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Temperature and high pressure stability of lycopene and vitamin C of watermelon Juice

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The retention of nutrient components of fruit juices during processing is an important criterion to produce better quality fruit products. Stability of nutrient components during processing vary from product to product and processing methods. Information about kinetic study of particular nutrient component under different processing conditions would enable to optimize processing parameters for better quality retention. Therefore the objective of this research was to evaluate the effect of thermal and high pressure food processing methods on stability of vitamin C and lycopene of watermelon juice. Watermelon juice was subjected to different thermal (70 to 90°C) and high pressure (400 to 600 MPa) treatments for different interval of times and the residual vitamin C and lycopene concentrations were measured. The destruction of nutrients in both thermal and high pressure processing conditions obey first order reaction rate kinetic model. In both processing conditions lycopene remains more stable as compared to vitamin C. The degradation rates of both components were faster in thermal treatment as compared to high pressure. The *D* value of vitamin C ranged from 40 to 176 min ($z_{=}$ 30.8°C) and 4 to 24 h ($z_{p=}$ 257 MPa) in thermal and high pressure treatments respectively whereas the *D* value of lycopene ranged from 15 to 83 h ($z_{=}$ 24.5°C) and 61 to 258 h ($z_{P=}$ 318 MPa) for thermal and high pressure treatments respectively. Therefore high pressure ensures better retention of the nutrients as compared to thermal treatment and hence can be used to pasteurize better quality watermelon juice.

Key words: Vitamin C, lycopene, thermal, high pressure, destruction kinetics, watermelon.

INTRODUCTION

Food processing is one of the major means to produce safe foods for consumer's use. Most of the food products in stores are produced in either one or more than one type of food processing technologies. Thermal processing of foods is the major means of production of majority of foods. Particularly, in the canning industry thermal processing has enabled to produce safe and shelf stable products. However due to intensive heat treatment the process has also an effect on heat sensitive quality components of foods. For instance heating accelerates

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the oxidation process of vitamin C, thus thermal treatments result in loss of the vitamin content in fruits and vegetables and the milder the treatment, the better the vitamin C retention in juices (Dewanto et al., 2002).

In order to overcome the above mentioned limitations various novel thermal and non thermal processing technologies have been developed to preserve mainly liquid foods. One of the major non thermal processing technologies which have gain momentum and application from time to time is the use of high pressure processing technology. In this process the packaged or unpackaged beverages are subjected to pressures between 100 and 1000 MPa inside a cylindrical pressure vessel. Developed high pressure processing allows microbial inactivation at temperatures below those used during conventional thermal pasteurization, providing better retention of antioxidant compounds and essential nutrients, (Hancock and Stewart, 2010). The process is used on a variety of products including fruit juices, fruit purees and jams (Bertucco and Spilimbergo, 2006). It has been also generally admitted that high pressure affects minimally low molecular weight compounds such as vitamins, pigments, antioxidants and flavour components when compared to thermal processes, as it keeps covalent bonds intact. This effect is especially important in fruits and vegetables that are rich sources of these compounds. A study showed that the antioxidant capacity in carrot and tomato juice treated by high pressure was retained more compared to thermal treated samples (Saner, 2007). Bignon (1996) also observed that the decrease in vitamin C content of strawberries and guava puree treated with high pressure was much lower as compared to the fresh product.

Nowadays there is an increasing demand for high quality, nutrient and antioxidant rich fruit and vegetable products. Studies have shown that high consumption of fruits and vegetables can provide health benefits due to their antioxidant components including carotenoids, phenolic, flavonoids compounds and vitamins (Sánchez-Moreno et al., 2003). Watermelon (*Citrullus lanatus*) is a native plant of tropical Africa; it has relatively low vitamin C content compared with other citrus fruits. However, it is rich in carotenoids. Some of the carotenoids in watermelon include lycopene, phytofluene, phytoene, beta-carotene, lutein, and neurosporene. Lycopene makes up the majority of the carotenoids in the fruit and responsible for its red colour. The carotenoid content varies depending on the variety of the watermelon. Depending on the variety, carotenoid content in red fleshed watermelon varies from 37 – 121 mg/kg fresh weight, where as lycopene varies from (23.0–72.0µg/g of weight) (Xianquan et al., 2005). Carotenoids have antioxidant activity and free-radical scavenging property. Several researches have reported an association between dietary lycopene consumption and lower incidence in diseases such as prostate and oral cancers and may also help reduce risks of cardiovascular disease (Oms-Oliu et al., 2009). Maintenance of vitamin C and lycopene in thermally processed products has always been a major challenge in food processing. Vitamin C loss and undesirable degradation of lycopene in watermelon juice affects the health promoting ability, sensory characteristics and its natural appearance (Sharma, et al., 2008). Therefore, the objective of this study was to determine the degradation kinetics of vitamin C and lycopene of watermelon juice under different thermal and high pressure treatment conditions.

MATERIALS AND METHODS

Watermelon juice preparation

Watermelons (*Citrullus lanatus*) fruits were purchased at commercial maturity from a local supermarket (Montreal, Canada). Fruits cut into pieces and pulps were mixed in order to avoid fruit to fruit and maturity variation. Mixed pulp was stored at – 40°C until the required juice was made. Before experimentation the pulp was thawed and the juice extracted with a household juice processer. Double layer cheese cloth was used to filter the juice from the pulp. The natural pH of the juice founded around (5.48±0.02) and this relative high pH may support the growth of microorganisms and hence, the pH was adjusted to 4.4 with citric acid.

Thermal treatment

Juice (40 ml) was transferred into test tubes (15 cm length, 1.5 cm diameter and 0.1 cm thickness) and thermally treated at different temperatures (70, 80 and 90°C) for different pre set time intervals in a water bath (HAAKE P5, Type 003-5007, Karlsruhe, Germany). During heat treatment, the temperature was registered using data acquisition system and K- type thermocouples. For all temperatures investigated, a coming-up time of 2 min was taken into account and temperatures varied ± 1°C during the isothermal phase. Following heating, samples were taken out in regular time intervals and immediately cooled in an ice-water bath to avoid further heat degradation effect.

High pressure treatment

For the pressure treatments, 50 ml juice was filled into small flexible polyethylene plastic bags that were sealed, covered by another plastic bag and taking care to leave no air inside either of the two bags, to prevent them from breaking as a result of the pressure and prevent oxidation of nutrient components. The packaged samples were left at room temperature for 2 h to equilibrate to the ambient atmospheric condition (25°C). The initial water temperature (used as the pressure-transmitting fluid) was at 25ºC. Samples were pressurized using a laboratory pilot scale isostatic high pressure unit (ACP, TYPE ACIP 6500/5/12 VB, France, capacity with working pressure range of 100-600 MPa and temperature range of -20 to +80°C.), employing pressures from 400 to 600 MPa with pressure build up rate of 1 min, with different holding time (400 MPa (60, 80 and 100 min); 500 Mpa (30, 60 and 90 min); 600 MPa (15, 30 and 45 min). During pressure build up time a temperature increase to 30-34°C was observed and average of 32°C was taken as holding phase temperature. In order to exclude the effect of pressure build up phase samples at zero time were subjected for pressurization for 1 min and immediate depressurization without holding time. It was assumed that there were no vitamin C and lycopene degradation at

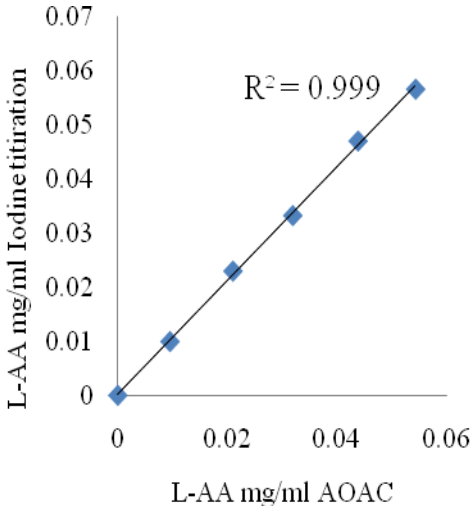

Figure 1. Vitamin C estimation capacity of iodine titration method as compared with official AOAC 967.21 method.

this temperature and all the effects were assumed exclusively from the pressure.

Vitamin C estimation

Due to the Red-Pink color of watermelon juice it is hard to identify the end point of titration (rose-pink color) using indicator solution (2,6-dichloroindophenol Na salt) if the official AOAC 967.21 method is applied. Because of this the vitamin C content of samples was determined using iodine titration method as indicated by Ajibola et al. (2009) and Spínola et al. (2012). Since this method is not an official method, its validity was cross checked with official AOAC 967.21 method using known concentrations (0.01 – 0.05 mg/ ml, pH 3.63) of standard vitamin C solutions. The result confirmed that the estimation capacity of iodine titration method was found almost equivalent to the official method with high degree of correlation (R^2=0.999) (Figure 1).

Extraction and quantification of lycopene

The low volume hexane extraction method with a little modification was performed as indicated in Fish et al. (2002). Approximately 0.6 g duplicate samples were weighed from each watermelon juice into two 50 ml centrifuge tubes covered by aluminum foil to exclude the degradation of lycopene by light. The mixture that contained 5 ml of 0.05% (w/v) butylated hydroxytoluene (BHT) dissolved in acetone, 5 ml of 95% USP grade ethanol, and 10 ml of hexane. After the samples were mixed with the extraction solution, samples covered by ice and thoroughly shacked using horizontal shaker (Belly Button, BBUAAUV1S, Greensboro, USA) for 15 min. After shaking, 3 ml of distilled water was added and the shaking continued for additional 5 min. Then the samples were left at room temperature for 5 min to make the phase separation. Eventually the absorbance of the upper, hexane layer was measured in a 1 cm path length quartz cuvette at 503 nm wave length using spectrophotometer (Novaspec II Visible, England). Before samples measurement, the spectrophotometer was calibrated with hexane as a blank. The final lycopene content of sample was analyzed as indicated in Fish et al. (2002) (Equation 1).

$$Lycopene(mg/kg(sample)) = \frac{A_{503} * 31.2}{g(juice)} \quad (1)$$

Where, 31.2 is the molar extinction coefficient of lycopene; *g* gram of fruit juice used for analysis, and A_{503} absorbance at 503 nm.

Data analysis

Vitamins and lycopene degradation values are generally considered to follow first order kinetics (Ahmed et al., 2002; Polydera et al., 2003; Sharma et al., 2008; Vikram et al., 2005). The rate of degradation of the components is mathematically expressed as:

$$-\frac{dC}{dt} = -k(C_o) \quad (2)$$

Where, *k* is the rate constant; *C* concentration at time *t*; *Co* initial concentration at time zero, *n* the order of reaction.

Under isothermal and isobaric conditions, the inactivation rate *k* is constant and for first order reaction *n* =1. The integration of Equation 2 is expressed in Equation 3 form.

$$\ln C = \ln C_o - kt \quad (3)$$

For the first order reaction, a plot of ln *C* versus *t* will be a straight line, and the rate constant is represented by the slope. The decimal reduction time (*D*) of the quality factors can be calculated from equation four or from the inverse slope of logarithmic order of residual concentration of the quality factors versus time. *D* value indicates the heating time results in 90% destruction of vitamin C or lycopene content as compared to time zero concentration at constant temperature.

$$D = \frac{2.303}{k} \quad (4)$$

Temperature dependency of the reactions can be explained either through thermal death time (TDT) or Arrhenius kinetic method. In the former case the temperature sensitivity of quality factors at different temperature levels as thermal resistance curve which is represented as log *D* versus temperature. From inverse slope of the curve line the temperature sensitive indicator (z value) can be calculated. The z value represents the temperature level increase required to achieve ten-fold decrease in *D* values. In the later case the Arrhenius kinetic model, is one of the most important model to predict the effect of temperature on specific reaction rate, *k* (min^{-1}). The effect of temperature (in absolute form) on the reaction rate constant is explained by Arrhenius, in Eq. (5 and 6).

$$k = k_o e^{-Ea/RT} \quad (5)$$

$$\ln k = \ln k_{Tref} + \left[\frac{E_a}{R}\left(\frac{1}{T_{Tref}} - \frac{1}{T}\right)\right] \quad (6)$$

Where, k_{Tref} is reaction rate constant at reference temperature, *Ea* is the activation energy (kJ/mole), and *R* the molar gas constant

(8.314 J/mole °K, *T* temperature (°K) at time *t*.

The graph *ln k* versus *1/T* will give us a linear line from which the inverse slope is used to calculate the E_a required for the reaction.

The effect of pressure on reaction rate constant at constant temperature can be expressed by theory of Eyring, where reaction rates are based on the formation of an unstable intermediate complex, which is in quasi-equilibrium with the reactants. At constant temperature, the theory is expressed in equations 7 and 8, (Heldman and Lund, 2007).

$$\left(\frac{d\ln k}{dp}\right)_T = -\frac{\Delta V}{RT} \quad (7)$$

The integration of Equation 7 yields Equation 8 and rate constant, *k* is expressed as:

$$\ln k = \ln k_{\Pr ef} + \left[\frac{V_a}{RT}\left(P_{\Pr ef} - P\right)\right] \quad (8)$$

Where, k_{Pref} is a rate constant at reference pressure P_{Pref}; V_a is the volume of activation, *R* is the molar gas constant (8.314 J/mole °K), *T* temperature (°K) at time *t*.

Based on experimental data, *k* and *D* values were calculated from linear regression of the natural (ln) and ten-based (log) logarithms of the concentration retention versus processing time. The E_a and *z* values were estimated from linear regressions of ln (*k*) versus (*1/T*) and of log (*D*) versus *T*, respectively. From a practical point of view, the activation volume can be determined from the slope (−*Va/RT*) of the plot of ln *k* versus *P* at constant temperature.

RESULTS AND DISCUSSION

Temperature stability of vitamin C and lycopene

The degradation of vitamin C during thermal processing operations has received much attention due to its instability to heat, light, metal catalysts, oxygen, and its relatively high water solubility.

Therefore studying thermal stability of vitamin C content of watermelon juice is an important input in processing of the fruit juice.

Temperature stability of vitamin C and lycopene of watermelon juice were studied after subjecting the samples to various temperatures and heating time conditions. The log-linear decrease of the vitamin C and lycopene as a function of heating time are illustrated in Figures 2 and 3. The figure shows that a decrease in the concentration of the vitamin and lycopene as a function temperature and heating time. The estimated kinetic parameters are summarized in Tables 1 and 2.

Previous works in orange juice confirmed that vitamin C degradation followed first order degradation kinetics (Polydera et al., 2003; Vikram et al., 2005) which was also observed in this work. The rate of the vitamin degradation in the study increases with an increase in temperature from 70 to 90°C (Table 1). The data obtained for the effect of temperature on vitamin C content were not comparable with reported values of Vieira et al. (2000) and Vikram et al. (2005). Difference in *D* and *k*

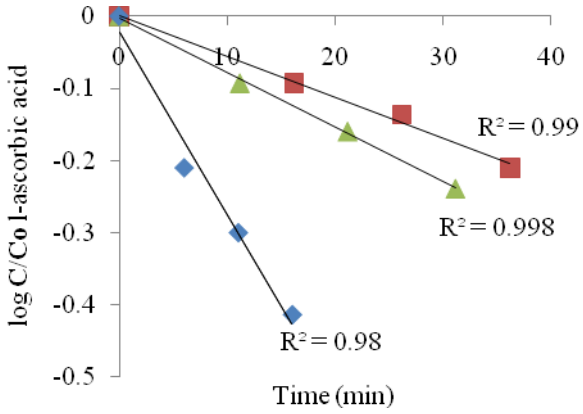

Figure 2. Semi log plot of thermal stability of vitamin C of watermelon juice under: (■) 70 °C, (▲) 80 °C, (♦) 90°C)) heated for different time durations.

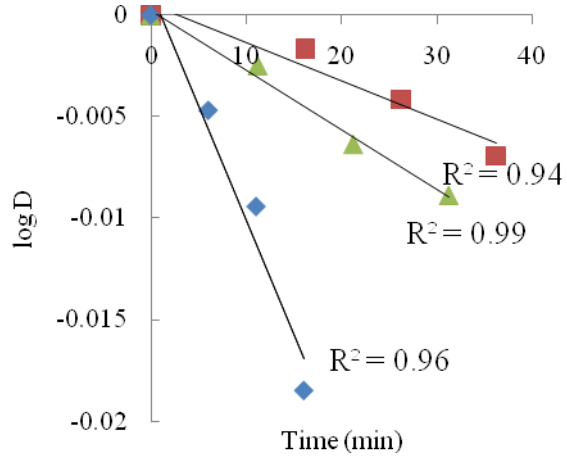

Figure 3. Thermal stability of lycopene of watermelon juice under different temperature: ((■) 70 °C, (▲) 80 °C, (♦) 90°C)) heated for different time durations.

Table 1. *D*, *k*, *z*, and *E*a values for the thermal degradation of vitamin C of watermelon juice.

T (°C)	*D* (min)	*k* (min-1)	R^2
70	175.97±2.5*	0.013093±0.00019	0.99
80	132.62±7.96	0.017491±0.0011	0.998
90	39.5±0.71	0.058393+0.0011	0.98
	z = 30.8±0.067°C	Ea = 18.37±0.057kcal/mole	0.89

*Standard error

value can be due to the fact that they measured vitamin C for different products. On the other hand, Van den Broeck et al. (1998) reported higher *D* values for the thermal degradation of vitamin C in squeezed tomatoes

Table 2. *D*, *k*, *z*, and *E*a values for the thermal degradation of lycopene of watermelon juice.

T(°C)	*D* (hour)	*k* (hour^{-1})	R^2
70	83.33±13.9*	0.02418±0.0017	0.94
80	57.5±1.03	0.03938±0.00035	0.99
90	14.5+0.06	0.1596±0.00035	0.96
	z=24.5°C±1.8	Ea=23.35±1.85 kcal/mole	0.92

*Standard error.

and oranges. For instance the vitamin C from orange found more heat sensitive as compared with tomato source which have been studied in temperature range of 120-150°C (Van den Broeck et al., 1998). This shows vitamin C stability varies from product to product which could be associated with total vitamin C content. Vitamin C from watermelon juice in this work found more temperature sensitive than a source from orange and tomato (Van den Broeck et al., 1998). This variation might be contributed due to agro ecological or agronomical difference where the fruits were grown. Furthermore a compositional variation in juices might play also a protective role in case of orange and tomato as compared to watermelon juice.

These days the nutritional and health benefits of lycopene of watermelon juice are well known. Xianquan et al. (2005) indicated that, under different food processing conditions, lycopene undergoes degradation via isomerization and oxidation, which impact its bioactivity and reduce the functionality for health benefits. Therefore, food processing technologies should ensure the availability of sufficient amount of lycopene after a given thermal process. For this reason it is pertinent to study thermal degradation behaviour of lycopene. Likewise vitamin C degradation, lycopene degradation also obeys first order reaction (Figure 3) and hence lycopene degradation is temperature dependent and increases with an increase in temperature. The rate constants (Table 2) show an increase with heating and this result is in agreement with earlier reports of Ahmed, et al. (2002) and Sharma et al. (2008).

Lycopene may be expected to undergo two changes during processing and storage: isomerization from all-trans to mono-cis or poly-cis forms, and oxidation (Cole and Kapur, 1957). Different reports indicated that isomerization is the main reaction during heating for short period of time at low temperature, but with an increase in treatment condition the degradation reaction dominated (Lee and Chen, 2002; D'Evoli et al., 2013). The all-trans isomer of lycopene is the most predominant geometrical isomer in fruits and vegetables and is the most thermodynamically stable form (Xianquan et al., 2005). Lycopene from canola oil treated at a temperature range of 100 to 180°C showed the degradation of trans isomer as compared to samples treated below 100°C (Shi et al., 2002). In a similar work lycopene from carrot source remained heat stable even treated at 70°C for 5 h, but the degradation was fast with enhanced degree of isomerization when temperature increased above 100°C (Mayer-Miebach, et al., 2005). Comparison results of Tables 1 and 2 indicate that the rate of thermal degradation of vitamin C is faster than lycopene. For instance at 90°C vitamin C required less than an hour but lycopene required more than 14 h to reach 90% degradation. Therefore vitamin C could be taken as indicator nutrient component as compared to lycopene to determine the effect of heat treatment on quality of watermelon juice.

The temperature dependence of the *D* value of the vitamin and lycopene are given by the *z* value. Estimated z value and activation energy of vitamin C in temperature range of 70 to 90°C were found to be 30.8°C and 18.37 kcal/mole respectively (Table 1). These values are in close agreement with vitamin C from orange and tomato sources (Van den Broeck et al., 1998), but they are lower than almost by half when compared with pure vitamin C tested in phosphate buffer (Oey et al., 2006). Meanwhile the z value and activation energy of lycopene for the same temperature range were estimated as 24.5°C and 23.35 kcal/mole respectively (Table 2). The activation energy in this work was found higher than lycopene from tomato olioresine (11.5 -15 kcal/mole) (Hackett et al., 2004). Furthermore the activation energy of all-trans lycopene degradation was reported as 14.5 kcal/mol for standard lycopene (Lee and Chen, 2002), 6.7 kcal/ mole in olive oil-tomato emulsion (Colle et al., 2010) and 19.8 kcal/mol in safflower oil (Henry et al., 1998). Generally, the degradation of lycopene is high with an increase in temperature and treatment time, particularly when the temperature is above 100°C. However under studied temperature range the rate of degradation was not high. There might be isomerization of the *trans* form in *cis*-forms with this temperature range which were not studied during the experiment.

High pressure stability of vitamin C and lycopene

High pressure processing is one of the non-thermal processing technologies which allows to process foods in low or reduced thermal effect for better quality retention. When the semi log residual concentration of vitamin C and lycopene versus time were plotted, both obey first order reaction model (Figures 4 and 5). The kinetic parameters, at different pressure levels are shown in Tables 3 and 4. In both cases the degradation rates are by far lower than thermal effect. There are several reasons indicated by different workers about the benefit of high pressure in retention of quality parameters as compared to heat treatment. However the main reason is, high pressure does not break down the covalent hydrogen, ionic or hydrophobic bonds. Covalent bonds are resistant to pressure, which means that low molecular

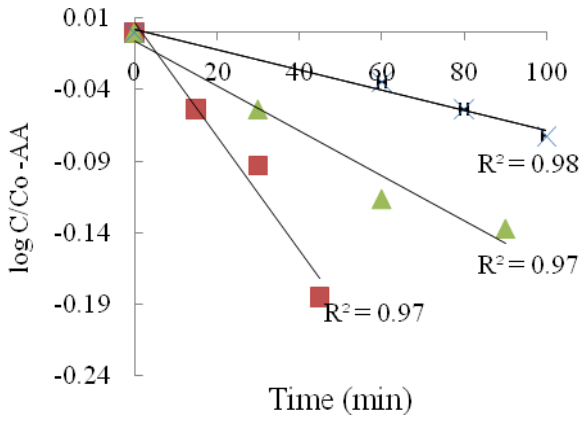

Figure 4. Effect of pressure and treatment time on stability of vitamin C of watermelon juice under different pressure: (×) 400 MPa, (▲) 500 MPa, (■) 600 MPa for different durations.

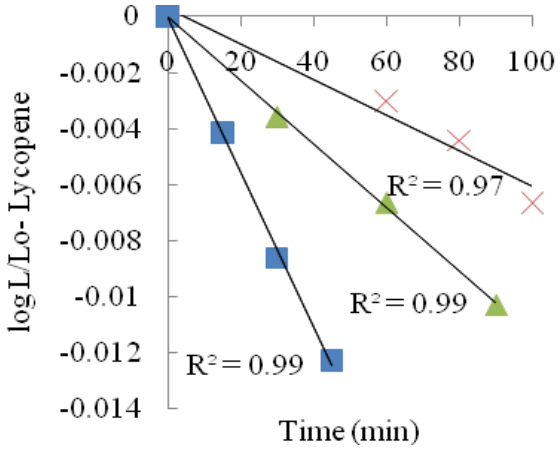

Figure 5. Stability of lycopene of watermelon juice under different pressure: (×) 400 MPa; (▲) 500 MPa; (■) 600 MPa for different durations.

Table 3. *D*, *k*, z_p, and V_a values for the high pressure destruction of vitamin C

P (Mpa)	*D* (h)	*k*(h^{-1})	R^2
400	23.71±2.34*	0.09811±0.0097	0.98
500	10.97±2.15	0.21832±0.043	0.97
600	4.27±0.56	0.54856±0.072	0.97
	z_p =257.3±37 MPa	V_a = -28.8±3.9 cm^3/mole	0.98

*Standard error.

Table 4. *D*, *k*, z_p, and V_a values for the high pressure destruction of lycopene.

P (Mpa)	*D* (h)	*k*(h^{-1})	R^2
400	257.95±19.85*	0.00898±0.0007	0.97
500	145.2±6.3	0.01589±0.038	0.99
600	60.6±1.1	0.038±0.0007	0.99
	z_p= 318.2±15.2	V_a= -24.24±1.01 cm^3/mole	0.98

*Standard error.

weight food components responsible for nutritional and sensory characteristics remain intact during pressure treatment, whereas high molecular weight components whose tertiary structure is important for functionality determination are sensitive to pressure (Tewari et al., 1999). Therefore, this behaviour plays a role for better retention of vitamin C and lycopene in high pressure processing as compared to thermal. This result is also in agreement with pressure stability of vitamin C of orange juice (Polydera et al., 2005).

The pressure dependency of *D* value is expressed by z_p value, which is defined as pressure increase required to reduce the *D* value by a factor of 10. Based up on this, z_p values of vitamin C and lycopene were estimated 257.95 and 318.2 MPa respectively. This result along with other kinetic parameters in table 3 and 4 confirm the variation in pressure stability of the two components of watermelon juice. Even though the stabilities of these components were better in pressure treatment as compared to heat, vitamin C was found relatively more sensitive to pressure effect as compared to lycopene. Hence likewise thermal treatment vitamin C can also be used as an indicator nutrient component to evaluate the effect of pressure treatments in processing of watermelon juice.

The kinetic degradation data could be used to calculate the activation volume *Va* of the pressure-induced destruction reaction using the *Eyring* equation (Equation 8). Activation volume was calculated for both components in studied pressure range (Tables 3 and 4) at constant temperature (32°C). According to the *Braun-Le Chatelier* principle under equilibrium conditions, processes associated with volume decrease are encouraged by pressure, whereas processes involving volume increase are inhibited by pressure (Butz and Tauscher, 1998). In this work a negative activation volume (*Va*<0) indicates that the nutrient degradation increases with an increase in pressure. The result confirms more negative shift in volume per mole of molecule for vitamin C (-28.8±3.9 cm^3/mole) than lycopene (-24.24±1.01 cm^3/mole). More shifts in decrease of volume for effect of pressure could result in change and modification of the inherent structure of the compounds and leads to more degradation.

Qiu et al. (2006) studied the effect of pressure and storage conditions of lycopene of standard solution and from tomato puree. He reported that lycopene from standard solution showed pressure stability up to 400 MPa (only 2% losses), but the loose jumped to 20.8 and

Table 5. Percent lycopene and vitamin C residue retained after different pressure and temperature treatments for time combinations.

Pressure (MPa)	Treatment time (min)	Lycopene %	Vitamin C %	Temperature (°C)	Treatment time (min)	Lycopene %	Vitamin C %
	0	100.0	100.0		0	100.0	100.0
	60	99.3	92.3		15	99.2	80.6
400	80	99.0	88.5	70	25	98.1	73.1
	100	98.5	84.6		35	97.0	61.5
	0	100	100		0	100	100
	30	99.2	88.4		10	98.5	78.9
500	60	98.5	76.9	80	20	97.6	69.2
	90	97.7	73.1		30	96.2	57.7
	0	100	100		0	100.0	100
	15	99.1	87.3		5	98.7	61.5
600	30	98.0	80.6	90	10	97.1	50.0
	45	97.2	65.3		15	95.8	38.5

56.3% at 500 and 600 MPa respectively. However the stability of lycopene from tomato puree remained persistent up to 600 MPa (only 5% loss) which is in close agreement with result of this work (Table 5). Therefore the presence of various macromolecules in the juices could play protective role to enhance pressure resistance of lycopene as compared to standard lycopene solution.

Conclusion

To summarize, although heat is the most common method for preservation, it is well known today that the consequences of conventional intensive heating are not necessarily good for the products in terms of consumers' acceptability. High pressure processing constitutes an alternative method to conventional thermal pasteurization for the preservation of watermelon juice. Vitamin C and lycopene degradation rates were found very low in high pressure processing. In addition to this, the stability of red lycopene rich component of watermelon juice for thermal treatment is very poor but remained stable in all studied temperature range. Therefore thermal treatment is not recommended to pasteurize watermelon juice. Therefore high pressure processing is recommended to produce stable nutrient rich and better quality juice. Various studies showed that, sensorial properties of pressure treated fruit juice samples are more or less comparable with control samples (Daoudi et al., 2002; Matser et al., 2004; Barba et al., 2012) due to minimal or limited effect of pressure on various chemical bonds. In terms of safety point of view, by choosing appropriate pressure treatment conditions (like higher pressure shorter time or vise versa), it is possible to kill pathogenic and spoilage vegetative cells to get shelf stable fruit juices stored at refrigerated temperature (Matser et al., 2004; Black et al., 2007). Overall, high pressure showed a potential in preserving and improving valuable attributes of watermelon juices as compared with conventional thermal treatment method which could be the same for other fruit juices.

Conflict of interests

The author(s) did not declare any conflict of interest.

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