# The effect of microwave (MW) treatment on the physical and chemical properties of some fruit juices

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## Abstract

The effect of conventional pasteurization at temperatures (65, 85, 90) °C and for a period of (30 min, 15 min, 15 sec) was studied respectively for three types of natural juices represented by orange, pomegranate and red grapes in comparison with microwave treatment at (750-800 W, 2450 MHz) for a period of (30, 60, 90) sec, then evaluating the quality characteristics and effectiveness of the treatment in preserving the nutritional value in the refrigerator at 5 °C for 28 days. The microwave treatment exhibited more stability to the pH and titratable acidity of the juices during the storage period compared to the conventional treatment, which showed a gradual increase in acidity during the storage period. The results of the statistical analysis did not show a significant difference ($p > 0.05$) in the concentration of total dissolved solids (TSS) between the treatments and the different conditions used in the study, and it showed clear stability until the third week of storage with a slight decrease in the fifth week. Regarding the AA content, the microwave treatment for 30 sec was less degradable compared to the conventional pasteurization which gave the lowest content of AA at 65 °C for 30 min. The use of microwave also reduced the formation of hydroxymethylfurfural (HMF) at 30 and 60 sec and reduced the deterioration of sugars during the treatment and storage period for all juices compared to the conventional treatment. Both treatments showed good effectiveness in inhibiting the pectin methyl esterase, but the microwave treatment was more efficient despite the microwave treatment for 30 sec which was the lowest compared to the treatments at 60 and 90 sec, which helped in reducing the changes that may occur in the concentration of total dissolved solids and thus improving and stabilizing the juices during the storage period.

**Keywords:** Microwave, HMF, Juice, orange, ascorbic acid, PME

## Introduction

Fruit juice is known as a product containing many complex nutrients [1], active compounds, vitamins, minerals [2], carbohydrates, as well as compounds that are of health importance such as antioxidants [3], anti-inflammatory [4], antimicrobials [5] and anticancer [6]. The most important feature of natural juices is that they can be easily consumed and thus obtain the nutritional value of the fruit made from them [7]. The consumer demand for healthy foods was increased rapidly, therefore the global market has begun to focus and stimulate the natural juice industry [8]. The juice industry is currently showing great development due to the change in lifestyle, consumers' desire to choose healthy products, and enhanced buying capacity [9]. The most important of these are orange juice [10] extracted from fresh oranges (Citrus sinensis) [11], pomegranate juice [12] and grape juice [13]. According to data from the US Department of Agriculture (2019), about 1.7 million tons of orange juice were consumed in 2018 worldwide. While the global market site indicated that pomegranate crop revenues amounted to 235.94 million US dollars in 2021, and reached approximately 248.4 million US dollars in 2022, the annual rate of pomegranate product revenues was estimated at 5.4%, and pomegranate juice was ranked second in terms of market consumption and revenues over other

products manufactured from pomegranate fruits [14].

The International Organization of Vine and Wine (OIV, 2023) indicated that the global production of fresh grapes in 2022 amounted to 77,272,391 tons with a cultivated area of 7,237,370 hectares [15]. Therefore, many studies tried to find appropriate methods for preserving food by treating it with heat, which is more effective in reducing the negative effects that occur to flavors, essential nutrients and vitamins due to the low temperature at which it is treated [16]. When food is exposed to heat treatments, it affects its quality, so choosing the temperature and time period for treatment is of great importance, and factories producing juices may seek to use the pasteurization process while maintaining its nutritional and sensory quality [17]. Pectin methyl esterase inhibition is one of the most important manufacturing processes for juice processing because it affects the cloudiness of juices and is responsible for viscosity and color changes in addition to changes that affect taste and flavor. Therefore, the PME inhibition process is an indicator of the efficiency of the juice pasteurization process [18]. AA is a water-soluble compound and a natural antioxidant. During the treatment of fruits and vegetables at temperatures and in the presence of oxygen, AA is exposed to decomposition. Therefore, the decrease in the AA content is an indicator of the general deterioration of the quality [19]. AA hydrolysis can also lead to non-enzymatic browning. Therefore, the loss of AA is not only nutritionally important, but also affects changes in taste and color [20, 21, 22]. Hydrolysis also leads to the loss of sucrose [23] and the formation of hydroxymethylfurfural [24]. Therefore, many studies conducted at different times and up to the present day have sought to find solutions to the problems resulting from conventional food processing methods [25], which often lead to accelerated quality deterioration and thus help the growth of microorganisms [26] and reduce the effectiveness of biological compounds and cause negative effects that result in reduced storage life [27] and irregularity in the shape of the structural composition of cells [28]. The trend has become towards microwave treatment, which is known as one of the types of electromagnetic rays that are characterized by great power, high efficiency and short treatment time [29,30]. Wu et al. [30] indicated that heating in the microwave is uneven in all directions, and this is one of the main disadvantages of microwave treatment, especially in solid or semi-solid foods. Despite the many advantages of microwave treatment, its use is still limited in laboratories and has not been used at the level of large manufacturing laboratories due to the lack of practical information for manufacturing products in large quantities [31]. Therefore, the study aimed to know the effect of temperatures and the time period of the known conventional pasteurization on the physicochemical properties of natural juices in comparison with microwave treatment and find the best conditions that can preserve the nutritional value of natural juices and their quality during storag.

## Materials and methods

### Fruits of orange, pomegranate, and grape

The fruits of (oranges, pomegranates and grapes) were purchased and selected, ripe and meeting the quality requirements for juice production, and available in the local markets of Basra Governorate. The oranges were of the Egyptian type orange, variety (Citrus sinensis), the pomegranate was of the type known as the Yemeni pomegranate (Punica granatum), and the red grapes were of the type (Vitis labrusca).

### Preparing natural juice (orange, pomegranate, grape)

The fresh orange juice used in the study was prepared by cleaning the orange fruits and washing with running water (tap)

several times to get rid of dirt and dust [17]. The juice was obtained using citrus squeezer and then filtering the extracted juice directly through two layers of gauze with small pores to get rid of the remains of orange pulp and seeds. The pomegranate juice was prepared according to the method mentioned by [32] by using pressure on the fruits and then removing the residues represented by peels, pulp and seeds. Grape juice was obtained by crushing or pressing with a Chinese home grape juicer from VENJOYIT.

The juice (Orange, pomegranate, grape) was filled in shaded containers and divided into two groups, three conventional pasteurization treatments and three microwave pasteurization treatments for three replicates for each treatment: three fresh untreated juice samples representing orange, pomegranate and grape juice, symbolized by (T0-OR, T0-PO, T0-GR), respectively. The juice treated in the conventional way at different temperatures and time periods, which are T1 (65°C for 30 min) for each of orange, pomegranate and grape juice (T1-OR, T1-PO, T1-GR) respectively, and the second treatment is T2 (85°C for 15 min) for each of (T2-OR, T2-PO, T2-GR), while the third treatment is T3 at 95°C for 15 seconds (T3-OR, T3-PO, T3-GR), respectively. Microwave treated sample (output 750-800 W 2450MHz) for 30 seconds each of orange, pomegranate and grape juices representing treatments T4 (T4-OR, T4-PO, T4-GR), 60 seconds T5 (T5-OR, T5-PO, T5-GR) and 90 seconds T6 (T6-OR, T6-PO, T6-GR).

**Determination of pH**

The pH was determined according to method mentioned by Abiola *et al*. [33] by taking 10 ml of juice using a pH-meter (Pye – Unicam-England).

**Determination of Total Titratable Acidity (TA)**

The total titratable acidity was determined following the method outlined by [34]. A 5 mL sample of juice was diluted with distilled water to a total volume of 50 mL in a beaker. From this solution, a 5 mL aliquot was transferred into a conical flask, and two drops of phenolphthalein indicator were added. The sample was then titrated with 0.1 M NaOH until the endpoint was reached. The conversion factor used for citric acid calculation was 0.007005%. The total acidity was expressed as percentage of citric acid (% citric acid) using Eq. 1

$$\% \text{ TA} = V(0.1 \text{ M NaoH}) \times M(\text{NaOH}) \times 0.007005 \% \text{ -- (1)}$$

**Total solids concentration**

Total solids were estimated using a refractometer (SCO, Germany). The device was zeroed with distilled water after ensuring that the prism was cleaned before and after the measurement, and the table for converting refractive index values to brix values was used.

**AA determination**

Iodometric method AOAC [35] was followed to estimate AA, by weighing 1 g of juice and adding 100 ml of 2% hydrochloric acid solution, mixing well and leaving for 15 min, then purifying it with filter paper and taking 5 ml of the filtrate and adding 5 ml of distilled water and 3 ml of 1% potassium iodide, and preparing 1% starch reagent immediately and adding 2 ml to the mixture and titrating it with potassium iodate $KIO_3$ at a concentration of 0.0017 M until it reaches the end point of the reaction and the color changes to dark brown, and it is calculated using the following equation: AA (sample mg/100 ml) = 0.88 × volume of $KIO_3$coming out of the burette (ml).

$$\text{AA content (mg⁄100 ml sample)} = 0.88 \times \text{iodine solution (ml)}$$

**Hydroxymethyl Furfural (HMF)**

The determination of HMF was conducted according to the method outlined

by [36]. To 5 mL of juice sample, 5 mL of 95% ethyl alcohol was added. The mixture was then centrifuged at 1000 g for 15 min. The supernatant was divided into two portions. For the HMF analysis, 2 mL of the supernatant was transferred into a 16 mL screw-cap tube. To this, 2 mL of 12% w/w trichloroacetic acid (TCA; Sigma, Germany) and 2 mL of 0.025 M thiobarbituric acid (TBA; BDH Limited, England) were added. The tubes were incubated in a water bath (Grant, England) at 40°C (±0.5°C) for 50 min. After incubation, the tubes were cooled using tap water, and the absorbance was measured at 443 nm. HMF concentration was quantified using a calibration curve of HMF (Aldrich, Germany).

### Pectin Methyl Esterase (PME)

PME content was measured according to Kimball [37] with minor modifications. A 1% pectin-salt solution was prepared by dissolving 15.3 g of NaCl and 10 g of pectin in distilled water. Stock solutions of NaOH (2 N and 0.05 N) were also prepared. For PME determination, 10 mL of tomato juice was mixed with 40 mL of the pectin-salt solution in a 100 mL beaker. The beaker was placed inside a larger 250 mL beaker filled with water and stirred magnetically at 30°C. To achieve neutrality, a few drops of 2 N NaOH were added to the mixture. PME activity was determined by adding 0.1 mL of 0.05 N NaOH, and the time taken to reach the target pH was recorded. The PME activity was calculated using the following equation:

$$\text{PME (unit/ml)} = \frac{NaOH\ (0.05N) * 0.1\ ml\ NaOH\ (0.05N)}{10\ ml\ of\ sample * time\ (minute)}$$

### Fourier transform infrared (FTIR)

The oranges, pomegranates, and grapes, converted to juice and heated in a conventional and microwave oven, were analyzed in the IR dynamometer of SHIMADZU, a Japanese company, in collaboration with the Polymer Research Center at the University of Basra.

FTIR 84002 model (2000). The IR range of frequency measurement is from 400 to 4000 $cm^{-1}$.

## Results and discussion

### pH values

Table (1) demonstrates the average PH levels in raw natural juice no additives of the orange, pomegranate, grape as compared to the normal and microwaved juice. The findings of the research indicated that the pH value of the control specimens of orange, pomegranate and grape juice (T0-OR, T0-PO, T0-GR) was 4.33, 3.33 and 3.32, respectively. The pH values in different conditions of conventional orange juice treatments (T3-OR-T1-OR) and in the case of microwave (T6-OR-T4-OR) were 4.32-4.31 and 4.33-4.30, respectively. The pH values in different conditions of traditional and microwave pomegranate juice treatments (T3-PO-T1-PO and (T6-PO-T4-PO) ranged from 3.32-3.31 and 3.33-3.29, respectively. Talking about the grape juice, the pH values for both treatments and across the range of conditions used (T3-GR-T1-GR and (T6-GR-T4-GR) spanned from 3.31-3.30 and 3.31-3.29. It can be seen that the pH values are consistent for all juice treatments; however, the microwave treatment for all juices for just 1 minute and a half led to a lower pH comparing to the treatments T4-OR, T4-PO, and T4-GR. These treatments were the most effective ones and their pH levels were identical to that of the control sample which was treated with microwave for 60 seconds and were the same as those found for all the other juice types.

The data from this research agree with the results of [38]. the pH of the tested juice did not vary according to the processing technology used. The information obtained through the analysis of the data is that there were no differences that are sufficiently

significant ($p > 0.05$) between the pH values in all treatments (e.g. shown for orange, pomegranate and grape juices) (C) and their counterparts treated the traditional way as well as no differences ($p > 0.05$) in the pH values of the treated samples. the control-one and the microwave ones which were identified by the letters T1-OR, T2-OR, T3-OR, and T1-PO, T2-PO, T3-PO, and T1-GR, T2-GR, T3-GR respectively and the T4-OR, T4-PO devices were operated in the microwave oven and T5-OR, T5-PO, T5-GR) The rest of the tallies were also close. Also, the results of the statistical examination detected ni negligible differences ($p > 0.05$) in the pH values of the juice samples that were cured by means of microwaving (T6-OR, T6-PO, T6-GR) in comparison with the rest of the treatments. These findings corresponded to those mentioned by [39] who stated that, as stability was found in the pH values of the juices before and after treatment, both conventionally and in the microwave.

**Table 1. Average pH values of untreated natural juices (orange, pomegranate, grape) and comparison with juices treated conventionally and by microwave**

| Treatments | Orange juice | pH | Pomeg. juice | pH | Grape juice | pH |
|---|---|---|---|---|---|---|
| Control | T0-Or | 4.33±0.01423 [a] | T0-Po | 3.33±0.0170 [a] | T0- Gr | 3.32±0.04949 [a] |
| conventional | T1-Or | 4.32± 0.0070 [a] | T1-Po | 3.32± 0.01436 [a] | T1-Gr | 3.31± 0.07106 [a] |
| | T2-Or | 4.32±0.0040 [a] | T2-Po | 3.32±0.02121 [a] | T2-Gr | 3.31±0.00678 [a] |
| | T3-Or | 4.31±0.01414 [a] | T3-Po | 3.31±0.00710 [a] | T3-Gr | 3.30± 0.01213 [a] |
| Microwave | T4-Or | 4.33±0.0710 [a] | T4-Po | 3.33± 0.02122 [a] | T4-Gr | 3.32±0.00718 [a] |
| | T5-Or | 4.31±0.0213 [a] | T5-Po | 3.31±0.02132 [a] | T5-Gr | 3.31±0.07821 [a] |
| | T6-Or | 4.30± 0.01136 [b] | T6-Po | 3.29±0.00718 [b] | T6-Gr | 3.29±0.02123 [b] |

Figure (1) shows the pH values of orange, pomegranate and grape juice for each of the control samples of juices and those treated in the conventional and microwave methods during the storage period of 28 days and monitoring the changes that occur in each treatment during storage at a temperature of 5 °C. The results showed that the control sample of orange, pomegranate and grape juice showed a Noticeable change from the first week of all treatments until the end of the storage period, ranging from 4.29-1.32 for orange juice, while the pomegranate and grape juice for the same storage period had a pH of 3.23-2.36 and 3.18-2.39, respectively. It is noted that the pH of all untreated juices increased significantly during storage compared to the heat-treated juice samples for all conditions used. The pH values of orange, pomegranate and grape juices were given during the conventional treatment conditions (T1-OR, T2-OR, T3-OR) and (T1-PO, T2-PO, T3-PO) and (T1-GR, T2-GR, T3-GR) on the seventh day of storage and until the end of the period were (3.28-2.97, 3.32-3, 3.32-3.08) and (4.32-3.15, 4.27-3.13, 4.32-3.12) and (3.33-2.23, 3.32-2.19, 3.33-2.09) and (3.31-2.97, 3.32-3, 3.32-3.08), respectively.

Regarding the microwave treatment, the pH values of each of the orange juice samples were (4.33-3.93, 4.33-4.27, 4.32-4.03) for T4-OR, T5-OR, T6-OR respectively; while the pH values for the pomegranate juice samples were (3.34-3.13, 3.33-3.19, 3.33-3.22) for T1-PO, T2-PO, T3-PO, respectively. It is noted that despite the similarity of the pH values on the first day of storage, the pH values varied at the fourth and fifth weeks depending on the conventional treatment of temperature and time period in orange juice. The figure shows that the pH remained stable until the third week and the decrease was slight.

When measuring the pH in the fourth and fifth weeks, the decrease was higher for all juices (orange, pomegranate, grape). The pH values of microwave-treated juices exhibited a lower level of change and were relatively stable for the entire storage period compared to control juice samples and those juices that were treated conventionally. These data are in agreement with the findings of [33], who revealed that the pH value of orange juice was decreased during the third week of storage. Biswas et al. [40] also mentioned that the pH of fruit juices decreased from 3.9 to 3.6 within 21 days. Hossain et al. [41] also mentioned that a slow decrease in pH during storage. Orange and pomegranate juice that was treated in the traditional way possessed a lower pH value than grape juice during the last two weeks. This might be primarily attributed to the fact that orange and pomegranate juice contain higher concentrations of acids, which in turn results in a greater reduction in the pH value during the storage period, compared to grape juice, which is rich primarily in sugar content and therefore provides great stability in pH values. Additionally, it might also be because through the growth of microorganisms, there is a creation of acids which might lead to the increase in the concentration.

concentration.

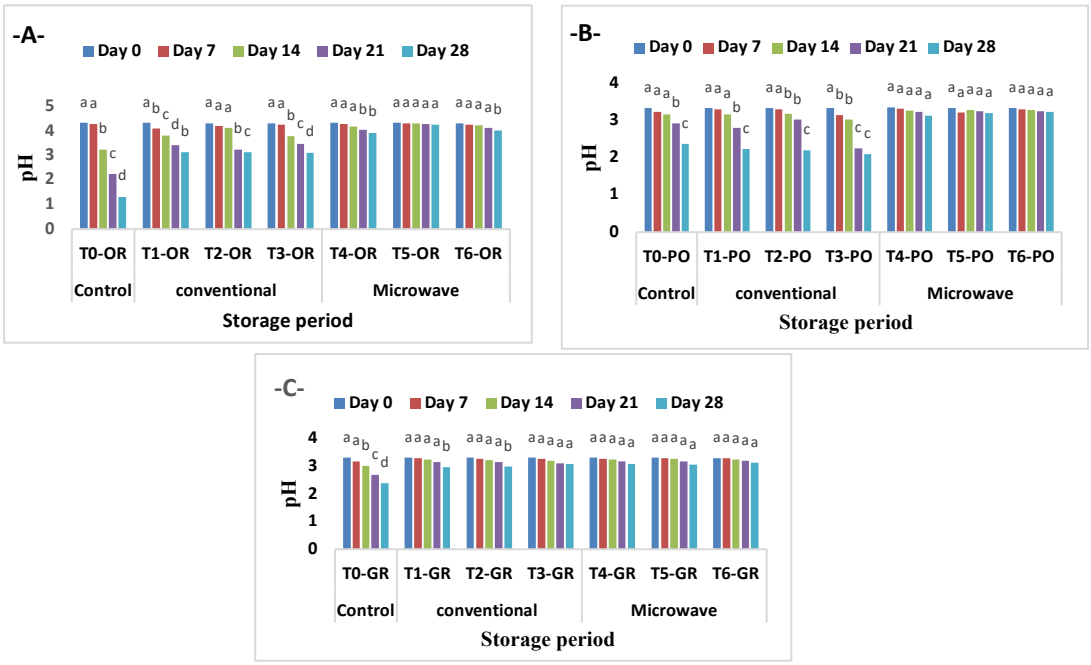



**Figure (1) pH values of (A) orange, (B) pomegranate and (C) grape juice for all conventional, microwave treatments and control sample during the storage period of 28 day.**

## Total titratable acidity (TA)

Table (2) shows the total titratable acidity (TA) values of the juices (orange, pomegranate and grape). The total titratable acidity values of the control of orange juice T0-OR, reached (7.31%), while the control of pomegranate juice, reached (0.34%) and the control sample of grape juice, reached (0.78%). It is also noted from the results that the three juice samples that were exposed to the treatment conditions T1 and T2 in the conventional method and the microwave treatment 5T gave equal content of the TA content, which is (7.33, 0.35, 0.80%) for each of the orange, pomegranate and grape juices, respectively. The juice samples for the treatment T4-OR, T4-PO, T4-GR showed the best content of the TA and were close to the control sample, while the juice

treatment by microwave for a minand a half was the highest in the TA content compared to the rest of the samples. The changes in the titratable acidity due to different treatments were minimal for all of the treatments and for only three of the juices. These results coincide with the observations of [42] who state that there were no ifferences in the TA of the camu-camu juice using either the traditional or the microwave methods.

The results of the statistical analysis showed no significant differences ($p > 0.05$) between the TA value of the control orange, grape, and pomegranate juices and those treated in the usual way. The results of the statistical analysis also demonstrated no significant differences ($p > 0.05$) in the TA between the control samples and the samples treated in the conventional way (T1-OR, T2-OR, T3-OR and T1PO, T2-PO, T3-PO and T1-GR, T2-GR, T3-GR) and the juice samples treated with the microwave (T4-OR, T4-PO, T4-GR and T5-OR, T5-PO,(T5-GR). The results of the statistical analysis also revealed slight significant differences in the TA values for the conventional treatment and the microwave treatment in each of the treatments (T6-OR, T6-PO, T6-GR). This is what Yuan et al. [43] indicated when treating red grape juice with the microwave and conventionally, with a decrease in the TA content, which is inversely proportional to the increase in pH.

**Table (2) Average titratable acidity values of untreated natural juices (orange, pomegranate, grape) and comparison with juices treated conventionally and by microwave**

| Treatment | Orange juice | %TA | Pomeg. juice | %TA | Grape juice | %TA |
|---|---|---|---|---|---|---|
| Control | T0-OR | 7.31±0.0494 [a] | T0-PO | 0.34±0.02828 [a] | T0-GR | 0.78±0.04949 [a] |
| Conventional | T1-OR | 7.33±0.0112 [a] | T1-PO | 0.35± 0.01414 [a] | T1-GR | 0.80 ± 0.04418 [a] |
| | T2-OR | 7.33±0.0222 [a] | T2-PO | 0.35±0.01134 [a] | T2-GR | 0.80±0.04228 [a] |
| | T3-OR | 7.34±0.0789 [a] | T3-PO | 0.36± 0.02122 [a] | T3-GR | 0.81± 0.04111 [a] |
| Microwave | T4-OR | 7.31±0.0141 [a] | T4-PO | 0.34± 0.02112 [a] | T4-GR | 0.78± 0.02822 [a] |
| | T5-OR | 7.33±0.0112 [a] | T5-PO | 0.35±0.02121 [a] | T5-GR | 0.80± 0.0112 [a] |
| | T6-OR | 7.35± 0.0335 [b] | T6-PO | 0.37±0.01124 [b] | T6-GR | 0.83±0.02211 [b] |

Figure (2) shows the TA of orange, pomegranate and grape juice for each of the control samples of juices and those treated in the conventional and microwave methods during the storage period of 28 days and monitoring the changes that occur in each treatment when stored at a temperature of 5°C. The results showed that the control sample of orange, pomegranate and grape juice showed a observable change in the TA since the first week of all treatments until the end of the storage period, as the T0-OR sample ranged from (7.31-%7.45) and T0-PO reached (0.34-0.51%), while T0-GR (0.78-1.16%), which is the highest compared to the juice samples treated in the conventional and microwave method. The conventional treatment samples (T1-OR, T1-PO, (T3-GR) exhibited TA values close to the control samples at the fifth week of the storage period, as it reached (7.42, 0.46, 1%), respectively. As for the juice samples treated conventionally under the conditions (T2-OR, T2-PO, T2-GR) and (T3-OR, T3-PO, T3-GR) at a storage period from the second week until the fifth week, it ranged from (7.34-7.41, 0.36-0.48, 0.80-0.99%) and (7.35-7.4, 0.36-0.45, 0.81-0.92%). The

microwave treatment showed a lower content of TA during the second week until the fifth week of storage period for all types of juices and for the three treatments, which are (T4-OR, T5-OR, T6-OR) and (T4-PO, T5-PO, T6-PO) and (T4-GR, T5-GR, T6-GR) and ranged (7.32-7.38, 7.33-7.37, 7.35-7.38) and (0.34-0.39, 0.35-0.4, 0.37 0.4%) and (0.8-0.86, 0.83-0.88, 0.83-0.88%) , respectively. The results showed that the TA was low or close in the first two weeks, but it started to increase with the progress of the storage period. These results were in agreement with Abiola et al. [33] who found that TA increased with the increase in the number of weeks of storage. The treatment of juices by rapid pasteurization at a temperature of 95°C for 15 seconds is the best treatment for the conventional method compared to the control sample and the two treatments represented by a temperature of 65°C for 30 min and a temperature of 85 for 15 min. As for the treatment of the three juices and all conditions by microwave, it showed the lowest content of titratable acidity compared to all conventional treatments and the control sample. This may be due to the possibility of microwave treatment in eliminating microorganisms to a greater extent compared to untreated juice samples. Also, the conventionally treated juice samples that had been preserved until the third week had a slight increase compared to the end of the storage period after 28 days. This is what Nwachukwu and Ezejiaku [44] who noticed an increase in the TA of orange juice with an increase in the number of weeks of storage due to the increase in the effectiveness of fermentation resulting from the increased growth of microorganisms in the juice.

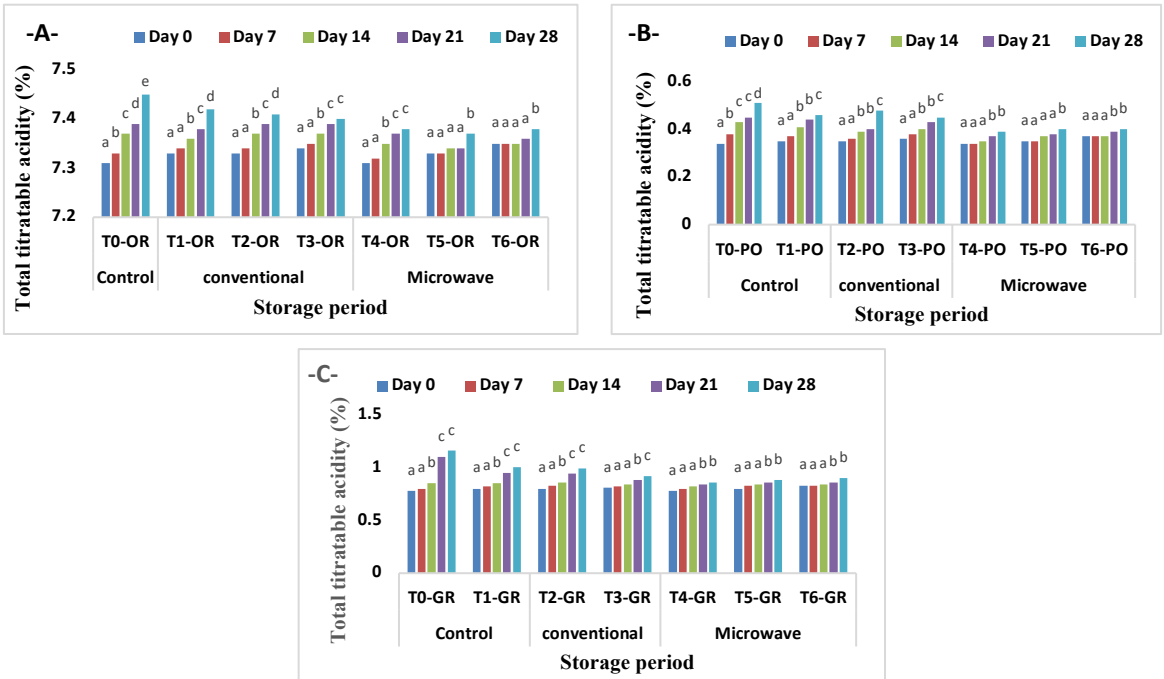



**Figure (2) Total titratable acidity (%) of orange (A), pomegranate (B) and grape juice (C) for all conventional, microwave and the control sample during the storage period of 28 days.**

**Total Soluble Solids (TSS%)**

Table (3) shows the average values of TSS for samples of fresh orange, pomegranate and grape juices in comparison with juice samples treated in the conventional way at different temperatures and time periods, which were (65, 85, 95 Cº) and (30 min, 15 min, 15 sec), and juice samples treated in the microwave (30, 1, 1.5 min), giving the TSS for all juices represented by the control samples T0-OR, T0-PO, T0-GR, which amounted to (10.45, 14.51, 16.47 Brixº), respectively. The results showed that the TSS did not change with the different conditions used and was equal to the control samples for both the conventional treatment samples (T1-OR, T2-OR, T3-OR and T1-PO, T2-PO, T3-PO and T1-GR, T2-GR, T3-GR) and the microwave treatment (T4-OR, T5-OR, T4-PO, T5-PO, T4-GR). The results showed a slight change in the TSS for the microwave treatment for each sample (T6-OR, T6-PO) which reached (10.46, 14.52 Brixº) respectively.

The microwaved grape juice samples represented by (T5-GR, T6-GR) gave a slightly higher TSS than the rest of the treatments and reached (16.48, 16.49 Brixº), respectively. This result was in agreement with [45] who indicated that the temperatures and time duration of the treatments used had little effect on TSS. The reason for these differences in the TSS may be due to the difference in the chemical composition of the juices and their content of organic acids or reducing sugars. The results of the statistical analysis showed no significant differences ($p > 0.05$) in the content of TSS between the control samples of juices and all treatments of conventional juices and microwave treatments under all conditions used in the study.

**Table (3) Average percentage of TSS for untreated natural juices (orange, pomegranate, grape) in comparison with juices treated conventionally and by microwave**

| Treatment | Orange juice | %TSS | Pomeg. juice | %TSS | Grape juice | %TSS |
|---|---|---|---|---|---|---|
| Control | T0-OR | 10.45±0.0214 [a] | T0-PO | 14.51±0.02828 [a] | T0-GR | 16.47±0.0114 [a] |
| Conventional | T1-OR | 10.45±0.0113 [a] | T1-PO | 14.51± 0.01414[a] | T1-GR | 16.47± 0.0121[a] |
| | T2-OR | 10.45±0.0103 [a] | T2-PO | 14.51±0.01134 [a] | T2-GR | 16.47±0.0021[a] |
| | T3-OR | 10.45±0.0115 [a] | T3-PO | 14.51 ± 0.02122[a] | T3-GR | 16.47± 0.0121[a] |
| Microwave | T4-OR | 10.45±0.0112 [a] | T4-PO | 14.51± 0.02112[a] | T4-GR | 16.47± 0.0021[a] |
| | T5-OR | 10.45±0.0106 [a] | T5-PO | 14.51±0.02121[a] | T5-GR | 16.48±0.0112[a] |
| | T6-OR | 10.46 ±0.0124[a] | T6-PO | 14.52±0.01124 [a] | T6-GR | 16.49± 0.0134[a] |

Figure (3) shows the TSS for each of orange, pomegranate and grape juices for the control samples and juice samples treated in the conventional and microwave during for 28 days at 5°C. The results showed that the control sample of orange juice had value of TSS in the first and second weeks, reaching (10.45 Brixº), which is the same concentration as the rest of the orange juice samples treated in the conventional way at time zero, but the TSS began to decrease with the advancement of the storage period, ranging from the third week until the end of the storage period (10.44-10.40 Brixº). As for the juice samples treated in the conventional ways represented by (T1-OR, T2-OR), they did not show any change in the concentration of total solids in the first

two weeks of storage, but a slight change occurred in the third week, ranging (10.44-10.42 Brixº), which is close to the control sample. These results were in agreement with Leahu *et al*. [46] who found stability in the TSS at the first weeks of storage in pasteurized orange juice. As for the T3-OR treatment, there was no change in the TSS in the fourth and fifth weeks, which reached 10.45% and 10.43 Brixº, respectively. As for the samples of orange juice treated with microwaves, the results gave stability in the TSS for all treatments, which reached 10.45% at time zero and until days 21 and 28, and the change was very small, which was 10.44 Brixº. As for the T6-OR orange juice treatment, it gave a slightly higher content of TSS than the rest of the treatments, and there was a very slight change in the TSS during the storage period, ranging between 10.46-10.45 Brixº. As for pomegranate juice, the control sample gave a decrease in the TSS at the third week of storage until the end of the period. While the results did not show a change in the TSS for pomegranate juice except in the third week for each of the treatments (T1-PO and T2-PO), the rest of the treatments (T3-PO, T4-PO, T5-PO, T6-PO) showed a decrease in the TSS in the fourth week, and it was slight during the storage period.

As for the grape juice sample, the treatment sample T0-GR and T1-GR gave from the first day until the end of storage the TSS (16.47-16.43 Brixº) and (16.47-16.44 Brixº), respectively. As for the grape juice samples of the treatments (T3-GR, T4-GR, T5-GR, T6-GR), the values of TSS ranged from the first day to the fifth week (16.47-16.44, 16.47-16.45, 16.48-16.46, 16.49-16.47 Brixº) and the change in TSS in the third and fourth weeks was very slight. These results were in consistent with [47] who mentioned that the amount of TSS remains constant in grapefruit samples stored
in the refrigerator after conventional pasteurization. The samples treated with microwave maintained the TSS without change when stored for 30 days. These results were in consistent with [46] who reported that TSS remained almost constant in the first weeks of storage on juice produced from a mixture of orange, kiwi and apple. Rivas *et al*. [48] also indicated that the decrease in TSS of juice stored for seven weeks.

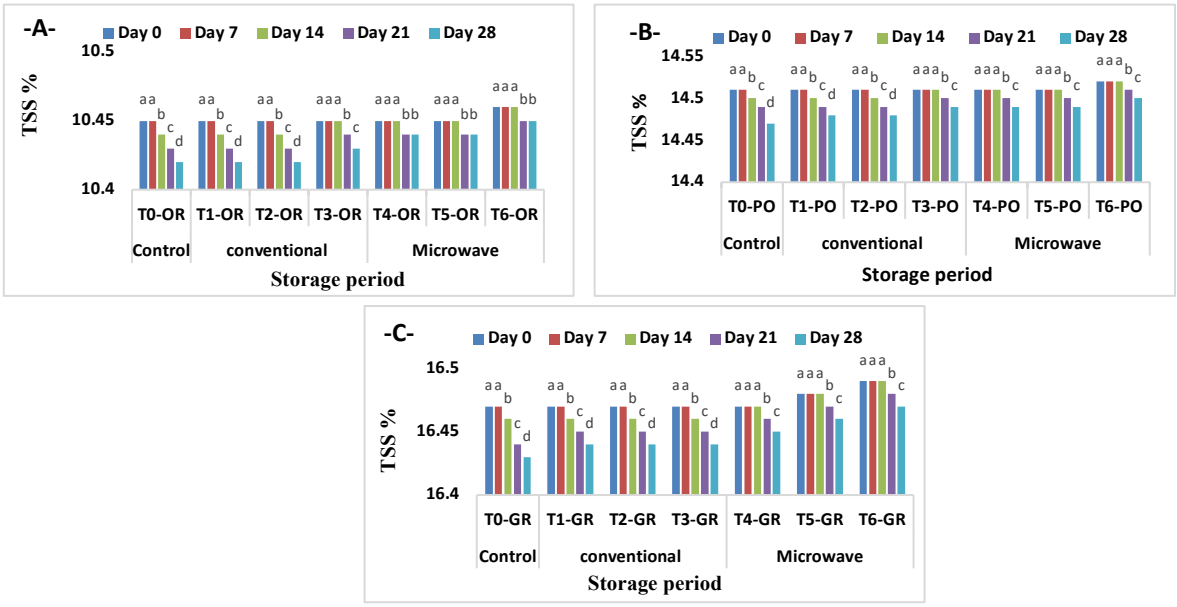



**Figure (3) Average values of TSS for orange (A), pomegranate (B) and grape juice (C) for all conventional, microwave treatments and the control sample during 28 days.**

**AA content (AA)**

Table (4) shows the AA content (AA) for control samples of orange, pomegranate and grape juice in comparison with juice samples treated in the conventional way and juice samples treated in the microwave. The control samples for all samples exhibited the highest content of AA, which were (33.35, 17.45, 9.88 mg/100 ml) for each of orange, pomegranate and grape juice, respectively. The results indicate that slow, conventional treatments, where juices were exposed to higher temperatures for extended periods, resulted in lower AA content compared to treatments involving short-duration exposure to high temperatures. Specifically, the treatments T1-OR, T2-OR, T1-PO, T2-PO, T1-GR, and T2-GR yielded AA levels of 25.11 and 22.45 mg/100 mL for orange juice, 11.76 and 10.37 mg/100 mL for pomegranate juice, and 6.5 and 7 mg/100 mL for grape juice. This indicates that treatment for 15 min at 85°C caused more loss of AA as compared to 30 min of pasteurization at 65°C. The findings of the statistical analysis revealed no significant differences in the AA ($p>0.05$) levels among the samples of each treatment (T1-OR, T3-OR). Similarly, for other juices, the differences of AA values were not significant among the various treatment samples (T1-PO, T3-PO, (T1-GR, T3-GR) and (T1-GR, T3-GR) although rapid pasteurization T3 was presented with more than the other traditional methods in all types of juices. The AA content of the samples (T3-OR, T3-PO, T3-GR) were (25.25, 12.45, 7.25 mg/100 ml) respectively. These findings harmonized with Ding [49] who recorded a decrease in the AA content by increasing the time and temperature with these new fermenting protocols. Juice quality increased due to application of the microwaves in the study compared to the conventional methods. The microwave treatment for 30 seconds was the lowest and the closest to fresh juice samples on the decomposition of AA, which was only slightly different from the fresh juice

samples. Hashemi et al. [50] indicated no significant differences ($p>0.05$) in the AA content in all watermelon juice treated with microwave and compared to conventional pasteurization s until 20 seconds of treatment time.

The juice samples for other microwave treatment ranged (30.12, 29.15 mg/100 ml) for (T5-OR, T6-OR) and (14.57, 13.33 mg/100 ml) for (T5-PO, 6P )and (8.28, 8 mg/100 ml) for (T5-GR, T6-GR) respectively. The results of the statistical analysis showed that there were no significant differences ($p > 0.05$) between the AA content in the control sample (T0-PO) for grape juice and the AA content in the samples treated with microwave (T4-PO, T5-PO, T6-PO) as well as the case with pomegranate juice. These results were close to what was mentioned by Kumar et al. [51] when studying the AA content in grapefruit juice, which found that the effect of treatment or pasteurization Microwaving was less than conventional pasteurization.

**Table (4) Average AA content (AA mg/100 mL) in untreated natural juices (orange, pomegranate, grape), as well as those treated using conventional and microwave methods.**

| Treatment | Orange juice | AA mg/100ml | Pomeg. juice | AA mg/100ml | Grape juice | AA mg/100ml |
|---|---|---|---|---|---|---|
| Control | T0-OR | 33.35±0.1124$^{a}$ | T0-PO | 17.45±0.3114$^{a}$ | T0-GR | 9.88±0.2828$^{a}$ |
| Conventional | T1-OR | 25.11±0. 4542$^{c}$ | T1-PO | 11.76±2.1140$^{c}$ | T1-GR | 6.5 ±1.1320$^{d}$ |
| | T2-OR | 22.45± 0.1909 $^{d}$ | T2-PO | 10.37±0.6213$^{d}$ | T2-GR | 7±0.1710$^{c}$ |
| | T3-OR | 25.25±0.2545$^{c}$ | T3-PO | 12.45±0.2641$^{c}$ | T3-GR | 7.25±0.7110$^{c}$ |
| Microwave | T4-OR | 31.11±0.7071$^{b}$ | T4-PO | 15.64±0.2350$^{b}$ | T4-GR | 8.76±0.2121$^{a}$ |
| | T5-OR | 30.12±1.1710$^{b}$ | T5-PO | 14.57±0.0353$^{b}$ | T5-GR | 8.28±0.0112$^{a}$ |
| | T6-OR | 29.15 ±0.5371$^{b}$ | T6-PO | 13.33±0.01124$^{b}$ | T6-GR | 8±0.01134$^{a}$ |

Figure (4) shows the values of AA content for each of the orange, pomegranate, grape juices for the control samples and the samples treated in the conventional and microwave methods at 5°C for 28 days. The results showed that the control samples of all juices gradually decreased in AA content from the first week until the end of the storage period. The AA content ranged from (33.35-7.5, 17.45-5.4, 9.88-3.11) mg/100 ml for each of (T0-OR, T0-PO, T0-GR), respectively. The results revealed variations in the impact of treatment type, temperature, duration, and juice type on ascorbic acid (AA) content. Traditional treatment at 65°C for 30 minutes resulted in the lowest AA content compared to treatments at 85°C for 15 minutes and 95°C for 15 seconds. The rapid treatment gave the highest AA content with a slight difference at the end of the storage period for all juices, which are (T1-OR, T2-OR, T3-OR) (18.10, 20, 22.27.14 mg/100 ml) and (T1-PO, T2-PO, T3-PO) (6.57, 6.78, 7) mg/100 ml) and (T1-GR, T2-GR, T3-GR) (3.5, 4.66, 4.9 mg/100 ml), respectively. The results showed that microwave treatment of juices is the best retention of AA content during the storage period and until the end of storage compared to the conventional method. The less the juice is exposed to microwave treatment, the more the juice quality and nutritional value are preserved. The reason for the decrease in the AA content in the juice samples treated with microwave may be due to the heat generated during treatment and oxidation during storage period [52]. The results also agreed with Igual et al. [47] who found a significant decrease in AA content of grapefruit juice treated with the conventional method, while the microwave method resulted in a lower reduction.

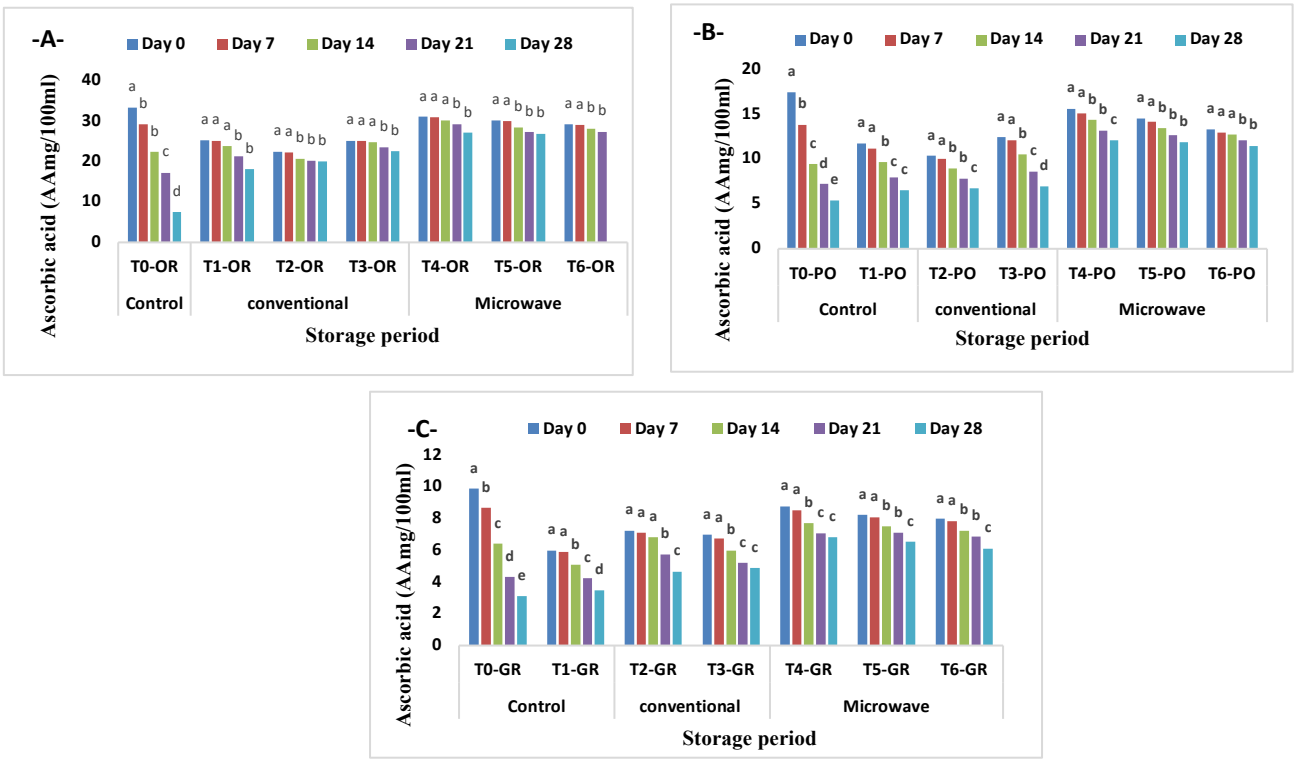



**Figure (4) Ascorbic acid content values (AAmg/100ml) for orange (A), pomegranate (B) and grape juices (C) for all conventional, microwave treatments and the control sample during 28 days.**

## Hydroxymethylfurfural content (HMF)

Table (5) shows the average values of (HMF) for control samples of orange, pomegranate and grape juices and juice samples treated in the conventional way. The results showed that the natural juice samples (control) had a very low content of HMF, which was (0.04, 0.54, 0.63 ppm) for orange, pomegranate and grapes, respectively. The juice samples treated in the conventional way had the highest content of HMF (0.28, 1.71 and 1.61 ppm) at 85 °C for 15 min for each of orange, pomegranate and grape juices, respectively. This may be due to the fact that the treatment period is long compared to the high temperature. This result was in agreement with Mert [53] who processed and pasteurized grape juice at a temperature of 65 °C for 30 minutes.

The conventional treatment at 95°C exhibited lower content of HMF, which reached (0.09, 0.92 and 0.88 ppm) respectively for all juice samples. This may be related to the rapid heat exposure that is known as the best treatment among other options used in the experiment. With respect to the microwave treatment of juices, implementing this treatment in the shortest time, 30 seconds, showed the lowest content of hydroxymethylfurfural in the samples of all orange, pomegranate and grape juices, which had the following values of (0.07, 0.68 and 0.67 ppm). It was continued by treating (T5-OR, T5-PO, T5-GR) for 60 seconds that even had a little higher hydroxymethylfurfural content than the first treatment by getting (0.09, 0.77, 0.82 ppm). The outcomes of the study match what Çağlar et al. [54] found out, raisin juice HMF content in microwave-pasteurized samples was 42% lower than in conventionally treated samples. The statistical analysis confirmed that HMF in the orange juice control sample had no significant differences ($p > 0.05$) and also in the HMF content of the juice sample that was microwave-treated for 30 or 60 seconds ($t= 2570$). The traditional treatment (T3-OR) resulted in a significant difference ($p < 0.05$) in HMF content compared to the juice samples treated in the conventional way (T1-OR, T2-GR). Results also announced that there were no big differences ($p>0.05$) in the level of HMF between the ordinary

juice sample (T1-OR, T2-OR) and the orange juice sample microwaved (T6-OR). The statistical tests disclosed significant

differences ($p<0.05$) in the hydroxymethylfurfural of the pomegranate juice control sample T0-PO and the treated juice samples for each of the (T1-PO, T2-PO, T3-PO, T6-PO). The statistical tests also demonstrated significant differences ($p<0.05$) in the level of HMF in the non-treated sample (T2-PO) and between the levels of HMF in the treated pomegranate juice samples (T0-PO, T1-PO, T3-PO, T6-PO). The HMF did not change much ($p>0.05$) in the control sample (T0-PO) compared to the treated juice samples (T4-PO, T5-PO). The results are supported by a study by Karadeniz et al. [55] that showed that the HMF content increased linearly with the temperature rise and storage time.

**Table 5: Average hydroxymethylfurfural (HMF) content (ppm) in untreated natural juices (orange, pomegranate, grape) compared to those treated using conventional and microwave methods**

| Treatment | Orange juice | HMF (ppm) | Pomeg. juice | HMF (ppm) | Grape juice | HMF (ppm) |
|---|---|---|---|---|---|---|
| Control | T0-OR | $0.04\pm0.0227^{a}$ | T0-PO | $0.54\pm0.3114^{a}$ | T0-GR | $0.63\pm0.1414^{a}$ |
| Conventional | T1-OR | $0.23\pm0.3232^{b}$ | T1-PO | $1.26\pm0.0332^{b}$ | T1-GR | $1.21\pm1.2122^{b}$ |
| | T2-OR | $0.28\pm0.1334^{b}$ | T2-PO | $1.71\pm0.4545^{c}$ | T2-GR | $1.610\pm0.1710^{c}$ |
| | T3-OR | $0.09\pm0.2121^{a}$ | T3-PO | $0.92\pm0.1444^{b}$ | T3-GR | $0.88\pm0.7110^{c}$ |
| Microwave | T4-OR | $0.07\pm0.2233^{a}$ | T4-PO | $0.68\pm0.04242^{a}$ | T4-GR | $0.67\pm0.2121^{a}$ |
| | T5-OR | $0.09\pm1.0111^{a}$ | T5-PO | $0.77\pm0.2221^{a}$ | T5-GR | $0.82\pm0.0112^{a}$ |
| | T6-OR | $0.25\pm0.2211^{b}$ | T6-PO | $0.92\pm0.07171^{b}$ | T6-GR | $1.10\pm0.0134^{c}$ |

Figure (5) shows the average values of HMF content for each of the orange, pomegranate, grape juices for the control samples and c the juice samples treated in the conventional way and microwaved under the conditions used in the study and following up the preservation of the juices at a temperature of 5°C for 28 days. The HMF content gave slight changes to all juice samples for the different treatments during the storage period, even the control samples of orange, pomegranate and grape juices, whose content was very low despite being natural and untreated, as each of (T0-OR, T0-PO, T0-GR) from the second week until the end of the storage period reached (0.041-0.046, 0.54-0.60, 0.65-0.73 ppm). The results showed that the orange juice samples treated conventionally and by microwave started to increase the content of HMF at the third week except for the treatment (T4-OR) which gave a slight increase from the first week which ranged from the first week to the end of the storage period (0.070-0.080 ppm). The two conventional treatments at (65°C, 30 minutes and 85°C, 15 minutes) showed the highest content of HMF while the lowest content of HMF was in the juice samples treated by microwave at 30 seconds followed by the microwave treatment for one minute. The juice samples treated with microwaves for 90 seconds exhibited the highest HMF content compared to those treated for a shorter duration, closely resembling the levels observed in the conventional treatments (T1-OR, T2-OR).

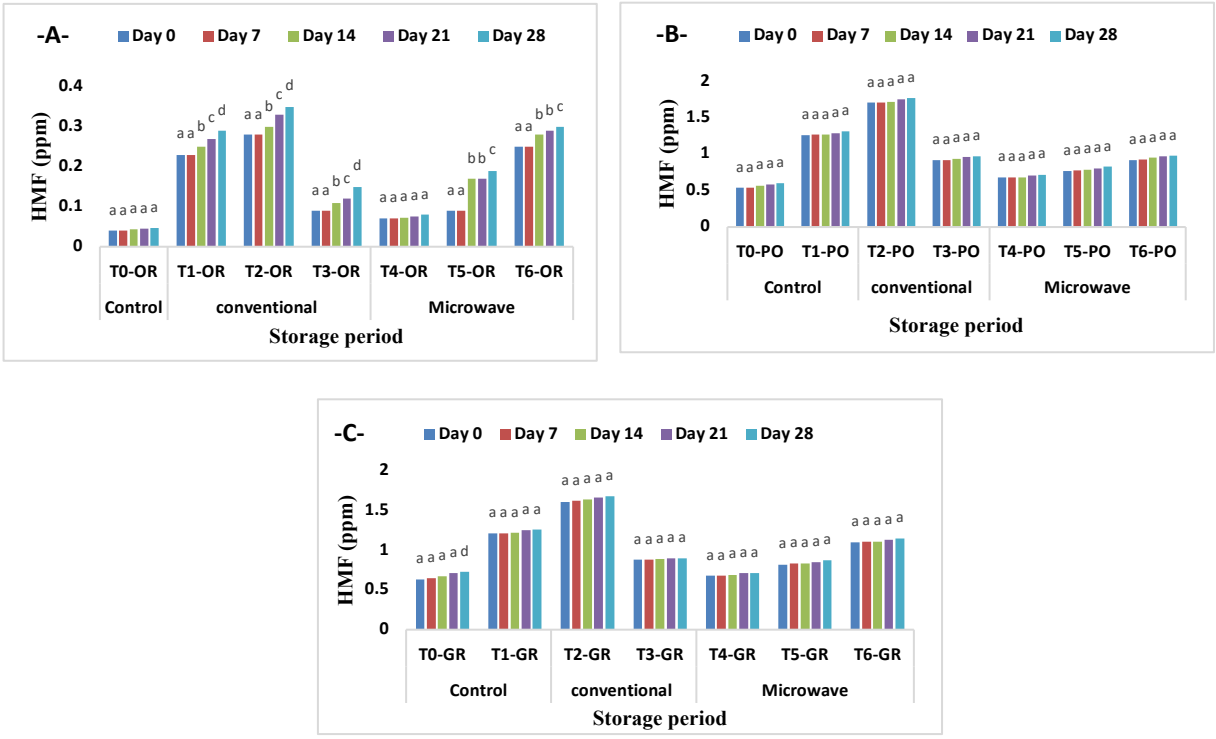



**Figure (5) Average values of hydroxymethylfurfural (HMF ppm) for orange (A), pomegranate (B) and grape juice (C) for all conventional, microwave treatments and the control sample during 28 days.**

## Pectin Methylesterase (PME)

Table (6) shows the average values of the activity content of (PME) for the control samples of orange, pomegranate, grape juices, and the juice samples treated at 65°C for 30 minutes, 85 °C for 15 minutes, 95°C for 15 seconds and juice samples treated in the microwave at 1400 W at a frequency of 50 Hz (30, 1, 1.5 min). The results showed a variation in the activity of PME for the juice samples and in the efficiency of enzyme inhibition, as the conventional treatment at 95°C for 15 seconds gave less activity for the PME compared to other conventional methods. The results showed significant differences ($p<0.05$) in the activity of the enzyme between the three conventional treatments in orange juice (T1-OR, T2-OR, T3-OR) as well as in grape juice, the three conventional treatments (T1-GR, T2-GR, T3-GR) showed significant differences ($p<0.05$) in enzyme activity values. While in pomegranate juice, there were no significant differences in pectin methyl esterase activity values between the conventional treatments used. Also, juice samples treated with microwave (1, 1.5 minutes) did not give significant differences ($p>0.05$) between each of (T5-PO, T6-PO). The results showed that the treatment for the shortest time and the highest temperature (95°C for 15 seconds) revealed the lowest PME enzyme activity compared to the other two treatments and for all juices, reaching (0.34, 0.051, 0.09 Unit/ml), respectively. The microwave treatment for a minute and a half showed the highest inhibition of the enzyme activity for all types of juices (orange, pomegranate, and grapes), which reached PME activity (0.089, 0.021, 0.033 Unit/ml), respectively. The results were consistent Tajchakavit & Ramaswamy, with [56] who noted that the enzyme inhibition in orange juice was faster by Microwave heating compared to conventional thermal heating. The result were in agreement with Amaro & Tadini,

[57] who found that microwave treatment was effective in inactivating or inhibiting the PME enzyme in orange juice.

**Table (6): Average Pectin Methyl Esterase (PME) activity (Unit/mL) in untreated natural juices (orange, pomegranate, grape) compared to those treated using conventional and microwave methods.**

| Treatment | Orange juice | (Unit/ml) PME | Pomeg. juice | PME (Unit/ml) | Grape juice | PME (Unit/ml) |
|---|---|---|---|---|---|---|
| Control | T0-OR | $1.410\pm0.1115^{a}$ | T0-PO | $0.84\pm2.3114^{a}$ | T0-GR | $1.49\pm0.1144^{a}$ |
| Conventional | T1-OR | $0.74\pm0.1223^{b}$ | T1-PO | $0.086\pm0.1177^{b}$ | T1-GR | $0.88\pm0.2122^{b}$ |
| | T2-OR | $0.53\pm0.2314^{c}$ | T2-PO | $0.072\pm0.1414^{b}$ | T2-GR | $0.31\pm1.1540^{c}$ |
| | T3-OR | $0.34\pm0.07171^{d}$ | T3-PO | $0.051\pm0.1777^{b}$ | T3-GR | $0.09\pm0.2660^{d}$ |
| Microwave | T4-OR | $0.66\pm0.0047^{b}$ | T4-PO | $0.22\pm0.0212^{c}$ | T4-GR | $0.79\pm0.2121^{b}$ |
| | T5-OR | $0.25\pm0.0111^{d}$ | T5-PO | $0.035\pm0.2241^{b}$ | T5-GR | $0.081\pm2.0514^{d}$ |
| | T6-OR | $0.089\pm0.2211^{e}$ | T6-PO | $0.021\pm0.07171^{b}$ | T6-GR | $0.033\pm0.6110^{e}$ |

Figure (6) shows the average values of PME for each of the orange, pomegranate, grape juices for the control samples and the juice samples treated in the conventional and microwave methods under the conditions used in the study and following up on the preservation of the juices at 5 °C for 28 days. The results showed that the activity of PME was affected by the different treatments during the storage period. The conventional treatment of juices at 95 °C had the lowest activity of the enzyme, which began to increase from the 14th day until the end of the storage period, as the activity of PME reached (0.38-0.43 Unit/ml) and (0.053-0.058 Unit/ml) for the treatment (T3-OR, T3-PO) for both orange and pomegranate juices. An increase in the activity of the PME enzyme was observed in grape juice from the seventh day until the end of the storage period. The conventional treatment at 65°C and 30 min exhibited the highest activity of the PME enzyme compared to the rest of the treatments. The results also showed that the effect of microwave treatment for 30 sec was similar in the activity values of the PME enzyme with the conventional treatment at 65 °C. The microwave pasteurization for a minute and a half for was effective to inhibit PME all treated juice samples. PME values were (0.089-0.097, 0.021-0.031, 0.034-0.039 Unit/ml) for each of the treatment samples (T6-OR, T6-PO, T6-GR), respectively. In general, the results showed that microwave pasteurization of juices was sufficient in inhibiting the activity of PME for all treatments compared to conventional pasteurization methods.

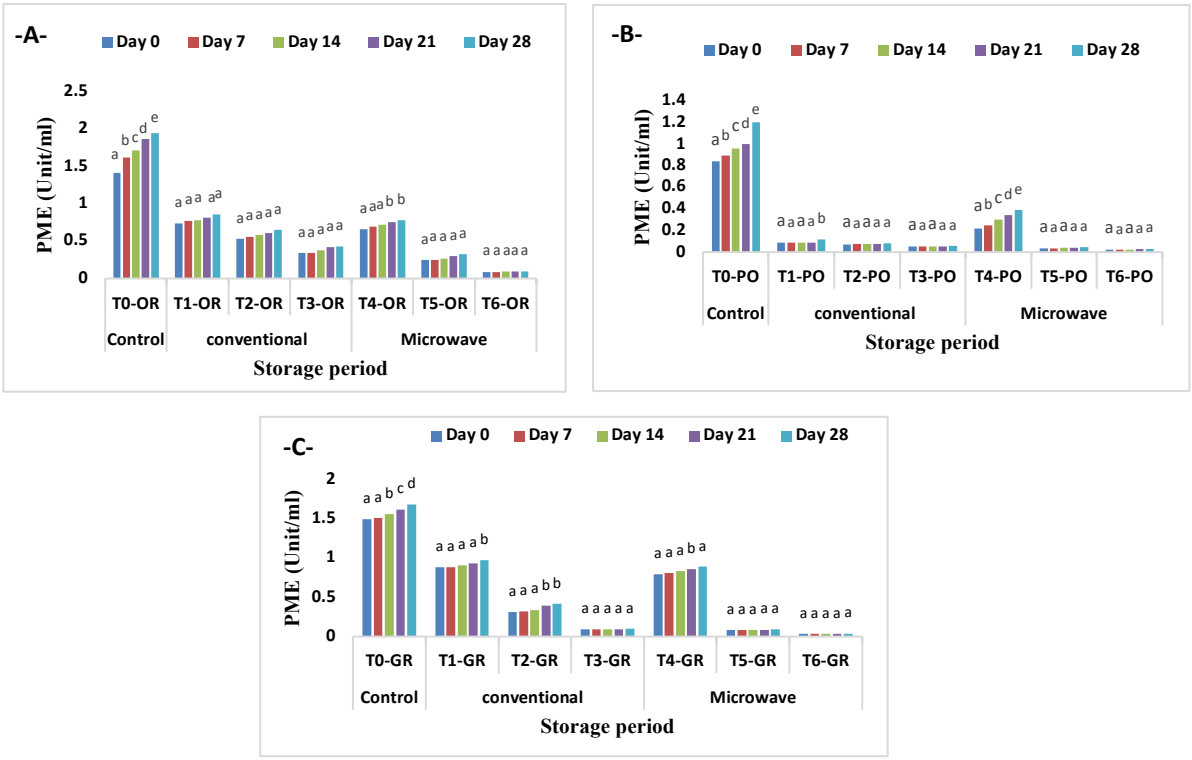



**Figure (6) Average values of pectin methyl esterase activity (PME Unit/ml) for orange (A), pomegranate (B) and grape juice (C) for all conventional, microwave treatments and the control sample during 28 days.**

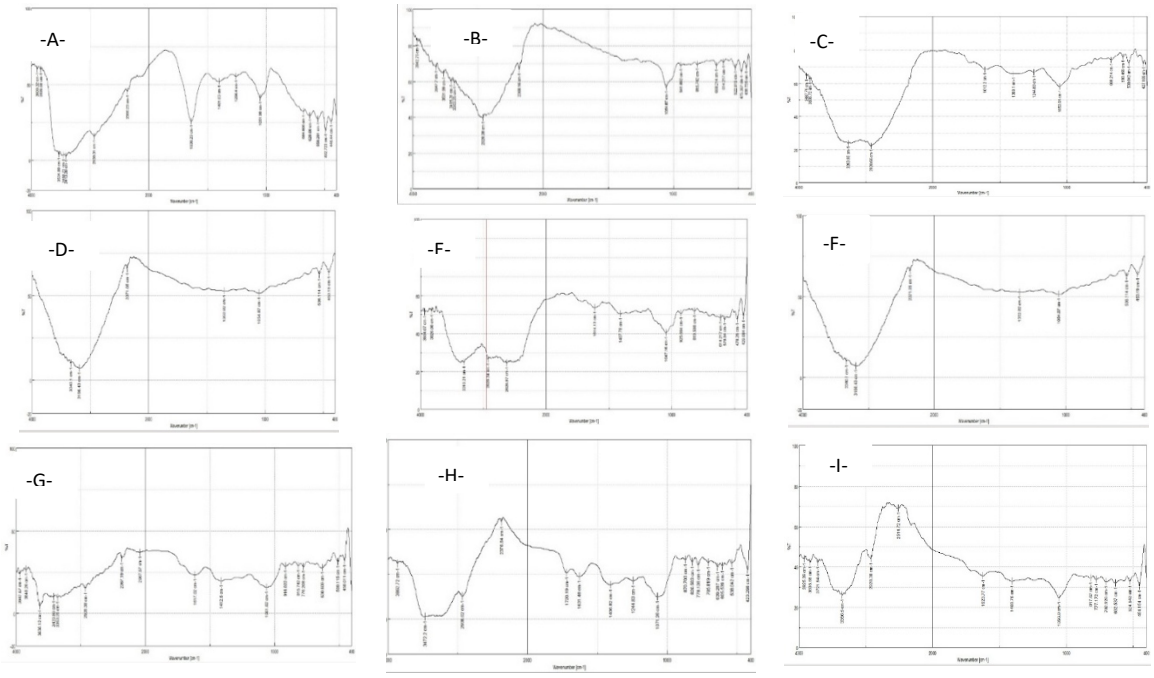
## Fourier transform infrared (FTIR)

Table (7) shows the most important peaks and active groups for each of the control samples of orange, pomegranate and grape juice treated conventionally and by microwave. It is noted that a wide band appears through the plots in each of the control samples T0-OR, T0-PO and T0-GR at a wave number of 3900.32 $cm^{-1}$ due to the stretching vibration corresponding to the hydroxyl groups O-H [58,59]. The presence of these peaks was observed in the remaining six samples of the treatments pasteurized conventionally and by microwave for each of orange, pomegranate and grape juice, whose vibration falls within the wave number of 3000-4000 $cm^{-1}$[58,59]. The control samples T0-PO, T0-GR, an intermediate band was found at wave numbers $cm^{-1}$ 3862.72, 3870.43 due to the stretching vibration corresponding to the hydroxyl groups and alcohols [60]. The results also showed that there are four peaks or bands in the T0-OR sample, whose wave numbers ranged between cm-13413.39-3839.58 due to the stretching vibration corresponding to the alcohol group O-H [60]. Their oscillations are consistent with the vibrations of the active groups that fall within the absorption limits compatible with the hydroxyl groups O-H, whose wave range ranges between $cm^{-1}$ 3200-3550 [60] or whose vibrational amplitude is between the wavenumber $cm^{-1}$ 3000-3700 [61].

The samples of T0-PO, T0-GR exhibited a medium band due to the stretching vibration corresponding to the alkene group H-CH at wavenumbers 2938.02, 2918.73, respectively [62]. In the third spectrum of the T0-PO and T0-GR samples, groups related to carbonyls were found, which are located within wavenumbers $cm^{-1}$ 1720.19 and 1594.84, respectively [63,64]. A weak stretching band was found in the T0-PO sample, which is identical to the carboxylic acid groups -COO, C=O at wavenumber cm-11406.82

[65]. A vibrational band appeared at the eighth spectrum in the T0-GR sample and at the ninth spectrum in the T6-PO sample at wave numbers 1055.84 and 1059.69 $cm^{-1}$, which fall within the vibration identical to the Phosphate ion [66]. Strong bands due to hydroxyl groups appear in the T1-OR sample, located from the first spectrum to the fifth spectrum, at wavenumbers 3942.75, 3677.7, 3531.99, 3415.31, 3363.25 $cm^{-1}$, respectively [61, 67, 68, 60]. It was also observed that there are three bands due to hydroxyl groups O-H in pomegranate and grape juice at wavenumbers ranging from 3925.39-3721.94, which are produced by water molecules [58, 59].

Orange juice sample (T1) treatment exhibited a medium band located at the eighth spectrum at wavenumber 1054.87 $cm^{-1}$ which indicates the presence of carboxylic acid group C=O and also corresponds to the C–N stretching vibrations of aromatic amines [69]. These peaks, which belong to -COOH groups, appeared in both T1-OP and T1-GR samples at wavenumber 12514.72 $cm^{-1}$ and 2363.334 $cm^{-1}$, respectively [70]. These bands were also observed at absorbance 1054.87 $cm^{-1}$ in T3-OR sample and 1053.91 $cm^{-1}$ in T4-GR sample which corresponds to the stretching of carboxylic groups [69,71]. The results of the infrared spectroscopy showed the presence of weak spectral bands in the three conventionally treated samples and the three microwave-treated samples for all juices used in the study due to the bending vibration identical to the C-H Alkyne groups, which lie between the wavenumbers of 680-1610 $cm^{-1}$ [66]. The infrared spectral results indicated a number of spectral bands with asymmetrical stretches in each of the samples T2-PO, T2-GR, T3-GR, T4-PO, T4-GR, T6-PO at wavenumbers 2936.09, 2923.56, 2906.40, 2928.45, 2934.16 $cm^{-1}$ respectively, correspond to the H-C-H (Asymmetrical stretch) groups which fall within the wavenumbers 3000-2850 $cm^{-1}$ [62]. Extension bands appear in each of the juice samples represented by T1-PO, T1-GR, T2-OR, T3-OR, T4-PO, T4-GR, T5-GR, T6-OR-T6-PO and T6-GR, which fall within the wavenumber 1650±1600, which are due to the ketone groups [66].



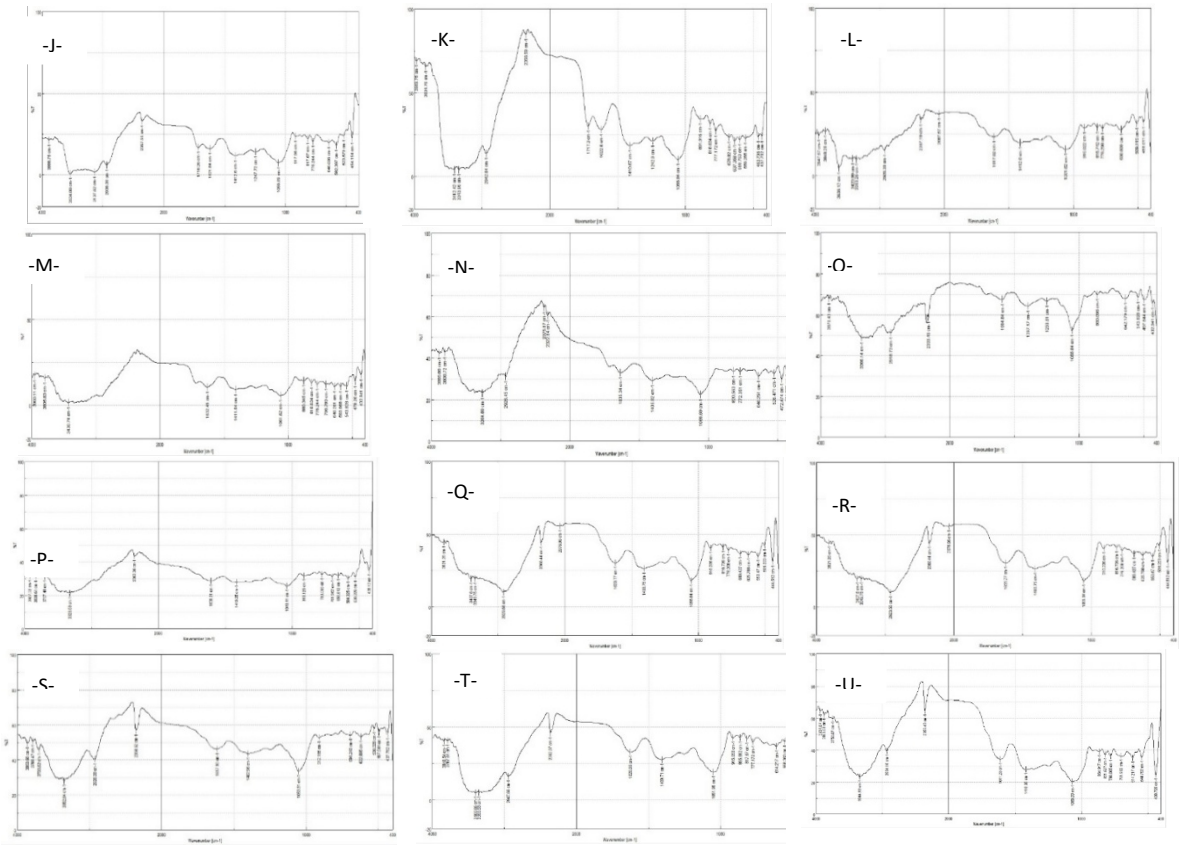



**Figure (7): A. Infrared spectrum of orange juice (T0), B. Infrared spectrum of orange juice (T1), C. Infrared spectrum of orange juice (T2), D. Infrared spectrum of orange juice (T3), E. Infrared spectrum of orange juice (T4), F. Infrared spectrum of orange juice (T5), G. Infrared spectrum of orange juice (T6), H. Infrared spectrum of pomegranate juice (T0), I. Infrared spectrum of pomegranate juice (T1), J. Infrared spectrum of pomegranate juice (T2), K. Infrared spectrum of pomegranate juice (T3), L. Infrared spectrum of pomegranate juice (T4), M. Infrared spectrum of pomegranate juice (T5), N. Infrared spectrum of pomegranate juice (T6), O. Infrared spectrum of grape juice (T0), P. Infrared spectrum of grape juice (T1), Q. Infrared spectrum of grape juice (T2), R. Infrared spectrum of grape juice (T3), S. Infrared spectrum of gape juice 4), T. Infrared spectrum of grape juice (T5), U. Infrared spectrum of grape juice' (T6)**

Table (7) observed wavenumbers (cm-1) and assignments for all the natural juices

| Treatment | Wave number (cm-1) OR | Functional Group | Assignment | Group frequency cm-1 | Source | Wave number (cm-1) PO | Functional Group | Assignment | Group frequency cm-1 | Source | Wave number (cm-1) GR | Functional Group | Assignment | Group frequency cm-1 | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T0 | 3900.32 | Hydroxyl | O-H from (H2O) | 4000–3000 | [58,59] | 3862.72<br>3472.2 | Hydroxyl Alcohol | O-H medium | 3300-3900 | [60] | 3870.43<br>3366.14 | Hydroxyl Alcohol | O-H medium | 3300-3900 | [60] |
| | 3839.58<br>3534.88<br>34.58.71<br>3413.39 | HydroxylAlcohol | O-H (medium) | 3300-3900 | [60] | 2938.02 | Alkanes | H-C-H Stretch | 3000-2850 | [62] | 2918.73 | Alkanes | H-C-H Stretch | 3000-2850 | [62] |
| | | | | | | 2376.84 | hydroxyl | -OH | 2366.23–3318.89 | [65] | 2333.45 | hydroxyl | —O–H stretch | - | [72] |
| | | | | | | 1720.19 | Carbonyl | C=O | - | [63] | 1594.84 | Carbonyl | C=O | - | [64] |
| | 2930.31 | Alkanes | C-H Bend | - | [73] | 1631.48 | Carboxylic acids | COOH | - | [68] | 1055.84 | Phosphate ion | - | 1100±1000 | [66] |
| | 2366.23 | | -OH | 2366.23–3318.89 | [65] | 1406.82 | Carboxylic acid | –COO C = O | - | [74] | 860.096 | Alkyne | CH bend | 860.096 | [75] |
| | 1638.23 | Alkene | C=C | 1630-1670 | [60] | 870.703 | Alkenes | C=C Stretch | - | [76] | 642.179 | Alkyne | C-H bend | 680-610 | [66] |
| T1 | 3942.75 | hydroxyl | O-H from (H2O) | 4000–3000 | [85,59] | 3925.39<br>3836.68<br>3721.94 | Hydroxyl | O-H from (H2O) | 4000–3000 | [58,59] | 3927.32<br>3838.61 | hydroxyl | O-H from (H2O) | 4000–3000 | [58,59] |
| | 3647.7 | hydroxyl | O-H | 3000–3700 | [61] | 3356.5 | Amines | C=O | - | [73] | 3707.48 | hydroxyl | O-H | 3000–3700 | [61] |
| | 3531.99 | hydroxyl | O-H Unsubstituted | - | [67] | 2928.38 | alkane | C-H stretch | - | [76] | 3328.53 | hydroxyl | O-H | 3000–3700 | [61] |
| | 3415.31 | hydroxyl | O-H stretching | - | [68] | 2514.72 | Carboxylic acids | -COOH | 2500-3300 | [70] | 2363.34 | Carboxylic acids | -COOH | 2500-3300 | [70] |
| | 3363.25 | | O-H strong | 3200-3550 | [60] | 1623.77 | Ketone | C=C stretch | - | [79] | 1609.31 | Quinone or ketone | C=O | 1650±1600 | [62] |
| | 1054.87 | Carboxylic acid, .aliphatic | C-O C=O C-N | 1054.87 | [69] | 817.67 | Alkyne | C-H | 915-890 | [62] | 1419.35 | carboxylate | C–OO | - | [92] |
| | 668.214 | Alkyne | C-H bend | 610-680 | [62] | 632.537 | Alkyne | C-H bend | 610-680 | [62] | 1040.41 | - | C-O | - | [77] |
| | 614.217 | Alkyne | C-H bend | 610-680 | [62] | 614.271 | Alkyne | C-H bend | 610-680 | [62] | 656.643 | Alkyne | C-H bend | 610-680 | [62] |
| T2 | 3887.79<br>3835.72 | hydroxyl | O-H from (H2O) | 4000–3000 | [58,59] | 3888.75<br>3534.88 | hydroxyl | O-H from (H2O) | 4000–3000 | [58,59] | 3821.26 | hydroxyl | O-H from (H2O) | 4000–3000 | [58,59] |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3263.93 | hydroxyl | O-H stretch | 3550-3200 | [62] | 3137.62 | hydroxyl | O-H stretch | 3550-3200 | [62] | 3407.6 3349.75 | hydroxyl | O-H stretch | 3550-3200 | [62] |
| | 2920.66 | aliphatic | C-H | - | [78] | 2936.09 | Alkanes | H-C-H Asymmetrical Stretch | 3000-2850 | [62] | 2923.56 | Alkanes | H-C-H Asymmetrical Stretch | 3000-2850 | [62] |
| | 1612.2 | Ketone | C=C stretch | - | [79] | 2367.55 | hydroxyl | -OH | 2366.23–3318.89 | [65] | 817.95 | Aromatics | C-H | 900-675 | [62] |
| | 1399.1 | Alkanes | C-H Bend | 1470-1350 | [58] | 1718.26 | hydroxyl | OH | - | [93] | 669.427 | Alkyne | C-H bend | 680-610 | [62] |
| | 1053.91 | Alkyl- | C-O-C | 1150-1050 | [66] | 1412.6 | Vinyl | CH | 1410-1420 | [66] | 625.788 | Alkyne | C-H bend | 680-610 | [66] |
| T3 | 3340.1 | hydroxyl | C–OH | 3450–3350 | [80,81] | 3969.75 | hydroxyl | O-H from water molecule (H2O) | 4000–3000 | [58,59] | 3821.26 | hydroxyl | O-H from water molecule (H2O) | 4000–3000 | [58,59] |
| | 2371.05 | ketones | C=O stretch | 2371.05 | [82] | 38.34.76 | Alcohol | O-H (medium) | 3300-3900 | [60] | 2923.56 | Alkanes | H-C-H Asymmetrical Stretch | 3000-2850 | [62] |
| | 1352.82 | Aromatics, alkanes | C-H | 1352.82 | [69] | 3412.42 | hydroxyl | O-H stretch | 3550-3200 | [66] | 2360.44 | alkyl | CH | - | [83] |
| | 1054.87 | Carboxylic acid, | C=O C-O | 1054.87 | [69] | 2942.84 | hydroxyl | OH stretching | - | [85] | 1623.77 | carbonyl | C=O | - | [84] |
| T4 | 3934.07 | Alcohol | O-H medium | - | [60] | 3805.96 3808.72 3204.80 | hydroxyl | O-H from (H2O) | 4000–3000 | [58,59] | 3836.68 3788.47 3703.62 3352.64 | hydroxyl | O-H from (H2O) | 4000–3000 | [58,59] |
| | 3826.08 | hydroxyl | O-H | - | [91] | 2906.40 | Alkanes | H-C-H Asymmetrical Stretch | 3000-2850 | [62] | 2928.38 | Alkanes | H-C-H Asymmetrical Stretch | 3000-2850 | [62] |
| | 2929.34 | hydroxy | O-H band | - | [73] | 2370.77 | hydroxyl | -OH | 2366.23–3318.89 | [65] | 1617.98 | Quinone or ketone | C=O | 1650±1600 | [66] |
| | 1614.13 | alkenes | O-H strong | - | [90] | 1637.30 | Quinone or ketone | C=O | 1650±1600 | [66] | 1053.91 | carboxylic | C-O Stretching vibrations of | - | [71] |
| | 819.598 | Aromatics | C-H | 900-675 | [62] | 772.351 | Aromatics | C-H | 900-675 | [62] | 622.895 | Alkyne | C-H bend | 680-610 | [66] |
| | 1407.78 | Alkanes | C-H Bend | 1470-1350 | [62] | 640.257 | Alkyne | C-H bend | 610-680 | [66] | 614.217 | Alkyne | C-H bend | 680-610 | [66] |
| T5 | 3872.36 | hydroxyl | O-H from (H2O) | 4000–3000 | [58,59] | 3960.11 3805.83 | hydroxyl | O-H from (H2O) | 4000–3000 | [58,59] | 3840.54 3787.51 | hydroxyl | O-H from (H2O) | 4000–3000 | [58,59] |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 3430.74 | | | | | 3400.85<br>3355.53 | | | | |
| | 3708.44 | hydroxyl | O-H | 3655.41-<br>3708.44 | [86] | 1632.45 | Amino acid<br>s | CH stretch | - | [87] | 2947.66 | Ketones | CH stretch | - | [87] |
| | 3642.87 | Alcohol | O-H<br>medium | 3300-3900 | [60] | 1411.64 | Vinyl | CH | 1410-1420 | [66] | 1626.66 | Quinone<br>or ketone | C=O | 1650±1600 | [66] |
| | 3332.39 | Alcohols<br>and<br>Phenols | O-H<br>Stretch | 3600-3100 | [62] | 880.345 | Aromatics | C-H | 900-675 | [62] | 865.882<br>817.67 | Aromatic<br>s | C-H | 900-675 | [62] |
| | 1597.73 | aromatics | C-C stretch | - | [88] | 706.783 | hydroxyl | H–O<br>vibration | - | [89] | 777.172 | Aromatic<br>s | C-H | 900-675 | [62] |
| | 613.252 | Alkyne | C-H<br>bend | 680-610 | [66] | 640.251 | Alkyne | C-H<br>bend | 610-680 | [66] | 614.217 | Alkyne | C-H<br>bend | 610-680 | [66] |
| T6 | 3947.57<br>3848.26<br>3636.12<br>3423.99 | hydroxyl | O-H<br>from (H2O) | 4000–3000 | [58,59] | 3808.72 | hydroxyl | O-H<br>from (H2O) | 4000–3000 | [58,59] | 3934.07<br>3880.08<br>3750.87 | hydroxyl | O-H<br>(H2O) | 4000–3000 | [58,59] |
| | 3363.25 | Alcohol | O-H<br>(medium) | 3300-3900 | [60] | 3264.89 | Alcohols<br>and<br>Phenols | Hydrogen<br>Bonded<br>O-H<br>Stretch | 3600-3100 | [62] | 3344.93 | Alcohols<br>and<br>Phenols | Hydrogen<br>Bonded<br>O-H<br>Stretch | 3600-3100 | [62] |
| | 3423..99 | hydroxyl | O-H<br>from water<br>molecule<br>(H2O) | 4000–3000 | [58,59] | 2926.45 | Alkanes | H-C-H<br>Asymmetri<br>cal<br>Stretch | 3000-2850 | [62] | 2934.16 | Alkanes | H-C-H<br>Stretch | 3000-2850 | [62] |
| | 1617.02 | Quinone or<br>ketone | C=O | 1650±1600 | [66] | 1635.34 | Quinone or<br>ketone | C=O | 1650±1600 | [66] | 1611.23 | Quinone<br>or ketone | C=O | 1650±1600 | [66] |
| | 1412.6 | Phenolorte<br>rtiaryalcoh<br>ol | OH bend | 1410±1310 | [66] | 1059.69 | Phosphate<br>ion | - | 1100±1000 | [66] | 614.217 | Alkyne | C-H<br>bend | 680-610 | [66] |

**Conclusion**

The results of the study showed that the physicochemical properties of orange, pomegranate and grape juices were affected by the type of treatment, temperature and time period, The juice treatments gave a great similarity in the values of pH and TA and a slight change at the third week of storage. Also, the microwave treatment for 30 seconds had no effect on the concentration of TSS compared to the conventional treatments (T1, T2, T3) which had a slight effect on TSS. The AA content was less affected by the conventional pasteurization treatment at 95 °C for 15 sec compared to the treatment at 65 °C for 30 min which led to a decrease in the AA content in the juices. In contrast, the microwave treatment of juices was more efficient to preserve the AA. The results also showed that treating the juices at 85 °C for 15 min helped to form the highest content of HMF compound due to exposure to more heat, while the microwave treatment for 30 sec showed the lowest values of HMF compound content. The study showed that all treatments were effective in inhibiting the PME, but the effectiveness decreased significantly and clearly when treating the juices with microwave and gave less effectiveness with prolonging the treatment period. The treatment with conventional slow pasteurization at 65 °C for 30 min was the least efficient in inhibiting the enzyme. Thus, this study concludes that treatment with rapid pasteurization at 95 °C for 30 sec was superior in preserving the nutritional value of natural juices compared to the two conventional treatments. The microwave treatment minimized chemical changes that could negatively impact the value and quality of natural juices, making it a viable alternative to traditional pasteurization. The infrared spectra of orange juice (Citrus sinensis), the Yemeni pomegranate (Punica granatum), and the red grapes were of the type (Vitis labrusca) varieties in the 4000-400 cm-1 region was proposed.

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