EFFECTS OF ELECTRICAL PRE-TREATMENT APPLICATIONS ON YIELD AND QUALITY OF GRAPE JUICE

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Abstract
Foça Karası (Izmir-Turkey) variety red grapes are used as raw material and grape mash subjected to ohmic heating, microwave heating and conventional thermal treatment before pressing and pressed. Then grape juice samples were pasteurized at 90 °C for 1.5 minutes. After production of red grape juices; effects of ohmic heating and microwave heating treatment on the yield of grape juice were calculated. In addition anthocyanin contents, total phenolics, color (L, a, b, ΔE, ΔC) values, viscosity, pH, obrix and total acidity were analyzed before and after pasteurization. The results showed that highest yield were determined for microwave and ohmic heating applied samples; the increasing of yield was found 10% for ohmic heated samples and 15% for microwave heated samples. Microwave and ohmic heating applications before pressing step also increased anthocyanin and total phenolic compounds of grape juice comparing the control samples ($P \leq 0.05$).

Keywords: Microwave heating, ohmic heating, thermal heating, mash, grape juice

ÜZÜM SUYU ÜRETİMİNDE ELEKTRİKSEL ÖN İŞLEM UYGULAMALARININ VERİM VE KALİTE ÜZERİNE ETKİLERİ

Özet
Araştırmada hammadde olarak Foça Karası (Izmir-Türkiye) kırmızı üzüm çeşidi kullanılmıştır. Üzüm mayşesine presleme öncesinde ohmik ısıtma, mikrodalga ısıtma ve geleneksel ısıtma uygulamaları yapılmış ve preslenmiştir. Elde edilen üzüm suları 90 °C'de 1.5 dakika süreyle pastörize edilmiştir. Üretimler sonrasında ohmik ve mikrodalga ısıtma uygularının üzüm suyu verimleri hesaplanmıştır. Ek olarak pastörizasyon öncesi ve sonrasında ki toplam antosiyanin ve fenolik madde içerikleri ile renk (L, a, b, ΔE, ΔC), viskozite, pH, obriks ve toplam asitlik değerleri belirlenmiştir. Sonuçlara göre en yüksek meyve suyu verimi mikrodalga ve ohmik ısıtma uygulanan örneklerde saptanmıştır; mikrodalga uygulaması ile %15; ohmik ısıtma uygulaması ile %10 verim artışı sağlanmıştır. Aynı zamanda ön işlem mikrodalga ve ohmik ısıtma uygulamalarıyla antosiyanin ve toplam fenolik madde içeriklerinde de kontrol grubu örneklere göre artış olduğu belirlenmiştir ($P \leq 0.05$).

Anahtar kelimeler: Mikrodalga ısıtma, ohmik ısıtma, termal ısıtma, mayşe, üzüm suyu.

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INTRODUCTION

Grapes are the world's largest fruit crop apart from oranges with an annual world production of 63 million tons in 2007 (1). And grapes, which are rich sources of polyphenolic compounds, have tremendous potential for use in the development of such products (2). Antioxidants including vitamins, flavonoids, and phenols represent one group of utraceuticals found in grapes (3) and have demonstrated a wide range of health benefits (4-9).

Grape juice production includes washing, crushing and mash heating steps before pressing. Pressing step of production is highly affected to juice yield and nutritional composition of grape juice. And this process of fruit juice is slow, laborious and highly energy-consuming step in the production. So that various methods have been investigated to improve efficiency and increase yield of fruit juices in pressing step. Novel techniques such as PEF, ohmic heating and microwave heating could be applied to increase pressing yield for different fruits.

Microwave heating is an electrical thermal method which inactivates enzymes and microorganisms without significant adverse effects on flavor and nutrients. Microwave heating is based on the transformation of alternating electromagnetic field energy into thermal energy by affecting the polar molecules of a material. In microwave heating, heat is generated directly into the material, leading to faster heating rates, compared to conventional heating where heat is usually transferred from the surface to the interior (10).

Ohmic heating is based on the passage of electrical current through a food product that has electrical resistance. The electrical energy is converted to heat. Instant heating occurs depending on the current passing through the food material. The uniform heat generation that results gives uniform temperature distribution, especially for liquid foods. Ohmic heating is used in a wide range of applications such as preheating, blanching, pasteurization, sterilization, extraction of food products (11). Its advantages compared to conventional heating include maintaining the colour and nutritional value of food, short processing time and higher yield (11-14).

The main purpose of this research was to determine the effects of ohmic heating, microwave heating and conventional thermal heating which applied as pretreatment on yield and quality (anthocyanin contents, total phenolics, color etc) of red grape juice before and after pasteurization and to compare the results with that of the conventional mash heating method.

MATERIALS AND METHODS

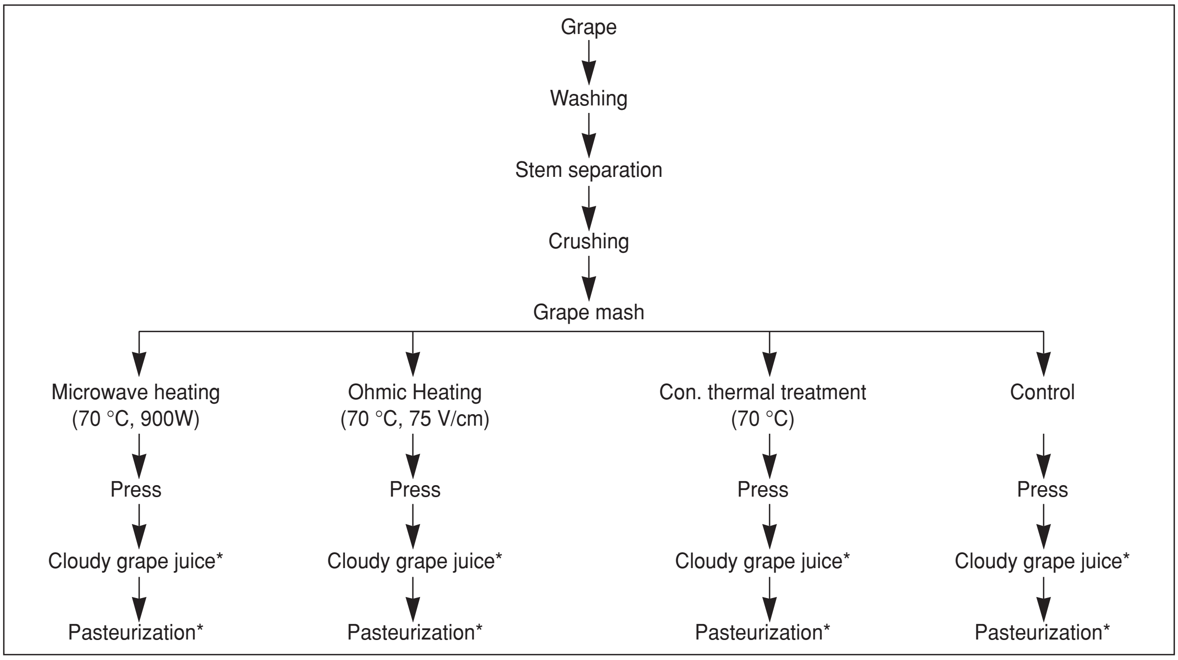
Material and Processing Method

Red grapes (*Vitis Vinifera*) of Foça Karası (Izmir-TURKEY) variety used as raw material in this study. Foça Karası variety widely-used for wine and fruit juice processing in Turkey. Grapes were purchased from local market and were stored overnight in a refrigerator at +4 °C and 85% RH (relative humidity) until juice production. Grapes were washed, spared from stem and then crushed for 5 sec by using a laboratory type blender (Waring, USA). After these pretreatments grape mashes subjected to ohmic heating (OH), microwave heating (MH) and conventional thermal processing (TH) before pressing. Treatment conditions were based on results of previous studies and heating temperature (70 °C) chosen from industrial applications (15). Processing scheme of grape juice is shown in Figure 1.

Microwave applications were achieved with using microwave oven (ARÇELİK MD 595, 2450 Mhz). Grape mash samples of 500g were placed in 20 cm diameter glass tray. The grape mashes were heated until 70 oC (heating time 260 sec) at 900W.

Ohmic heating applied by a box type static ohmic heating equipment with 500g grape mash. Details of ohmic heating system used are given by Yildiz and Baysal (2006) (16). And productions were carried out at chosen conditions for ohmic heating at 75 Volt/cm at 50 Hz a.c.and heated until 70 °C (heating time 5 sec). The temperature of the samples was measured both at the beginning and the end of the heating application.

Conventional thermal treatment was applied by heating the grape mash in a pan with steam jacket (pressure1.5 bar, final temperature 70 °C,



heating time 45 sec). The temperature of the samples was measured both at the beginning and the end of the heating application.

All temperature measurements were taken from the center of grape mashes.

After these applications grape mashes were pressed without cooling at 0-20 kN for 40 sec (at beginning), 20 kN-60 sec; 20-30 kN for 20 sec and 30 kN-60 sec (final) pressures by using hydraulic press (Karl Kolb, West-Germany). Total pressing time was applied 3 min. for each sample. Then pasteurization treatment was realized in a water bath (DKZ Series). 200 ml bottled grape juice were heated until 90°C and keep at same temperature for 90 sec for all processed samples.

Analyses

After production of red grape juices; effects of microwave heating, ohmic heating and conventional thermal heating treatment on the yield of grape juice were calculated. In addition total anthocyanin contents, total phenolics, color (L, a, b, ΔE, ΔC) values, viscosity, pH, brix and total acidity were analyzed before and after pasteurization. Analyses were performed with analytical methods which were given below:

Yield (%): To compare the extraction yields obtained from treatment methods, yield Y (%) and increased yields (%) were calculated according to the equation 1, 2:

$$\text{Yield (\%)} = \frac{[\text{mash (g)} - \text{grape pomace (g)}]}{\text{mash (g)}} \times 100 \qquad (1)$$

$$\text{Increased Yield (\%)} = \frac{[\text{treatment yield (\%)} - \text{control yield (\%)}]}{\text{control yield (\%)}} \times 100 \qquad (2)$$

Total anthocyanin contents (TAC): TAC of grape juices were determined by pH differential method using two buffer systems: potassium chloride buffer, pH 1.0 (0.025 M) and sodium acetate buffer, pH 4.5 (0.4 M) TAC measurements of grape juices determined at 535 nm and (mg cyanidin-3-glucoside/ 100 ml of grape juice) was calculated with molar absorptivity of cyanidin-3-glucoside (26.900) (17).

Total phenolics (TF): Phenols were measured in samples of each grape juice at 760 nm using the Folin-Ciocalteu reagent diluted 10-fold before use (Sigma Chemical Co., St. Louis, MO), with gallic acid (3,4,5-trihydroxybenzoic acid) as the standard and measurement at 760 nm after reaction for 2 hours (18).

Viscosity, °brix, pH, and total acidity: The viscosity of grape juices was determined by using Cappiler viscometer at room temperature (water value 12.45 sec) and the results were given as flow time (sec). Total soluble solids (%) of the juice were measured using a Krüss DR 201-95 refractometer (19). Juice pH was measured with a WTW-Inolab (level 1) pH meter (20). Total acidity (citric acid in %) was measured by placing 5 ml of juice into 25 ml of deionized water and titrating with 0.1 N sodium hydroxide to end point of pH 8.1(20).

Color values: The colors of grape juices were measured with a Hunter Lab Color flex (CFLX 45-2 Model Colorimeter, Hunter Lab, Reston, VA). Grape juices were placed on the light port using a 5 cm diameter glass dish with cover. Color parameters were recorded as L* (lightness), a* (redness) and b* (yellowness). And total color differences (ΔE) and chroma values (ΔC) were also calculated with reference grape juice color according to equations 3, 4. Reference color values before pasteurization: L_{ref} 9.27; a_{ref} 11.87; b_{ref} 1.94; after pasteurization: L_{ref} 11.71; a_{ref} 12.93; b_{ref} 4.57.

$$\Delta E= [(L-L_{ref})^2+(a-a_{ref})^2 + (b-b_{ref})^2]^{0.5} \quad (3)$$

$$\Delta C = [(a-a_{ref})^2 + (b-b_{ref})^2]^{0.5} \quad (4)$$

Statistical analysis: The results were submitted to ANOVA and Duncan test to evaluate differences between treatments using SPSS 11.5 (SPSS Inc., Chicago, USA); and significance level was set at $P \leq 0.05$. Statistically significant differences were compared with treatment groups before and after pasteurization. Each experiment was repeated twice.

RESULTS AND DISCUSSION

The juice yield of control group was found 79.20% where the yield found 91.06 % for MW; 87.23% for OH and 83.34% TH groups. And the increased yields were calculated as 14.97 %; 10.14%; 5.23% for MH, OH, TH groups respectively (Table 1). Significant differences evaluated between all treated groups for juice yield (%) and increased yield (%). Haight and Gump (1994) (21) found that the yield increasing of grape juice between 4.9-8.5% in macerating (pectinases) enzyme treated samples. Threlfall et al., (2005) (2) evaluated the grape juice yield after thermal heating treatment. They found grape juice yields 70.7-78.6% for thermal heating group and 53.2-63.4% for non-heated group. And hot pressing grape mashes for juice production has been shown to increase the juice yield 50% to 70% (22). And OH treatment increases product yield approximately 7% and 12% in tomato puree and paste production, respectively (14). And nearly 10% increases were reported by Okilov, (1995) (23) for citrus juices after electrical applications. Wang and Sastry (2002) (13) also reported that microwave and ohmic heating of apple mashes cause increasing of fruit juice yield. And they evaluated that the thermal effect of ohmic pretreatment on increasing juice yield increased with the pretreatment temperature; however for microwave pretreatment the situation reversed, which might be due to moisture loss at a comparatively high temperature in microwave heating. It wasn't found any data which compare grape juice yields of OH, MH and TH treated samples at the literature.

Table 1. Yields of grape juices*

Treatments	Yield (%)	Increased Yield (%)
Microwave heating	$91.06^a \pm 1.2$	$14.97^a \pm 0.6$
Ohmic heating	$87.23^b \pm 1.7$	$10.14^b \pm 0.8$
Conventional thermal treatment	$83.34^c \pm 1.1$	$5.23^c \pm 0.5$
Control	$79.20^d \pm 0.9$	------

* Statistically significant difference shown levels a, b, c, d compared with same column ($P \leq 0.05$).

Total anthocyanin contents (TAC) and total phenolics (TP) of grape juices shown at table 2 and TAC contents of samples were found significantly different ($P \leq 0.05$) before and after pasteurization of treated groups. The highest TAC content was determined for MH group (15.05 mg/100 ml) where 13.64 mg/100ml for TH, 10.55 mg/100ml for OH and 3.087 mg/100ml for control group before pasteurization. After pasteurization TAC contents of samples were evaluated in same sorting; 18.87 (MH), 16.18 (TH), 13.01 (OH) and 7.68 mg/100 ml (control). Netzel et al., (2003) (24) investigated low TAC values of grape juices as between 3-5.2 mg/100ml. Comparing the Netzel et al., (2003) (24) higher TAC evaluated in this study. This could be the different variety used as raw material and/or applied hot press conditions. Fazaeli et al. (2011) evaluated that applying microwave instead of conventional heating method can decrease the degradation of anthocyanin in pomegranate juices.

TP contents of samples were also found significantly different ($P \leq 0.05$) before and after pasteurization. TP content of control group were observed 3671.55 mg/l where 5206.62 mg/l for

MH; 4702.33 mg/l for OH; and 4736.56 mg/l for TH application group before pasteurization step. After pasteurization phenolic contents were evaluated as; 5447.23 mg/l (MH), 4760.48 mg/l (OH), 4731.21 mg/l (TH), 3781.38 mg/l (control). According to literature, Gerard and Roberts (2004) (6) was also detected highest total phenolics for microwave heated apple juices. Threlfall et al., (2005) (2) and Netzel et al., (2003) (24) also determined highest TP content in heated grape juice samples.

Viscosity and soluble solid (°Brix) contents of grape juices were given at table 3. The viscosity results of samples were changed between 16.34-17.5 sec before pasteurization and 13.5-14.47 sec after pasteurization of grape juices. And the viscosity of samples were also found significantly different (*P*≤ 0.05) before and after pasteurization for all treatment groups. The result showed good agreement with the literature values. Shcheglov et al., (1983) (25) reported decreasing of viscosity after OH application of tomato paste production. And Demirdöven (2009) (26) also found decreasing of viscosity after MD and OH applications on orange juice production.

The °brix results of samples were changed between 16.45%-17.97% and the lowest soluble solid value evaluated for OH application group (16.45%). And there were no significant differences evaluated between MH and control samples before pasteurization (P>0.05). After pasteurization step soluble solid contents are significantly different (*P*≤ 0.05). The highest °Brix value determined for MH (18.4%) where it was measured 17.86% for TH, 17.45% for control and 16.45% OH groups. Also other researchers evaluated high soluble solid values after heating treatments for grape and apple samples (2, 23, 27). The reason of high obrix value could be cell break down during MH.

pH and total acidity of grape juices were given at tab. 4. No significant differences were observed for pH levels of TH (4.145) and control (4.150) samples before pasteurization and after pasteurization only OH (4.042) group was different from others (*P* >0.05). Total acidity results of samples were changed between 2.61-2.81% before pasteurization and 2.39-2.92% after pasteurization of grape juices. And total acidity of samples were found significantly different (*P*≤0.05) before and after pasteurization for all treatment groups. And with reference to literature data alike results shown by different researchers (2, 23, 27).

Colour values of samples were given at table 5. L* value which indicates the luminosity of the samples were found between 4.15-9.27 before

Table 2. Total anthocyanin and total phenolic contents of Grape juices*

Treatments	Total anthocyanin (mg/100 ml)		Total phenolics (mg/l)	
	before pasteurization	after pasteurization	before pasteurization	after pasteurization
Microwave heating	15.05ª±0.8	18.87ª±0.5	5206.62ª±1.8	5447.23ª±4.5
Ohmic heating	10.55ᵇ±0.7	13.01ᵇ±0.4	4702.33ᵇ±2.6	4760.48ᵇ±1.6
Conventional thermal treatment	13.64ᶜ±0.4	16.18ᶜ±0.8	4736.56ᶜ±3.0	4731.21ᶜ±1.9
Control	3.087ᵈ±0.3	7.68ᵈ±0.6	3671.55ᵈ±2.2	3781.38ᵈ±2.5

* Statistically significant difference shown levels a, b, c, d compared with same column (*P* ≤ 0.05).

Table 3. Viscosity and obrix of grape juices*

Treatments	Viscosity (sec)		°Brix	
	before pasteurization	after pasteurization	before pasteurization	after pasteurization
Microwave heating	15.91ª±0.9	14.45ª±0.3	17.8ª±0.1	18.4ª±0.2
Ohmic heating	17.5ᵇ±0.3	13.8ᵇ±0.1	16.45ᵇ±0.1	16.45ᵇ±0.2
Conventional thermal treatment	16.34ᶜ±0.4	13.5ᶜ±0.1	17.97ᶜ±0.1	17.86ᶜ±0.1
Control	16.85ᵈ±0.1	14.47ª±0.2	17.72ª±0.1	17.45ᵈ±0.2

* Statistically significant difference shown levels a, b, c, d compared with same column (*P* ≤ 0.05).

pasteurization, and 4.76-11.71 after pasteurization. The differences of L* values between the different groups were found statistically significant ($P \leq 0.05$) before and after pasteurization. As expected the highest L* values determined for control group before (9.27) and after (11.71) pasteurization. In heating applications highest L* values evaluated for MH (5.32) before pasteurization and TH (5.25) after pasteurization. The mean a* was found significantly higher (P≤0.05) for control group grape juice (+11.87) than other groups before pasteurization. And there were no significant differences evaluated between OH (+7.25) and TH (+7.60) before pasteurization. Similarly, after pasteurization there were no significant differences observed for MH (+9.50) and OH (+9.40) treated samples (P >0.05). In heating applications highest a* values evaluated for MH before pasteurization (9.10) and after pasteurization (9.50). b* values are significantly higher (P≤0.05) for the control samples (+1.94) before pasteurization and (+4.57) after pasteurization. There were no significant differences observed between MH (+0.85) and TH (+0.95) groups for b* values before pasteurization. After pasteurization, there were no significant differences evaluated between heating treatments; MH (+0.30), OH (+0.30) and TH (+0.40) groups (P>0.05). Threlfall et al., (2005) (2) observed that heating treatment increased the red color and yellow/brown pigments and decreased the L values (increased darkness) in grape juice. The results were showed good agreement with the literature color values (2, 22, 28, 29).

Total colour differences (ΔE), which indicate the magnitude of the colour difference between grape juices, is shown in table 6. It has been considered that ΔE of 2 would be a noticeable visual difference for a number of situations (30, 31). The minimum ΔE value determined for MW heated samples (5.58) and the highest total colour differences were determined for OH group (7.18) before pasteurization step. After pasteurization, the minimum ΔE value calculated for OH (8.84) and the highest ΔE value evaluated for TH (9.29). The differences of ΔE values between the different groups were found statistically significant ($P \leq 0.05$) before and after pasteurization. The chroma values (ΔC) of grape juices are shown in tab.6. ΔC values between the different groups were also found statistically significant ($P \leq 0.05$) before and after pasteurization. The minimum ΔC values calculated for MH (3.94) before pasteurization and for OH (5.53) after pasteurization. According to these results, heating treatments affected the ΔE and ΔC values of grape juices. But minimum color differences and chroma values evaluated by electrical

Table 4. pH and total acidity of grape juices*

Treatments	pH		Total acidity (%)	
	before pasteurization	after pasteurization	before pasteurization	after pasteurization
Microwave heating	4.132^{a}±0.004	4.133^{a}±0.060	2.81^{a}±0.01	2.92^{a}±0.04
Ohmic heating	4.047^{b}±0.003	4.042^{b}±0.009	2.67^{b}±0.02	2.53^{b}±0.01
Conventional thermal treatment	4.145^{c}±0.005	4.133^{a}±0.070	2.61^{c}±0.01	2.65^{c}±0.03
Control	4.150^{c}±0.002	4.121^{a}±0.078	2.53^{d}±0.04	2.39^{d}±0.05

* Statistically significant difference shown levels a, b, c, d compared with same column ($P \leq 0.05$).

Table 5. Color (L, a, b) values of grape juices*

Treatments	L		a		b	
	before past.	after past.	before past.	after past.	before past.	after past.
Microwave heating	5.32^{a}±0.003	4.76^{a}±0.002	+9.10^{a}±0.024	+9.50^{a}±0.10	+0.85^{a}±0.10	+0.30^{a}±0.10
Ohmic heating	4.15^{b}±0.002	4.81^{b}±0.001	+7.25^{b}±0.030	+9.40^{a}±0.2	+0.25^{b}±0.13	+0.30^{a}±0.12
Conventional thermal treatment	4.54^{c}±0.006	5.25^{c}±0.003	+7.60^{b}±0.020	+8.47^{b}±0.3	+0.95^{a} ±0.05	+0.40^{a}±0.08
Control	9.27^{d}±0.009	11.71^{d}±0.001	+11.87^{c}±0.012	+12.93^{c}±0.2	+1.94^{c}±0.06	+4.57^{b}±0.232

* Statistically significant difference shown levels a, b, c, d compared with same column ($P \leq 0.05$).

Table 6. Color (ΔE, ΔC) values of grape juices*

Treatments	ΔE		ΔC	
	before pasteurization	after pasteurization	before pasteurization	after pasteurization
Microwave heating	5.58[a]±0.5	9.1[a]±0.0	3.94[a]±0.05	5.88[a]±0.02
Ohmic heating	7.18[b]±0.3	8.84[b]±0.1	5.04[b]±0.01	5.53[b]±0.01
Conventional thermal treatment	6.98[c]±0.2	9.29[c]±0.05	5.14[c]±0.02	6.68[c]±0.03

*Statistically significant difference shown levels a, b, c compared with same column ($P \leq 0.05$). (*Reference color values before pasteurization: L_{ref} 9.27; a_{ref} 11.87; b_{ref} 1.94; after pasteurization: L_{ref} 11.71; a_{ref} 12.93; b_{ref} 4.57).

methods then conventional thermal heating application. Similar results were determined for pomegranate and sour-cherry juice production by electrical methods (15).

CONCLUSIONS

The results showed that heating of grape mash before pressing is affective on juice yield and there were significant differences between the heating treatments. Higher yields were observed for MH and OH groups comparing the conventionally heated group. And the increased of yield were evaluated as 14.97% for microwave heating; 10.14% for ohmic heating and 5.23% for conventional thermal heating group comparing the control group (unheated). The highest total anthocyanin and phenolics were determined for microwave heating application. In addition the highest a (red color) and minimum color differences (ΔE) observed again for microwave heating group. On the other hand ohmic heating application can also be used for increasing of yield; but microwave heating treatment was found more effectual than ohmic heating applications for increased of juice yields. Additionally ohmic heating application indicates the highest total phenolics, highest a (red color) and minimum color differences (ΔE) as compared with the conventional thermal heating. As a result; microwave heating and ohmic heating applications can be used as a pre-treatment for grape juice production line. Further studies are needed to be exploring the effect of microwave heating and ohmic heating applications as pretreatment of different fruits.

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