.45^{NS}	-	0.71^{NS}			
Capsicum halves	6.8	7.9	7.9	7.9	8.0	7.8	2.00^{NS}	0.17^{NS}	1.89^{NS}

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio

NS – Non-significant

the other hand, on dry weight basis, the ADF content of fresh French beans (6.0 cm) was 15.0 per cent which increased to 15.8 per cent after blanching but remained same after freezing. Statistically, the increase was non-significant. The ADF content remained in the narrow range of 15.8 to 15.9 per cent during the frozen storage period of six months and hence no significant change was visible. From the overall analysis of variance, it was concluded that the processing and frozen storage period of six months had non-significant effect on the ADF content of French beans (6.0 cm) on fresh as well as dry weight basis.

The ADF content of fresh French beans having 1.0 cm cut was 1.41 per cent which was higher than that of the fresh French beans having 6.0 cm cut. The ADF content was higher in French beans having 6.0 cm cut than the French beans (1.0 cm) after blanching, freezing and throughout the frozen storage period of six months. The corresponding as well as overall range was 1.22 to 1.46 per cent on fresh weight basis. On the other hand, on dry weight basis, the ADF content of fresh French beans (6.0 cm) was 15.0 per cent which was slightly higher than that of the French beans (1.0 cm). But, it was higher in French beans (1.0 cm) than the French beans (6.0 cm) after blanching, freezing and during frozen storage period of six months. The corresponding range was 15.8 to 16.1 per cent. The overall range on the other hand was 14.9 to 16.1 per cent. The statistical analysis revealed that the ADF content of two types of cuts of French beans was not significantly different from each other throughout the processing and frozen storage period of six months on fresh as well as dry weight basis.

The ADF content of fresh okra rings was 1.46 per cent which decreased to 1.09 per cent after blanching and then increased slightly to 1.10 per cent after freezing on fresh weight basis. This decrease was statistically significant ($P \leq 0.05$). The ADF content remained 1.10 to 1.13 per cent throughout the frozen storage period of six months and hence no statistical change was observed. The overall analysis of variance, however, revealed that the processing and frozen storage period of six months had significant ($P \leq 0.05$) effect on the ADF content of okra rings. On the other hand, on dry weight basis, ADF content of fresh okra rings was 12.7 per cent which increased to 14.0 per cent after blanching, remained same after freezing and varied within a narrow range of 14.1 to 14.2 per cent throughout the frozen storage period of six months. The change was not statistically significant. The overall analysis of variance also confirmed that the processing and frozen storage period had non-significant effect on the ADF content of the okra rings on dry weight basis,

The ADF content of fresh okra trimmed was 1.45 per cent which decreased to 1.25 per cent after blanching and then increased slightly to 1.26 per cent after freezing on fresh weight basis. However, it remained 1.26 to 1.27 per cent during the frozen storage period of six months. These changes were statistically non-significant. On dry weight basis, the ADF content of fresh okra trimmed was 12.9 per cent which was increased to 14.0 per cent after blanching, was same after freezing and remained stable at 14.1 per cent throughout the frozen storage period of six months. These changes were again non-significant. From the overall analysis of variance also, it was concluded that the processing and frozen storage period of six months had non-significant effect on the ADF content of okra trimmed on fresh as well as dry weight basis.

The ADF content of fresh okra rings was 1.46 per cent which was slightly higher than that of the fresh okra trimmed. But it was slightly higher in okra trimmed after blanching, freezing and throughout the frozen storage period of six months, the corresponding range being 1.09 to 1.27 per cent on fresh weight basis. The overall range was 1.09 to 1.46 per cent. On the other hand, the ADF content of fresh okra trimmed was higher than that of the okra rings, on dry weight basis, the corresponding value being 12.9 per cent. But the ADF content of both the cuts was same after blanching, freezing and after four months of frozen storage period, the corresponding values being 14.0, 14.0 and 14.1 per cent. The ADF content of okra rings was higher after two and six months of frozen storage period than that of the okra trimmed. The overall range was 12.7 to 14.2 per cent for ADF content. But the statistical analysis revealed that the ADF content of two types of cuts of okra was statistically not different from each other after processing and throughout frozen storage period of six months on fresh as well as dry weight basis.

The ADF content of fresh capsicum halves was 0.50 per cent which increased to 0.57 per cent after blanching and remained same after freezing on fresh weight basis. This variation was statistically non-significant. The ADF content remained in the narrow range of 0.57 to 0.58 per cent during the frozen storage period of six months and hence no statistical change was evident. On dry weight basis, the ADF content of fresh capsicum halves was 6.8 per cent which increased to 7.9 per cent after blanching but remained same after freezing. The variation was statistically non-significant. The corresponding level remained between 7.8 and 8.0 per cent throughout the frozen storage period of six months. This change was also statistically non-significant. The overall statistical analysis confirmed that the processing and frozen storage period of six months had non-significant effect on the ADF content of capsicum halves on fresh as well as dry weight basis.

From the overall analysis of variance, it was concluded that statistically the processing and frozen storage period of six months had non-significant effect on the ADF content of the samples of the vegetables on fresh as well as dry weight basis. The decrease in ADF content of okra rings was observed on fresh weight basis. The reason might be higher absorption of water during blanching due to larger surface area coupled with porous structure. Blanching might also have resulted in leaching of some soluble fibre components. Herranz *et al* (1983) reported that boiling resulted in an increase in ADF content of frozen vegetables on dry weight basis but a decrease in ADF content on fresh weight basis. Chen (1986) reported that the fibre content increased during frozen storage for five months. So, the observation of the present study are in line with those reported in the literature.

4.4.5. β-carotene : The β-carotene content of fresh, processed and frozen stored vegetables on fresh weight basis is shown in Tables 4.27 and 4.28, on fresh and dry weight basis, respectively. The data revealed that the β-carotene content of fresh French beans having 1.0 cm cut was 123.0 μg/100g which after blanching decreased to 95.9 μg/100g and further decreased to 95.3 μg/100g after freezing on fresh weight basis. Statistically, the blanching process significantly ($P \leq 0.01$) reduced the β-carotene

Table 4.27 Effect of processing and frozen storage on retention of β-carotene content (μg/100g, fresh weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	123.0	95.9	95.3	92.8	89.9	86.0	65.78** (8.811)	5.78^{NS}	49.03** (6.516)
French bean 6.0cm	125.0	100.0	99.5	96.8	94.3	91.3	26.30* (12.841)	0.81^{NS}	4.49* (10.251)
t-value	0.47^{NS}	1.28^{NS}	1.54^{NS}	1.17^{NS}	1.93^{NS}	2.27^{NS}			
Okra rings	49.0	39.5	39.3	38.1	36.7	35.2	19.45* (5.677)	0.98^{NS}	19.97** (3.770)
Okra trimmed	50.0	40.7	40.5	39.3	37.9	36.5	10.23* (7.664)	1.24^{NS}	9.56** (5.341)
t-value	0.36^{NS}	1.27^{NS}	0.57^{NS}	0.80^{NS}	0.79^{NS}	0.70^{NS}			
Capsicum halves	435.0	348.0	344.5	334.0	318.0	302.4	319.34** (10.07)	20.46** (7.69)	331.24** (9.419)

F^1-ratio for fresh, blanched and frozen (o month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant
* - significant at 5% level; ** - significant at 1% level
Figures in parenthesis indicate C.D. values

Table 4.28 Effect of processing and frozen storage on retention of β-carotene content (μg/100g, dry weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	1297.4	1251.9	1237.6	1205.1	1169.0	1116.8	2.07^{NS}	5.75^{NS}	8.0* (78.343)
French bean 6.0cm	1355.7	1096.5	1083.8	1054.4	1025.0	992.3	24.52* (139.967)	2.77^{NS}	23.37** (93.313)
t-value	1.28^{NS}	4.33*	5.00^{NS}	3.95^{NS}	4.95*	4.29^{NS}			
Okra rings	424.2	503.8	497.4	479.8	458.7	440.0	14.03* (53.35)	5.54^{NS}	7.70* (39.756)
Okra trimmed	444.0	454.2	450.0	436.6	421.1	405.5	0.09^{NS}	1.24^{NS}	1.31^{NS}
t-value	0.80^{NS}	4.52*	1.98^{NS}	2.47^{NS}	2.18^{NS}	1.59^{NS}			
Capsicum halves	5878.3	4767.1	4719.1	4575.3	4356.1	4086.4	462.81** (205.594)	95.63** (105.148)	506.52** (128.39)

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio

NS – Non-significant

* - significant at 5% level; ** - significant at 1% level

Figures in parenthesis indicate C.D. values

content of French beans (1.0 cm). On the other hand, the β-carotene content remained between 86.0 to 95.3 μg/100g during the frozen storage period of six months and there was no statistically significant change. However, the overall analysis of variance revealed that the processing and frozen storage period of six months had significant ($P \leq 0.01$) effect on he β-carotene content of French beans (1.0 cm), on fresh weight basis.

The β-carotene content, on dry weight basis, was 1297.4 μg/100g in fresh French beans, decreased to 1251.9 μg/100g in blanched and further decreased to 1237.6 μg/100g in frozen French beans (1.0 cm). Statistically, this reduction was non-significant. The β-carotene content remained between 1116.8 and 1237.6 μg/100g during the frozen storage period of six months and this change was statistically non-significant. From the overall statistical analysis, it was concluded that the processing and frozen storage period had significant ($P \leq 0.05$) effect on the β-carotene content of French beans (1.0 cm) on dry weight basis.

The β-carotene content of fresh French beans having 6.0 cm cut was 125.0 μg/100g which was reduced to 100.0 μg/100g after blanching and further reduced to 99.5 μg/100g after freezing, on fresh weight basis. Statistically, the reduction was significant ($P \leq 0.05$). On the other hand, the β-carotene content remained in the narrow range of 91.3 to 99.5 μg/100g, throughout the frozen storage period of six months and hence the variation was statistically non-significant. From the overall analysis of variance, it was observed that the processing and frozen storage period of six months had significant ($P \leq 0.05$) effect on the β-carotene content of French beans (6.0 cm) on fresh weight basis.

On dry weight basis, the β-carotene content of French beans having 6.0 cm cut was 1355.7 μg/100g, which was reduced to 1096.5 μg/100g after blanching and further reduced to 1083.8 μg/100g after freezing. From analysis of variance, it was observed that blanching significantly ($P \leq 0.05$) reduced the β-carotene content of French beans (6.0 cm). However, it remained between 992.3 and 1083.8 μg/100g during the frozen storage period of six months and statistically, the variation was non-significant. From the overall analysis of variance, it was concluded that the processing and frozen storage period had significant ($P \leq 0.01$) effect on the β-carotene content of French beans (6.0 cm).

On fresh weight basis, β-carotene content of French beans having 6.0 cm cut was higher than that of the French beans having 1.0 cm cut in fresh stage, after processing and during frozen storage period of six months, the corresponding overall range was 86.0 to 125.0 μg/100g. However, the statistical analysis revealed that the β-carotene content of two types of cuts of French beans was significantly not different from each other, throughout the processing and frozen storage period on fresh weight basis. The β-carotene content, on dry weight basis, was 1355.7 μg/100g in fresh French beans (6.0 cm) which was more than that of fresh French beans (1.0 cm), but the difference was not statistically significant. On the other hand, the β-carotene content of French beans (1.0 cm) was higher than the French beans (6.0 cm) after blanching, freezing and throughout frozen storage period of six months. The corresponding range was 992.3 to 1251.9 μg/100g and the differences were statistically significant ($P \leq 0.05$) only after blanching and after four months of frozen storage. The overall range was 992.3 to 1355.7 μg/100g.

It was observed from the Table 4.29 that the per cent reduction in β-carotene content of French beans having 1.0 cm cut was 22.0 and 3.5 per cent after blanching, on fresh and dry weight basis, respectively. Freezing had minimum effect on the β-carotene content and reduction was only 0.6 and 1.14 per cent on fresh and dry weight basis, respectively. During six months of frozen storage period, the reduction of β-carotene content was 9.7 per cent on fresh as well as dry weight basis. The overall losses in β-carotene content were 30.0 and 13.9 per cent on fresh and dry weight basis, respectively. On the other hand, the per cent reduction of β-carotene in French beans having 6.0 cm cut was 20.0 and 19.1 per cent after blanching on fresh and dry weight basis, respectively. The losses after freezing were far less, the values being 0.5 and 1.1 per cent on fresh and dry weight basis, respectively. During six months of frozen storage period, the reduction was 8.2 and 8.4 per cent on fresh and dry weight basis, respectively. The corresponding overall losses were 27.0 and 26.8 per cent. The overall reduction of β-carotene content was 30.0 per cent in French beans having 1.0 cm cut which was higher than that of the French beans having 6.0 cm cut on fresh weight basis. On dry weight basis, the overall losses were 26.8 per cent in French beans having 6.0 cm cut which was more than that of the French beans having 1.0 cm cut.

The β-carotene content of fresh okra rings was 49.0 μg/100g which was reduced to 39.5 μg/100g after blanching and further decreased slightly to 39.3 μg/100g after freezing on fresh weight basis. Statistically, the processing had significant ($P \leq 0.05$) effect on the β-carotene content of okra rings. On the other hand, the β-carotene content remained almost stable between 35.2 and 39.3 μg/100g, during the frozen storage period

Table 4.29 Losses (%, fresh weight basis) of β-carotene content during processing and frozen storage.

Vegetable	Blanching	Freezing	Six months frozen storage	Overall losses
French bean 1.0cm	22.0 (-3.5)	0.6 (-1.14)	9.7 (-9.7)	30.0 (-13.9)
French bean 6.0cm	20.0 (-19.1)	0.5 (-1.1)	8.2 (-8.4)	27.0 (-26.8)
Okra rings	19.4 (+18.7)	0.5 (-1.3)	10.4 (-11.5)	28.1 (+3.7)
Okra trimmed	18.6 (+2.2)	0.5 (-0.9)	9.8 (-9.8)	27.0 (-8.6)
Capsicum halves	30.0 (-18.9)	1.0 (-1.0)	12.2 (-13.4)	30.5 (-30.5)

Figures in parenthesis are on dry weight basis.

of six months and statistically, this change was non-significant. The overall analysis of variance revealed that the processing and frozen storage period of six months had significant ($P \leq 0.01$) effect on the β-carotene content of okra rings on fresh weight basis.

The β-carotene content, on dry weight basis, was 424.2 μg/100g in fresh okra rings, increased to 503.8 μg/100g after blanching and then decreased to 497.4 μg/100g after freezing. Statistically, these changes were significant ($P \leq 0.05$). But the β-carotene content remained in the narrow range of 440.0 to 497.4 μg/100g during the frozen storage period of six months and hence no statistical change was evident. The overall analysis of variance revealed that the processing and frozen storage period had significant ($P \leq 0.05$) effect on the β-carotene content of okra rings on dry weight basis.

The β-carotene content of fresh okra trimmed was 50.0 μg/100g, which was reduced to 40.7 μg/100g after blanching and further reduced slightly to 40.5 μg/100g after freezing, on fresh weight basis. Statistically, this reduction was significant ($P \leq 0.05$). On the other hand, the β-carotene content remained in the narrow range of 36.5 to 40.5 μg/100g, throughout the frozen storage period of six months and the variation was statistically non-significant. However, from the overall analysis of variance, it was concluded that the processing and frozen storage period of six months had significant ($P \leq 0.01$) effect on the β-carotene content of okra trimmed on fresh weight basis. On dry weight basis, the β-carotene content of fresh okra trimmed was 444.0 μg/100g, increased to 454.2 μg/100g after blanching and then decreased to 450.0 μg/100g after freezing. Statistically, these changes were non-significant. The β-carotene content remained between 405.5 to 450.0 μg/100g during the frozen storage period of six months and the variation was non-significant. From the overall statistical analysis also, it was confirmed that the processing and frozen storage period had non-significant effect on the β-carotene content of okra trimmed.

The β-carotene content of okra trimmed was higher than that of the okra rings in fresh stage, after processing and during frozen storage period of six months. The corresponding overall range was 35.2 to 50.0 μg/100g on fresh weight basis. The statistical analysis indicated that the β-carotene content of two types of cuts of okra was statistically not different from each other, in the fresh stage, after processing and during frozen storage period of six months on fresh weight basis. The β-carotene content, on dry weight basis, was 444.0 μg/100g in fresh okra trimmed and was more as compared to that of fresh okra rings, but the difference was not statistically significant. However, the β-carotene content of okra rings was higher than that of the okra trimmed after blanching, freezing and throughout frozen storage period of six months. The corresponding as well as overall range was 405.5 to 503.8 μg/100g and the differences were statistically significant ($P \leq 0.05$) only after blanching.

The data in Table 4.29 revealed that β-carotene content of okra rings reduced by 19.4 per cent during blanching, 0.5 per cent during freezing and 10.4 per cent during six months of frozen storage while the overall losses were 28.1 per cent on fresh weight basis. On the other hand, on dry weight basis, there was +18.7 per cent change after blanching in β-carotene content of okra rings, -1.3 per cent after freezing and -11.5 per cent during six months of frozen storage. Overall, there was +3.7 per cent change in β-carotene content on dry weight basis. The corresponding losses in okra trimmed were

18.6 per cent during blanching, only 0.5 per cent during freezing and 9.8 per cent during six months of frozen storage while the overall losses were 27.0 per cent on fresh weight basis. On the other hand, on dry weight basis, there was +2.2 per cent change after blanching in β-carotene content of okra trimmed, only -0.9 per cent after freezing and -9.8 per cent during six months of frozen storage. The overall change was -8.6 per cent on dry weight basis. So, the overall reduction of β-carotene content was 28.1 per cent in okra rings which was more than that of the okra trimmed, on fresh weight basis. On dry weight basis, however, the overall change was -8.6 per cent in okra trimmed which was more than that of the okra rings.

The β-carotene content of fresh capsicum halves was 435.0 μg/100g which was reduced to 348.0 μg/100g after blanching and further slightly reduced to 344.5 μg/100g after freezing on fresh weight basis. Statistically, the decrease was significant ($P \leq 0.01$). The β-carotene content was reduced to 334.0 μg/100g after two months of frozen storage, 318.0 μg/100g after four months and to 302.4 μg/100g after six months of frozen storage. From the analysis of variance, it was evident that the frozen storage period had significant ($P \leq 0.01$) effect on the β-carotene content of capsicum halves. The overall statistical analysis also confirmed that the processing and frozen storage period had significant ($P \leq 0.01$) effect on the β-carotene content of capsicum halves on fresh weight basis.

The β-carotene content, on dry weight basis, was 5878.3 μg/100g in fresh capsicum halves which decreased to 4767.1 μg/100g after blanching and to 4719.1 μg/100g after freezing. Statistically, this reduction was significant ($P \leq 0.01$). The β-carotene content was reduced to 4575.3 μg/100g after two months of frozen storage period, further 4356.1 μg/100g after four months and then 4086.4 μg/100g after six months of frozen storage period. This reduction was also statistically significant ($P \leq 0.01$). From the overall analysis of variance, it was observed that the processing and frozen storage period had significant ($P \leq 0.01$) effect on the β-carotene content of capsicum halves on dry weight basis also.

The losses of β-carotene content in capsicum halves during blanching, freezing and six months of frozen storage were 30.0, 1.0 and 12.2 per cent, respectively, on fresh weight basis (Table 4.29). On dry weight basis, the corresponding values were 18.9, 1.0 and 13.4 per cent. The overall losses of β-carotene in capsicum halves were 30.5 per cent on fresh as well as dry weight basis.

It is also clear from the Fig. 3 that the major β-carotene loss was due to the blanching process. Howard *et al* (1996) observed that steam blanching reduced β-carotene content by about 15 per cent in carrots. Kaur and Kapoor (2001), on the other hand, reported that carrots and French beans lost 50.3 per cent of total carotenoids during blanching for five minutes in boiling water, as carotenoids are susceptible to oxidative loss caused by heat and light. Park (1987) reported that the destruction of carotenes during processing was expected to be low, if the initial concentration of carotenes in vegetables is low. Bubicz *et al* (1990) reported significant decrease of the β-carotene content in carrots during the frozen storage period of 10 months. In the present study, on fresh weight basis, the losses during blanching ranged 18.6 to 22.0 per cent and overall losses after six months of frozen storage varied from 27.0 to 30.5 per cent. The

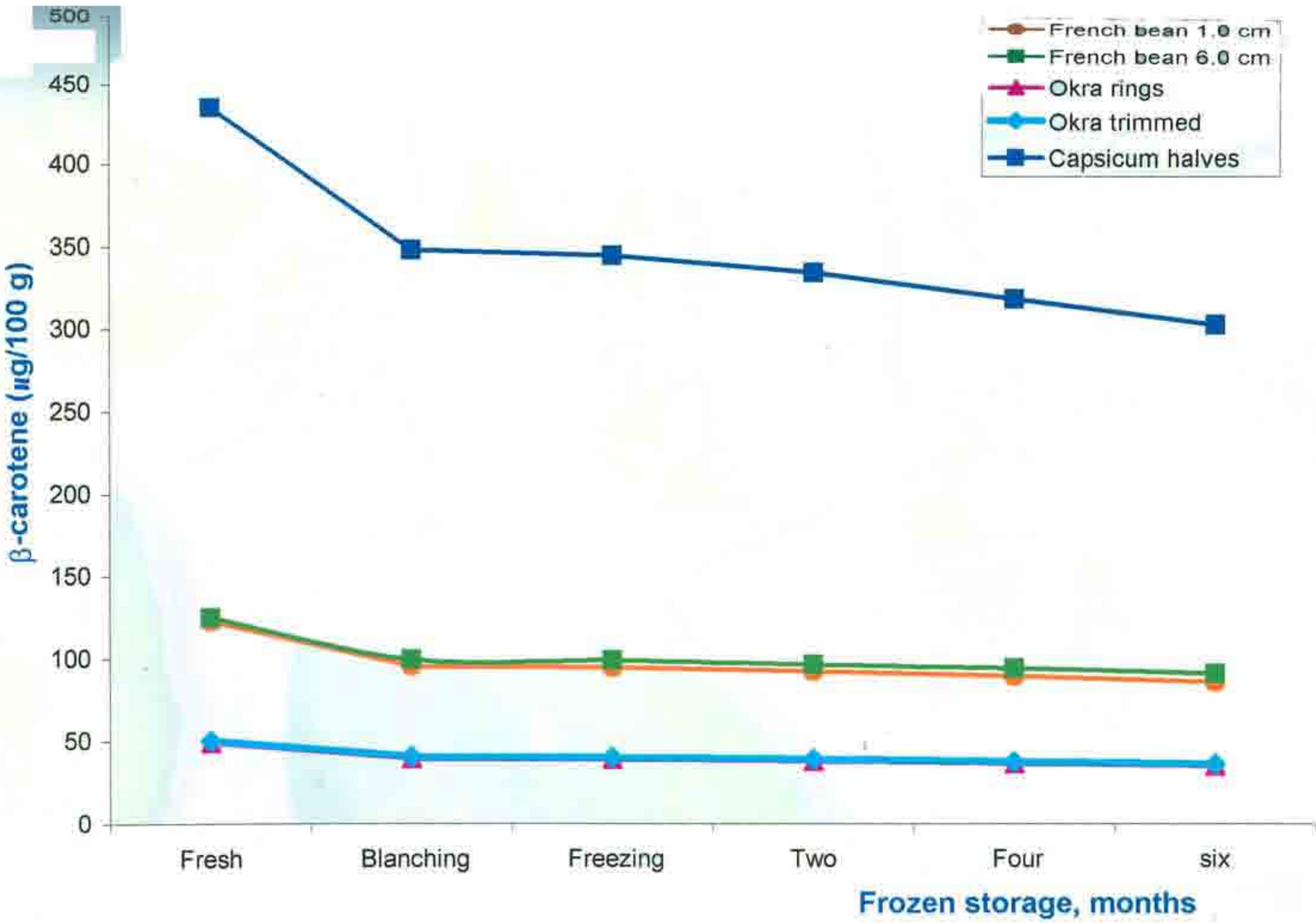

Fig 3 Effect of processing and frozen storage on β-carotene content of the vegetables on fresh weight basis

difference in the losses in β-carotene observed in the present study as compared to the literature reports could be due to the differences in time, temperature and medium of blanching. However, on dry weight basis, after blanching, there appeared to be some gain in β-carotene content of okra rings and trimmed. This can be attributed to absorption of water during blanching and loss of some soluble solids. As a matter of fact the β-carotene content was reduced significantly on fresh weight basis. Statistically significant reductions were also detected by Lisiewska and Kmiecik (2000) in the concentration of carotenoids, β-carotene and lycopenes during storage of frozen tomato.

4.4.6 Ascorbic acid (AA) : The data in Tables 4.30 and 4.31 presents the AA content of fresh, processed and frozen stored vegetables on fresh and dry weight basis, respectively. It was observed that the AA content of fresh French beans having 1.0 cm cut was 25.2 mg/100g which after blanching decreased to 19.6 mg/100g and further decreased to 19.5 mg/100g after freezing, on fresh weight basis. Statistically, this decrease was significant ($P \leq 0.05$). The AA content remained in the narrow range of 18.0 and 19.5 mg/100g during the frozen storage period of six months and hence no statistical change. From the overall analysis of variance, it was concluded that the processing and frozen storage period of six months had significant ($P \leq 0.01$) effect on the AA content of French beans (1.0 cm) on fresh weight basis. On dry weight basis, the ascorbic acid content of French beans (1.0 cm) was 265.8 mg/100g which after blanching decreased to 255.8 mg/100g and further to 253.2 mg/100g after freezing. However, these changes were statistically non-significant. The AA level remained between 233.7 and 253.7 mg/100g during six months of frozen storage period and hence no statistical

Table 4.30 Effect of processing and frozen storage on retention of ascorbic acid content (mg/100g, fresh weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	25.2	19.6	19.5	19.0	18.6	18.0	29.39* (1.607)	4.48^{NS}	46.55** (1.076)
French bean 6.0cm	26.0	21.3	21.2	21.2	20.8	20.1	7.83^{NS}	1.21^{NS}	7.69* (3.274)
t-value	0.39^{NS}	4.71*	6.01*	2.2^{NS}	4.12^{NS}	3.90^{NS}			
Okra rings	15.0	12.6	12.5	12.3	12.1	11.8	20.03* (1.428)	2.74^{NS}	20.52** (0.882)
Okra trimmed	15.3	13.1	13.0	12.7	12.4	12.3	18.78* (1.355)	1.08^{NS}	18.87** (0.882)
t-value	0.59^{NS}	3.54^{NS}	0.93^{NS}	1.41^{NS}	1.34^{NS}	1.77^{NS}			
Capsicum halves	145.0	107.0	106.4	103.4	100.8	98.3	281.55** (5.952)	13.86* (3.667)	269.09** (3.669)

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant
* - significant at 5% level; ** - significant at 1% level
Figures in parenthesis indicate C.D. values

Table 4.31 Effect of processing and frozen storage on retention of ascorbic acid (mg/100g, dry weight basis) of the vegetables

Vegetable	Fresh	Blanched	Frozen storage period, months				F^1-ratio	F^2-ratio	F^3-ratio
			0	2	4	6			
French bean 1.0cm	265.8	255.8	253.2	246.7	241.8	233.7	0.29^{NS}	1.20^{NS}	1.13^{NS}
French bean 6.0cm	281.9	233.5	230.9	230.9	226.0	218.4	24.60* (17.574)	4.87^{NS}	44.72** (11.737)
t-value	0.74^{NS}	5.3*	6.55*	1.22^{NS}	3.11^{NS}	2.23^{NS}			
Okra rings	129.8	160.7	158.2	154.9	151.2	147.5	32.52** (13.547)	4.05^{NS}	17.90** (9.082)
Okra trimmed	135.8	146.2	144.4	141.1	137.7	136.6	2.75^{NS}	1.07^{NS}	2.28^{NS}
t-value	1.34^{NS}	8.53^{NS}	2.23^{NS}	4.06^{NS}	5.24^{NS}	3.27^{NS}			
Capsicum halves	1959.4	1486.1	1457.5	1416.4	1380.8	1328.3	244.60** (81.4039)	16.39* (50.172)	251.43** (50.117)

F^1-ratio for fresh, blanched and frozen (0 month) samples; F^2-ratio for frozen stored samples; F^3 overall F-ratio
NS – Non-significant
* - significant at 5% level; ** - significant at 1% level
Figures in parenthesis indicate C.D. values

variation. The overall analysis of variance revealed that the processing and frozen storage period had non-significant effect on the AA content of French beans (1.0 cm) on dry weight basis.

The AA content of French beans having 6.0 cm cut was 26.0 mg/100g which decreased to 21.3 mg/100g after blanching and further to 21.2 mg/100g after freezing, on fresh weight basis. Statistically, these changes were non-significant. The AA content remained between the narrow range of 20.1 to 21.2 mg/100g, during six months of frozen storage period and hence no statistical variation. The overall statistical analysis, however, revealed that the processing and frozen storage period of six months had significant ($P \leq 0.05$) effect on the AA content of French beans (6.0 cm) on fresh weight basis. On the other hand, the AA content of fresh French beans having 6.0 cm cut was 281.9 mg/100g which decreased to 233.5 mg/100g after blanching and further to 230.9 mg/100g after freezing, on dry weight basis. Statistically, this decrease was significant ($P \leq 0.05$). The AA level remained within a narrow range throughout the frozen storage period, the limits being 218.4 and 230.9 mg/100g and hence no statistical change. The overall analysis of variance also revealed that the processing and frozen storage period had significant ($P \leq 0.01$) effect on the AA content of French bans (6.0 cm) on dry weight basis.

The ascorbic acid content of French beans having 6.0 cm cut was higher than that of the French beans having 1.0 cm cut in fresh stage, after processing and during frozen storage period of six months, the corresponding overall range being 18.0 to 26.0 mg/100g on fresh weight basis. However, the statistical analysis revealed that the ascorbic acid of two types of cuts of French beans was statistically not different in fresh stage and during frozen storage period of six months but was significantly ($P \leq 0.05$) different from each other after blanching and freezing on fresh weight basis. On the other hand, on dry weight basis, the AA content of fresh French beans (6.0 cm) was 281.9 mg/100g which was more than that of the French beans (1.0 cm), but the difference was not statistically significant. The ascorbic acid content of French beans (1.0 cm) was higher than that of the French beans (6.0 cm) after blanching, freezing and throughout frozen storage period of six months, the corresponding range being 218.4 to 255.8 mg/100g. However, the differences were statistically significant ($P \leq 0.05$) only after blanching and freezing. Further, the overall statistical analysis revealed that the AA content of the two types of cuts of French beans was statistically not different from each other in fresh stage and during frozen storage period of six months. However, the significant ($P \leq 0.05$) differences were observed from each other after blanching and freezing processes only on dry weight basis.

The data in Table 4.32 revealed that the AA content of French beans (1.0 cm) was reduced by 22.2 per cent during blanching, 0.6 per cent during freezing process and 7.5 per cent during frozen storage period of six months while the overall losses were 28.5 per cent, on fresh weight basis. On dry weight basis, the corresponding per cent reduction was 3.7 per cent, 1.0, 7.7 and 12.0 per cent. On the other hand, the AA content of French beans (6.0 cm) was reduced by 18.0 per cent during blanching, 0.46 per cent during freezing and 5.1 per cent during frozen storage period of six months while overall losses were 22.6 per cent, on fresh weight basis. The corresponding per cent reduction on dry weight basis was 17.1, 1.1, 5.4 and 22.5 per cent. The overall loss of AA content was 28.5 per cent in French beans having 1.0 cm cut which was more than that of the French beans having 6.0 cm cut, on fresh weight basis. But the overall loss on dry weight basis was 22.5 per cent in French beans having 6.0 cm cut and was higher than that of the French beans having 1.0 cm cut.

The AA content of fresh okra rings was 15.0 mg/100g, which decreased to 12.6 mg/100g after blanching and further to 12.5 mg/100g after freezing on fresh weight basis. These changes were statistically significant ($P \leq 0.05$). The AA content remained between the narrow range of 11.8 to 12.5 mg/100g during the frozen storage period of six months and the change was statistically non-significant. From the overall analysis of variance, it was observed that the processing and frozen storage period had significant ($P \leq 0.01$) effect on the AA content of okra rings, on fresh weight basis. The AA content, on dry weight basis, was 129.8 mg/100g in fresh okra rings which increased to 160.7 mg/100g after blanching and then decreased to 158.2 mg/100g after freezing. Statistically, these changes were significant ($P \leq 0.01$). The AA content of okra rings remained between 147.5 and 158.9 mg/100g, during the frozen storage period of six months and the change was statistically non-significant. The overall analysis of variance revealed that the processing and frozen storage period had significant ($P \leq 0.01$) effect on the AA content of okra rings on dry weight basis.

The ascorbic acid (AA) content of fresh okra trimmed was 15.3 mg/100g which after blanching decreased to 13.1 mg/100g and further decreased slightly to 13.0 mg/100g after freezing, on fresh weight basis. This decrease was statistically significant ($P \leq 0.05$).

The AA content remained in the narrow range of 12.3 to 13.0 mg/100g during the frozen storage period of six months and hence the variation was non-significant. The overall statistical analysis indicated that the processing and frozen storage period had significant ($P \leq 0.01$) effect on the AA content of okra trimmed, on fresh weight basis. On the other hand, the AA content of okra trimmed, on dry weight basis, was 135.8 mg/100g which after blanching increased to 146.2 mg/100g and then decreased to 144.4 mg/100g after freezing. These changes were statistically non-significant. The AA content remained between the narrow limits of 136.6 and 144.4 mg/100g during the frozen storage period of six months and statistically, the variation was non-significant. The overall analysis of variance also indicated that the processing and frozen storage period had non-significant effect on the AA content of okra trimmed, on dry weight basis.

The AA content of fresh okra trimmed was higher than that of the okra rings in fresh stage, after processing and during frozen storage period of six months, the corresponding overall range was 11.8 to 15.3 mg/100g, on fresh weight basis. The statistical analysis revealed that the AA content of two types of cuts of okra was significantly not different from each other in fresh stage, after processing and during frozen storage period of six months on fresh weight basis. The AA content, on dry weight basis, was 135.8 mg/100g in fresh okra trimmed which was more than that of the fresh okra rings. The differences, however, were not statistically significant. The AA content of okra rings was higher than the okra trimmed after blanching, freezing and throughout the frozen storage period of six months, the corresponding range was 136.6 to

160.7 mg/100g and the differences were again statistically non-significant. The overall range was 129.8 to 160.7 mg/100g.

It was observed from the Table 4.32 that the AA content of okra rings was reduced by 16.0 per cent during blanching, 0.79 per cent during freezing process and 5.6 per cent during frozen storage period of six months while the overall losses were 21.3 per cent on fresh weight basis. But on dry weight basis, there was +19.2 per cent change after blanching, -1.5 per cent after freezing, -6.7 per cent after six months of frozen storage period and +13.6 per cent overall change in the AA content of okra rings. On the other hand, the AA content of okra trimmed was reduced by 14.3 per cent during blanching, 0.76 per cent during freezing and 5.4 per cent during frozen storage period of six months while the overall losses were 19.6 per cent, on fresh weight basis. On dry weight basis, there was +7.6 per cent change after blanching, -1.2 per cent after freezing, -5.4 per cent after six months of frozen storage period and +0.58 per cent overall change in the AA content of okra trimmed. However, the overall loss of AA content was 21.3 per cent in okra rings which was more than that of the okra trimmed on fresh weight basis, whereas the overall change was +13.6 per cent in okra rings, on dry weight basis, which was more than that of okra trimmed.

The AA content of fresh capsicum halves was 145.0 mg/100g which was reduced to 107.0 mg/100g after blanching and further reduced to 106.4 mg/100g after freezing on fresh weight basis. This reduction was statistically significant ($P \leq 0.01$). The AA content was reduced from 106.4 to 98.3 mg/100g during the frozen storage period of six months. This reduction was again statistically significant ($P \leq 0.05$). The overall analysis of variance also indicated that the processing and frozen storage period had significant ($P \leq 0.01$) effect on the AA content of capsicum halves, on fresh weight basis. Similar results were obtained on dry weight basis and the AA content in fresh, blanched and frozen capsicum halves was 1959.4, 1486.1 and 1457.5 mg/100g, respectively. The AA content was reduced from 1457.5 to 1328.3 mg/100g during six months of frozen storage period. This variation was statistically significant ($P \leq 0.05$). From the overall analysis of variance, it was concluded that the processing and frozen storage period had significant ($P \leq 0.01$) effect on the AA content of capsicum halves on dry weight basis also.

It was observed from the Table 4.32 that the AA content of capsicum halves reduced 26.2 per cent during blanching, 0.56 per cent during freezing and 7.6 per cent during six months of frozen storage period while the overall losses were 32.2 per cent, on fresh weight basis. On the other hand, on dry weight basis, the corresponding losses of AA content were 24.1, 1.9, 8.8 and 32.3 per cent.

It is clear from the Fig. 4 that major ascorbic acid loss was due to the blanching process i.e. 14.3 to 26.2 per cent in all the three vegetables, on fresh weight basis. The freezing process caused little change in the AA of the vegetables. The losses of ascorbic acid during blanching may be due to leaching as it is water soluble vitamin. Further, vitamin C is readily oxidized by heat under alkaline or neutral conditions. However, on dry weight basis, after blanching, there appeared to be some gain in AA content of okra rings and okra trimmed. This can be due to absorption of water during blanching and

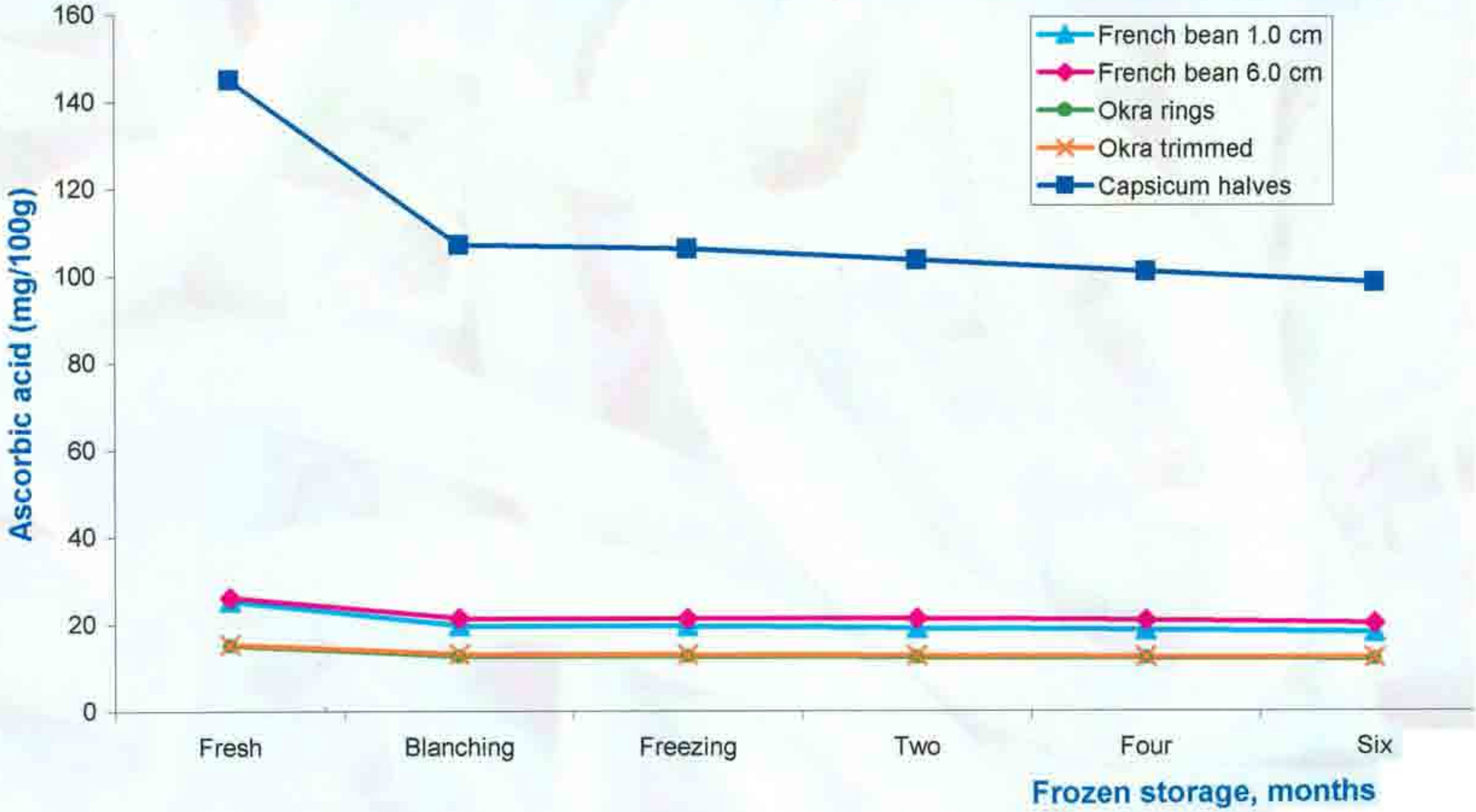

Fig 4 Effect of processing and frozen storage on ascorbic acid of the vegetables on fresh weight basis

Table 4.32 Losses (%, fresh weight basis) of ascorbic acid content during processing and frozen storage.

Vegetable	Blanching	Freezing	Six months frozen storage	Overall losses
French bean 1.0cm	22.2 (-3.7)	0.6 (-1.0)	7.5 (-7.7)	28.5 (-12.0)
French bean 6.0cm	18.0 (-17.1)	0.46 (-1.1)	5.1 (-5.4)	22.6 (-22.5)
Okra rings	16.0 (+19.2)	0.79 (-1.5)	5.6 (-6.7)	21.3 (+13.6)
Okra trimmed	14.3 (+7.6)	0.76 (-1.2)	5.4 (-5.4)	19.6 (+0.58)
Capsicum halves	26.2 (-24.1)	0.56 (-1.9)	7.6 (-8.8)	32.2 (-32.3)

Values in parenthesis are on dry weight basis oss of some soluble solids. As a matter of fact, the AA content was reduced significantly on fresh weight basis.

Kaur and Kapoor (2000) reported 26 mg/100g AA in fresh French beans and found 66 per cent loss after five minutes of blanching in boiling water. Ramesh *et al* (2002) reported 23.8 per cent loss of AA in bell peppers after 4.5 minutes of blanching in boiling water. In the present study, the loss of AA after blanching was 18.0 to 22.2 per cent, which was on the lower side as compared to the literature reports. Favell (1997) reported that the loss of AA in peas after the frozen storage period of 10 months was less than 10 per cent. In the present investigation, the losses after frozen storage period of six months ranged between 5.1 and 7.5 per cent in case of French beans.

Lisiewska and Kmiecik (1996) also postulated that during the freezing process, the greatest losses of AA occurred from blanching, the losses being 41 to 42 per cent in broccoli and 28 to 32 per cent in cauliflower. It was also reported that the freezing process itself did not bring about significant change in AA content in the vegetables.

During storage of vegetables, AA loss may be from enzymic oxidation due to the action of ascorbic acid oxidase. Pruthi (1999) observed no loss of AA during nine months of storage at –40°C but at two higher temperatures (-23°C and –26°C), a relatively rapid loss of AA was observed. Howard *et al* (1996) reported that AA level decreased linearly by about 10 percent per week during storage of carrots at 4°C.

Desrosier and Tressler (1977) reported that cauliflower retained 80 per cent AA when it was frozen. Further, 60 per cent AA was retained after six months of frozen storage. Aparicio-Cuesta and Garcia-Moreno (1988) observed that during storage of cauliflower at –22°C, 25 per cent AA was lost after 13 months and 62.2 per cent after 30 months. In the present study, the overall loss of AA after blanching and six months of frozen storage period ranged from 19.6 to 32.2 on fresh weight basis, which was within the range reported in the literature.

The AA loss can be reduced if blanching is carried out with steam instead of water and further by storing the product at much lower temperature of –40°C, where no loss is expected due to oxidation. But both steam blanching and maintenance of the temperature at -40°C is not economical.

4.5 Organoleptic evaluation of frozen vegetables

The fresh, blanched and frozen stored vegetables were evaluated for organoleptic scores in the form of French beans-potato, French beans-potato fry, okra-onion, okra fry and stuffed capsicum. Fresh vegetables available in the local market were used as control in the vegetables. At 0 and 2 months, the fresh samples of the same crop were used as standard.

4.5.1. Organoleptic scores of fresh French bean (1.0 cm) vegetables : The organoleptic scores of fresh French beans (1.0 cm) in the form of French beans–potato vegetables and those of market fresh available during the months of September, November and January are shown in Table 4.33. The average scores of colour, flavour, texture, taste and overall acceptability of fresh French beans were 4.00 ± 0.141, 4.00 ± 0.141, 4.00 ± 0.200, 4.10 ± 0.118 and 3.80 ± 0.145, respectively. While the mean scores of the market fresh beans available in the month of September were 4.00 ± 0.122, 3.90 ± 0.138, 3.80 ± 0.145, 4.10 ± 0.118 and 4.00 ± 0.200, respectively. The corresponding

Table 4.33 Organoleptic scores of fresh French bean (1.0 cm) vegetables (mean ±S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
French bean	4.00±0.141	4.00±0.141	4.00±0.200	4.10±0.118	3.80±0.145
Market fresh					
I	4.00±0.122	3.90±0.138	3.80±0.145	4.10±0.118	4.00±0.200
II	4.10±0.095	4.00±0.212	3.95±0.179	4.10±0.118	3.80±0.202
III	4.10±0.155	4.05±0.179	4.10±0.118	3.90±0.118	3.80±0.145
Fr	0.69^{NS}	0.33^{NS}	2.25^{NS}	0.81^{NS}	0.39^{NS}

Market fresh I, II and III are fresh French beans available in the months of September, November and January, respectively.

Fr – Friedman two-way analysis of variance by ranks statistics

NS – Not significant

scores for the market fresh beans available in the month of November were 4.10 ± 0.095, 4.00 ± 0.212, 3.95 ± 0.179, 4.10 ± 0.118 and 3.80 ± 0.202, respectively while those of market fresh beans available in the month of January were 4.10 ± 0.155, 4.05 ± 0.179, 4.10 ± 0.118, 3.90 ± 0.118 and 3.80 ± 0.145, respectively. It was observed from the data that the colour of the market fresh beans available in the months of November and January was better than that of French beans available in the months of July and September though the difference were not statistically significant. It may be because during the November and January beans were transported from Himachal Pradesh whose colour was better. The scores for flavour and texture of the market fresh beans available in the month of September were lower than those of the fresh beans available in the months of July, November and January, but the differences were again statistically non-significant. The scores for the taste of the market fresh beans available in the month of January were lower than those of the fresh beans available in other three months though statistically significant differences were not observed. The scores for overall acceptability of fresh French beans obtained in the month of September were higher as compared to the corresponding scores in the other three months irrespective of the source i.e. local or transported from Himachal Pradesh.

4.5.2. Effect of processing and frozen storage on organoleptic scores of French bean (1.0 cm) vegetables

The organoleptic evaluation for colour, flavour, texture, taste and overall acceptability are summarized in Table 4.34.

Table 4.34 Organoleptic scores of processed and frozen stored French bean (1.0 cm) vegetables (mean ±S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Fresh	4.00±0.141	4.00±0.141	4.00±0.200	4.10±0.118	3.80±0.145
Blanched	4.65±0.101	3.90±0.138	3.90±0.063	4.00±0.141	3.90±0.118
Frozen stored					
0	4.75±0.106	4.20±0.105	3.85±0.142	3.95±0.179	3.95±0.149
I	4.70±0.145	4.30±0.161	4.35±0.123	4.30±0.161	4.40±0.118
II	4.70±0.126	4.30±0.126	4.40±0.118	4.40±0.095	4.20±0.126
III	4.60±0.095	4.25±0.106	4.40±0.118	4.20±0.145	4.30±0.161
Fr1	8.75*	3.35^{NS}	0.15^{NS}	0.2^{NS}	1.05^{NS}
Fr2	0.65^{NS}	0.20^{NS}	0.45^{NS}	1.05^{NS}	0.45^{NS}
Fr3	11.51*	8.01^{NS}	12.80*	7.0^{NS}	0.5^{NS}
CD at 5% level	10.00				

Frozen stored 0, I, II and III are frozen stored French beans after 0, 2, 4 and 6 months respectively.
Fr – Friedman two-way analysis of variance by ranks statistics
Fr1 – for fresh, blanched and frozen (0 month) samples
Fr2 – for frozen stored samples
Fr3 – for fresh, blanched, frozen and stored samples
NS – Not significant
* Significant at 5% level

Effect of processing : The French beans (1.0 cm) were evaluated as fresh, after blanching and freezing to see the effect of processing on organoleptic acceptability of the beans in the form of French beans-potato vegetable. The scores for colour of fresh French beans (1.0 cm) were 4.00 ± 0.141 which after blanching increased to 4.65 ± 0.101 and further increased to 4.75 ± 0.106 after freezing. From the Friedman two-way analysis of variance, it was concluded that the processing had significant ($P \leq 0.05$) effect on the colour. The colour of beans improved and became greener. This may be because of the initial brightening of the green colour resulting from the removal of air from the vegetable surface and from the intercellular spaces during blanching. The scores for flavour of fresh French beans (1.0 cm) were 4.00 ± 0.141 which decreased to 3.90 ± 0.138 after blanching and then increased to 4.20 ± 0.105 after freezing. The flavour of frozen beans also improved but the difference was statistically non-significant. On the other hand, the scores for texture of fresh French beans (1.0 cm) were 4.00 ± 0.200 which decreased to 3.90 ± 0.063 after blanching and further to 3.85 ± 0.142 after freezing. The texture of processed beans slightly affected but the differences were statistically non-significant. The scores for taste of fresh French beans were 4.10 ± 0.118 which after blanching decreased to 4.00 ± 0.141 and further to 3.95 ± 0.179 after freezing, but the decrease was again statistically non-significant. The scores for overall acceptability of fresh French beans were 3.80 ± 0.145 which after blanching increased to 3.90 ± 0.118 and further to 3.95 ± 0.149 after freezing. The overall acceptability of frozen beans increased as compared to both fresh and blanched beans. This may be because of the improved colour and flavour of the frozen beans (Plates 4.1 and 4.2).

Plate 4.1. Fresh, blanched and frozen stored French beans(1.0 cm)

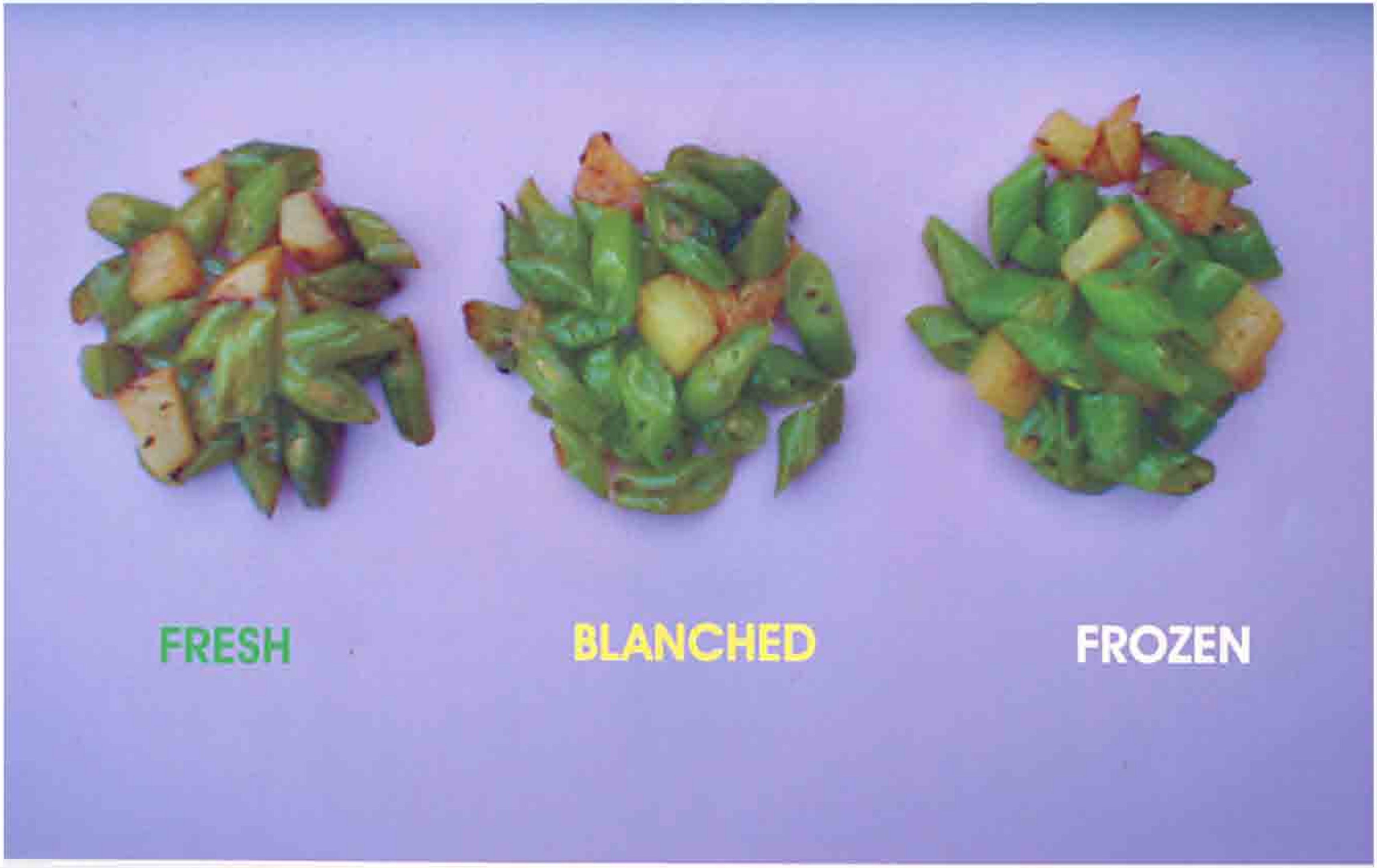

Plate 4.2. Processed and frozen stored French beans-potato vegetables.

Effect of frozen storage : The French beans (1.0 cm) in the form of French beans-potato vegetable, were evaluated after every two months of frozen storage period for six months. The scores for colour decreased slightly from 4.75 ± 0.106 to 4.70 ± 0.145 after the frozen storage period of two months, while the scores were 4.70 ± 0.126 and 4.60 ± 0.095 after the frozen storage of four and six months, respectively. Although, the frozen storage reduced the scores of colour yet the reduction was non-significant. On the other hand, the scores for flavour increased from 4.20 ± 0.105 to 4.30 ± 0.161 after the frozen period of two months, remained same i.e. 4.30 ± 0.126 after four months and slightly decreased to 4.25 ± 0.106 after six months of frozen storage. The flavour of the French beans improved after frozen storage but the differences were statistically non-significant. The scores for texture of the French beans increased from 3.85 ± 0.142 to 4.35 ± 0.123 after the frozen storage period of two months and further increased to 4.40 ± 0.118 after four and six months of frozen storage. The increase was statistically non-significant. The scores for taste of the beans also increased from 3.95 ± 0.179 to 4.30 ± 0.161 after two months of frozen storage, further to 4.40 ± 0.095 after four months and then decreased to 4.20 ± 0.145 after six months of frozen storage. The increase in scores was statistically non-significant. The organoleptic scores for overall acceptability of French beans (1.0 cm) also increased from 3.95 ± 0.149 to 4.40 ± 0.118 after two months of frozen storage, then decreased to 4.20 ± 0.126 after four months and again increased to 4.30 ± 0.161 after six months of frozen storage. The increase in scores was statistically non-significant.

From overall analysis of variance, it was observed that the processing and frozen storage period had significantly ($P \leq 0.05$) improved the colour and flavour of the French beans, but non-significant effect on all the other parameters of organoleptic evaluation of French beans (1.0 cm). The results of the study concluded that the French beans (1.0 cm) could be stored for a period of six months at –20 to – 25°C without any significantly adverse change in colour, flavour, texture, taste and overall acceptability (Figs. 5 to 9).

4.5.3. Comparison of the market fresh and frozen French bean (1.0 cm) vegetables: The frozen French beans (1.0 cm) were compared with the market fresh French beans available at that time in order to evaluate the organoleptic acceptability of frozen French beans in comparison to market fresh beans in the form of French beans-potato vegetable (Table 4.35). The scores for colour of frozen beans (1.0 cm) after two, four and six months of storage period were 4.70 ± 0.145, 4.70 ± 0.126 and 4.60 ± 0.095, respectively, whereas the scores of market fresh beans available in the corresponding months, i.e. September, November and January were 4.00 ± 0.122, 4.10 ± 0.095 and 4.10 ± 0.155, respectively. The average scores for colour of frozen stored French beans were significantly ($P \leq 0.05$) higher as compared to those of market fresh beans available in the respective months.

The scores for flavour of frozen French beans (1.0 cm) after two, four and six months of frozen storage were 4.30 ± 0.161 and 4.30 ± 0.126 and 4.25 ± 0.106, respectively, while those of market fresh available in the corresponding months were 3.90 ± 0.138, 4.00 ± 0.212 and 4.05 ± 0.179. The mean scores for flavour of frozen stored beans were higher than those of the market fresh but these differences were statistically

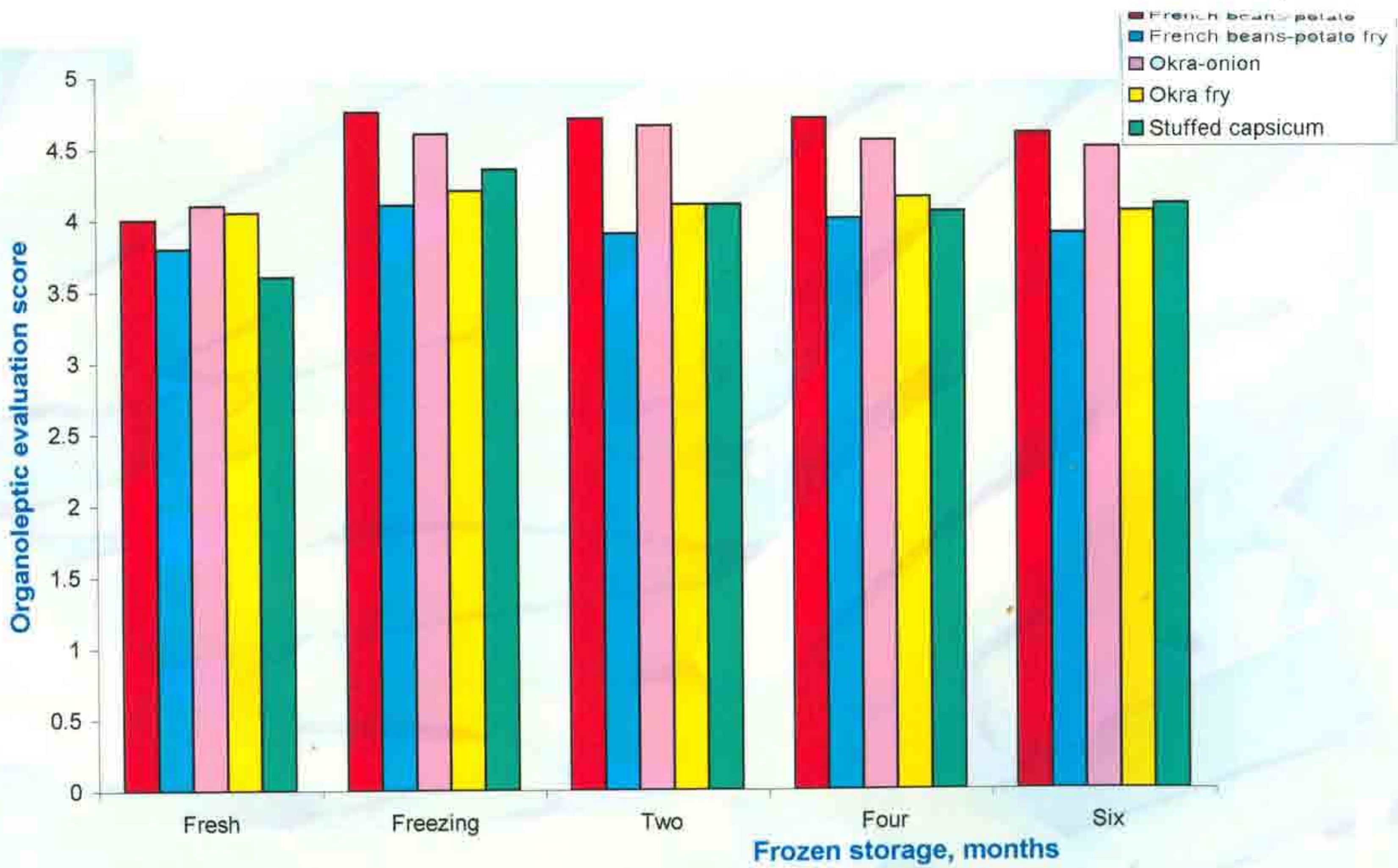

Fig 5 Effect of processing and frozen storage on colour score of the vegetables

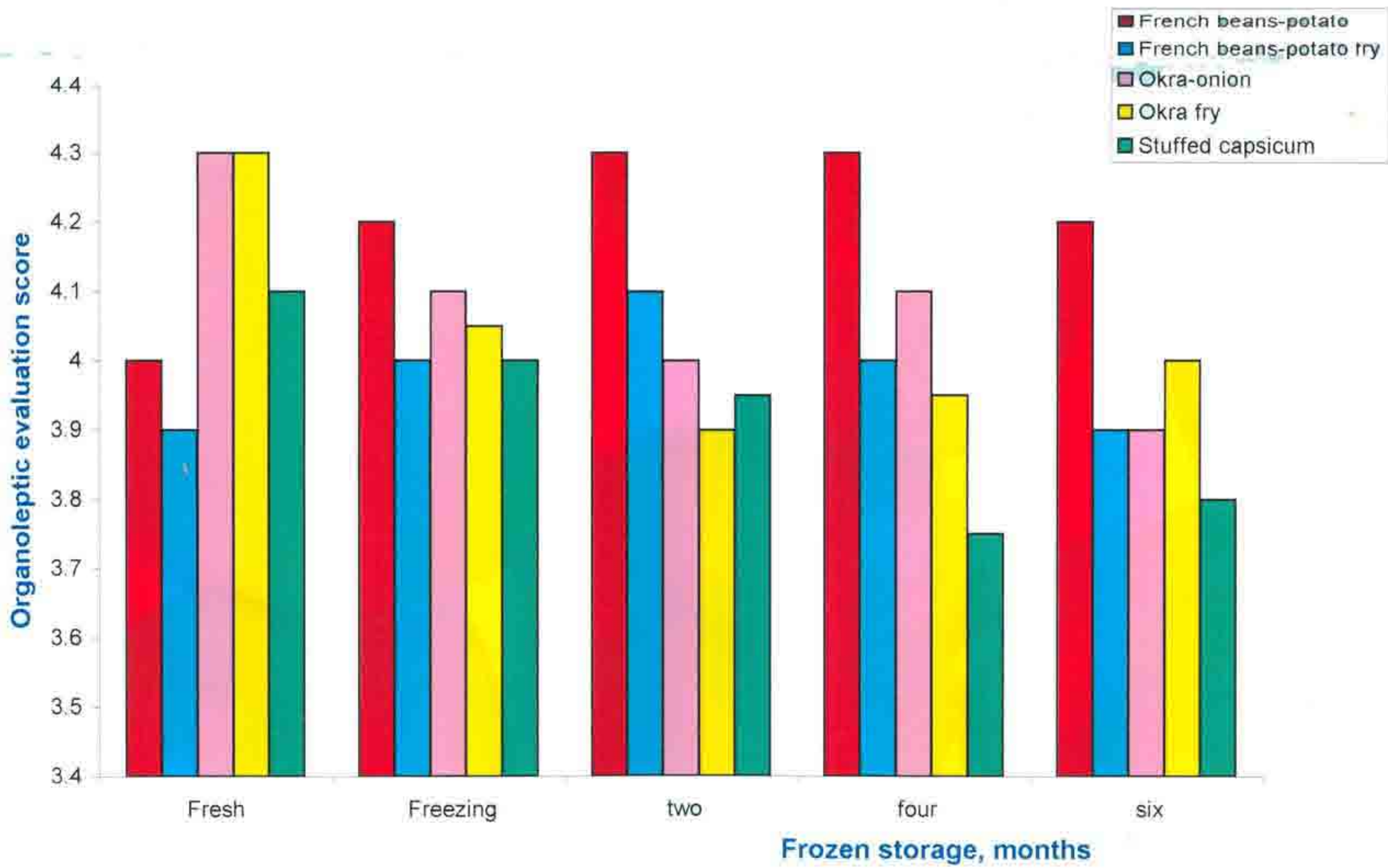

Fig 6 Effect of processing and frozen storage on flavour score of the vegetables

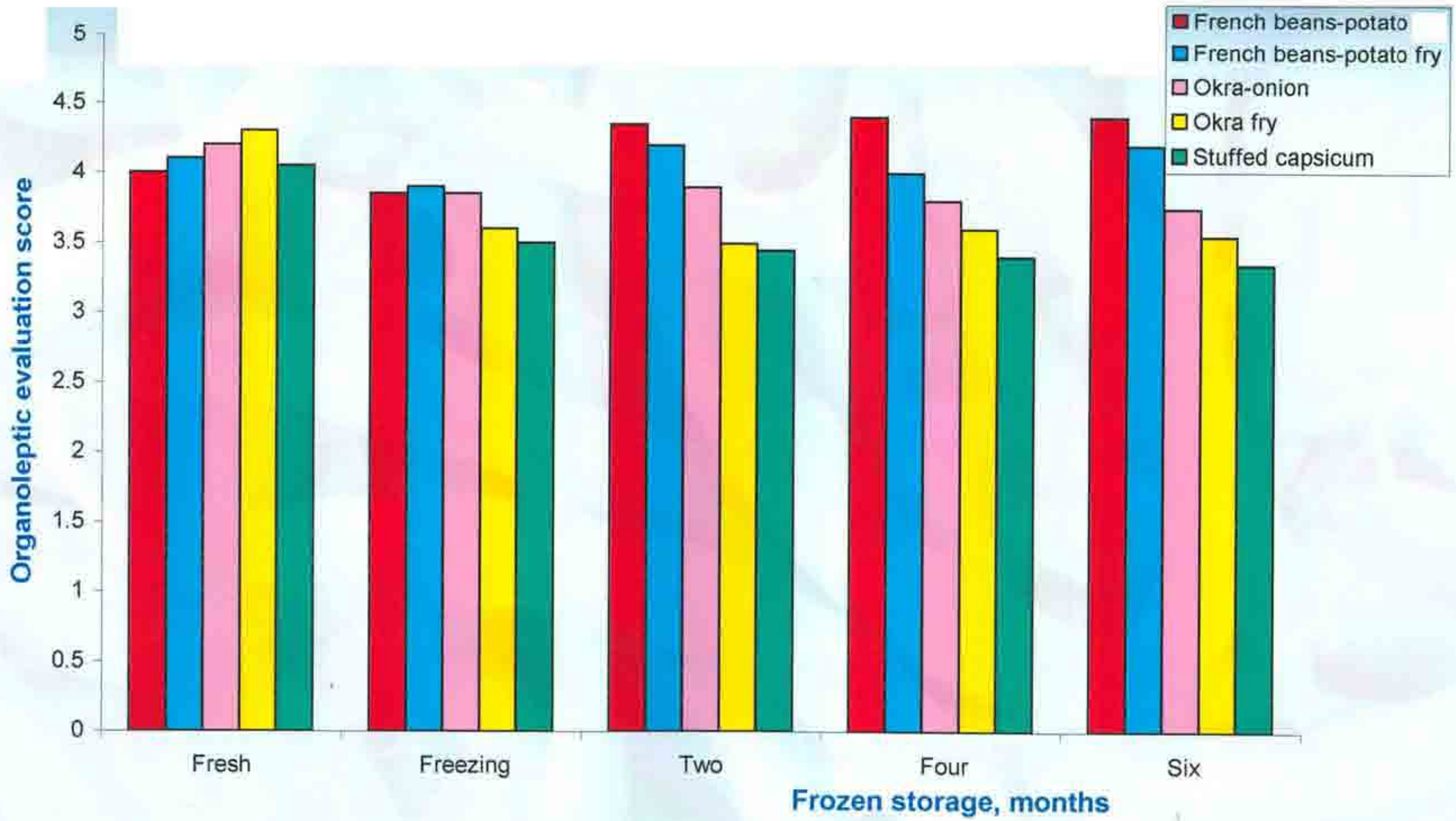

Fig 7 Effect of processing and frozen storage on texture score of the vegetables

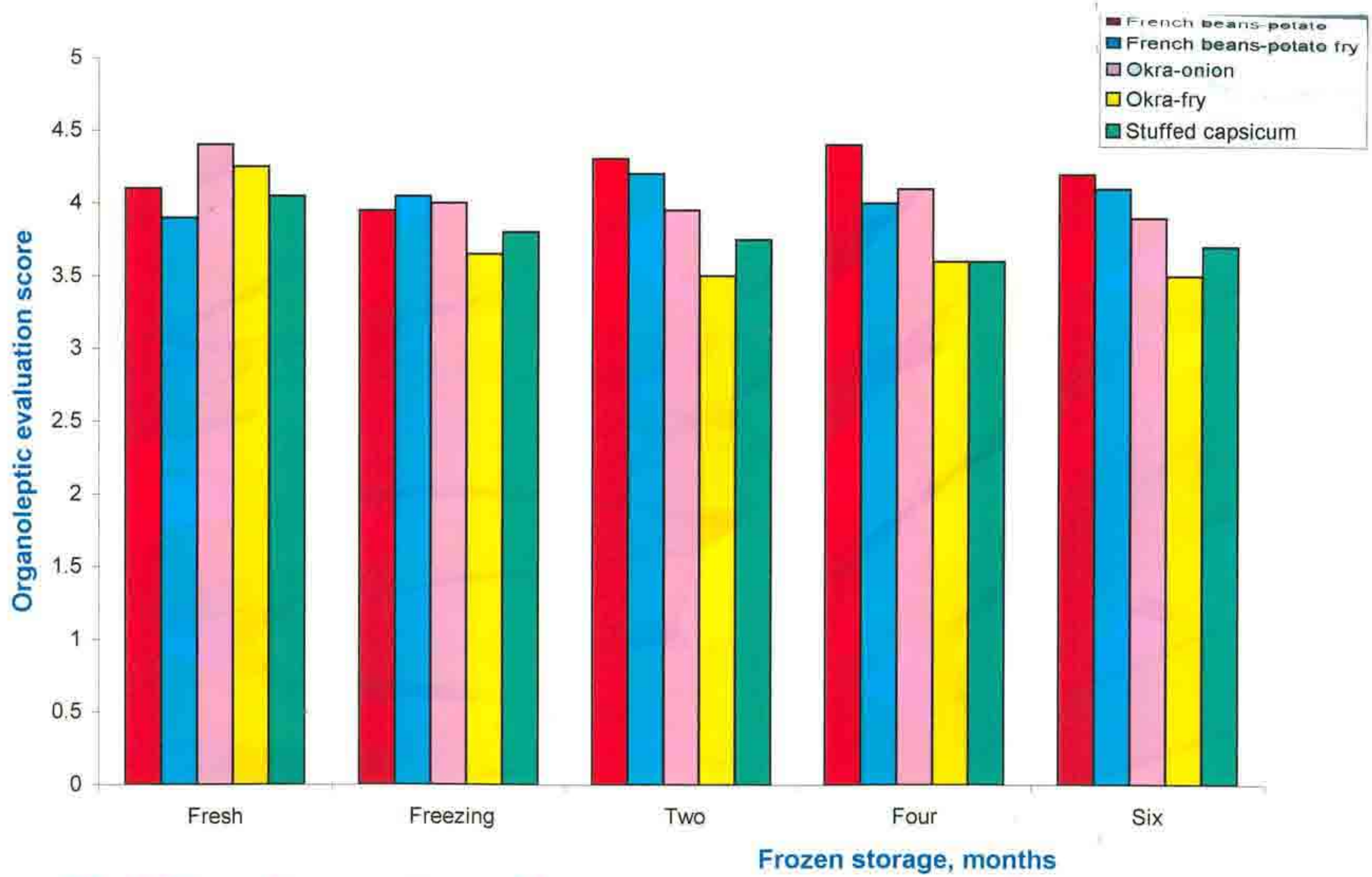

Fig 8 Effect of processing and frozen storage on taste score of the vegetables

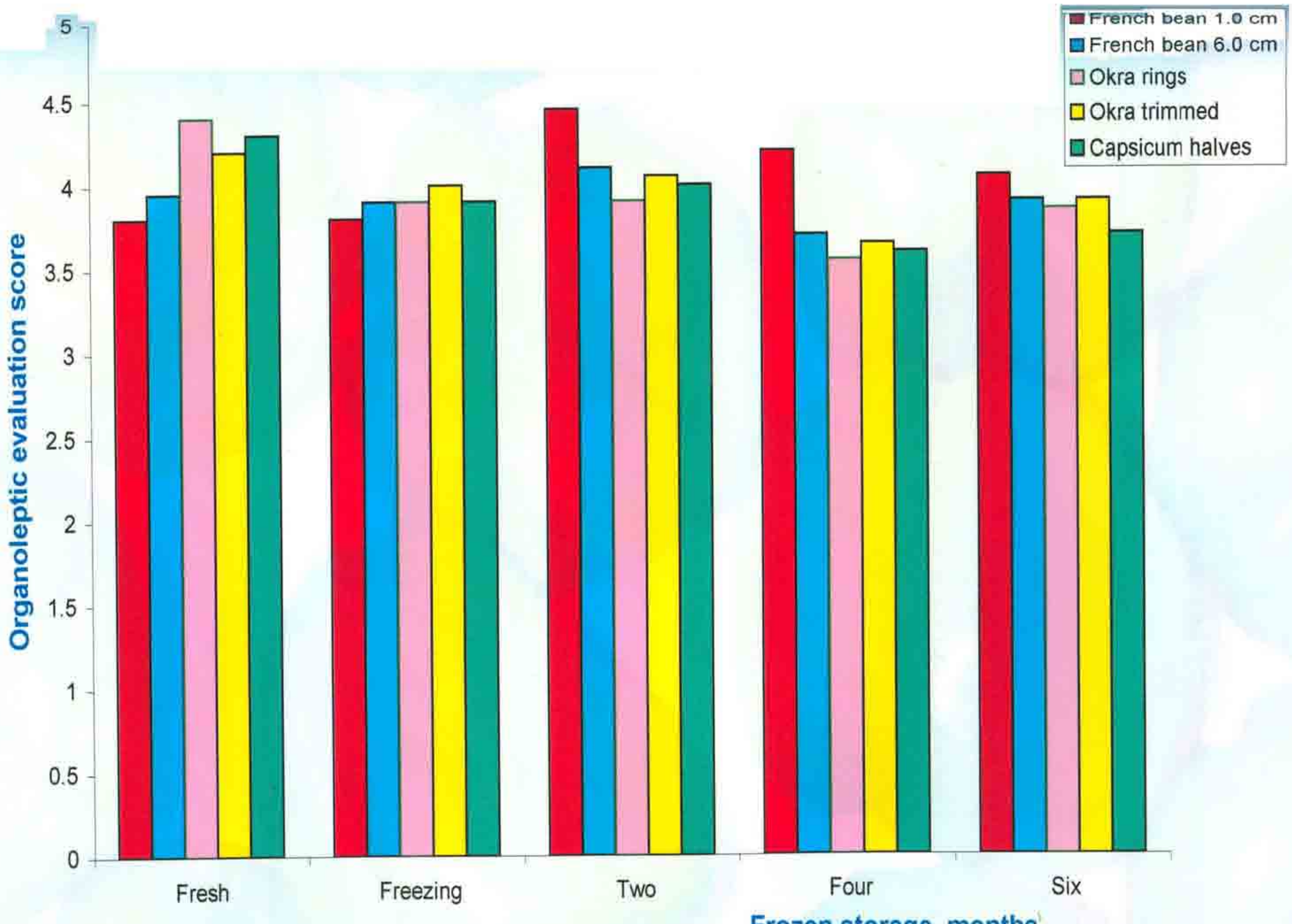

Fig 9 Effect of processing and frozen storage on overall acceptability score of the vegetables

Table 4.35 Organoleptic scores of market fresh and frozen stored French bean (1.0 cm) vegetables (mean ±S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Frozen stored I	4.70±0.145	4.30±0.161	4.35±0.123	4.30±0.161	4.40±0.118
Market fresh I	4.00±0.122	3.90±0.138	3.80±0.145	4.10±0.118	4.00±0.200
Wx value	142	126	134.5	118	125
P	0.0019*	0.0615 NS	0.0144*	0.1763 NS	0.0716 NS
Frozen stored II	4.70±0.126	4.30±0.126	4.40±0.118	4.40±0.095	4.20±0.126
Market fresh II	4.10±0.095	4.00±0.212	3.95±0.179	4.10±0.118	3.80±0.202
Wx	140	120	128	129	125.5
P	0.0034*	0.1399 NS	0.0446*	0.0376*	0.0716 NS
Frozen stored III	4.60±0.095	4.25±0.106	4.40±0.118	4.20±0.145	4.30±0.161
Market fresh III	4.10±0.155	4.05±0.179	4.10±0.118	3.90±0.118	3.80±0.145
Wx	133	114	126	122	130
P	0.0177*	0.2644 NS	0.0615 NS	0.1088 NS	0.0315*

Frozen stored I, II and III are frozen stored French beans after 2, 4 and 6 months of storage period, respectively.
Market fresh I, II and III are fresh French beans available in the months of September, November and January, respectively
Wx - Wilcoxon Mann Whiteney u-value
P – Probability
NS – Not significant
* - Significant at 5% level

not significant. The scores for texture of beans after two, four and six months of frozen storage were 4.35 ± 0.123, 4.40 ± 0.118 and 4.40 ± 0.118, respectively, whereas those of market fresh beans available in the respective months were 3.80 ± 0.145, 3.95 ± 0.179 and 4.10 ± 0.118, respectively. The mean scores for texture of frozen stored beans were higher than those of the market fresh and the differences were significant ($P \leq 0.05$) after two and four months (September and November) frozen storage and not after six months (January) of frozen storage.

The scores for taste of fresh beans (1.0 cm) after two, four and six months of frozen storage were 4.30 ± 0.161, 4.40 ± 0.095 and 4.20 ± 0.145, respectively, while those of market fresh available in the respective months were 4.10 ± 0.118, 4.10 ± 0.118 and 3.90 ± 0.118. The average scores for taste of frozen stored beans were higher than those of respective off-season market fresh beans but the difference was significant ($P \leq 0.05$) after four months (November) of frozen storage and not after two and six months (September and January) of frozen storage. The mean scores for overall acceptability of frozen stored beans were 4.40 ± 0.118, 4.20 ± 0.126 and 4.30 ± 0.161, after two, four and six months, respectively, whereas those of corresponding off-season market fresh beans available in the month of September, November and January were 4.00 ± 0.200, 3.80 ± 0.202 and 3.80 ± 0.145, respectively. The mean scores for overall acceptability of frozen stored beans were higher than those of market fresh beans and the differences were statistically non-significant after two and four months (September and November) frozen storage but significant ($P \leq 0.05$) after six months (January) frozen storage. Overall, all the parameters of organoleptic evaluation of French beans (1.0 cm) scored better having the mean scores of 4.20 to 4.70 as compared to the market fresh samples in the respective months whose organoleptic mean scores were 3.80 to 4.10. This may be because blanching and freezing improved the colour, flavour, texture, taste and overall acceptability of the vegetables. The varietal difference of the beans could be another reason for differences in scores. Sajjananatakul (1986) also reported that rapid freezing produced high quality product. In the present study, the beans were subjected to IQF, where freezing was done rapidly and hence the loss in the quality parameters of the beans is expected to be minimal. Secondly, the fresh beans purchased were of high quality and at the right maturity stage. Hence, the frozen beans were quite acceptable as the overall acceptability scores were above 4.00 i.e. very good.

4.5.4. Organoleptic scores of fresh French bean (6.0 cm) vegetables : The organoleptic scores of 'French beans-potato fry' vegetable prepared from fresh French beans (6.0 cm) and that of market fresh available during the period of September, November and January are presented in Table 4.36. The mean scores for colour, flavour, texture, taste and overall acceptability of fresh French beans were 3.80 ± 0.145, 3.90 ± 0.155, 4.10 ± 0.170, 3.90 ± 0.197 and 3.80 ± 0.161, respectively and those of market fresh beans available in the month of September were 3.60 ± 0.118, 3.75 ± 0.127, 3.95 ± 0.085, 3.90 ± 0.118 and 3.70 ± 0.118, respectively. It was observed from the data that except taste, the scores of all the parameters of organoleptic evaluation of fresh French beans were higher than those of market fresh beans available in the month of September, though the differences were not significant.

Table 4.36 Organoleptic scores of fresh French bean (6.0 cm) vegetables (mean ±S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
French bean	3.80±0.145	3.90±0.155	4.10±0.170	3.90±0.197	3.80±0.161
Market fresh					
I	3.60±0.118	3.75±0.127	3.95±0.085	3.90±0.118	3.70±0.118
II	3.65±0.123	3.80±0.077	3.95±0.193	3.85±0.123	3.70±0.126
III	3.70±0.104	3.80±0.145	3.90±0.094	3.90±0.155	3.75±0.101
Fr	0.63^{NS}	1.05^{NS}	0.45^{NS}	0.27^{NS}	1.02^{NS}

Market fresh I, II and III are fresh French beans available in the months of September, November and January, respectively.

Fr – Friedman two-way analysis of variance by ranks statistics

NS – Not significant

The mean scores for colour, flavour, texture, taste and overall acceptability of market fresh beans available in the month of November were 3.65 ± 0.123, 3.80 ± 0.077, 3.95 ± 0.193, 3.85 ± 0.123 and 3.70 ± 0.126 and those of market fresh beans available in the month of January were 3.70 ± 0.104, 3.80 ± 0.145, 3.90 ± 0.094, 3.90 ± 0.155 and 3.75 ± 0.101, respectively.

The data depicted that the organoleptic scores of the market fresh beans available in the months of September, November and January were comparable but the scores for fresh French beans were higher, although these differences were not statistically significant. It may be due to varietal difference.

4.5.5. Effect of processing and frozen storage on organoleptic scores of French bean (6.0 cm) vegetables

Table 4.37 presents the organoleptic scores of French beans-potato fry vegetable from fresh, processed and frozen stored French beans (6.0 cm).

Effect of processing : The mean scores for colour of fresh French beans (6.0 cm) were 3.80 ± 0.145 which after blanching increased to 4.10 ± 0.137 and remained same after freezing. Though, the colour of beans improved after blanching but the Friedman two-way analysis of variance revealed that the processing had non-significant effect on the colour of beans. The scores for flavour of fresh French beans (6.0 cm) were 3.90 ± 0.155 which remained same after blanching and then increased to 4.00 ± 0.122 after freezing. The scores for flavour of frozen beans also improved but the differences were statistically non-significant. On the other hand, the scores for texture of fresh French beans (6.0 cm) were 4.10 ± 0.170 which decreased to 4.00 ± 0.122 after blanching and further to 3.90 ±

Table 4.37 Organoleptic scores of processed and frozen stored French bean (6.0 cm) vegetables (mean ±S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Fresh	3.80±0.145	3.90±0.155	4.10±0.170	3.90±0.197	3.80±0.161
Blanched	4.10±0.137	3.90±0.118	4.00±0.122	4.00±0.173	4.00±0.122
Frozen stored					
0	4.10±0.137	4.00±0.122	3.90±0.138	4.05±0.179	3.90±0.118
I	3.90±0.155	4.10±0.155	4.20±0.126	4.20±0.189	3.90±0.126
II	4.00±0.122	4.00±0.100	4.00±0.158	4.00±0.122	4.00±0.158
III	3.90±0.118	3.90±0.118	4.20±0.145	4.10±0.184	3.90±0.077
Fr1	3.80^{NS}	0.35^{NS}	0.95^{NS}	1.40^{NS}	0.95^{NS}
Fr2	0.60^{NS}	1.40^{NS}	1.35^{NS}	1.25^{NS}	1.40^{NS}
Fr3	4.37^{NS}	1.98^{NS}	6.30^{NS}	3.11^{NS}	8.48^{NS}

Frozen stored 0, I, II and III are frozen stored French beans after 0, 2, 4 and 6 months respectively.
Fr – Friedman two-way analysis of variance by ranks statistics
Fr1 – for fresh, blanched and frozen (0 month) samples
Fr2 – for frozen stored samples
Fr3 – for fresh, blanched, frozen and stored samples
NS – Not significant

0.138 after freezing. The texture of processed beans was affected but the differences were statistically non-significant. The scores for taste of fresh French beans (6.0 cm) were 3.90 ± 0.197 which after blanching increased to 4.00 ± 0.173 and further to 4.05 ± 0.179 after freezing, but the increase was again non-significant. The scores for overall acceptability of fresh French beans were 3.80 ± 0.161 which after blanching increased to 4.00 ± 0.122 and then slightly decreased to 3.90 ± 0.118 after freezing. The overall acceptability of frozen French beans increased as compared to fresh beans. This may be because of the improved colour, flavour and taste of the frozen beans (Plate 4.3 and 4.4).

Effect of frozen storage : The French beans (6.0 cm) in the form of French beans-potato fry vegetable were evaluated after every two months of frozen storage period for six months. The scores for colour decreased slightly from 4.10 ± 0.137 to 3.90 ± 0.155 after the frozen storage period of two months, while the scores were 4.00 ± 0.122 and 3.90 ± 0.118 after the frozen storage of four and six months, respectively. Although the frozen storage reduced the scores of colour yet these were higher than those of the fresh beans. This might be due to the reason that the griddle fry maṣala which contains *amchoor* and other spices affected the colour of the beans. Further, this reduction was statistically non-significant. On the other hand, the scores for flavour increased from 4.00 ± 0.122 to 4.10 ± 0.155 after the frozen storage period of two months, decreased to 4.00 ± 0.100 after four months and further to 3.90 ± 0.118 after six months of frozen storage. These changes in flavour were statistically non-significant. The scores for texture of the French-beans also increased from 3.90 ± 0.138 to 4.20 ± 0.126 after two months storage, then decreased to 4.00 ± 0.158 after four months and again increased to

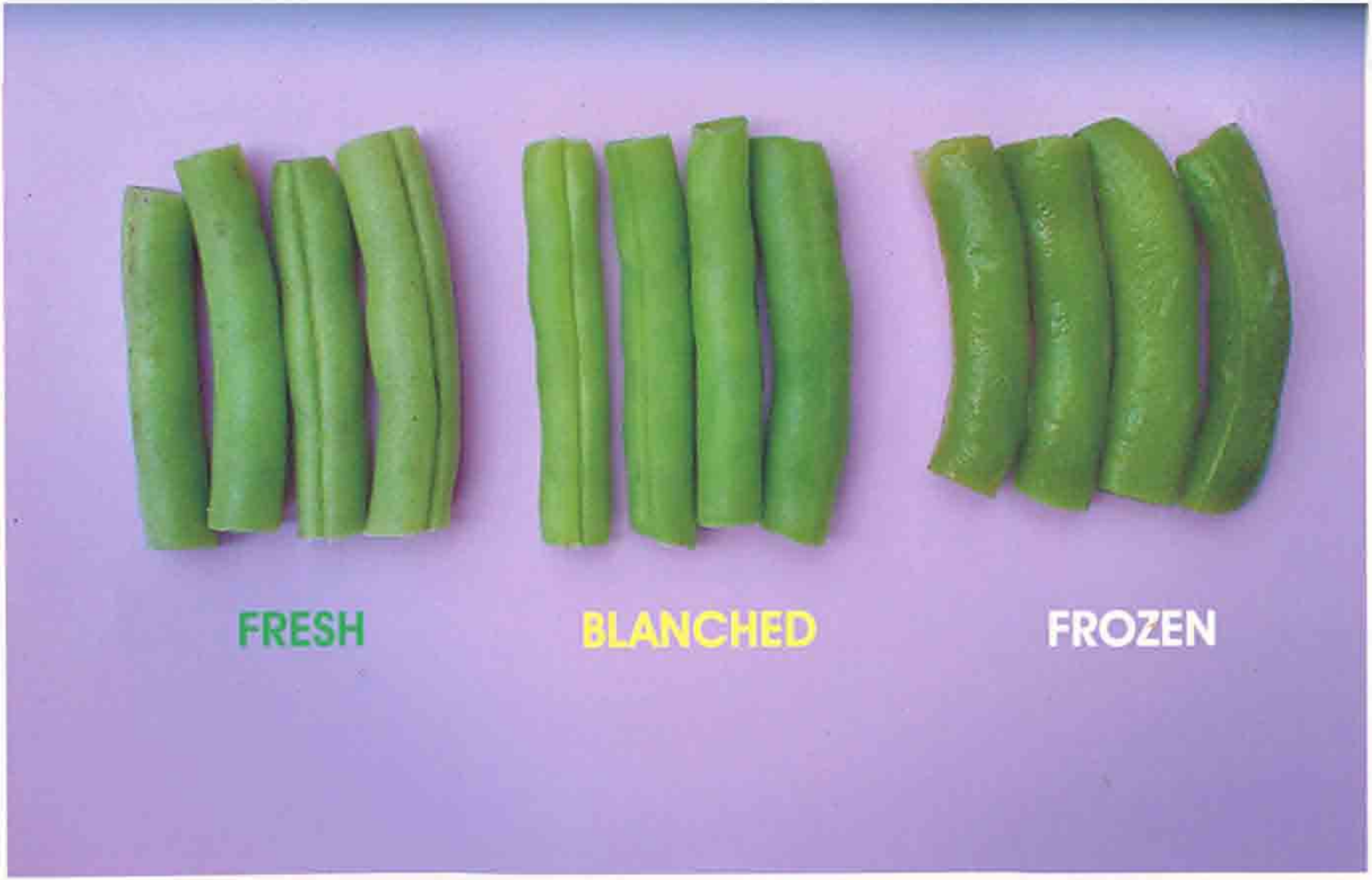

Plate 4.3 . Fresh, blanched and frozen stored French beans(6.0 cm)

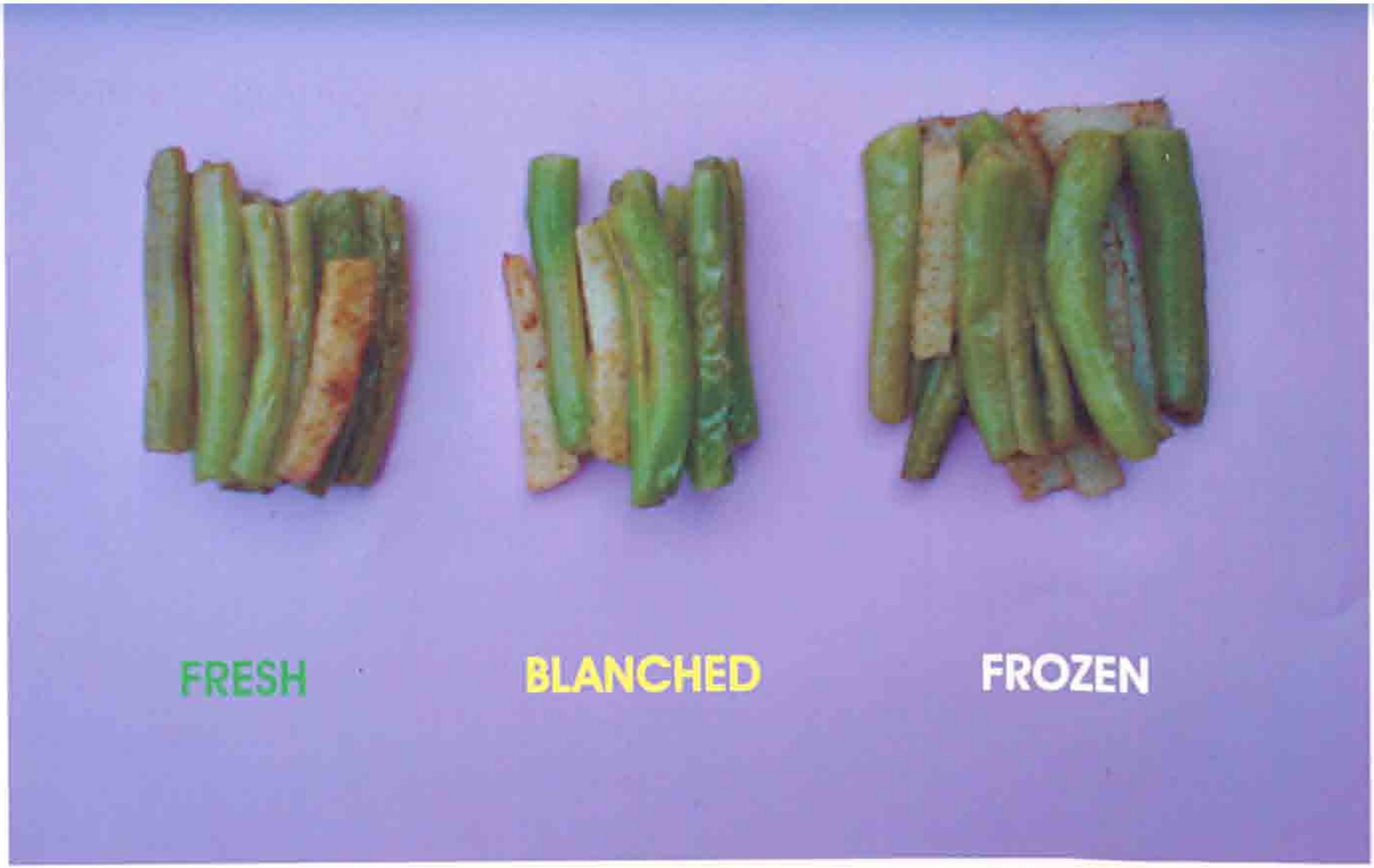

Plate 4.4. Processed and frozen stored French beans-potato fry vegetables.

4.20 ± 0.145 after six months of frozen storage. The change in scores of texture was statistically non-significant. The scores for taste of the beans also increased after two months frozen storage from 4.05 ± 0.179 to 4.20 ± 0.189, then decreased to 4.00 ± 0.122 after four months and again increased to 4.10 ± 0.184 after six months of frozen storage. These variations were statistically non-significant. The average scores for overall acceptability of French beans (6.0 cm) were 3.90± 0.118 and 3.90 ± 0.126, immediately after freezing and after two months of frozen storage, increased to 4.00 ± 0.158 after four months and then decreased to 3.90 ± 0.077 after six months of frozen storage. The scores for overall acceptability changed slightly but the differences were statistically non-significant.

From overall analysis of variance, it was concluded that the processing and frozen storage period had improved the colour, flavour, texture, taste and overall acceptability of French beans (6.0 cm) but these changes were statistically non-significant (Figs. 5 to 9). Hence the frozen French beans can be stored for a period of six months at –20 to –25°C without significant change in colour, flavour, texture, taste and overall acceptability. Pruthi (1989) reported that the frozen foods had better nutritive value, flavour and appearance than the food preserved by any other processing technique like canning, bottling or dehydration. Dhaliwal (2002) also reported that during the frozen storage period of six months, very little change occurred in appearance, colour, flavour, taste and overall acceptability of peas, cauliflower and carrots.

4.5.6. Comparison of the market fresh and frozen stored French bean (6.0 cm) vegetables

The data regarding the comparison of market fresh and frozen stored French beans (6.0 cm) in the form of French beans-potato fry vegetable is presented in Table 4.38. The scores for colour of frozen beans (6.0 cm) after two, four and six months of frozen storage period were 3.90 ± 0.155, 4.00 ± 0.122 and 3.90 ± 0.118, respectively, whereas the scores of market fresh beans available in the corresponding months, i.e. September, November and January were 3.60 ± 0.118, 3.65 ± 0.123 and 3.70 ± 0.104, respectively. The average scores for colour of frozen stored beans were higher than those of the market fresh beans available in the respective months, because blanching and freezing improved the colour, but the differences between two were statistically non-significant.

The scores for flavour of frozen French beans (6.0 cm) after two, four and six months of frozen storage were 4.10 ± 0.155, 4.00 ± 0.100 and 3.90 ± 0.118, respectively, while those of market fresh available in the corresponding months were 3.75 ± 0.127, 3.80 ± 0.077 and 3.80 ± 0.145. The mean scores for flavour of frozen stored beans were higher than those of the market fresh ones because blanching and freezing improved the flavour, but the differences were statistically non-significant. The mean scores for texture of beans (6.0 cm) after two, four and six months of frozen storage were 4.20 ± 0.126 4.00 ± 0.158 and 4.20 ± 0.145, respectively, whereas those of market fresh beans available in the respective months were 3.95 ± 0.085, 3.95 ± 0.193 and 3.90 ± 0.094. The

Table 4.38 Organoleptic scores of market fresh and frozen stored French beans (6.0 cm) vegetables (mean ±S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Frozen stored I	3.90±0.155	4.10±0.155	4.20±0.126	4.20±0.189	3.90±0.126
Market fresh I	3.60±0.118	3.75±0.127	3.95±0.085	3.90±0.118	3.70±0.118
Wx	119	126.5	122	122	118
P	0.1575 NS	0.0615 NS	0.1088 NS	0.1088 NS	0.1763 NS
Frozen stored II	4.00±0.122	4.00±0.100	4.00±0.158	4.00±0.122	4.00±0.158
Market fresh II	3.65±0.123	3.80±0.077	3.95±0.193	3.85±0.123	3.70±0.126
Wx	125.5	121	105	113.5	120.5
P	0.0716 NS	0.1237 NS	0.5147 NS	0.2894 NS	0.1399 NS
Frozen stored III	3.90±0.118	3.90±0.118	4.20±0.145	4.10±0.184	3.90±0.077
Market fresh III	3.70±0.104	3.80±0.145	3.90±0.094	3.90±0.155	3.75±0.101
Wx	117	111	124	115.5	117
P	0.1965 NS	0.3421 NS	0.0827 NS	0.2406 NS	0.1965 NS

Frozen stored I, II and III are frozen stored French beans after 2, 4 and 6 months of storage period, respectively.

Market fresh I, II and III are fresh French beans available in the months of September, November and January, respectively

Wx - Wilcoxon Mann Whiteney u-value

P – Probability

NS – Not significant

average scores for texture of frozen stored beans (6.0 cm) were higher than those of the market fresh but the differences were statistically non-significant.

The scores for taste of French beans (6.0 cm) after two, four and six months of frozen storage were 4.20 ± 0.189, 4.00 ± 0.122 and 4.10 ± 0.184, respectively, while those of market fresh available in the respective months were 3.90 ± 0.118, 3.85 ± 0.123 and 3.90 ± 0.155. The average scores for taste of frozen stored beans were higher than those of respective off-season market fresh beans, this may be because of varietal difference and stage of maturity of the beans. However, the differences were statistically non-significant. The mean scores for overall acceptability of frozen stored beans were 3.90 ± 0.126, 4.00 ± 0.158 and 3.90 ± 0.077 after two, four and six months respectively, whereas those of corresponding off-season market fresh beans were 3.70 ± 0.118, 3.70 ± 0.126 and 3.75 ± 0.101. However, these differences were statistically non-significant. The average scores for overall acceptability of frozen stored beans were higher than those of respective off-season market fresh beans. This was because the colour, flavour, texture and taste of the frozen beans was better than the market fresh ones.

Overall, all the parameters of organoleptic evaluation of frozen French beans (6.0 cm) scored better having the mean scores of 3.90 to 4.20 as compared to the market fresh samples in the respective months whose organoleptic mean scores ranged from 3.60 to 3.95. The main reason could be blanching and freezing which improved the colour, flavour, texture, taste and overall acceptability of the vegetables. So, the frozen stored French beans (6.0 cm) were more acceptable than market fresh ones. Further, the beans which were frozen stored, were of good quality and at proper stage of maturity. Simpson

(1962) reported that freezing maintained the quality of vegetables far better than any other method of preservation. But, even freezing can not improve the quality of the original vegetable. So, it is essential that vegetables for freezing should be of the best quality including colour and at the right stage of maturity. In the present study, the fresh beans used for freezing purpose were of very good quality.

4.5.7. Organoleptic scores of fresh okra (rings) vegetables : The data presented in Table 4.39 represents the evaluation scores for fresh experimental okra rings and those available in the month of September, November and January in the form of Okra-onion vegetables. The mean scores for colour, flavour, texture, taste and overall acceptability of fresh okra were 4.10 ± 0.170, 4.30 ± 0.145, 4.20 ± 0.161, 4.40 ± 0.184 and 4.45 ± 0.193, respectively and those of market fresh available in the month of September were 4.00 ± 0.187, 4.05 ± 0.165, 4.10 ± 0.118, 4.05 ± 0.131 and 4.20 ± 0.145, respectively.

It was observed from the data that the scores for all the parameters of organoleptic evaluation of fresh okra were higher than those of the fresh okra available in the month of September, although no significant differences were observed.

The mean scores for the market fresh okra available in the month of November were 3.85 ± 0.072, 3.95 ± 0.085, 4.05 ± 0.179, 4.00 ± 0.100 and 4.00 ± 0.110, respectively and the corresponding scores for the market fresh okra available in the month of January were 3.80 ± 0.145, 4.00 ± 0.141, 4.00 ± 0.200, 3.90 ± 0.118 and 4.00 ± 0.101, respectively. It was observed that the organoleptic scores of market fresh okra available in the month of November and January were almost same with slight change in

Table 4.39 Organoleptic scores of fresh okra (rings) vegetables (mean ±S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Okra rings	4.10±0.170	4.30±0.145	4.20±0.161	4.40±0.184	4.45±0.193
Market fresh					
I	4.00±0.187	4.05±0.165	4.10±0.118	4.05±0.131	4.20±0.145
II	3.85±0.072	3.95±0.085	4.05±0.179	4.00±0.100	4.00±0.110
III	3.80±0.145	4.00±0.141	4.00±0.200	3.90±0.118	4.00±0.101
Fr	2.73^{NS}	2.79^{NS}	0.39^{NS}	3.9^{NS}	6.69^{NS}

Market fresh I, II and III are fresh okra ring available in the months of September, November and January, respectively.

Fr – Friedman two-way analysis of variance by ranks statistics

NS – Not significant

the scores of colour, flavour, texture and taste, though the differences were non-significant.

The scores for all the organoleptic parameters of experimental fresh okra were higher than the off-season market fresh okra available in the months of September, November and January. There was a gradual decline in the scores for all the parameters of off-season market fresh okra, but no significant differences were observed. Pruthi (1999) reported that for obtaining the best results, it is essential to freeze fresh vegetables when they are in peak condition and buy early in the season when the vegetables are tender. The results of present study support the observations reported in the literature.

4.5.8. Effect of processing and frozen storage on organoleptic scores of okra (rings) vegetables

The data on organoleptic scores of okra-onion vegetable from fresh, processed and frozen stored okra rings, have been presented in Table 4.40.

Effect of processing : The organoleptic scores for colour of fresh okra rings were 4.10 ± 0.170 which after blanching increased to 4.60 ± 0.155 and remained same after freezing. From the analysis of variance, it was observed that the processing had significant ($P \leq 0.05$) effect on the colour. The colour of okra rings improved and became greener. This may be because of the initial brightening of the green colour due to the removal of air from the vegetable surface and from the intercellular spaces during blanching. On the other hand, the scores for flavour of fresh okra rings were 4.30 ± 0.145 which decreased to 4.05 ± 0.165 after blanching and then increased to 4.10 ± 0.170 after freezing. The scores for flavour decreased after blanching and freezing, although

Table 4.40 Organoleptic scores of processed and frozen stored okra (rings) vegetables (mean ±S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Fresh	4.10±0.170	4.30±0.145	4.20±0.161	4.40±0.184	4.45±0.193
Blanched	4.60±0.155	4.05±0.165	3.90±0.138	4.10±0.170	4.05±0.165
Frozen stored					
0	4.60±0.155	4.10±0.170	3.85±0.123	4.00±0.141	4.10±0.118
I	4.65±0.101	4.00±0.100	3.90±0.155	3.95±0.149	3.90±0.138
II	4.55±0.131	4.10±0.063	3.80±0.126	4.10±0.063	4.05±0.111
III	4.50±0.141	3.90±0.155	3.75±0.190	3.90±0.095	4.00±0.158
Fr1	6.35*	3.15^{NS}	4.55^{NS}	2.60^{NS}	6.65*
Fr2	0.20^{NS}	0.35^{NS}	0.35^{NS}	1.55^{NS}	0.35^{NS}
Fr3	6.5^{NS}	4.47^{NS}	4.07^{NS}	5.88^{NS}	6.57^{NS}
CD at 5% level	10.00				10.00

Frozen stored 0, I, II and III are frozen stored okra ring after 0, 2, 4 and 6 months respectively.
Fr – Friedman two-way analysis of variance by ranks statistics
Fr1 – for fresh, blanched and frozen (0 month) samples
Fr2 – for frozen stored samples
Fr3 – for fresh, blanched, frozen and stored samples
NS – Not significant
* - Significant at 5% level

the changes were non-significant. The scores for texture of fresh okra rings were 4.20 ± 0.161 which decreased to 3.90 ± 0.138 after blanching and further to 3.85 ± 0.123 after freezing. The texture of processed okra rings was slightly affected but the differences were statistically non-significant.

The average scores for taste of fresh okra rings were 4.40 ± 0.184 which after blanching decreased to 4.10 ± 0.170 and further to 4.00 ± 0.141 after freezing. However, these changes were statistically non-significant. The scores for overall acceptability of fresh okra rings were 4.45 ± 0.193 which after blanching decreased to 4.05 ± 0.165 and then increased slightly to 4.10 ± 0.118 after freezing. The scores for overall acceptability decreased significantly ($P \leq 0.05$) after blanching and freezing as compared to the fresh okra rings. The main reason was negative effect on flavour, texture and taste of the vegetables (Plates 4.5 and 4.6).

Overall, the scores for all the organoleptic parameters in case of blanched okra were lower than the fresh samples except for colour. However, the differences in the scores of the fresh, blanched and frozen okra rings were not significant except on colour and overall acceptability where the differences were significant ($P \leq 0.05$). Hence processing had no significant detrimental effect on the organoleptic scores of okra rings rather blanching improved the colour of the okra rings.

Effect of frozen storage : The mean scores for colour of the immediately frozen okra rings, in the form of okra-onion vegetable were 4.60 ± 0.155 which after two months of frozen storage increased to 4.65 ± 0.101, then decreased to 4.55 ± 0.131 and 4.50 ± 0.141 after the frozen storage of four and six months, respectively. Although the frozen

Plate 4.5. Fresh, blanched and frozen stored okra(rings)

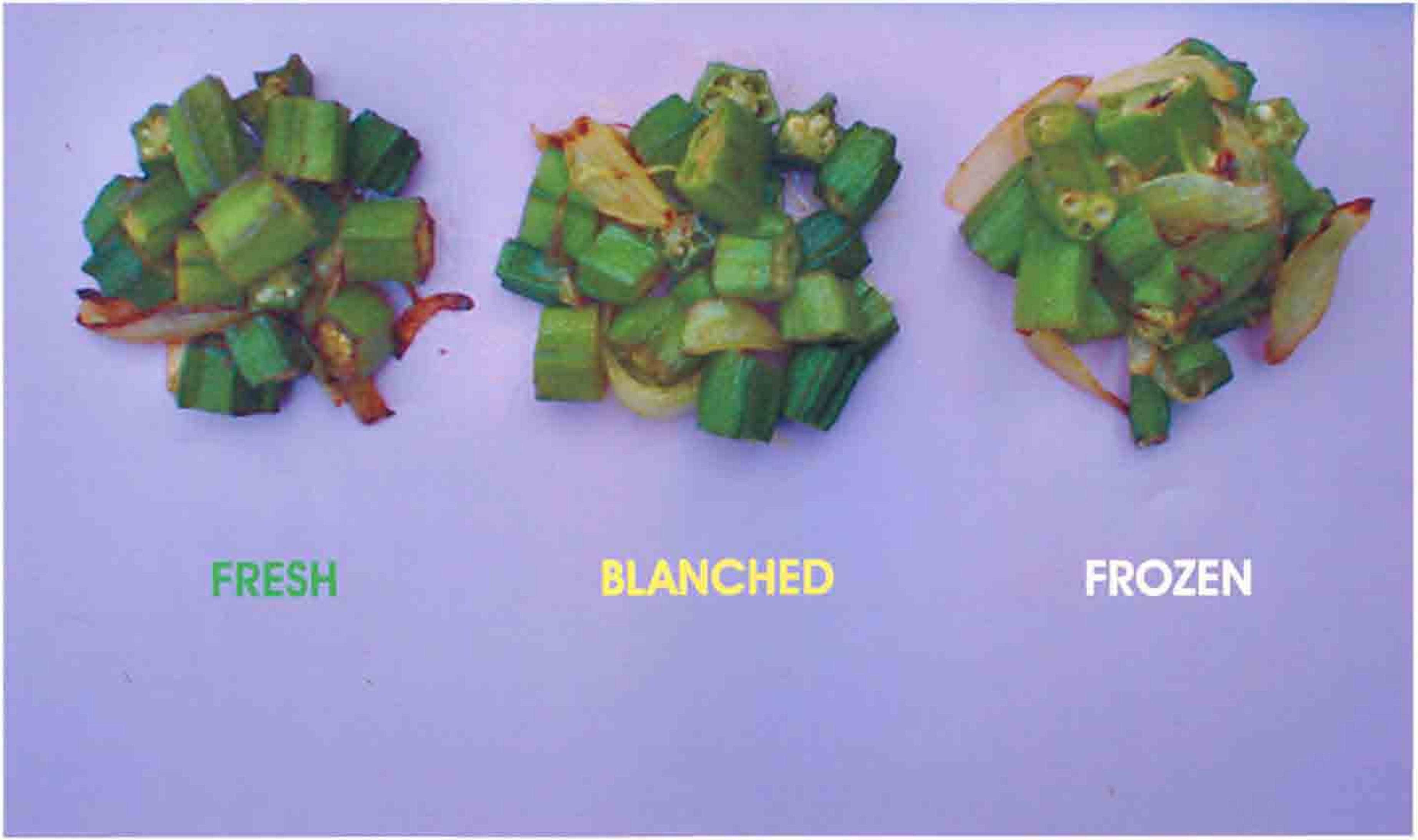

Plate 4.6. Processed and frozen stored okra-onion vegetables.

storage reduced the scores of colour yet the scores were higher than those of the fresh okra rings. Further, this reduction was statistically non-significant. The scores for flavour also decreased from 4.10 ± 0.170 to 4.00 ± 0.100 after two months of frozen storage, then increased to 4.10 ± 0.063 after four months and again decreased to 3.90 ± 0.155 after six months of frozen storage. These changes in flavour were statistically non-significant. The scores for texture of the okra rings also increased from 3.85 ± 0.123 to 3.90 ± 0.155 after two months frozen storage, then decreased to 3.80 ± 0.126 after four months and further to 3.75 ± 0.190 after six months of frozen storage. However, the decrease in scores of texture was statistically non-significant. The scores for taste of the okra rings decreased from 4.00 ± 0.141 to 3.95 ± 0.149 after two months frozen storage, then increased to 4.10 ± 0.063 after four months and again decreased to 3.90 ± 0.095 after six months of frozen storage. These variations were statistically non-significant. The average scores for overall acceptability of okra rings decreased from 4.10 ± 0.118 to 3.90 ± 0.138 after two months of frozen storage, increased to 4.05 ± 0.111 after four months and then decreased to 4.00 ± 0.158 after six months of frozen storage. The scores for overall acceptability varied slightly but the differences were statistically non-significant.

From overall analysis of variance, it was observed that the processing and frozen storage period improved the colour only but had no significant effect on colour, flavour, texture, taste and overall acceptability of okra rings (Figs. 5 to 9). Tressler *et al* (1957) suggested that okra at proper maturity produced an excellent frozen product suitable for use as a cooked vegetable. The results of the present study are in conformity with the reports in the literature. Hence the frozen okra rings can be stored for a period of six months at –20 to –25°C without significant changes.

4.5.9. Comparison of the market fresh and frozen stored okra (rings) vegetables : The data shown in Table 4.41 represents the comparison of market fresh and frozen stored okra rings in the form of okra-onion vegetable. The score for colour of frozen okra after two, four and six months of frozen storage period were 4.65 ± 0.101, 4.55 ± 0.131 and 4.50 ± 0.141, respectively, whereas the scores of market fresh okra rings available in the corresponding months, i.e. September, November and January, were 4.00 ± 0.187, 3.85 ± 0.072 and 3.80 ± 0.145, respectively. The scores for colour of the frozen okra rings were higher than those of the off-season market fresh okra rings available in the respective months. Further, the differences between the two were statistically significant ($P \leq 0.05$) after two and six months, while the corresponding differences were highly significant ($P \leq 0.01$) after four months. It was apparent that blanching and freezing improved the colour of okra.

The scores for flavour of frozen okra rings after two, four and six months of frozen storage were 4.00 ± 0.100, 4.10 ± 0.063 and 3.90 ± 0.155, respectively, while those of market fresh available in the corresponding months were 4.05 ± 0.165, 3.95 ± 0.085 and 4.00 ± 0.141. The mean scores for flavour of market fresh okra rings were higher in comparison to frozen okra rings after two and six months of frozen storage period, the reason may be varietal difference, but the differences were statistically non-significant. The mean scores for texture of okra rings after two, four and six months of frozen storage were 3.90 ± 0.155, 3.80 ± 0.126 and 3.75 ± 0.190, respectively, whereas

Table 4.41 Organoleptic scores of market fresh and frozen stored okra (rings) vegetables (mean ±S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Frozen stored	4.65±0.101	4.00±0.100	3.90±0.155	3.95±0.149	3.90±0.138
Market Fresh I	4.00±0.187	4.05±0.165	4.10±0.118	4.05±0.131	4.20±0.145
Wx	135.5	98	95	100	88.5
P	0.0116*	0.3153 NS	0.2406 NS	0.3697 NS	0.1088 NS
Frozen stored II	4.55±0.131	4.10±0.063	3.80±0.126	4.10±0.063	4.05±0.111
Market fresh II	3.85±0.072	3.95±0.085	4.05±0.179	4.00±0.100	4.00±0.110
Wx	144.5**	118	91.5	113	112.5
P	0.0010	0.1763 NS	0.1575 NS	0.2894 NS	0.3153 NS
Frozen stored III	4.50±0.141	3.90±0.155	3.75±0.190	3.90±0.095	4.00±0.158
Market fresh III	3.80±0.145	4.00±0.141	4.00±0.200	3.90±0.118	4.00±0.101
Wx	139	101	97.5	102	116.5
P	0.0045*	0.3980 NS	0.2894 NS	0.4267 NS	0.2179 NS

Frozen stored I, II and III are frozen stored okra ring after 2, 4 and 6 months of storage period, respectively.

Market fresh I, II and III are fresh okra ring available in the months of September, November and January, respectively

Wx - Wilcoxon Mann Whiteney u-value

P – Probability

NS – Not significant

* - Significant at 5% level

** - Significant at 1% level

those of market fresh okra rings available in the respective months were 4.10 ± 0.118, 4.05 ± 0.179 and 4.00 ± 0.200. The average scores for texture of off-season market fresh okra rings were higher as compared to the frozen ones but the differences were statistically not significant.

The scores for taste of okra rings after two, four and six months of frozen storage were 3.95 ± 0.149, 4.10 ± 0.063 and 3.90 ± 0.095, respectively, while those of market fresh available in the respective months were 4.05 ± 0.131, 4.00 ± 0.100 and 3.90 ± 0.118. The average scores for taste of frozen stored okra rings were lower than market fresh ones after two months, were higher after four months but were same after six months. However, statistically, these variations were non-significant. This may be because of varietal differences. The mean scores for overall acceptability of frozen stored okra rings were 3.90 ± 0.138, 4.05 ± 0.111 and 4.00 ± 0.158 after two, four and six months respectively, whereas those of corresponding off-season market fresh okra rings were 4.20 ± 0.145, 4.00 ± 0.111 and 4.00 ± 0.101. However, the differences were statistically non-significant between the two types of vegetables in September, November and January.

Overall, the mean scores of all the parameters of organoleptic evaluation of frozen okra rings were between 3.75 to 4.65 whereas those of the market fresh samples available in the respective months ranged from 3.80 to 4.20. So, it can be concluded that the market fresh okra as well as frozen stored okra for two, four and six months were equally acceptable. Sistrunk *et al* (1960) reported that okra when compared to other vegetables, has been found to be well adopted to freezing preservation. The results of the present study also confirmed the same.

4.5.10 Organoleptic scores of fresh okra (trimmed) vegetables : The organoleptic scores of okra griddle fry vegetable prepared from fresh and off-season market fresh okra trimmed available during the months of September, November and January are given in Table 4.42. The overall scores for colour, flavour, texture, taste and overall acceptability of fresh okra trimmed were 4.05 ± 0.085, 4.30 ± 0.145, 4.30 ± 0.176, 4.25 ± 0.226 and 4.20 ± 0.176, respectively and those of market fresh okra available in the month of September were 3.90 ± 0.085, 4.00 ± 0.173, 4.05 ± 0.149, 4.10 ± 0.138 and 4.05 ± 0.165, respectively. The corresponding scores for the market fresh okra available in the month of November were 3.80 ± 0.105, 4.05 ± 0.149, 3.95 ± 0.179, 4.00 ± 0.122 and 4.05 ± 0.179 while those of market fresh okra available in the month of of January were 3.65 ± 0.142, 3.95 ± 0.131, 3.90 ± 0.094, 4.10 ± 0.137 and 3.90 ± 0.094, respectively. It was observed from the data that the scores for all the organoleptic parameters of the market fresh okra available during September, November and January, were lower than that of the fresh okra available in the peak season (July). All the scores for organoleptic parameters except taste of the market fresh okra available in the month of January were lowest as compared to experimental fresh okra (July) whereas the scores for taste of market fresh available in the month of November were lowest, but the differences were not statistically significant. This may be because of the fresh okra was locally grown in Punjab while the off-season market fresh samples were transported from Calcutta and the varieties were different..

Table 4.42 Organoleptic scores of fresh okra (trimmed) vegetables (mean ± S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Okra trimmed	4.05±0.085	4.30±0.145	4.30±0.176	4.25±0.226	4.20±0.176
Market fresh					
I	3.95±0.085	4.00±0.173	4.05±0.149	4.10±0.138	4.05±0.165
II	3.80±0.105	4.05±0.149	3.95±0.179	4.00±0.122	4.05±0.179
III	3.65±0.142	3.95±0.131	3.90±0.094	4.10±0.137	3.90±0.094
Fr	6.15^{NS}	1.41^{NS}	2.91^{NS}	1.77^{NS}	1.8^{NS}

Okra trimmed and market fresh I, II and III are fresh capsicum available in the months of July, September, November and January, respectively.

Fr – Friedman two-way analysis of variance by ranks statistics

NS – Not significant

4.5.11 Effect of processing and frozen storage on organoleptic scores of okra (trimmed) vegetables :

The data in Table 4.43 represents the organoleptic evaluation scores of okra fry vegetables from fresh, processed and frozen stored okra trimmed.

Effect of processing : The average scores for colour of fresh okra trimmed were 4.05 ± 0.085 which after blanching increased to 4.25 ± 0.106 and then decreased to 4.20± 0.145 after freezing. From the analysis of variance, it was observed that the processing had non-significant effect on the colour, although the colour of okra trimmed improved and became greener. On the other hand, the scores for flavour of fresh okra trimmed were 4.30 ± 0.145 which decreased to 4.10 ± 0.155 after blanching and further to 4.05 ± 0.111 after freezing. There was a gradual decline in the scores for flavour but this reduction was statistically non-significant. The scores for texture of fresh okra trimmed were 4.30 ± 0.176 which decreased to 3.80 ± 0.189 after blanching and further to 3.60 ± 0.094 after freezing. It was observed that the scores for texture declined gradually, but the differences were statistically non-significant.

The mean scores for taste of fresh okra trimmed were 4.25 ± 0.226 which after blanching decreased to 3.90 ± 0.184 and further to 3.65 ± 0.142 after freezing, but this decrease was again statistically non-significant. The average scores for overall acceptability were 4.20 ± 0.176 which decreased to 3.85 ± 0.159 after blanching and further to 3.70 ± 0.105 after freezing. The scores for overall acceptability decreased after blanching and freezing in comparison to experimental fresh okra trimmed. The main

Table 4.43 Organoleptic scores of processed and frozen stored okra (trimmed) vegetables (mean ± S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Fresh	4.05±0.085	4.30±0.145	4.30±0.176	4.25±0.226	4.20±0.176
Blanched	4.25±0.106	4.10±0.155	3.80±0.189	3.90±0.184	3.85±0.159
Frozen stored					
0	4.20±0.145	4.05±0.111	3.60±0.094	3.65±0.142	3.70±0.105
I	4.10±0.138	3.90±0.170	3.50±0.100	3.50±0.122	3.55±0.111
II	4.15±0.123	3.95±0.111	3.60±0.118	3.60±0.095	3.65±0.142
III	4.05±0.149	4.00±0.122	3.55±0.110	3.50±0.122	3.60±0.118
Fr^1	1.85 ^{NS}	2.15 ^{NS}	9.8 ^{NS}	4.05 ^{NS}	4.85 ^{NS}
Fr^2	0.95 ^{NS}	0.35 ^{NS}	0.35 ^{NS}	0.45 ^{NS}	0.65 ^{NS}
Fr^3	2.21 ^{NS}	5.65 ^{NS}	13.15*	10.3 ^{NS}	11.00 ^{NS}
CD at 5% level			10.80		

Frozen stored 0, I, II and III are frozen stored okra trimmed after 0, 2, 4 and 6 months respectively.
Fr – Friedman two-way analysis of variance by ranks statistics
Fr1 – for fresh, blanched and frozen (0 month) samples
Fr2 – for frozen stored samples
Fr3 – for fresh, blanched, frozen and stored samples
NS – Not significant
- significant at 5% level

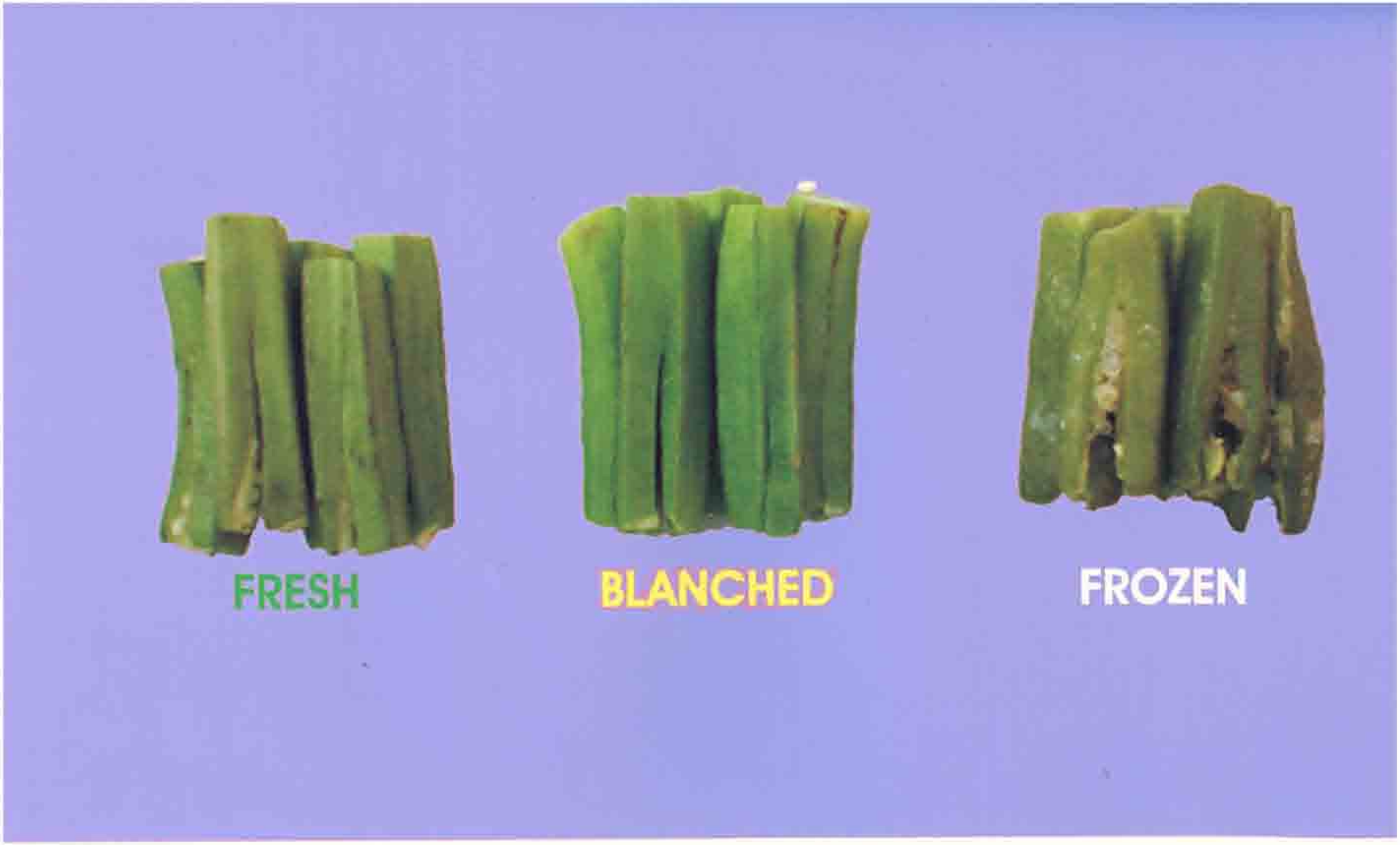

Plate 4.7. Fresh, blanched and frozen stored okra(trimmed)

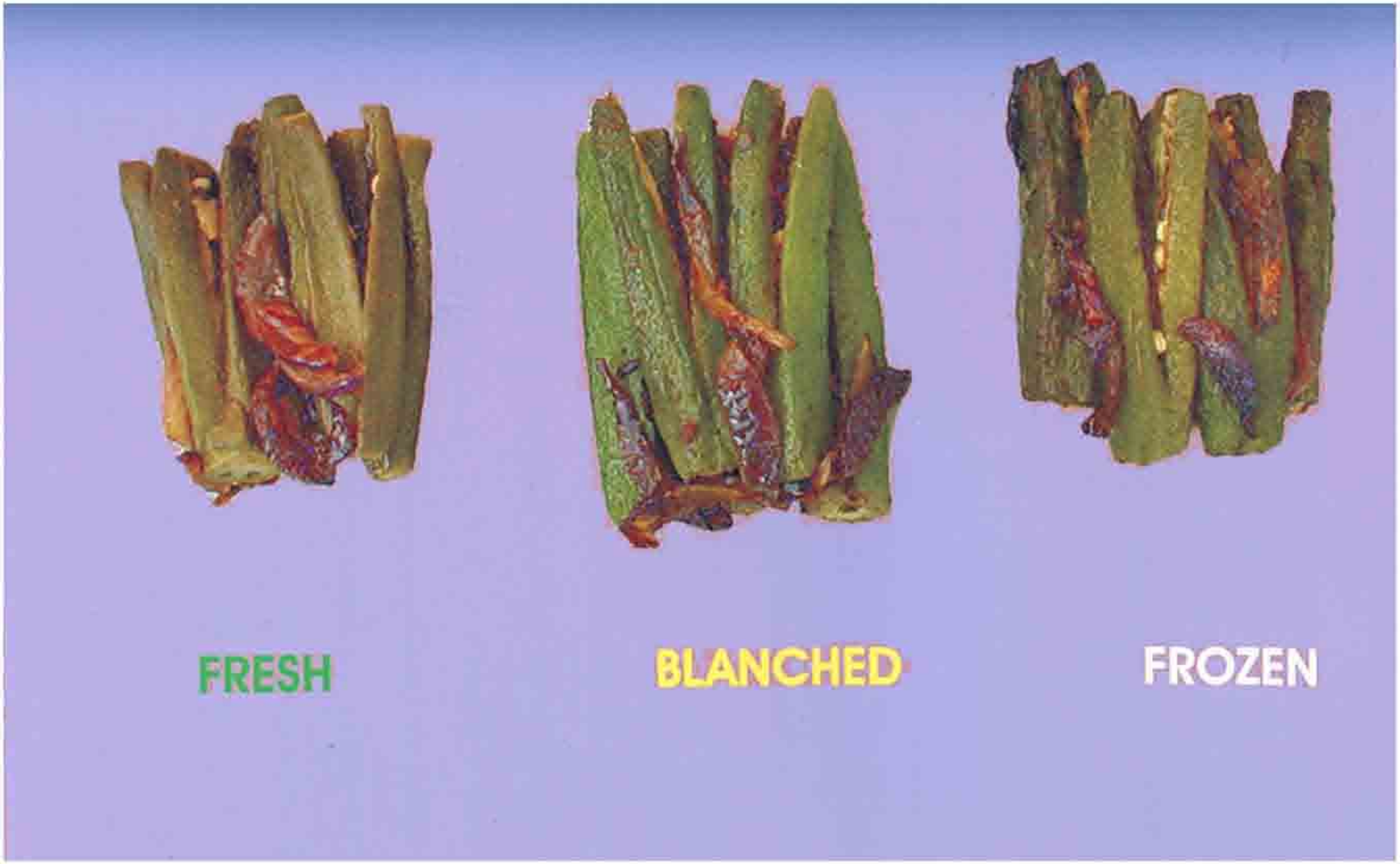

Plate 4.8. Processed and frozen stored okra fry vegetables.

reason was negative effect on flavour, texture and taste of the vegetables (Plates 4.7 and 4.8).

Overall, the scores for all the organoleptic parameters except colour were lower in case of blanched and frozen okra trimmed than those of experimental fresh samples. However, the differences in the scores of the fresh, blanched and frozen okra trimmed were not statistically significant. Hence, it can be concluded that blanching improved the colour and processing had no adverse effect on the organoleptic scores of trimmed okra.

Effect of frozen storage : The mean scores for colour of the immediately frozen okra trimmed, in the form of okra fry vegetable were 4.20 ± 0.145 which after two months of frozen storage decreased to 4.10 ± 0.138, then decreased to 4.15 ± 0.123 after four months and again decreased to 4.05 ± 0.149 after six months of frozen storage. Although the frozen storage reduced the scores of colour yet the scores were equal to fresh okra trimmed. Further, this reduction was statistically non-significant. The scores for flavour also decreased from 4.05 ± 0.111 to 3.90 ± 0.170 after two months of frozen storage, then increased to 3.95 ± 0.111 after four months and further increased to 4.05 ± 0.149 after six months of frozen storage. However, these changes in flavour were statistically non-significant. The scores for texture of okra trimmed also decreased from 3.60 ± 0.094 to 3.50 ± 0.100 after two months frozen storage, then increased to 3.60 ± 0.118 after four months and again decreased to 3.55 ± 0.110 after six months of frozen storage. The decrease in scores of texture was statistically non-significant.

The scores for taste of the trimmed okra decreased from 3.65 ± 0.142 to 3.50 ± 0.122 after two months frozen storage, then increased to 3.60 ± 0.095 after four months and again decreased to 3.50 ± 0.122 after six months of frozen storage. These variations were statistically non-significant. The average scores for overall acceptability of okra trimmed decreased from 3.70 ± 0.105 to 3.55 ± 0.111 after two months, then increased to 3.65 ± 0.142 after four months and again decreased to 3.60 ± 0.118 after six months of frozen storage. The scores for overall acceptability decreased due to the decline in the average scores of colour, flavour, texture and taste, but the decline was statistically non-significant (Figs. 5 to 9).

From overall Friedman two-way analysis of variance, it was observed that the processing and frozen storage period had no significant effect on colour, flavour, taste and overall acceptability but significantly ($P \leq 0.05$) affected the texture after processing and six months of frozen storage period, even then the frozen okra was acceptable to the consumer. Hence the frozen okra can be stored for a period of six months at –20 to –25°C. Prestamo *et al* (1998) studied the blanching and freezing effects on the microscopic structure of carrots. The researchers found that in the blanched samples, the firmness was reduced by only 21.5 per cent as a result of gel formation due to the heating effect on the pectic substances. The firmness of the frozen samples decreased by about 50 per cent as compared to the raw samples.

4.5.12 Comparison of the market fresh and frozen stored okra (trimmed) vegetables

The data in Table 4.44 shows the comparison of market fresh and frozen okra trimmed in the form of okra fry vegetable. The mean scores for colour of frozen okra trimmed after two, four and six months of frozen storage period were 4.10 ± 0.138, 4.15 ± 0.123 and 4.05 ± 0.149, respectively, whereas the scores of market fresh okra available in the

Table 4.44 Organoleptic scores of market fresh and frozen stored okra (trimmed) vegetables (mean ± S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Frozen stored I	4.10±0.138	3.90±0.170	3.50±0.100	3.30±0.122	3.55±0.111
Market fresh I	3.95±0.085	4.00±0.173	4.05±0.149	4.10±0.138	4.05±0.165
Wx	116.5	99.0	74.0	72.5	77
P	0.2179^{NS}	0.3421^{NS}	0.0093*	0.0057*	0.0177*
Frozen stored II	4.15±0.123	3.95±0.111	3.60±0.118	3.60±0.095	3.65±0.142
Market fresh II	3.80±0.105	4.05±0.149	3.95±0.179	4.00±0.122	4.05±0.179
Wx	128.5	100.5	91	79	85
P	0.0446*	0.3697^{NS}	0.1575^{NS}	0.262*	0.0716^{NS}
Frozen stored III	4.05±0.149	4.00±0.122	3.55±0.110	3.50±0.122	3.60±0.118
Market fresh III	3.65±0.142	3.95±0.131	3.90±0.094	4.10±0.137	3.90±0.094
Wx	128	108.5	80.5	73	85
P	0.0446*	0.4267^{NS}	0.0315*	0.0073*	0.0716^{NS}

Frozen stored I, II and III are frozen stored okra trimmed after 2, 4 and 6 months of storage period, respectively.
Market fresh I, II and III are fresh okra trimmed available in the months of September, November and January, respectively
Wx - Wilcoxon Mann Whiteney u-value
P – Probability
NS – Not significant
* - Significant at 5% level

corresponding months, i.e. September, November and January were 3.95 ± 0.085, 3.80 ± 0.105 and 3.65 ± 0.142, respectively. The scores for colour of the frozen okra trimmed were significantly higher than those of the market fresh okra available in the months of November and January. However, the differences were statistically significant only after four and six months of frozen storage and the mean scores were higher because blanching and freezing improved the colour of okra.

The scores for flavour of frozen okra trimmed after two, four and six months of frozen storage 3.90 ± 0.170, 3.95 ± 0.111 and 4.00 ± 0.122, respectively, while those of market fresh available in the corresponding months were 4.00 ± 0.173, 4.05 ± 0.149 and 3.95 ± 0.131. The mean scores for flavour of off-season market fresh okra trimmed were higher in comparison to frozen okra after two, four and six months of frozen storage period, the reason may be varietal difference. However, the differences were statistically non-significant. The mean scores for texture of frozen okra trimmed after two, four and six months of frozen storage were 3.50 ± 0.100, 3.60 ± 0.118 and 3.55 ± 0.110, respectively, whereas those of off-season market fresh okra trimmed available in the respective months were 4.05 ± 0.149, 3.95 ± 0.179 and 3.90 ± 0.094. The average scores for texture of off-season market fresh okra trimmed were significantly ($P \leq 0.05$) higher as compared to the frozen stored okra trimmed after two and six months, but the differences were statistically non-significant after four months of frozen storage period. It was observed that the freezing process adversely affected the texture of okra trimmed.

The mean scores for taste of okra trimmed after two, four and six months of frozen storage were 3.30 ± 0.122, 3.60 ± 0.095 and 3.50 ± 0.122, respectively, while those of market fresh available in the respective months were 4.10 ± 0.138, 4.00 ± 0.122 and 4.10 ± 0.137. The average scores for taste of frozen stored okra trimmed were significantly ($P \leq 0.05$) lower than off-season market fresh ones throughout the six months of frozen storage period. The mean scores for overall acceptability of frozen stored okra trimmed were 3.55 ± 0.11, 3.65 ± 0.142 and 3.60 ± 0.118 after two, four and six months, respectively, whereas those of corresponding off-season market fresh okra trimmed were 4.05 ± 0.165, 4.05 ± 0.179 and 3.90 ± 0.094. These differences were statistically significant ($P \leq 0.05$) after two months but non-significant after four and six months of frozen storage.

Overall, the average scores of all the parameters of organoleptic evaluation of frozen okra trimmed ranged between 3.30 and 4.15 whereas those of the market fresh samples available in the respective months ranged from 3.65 to 4.10. It was observed that the scores for all organoleptic parameters of market fresh okra trimmed except that of the colour were higher as compared to the six month old frozen stored okra trimmed. This was because blanching improved the colour of frozen okra. As the scores for all organoleptic parameters of frozen okra trimmed were between good and very good, so it can be concluded that the frozen okra trimmed after six months of storage period was acceptable.

4.5.13. Organoleptic scores of fresh capsicum (halves) vegetables : The organoleptic scores for fresh experimental capsicum halves and those of available in the month of September, November and January in the form of stuffed capsicum vegetables are given in Table 4.45. The mean scores for colour, flavour, texture, taste and overall

Table 4.45 Organoleptic scores of fresh capsicum (halves) vegetables (mean ± S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Capsicum	3.60±0.138	4.10±0.155	4.05±0.111	4.05±0.072	4.05±0.070
Market fresh					
I	3.45±0.111	4.00±0.100	4.00±0.158	4.05±0.110	4.00±0.138
II	3.60±0.118	4.10±0.118	4.05±0.118	4.00±0.141	4.05±0.095
III	3.60±0.138	4.00±0.122	4.00±0.100	3.90±0.155	4.00±0.100
Fr	0.39^{NS}	0.27^{NS}	0.39^{NS}	1.59^{NS}	0.45^{NS}

Capsicum and market fresh I, II and III are fresh capsicum available in the months of July, September, November and January, respectively.

Fr – Friedman two-way analysis of variance by ranks statistics

NS – Not significant

acceptability of fresh capsicum were 3.60 ± 0.138, 4.10 ± 0.155, 4.05 ± 0.111, 4.05 ± 0.072 and 4.05 ± 0.070, respectively and those of market fresh available in the month of September were 3.45 ± 0.111, 4.00 ± 0.100, 4.00 ± 0.158, 4.05 ± 0.110 and 4.00± 0.138, respectively. It was observed from the data that the scores for all the organoleptic parameters of experimental fresh capsicum except taste were higher than the off-season market fresh available in the month of September, although these differences were statistically non-significant. The scores for colour of capsicum of both the above mentioned samples were same.

The mean scores for colour, flavour, texture, taste and overall acceptability of the off-season market fresh available in the month of November were 3.60 ± 0.118, 4.10 ± 0.118, 4.05 ± 0.118, 4.00± 0.141 and 4.05 ± 0.095, respectively and those of off-season market fresh available in January were 3.60 ± 0.138, 4.00 ± 0.122, 4.00 ± 0.100, 3.90 ± 0.155 and 4.00 ± 0.100, respectively. It was observed that the organoleptic scores for colour, flavour, texture and overall acceptability of off-season market fresh capsicum available in the month of November and January were very close to those of the capsicum available in the month of July, except for taste. The mean scores for taste of off-season market fresh capsicum available in the months of September and November were higher as compared to available in the month of January though the differences were non-significant.

4.5.14. Effect of processing and frozen storage on organoleptic scores of capsicum (halves) vegetables

The data regarding the organoleptic scores of fresh, processed and frozen stored capsicum halves in the form of stuffed capsicum vegetables is shown in Table 4.46.

Effect of processing : The organoleptic scores for colour of fresh capsicum halves in the form of stuffed capsicum vegetable were 3.60 ± 0.138 which after blanching increased to 4.20 ± 0.105 and further to 4.35 ± 0.101 after freezing. The data revealed that the scores for colour of the blanched and frozen samples improved as compared to fresh ones. The main reason could be removal of air from the surface and the intercellular spaces of the vegetables during blanching. From the Friedman two-way analysis of variance, it was concluded that these changes in colour were statistically significant ($P \leq 0.05$). Hence processing improved the colour. The scores for flavour of fresh capsicum halves were 4.10 ± 0.155 which decreased to 3.90 ± 0.155 after blanching and then increased to 4.00 ± 0.100 after freezing. The scores for flavour decreased after blanching and freezing but this decrease was statistically non-significant. The scores for texture of fresh stuffed capsicum halves were 4.05 ± 0.111 which after blanching decreased to 3.70 ± 0.190 and further to 3.50 ± 0.187 after freezing. The data indicated that the texture was affected adversely and the differences were significant ($P \geq 0.05$).

The average scores for taste of the fresh capsicum halves were 4.05 ± 0.072 which after blanching decreased to 3.80 ± 0.105 and remained after freezing at 3.80 ± 0.077, but the decrease was statistically significant ($P \geq 0.05$). The scores for overall acceptability of capsicum halves were 4.05 ± 0.070 which after blanching decreased to

Table 4.46 Organoleptic scores of processed and frozen stored capsicum (halves) vegetables (mean ± S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Fresh	3.60±0.138	4.10±0.155	4.05±0.111	4.05±0.072	4.05±0.070
Blanched	4.20±0.105	3.90±0.155	3.70±0.190	3.80±0.105	3.85±0.123
Frozen stored					
0	4.35±0.101	4.00±0.100	3.50±0.187	3.80±0.077	3.90±0.094
I	4.10±0.155	3.95±0.193	3.45±0.205	3.75±0.127	3.85±0.201
II	4.05±0.179	3.75±0.177	3.40±0.184	3.60±0.184	3.90±0.094
III	4.10±0.155	3.80±0.145	3.35±0.159	3.70±0.105	3.70±0.126
Fr^1	9..05*	1.05^{NS}	43.55*	38.85*	0.65^{NS}
Fr^2	0.05^{NS}	0.45^{NS}	0.30^{NS}	0.95^{NS}	0.60^{NS}
Fr^3	16.5*	1.31^{NS}	10.15^{NS}	2.67^{NS}	2.2^{NS}
CD at 5% level	10.70				

Frozen stored 0, I, II and III are frozen stored capsicum after 0, 2, 4 and 6 months respectively.
Fr – Friedman two-way analysis of variance by ranks statistics
Fr1 – for fresh, blanched and frozen (0 month) samples
Fr2 – for frozen stored samples
Fr3 – for fresh, blanched, frozen and stored samples
NS – Not significant
* · significant at 5% level

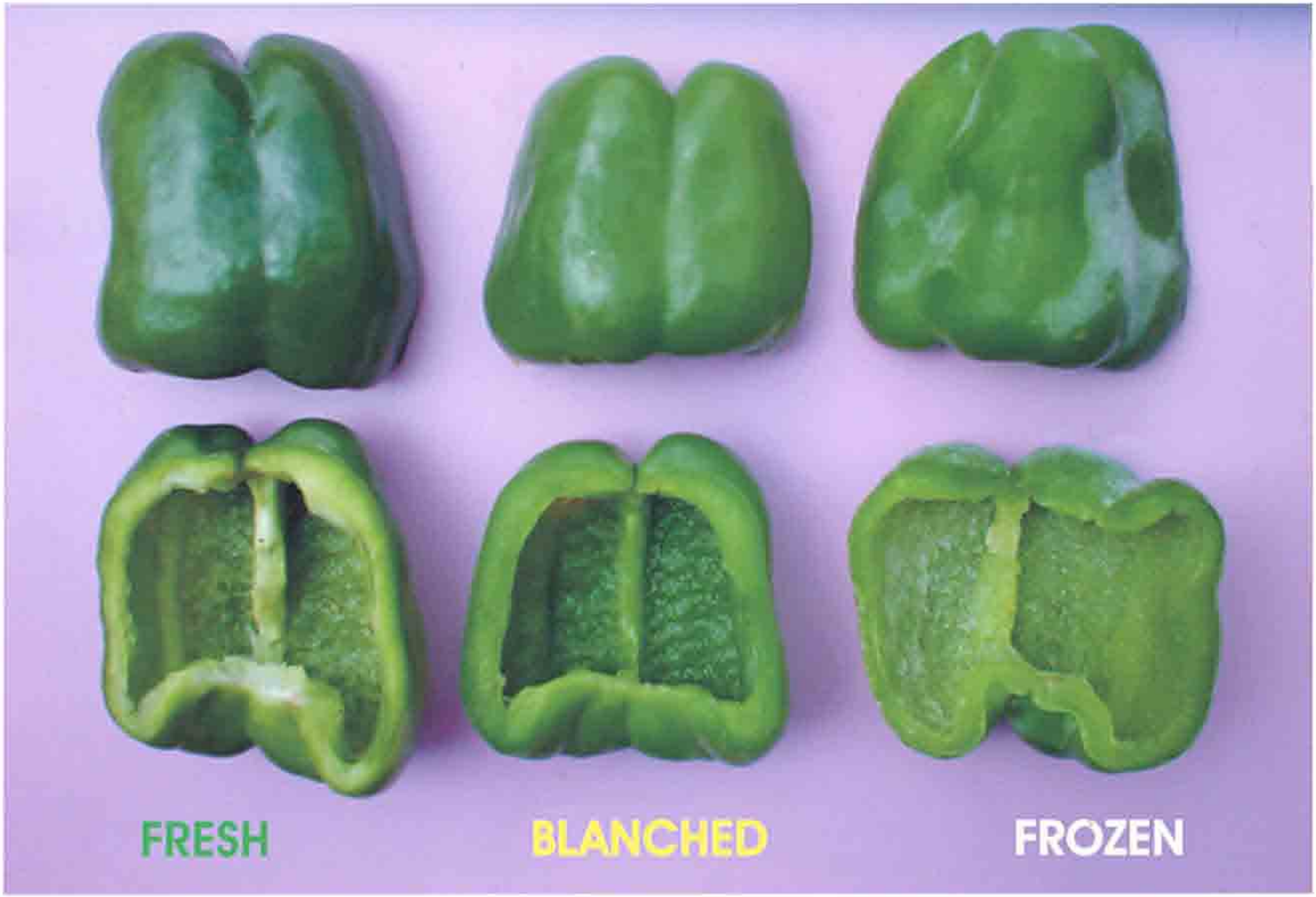

Plate 4.9. Fresh, blanched and frozen stored capsicum(halves)

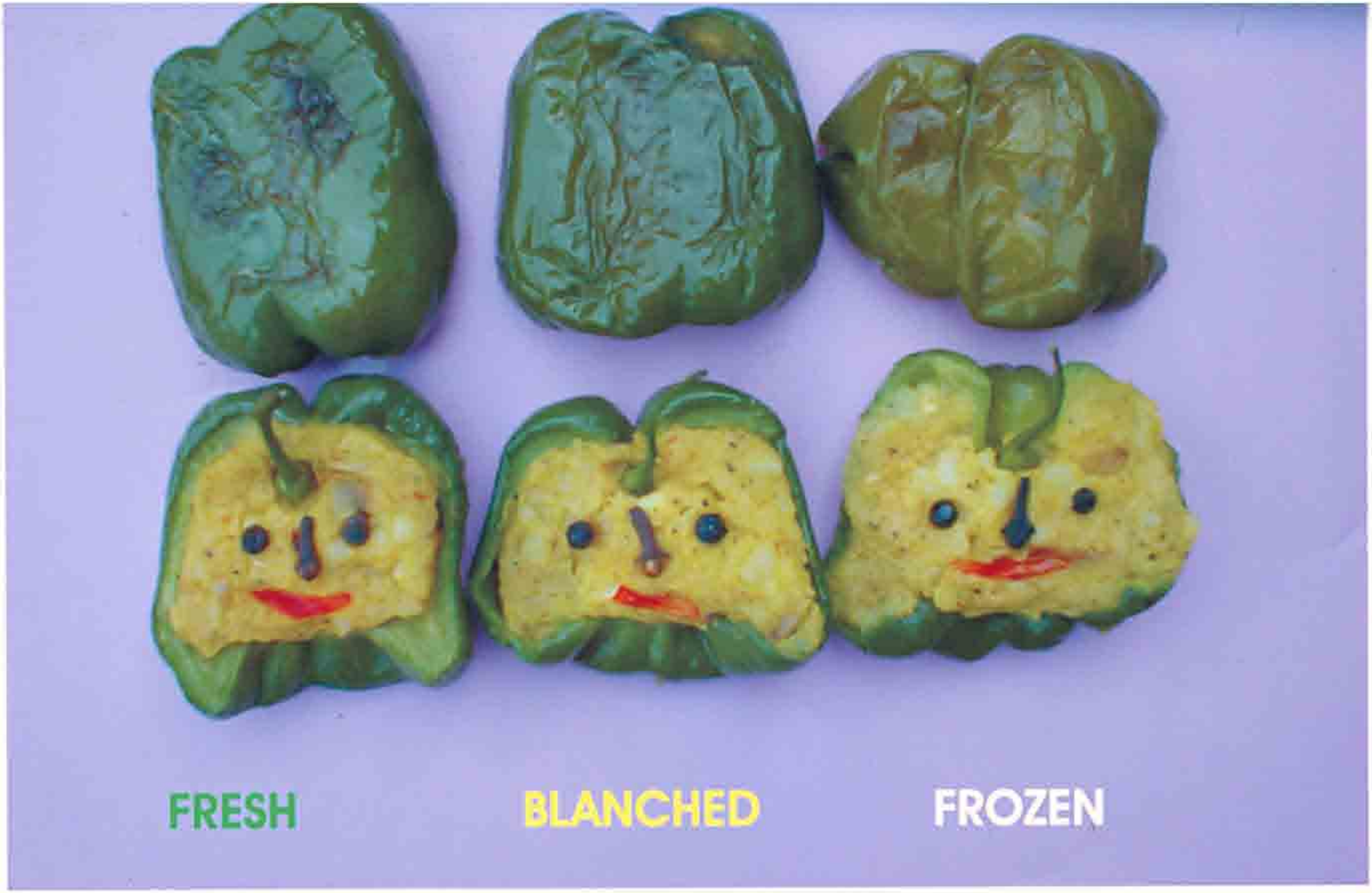

Plate 4.10. Processed and frozen stored stuffed Capsicum vegetables.

3.85 ± 0.123 and then increased slightly to 3.90 ± 0.094 after freezing. The scores for overall acceptability decreased non-significantly after blanching and freezing as compared to the fresh capsicum halves. So processing had adverse effect on the texture and taste of the vegetables but improved the colour and did not effect the flavour and overall acceptability significantly (Plates 9 and 10).

Effect of frozen storage : The average scores for colour of the frozen capsicum halves (0 month), in the form of stuffed capsicum vegetable were 4.35 ± 0.101 which after two months of frozen storage decreased to 4.10 ± 0.155, further to 4.05 ± 0.179 after four months and then increased to 4.10 ± 0.155 after six months of frozen storage. Though the frozen storage reduced the scores for colour yet these were higher than the fresh stuffed capsicum halves. Further, this reduction was statistically non-significant. The scores for flavour also decreased from 4.00 ± 0.100 to 3.95 ± 0.193 after two months, further to 3.75 ± 0.177 after four months and then increased to 3.80 ± 0.145 after six months of frozen storage. These changes in flavour were statistically non-significant. The scores for texture of the capsicum halves again decreased from 3.50 ± 0.187 to 3.45 ± 0.205 after two months, further to 3.40 ± 0.184 and 3.35 ± 0.159 after four and six months of frozen storage, respectively. The gradual decline in scores of texture was statistically non-significant. The scores for taste of the capsicum halves decreased from 3.80 ± 0.077 to 3.75 ± 0.127 after two months, further to 3.60 ± 0.184 after four months and then increased to 3.70 ± 0.105 after six months of frozen storage. These variations were statistically non-significant. The mean scores for overall acceptability of capsicum halves decreased from 3.90 ± 0.094 to 3.85 ± 0.201 after two months, then increased to

3.90 ± 0.094 after four months and again decreased to 3.70 ± 0.126 after six months of frozen storage. There was decline in the scores for overall acceptability but the differences were statistically non-significant (Figs. 5 to 9).

From the overall Friedman two-way analysis of variance, it was observed that the processing and frozen storage period had improved the colour significantly ($P \leq 0.05$) but had no effect on flavour, texture, taste and overall acceptability of stuffed capsicum halves. Hence, it can be concluded that frozen stored capsicum was acceptable to the consumer.

4.5.15. Comparison of the market fresh and frozen stored capsicum (halves) vegetables

The data in Table 4.47 shows the comparison of market fresh and frozen capsicum halves in the form of stuffed capsicum vegetables. The mean scores for colour of frozen capsicum after two, four and six months of frozen storage period were 4.10 ± 0.155, 4.05 ± 0.179 and 4.10 ± 0.155, respectively, whereas the scores of off-season market fresh capsicum available in the corresponding months, i.e. September, November and January were 3.45 ± 0.111, 3.60 ± 0.118 and 3.60 ± 0.138. The scores for colour of the frozen capsicum halves were significantly ($P \leq 0.05$) higher than those of the off-season market fresh capsicum halves available in the respective months. The results revealed that blanching and freezing improved the colour of capsicum halves.

The scores for flavour of frozen capsicum halves after two, four and six months frozen storage were 3.95 ± 0.193, 3.75 ± 0.177 and 3.80 ± 0.145, respectively, while those of market fresh available in the corresponding months were 4.00 ± 0.100,

Table 4.47 Organoleptic scores of market fresh and frozen stored capsicum (halves) vegeetables (mean ± S.E.)

Product	Colour	Flavour	Texture	Taste	Overall acceptability
Frozen stored I	4.10±0.155	3.95±0.193	3.45±0.205	3.75±0.127	3.85±0.201
Market fresh I	3.45±0.111	4.00±0.100	4.00±0.158	4.05±0.110	4.00±0.138
Wx	138.5	104.0	83.5	85.5	101.0
P	0.0057*	0.4853 NS	0.0526 NS	0.0716 NS	0.3980 NS
Frozen stored II	4.05±0.179	3.75±0.177	3.40±0.184	3.60±0.184	3.90±0.094
Market fresh II	3.60±0.118	4.10±0.118	4.05±0.118	4.00±0.141	4.05±0.095
Wx	128.0	91	73	81.5	89
P	0.0446*	0.1575 NS	0.0073*	0.0376*	0.1237 NS
Frozen stored III	4.10±0.155	3.80±0.145	3.35±0.159	3.70±0.105	3.70±0.126
Market fresh III	3.60±0.138	4.00±0.122	4.00±0.100	3.90±0.155	4.00±0.100
Wx	131.0	93	72	93	87
P	0.0262*	0.1965 NS	0.0057*	0.1965 NS	0.0952 NS

Frozen stored I, II and III are frozen stored capsicum after 2, 4 and 6 months of storage period, respectively.
Market fresh I, II and III are fresh capsicum available in the months of September, November and January, respectively
Wx - Wilcoxon Mann Whiteney u-value
P – Probability
NS – Not significant
* - Significant at 5% level

4.10 ± 0.118 and 4.00 ± 0.122. The mean scores for flavour of off-season market fresh capsicum halves were higher in comparison to those of frozen capsicum halves for two to six months. The reason may be varietal difference but the differences were statistically non-significant. The mean scores for texture of frozen capsicum halves after two, four and six months of frozen storage were 3.45 ± 0.205, 3.40 ± 0.184 and 3.35 ± 0.159, respectively, whereas those of off-season market fresh capsicum halves available in the respective months were 4.00 ± 0.158, 4.05 ± 0.118 and 4.00 ± 0.100. The average scores for texture of off-season market fresh capsicum halves were significantly ($P \leq 0.05$) higher as compared to the frozen stored capsicum halves after four and six months. However, the differences were statistically non-significant after two months of frozen storage period. This was due to the adverse effect of freezing process on the capsicum as after freezing the texture becomes soft.

The mean scores for taste of capsicum (halves) after two, four and six months of frozen storage were 3.75 ± 0.127, 3.60 ± 0.184 and 3.70 ± 0.105, respectively, while those of off-season market fresh available in the respective months were 4.05 ± 0.110, 4.00 ± 0.141 and 3.90 ± 0.155. The mean scores for taste of off-season market fresh capsicum halves were higher in comparison to the frozen stored capsicum halves throughout the six months of frozen storage period. The results revealed the adverse effects of freezing on texture of capsicum. However, the differences were statistically non-significant after two and six months and significant ($P \leq 0.05$) only after four months of frozen storage period. The mean scores for overall acceptability of frozen stored capsicum halves were 3.85 ± 0.201, 3.90 ± 0.094 and 3.70 ± 0.126 after two, four and six months, respectively, whereas those of the off-season market fresh capsicum halves were 4.00 ± 0.138, 4.05 ± 0.095 and 4.00 ± 0.100 in the respective months. These differences were statistically non-significant though the scores of off-season market fresh capsicum halves were higher in comparison to the frozen stored capsicum halves. The main reason could be adverse effect of processing and freezing on flavour, texture and taste of capsicum.

Overall, the average scores of all the parameters of organoleptic evaluation of capsicum halves were between 3.35 and 4.10 whereas those of the off-season market fresh samples available in the respective months ranged from 3.45 to 4.10. It was observed that the scores for all the parameters of organaoleptic evaluation of off-season market fresh capsicum halves except that of the colour, were higher in comparison to frozen stored capsicum halves. This was because blanching improved the colour while freezing had adverse effect on flavour, texture and taste. As the scores for all organoleptic parameters of frozen capsicum halves were between good and very good, it can be concluded that the capsicum halves could be frozen stored for six months.

4.6. Economics of frozen vegetables

Taking into consideration all the costs namely raw material, transportation and grading, labour for cutting the vegetables, blanching and freezing, the factory price of the frozen okra was about Rs.18.50 per kg, which was supplied to the whole sale market at the rate ofRs.23.00 per kg (Table 4.48). The consumer got the frozen okra in the market at the retail price of Rs.29.00 per kg. On the other hand, the off-season price of fresh okra fluctuated around Rs.50.00 per kg. Thus, there is a net loss of Rs.21.00 per kg to the

Table 4.48 Economics of frozen vegetables

Parameters	Cost/kg (Rs)		
	French bean	**Okra Variety Shagun**	**Capsicum**
Frozen vegetables			
Cost of fresh vegetables	14.00	5.00	14.00
Labour and freezing cost	5	3	6
Frozen storage cost at –20 to –25°C for six months	10.00	10.00	10.00
Packing	0.50	0.50	0.50
Factory cost	29.50	18.50	29.50
Whole sale price	36.00	23.00	36.00
Retail price	45.00	29.00	45.00
Fresh Vegetables			
Off-season market price	60.00	50.00	60.00
Difference between the cost of fresh and frozen vegetables	15.00	21.00	15.00
Benefit in purchasing frozen vegetable (%)	25.00	42.00	25.00

consumer if he purchased the off-season fresh okra from the market. The consumers have to pay 42 per cent higher price for the off-season fresh okra. In addition, the consumer will have to wash and cut them. The factory price of the frozen capsicum and French beans was Rs.29.50 per kg each, which were supplied to the wholesale market at the rate of Rs.36.00 per kg each. The consumer got the frozen capsicum and French beans in the market at the retail price of Rs.45.00 per kg each. On the other hand, the off-season price of fresh capsicum and French beans was Rs.60.00 per kg each. Taking into consideration, the preparatory losses of okra, capsicum and French bean, the price of okra came out to be Rs.60.00 per kg. In case of capsicum, it was Rs.72.00 per kg and Rs. 66.00 per kg in case of beans. The removal of stem and ends result in losses of 20 per cent in okra, 10 per cent in French beans and 20 per cent in case of capsicum. The consumer had to pay much more for the off-season vegetables. It was seen that major portion of the benefit went to the trader and not to the producer. In order to make vegetable growing more profitable to the farmer, the government as well as private sector can be involved in frozen storage of the vegetables so that the major share of benefit goes to the producer and some relief to the consumer. Above all, to make vegetable growing remunerative to the farmer and promoting crop diversification, value addition to such perishable produce by minimal processing at the village level such as removal of inedible parts, sorting, slicing, shelling, peeling, packing etc. would make the transportation easy and minimise the losses. It will also generate employment for women in rural areas, minimise migration from village to towns, alongwith increasing exports. Further, secondary processing such as refrigeration, freezing etc. would give an added advantage.

Hence, the frozen vegetables are not only economical but also nutritious. Moreover frozen vegetables required less time in cooking. In each package, 100 per cent edible portion of food was available i.e. no syrup brine, gravy, peeling or preparatory losses etc. Further, the frozen vegetables were more hygienic, convenient to handle when packed and sealed.

Hence, freezing provides a great variety of seasonal vegetables all the year round in a good condition and at no additional cost. But in India, still the frozen foods are not so popular. This is mainly because of lack of conceptual understanding. There is a general feeling amongst the consumers that preserved or frozen food products are inferior as compared to fresh vegetables. As a matter of fact, this is a wrong notion. Provided the processing is done properly, frozen foods are in no way inferior to off-season fresh foods in most cases. The consumption of electricity in the frozen food industry is far higher than that in any other form of food preservation like canning, bottling etc. The shortage of power supply all over the country has restricted the growth of this sector. The Indian Highway System and internal link roads are amongst the poor in the world, thereby not only restricting the transportation of the frozen vegetables but also increasing the vehicle maintenance and fuel costs as well. There is also shortage of technically trained manpower in this field. The poor quality of raw material is another serious problem for the food industry which adversely affects quality of processed food thus making good quality final product more expensive. Contract farming with growers needs to be promoted on a large scale with the help of private sector as well as centre/state government. On removal of the above constraints, the frozen food industry can make good progress in due course and it can be remunerative to the farmers. Export of frozen vegetables can also generate revenue for the government but from quality point of view, there is tough competition under the regime of World Trade Organisation.

Discussion

The results of the present study revealed that the total solids of okra were maximum followed by French beans and minimum in capsicum. The processing and frozen storage had highly significant ($P \leq 0.01$) effect on the French beans (1.0 cm), okra rings and okra trimmed. The larger surface area of French beans (1.0 cm) and okra rings coupled with porous structure resulted in higher water absorption during blanching. Further, blanching also caused leaching of soluble solids resulting in loss of total solids. So, French beans (6.0 cm) had significantly ($P \leq 0.05$) higher amount of total solids than French beans (1.0 cm) while okra trimmed had significantly ($P \leq 0.05$) more than that of okra rings throughout the processing and frozen storage period. The capsicum was cut into halves only and the minimum losses took place after processing while maximum losses were in French beans (1.0 cm) and okra rings. This was due to the larger size of cuts and exposure of smaller surface area during water blanching. Brown (1977) reported that in green beans large intercellular cavities that were rich in air, could be found in parenchyma. During blanching, the air is replaced by liquid. Bomben *et al* (1975) reported that the moisture content of Brussels sprouts increased after blanching because the voids between leaves entrap candensate. Lisiewska and Kmiecik (2000) reported that blanching reduced the dry matter by 18-20 per cent in broccoli and 9-10 per cent in cauliflower. The results obtained in the present study follow the above mentioned pattern.

The pH of okra was highest and that of capsicum was lowest. The pH of both the cuts of French beans and okra were statistically not different from each other and no effect of processing and frozen storage was observed on pH of the vegetables. Similarly, there was no significant change in titrable acidity during processing and frozen storage period of six months. The standardized blanching conditions ensured no change in texture of the vegetables. However, residual peroxidase activity remained in the vegetables after blanching and during frozen storage. The observations revealed that there was no adverse effect of residual peroxidase activity on the quality of the frozen vegetables.

The microbial count was maximum in okra rings followed by French beans and minimum in capsicum. The main reason was hairy and sticky surface of okra rings which embedded maximum number of microbes, followed by somewhat smooth but ridged surface of beans and minimum in case of very smooth and easily washable surface of capsicum. The French beans (1.0 cm) had significantly ($P \leq 0.05$) lower microbial count than French beans (6.0 cm) and okra trimmed had significantly ($P \leq 0.05$) lower than those of okra rings after processing and frozen storage. Further, the total reduction in microbial count ranged from 99.1 to 99.6 per cent in all the cuts of the vegetables but 88.7 to 93.5 per cent reduction was during blanching, which was significant ($P \leq 0.01$). So blanching and freezing ensure availability of safe vegetables with respect to microbial load which is very-very high in fresh vegetables. Similar reports in the literature endorse the results of the present study. Baardseth and Slinde (1983) reported that the unblanched sample of carrot had a total count of 3.50 x 10^3 cfu/g but was reduced in the heat-treated samples to 50 per cent of the original value. Dhaliwal (2002) reported 98.9 to 99.9 per cent reduction after blanching and frozen storage of six months in case of peas, cauliflower and carrots.

Regarding the nutritional characteristics, it was observed that the protein content was maximum in case of okra followed by French beans and minimum in case of capsicum on fresh weight basis. On the other hand, on dry weight basis, the protein content was maximum in okra followed by French beans and again minimum in capsicum. The processing and frozen storage period of six months had no effect on the protein content of all the vegetables on fresh weight basis. However, on dry weight basis, after blanching, there appeared to be some gain in protein content of okra rings and trimmed. This can be attributed to absorption of water during blanching and loss of some soluble components. As a matter of fact, the protein content was slightly reduced on fresh weight basis. The differences between two types of cuts of French beans and okra were non-significant. Adams (1981) also reported three per cent loss when green beans were blanched in water for three minutes. These losses may be due to denaturation and solubilization of proteins. Dhaliwal (2002) also reported no significant effect of processing and frozen storage period of six months on the protein content of peas.

The fat and fibre contents of French beans were maximum followed by okra and minimum in capsicum on fresh weight basis. Similar results were obtained on dry weight basis in case of fat content whereas the crude fibre was maximum in French beans followed by capsicum and minimum in okra. The mineral content in the form of ash content was maximum in case of okra followed by capsicum and minimum in French beans on fresh weight basis whereas on dry weight basis, it was maximum in capsicum followed by okra and French beans.

The differences between the two types of cuts of French beans and okra were non-significant in case of fat, crude fibre and ash content on fresh as well as dry weight basis. Further, the processing and frozen storage had no effect on these nutrients on fresh weight basis but on dry weight basis there was increase in these nutrients in case of French beans (1.0 cm), okra rings and okra trimmed. It was again due to the absorption of water during blanching and loss of some soluble components. It can be safely interpreted from the results that the processing and frozen storage did not reduce significantly the crude fat, fibre and total mineral content of the vegetables. This aspect is very important as vegetables are considered rich source of minerals.

The available carbohydrates were maximum in case of okra followed by French beans and minimum in case of capsicum on fresh weight basis, whereas on dry weight basis, carbohydrates were maximum in okra followed by capsicum and minimum in French beans. The processing and frozen storage period of six months had significant ($P \leq 0.01$) decrease in the carbohydrate content of French beans (1.0 cm), okra rings and okra trimmed on fresh weight basis. The increase or decrease in the proximate principles inversely affected the carbohydrate content. The results revealed that the total solids decreased due to increase in moisture content or leaching losses during blanching and freezing. So the corresponding change in the available carbohydrates was observed after blanching, freezing and frozen storage period of six months.

The total sugars and pectin content were maximum in okra followed by French beans and minimum in capsicum on fresh weight basis and pectin on fresh as well as dry weight basis. The concentration of the nutrients in both types of cuts of French beans and okra were almost same throughout processing and frozen storage period. Further, the processing and frozen storage had no significant effect on the sugar and pectin content on fresh weight basis, but on dry weight basis, there was a significant ($P \leq 0.05$) increase in sugar content of French beans (1.0 cm) and highly significant ($P \leq 0.01$) increase in okra rings and okra trimmed along with increase in pectin content. This can again be attributed to absorption of water during blanching and loss of soluble components. According to Adams (1981), the total sugars of green beans were reduced by three per cent during water blanching in three minutes. Dhaliwal (2002), however, reported that processing and frozen storage period of six months resulted in non-significant reduction in total sugars and pectin content in peas, cauliflower and carrots.

The neutral detergent fibre (NDF) content was nearly same in French beans as well as okra and minimum in case of capsicum on fresh weight basis. On the other hand, NDF content was maximum in French beans followed by okra and minimum in capsicum on dry weight basis. On the other hand, the acid detergent fibre (ADF) content was maximum in okra followed by French beans but minimum in capsicum on fresh weight basis. On dry weight basis, the ADF content was maximum in French beans followed by okra but again minimum in capsicum. The processing and frozen storage had significant

($P \leq 0.05$) decrease in the NDF content of French beans (1.0 cm) on fresh weight basis and on NDF and ADF contents in case of okra rings on fresh weight basis but significant ($P \leq 0.05$) increase on dry weight basis. The differences between two types of cuts of French beans and okra were non-significant with respect to NDF and ADF on fresh and dry weight basis. Herranz *et al* (1983) reported that boiling resulted in an increase in NDF, ADF and cellulose contents in case of green beans and peas on dry weight basis but a decrease on fresh weight basis. Similar observations have been recorded in the present investigation that during blanching and frozen storage dietary fibre could absorb water for stabilization or the soluble component could leach out. From the findings, it can be concluded that frozen vegetables, like fresh vegetables, are important source of dietary fibre.

The capsicum halves had maximum β-carotene and ascorbic acid (AA) followed by French beans and minimum in case of okra on fresh and dry weight basis. The French beans (6.0 cm) and okra trimmed retained more of these vitamins than French beans (1.0 cm) and okra rings, respectively after blanching, freezing and six months of frozen storage. The differences in the β-carotene content between two types of cuts of French beans and okra were non-significant on fresh weight basis. But, on dry weight basis, β-carotene content was significantly ($P \leq 0.05$) different in two types of cuts of French beans after blanching and four months frozen storage whereas in two types of cuts in case of okra, the differences were significant ($P \leq 0.05$) after blanching only. On the other hand, the differences in the AA content of two types of cuts of French beans were significantly ($P \leq 0.05$) reduced after blanching and freezing on fresh and dry weight basis. The processing and frozen storage had highly significant ($P \leq 0.01$) effect on the β-carotene content of French beans (1.0 cm), okra rings, okra trimmed and capsicum but had a significant ($P \leq 0.05$) effect on the β-carotene content of French beans (6.0 cm) on fresh weight basis. On the other hand, on dry weight basis, the processing and frozen storage had no effect on β-carotene of okra trimmed, significant ($P \leq 0.05$) effect on okra rings and French beans (1.0 cm) and highly significant ($P \leq 0.01$) on French beans (6.0 cm) and capsicum. The processing and frozen storage had highly significant ($P \leq 0.01$) effect on the AA content of the four cuts of the vegetables but significant ($P \leq 0.05$) effect on French beans (6.0 cm) only on fresh weight basis. But on dry weight basis, the corresponding effect was non-significant in case of French beans (1.0 cm) and okra rings but highly significant ($P \leq 0.01$) in case of French beans (6.0 cm), okra rings and capsicum. The total change in β-carotene ranged from -27.0 to -30.5 and +3.7 to -30.5; and in AA -19.6 to -32.2 and +13.6 to –32.3 per cent on fresh and dry weight basis, respectively in all the cuts of the vegetables but -18.6 to -30.0 and +18.7 to –19.1 per cent; and -14.3 to -26.2 and +19.2 to –24.1 per cent change respectively, was during blanching only. Inspite of significant reduction during processing in the vitamin contents, the vegetables retained 35.2 to 302.4 μg/100g of β-carotene and 11.8 to 98.3 mg/100g AA and can contribute significant amount of these nutrients to the daily diet. The main reason for the losses of nutrients was blanching process, which can be considered as a part of cooking, since nearly all vegetables are cooked before consumption and frozen vegetables are already partly cooked and took much less time in cooking. In case of β-carotene, reduction may be due to oxidation caused by heat and in

AA due to leaching as it is water soluble and oxidation by heat on fresh weight basis. However, on dry weight basis, after blanching, there appeared to be some gain in β-carotene and AA contents of okra rings and trimmed. This can be attributed to absorption of water during blanching and loss of some soluble solids. As a matter of fact, the β-carotene and AA contents were reduced significantly on fresh weight basis. Statistically, significant reductions were also detected by Lisiewska and Kmiecik (2000) in the concentration of carotenoids, β-carotene and lycopenes. Kaur and Kapoor (2001) reported 66 per cent loss in AA after five minutes of blanching in boiling water in French beans. Further, Dhaliwal (2002) also reported 30.0 to 42.6 per cent reductions in β-carotene of carrots and 25.5 to 28.5 per cent in AA content of peas, cauliflower and carrots on fresh as well as dry weight basis.

On the whole, the results revealed that processing and frozen storage changes in pH, acidity, protein, fat, fibre, ash, total sugars and pectin of all the vegetables were non-significant. The reduction was highly significant ($P \leq 0.01$) after blanching and frozen storage in the microbial count of all the five types of the vegetables; β-carotene and AA in French beans (1.0 cm), okra rings, okra trimmed and capsicum but in French beans (6.0 cm), the decrease was only significant ($P \leq 0.05$). However, the decrease in total solids and available carbohydrates in French beans (1.0 cm), okra rings and okra trimmed was highly significant ($P \leq 0.01$) whereas NDF in French beans (1.0 cm) and okra rings but ADF in okra rings decreased significantly ($P \leq 0.05$) after processing and frozen storage.

On the basis of organoaleptic evaluation, it was observed that the scores for colour, flavour, texture, taste and overall acceptability for all the frozen stored vegetables and off-season market fresh vegetables ranged from 3.90 to 4.70 and 3.45 to 4.10; 3.75 to 4.30 and 3.75 to 4.10; 3.35 to 4.40 and 3.80 to 4.10; 3.30 to 4.40 and 3.85 to 4.10; and 3.55 to 4.40 and 3.70 to 4.20, respectively. The overall organoleptic evaluation scores for colour of frozen stored French beans (1.0 cm), okra rings and capsicum were significantly ($P \leq 0.05$) higher than the respective off-season market fresh vegetables. Further, the scores for texture of frozen stored French beans (1.0 cm) were significantly ($P \leq 0.05$) higher, on the other hand scores for texture of frozen stored capsicum and okra trimmed were significantly ($P \leq 0.05$) lower than those of the respective off-season market fresh vegetables. However, the scores for all the other parameters were non-significantly different.

It could be inferred from the results that the frozen French beans (1.0 cm) had highest score for overall acceptability followed by okra rings, French beans (6.0 cm), capsicum halves and lowest of okra trimmed, yet the scores of overall acceptability of frozen vegetables varied between 3.30 to 4.70 i.e. good and very good, indicating that the frozen vegetables were acceptable in the cooked form in traditional Punjabi recipes.

From economic point of view also, the frozen storage of vegetables is beneficial both to producers and consumers because after taking into consideration, all the processing and frozen storage expenses, the retail market prices of the frozen vegetables were 25 to 42 per cent lower than the off-season market fresh vegetables. The producers are likely to earn more because crash in prices during glut season will be prevented if bulk of the fresh vegetables is diverted for value addition through processing and frozen storage. Further, the frozen storage of vegetables can lead to crop diversification if the farmers get remunerative prices for his produce. On the other hand, the consumer will get hygienic and 100 per cent edible portion of vegetables at comparatively lower price as compared to market fresh off-season vegetables. The third category of beneficiaries can be rural women if involved in minimal processing before the blanching process and this category will be of rural poor if the primary processing and frozen storage plants are located in the villages.

So, on the whole, the frozen stored French beans, okra and capsicum, in addition to their improved quality, economics, nutritive value and consumer acceptability can be remunerative to farmers and helpful in crop diversification. Hence, frozen storage of vegetables is an ideal proposition in the current times from all angles and all the three vegetables are suitable for this type of value addition.

CHAPTER-V

SUMMARY

CHAPTER – V

SUMMARY

The present investigation was undertaken to study the effect of processing and frozen storage on the nutrient content of vegetables, especially the labile nutrients, to determine the optimum shelf life and to evaluate the organoleptic acceptability of frozen vegetables in commonly used traditional recipes.

For this purpose, three popular summer vegetables i.e. okra (variety Shagun), French beans and capsicum of local varieties were selected.

The vegetables were washed thoroughly, their stems and ends were cut off. Medium and large okra pods were cut into rings whereas small okra pods were slitted in the centre. French beans were sliced into 1.0 and 6.0 cm pieces. Capsicum was cut into halves and the stems and seeds were removed. The okra rings and French beans (1.0 cm) were blanched at 95°C for two minutes and capsicum was blanched at 85°C for two minutes. The French beans (6.0 cm) and okra trimmed were blanched at 95°C for three minutes.

The vegetables were frozen by IQF technique where the frozen vegetables were subjected to an upward cold air stream (approximately –40°C) of high velocity. The

freezing process was completed in five minutes. The process of blanching and freezing was done at PAGRO Foods Ltd., Fatehgarh Sahib, Punjab.

The frozen vegetables were packed in polythene bags (HDPE, 200 gauge) followed by polythene-coated cartons and kept in cold storage room at –20 to –25°C.

The samples were taken as fresh, immediately after blanching and freezing as well as after two, four and six months of frozen storage. The evaluation of processed and frozen vegetables was carried out for quality, nutritional and organoleptic characteristics.

Under the quality characteristics, total solids, pH, titrable acidity, peroxidase enzyme test and total microbial count were determined. Further, proximate composition, total sugars, pectin, fibre fractions, β-carotene and ascorbic acid were estimated.

Under organoleptic evaluation, five different recipes were prepared from the fresh, blanched, frozen and frozen stored vegetables after two, four and six months of period. The recipes prepared were: French beans-potato, French beans-potato fry, okra-onion, okra fry and stuffed capsicum vegetables.

The organoleptic evaluation was done using ranking method of Larmond (1982). It was a five point scale where the recipe which was liked the most was given the score of five and that which was liked the least was given the score of one. Five acceptability characteristics-colour, flavour, taste, texture and overall acceptability were evaluated. A trained panel of ten judges was selected for the evaluation of recipes which was carried out thrice and average scores were calculated. The results of the study were statistically analysed by the Friedman two-way analysis of variance by ranks, the Wilcoxan Mann Whitney test, one way analysis of variance and unpaired 't' test.

The total solids of fresh, processed and frozen stored French beans (1.0 cm), French beans (6.0 cm), okra rings, okra trimmed and capsicum halves ranged from 7.66 to 9.48, 9.12 to 9.22, 7.84 to 11.55, 8.96 to 11.26 and 7.3 to 7.4 per cent, respectively. The differences were statistically significant ($P \leq 0.01$) only in case of French beans (1.0 cm), okra rings and okra trimmed. The total solids of both types of cuts of French beans and okra were significantly ($P \leq 0.05$) different from each other after processing and frozen storage period of six months.

The pH of fresh, processed and frozen stored French beans (1.0 cm), French beans (6.0 cm), okra rings, okra trimmed and capsicum halves varied from 6.08 to 6.21, 6.18 to 6.31, 6.69 to 6.87, 6.45 to 6.65 and 5.37 to 5.50. The titrable acidity of fresh French beans, okra and capsicum ranged from 0.0096 to 0.102, 0.0064 to 0.0076 and 0.0179 to 0.0192 per cent. Statistically, the processing and frozen storage period had no effect on pH and acidity of the vegetables and differences between the two types of cuts were also statistically non-significant.

The total microbial count of fresh, processed and frozen stored French beans (1.0 cm), French beans (6.0 cm), okra rings, okra trimmed and capsicum halves ranged from 1.99×10^2 to 5.30×10^4, 4.10×10^2 to 4.90×10^4, 2.87×10^2 to 5.50×10^4, 2.50×10^2 to 5.00×10^4 and 3.10×10^2 to 4.20×10^4 cfu/ml. The total reduction in microbial count during processing and frozen storage ranged from 99.1 to 99.6 per cent in all the cuts of the vegetables but 88.7 to 93.5 per cent reduction was during blanching only. Statistically, the reduction in microbial count was highly significant ($P \leq 0.01$) in all the cuts of the three vegetables. The differences between the two types of cuts of French beans were also highly significant ($P \leq 0.01$) after processing as well as after frozen storage period of six months.

As the peroxidase enzyme was not completely inactivated during blanching, its activity remained throughout the frozen storage period. However, the residual enzymic activity had no detrimental effect on the quality of frozen vegetables.

On fresh weight basis, the protein content of the fresh, processed and frozen stored French beans (1.0 cm), French beans (6.0 cm), okra rings, okra trimmed and capsicum halves ranged from 1.60 to 1.90, 1.80 to 1.90, 1.95 to 2.20, 1.97 to 2.20 and 1.15 to 1.40 g/100g, respectively. The differences were statistically non-significant. On dry weight basis, the corresponding levels ranged from 20.4 to 22.1, 19.5 to 20.6, 19.0 to 26.1, 19.5 to 23.7 and 15.6 to 18.9 g/100g, respectively. The differences were statistically significant ($P \leq 0.05$) only in case of okra rings and okra trimmed. On fresh weight basis, the crude fat content of the above listed vegetables ranged from 0.67 to 0.68, stable at 0.67, 0.42 to 0.43 in both cuts of okra and 0.24 to 0.25 g/100g, respectively. The respective values, on dry weight basis, ranged from 7.1 to 8.8, 7.2 to 7.3, 3.7 to 5.4, 3.8 to 4.8 and 3.3 to 3.4 g/100g. On fresh weight basis, the crude fibre content of the corresponding vegetables ranged from 1.48 to 1.70, 1.63 to 1.80, 0.98 to 1.30, 1.02 to 1.40 and 0.98 to 1.10 g/100g. The respective ranges on dry weight basis were 17.9 to 19.5, 17.7 to 19.5, 11.2 to 12.7, 11.3 to 12.4 and 13.2 to 14.8 g/100g. Statistically, the processing and frozen storage period of six months had no effect on crude fat and fibre content of the vegetables. The differences between the two types of cuts of French beans and okra were also statistically non-significant.

On fresh weight basis, the ash content of the above mentioned vegetables ranged from 0.48 to 0.50, 0.48 to 0.49, 0.59 to 0.62, 0.59 to 0.61 and 0.54 to 0.57 g/100g, respectively. The differences were statistically non-significant. The corresponding levels on dry weight basis ranged from5.2 to 6.2, 5.2 to 5.3, 5.3 to 7.6, 5.4 to 6.6 and 7.4 to 7.7 g/100g, respectively. The differences were statistically highly significant ($P \leq 0.01$) only in case of okra rings and okra trimmed.

On fresh weight basis, the available carbohydrate content of fresh, processed and frozen stored French beans (1.0 cm), French beans (6.0 cm), okra rings, okra trimmed and capsicum halves ranged from 3.30 to 4.70, 4.36 to 4.60, 3.78 to 7.00, 4.76 to 6.62 and 4.08 to 4.49 g/100g, respectively. The differences were statistically highly significant ($P \leq 0.01$) only in case of French beans (1.0 cm), okra rings and okra trimmed. The differences between the two types of cuts of French beans were statistically significant ($P \leq 0.05$) after blanching while after four and six months these differences were highly significant ($P \leq 0.01$). The differences between the two types of cuts of okra were also highly significant ($P \leq 0.01$) after blanching as well as after four and six months of frozen storage. The corresponding values, on dry weight basis, ranged from 35.8 to 40.0, 38.2 to 40.2, 40.5 to 49.2, 44.3 to 47.6 and 47.8 to 53.0 g/100g, respectively. The variation was statistically significant ($P \leq 0.05$) only in case of okra rings. The differences in available carbohydrate content between the two types of cuts of French beans were statistically significant ($P \leq 0.01$) after blanching.

On fresh weight basis, the total sugars of the above mentioned vegetables ranged from 38.2 to 40.2, 39.0 to 40.3, 49.0 to 51.0, 50.0 to 51.5 and 36.2 to 38.0 mg/g. The differences were statistically non-significant. The corresponding levels, on dry weight basis, ranged from 424.0 to 503.9, 423.9 to 437.0, 441.5 to 628.8, 457.3 to 560.2 and 490.5 to 513.5 mg/g, respectively. The differences were statistically significant in case of French beans 1.0 cm ($P \leq 0.05$) while in okra rings and okra trimmed, these were highly significant ($P \leq 0.01$). The differences between the two types of cuts of French beans were statistically highly significant ($P \leq 0.01$) after blanching and significant ($P \leq 0.05$) after freezing in French beans while the differences were highly significant ($P \leq 0.01$) after blanching and freezing in case of okra rings as well as okra trimmed.

The pectin content of the fresh, processed and frozen stored French beans (1.0 cm), French beans (6.0 cm), okra rings, okra trimmed and capsicum halves, on fresh weight basis, ranged from 0.63 to 0.70, 0.65 to 0.70, 0.95 to 1.00, 0.97 to 1.00 and 0.37 to 0.40 per cent, respectively. The differences were statistically non-significant. The corresponding values, on dry weight basis, ranged from 7.3 to 8.3, 7.0 to 7.6, 8.6 to 12.2, 8.8 to 11.0 and 5.0 to 5.4 per cent, respectively. The differences were statistically highly significant ($P \leq 0.01$) in case of okra rings and significant ($P \leq 0.05$) in okra trimmed. The differences between two types of cuts were statistically non-significant on fresh as well as dry weight basis.

The neutral detergent fibre (NDF) of the above mentioned vegetables, on fresh weight basis, ranged from 1.64 to 1.92, 1.89 to 1.95, 1.53 to 1.91, 1.70 to 1.90 and 1.05 to 1.15 per cent, respectively. The differences were statistically significant ($P \leq 0.05$) in case of French beans (1.0 cm) and okra rings. The corresponding values, on dry weight basis, ranged from 20.3 to 21.6, 20.5 to 21.3, 16.6 to 19.6, 16.9 to 19.1 and 14.2 to 15.9 per cent, respectively. The differences were statistically significant ($P \leq 0.05$) in case of okra rings only. However, the differences between two types of cuts of French beans and okra were statistically non-significant on fresh as well as dry weight basis. On fresh weight basis, the acid detergent fibre (ADF) content of the above mentioned vegetables ranged from 1.22 to 1.41, 1.38 to 1.46, 1.09 to 1.46, 1.25 to 1.45 and 0.50 to 0.58 per cent. The differences were statistically significant ($P \leq 0.05$) in case of okra rings only. The corresponding values, on dry weight basis, ranged from 14.9 to 16.1, 15.0 to 15.9, 12.7 to 14.2, 12.9 to 14.1 and 5.5 to 6.6 per cent, respectively. The differences were statistically non-significant. Further, the differences between two types of cuts of French beans and okra were statistically non-significant on fresh as well as dry weight basis.

On fresh weight basis, the β-carotene content of the fresh, processed and frozen stored French beans (1.0 cm), French beans (6.0 cm), okra rings, okra trimmed and capsicum halves ranged from 86.0 to 123.0, 91.3 to 125.0, 35.2 to 49.0, 36.5 to 50.0 and 302.4 to 435.0 μg/100g, respectively. The total reduction ranged from 27.0 to 30.5 per cent in all the cuts of the vegetables but 18.6 to 30.0 per cent reduction was during blanching on fresh weight basis. The differences were highly significant ($P \leq 0.01$) in all the cuts of the vegetables except French beans (6.0 cm), in which the differences were only significant ($P \leq 0.05$). The corresponding values, on dry weight basis, ranged from 1116.8 to 1297.4, 992.3 to 1355.7, 424.2 to 503.8, 405.5 to 454.2 and 4086.4 to 5878.3 μg/100g, respectively. The overall change ranged from +3.7 to –30.5 per cent in all the cuts of the vegetables but +18.7 to -19.1 per cent change was during blanching on dry weight basis. The differences were statistically highly significant ($P \leq 0.01$) in case of French beans (6.0 cm) and capsicum halves whereas these were significant ($P \leq 0.05$) in case of French beans (1.0 cm) and okra rings and non-significant in case of okra trimmed. However, the differences between two types of cuts were non-significant on fresh weight basis but significant ($P \leq 0.05$) in both types of cuts of French beans after blanching and four months of frozen storage and in both cuts of okra ($P \leq 0.05$) after blanching only.

The ascorbic acid (AA) content of fresh, processed and frozen stored French beans (1.0 cm), French beans (6.0 cm), okra rings, okra trimmed and capsicum halves ranged from 18.0 to 25.2, 20.1 to 26.0, 11.8 to 15.0, 12.3 to 15.3 and 98.3 to 145.0 mg/100g, respectively on fresh weight basis. The overall reduction ranged from 19.6 to 32.2 per cent in all the cuts of the vegetables but 14.3 to 26.2 per cent reduction was during blanching on fresh weight basis. The differences were highly significant ($P \leq 0.01$) in all the cuts of the vegetables except French beans (6.0 cm), in which the differences were only significant ($P \leq 0.05$). The differences between two types of cuts of French beans were significant ($P \leq 0.05$) after blanching and freezing only. The corresponding levels, on dry weight basis, ranged from 233.7 to 265.8, 218.4 to 281.9, 129.8 to 160.7, 135.8 to 146.2 and 1328.3 to 1959.4 mg/100g, respectively. The overall change in ascorbic acid level ranged from +13.6 to -32.3 per cent in all the cuts of the vegetables but +19.2 to -24.1 per cent change was during blanching process on dry weight basis. The differences were highly significant ($P \leq 0.01$) in French beans

(6.0 cm), okra rings and capsicum halves. However, the differences between two types of cuts were significant ($P \leq 0.05$) in case of French beans after blanching and freezing only.

The organoleptic evaluation scores of fresh, processed and frozen stored French beans (1.0 cm) in the form of French beans-potato vegetables for colour, flavour, texture, taste and overall acceptability ranged from 4.00 ± 0.141 to 4.75 ± 0.106, 3.90 ± 0.138 to 4.30 ± 0.161, 3.85 ± 0.142 to 4.40 ± 0.118, 3.95 ± 0.179 to 4.20 ± 0.145 and 3.80 ± 0.145 to 4.40 ± 0.118, respectively. The scores were significantly ($P \leq 0.05$) higher in case of colour and texture after processing and frozen storage. Overall, all the parameters of organoleptic evaluation of frozen stored French beans (1.0 cm) scored better having the mean scores of 4.20 to 4.70 as compared to the off-season market fresh samples in the respective months whose organoleptic mean scores ranged from 3.80 to 4.10. The corresponding scores of fresh, processed and frozen stored French beans (6.0 cm) in the form of French beans-potato fry vegetables ranged from 3.80 ± 0.145 to 4.10 ± 0.137, 3.90 ± 0.118 to 4.10 ± 0.155, 3.90 ± 0.138 to 4.20 ± 0.145, 3.90 ± 0.197 to 4.20 ± 0.189 and 3.80 ± 0.161 to 4.00 ± 0.158, respectively. The differences were statistically non-significant for all the parameters. Overall, all the parameters of organoleptic evaluation of frozen French beans (6.0 cm) scored better having the mean scores of 3.90 to 4.20 as compared to the off-season market fresh samples in the respective months whose organoleptic mean scores ranged from 3.60 to 3.95.

The organoleptic evaluation scores of fresh, processed and frozen stored okra rings in the form of okra-onion vegetables for colour, flavour, texture, taste and overall acceptability ranged from 4.10 ± 0.170 to 4.65 ± 0.101, 3.90 ± 0.155 to 4.30 ± 0.145, 3.75 ± 0.190 to 4.20 ± 0.161, 3.90 ± 0.095 to 4.40 ± 0.184 and 3.90 ± 0.138 to 4.45 ± 0.193, respectively. The differences were significant ($P \leq 0.05$) in case of colour and overall acceptability after blanching only. Overall, the mean scores of all the parameters of organoleptic evaluation of frozen okra rings were between 3.75 to 4.65 whereas those of the off-season market fresh samples available in the respective months ranged from 3.80 to 4.20. The respective scores of fresh, processed and frozen stored okra trimmed in the form of okra fry vegetables ranged from 4.05 ± 0.085 to 4.25 ± 0.106, 3.90 ± 0.170 to 4.30 ± 0.145, 3.50 ± 0.100 to 4.30 ± 0.176, 3.50 ± 0.122 to 4.25 ± 0.226 and 3.55 ± 0.111 to 4.20 ± 0.176, respectively. The differences were statistically significant ($P \leq 0.05$) in case of texture only. Overall, the average scores of all the parameters of organoleptic evaluation of frozen okra trimmed ranged between 3.30 to 4.15 whereas those of the off-season market fresh samples available in the respective months ranged from 3.65 to 4.10.

The organoleptic evaluation scores of fresh, processed and frozen stored capsicum halves in the form of stuffed capsicum vegetables for colour, flavour, texture, taste and overall acceptability ranged from 3.60 ± 0.138 to 4.35 ± 0.101, 3.75 ± 0.177 to 4.10 ± 0.155, 3.35 ± 0.159 to 4.05 ± 0.111, 3.60 ± 0.184 to 4.05 ± 0.072 and 3.70 ± 0.126 to 4.05 ± 0.070, respectively. The differences were statistically significant ($P \leq 0.05$) in case of colour, texture and taste of the vegetables. Overall, the scores of all the parameters of organoleptic evaluation of capsicum halves ranged between 3.35 and 4.10 whereas those of the off-season market fresh samples available in the respective months ranged from 3.45 to 4.10. Overall, all the mean scores for colour of frozen stored French beans (1.0 cm), okra rings and capsicum were significantly ($P \leq 0.05$) higher than those of the respective off-season market fresh vegetables. Further, the scores for texture of frozen stored French beans (1.0 cm) were significantly higher while the scores for texture of off-season market fresh okra trimmed and capsicum were significantly ($P \leq 0.05$) higher. For all the other organoleptic parameters, the differences were statistically non-significant. But in all cases of frozen vegetables, the scores were between 3.80 and 4.70, i.e. good and very good, indicating that the frozen vegetables were acceptable in the cooked form in traditional Punjabi recipes.

Keeping in view the cost of raw material, labour for preparation of the vegetables, blanching, freezing and packing, the retail market prices of the frozen vegetables were 25 to 42 per cent lower than the off-season market fresh vegetables.

Thus frozen vegetables in addition to their improved quality, economics, nutritive value and consumer acceptability, can help farmers and processors in overcoming seasonal gluts, remunerative to farmers and helpful in crop diversification. However, Govt. support in the form of good roads, efficient refrigerated transport system, provision of loans and regular power supply in rural areas is vital to encourage frozen storage food industry.

Suggestions for future research

- Special attention must be paid to objective sensory evaluation of quality attributes of frozen foods during frozen storage using appropriate equipment
- The studies are needed on the suitability of different varieties of vegetable for frozen storage.
- The nutrient losses are expected to be much more while handling the produce from harvesting to processing as compared to processing and post-processing losses. The impact of time elapsed between the harvesting and processing, type of packaging and size of individual pack may be studied so that suitable measures could be suggested for reducing pre-processing losses.
- Once frozen vegetables are taken out of the stores, these are subjected to variable temperature and storage periods at the retail points and in the households. The impact of these handling conditions may be studied to evaluate the shelf life and nutrient losses.
- The efficacy of the freezing technology on raw and cooked ready-to-serve vegetables in terms of retention of nutritive value, convenience and economics also needs to be assessed.
- There is need to study the suitability of frozen vegetables in other recipes like *pulao,* mixed vegetable, noodles etc.
- As blanching is important to maintain quality, the economics of steam blanching must be evaluated especially in case of okra and capsicum to retain texture and to avoid losses of water soluble nutrients.

REFERENCES

Adams J B (1981) Blanching of vegetables. *Nutr Fd Sci* **73**: 11-13

Aguado V, Vitas A and Garcia-Jalon I (1997) Comparative study of 3 enrichment methods for recovery and isolation of *L monocytogens* from foods. *Alimentaria* **288**: 113-19 (Original not seen. Abstr in FSTA, AN : 1998-2001/05).

Amaro M A, Moreno R and Zurera G (1988) Nutritional estimation of changes in mineral content during frozen storage of white asparagus. *J Fd Qual* **21** (6) : 445-58.

Anon (1992) Wealth of India. A dictionary of Indian raw material and industrial products. CSIR, New Delhi **3** : 218.

Anon (1999) Processed fruits and vegetables. Singhal V (ed) *Indian Agriculture* 1999 pp 33, 43, 90, 143. Indian Economic Data Research Centre, New Delhi.

AOAC (1965) *Official Methods of Analysis.* Association of Official Analytical Chemists. Washington, DC, USA.

AOAC (1985) *Official Methods of Analysis* (16th edn) Association of Official Analytical Chemists. Washington, DC, USA.

AOVC (1966) *Methods of Vitamin Assay* (3rd edn). pp 306-12. Association of Vitamin Chemists, Inc., Inter-Science Publishers, New York.

Aparicio-Cuesta M P and Garcia-Moreno C (1988) Quality of frozen cauliflower during storage. *J Fd Sci* **53** (2) : 491-93.

Aparicio M P, Rivas J C, Santos C and Garcia C (1989) Influence of storage conditions on quality of frozen green beans (var checkmate). *Revuista-de-Agroquimica-y-Tecnologia-de Alimentos.* **29** (2) : 255-65. (Original not seen. Abstr in FSTA, AN: 1990-05-J0130, 1990-2001/05).

Aparicio-Cuesta M P, Mateous-Notario M P and Rivas-Gonzalo J C (1992) Sensory evaluations and changes in peroxidase activity during frozen storage of green beans. *J Fd Sci* **57** (5) : 1129-31.

Baardseth P (1977) Quality changes of frozen vegetables. *Fd Chem* **3** : 271-82.

Baardseth P and Naesset E (1989) The effect of lipid-degrading enzyme activities on quality of blanched or unblanched frozen stored cauliflower estimated by sensory and instrumental analysis. *Fd Chem* **32** : 39-46.

Baardseth P and Slinde E (1983) Peroxidase, catalase and palmitoyl – CoA hydrolase activity in blanched carrot cubes after storage at –20°C. *J Sci Fd Agric* **34** (11) : 1257-62.

Bakowski J, Kosson R, Elkner K, Michalik K and Kondratowicz J (1990) Effect of freezing technique on quality of frozen cauliflower. *Chlodnictwo* **25** (11) : 13-16.

Bao B and Chang K C (1994) Carrot juice colour, carotenoids and non-starchy polysaccharides as affected by processing conditions. *J Fd Sci* **59** (6) : 1155-58.

Barrett D M and Theerakulkait C (1995) Quality indicators in blanched, frozen and stored vegetables. *Fd Technol* **49** (1) : 62-65.

Barrett D M, Garcia E L, Russell G F, Ramirez E and Shirazi A (2000) Blanch time and cultivar effects on quality of frozen and stored corn and broccoli. *J Fd Sci* **65** (3) : 534-40.

Baardseth P and Naesset E (1989) The effect of lipid-degrading enzyme activities on quality of blanched or unblanched frozen stored cauliflower estimated by sensory and instrumental analysis. *Fd Chem* **32** (1) : 39-46.

Bognar A, Varela A, Garrids A and Lopez A (1998) Comparative study of frying to other cooking techniques influence on the nutritive value. *Grasas Aceites Sevilla* **49** : 250-60.

Bomben J L, Dietrich W C, Hudson H K, Hamilton H K and Farkas D F (1975) Yields and solids loss in steam blanching, cooling and freezing vegetables. *J Fd Sci* **40** (4) : 660-64.

Brecht P E, Keng L, Bisogni C A and Munger H M (1976) Effect of fruit portion, stage of ripeness and growth habit on chemical composition of fresh tomatoes. *J Food Sci* **41** : 945-48.

Breene W M (1985) *Industrial Processing of Fruits and Vegetables.* pp 153-63 University of Minnesota, Department of Food Science and Nutrition St. Paul, Minnesota 55108.

Brewer M S, Begum S and Bozeman A (1995) Microwave and conventional blanching effects on chemical, sensory and colour characteristics of frozen broccoli. *J Food Qual* **18** : 479-93.

Brown M S (1977) Texture of frozen fruits and vegetables. *J Texture Studies* **7** : 391.

Bubicz M, Majewski K and Piotrouski J (1990) Retention of carotenes, xanthophylls and alpha-tocopherol in frozen carrots. *Przeemysl-Fermentacyjny-I-owocowo-warzywny* **34** (1) : 20-21. (Original not seen. Abstr in FSTA, AN: 92-02-J0102, 1969-6/94).

Burger I H (1982) Effect of processing on nutritive value of food; meat and meat products. In: Recheigl M (ed.) Handbook of the nutritive value of processed food. Vol.1 CRC Press, Boca Raton, Florida, pp 323-36.

Carr J M (1984) *The physico-chemical changes occurring in green peas and strawberries during blanching, freezing and frozen storage.* M.Sc. Thesis, Univ. of California, Davis, USA.

Chang H W and Chen W L (1999) Effects of blanching conditions on quality of frozen prepared vegetables. *Fd Sci* **26** (6) : 596-604.

Chen A O (1986) A study of freezing time prediction on quality improvement of frozen fruits and vegetables. *Fd Sci China* **13** (1/2) : 78-92.

Clarice Sackett (1975) Fruit and vegetable facts and pointers – okra. A report United Fresh Fruit and Vegetable Association, North Washington at Madison **2** : 1-7.

Collins J L, Liao J Y and Penfield M P (1995) Chemical, physical and sensory attribute of formed and frozen, baked sweet potato. *J Fd Sci* **60** (3) : 465-67.

Cruickshank R (1969) *Medical Microbiology.* The English Language Book Society and Churchill, Livingstone.

Cumming D B, Stark R and Sanford K A (1981) The effect of an individual quick blanching method on ascorbic acid retention in selected vegetables. *J Food Proc Preservat* **5** : 31-37.

Czapski J and Szudyga K (2000) Frozen mushrooms quality as affected by strain, flush, treatment before freezing and time of storage. *J Fd Sci* **65** (4) : 722-23.

Desrosier N W and Tressler D K (1977) *Fundamentals of Food Freezing.* pp 110-15 AVI Publishing Co., Inc, Westport, Connecticut, USA.

Dhaliwal M (2002) *Nutritional and organoleptic evaluation of selected frozen vegetables.* Ph D dissertation, Punjab Agricultural University, Ludhiana, India.

Dietrick W C, Huxdsol C C and Guadagni D G (1970) Comparison of microwave, conventional and combination blanching of Brussels Sprouts for frozen storage. *Fd Technol* **24** : 613-17.

Drake S R, Spayd S E and Thompson J V (1981) The influence of blanch and freezing methods on the quality of selected vegetables. *J Fd Qual* **4** (4) : 271-78.

Dubois M, Gilles K A, Hamilton J K, Rebers P A and Smith F (1956) Colorimetric method for determination of sugars and related substances. *Anal Chem* **28** : 350.

Eheart M S and Odland D (1973) Quality of frozen green vegetables blanched in four concentrations of ammonium bicarbonate. *J Fd Sci* **38** : 954-58.

Erdman J, W Jr and Klein B P (1982) Harvesting, processing and cooking influences on vitamin C in foods. In "Ascorbic Acid Chemistry, Metabolism and Uses". Eds. Seib PA and Tolbert B M. American Chemical Society, Washington, D C pp 499-532.

Eskin N A M (1989) *Quality and Preservation of Vegetables.* pp 313. CRC Press, Boca Raton, FL, USA.

Favell D J (1997) A comparison of the vitamin C content of fresh and frozen vegetables. *Fd Chem* **62** (1) : 59-64.

Fellows P J (2000) *Food Processing Technology – Principles and Practices* (IInd edn) pp 432-33. CRC Press, Boca Raton Boston New York, Washington, DC.

Franceschi S, Parpinel M, Lavecchia C, Favero A, Talamini R and Negri E (1998) Role of different types of vegetables and fruit in the prevention of cancer of the colon, rectum and breast. *Epidemiology* **9** : 338-41.

Frazier W C (1967) *Food Microbiology.* pp 511-13. McGraw Hill Book Co., New York.

Fuchigami M, Miyazaki K and Hyakumoto N (1995) Frozen carrots texture and pectic components as affected by low temperature blanching and quick freezing *J Fd Sci* **60** (1) : 132-36.

Goering H K and VanSoest P J (1970) Forage fibre analysis (apparatus, reagents, procedure and some applications). In: US Department Agricultural Handbook, Series No. 379 (Anonymous).

Gola S, Previdi M P, Mutti P and Belloli S (1990) Microbiological investigations of frozen vegetables, incidence of *Listeria* and other psycrophilic pathogens. *Industria Conserve* **65** (1) : 36-38. (Original not seen. Abstr in FSTA, AN: 1990-11-J0013, 1990-2001/05).

Gomez S, Lata and Roy S K (2002) Effect of primary processing on microbial load of cauliflower and fenugreek. *J Fd Sci Technol* **39** (1) : 33-37.

Gopalan C, Rama Shastri B V and Balasubramaniam S C (1997) *Nutritive Value of Indian Foods*. pp 47-67. National Institute of Nutrition, ICMR, Hyderabad, India.

Gullet E A, Rowe D L and Hines R J (1984) Effect of microwave blanching on the quality of frozen green beans. *Can Inst Fd Sci Technol* **17** (4) : 247-52.

Gunes B and Bayindirh A (1993) Peroxidase and lipoxygenase inactivation during blanching of green beans, green peas and carrots. *Lebensm-wirs-und-Technol* **26** : 406-10.

Gupta J P and Saini S S (1995) *Introduction to Statistical Methods*. Kalyani Publishers, Ludhiana.

Halpin B E and Lee C Y (1987) Effect of blanching on enzyme activity and quality changes in green peas. *J Fd Sci* **52** (4) : 1002-05.

Herranz J, Valverde C V and Hidalgo E R (1981) Cellulose, hemicellulose and lignin content of raw and cooked spanish vegetables. *J Fd Sci* **46** : 1927-33.

Herranz J, Valverde C V and Hidalgo E R (1983) Cellulose hemicellulose and lignin content of raw and cooked processed vegetables. *J Fd Sci* **48** : 274-75.

Holdsworth S D (1990) Kinetic data-what is available and what is necessary? pp 174-90. In: *Processing and Quality of Foods* **(Vol 1)** Zeuthez P, Paulus J C, Erickson C, Gormley R, Linko P and Paulus K (ed) Applied Science, London, UK.

Howard L A, Wong A D, Perry A K and Klein B P (1999) β-carotene and ascorbic acid retention in fresh and processed vegetables. *J Fd Sci* **64** (5) : 929-30.

Howard L, Wong A, Perry A and Klein B P (1996) The stability of nutrients in fresh and processed vegetables. pp 96. In: IFT *Annual Meeting: Book of Abstracts* (Original not seen. Abstr in FSTA, AN: 1997-01-J0283, 1990-2001/05).

Hudson M A, Sharples V J, Pickford E and Leach M (1974) Quality of home frozen vegetables. *J Fd Technol* **9** (1): 95-103.

Hugo L T, Marcial S J and Ewa O R (1989) Effect of blanching on the quality of frozen storage of green beans. In: *Trends in Food Science.* Institute of Fd Sci and Technol, Singapore (Original not seen. Abstr in FSTA, AN: 1990-06-J0095, 1990-2001/05).

Hung Y C and Thompson D R (1989) Changes in texture of green peas during freezing and frozen storage. *J Fd Sci* **54** (1): 96-101.

Hussain A, Saeed M and Shaw W H (1991) Influence of varietal characteristics and packing material on freezing and preservation of various pea cultivars. *Pakistan J Sci Ind Res* **34** (9) : 327-30.

Jarris M C (1984) Structure and properties of pectin gels in plant cell walls. *Plant Cell and Environ* **7** : 153-64.

Kalia M and Sood S (1996) *Food Preservation and Processing* (Ist edn) pp 270-71. Kalyani Publishers, Ludhiana, India.

Katsaboxakis K and Papanicolaou D (1996) Loss of ascorbic acid in some fruits and vegetables during quick-freezing. *Sciences-des-Alliments* **16** (2) : 133-41. (Original not seen. Abstr in CAB Abstracts, AN: 971403296, 1996-98/07).

Kaur Bhupinder (1984) *Canning, dehydration and freeze preservation of okra (Hibiscus esculentus* L.) *Cultivars of different maturity in relation to the composition and product quality.* Ph D Dissertation, Punjab Agricultural University, Ludhiana, India.

Kaur C and Kapoor H C (2001) Effect of different blanching methods on the physico-chemical qualities of frozen French beans and carrot. *J Fd Sci* **38** (1) : 65-67.

Kawaguchi N, Powers J R, Cavalieri R P, Pelman J K (2000). Cystine lyase as indicator enzyme for broccoli blanching (abstract). In: IFT Annual meeting book of abstracts; 2000, June 11-14; Dallas Texas. Chicago, III, Institute of Food Technologists p. 137. Abstract 65A-37.

Khalilur M, Khan R and Malik A (2002) Microbiological quality of milk, vegetables and fruit juices. *J Fd Sci Technol* **39** (2) : 120-23.

Kidmose U and Martens H J (1999) Changes in texture, microstructure and nutritional quality of carrot slices during blanching and freezing. *J Sci Fd Agric* **79** 1747-53.

Klein B P (1992) *Fruits and vegetables in Food Theory & Applications.* pp 697-766. Bower J (ed), Macmillan Publihing Co., New York, NY.

Klein B P and Perry A K (1982) Ascorbic acid and vitamin A activity in selected vegetable from different geographical areas of the United States. *J Food Sci* **42** : 941-48.

Kochar G K and Sharma K K (1992) Fibre content and its composition in commonly consumed Indian vegetables and fruits. *J Fd Sci Technol* **29** (3) : 187-88.

Larmond E (1982) *Laboratory Methods for Sensory Evaluation of Food.* Publ 1637, Canada Dept Agric, Ottawa, Canada.

Latunde G O (1990) Effect of processing on iron levels and availability from some Nigerian vegetables. *J Sci Fd Agric* **53** : 355-61.

Lee C Y (1970) Effect of quick freezing on texture of peas. *Lebensm Wiss u Technol* **3** (1) : 21-22.

Lee C Y, Massey L M and Van Buren J P (1982a) Effects of post harvest handling and processing on vitamin content of pea. *J Fd Sci* **47** (3) : 961-64.

Lisiewska Z and Kmiecik W (1996) Effects of level of nitrogen fertilizer, processing conditions and period of storage of frozen broccoli and cauliflower on vitamin C retention. *Fd Chem* **57** (2) : 267-70.

Lisiewska Z and Kmiecik W (2000) Effect of storage period and temperature on the chemistry, composition and organoleptic quality of frozen tomato cubes. *Fd Chem* **70** (2) : 167-73.

Mallet C P (1993) *Frozen Food Technology.* pp 123-39. Blackie Academic and Professional, London.

Mann S K, Kaur H and Gulati T (1992) Effect of cooking on fibre content of vegetables. *J Fd Sci Technol* **29** (3) : 185-86.

Matthews R F, Locasio S J and Ozaki H T (1975) Ascorbic acid and carotene contents of peppers. *Proc Florida State Horticuet Soc* **88** : 263-65.

Michalik H and Halla M (1991) Evaluation of procesing quality in some carrot varieties. *Biuletyn Warzy Wniczy* **37** : 219-25 (Original not seen. Abstr in CAB Abstracts, AN: 941603014, 1993-94).

Morrison M H (1974) The vitamin C and thiamin contents of quick frozen peas. *J Fd Technol* **9** (4) : 491-500.

Muftugil N (1985) The peroxide enzymes activity of some vegetables and its resistance to heat. *J Sci Fd Agric* **36** (9) : 877-80.

Nursal B and Yucecan S (2001) Vitamin C losses in some frozen vegetables due to various cooking methods. (Original not seen. Abstr in FSTA, AN : 2001-03-J0683, 1990-2001/05).

Olaeta J A, Montgomery M W and Cain R F (1983) Effect of maturity on the physical and sensorial properties of frozen peas. *Agric Tecnia* **43** (1) : 53-60.

Oruna-Concha M J, Gonzalez Castro M J, Lopez Herandez J and Simal Lozano J (1996). Evaluation of sugar, starch, pectin and insoluble fibre contents in frozen green beans and pardon peppers. *Deutsche Lebensmittel Rundschau* **92** (9) : 278-81. (Original not seen. Abstr in FSTA, AN: 1997-05-J0096, 2001/05).

Park Y W (1987) Effects of freezing, thawing, drying and cooking on the carotene retention in carrots, broccoli and spinach. *J Fd Sci* **52** : 1022-25.

Polo M V, Lagara M J and Farre R (1991) The effect of freezing on mineral element content of vegetables. *J Fd Comp Anal* **5** (1) : 77-83.

Ponne C T, Baysal T and Yuksel D (1994) Blanching leafy vegetables with electro-magnetic energy. *J Fd Sci* **59** (5) : 1037-42.

Premavalli K S, Majumdar T K and Madhura C V (2001) Processing effect on colour and vitamins of green leafy vegetables. *J Fd Sci Technol* **38** (1) : 79-81.

Prestamo G, Fuster C and Risueno M C (1998) Effects of blanching and freezing on the structure of carrot cells and their implications for food processing. *J Sci Fd Agric* **77** (2) : 223-29.

Pruthi J S (1989) Marketing of quick frozen foods: present status, problems and prospects. *Indian Fd Packer* **43** (4) : 111-26.

Pruthi J S (1999) *Quick freezing preservation of foods – principle, practices, R&D needs Vol.II Foods of Plant Origin* pp 23-42. Allied Publishers Ltd., New Delhi.

Quenzer N M and Burns E E (1981) Effects of microwave, steam and water blanching on freeze-dried spinach. *J Fd Sci* **46** : 410-13.

Ramaswamy H S and Ranganna S (1989) Effect of blanching and sulfite treatment on the quality of frozen cauliflower. *J Fd Qual* **11** (6) : 443-52.

Ramaswamy H S and Fakhouri M O (1998) Microwave blanching: Effect on peroxidase activity, texture and quality of frozen vegetables. *J Fd Sci Technol* **35** (3) : 216-22.

Ramaswamy H S and Ranganna S (1981) Thermal inactivation of peroxidase in relation to quality of frozen cauliflower. *Can Inst Fd Technol J* **14** (2) : 139-43.

Ramesh M N, Wolf W, Tevini D and Bognar A (2002) Microwave blanching of vegetables. *J Fd Sci* **67** (1) : 390-98.

Ramirez E C and Whitaker J R (1998) Cystine lyase as blanching indicator in broccoli. *Ital J Food Sci* **10** (2) : 171-76.

Ranganna S (1995) *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. Tata McGraw Hill Publishing Co., Ltd, New Delhi, India.

Rao CN (1967) True vitamin A value of some vegetables. *J Nutr Dietet* **4** : 10-16.

Roy S S, Taylor T A ad Kramer H L (2001) Textural and ultratextural changes in carrot tissues as affected by blanching and freezing. *J Fd Sci* **66** (1) : 176-80.

Sadana B (1984) Effect of cooking on the composition of fibre in different foods. Ph D dissertation, Punjab Agricultural University, Ludhiana, India.

Sapers G M, Miller R L, Pilizota V and Kamp F (2001) Shelf life extension of fresh mushrooms by application of hydrogen peroxide and browning inhibitor. *J Fd Sci* **66** (2) : 362-63.

Sajjaanantakul T (1986) *Changes in pectin and in textural quality due to freezing and frozen storge of fruits and vegetable*. M Sc Thesis, Univ of California, Davis, USA.

Selman J D (1978) Vitamin C losses from peas during blanching in water. *Fd Chem* **3** (3) : 189-97.

Selman J D (1994) Vitamin retention during blanching of vegetables. *Fd Chem* **49** (2) : 137-47.

Senturk A (1997) Effects of technological processing steps on some frozen vegetable microbiological characteristics. *Kontrol Leboratuvar Mudurlugu Canakkali* **35** 40. (Original not seen. Abstr in FSTA, AN: 1998-05-J001159, 1990-2001/05).

Shyu S L, Hau L B and Sunthwang L (1999) Effect of vacuum frying temperature on the chemical components of fried carrot chips. *Fd Sci Agric Chem* **1** (1) : 61-66.

Siegel S and Castellan N J (1989) *Non-parametric Statistics for the Behavioral Sciences.* pp 176-80. McGraw Hill Book Co., New York.

Sies H and Stahl W (1995) Vitamin E and C, β-carotene and other carotenoids as antioxidants. *Am J Clin Nutr* **62** (suppl) : 1315-21.

Sikora Z and Wanger R (1988) Cultivation and evaluation of suitability for freezing of new cauliflower varieties. *Chlodnictwo* **23** (10) : 18-21. (Original not seen. Abstr in FSTA, AN: 1991-05-J0233, 1990-2001/05).

Simpson J I (1962) *The Frozen Food Cook Book and Guide to Home Freezing.* pp 99-115. The AVI publishing Co, Inc. Westport, Connecticut.

Sistrunk W A, Jones L G and Miller J C (1960) Okra pod growth habits. *Amer Hort Sci* **76** : 486.

Skrede G (1983) Changes in sucrose, fructose and glucose content of frozen strawberries with thawing. *J Fd Sci* **48** : 1094.

Splittstoesser D F and Corlett D A Jr (1980) Ascorbic plate counts of frozen blanched rye processed in the US. *J Food Protect* **43** : 17-19.

Splittstoesser D F, Wettergreen W P and Pederson C S (1961) Control of microorganisms during preparation of vegetables for freezing. I. Green beans. *Food Technol* **15** : 329-31.

Steinmetz K A and Potter J D (1996) Vegetables, fruit and cancer prevention – An view. *J Amer Diet Assoc* **96** : 1027-39.

Sungpuag P, Tangchitpianvit S, Chittchang U and Wasantwisut E (1999) Retinol and β-carotene content of indigenous raw and home prepared foods in North east Thailand. *Fd Chem* **64** : 163-67.

Svanberg S J M, Suortti T and Nyman E M G L (1997) Physiochemical changes in dietary fiber of green beans after repeated microwave treatments. *J Fd Sci* **62** (5) : 1006-10.

Theerakulkait C and Barret D M (1995) Lipoxygenase in sweetcorn germ : Isolation and Physiochemical properties. *J Food Sci* **60** (5) : 1029-1033, 1040.

Tressler D K, Van Arsdel W B and Capley M J (1957) The freezing preservation of foods (4th edn) Vol.I, 2, 3 and 4. The AVI Publishing Co, Westport, Conn.

Van Duyne F, Bruckart S, Chase J and Simpson J (1945) Ascorbic acid content of freshly harvested vegetables. *J Amer Diet Assoc* **21** : 153-54.

Vanderslice J T, Higgs D J, Hayes J M and Block G (1990) Ascorbic acid and hydroascorbic acid content of foods-as-eaten. *J Food Comp and Anal* **3** : 106-111.

Verma A (2002) Vegetables in Food basket for nutritional security. *Kisan World* **2** : 16.

Wagenknecht A C and Lee F A (1956) The action of lipoxidase in frozen raw peas. *Fd Res* **21** : 605-10.

Williams D C, Lim M H, Chen A O, Pangborn R M and Whitker J R (1986) Blanching of vegetables for freezing-which indicator enzyme to choose. *Fd Technol* **40** (6) : 130-40.

Wills R B H, Wong A W K, Scriven F M and Greenfield H (1984) Nutrient composition of Chinese vegetables. *J Agric Fd Chem* **32** (2) : 413-16.

Zyren J, Elkins E R, Dudek J A and Hagen R E (1983) Fibre contents of selected raw and processed vegetables, fruits and fruit juices as served. *J Fd Sci* **48** : 600-603.

Appendix - I

ORGANOLEPTIC SCORE CARD

Dated ____________________ **Name of the Evaluator** ________________ **Product** _________________

Treatments	Colour	Flavour	Texture	Taste	Overall acceptability
	5 4 3 2 1	5 4 3 2 1	5 4 3 2 1	5 4 3 2 1	5 4 3 2 1
S_1					
S_2					
S_3					
S_4					

Scores for various parameters

5-Excellent

4-Very good

3-Good

2-Fair

1-Poor

VITA

Name of the student	:	Jaswinder Kaur
Father's name	:	S. Major Singh Brar
Mother's name	:	Mrs. Jagir Kaur
Nationality	:	Indian
Date of birth	:	10th May, 1964
Permanent home address	:	

EDUCATIONAL QUALIFICATION

Bachelor Degree

University and year of award	:	Punjab Agricultural University Ludhiana, June, 1984
OGPA	:	3.93/4.00 basis

Master's Degree

University and year of award	:	Punjab Agricultural University, Ludhiana, December, 1986
OGPA	:	3.52/4.00 basis

Ph.D.

OCPA	:	7.61/10.00
Title of Master's Thesis	:	Assessment of nutritional status of low-socio-economic group of Faridkot district.

Title of Thesis	:	Organoleptic and nutritional quality of selected frozen summer vegetables
Name of the student And admission No.	:	Jaswinder Kaur (L-99-H.Sc.-46-D)
Major subject	:	Food and Nutrition
Minor subject	:	Food Science and Technology
Name and designation Of Major Advisor	:	Dr (Mrs) S.K. Mann Dean, College of Home Science, Punjab Agricultural University, Ludhiana
Degree to be awarded	:	Ph.D.
Year of award of degree	:	2003
Total pages in dissertation	:	२५९+1
Name of the university	:	Punjab Agricultural University, Ludhiana

ABSTRACT

Three summer vegetables namely okra rings and trimmed of variety-Shagun, French beans 1.0 and 6.0 cm cuts and capsicum halves of local varieties were water blanched, frozen by IQF method and stored at PAGRO Foods Ltd., Fatehgarh Sahib at –20 to –25°C. Organoleptic, nutritional and quality characteristics were evaluated for fresh, processed and frozen stored vegetables every second month for six months. The results revealed that processing and frozen storage changes in pH, acidity, protein, fat, fibre, ash, total sugars and pectin of all the vegetables were non-significant. The reduction was highly significant ($P \leq 0.01$) after blanching and frozen storage in the microbial count of all the five types of the vegetables; β-carotene and ascorbic acid in French beans (1.0 cm), okra rings, okra trimmed and capsicum but in French beans (6.0 cm) the decrease was significant ($P \leq 0.05$). However, the total solids and available carbohydrates in French beans (1.0 cm), okra rings and okra trimmed decreased significantly ($P \leq 0.01$) whereas neutral detergent fibre in French beans (1.0 cm) and okra rings; and acid detergent fibre in okra rings decreased significantly ($P \leq 0.05$) after processing and frozen storage. Inspite of 27.0 to 30.5 per cent losses in β-carotene and 19.6 to 32.2 per cent losses in ascorbic acid, on fresh weight basis, vegetables retained 35.2 to 302.4 μg/100g and 11.8 to 98.3 mg/100g of respective nutrients. The organaoleptic evaluation scores of frozen vegetables varied from good to very good, indicating that the frozen vegetables were acceptable in the cooked form in traditional Punjabi recipes. Keeping in view, all the processing and frozen storage expenses, the retail market prices of the frozen vegetables were 25-42 per cent lower than the off-season market fresh vegetables. Thus frozen stored vegetables in addition to their improved quality, economics, nutritive value and consumer acceptability, can help farmers and processors in overcoming seasonal gluts.

Key words: Vegetables, blanching, IQF, β-carotene, ascorbic acid, organoleptic acceptability.

Signature of Major Advisor

Signature of Student 30/4/2003