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Research Article

Effect of UV radiation as an alternative to thermal pasteurization on some properties of tomato juice

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ABSTRACT

Most foods are usually pasteurizedby thermal processes. Pasteurization can reduce organoleptic and nutritional characteristics of the products. Radiation isa new technique for reduction of food poisoning due to food consumption and increasing shelf life of the product. In the present study, the effect of UV radiation as a cold pasteurization was investigated on the quality of tomato juice (TJ) to improve sensory, chemical and microbial properties. Treatments T_1, T_2, T_3, T_4, were tomato juice with heat treatment (treatment temperature 60 °C- 2 min) as a control treatment, pasteurized samples (treatments 72 °C for 2min), irradiated samples (from 15cm- 30min), and irradiated samples (15cm- 60minute), respectively. T_3 and T_4 samples received radiation dose of 2.158 j/m^2. The prepared samples were stored at a refrigerator for 90 days and every 30 days, the chemical test (lycopene content, pH, acidity, vitamin C, and Brix), were performed. The results showed that pH has significantly increased (p ・ 0.05) in all four treatments during storage. Generally the effects of irradiation on the Brix were not significant (p ・ 0.05). By increasing irradiation time, amounts of lycopene significantly increased (p ・ 0.05), also decreases were observed in both treatments T_3 and T_4 during storage. Radiation compared to the thermal treatment was successful in retaining and increasing the amount of vitamin C, which was significantly increase in T_4 treatment (p ・ 0/05), in first day. pH were reduced during storage in all samples.

Key words: tomato juice, lycopene, pasteurization, ultraviolet radiation, quality and shelf life properties.

INTRODUCTION

Nowadays, demand of the consumers for minimally processed products with high quality has increased remarkably. Foods and drinks with fresh, healthy and enriched flavours are preferred (Hayes *et al.*, 1998).Low storability characteristics of tomato juice (TJ) as one of the main agricultural products leads to its spoilage if proper measures are not taken to improve its shelf life. Storing this product, making beverages from it and other products are some of the ways which enables us to store it for relatively longer periods of time. Too do this, introducing a suitable pasteurization method with minimal loss of useful ingredients is of outmost importance (Luh*et al.*, 1998).

Compared to heat treatment, UV treatment, as a way of maintenance, changes the nature of the product the least (Rajeev *et al.*, 2011). Treating food products using radiation is a new method of lowering the risk of food poisoning among the consumers and, nowadays, number of the developed countries in the world are using it in food industry (Mahdavian*et al.*,1385). Sensitivity of various food products to radiation depends on their types. Proteins, carbohydrates and fats usually do not undergo any changes when radiated. The only changes which they suffer are a bit of decrease in their vitamins E and B. The change in the vitamins C content is negligible. Radiation treatment in a cold and anaerobic environment lowers the damage to nutritional value of the product (Mehdi Zadeh*et al.*,1389). UV radiation treatment of food products has been gaining gradual popularity in the food industry. In a research conducted, star fruit was treated with UV radiation. It was found out that radiation lowered its microbial content and increased its storability.(Rajeev *et al.*, 2011). Lycopene and beta-carotene are carotenoids with powerful antioxidant properties that enter the body mainly through fruits and vegetables (Neyestani and Qrughy, 1385) Lycopene is what gives tomato, watermelon and pink grapefruit their red color (Breemen*et al.*, 2008). Heating and homogenizing tomato results in destruction of cellular membrane of the cells leading to release of lycopene, and consequently, making it easier for the body to absorb it.However, heating methods such as pasteurization leads to destruction of carotenoids and vitamin C (Rodrigo *et al.*, 2007). Studies show an inverse relationbetweenabsorption oflycopene, soluble in fat) in the bodyand possibilityof developingcancer (Cohn *et al.*, 2004).In recent years, theroleof lycopenein preventionofchronic diseases, such as prostate cancerhas receiveda lot of attention (Clinton, 1998). Since heat treatment can reduce the beneficial compoundssuch ascarotenoids likelycopeneandvitamin C in theTJ, it is tried to investigate the effects ofUV raysonthequalitative and chemical characteristicsandshelf lifeof tomato juicein this study.

UV rays' wavelengths are between 0/0144 micrometers 0/39 micrometers. UV rays are divided into three zones (Mahdaviyan*et al.*, 2006).

1. The long-wavelength ultraviolet or ultraviolet A (300 - 400 nm).
2. Intermediate wavelength ultraviolet or ultraviolet B (320 - 280 nm).
3. The short-wavelength ultraviolet or C wave length shorter than 280 nm).

In this study, the effect of ultraviolet radiation (UV-C) with wavelength shorter than 280 nm was used on tomato juice was investigated. It was selected due to the strong germicidal effects on sensory characteristics, microbial and shelf-life.

MATERIALS AND METHODS

Raw material:

Super-chief tomatoes with the scientific name ofLycopersicumesculantum were used. This plant produces tomatoes which are roundel, ripe and red in color. The tomatoes were grown in the farms in Outskirts of Tabriz, Iran, but were purchased from the produce market. The Chemicals used in this study were of analytical grade and were manufactured by Merck of Germany.

Tomato juice produced

In this stage, thirty kg. Of tomatoes was washed using tap water, and then, to make juicing easier, tomatoes were sliced into small pieces and passed through a filter. Then the filtered material was Cold Breaked (T = 60 °C - t = 2 min), (Lin and Chen, 2003).The resulting tomato juice was divided into the four following samples: T_1, control sample, T_2, pasteurized by heating, T_3, treated tomato juice using ultraviolet radiation for 30 minutes and T_4, under ultraviolet radiation for 60 minutes

Producing pasteurized tomato juice

Tomato juice was poured in the stainless steel containers and then placed in a hot water bath. When the temperature reached 72 °C in its center, it was pasteurized at this temperature for 2 minutes. The pasteurized tomato juice was quickly placed in an ice water bath, until the temperature reached 5 °C. Then, it was held in a refrigerator (4 °C) for experimentation (Lin and Chen, 2003).

UV-treated tomato juice production

The Cold Breaked tomato juice was poured into sterile containers (100mm × 15mm with depth 10mm) and then, it was exposed to UV (fluorescent light emission peak at 254 nm) for 30 and 60 minutes from the distance of 15 cm. On average, the samples received UV rays at a dose of 2.158 j / m² at room temperature (Rajeev *et al*., 2011). Then, various microbial tests such as yeast and mold, total bacterial count and sensory tests with three repetitions were carried out.

Chemical analysis

Tomato juices of different treatments were kept at refrigerator temperature for 90 days and every 30 days on production and, chemical tests were measured with 3 repeats of vitaminC, lycopene content, Brix, acidity and pH.

Vitamin C

The vitamin C content was measured by manual titration with 0.1% 2.6-dichlorophenol indophenol as the titrant. A standard solution of 0.1% ascorbic acid solution was prepared. The amount of standard ascorbic solution used to titrate 0.1% 2.6-dichlorophenol indophenol (DCPIP) as the titrant was recorded to compare with the juice. Then, 1ml owith the tomato juice drop by drop until the DCPIP was f 0.1% 2.6-dichlorophenol indophenol was placed into a specimen tube and titrated discoloured. The result was expressed as mg/100g. Two replications of the treatment were conducted. For each replication, duplicate measurements were carried out and the results averaged (Cesar *et al*., 1999).

The concentration of ascorbic acid of the juice is calculated by using the formula given below:

Volume of 0.1% ascorbic acid solution

Concentration of ascorbic acid = (3) × 100(mg ⁄ g)

Volume of fruit juice

Determination of the amount of lycopene

The amount of lycopene (mg /g) in the case of Tomato juices on days 1, 30, 60 and 90 was determined with a spectrophotometer according to (Javanmardi, 2006). One gram of the extract (Tomato juices) was weighed and 39mL of hexane/ethanol/acetone with the ratio of1/1/1was added and mixed for 10 minutes The resulting mixture was passed through a separation funnel and 15 ml of water was added to it. It was stirred gently, and then, it was left still for 15 minutes so that the two hydrophilic and lipophilic phases could be separated from one another. Finally, the phase containing lycopene was separated and its absorption was measured at wavelength of 503 nm. Hexane was used as the indicator (Cesar *et al*., 1999).

Lycopene(*mg/kg*) =*x* / *y* × *absorbtion* (503)× 3.12

Acidity

10grams of Tomato juice sample was weighed and 200 ml of distilled water was added to it. The resulting mixture was titrated with 0.1 N NaOH 0/1 until the pH =8 ± 0/2was reached. Total acidity was assessed based oncitric acid (W/V) (Nielsen, 1998).

Brix

The brix content of the samples on days 1, 30, 60 and 90 was measured at room temperature using refractometer (Fisher, 1995).

pH

the PH values of tomato juice samples on days 1, 30, 60 and 90 were measured at room temperature using a pH instrument(Inolab 730 WTW (England)) (Rajeev *et al*., 2011).

Statistical analysis

In this investigation, the effects oftreatments on characteristics of tomato juice samples,T_1, T_2, $T_3$and T_4, were measuredduring the90 daysof storagein refrigerator(4°C) in the form ofrepeatedmeasurements(Repeated measurementand3 replicateswere performed). Thedata obtainedfrom these measurements was analyzed usingtwo-way ANOVAat ($P< 0.05$) and using least squaresmean ($P<0.05$).To carry out these statistical operations, SAS 9.1 (SPSS statistical analysis software) was used (SPSS Inc. USA).

RESULTS AND DISCUSSION

Lycopene

Heatbreaks down the cell walls and leads to release of more lycopene (treatmentT_1). Moreover, excessive heat damages lycopene content of the TJ and lowers its useful amount (treatment, T_2). (table 1). UV-C treatment was effective in maintaining the lycopene content intact. The results showed that the radiation treated sample contained higher level of lycopene than the other samples, heat treated ones. Storing the TJ for 90 days lead to decrease in the amount of lycopene due to its sensitivity; however, the decrease was less in the UV-C treated samples in comparison to the heat treated ones. The result of this study were in line with the reporting of a research carried out on pineapple juice and ripe tomatoes (Shamsudin., 2014). In addition, an increase of 4.67% in lycopene content of a sample of TJ which had undergone heat treatment at 90 °C for 60 minutes was reported in comparison to fresh TJ sample (Odriozola*et al*., 2008).

Vitamin C

The amount of vitamin C, on day one of thermal treatment is reported inTable2. Vitamin Cisone of the most sensitive vitamins and undergoes quick oxidation when heated which leads to its total destruction. It was found out that UV-C prevented rapid decrease of the vitamin C content of the TJ sample (T_2) during the 90 days storage period. With the passage of time, the amount of vitamin C decreased a little bit in all of the TJ samples. This decrease was significant in the heat-treated sample in comparison with the other samples (P<0.05). The reason for this significant difference was sensitivity of this vitamin to heating. The highest content of vitamin C in the samples belonged to the radiation-treated sample (T4). The same type of results were reported in the research on pineapple juice (Shamsudin, 2014)

Acidity

The result of acidity of the samples of TJ during the 90 days storage period is reported in table 3. The highest acidity belonged to the radiation-treated samples. Increased acidity was due to the activity of the microorganisms, and maybe, some chemical reactions taken place in the samples. The most increase of acidity took place after the first 30 days of storage. To determine the precise cause of acidity increase and the process through which radiation-treatment affects acidity change, more comprehensive studies must be carried out. Considering the fact that the acidity of the TJ has changed in all the samples during the storage period, it could be said that UV-C radiation had no significant effect on the acidity of TJ. The findings of this study are in line with the reporting of a study conducted by Pan Jeranimo and colleagues on strawberry and fresh grapes in 2004.

Brix

Brixdegree isindication of the amount of dissolved solids in the solution. The higher the Brixdegree, the higher is the concentration of solid materialin the juice. The °Brixresults are displayedin Table4, below.The results indicate the treatment T_1has lower°Brix. This is due to the fact that the heat intensity was low (60 °C) and no UV-C treatment had taken place. This has caused low evaporation leading to low proportion of solid material content of TJ to its liquid content. In T_2 sample, heat treatment resulted in evaporation of water content of the TJ sample making the juice more concentrated. However, this change was not significant at P<0.05. study conducted by Caminiti and colleagues in 2012, it was shown that after radiation treatment of apple juice sample, no significant change had taken place in the solid content of the pulp-free apple juice sample. These findings were in line with the findings of the study carried out on pomegranate juice by Uysal Pala and colleagues in 2011.

pH value

The results of the pH for Tomato juice samples treated with radiation, control treatment, and pasteurized sample during the 90 days storage periodare providedin Table5. The heat-treated samples and the UV-C-treated ones had equal pH values. The pH values of the control samples were higher than the treated ones. Considering the increased acidity during the storage period in refrigerator, the pH values of the samples went down. This decrease in pH values in T_1, T_3 and T_4 were significant (P<0.05) in comparison to the T_2 sample.These findings were in line with the findings of the study carried out on pomegranate juice by Uysal Pala and colleagues in 2011 and the study by Shamsudin on pineapple juice in 2014.

Acceptability

from the panelists' point of view, T3 had the highest acceptability. The T_3 and T_4 had no significant difference with one another (P<0.05). The case was the same for T_1 and T_2.according to the panelists' assessments, the radiation-treated samples had higher acceptability. The reason for higher acceptability was homogeneous distribution of pulp in juice which gave it a better appearance, color, flavor and texture. The highest rating belonged to T_3=5 and T_4=4 and the lowest rating belonged to T_1 and T_2=1. The radiation-treated samples had higher acceptability than the heat-treated ones. The panelists reported odor of rotten fruit from the pasteurized samples. These findings were in line with the findings of the study carried out on pomegranate juice by Uysal Pala and colleagues in 2011 and on orange juice in 2013 and the study conducted by Santhirasegaram and colleagues on mango juice in 2012. In some cases, opposite findings have been reported, which could be due to difference in the type of fruit juice and different treatment methods.

T4	T3	T2	T1	Time
230/3±22/5^{Aa}	238/8±2/1^{Ab}	239/6±4/1^{Bb}	259/5±5/9^{Cc}	**1**
113/2±3/5^{Ca}	124/5±5/5^{Bb}	131/3±3/5^{Ac}	139/7±2/2^{Ad}	**30**
159/8±2/0^{Ba}	159/7±2/8^{Ca}	199/0±2/1^{Cc}	175/9±1/8^{Bb}	**60**
145/4±4/9^{Ba}	150/1±2/1^{Ca}	154/5±29/5^{Cc}	173/4±10/5^{Bb}	**90**

Table1. Results of changes in the amount of lycopene in tomato juice during storage.
Dissimilar SmallLatinlettersineachrowindicatesignificant differences (P < 0.05) between treatments at a given time. Dissimilar capital Latin letters in each column indicate significant differences (P < 0.05)at different timesisagiventreatment. T_1: control (under heat at 60 ° C for 2 min) T_2: pasteurized by heating to 72 °C for 2 minutes, T_3: irradiated for 30 minutes and T_4: in irradiated for 60 minutes.

Table 2. Results of changes in the amount of Vitamin C(mg / 100ml)during storage.

T4	T3	T2	T1	Time
12/71±0/20^{Aa}	12/18±0/27^{Ab}	9/52±0/17^{Ac}	12/68±0/10^{Aa}	**1**
12/57±0/16^{Aa}	12/44±1/02^{Aa}	9/41±0/20^{Ab}	12/54±0/16^{ABa}	**30**
12/65±0/40^{Aa}	12/19±1/01^{Ac}	9/41±0/09^{Ad}	12/33±0/27^{Bbc}	**60**
12/65±0/54^{Aa}	12/11±0/80^{Ab}	9/55±0/71^{Ac}	12/57±0/29^{ABa}	**90**

Dissimilar Small Latin letters in each row indicate significant differences (P < 0.05) between treatments at a given time.Dissimilar capital Latin lettersin each columnindicatesignificant differences(P < 0.05)at different timesisagiventreatment. T_1: control (under heat at 60 ° C for 2 min) T_2: pasteurized by heating to 72 ° C for 2 minutes, T_3: irradiated for 30 minutes and T_4: in irradiated for 60 minutes.

Table3. Results of changes in pH during samples Tomato juices treated in different ways.

T4	T3	T2	T1	Time
0/53±0/01^{Cb}	0/58±0/01^{Cb}	0/72±0/03^{Ba}	0/71±0/01^{Ca}	**1**
1/17±0/03^{Ba}	1/14±0/04^{Ba}	0/71±0/01^{Bb}	1/17±0/02^{Ba}	**30**
1/83±0/04^{Aa}	1/73±0/04^{Ab}	1/64±0/01^{Ac}	1/74±0/03^{Ab}	**60**
1/77±0/02^{Aa}	1/79±0/03^{Aa}	1/65±0/03^{Ab}	1/15±0/05^{Bc}	**90**

Dissimilar SmallLatinlettersineachrowindicatesignificant differences (P < 0.05) between treatments at a given time. Dissimilar capital Latin letters in each column indicate significant differences (P < 0.05) at different times are a given treatment. T_1: control (under heat at 60 ° C for 2 min) T_2: pasteurized by heating to 72 ° C for 2 minutes, T_3: irradiated for 30 minutes and T_4: in irradiated for 60 minutes.

Table4. Results of Brix during storage within 90 days.

T4	T3	T2	T1	Time
5/50±0/10^{Ab}	5/87±0/06^{Aa}	5/58±0/08^{Cb}	5/00±0/07^{Ac}	**1**
5/50±0/14^{Ab}	5/75±0/08^{Ba}	5/67±0/08^{Ba}	5/00±0/04^{Ac}	**30**
5/50±0/08^{Aa}	5/50±0/06^{Ca}	5/00±0/10^{Db}	4/75±0/06^{Bc}	**60**
5/50±0/11^{Ab}	5/50±0/08^{Cb}	6/00±0/09^{Aa}	5/00±0/09^{Ac}	**90**

Dissimilar Small Latin letters in each row indicate significant differences (P < 0.05) between treatments at a given time. Dissimilar capital Latin letters in each column indicate significant differences (P < 0.05) at different times are a given treatment. T_1: control (under heat at 60 ° C for 2 min) T_2: pasteurized by heating to 72 ° C for 2 minutes, T_3: irradiated for 30 minutes and T_4: in irradiated for 60 minutes.

Table 5. Results ofpH changesduring 90 days

T4	T3	T2	T1	Time
4/35±0/02^{Ab}	4/31±0/01^{Ac}	4/32±0/01^{BCbc}	4/54±0/02^{Aa}	**1**
3/79±0/04^{Bc}	3/80±0/05^{Bc}	4/41±0/03^{Aa}	3/83±0/02^{Bb}	**30**
3/62±0/01^{Db}	3/61±0/06^{Db}	3/56±0/01^{Dc}	3/67±0/01^{Ca}	**60**
3/71±0/05^{Cb}	3/71±0/03^{Cb}	4/23±0/01^{Ca}	3/57±0/03^{Dc}	**90**

Dissimilar SmallLatinlettersineachrowindicatesignificant differences (P < 0.05)betweentreatments at a given time.Dissimilar capital Latin lettersin each columnindicatesignificant differences(P < 0.05)at different timesisagiventreatment. T_1: control (under heat at 60 ° C for 2 min) T_2: pasteurized by heating to 72 ° C for 2 minutes, T_3: irradiated for 30 minutes and T_4: in irradiated for 60 minutes.

Table6. Results ofchanges inthe overall acceptabilityof theproductduring 90 days

T4	T3	T2	T1	Time
5/00±0/00^{Aa}	5/00±0/00^{Aa}	2/00±0/06^{Ac}	3/80±0/13^{Ab}	**1**
4/00±0/08^{Bb}	5/00±0/00^{Aa}	1/00±0/03^{Bc}	1/00±0/06^{Bc}	**30**
4/00±0/07^{Ba}	4/00±0/08^{Ba}	1/00±0/07^{Bb}	1/00±0/05^{Bb}	**60**
4/00±0/06^{Ba}	4/00±0/04^{Ba}	1/00±0/05^{Bb}	1/00±0/04^{Bb}	**90**

Dissimilar Small Latin letters in each row indicate significant differences (P < 0.05) between treatments at a given time. Dissimilar capital Latin letters in each column indicate significant differences (P < 0.05) at different times are a given treatment. T_1: control (under heat at 60 °C for 2 min) T_2: pasteurized by heating to 72 ° C for 2 minutes, T_3: irradiated for 30 minutes and T_4: in irradiated for 60 minutes.

CONCLUSION

Overall, according to the obtained results, it can be said that Tomato juices sample undergone UV-C radiation had better physical, chemical and qualitative properties than the other samples. Thus, UV-C radiation could be used as an alternate method to heat treatment methods such as pasteurization. UV radiation along with heat (appertization, 60℃, t=2 min.)Leads to durability of lycopene and vitamin content of tomato juice. This is of great importance from nutritional aspect of tomato juice. It is worth mentioning that the UV-C treated sample lacked all the negative features, such as sensory characteristics, of the other samples.

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