African Journal of Biotechnology Vol. 4 (1), pp. 102-103, January 2005
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2005 Academic Journals

Full Length Research Paper

Retention of β-carotene in frozen carrots under varying conditions of temperature and time of storage

Debjani Dutta, Utpal Raychaudhuri, Runu Chakraborty*

Department of Food Technology and Biochemical Engineering, Jadavpur University, Kolkata – 700032, India.

Accepted 15 August, 2004

Carrots were blanched and stored in a freezer to study the retention of β-carotene. Retention was found to be better in 3 min blanched samples than in 5 min ones. There was an increase in β-carotene content in carrots after 5 days at all storage temperatures: 0, –8, –14, and –18°C. Decrease was found to be insignificant compared to the initial value even after 80 days of storage time at –18°C and for 3 min blanch time.

Key words: Carrots, β-carotene, blanching, freezing, activation energy, storage time.

INTRODUCTION

The role of β-carotene has been subjected to vigorous studies in the recent years. Numerous epidemiological studies under diverse conditions have repeatedly demonstrated that populations that consume large amount of fruits and vegetables rich in β-carotene have dramatically lower risk of contracting various cancers (Wald et al., 1988). β -carotene is also claimed to protect against Alzheimer's disease (Zaman et al., 1992) and act as a suppressor of the Human Immuno Deficiency virus (Garewal et al., 1992).

The nutritional properties of β-carotene have been studied extensively, and its role as an antioxidant has been widely reported (Terao, 1989; Palozza and Krinsky, 1992). The tissue maintenance function of vitamin A is apparently related to its antioxidant function, most or all of which can be taken over by β-carotene. β -carotene is the principal precursor of vitamin A, which is involved in vision, cell differentiation, synthesis of glycoproteins, mucus secretion from the epithelial cells, and overall growth and development of bones (Wolf, 1980). Diets that are deficient in vitamin A have precipitated the death of children from measles, diarrhea, and other diseases because of impaired immunity (Sommer et al., 1983).

Thus the focus in recent years has been the methods. The effect preservation and retention of β-carotene in different fruits and vegetables by various of cooking and different methods of food preservation on the β-carotene content of some vegetables and fruits indigenous to Kenya (Gomez, 1981), India (Dikshit et al., 1988), Pakistan (Nagra and Kahn, 1988), Thailand (Speek et al., 1990), Bangladesh (Rahman et al., 1990) and Malaysia (Tee and Lim, 1991) have been evaluated. Blanching followed by freezing is an effective preservation technique for the retention of β-carotene in fruits and vegetables. Frozen food products maintain most of the physical, chemical and sensory properties of β-carotene. But, many of the physical, chemical, enzymatic and microbial changes which contribute to frozen food quality are highly dependent on storage conditions namely the combined effects of time and temperature. It is well known that abusive temperature conditions during storage and handling may lead to frozen products of inferior quality (Wells et al., 1987).

β-Carotene has been found in most yellow, orange, dark green leafy vegetables and fruits such as kale, pumpkin, spinach, papaya, apricots, and peaches. Carrots are said to be a major source of β-carotene. Carotene, a yellow orange pigment, is present in the chromoplasts in fresh carrot. Maintenance of the naturally colored pigments in stored foods has been a major challenge in food processing (Clydesdale et al., 1970; Ihl et al., 1998). Duration and temperature of storage are two of the important factors responsible for the loss of pigments and color, and special care must be taken to produce food that retains its bright attractive color during freezing. Change in color during freezing may therefore be used as a tool to evaluate the product quality.

*Corresponding author. E-mail: crunu@hotmail.com.

Our objective was to determine the change in β-carotene content of carrots of Indian variety with regard to its blanching time and its retention when subjected to different temperatures and times of storage, and also to introduce a graphical interpretation of food quality changes with respect to the β-carotene content of carrots with time and temperature of storage.

KINETIC MODEL

Time and temperature related changes in food quality could be modeled with the concepts of chemical kinetics. The kinetic parameter like rate constant and activation energy provide useful information of the quality changes, that is, the change in the concentration of β-carotene. The change is an index of concentration monitored under isothermal storage conditions and is modeled with the differential equation: -

$$d[C]/ dt = - K [C]^n \quad (1)$$

Where, C = concentration of β- carotene
t = time
K = reaction rate constant
n = reaction order (a curve fitting parameter)

The quality response of most foods has been observed to follow either a zero order (n= 0) or a first order (n= 1) reaction model.

The temperature dependence of the rate constant is often given by the Arrhenius relationship. The form of Arrhenius equation: -

$$k= k_0 \exp (-E_a/RT) \quad (2)$$

Where k_0 = constant, independent of temperature (also referred to as the pre exponential factor)
E_a = activation energy
R = ideal gas constant
T = absolute temperature.

When equation 2 is plotted as ln (k) versus 1/T, the result is a straight line, since

$$\ln (k) = \ln k_0 – Ea/R (1/T) \quad (3)$$

The values of k_0 and Ea may then be calculated from the slope and intercept of the plot respectively. Thus, by, estimating k_0 and E_a, the concentration of β-carotene can be predicted for combination of storage time (t) and temperature (T).

MATERIALS AND METHOD

Carrots (*Daucus carota*) grown in the suburbs around Kolkata were bought from the local market. The carrots were washed thoroughly, peeled and weighed. Carrots were cut into small pieces and blanched for 3 min or 5 min in boiling water and immediately cooled in tap water. They were dried with filter paper and sealed in polythene bags and stored at 0 , –8, –14, or –18°C in a Chest Freezer and were analysed for their β-carotene content at intervals of 5, 10, 20, 40 and 80 days.

The estimation of β-carotene was done after extraction of the sample with diacetone alcohol and petroleum ether and further purification with diacetone alcohol, methanolic KOH and distilled water. The resulting solution was filtered with anhydrous sodium sulphate and read on a spectrophotometer at 450 nm against petroleum ether as a blank (Ranganna, 1986). All the analytical work were repeated three times

Data Analysis

Mean concentration of β-carotene for each treatment was compared according to the multiple means comparison technique of Fishers LSD test (α = 0.05), under the restriction of a significant treatment effect for a 3 way analysis of variance (temperature, blanch time, concentration of β-carotene). Graphical modeling of the concentration changes of β-carotene was conducted with the software package STATISTICA 5.0 / Graph.

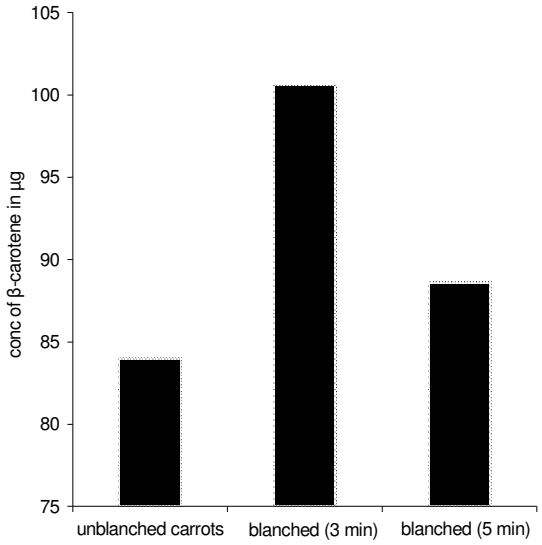


Figure 1. Variation in concentration of β-carotene in unblanched and blanched samples**.**

RESULTS AND DISCUSSION

Storage study

By modeling changes in the concentration of β-carotene content as a first order reaction, the resulting pre exponential factor k_0 and activation energy for 3 min blanch time were determined to be 11.9358 X 10^3 min^{-1} and 31.299 KJ/mol, respectively. For 5 min blanch time it was 83.71 X 10^2 min^{-1} and 31.23 KJ/mol, respectively.

The beta-carotene content of carrots blanched for 3 and 5 min and stored for a period of 80 days were compared using Fisher's LSD test. A significant

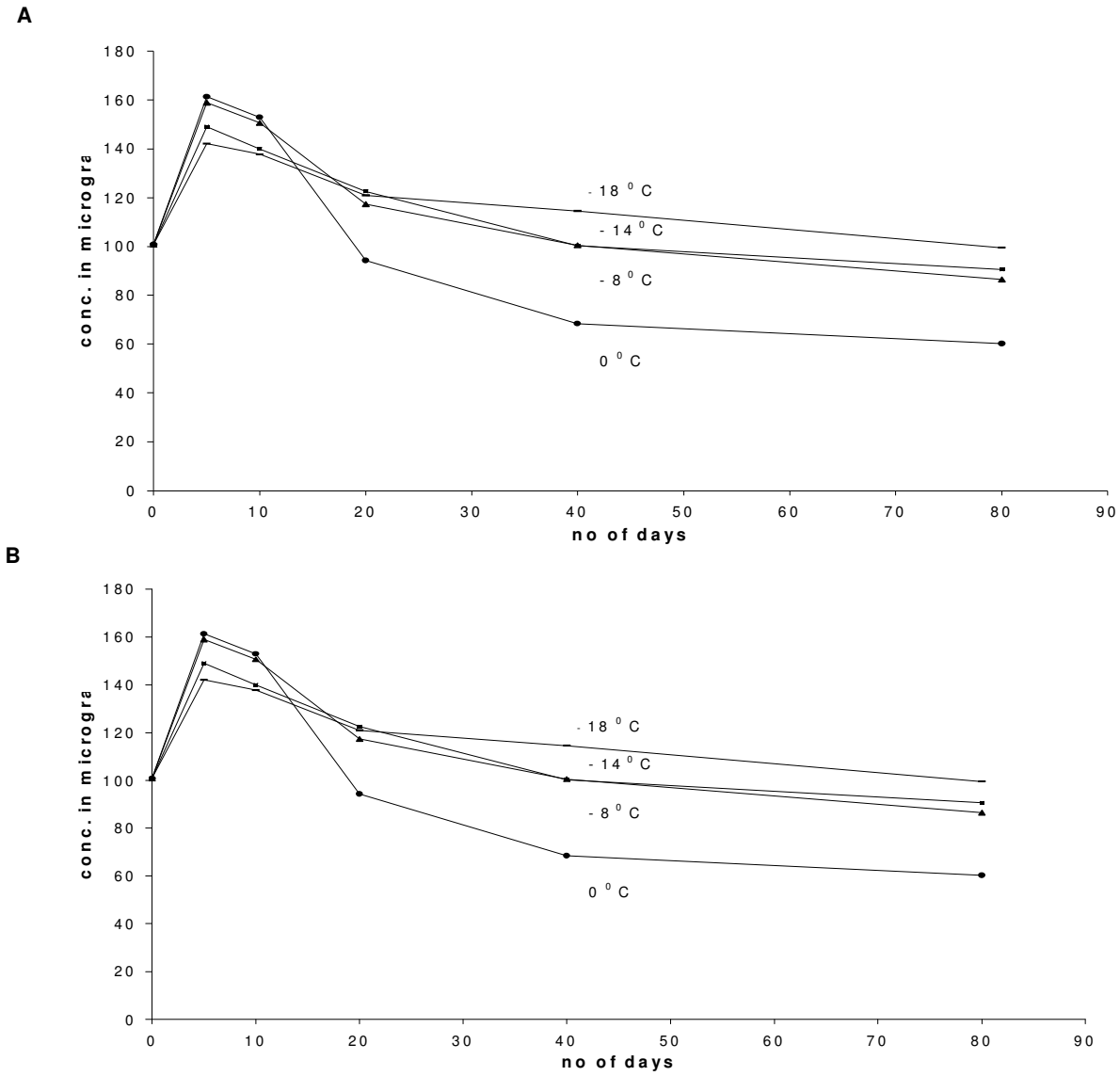


Figure 2. Comparison of β-carotene at different temperatures for 3 (A) and 5 (B) min blanch time.

difference is found in the beta-carotene content of carrots blanched for 3 and 5 min, respectively.

Blanching results in an increase in the β- carotene content (Figure 1), perhaps because of greater chemical extractability and loss of moisture and soluble solids which further concentrate the sample. Inactivation of certain oxidative enzymes takes place and it results in the breakdown of some structures leading to a higher bioavailability of β-carotene (Guerra–Vargas et al., 2001). Anderson et al. (1978), Braumam et al. (1982) and Grimme and Brown (1984) showed that carotenoids in plants are bound by protein. Heat treatment such as blanching, cooking and steaming help to release bound carotenoids and render them to be easily extractable and hence the β-carotene content has increased from 84 (fresh sample) to 100.8 µg/g (in 3 min. blanched sample) (Figure 1).

Carrots blanched for 3 min have higher β-carotene content (100.8 µg /g) than those blanched for 5 min (88.6 µg/g. It might be possible that some carotene have leached into the water solution due to prolong treatment. The carotene bound proteins are water soluble and blanching the carrots for a long time could result in the release of carotene from the carotene bound protein into the water.

An increase in β-carotene has been observed in all the four temperatures after the blanched carrots were stored for a period of 5 days. (Figures 2a and 2b).The increase is as high as 60% for 3 min blanching time and 30% for 5 min blanching time. The increase in the β-carotene

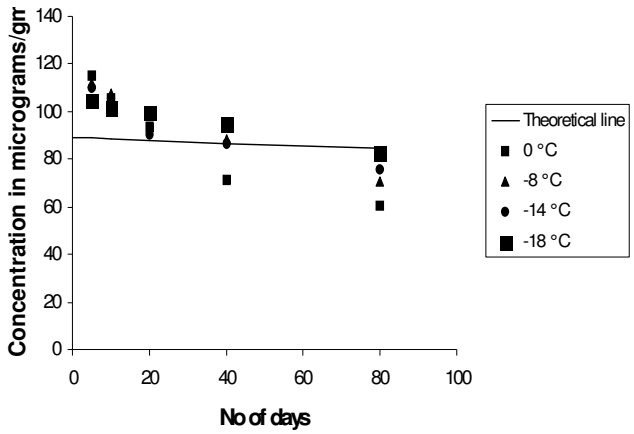


Figure (3a).

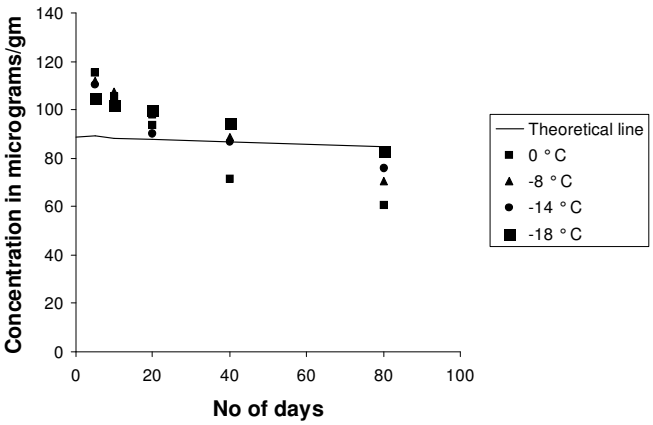


Figure (3b).

Figure 3. Variation in β-carotene in carrots with storage time for 3 (A) and 5 (B) min blanch time.

content during the first 5 days of storage could result from the continuation of physiochemical reaction such as biochemical synthesis, metabolic inter conversion and structural rearrangement. It is also reported that steaming results in greater than 100% retention of β-carotene in vegetables because of the release of carotene from the denatured carotene binding proteins (Dietz and Erdman, 1989).

But as the storage period increases, there is a significant decrease in the β-carotene content of carrot. The β-carotene content decreases more drastically over the period of 80 days. This loss of β-carotene could be due to non-oxidative changes (cis - trans isomerization, epoxide formation or heat degradation of tissues) (Aruna et al., 1999) or oxidative changes on exposure to light and oxygen.

The change in β- carotene content is insignificant compared to the initial value when the samples are stored at –18°C. There is a gradual decrease of the β-carotene content as the temperature is raised from –18 to 0°C, the loss being more significant at 0°C. The decrease is about 40.20% for 3 min blanching time and about 31.54 % for 5 min blanching time for a storage period of 80 days at 0°C, whereas for – 18°C it is 1.2 % for 3 min blanch time and 6.5% for 5 min blanch time.

The experimental β-carotene content values deviates from the theoretical value, as the temperature conditions are not considered individually in the model. Thus, from Figure 3 we can conclude that β-carotene content does decrease with temperature. Thus, low temperature freezing causes minimal loss of β-carotene because of retention of most of the nutrient at low temperature.

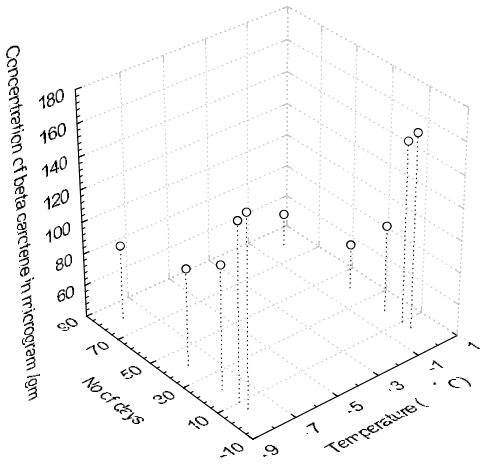


Figure (4a).

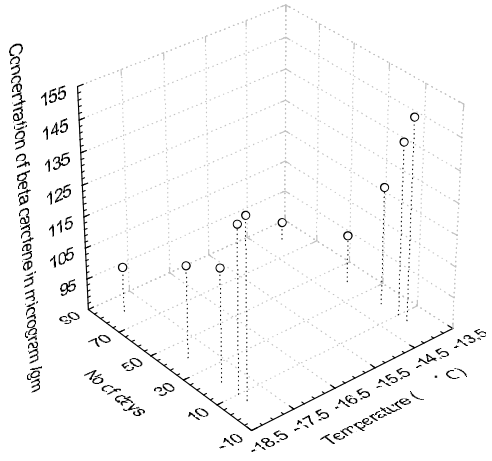
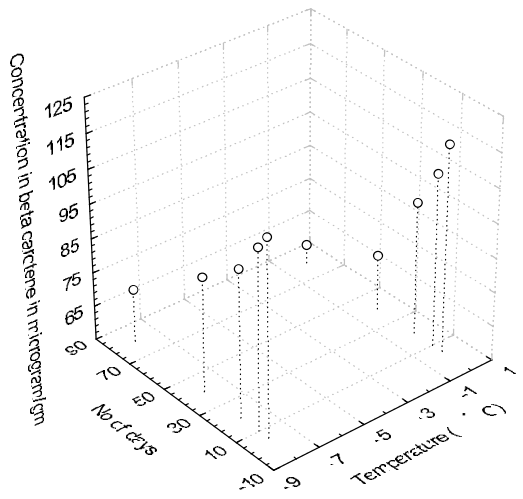


Figure (4b).

Figure 4. Three dimensional scatter plot for for 3 (A) and 5 (B) min blanch time at 0 and –8°C.

5A



5B

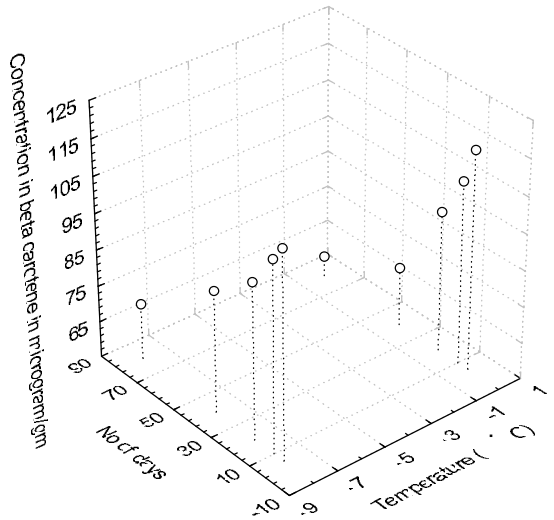
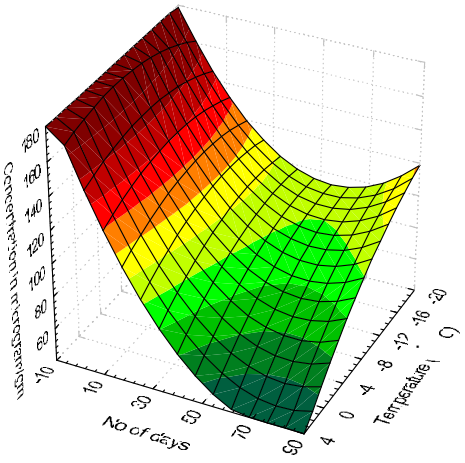


Figure 5. Three dimensional scatter plot for for 3 (A) and 5 (B) min blanch time at 0 and –8°C.

6A



6B

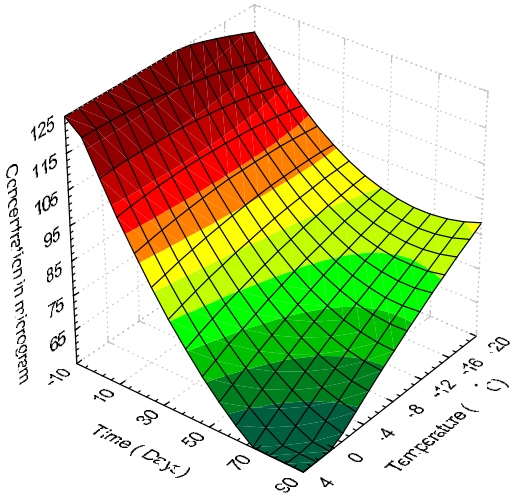


Figure 6. Quality response surface" for 3 (A) and 5 (B) min blanch time.

Quality response analysis

The time temperature related quality response for the changes in the concentration of β-carotene in carrots for 3 min and 5 min blanch times are depicted in the three dimensional scatter plots shown in Figures 4 and 5 which indicates that the decrease in β-carotene content is most insignificant for –18°C and for 3 min blanch.

A graphical representation of the time–temperature, concentration changes of β-carotene in carrots is shown in Figure 6. In these three dimensional representation, the β-carotene content as predicted by the first order reaction and Arrhenius equation is depicted as a Quality Response Surface (different from Response Surface Methodology). A Quality Response Surface in this study is intended to represent a product quality change or quality response, resulting from the temperature conditions encountered during frozen storage. The "Quality Response Surface" as defined here means a graphical mapping of the concentration changes of β-carotene which correspond to a time temperature combination. As seen from Figures 6a and 6b the three-dimensional visualization of the Quality Response Surface marked with lines and contours is somewhat difficult. Thus, an application of this graphical representation of "Quality Response Surface" is shown in Figure 7.

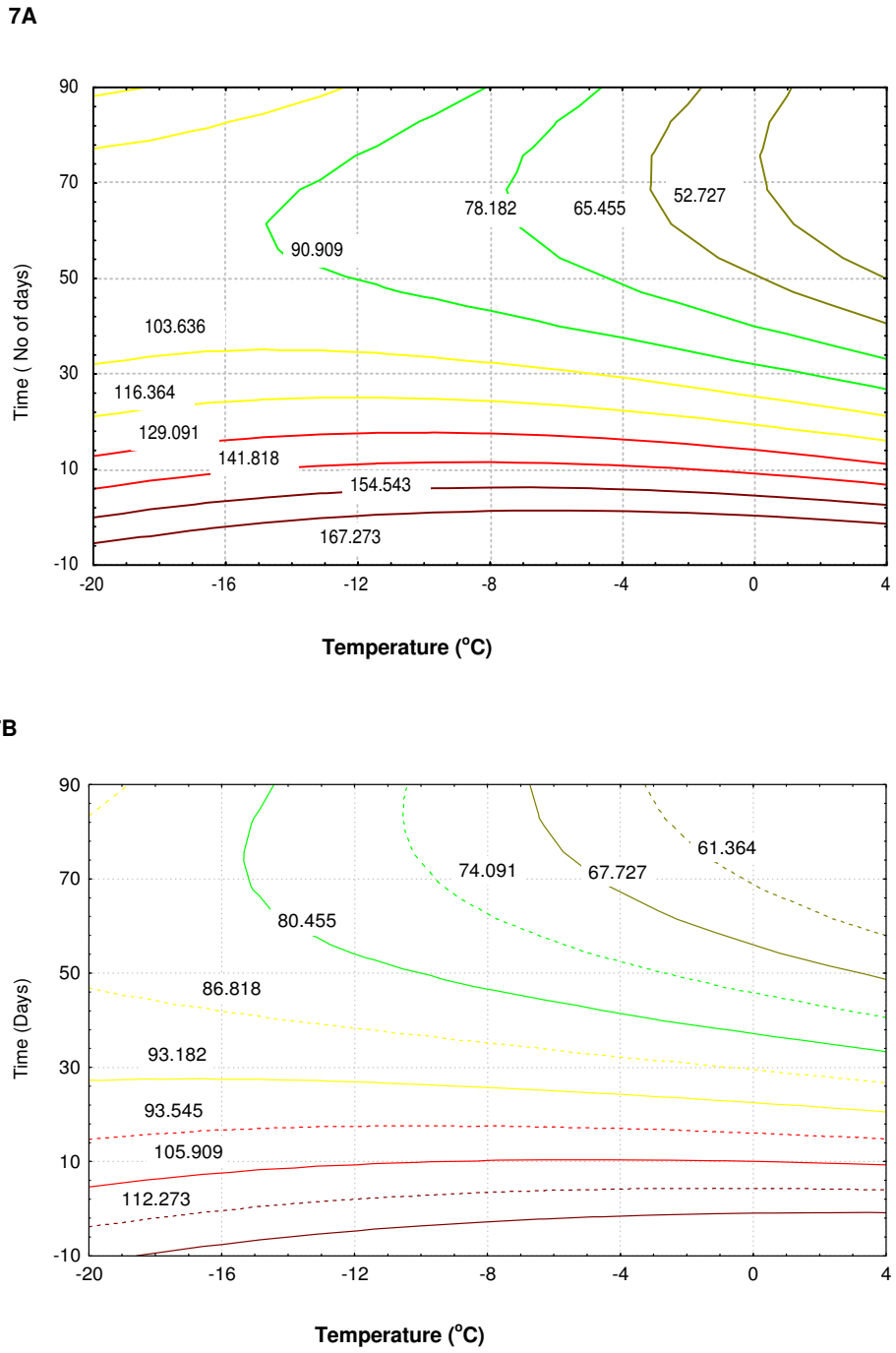


Figure 7. Quality contour diagram for 3 (A) and 5 (B) min blanch time.

Quality contour diagram

The contour diagram for β-carotene content "Quality Response Surface" is shown in Figure 7. The planar depiction of "Quality Response Surface" in Figure 6 illustrates the dominant contribution of the quadratic and interaction terms to the model. This means that the concentration of the β-carotene is dependent on the temperature and storage time. Lines of constant time are shown as horizontal lines extending from the time axis across the plot. Similarly, lines of constant temperature are drawn vertically from the temperature axis.

The axes of the quality contour diagram and the contours of constant β-carotene content provide a complete visual relationship between time, temperature and β-carotene content. Given the measures of any two of the three parameters, the third one can be determined. For example, the β- carotene content for 30 days at –16°C for

3 min blanch time would be 110 µg/g (approx) where as for the same at 5 min blanch time will be 93.182 µg/g (approx). Time and temperature combinations, which yield values between contours, can be estimated by interpolating between neighboring contours. The spacing of the contour lines provide information about the rate at which the β-carotene changes. Contours, which appear at closely spaced intervals (when moving along lines of constant temperature), represent the steepest portions of the "Quality Response Surface." This corresponds to the temperature conditions which result in more rapid change in β- carotene content.

In conclusion, β-carotene content does decrease when kept for a storage period of 80 days but the decrease is more evident at 0°C than at lower temperatures. 3 min blanch treatment is a better way of retaining beta-carotene than 5 min blanch treatment. Low temperature freezing retains most of the β-carotene in carrots and retention is highest at –18°C for both 3 min and 5 min blanching times.

ACKNOWLEDGEMENT

This research work is financially supported by the Departmental Special Assistance (DSA) programme under University Grant Commission (UGC), India.

REFERENCES

Anderson JM, Waldron JC, Thorne SW (1978).Chlorophyll protein complexes of spinach and barley thylakoids. FEBS Letl. 92: 227-233.

Aruna K, Vimala V, Dhanalakshmi K, Reddy V (1999). Physio-chemical changes during storage of Papaya fruit (*Carica papaya* L.) Bar (Thandra). J. Food Sci. Technol. 36: 428- 433.

Braumann T, Weber G, Grimme LH (1982). Carotenoid and Chlorophyll composition of light harvesting and reaction center proteins of the thylakoid membrane. Photobiochem. Photobiophys. 4: 1- 8.

Clydesdale FM, Fleischman DL, Francis FJ (1970). Maintenance of color in processed green vegetables. J. Food Prod. Dev. 4:127-130.

Dietz JM, Erdman JW (1989). Effects of thermal processing upon Vitamins and proteins in foods. Nutr. Today July/ August: 6-15.

Dikshit SN, Udipi SA, Rao A, Manohar V (1988). Separation of carotenoids and estimation of β-carotene content of selected Indian Food and food preparations by HPLC. J. Food Sci. Technol. 25: 39-41.

Garewal HS, Ampel NM, Watson RR, Prabhala RH, Dols CL (1992). A preliminary trial of β -carotene in subjects infected with the Human Immunodeficency Virus. J. Nutr. 122: 728-731.

Gomez MI (1981). Carotene content of some green leafy vegetables of Kenya and effects of dehydration and storage on carotene retention. J. Plant Foods. 3:231-244.

Grimme LH, Brown JS (1984). Functions of chlorophylls and carotenoids in thylakoid membranes. Adv. Photosyn. Res. 2:141-144.

Guerra-Vargas M, Jaramillo-Flores ME, Dorantes-Alvarez L, Hernandez-Sanchez H (2001). Carotenoid retention in canned pickled Jalapeno peppers and carrots as affected by Sodium Chloride, Acetic Acid and Pasteurization. J. Food Sci. 66:620-625.

Ihl M, Monslaves M, Bifani V (1998). Chlorophyllase inactivation as a measure of blanching efficiency and color retention of artichokes (Cynara scolymus L). Lebensm Wiss Technol. 31: 0 – 56.

Nagra SA, Kahn S (1988). Vitamin A (β - carotene) losses in Pakistani cooking. J. Sci. Food Agric. 46: 249-251.

Palozza P, Krinsky NI (1992). Communication. β-Carotene and α-tocopherol are synergistic antioxidants. Arch. Biochem. Biophys. 297:184- 187.

Rahman MM, Wahed MA, Ali MA. (1990). β-Carotene losses during different methods of cooking green leafy vegetables in Bangladesh. J. Food Composition Anal. 3: 47-53.

Ranganna S (1986).Handbook of Analysis and Quality Control for Fruit and Vegetable Products, 2nd ed. Tata Mcgraw Hill Publishing Co Ltd. New Delhi.

Sommer A, Hussain G, Tarwotjo I (1983). Increased mortality in children with mild Vitamin A deficiency. Lancet 1: 585-585.

Speek AJ, Speek – Saichua S, Schreurs WHP (1988).Total carotenoids and β - carotene contents of Thai vegetables and effects of processing. Food Chem. 27:245-251.

Tee ES, Lim CL (1991).The carotenoid composition and content of Malaysian vegetables and fruits by the AOAC and HPLC methods. Food Chem. 3: 309-339.

Terao J (1989). Antioxidant activity of β - carotene related carotenoids in solution. Lipids 24(7): 659-661.

Wald NJ, Tompson SG, Densem JW, Boreham J, Bailey A. (1988). Serum β carotene and subsequent risk of cancer. Results from BUPA study. Br. J. Cancer 57:428-433.

Wells JH, Singh RP, Noble AC (1987). A graphical Interpretation of time – temperature related quality changes in frozen food. J. Food Sci. 52 : 436-439.

Wolf G (1980). Vitamin A, In: Human Nutrition – A Comprehensive treatise. Nutrition and the adult: micro-nutrients vol 3B, (edited by R.B. Alfin – Slater and D. Kritchevsky) pp. 97-203, New York : Plenum Press.

Zaman Z, Roche S, Fielden, P, Frost PG, Nirilla DC, Cayley ACD (1992). Plasma concentration of Vitamin A and E and carotenoids in Alzheimer's disease. Age Aging 21: 91-96.