PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 6 (5): 472-477, 2007
ISSN 1680-5194

Influence of Home Freezing and Storage on Vitamin C Contents of Some Vegetables

B. Nursal Tosun and S. Yücecan
Department of Nutrition and Dietetics, Hacettepe University, 06100, Sıhhiye, Ankara, Turkey

Abstract: Okra, potatoes, green beans, broccoli, spinach and peas were included to determine the vitamin C levels of home freezing with the impact of processing and storage. Firstly, a preliminary study was done to find the high quality vegetables (in terms of Vitamin C) for freezing, then selected vegetables were prepared for freezing according to the appropriate nutritional principles and frozen. In the second phase, all frozen vegetables kept in the freezer (6 months) to evaluate the storage effects. Vitamin C analyses were conducted just after the pre-freezing operations that may cause Vitamin C destruction, freezing and storage (3. and 6. months). Spectrophotometric method (2,6-dichlorophenol indophenol) was used to determine the vitamin C levels. Depending on the vegetable type, pre-freezing operations caused 30.9-48.0% decrease in the initial vitamin contents. Home freezing alone did not make any significant difference, but 6 months of storage resulted a total of 42.4 (green beans) - 66.5 (broccoli) % decrease.

Key words: Vegetables, processing, home-freezing, storage, vitamin C

Introduction

Vegetables are one of the important food groups that can meet the daily needs of the body. With a high content of certain vitamins, minerals and phytochemicals, this group is suitable for the recommendations related to health protection and improvement (Hoard and Chism, 1996; Buescher *et al.*, 1999).

The perishable nature of these seasonal products limits the beneficial effects on human health. As nutrient content is closely related to their freshness and in today's life it is hard to find 'garden fresh' vegetables, there is an inevitable necessity to apply a preservation technique. Among the methods that are used to increase the stability of fresh produce with high quality, freezing seems to be one of the most common methods applied. It has been considered as the simplest and natural method (Makhlouf *et al.*, 1995; Favell, 1998; Davey *et al.*, 2000). Although the nutrients in frozen products could be protected more than other storage methods, there could be high levels of losses during pre-freezing and pre-consumption periods (Fennema, 1988; Fennema, 1993; Buescher *et al.*, 1999). Thus, the method of production has an impact on the bioactive ingredients' levels, activity and bioavailability (Clydesdale *et al.*, 1991; Nicoli *et al.*, 1999). Vitamin C, being the most sensitive vitamin, is used as an indicator to measure the degree of changes owing to processing (Paulus, 1989; Giannakourou and Taoukis, 2003).

During the last decade, there has been a considerable interest among Turkish women (no matter of their occupational status) to prepare and store frozen vegetables at home. The vast majority of the literature on frozen vegetables involves the experimental layout to determine the effects of various factors on the product quality, but no attention has been given to the home-scale freezing operations. Hence this study was planned to evaluate the vitamin C levels and the factors affecting the vitamin content during home freezing. For this purpose, research was conducted in the frame of pre-freezing, freezing and frozen storage periods.

Materials and Methods

Fresh vegetable samples: Okra, potatoes, green beans, broccoli, spinach and peas were chosen as the study materials. As the freshness of the vegetables differs according to the retail marketing conditions, the vegetable samples (1kg) were obtained from local open market, supermarket and green grocery. In order to reflect the variation, samples were collected in 3 different days and analyzed on the same day of which they were obtained.

Pre-freezing and freezing sampling: The samples for this stage were selected according to the results of retail markets. The highest vitamin C contents were determined in the vegetables that were obtained from local open markets, so these samples included for freezing. Home freezing guidelines (Van Duyne, 1983; Reynolds, 1993; Mader, 1997) were used to prepare the vegetables for freezing. For each of the vegetables, samples were taken at all the stages (washing, trimming, tip cutting, slicing, blanching, frying, cooling and freezing) that could affect the vitamin C levels. All the selected vegetables were collected in 3 different days and frozen for the same purpose mentioned in fresh vegetable sampling.

Frozen storage sampling: Home type freezer (Arçelik 805NF) was used for both freezing and storing the vegetables. In order to measure the impact of frozen

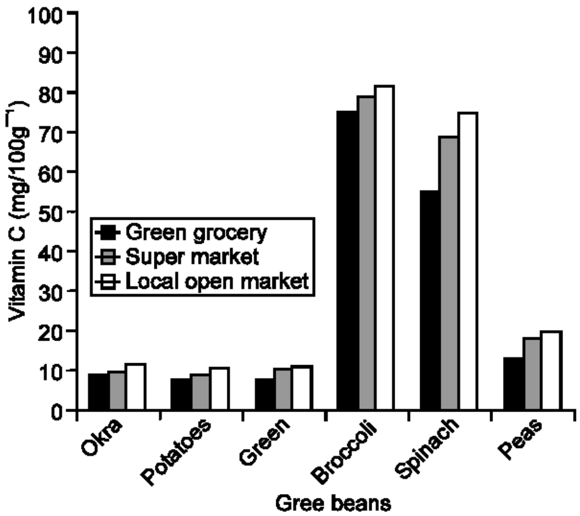

Fig. 1: The vitamin C content of fresh vegetables

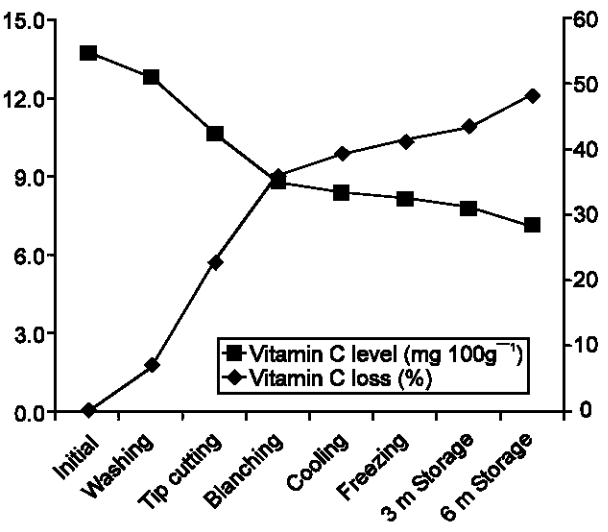

Fig. 2: Pre-freezing- freezing and storage effects on okra

storage, all the freezes were kept for 6 months at-18°C. The analyses were done after 3 and 6 months of storage.

Experimental preparation for the analyses: Each of the samples (10-70g, depending on the vegetable type) collected during pre-freezing, after freezing and frozen storage (month 3 and 6) were separately put into a glass container with 100 mL of a 3% metaphosphoric acid (HPO_3) and analyzed on the same day in Hacettepe University, Department of Nutrition and Dietetics Laboratories in Ankara. Before the analyses, all samples were homogenized for 1 minute in a Waring blender and vacuum-filtered through Whatman no 42 filter paper. The first 5 mL of the filtrate was discarded and the remaining filtrate was used for the analyses after making the necessary dilutions. This procedure was repeated three times for each of the sample.

Vitamin C analyses: Vitamin C levels were measured spectrophotometrically (8700 Model, Unicam) by the method in which 2,6-dichlorophenolindophenol dye is reduced by ascorbic acid (Anonymous, 1966). The details of the procedure are described elsewhere (Nursal and Yücecan, 2000).

Statistics: For the measured variables, mean and standard deviation ($\bar{x}$ ±S) is given as the descriptive statistics. Kruskal-Wallis variance analyses were used to test any difference between the applications in terms of vitamin C levels and the Multiple Comparisons method was used to define the parameter (application) that caused the significant difference (Conover, 1980).

Results

The analyses of fresh vegetables revealed that the highest vitamin C content for all of the samples was in local open market while the lowest was in green grocery samples (Fig. 1). Among the vegetables that were obtained from the local open market, broccoli and spinach had the highest vitamin C content (97.6±1.79 and 89.5±5.86 mg/100g, respectively), followed by peas (23.8±1.24), okra (13.6±1.49), potatoes (12.8±1.08) and green beans (12.7±0.76).

The initial vitamin C level of okra was decreased to 8.37±0.33 mg/100g (39.1% loss) after the pre-freezing operations (washing, tip cutting, blanching and cooling, respectively) (Fig. 2). Total vitamin loss reached to 47.9% at the end of 6 months of frozen storage. Vitamin C levels after the freezing process and subsequent storage period were significantly different ($p<0.05$) in comparison with the initial value. In the applications that are followed, the difference between the vitamin content of 'tip cutting and blanching', 'freezing and 3 months storage' and '3 and 6 months storage' was important ($p<0.05$).

Washing, peeling, slicing, frying and cooling were done to potatoes as pre-freezing applications of which resulted 48.0% vitamin loss (Fig. 3). Subsequent freezing and storage caused a total of 49.5 and 55.0% loss, respectively. With the exception of 'washing + peeling', all applications resulted in important differences ($p<0.05$) in the initial vitamin C levels. The vitamin C level differences were significant in the applications that followed each other ($p<0.05$), except that of 'frying-cooling' and 'cooling-freezing'.

The initial vitamin C content (12.7±0.76 mg/100g) of green beans decreased 24.7% after blanching (9.5±0.21 mg/100g). This value further decreased to 7.3±0.26 mg/100g by a total loss of 42.4% (Fig. 4). Each application was found to cause statistically important ($p<0.05$) difference in the vitamin content when compared with the

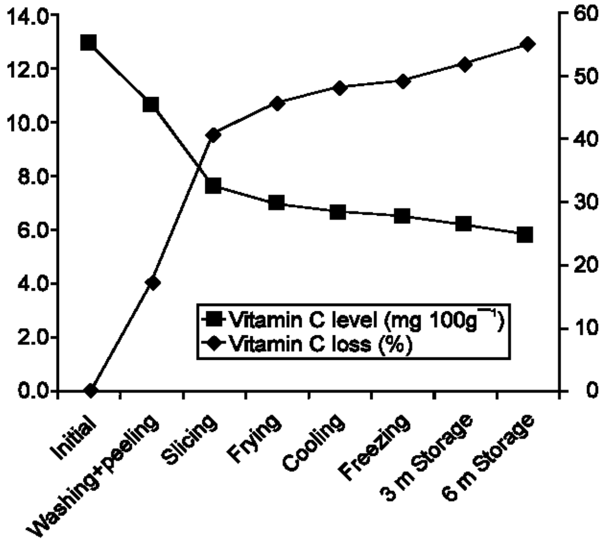

Fig. 3: Pre-freezing- freezing and storage effects on potatoes

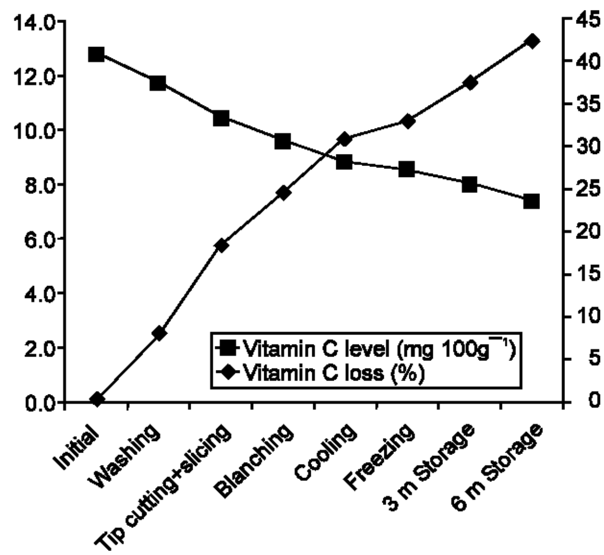

Fig. 4: Pre-freezing-freezing and storage effects on green beans

initial value. In the applications that are followed, only the difference after 'cooling and freezing' wasn't significant ($p>0.05$).

Washing, blanching, cooling was done as pre-freezing applications to fresh broccoli (97.6±1.79 mg/100g). Total vitamin loss was 31.3% just before freezing and this loss reached to 66.5% with a mean vitamin C level of 32.7±4.22 mg/100g (Fig. 5). Except washing, each application was found to cause statistically important ($p<0.05$) difference in the initial vitamin content. The vitamin C level differences after 'washing and blanching' and '3 and 6 months storage' were significant ($p<0.05$) in which the applications that are followed.

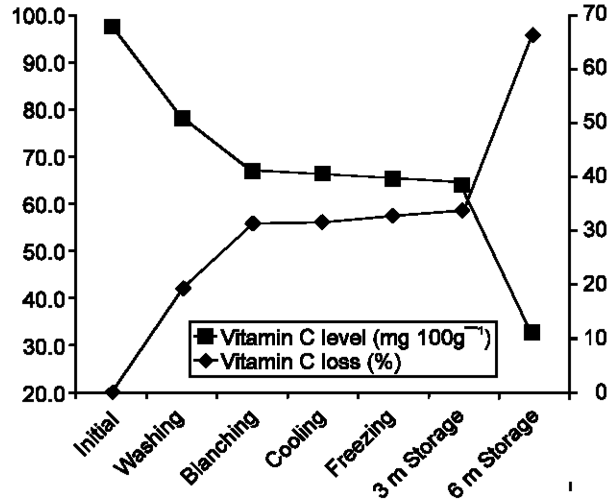

Fig. 5: Pre-freezing-freezing and storage effects on broccoli

Vitamin C content of fresh spinach samples were 89.5±5.86 mg/100g, while this amount decreased to 63.6±4.28, 59.9±4.64 and 32.2±4.89 mg/100g respectively after blanching (29.0% loss), freezing (33.1% loss) and 6 months of storage (64.0% total loss) (Fig. 6). Each application (except root cutting + washing) was found to cause significant ($p<0.05$) difference in the initial vitamin content. In the applications that are followed, the difference in vitamin contents after 'root cutting+washing and blanching' and '3 and 6 month storage' was important ($p<0.05$).

The first application that caused significant difference ($p<0.05$) in the initial vitamin C content (23.8±1.24 mg/100g) of peas was blanching (13.1±0.37 mg/100g). At the end of frozen storage period, vitamin C content of peas was decreased to 10.5±0.45 mg/100g with a total loss of 55.7% (Fig. 7). All applications were found to differ significantly from the initial vitamin content ($p<0.05$). In the applications that are followed, the difference between the vitamin content of 'blanching and cooling' and 'freezing and 3 months storage' was important ($p<0.05$).

Discussion

The vitamin C contents in this study, depending on the vegetable type, affected from both pre-freezing applications and frozen storage. The preparation of the vegetables for home freezing naturally includes different processes except blanching and cooling, though blanching period may also vary according to the vegetable type.

Before the freezing process, the vitamin C loss in okra was 35.9% as a result of washing, tip cutting, blanching (3 minutes in boiling water) and cooling (3-3.5 minutes under cold tap water) (Fig. 2). The two of the most

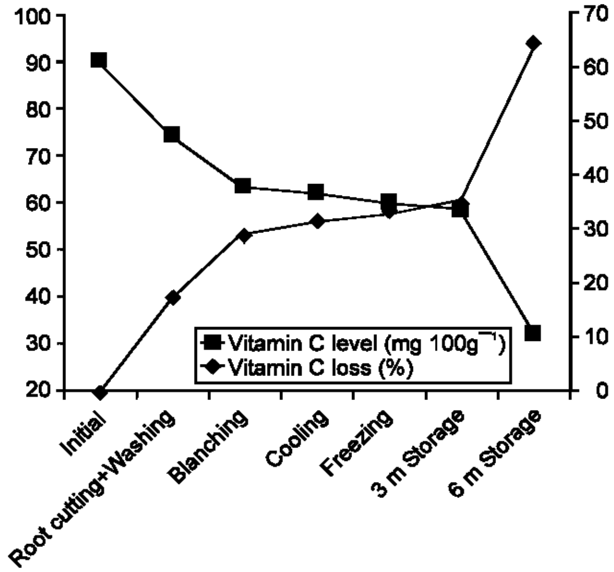

Fig. 6: Pre-freezing-freezing and storage effects on spinach

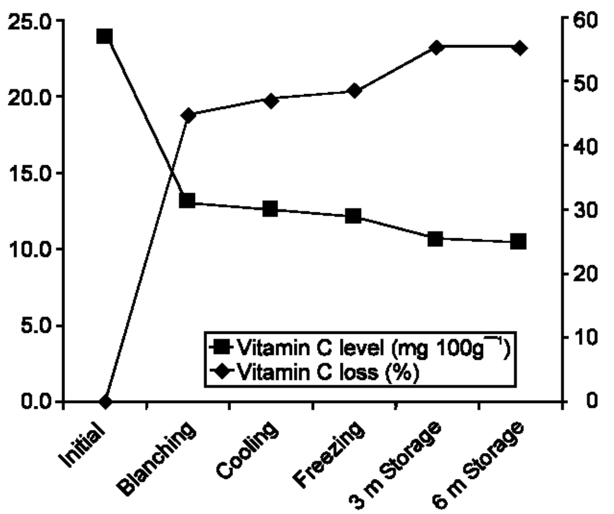

Fig. 7: Pre-freezing-freezing and storage effects on peas

important factors on the final quality of frozen product are the quality of the raw material and its suitability for freezing (Arthey, 1993; Cano, 1996). The degree of maturity can directly affect the quality and the blanching procedure should be selected according to the variety of okra (Ekinci and Kiliç, 1994). These factors generally cannot be considered during home freezing, so the important losses before freezing in this study can be related to these factors.

The initial vitamin C content of potatoes (12.8±1.08 mg/100g) was decreased by 17.7% after washing and peeling ($p>0.05$), slicing in strips increased this loss to 41.0% ($p<0.05$). Potato strips were fried for 5 minutes instead of blanching and this application caused a 45.7% decrease in the initial vitamin C level ($p<0.05$) (Fig. 3). This loss could be attributed to the tissue disruption initiated by peeling and slicing and acceleration by high temperature treatment (frying) which potentially increases the oxidation of the vitamin (Garrote *et al.*, 1988; Somogyi, 1990).

Washing, tip cutting and slicing the fresh green beans caused an 18.3% loss in the initial vitamin content ($p<0.05$) (Fig. 4). Such a loss during these applications is inevitable, so vegetables that are prepared along with the proper nutritional principles must be processed without any delay (Somogyi, 1990; Makhlouf *et al.*, 1995). Leaching into the blanching water and also hot environment increases the vitamin losses further in physically damaged vegetable tissue (Selman, 1994; Buescher *et al.*, 1999). This effect was reflected as 24.7 and 30.9% total loss after blanching (3 minutes in boiling water) and cooling (4 minutes under cold tap water) in this study.

Broccoli samples were only washed (19.6% vitamin loss) before blanching. The fresh broccoli samples in this study was marketed as ready- to-cook that they were already cut into pieces, so this may cause more vitamin to leach out during washing (Somogyi, 1990). The initial vitamin levels decreased 31.3 and 32.0% after blanching (3 minutes in boiling water) and cooling (2.5 minutes under cold tap water) (Fig. 5). Both of the applications corresponded significant ($p<0.05$) changes in the initial value indicating more detrimental effect of damaged tissue by a contact with heat and water (Clydesdale *et al.*, 1991; Selman, 1994).

Root cutting and washing without any further cutting was applied to the fresh spinach and this procedure resulted a 17.5% loss in the initial vitamin content ($p>0.05$). This loss increased to 29.0 and 31.4% after blanching 2 minutes in boiling water and cooling 2 minutes under cold tap water (Fig. 6). As the vegetables with a high surface to volume ratio, such as spinach and broccoli, are more susceptible to water and heat, blanching and cooling techniques without any water have been recommended for broccoli and spinach (Fennema, 1988; Wu *et al.*, 1992; Howard *et al.*, 1999).

In this study, peas were not washed separately; washing was done during blanching (1.5 minutes in boiling water). The decrease with a 45.0% loss in the initial vitamin content after blanching was significantly different ($p<0.05$) (Fig. 7). The studies on peas indicated a range between 4 and 45% loss after blanching and this decrease was attributed to the size and kind of the peas that is independent from the blanching process (Lee *et al.*, 1982; Selman, 1994; Cano, 1996). Generally, during the preparations for home freezing, pea size is not considered when setting the blanching condition and time.

It has been well shown that if raw material that is in good quality is used and proper pre-freezing operations is applied, freezing alone have no negative effect on the vitamin content (Fennema, 1993; Selman, 1994). In this study, all the vegetables were frozen in a home-type freezer for 24 hours at-18°C without any significant difference to the vitamin C contents in comparison with the previous cooling stage.

Since frozen vegetables are not consumed immediately, they were kept in the same freezer (-18°C) for 6 months; and analyzed after 3 and 6 months to determine the probable storage changes. In frozen okra, potatoes and green beans vitamin C levels continued to decrease till the end of 6 months of storage (Fig. 2-4). The differences between the vitamin C contents at month 3 and 6 were significant ($p<0.05$). Although no significant change observed during 3 months of storage in both broccoli and spinach, very important decreases occurred in the last 3 months ($p<0.05$) (Fig. 5, 6). On the contrary, the vitamin content of frozen peas significantly ($p<0.05$) decreased in the first 3 months of storage and stayed constant during the rest of the storage period (Fig. 7). It was reported that in order to minimize the vitamin C losses during frozen storage, raw vegetables of good quality, proper inactivation of the oxidative enzymes and prevention of storage temperature fluctuations are the key issues to be considered (Wu *et al.*, 1992; Howard *et al.*, 1999).

The chemical, biochemical and physical reactions may not completely stop during frozen storage, so the rates of these reactions can differ according to the storage temperature. If the vegetable is not packed with a water vapor and oxygen proof material, the ice crystals on the surface of the vegetable may be replaced by air, hence on the surfaces which directly contacts with oxygen, leading to oxidation of susceptible molecules like ascorbic acid. This kind of destruction can be accelerated in an increase in the storage temperature (i.e. opening of the freezer door frequently). As the vegetables which have high surface to volume ratio are more prone to this kind of loss, glazing which is applied during commercial freezing of spinach provides a good protection (Fellows, 1988; Persson and Löndahl, 1993). The period which the original quality conserved is called as ‘high quality storage life’. This period starts with the freezing and ends at the time in which the first perceived loss in quality (Fellows, 1988; Persson and Löndahl, 1993; Cano, 1996). For green beans and peas at-18°C, this period is 10 months and 6 months for spinach, while at-12°C, it is 3 months for green beans and peas and 2 months for spinach (Fellows, 1988; Cano, 1996). The critical period for packed frozen vegetables are during retail marketing and home storage, as storage temperatures could be higher than the required one and temperature fluctuations could be inevitable (Cano, 1996). The results of this study indicate that under uncontrolled conditions (such as home freezing and storage); the relative ‘high quality life’ could be during 3 months of storage for all the vegetables analyzed.

The nutrient losses in vegetables that are regarded as ‘hidden losses’ can occur between harvesting and consumption. From the consumer’s perspective, some inevitable nutrient losses may reach to a level that can affect the optimal nutritional benefits of vegetables unless appropriate preparation methods are used. Hence, one of the responsibilities of nutritionists, dietitians and food scientists is to disseminate the information regarding proper food preparation methods.

Acknowledgment

This research was supported by Hacettepe University Research Fund (98.T01.102.006).

References

Anonymous, 1966. Methods of Vitamin Assay. Interscience Publishers, New York, USA, pp: 237-307.

Arthey, D., 1993. Freezing of vegetables and fruits. In: Frozen Food Technology (Ed. by C.P. Mallett), Chapman and Hall, London, UK, pp: 237-269.

Buescher, R., L. Howard and P. Dexter, 1999. Postharvest enhancement of fruits and vegetables for improved human health. Hortic. Sci., 34: 1167-1170.

Cano, M.P., 1996. Vegetables. In: Freezing Effects on Food Quality (Ed. by L.E. Jeremiah) Marcel Dekker, New York, USA, pp: 247-298.

Clydesdale, F.M., C.T. Ho, C.Y. Lee, N.I. Mondy and R.L. Shewfelt, 1991. The effects of postharvest treatment and chemical interactions on the bioavailibility of ascorbic acid, thiamin, vitamin A, carotenoids and minerals. Critical Rev. Food Sci. Nutr., 30: 599-638.

Conover, W.J., 1980. Practical Non Parametric Statistics. John Wiley and Sons, New York, USA.

Davey, M.W., M. Van Montagu, D. Inze, M. Sanmartin, A. Kanellis, N. Smirnoff, I.J.J. Benzie, J.J. Strain, D. Favell and J. Fletcher, 2000. Plant L-ascorbic acid: chemistry, function, metabolism, bioavailability and effects of processing. J. Sci. Food Agri., 80:825-860.

Ekinci, A. and O. Kiliç, 1994. Effect of pre-freezing processes on the product quality during frozen storage of okra. Gida, 19: 243-248.

Favell, D.J., 1998. A comparison of the vitamin C content of fresh and frozen vegetables. Food Chem., 62: 59-64.

Fellows, P., 1988. Freezing. In: Food Processing Technology, Principles and Practice, Ellis Horwood, Chichester, England, pp: 375-400.

Fennema, O., 1988. Effects of freeze preservation on nutrients. In: Nutritional Evaluation of Food Processing (Ed. by E. Karmas and R.S. Harris). Van Nostrand Reinhold, New York, USA, pp: 269-317.

Fennema, O., 1993. Frozen foods: challenges for the future. Food Australia, 45: 374-380.

Garrote, R.L., E.R. Silva and R.A. Bertone, 1988. Effect of freezing on diffusion of ascorbic acid during water heating of potato tissue. J. Food Sci., 53: 473-474,487.

Giannakourou, M.C. and P.S. Taoukis, 2003. Kinetic modeling of vitamin C loss in frozen green vegetables under variable storage conditions. Food Chem., 83: 33-41.

Hoard, N.F. and G.W. Chism, 1996. Characteristics of edible plant tissues. In: Food Chemistry (Ed. by O.R. Fennema). Marcel Dekker, New York, USA, pp: 943-1012.

Howard, L.A., A.D. Wong, A.K. Perry and B.P. Klein, 1999. β-Carotene and ascorbic acid retention in fresh and processed vegetables. J. Food Sci., 64: 929-936.

Lee, C.Y., L.M. Massey and J.P. Van Buren, 1982. Effects of post-harvest and processing on vitamin contents of peas. J. Food Sci., 47: 961-964.

Mader, S.L., 1997. Freezing Vegetables. HYG-5333-97, Human Nutrition, The Ohio State University Extension, USA.

Makhlouf, J., J. Zee, N. Tremblay, A. Belanger, M.H. Michaud and A. Gosselin, 1995. Some nutritional characteristics of beans, sweet corn and peas (raw, canned and frozen) produced in the province of Quebec. Food Res. Int., 28: 253-259.

Nicoli, M.C., M. Anese and M. Parpinel, 1999. Influence of processing on the antioxidant properties of fruit and vegetables. Trends in Food Sci. Tech., 10: 94-100.

Nursal, B. and S. Yücecan, 2000. Vitamin C losses in some frozen vegetables due to various cooking methods. Nahrung, 44: 451-453.

Paulus, K., 1989. Vitamin degradation during food processing and how to prevent it. Bibliotheca Nutritio et Dieta, 43: 173-187.

Persson, P.O. and G. Löndahl, 1993. Freezing technology. In: Frozen Food Technology (Ed. by C.P. Mallett). Chapman and Hall, London, UK, pp: 20-58.

Reynolds, S., 1993. So Easy to Preserve. Bulletin 989, College of Agricultural and Environmental Sciences, Cooperative Extension Service, University of Georgia, USA.

Selman, J.D., 1994. Vitamin retention during blanching of vegetables. Food Chem., 49: 137-147.

Somogyi, J.C., 1990. Influence of food preparation on nutritional quality. J. Nutr. Sci. Vitaminol., 36: S1-S6.

Van Duyne, F.O., 1983. How to prepare fruits and vegetables for freezing. Circular 602, College of Agriculture, Extension Service in Agriculture and Home Economics, University of Illinois, USA.

Wu, Y., A.K. Perry and B.P. Klein, 1992. Vitamin C and β-Carotene in fresh and frozen green beans and broccoli in a simulated system. J. Food Quality, 15: 87-96.