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Comparison of Microbial Loads and Bioactive Compounds of the Grape Juice Samples Treated by Ultrasonication and Thermal Pasteurization

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Abstract

Background and Objective: Pasteurization is one of the most widely used methods in decreasing of microbial loads in fruit juices. Unfortunately, high temperatures destroy anthocyanins and polyphenolic compounds. Nutritional status and quality of fruit juices can be improved using other decontamination methods such as ultrasound process. This study was carried out to investigate effects of ultrasound on contents of bioactive compounds and microbial loads of red-grape juice samples. Results achieved under the optimum conditions of ultrasonication were compared to those under thermal pasteurization.

Material and Methods: Effects of three variables of ultrasound time (2, 6 and 10 min), temperature (0, 30 and 60 °C) and power (10, 105 and 200 W) on total phenol content, anthocyanin and total microbial count of the red-grape juices were studied. Design of experiments was carried out using response surface methodology (Box-Behnken design) followed by optimization. Quality of the optimized samples was compared to the quality of controls pasteurized at 90 °C for 30 s. Total phenol content, anthocyanin and total microbial count were assessed using Folin-Ciocalteu assay, spectrophotometry and total plate count method, respectively.

Results and Conclusion: The maximum levels of phenols and anthocyanin compounds and the minimum microbial loads were achieved at 144.34 W for 2 min at 60 °C. Based on the results, contents of total phenol and anthocyanin in samples treated by ultrasound under optimal conditions were significantly higher than those in samples pasteurized by thermal process. No significant differences were seen between total microbial counts of the samples processed by ultrasonication and thermal pasteurization. These results indicated that more bioactive compounds of phenols and anthocyanins could be preserved in grape juices under ultrasonication than those under thermal processes. In addition, a similar safety scheme of the microbial load was achieved by optimizing the conditions of ultrasound treatment.

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1. Introduction

Use of extracts or juices includes receiving of their nutritional benefits by the consumers. Juices are often thermally pasteurized before or after packaging. The most common method used to pasteurize fruit juices is thermal pasteurization. Thermal methods strongly affect inactivation of microorganisms; however, use of high pasteurization temperatures includes adverse effects on nutrients and nutritional values of the foods, including loss of vitamins, non-enzymatic browning, protein denaturation, loss of food flavor, color changes and decrease of quality (vitamins, phenolic compounds and anthocyanins). One of the non-thermal methods suggested by the studies includes use of ultrasound [1]. The word ultrasound is originated from the Latin word of ultra (superior) and sound. Ultrasound is a subset of sound waves generated at certain frequencies. Accordingly, these waves include energy and are considered non-thermal technologies [2]. This method is based on the propagation of an acoustic wavelength with a frequency of more than 20 kHz inside the materials. In this method, information on the characteristics of the materials are achieved by assessing interactions between the wavelength and the material [3]. Another use of ultrasound in foods includes inactivation of bacteria. However, it is believed that ultrasound with pressure and/or heat is more effective [4]. Some microorganisms include high thermal resistances. As a result, use of high heats to inactivate these microorganisms decreases nutritional value and sensory quality of the foods, altering functional characteristics of the foods. This problem can be solved using ultrasound. Inactivation of enzymes is similar to that of microorganisms and use of monothermosonication increases the effects [5]. Juices are liquids extracted from fruits with no fermentarions and include major processes such as pretreatments, extraction of extracts and post-press treatments. Fruits are usually concentrated to decrease shipping costs and product stability. Concentrates are easier to process, compared to fruits [6]. Commercialization of red fruits and vegetables enriched with water-soluble red pigments and polyphenols has been pupular recently [7].

There are more than 60 types of grapes that vary in color, taste, seed size and shape, pigments and concentrations of chemicals [8]. Grapes are divided into seeded and seedless and are found in red, black, yellow and green colors. Fruits grow best in regions, where the maximum temperature is not more than +40 °C and the minimum temperature is not less than -15 °C [9]. fruits are rich sources of flavonoid polyphenols such as catechins, quercetin, anthocyanins and proanthocyanidins, which are active antioxidants [10]. The most important plant bioactive substances found in diets with healing characteristics include various groups of polyphenols (anthocyanins, flavonoids, isoflavones and ellagic acid). Phenolic compounds are not only addressed as representatives of a group of antioxidant compounds, but also they are addressed as one of the major components of antimicrobial compounds responsible for the antimicrobial activities of plant extracts [11]. Anthocyanins are important compounds in red juices and are highly involved in juice color production and antioxidant activity because these compounds play important roles in prevention of cardiovascular diseases, neurological diseases and cancers [12]. Therefore, it seems necessary to develop and establish non-thermal techniques for industrial food production that preserve anthocyanins and decrease color changes in juices such as grape juices. Accordingly, researchers investigate for the appropriate alternatives of the thermal process. Treatment by ultrasound under various conditions (temperature, power and time) can variously affect contents of bioactive compounds and microbial loads in fruit juices. To the best of the authors' knowledge, optimization of ultrasound conditions in treatment of red-grape juices has not been studied. Therefore, this study was carried out to investigate the optimal conditions for decontamination of red-grape juices treated by ultrasound via retaining the most levels of bioactive compounds. Quantity of bioactive compounds and microbial loads of the grape juice samples treated by ultrasonication under optimal conditions was compared to those of the samples treated by thermal pasteurization.

2. Materials and Methods

2.1 Materials

Chemicals of Folin-Ciocalteu reagent, sodium hydroxide, buffers (pH 4.5 and 1) and plate count agar media were purchased from Merck, Germany.

2.2. Sample Preparation

Red grapes (*Vitis vinifera* L.) were purchased from the local markets of Urmia, Western Azerbaijan, Iran. After preparation, grapes were immediately transferred to the laboratory and washed with tap water and their stems were removed. Juices of the grapes were extracted using juicer (Tefal, France) and filtered four times using cheesecloth. The control sample was pasteurized using thermal method (90 °C for 30 s) [10]. Other samples were treatment using ultrasonic probe device (Model AMMM, Switzerland) based on the response surface methodology (Box-Behnken design) at 10-200 W for 2-10 min at 0-60 °C based on the treatment schedule (Table 1). Quantities of the bioactive compounds (total phenol and anthocyanins) and total counts of the microorganisms were assessed. The optimal sample with the maximum bioactive compounds and the minimum microbial loads was compared with the control sample.

Table 1. Treatment characteristics desiged by response surface methodology (Box-Behnken design)

Treatment	Power (w)	Temperature (°C)	Time (min)
1	105	30	6
2	10	60	6
3	10	30	2
4	200	0	6
5	10	0	6
6	105	60	10
7	105	60	2
8	105	30	6
9	200	30	10
10	105	30	6
11	105	0	10
12	200	60	6
13	10	30	10
14	105	0	2
15	200	30	2

2.3. Physicochemical Tests

The pH, acidity and Brix were assessed based on the Iranian National Standard No. 2685 [13].

2.4. Analysis of Bioactive Compounds

Total phenol content was assessed using spectrophotometer (Thermo Scientific Technologies, USA). In this method, Folin-Ciocalteu reagent was used and the adsorption of samples was measured at 765 nm. The calibration curve was plotted in the concentration range of 0.4-4 mg l^{-1} and results were expressed in mg l^{-1} of the sample [14]. Anthocyanin content (cyanidin-3-glucoside) was assessed using absorption spectrophotometry in the presence of two buffers. In this method, adsorption of the samples prepared by buffers at pH 4.5 and pH 1 was measured at 510 nm. Concentration of anthocyanin (µg l^{-1}) was calculated using Eq. 1 [15].

$$C = \Delta A / L \times M \times D \quad \text{Eq. 1}$$

Where, D was the dilution factor, ΔA was the difference between the two absorptions, M was the molar absorption of cyanidin-3-glucoside and L was length of the cell in centimeters.

2.5. Total Count of Microorganisms

Total count of microorganisms was carried out using plate count agar media with incubation under aerobic conditions at 30 °C for 72 h based on the Iranian National Standard No. 1-5272 (Food Chain Microbiology-a Comprehensive Method for Counting Microorganisms). Results were expressed as CFU ml^{-1} [16].

2.6. Statistical Analysis

Treatments were designed and optimized using response surface methodology (Box-Behnken design) and Minitab Software v.16. Overall, 15 treatments were introduced by the software. Duncan's one-way analysis of variance and Minitab Software v.16 were used to compare the optimal sample with the control sample (thermal pasteurization).

3. Results and Discussion

3.1 Physicochemical Properties

Results reported pH 3.95, acidity of 0.37% and Brix of 13% for the two grape juice samples with no changes in their highlighted characteristics after ultrasonication. Results of this study were similar to those of other studies. Accordingly, ultrasound processing included no significant effects on acidity and Brix of the grape juices [2] and pH of strawberry, carrot and barberry juices [3,4,17].

Phenolic compounds are plant secondary metabolites, including an aromatic ring and one or more hydroxyl groups. The most common phenolic compounds are formed by binding to mono and/or polysaccharides or binding to one or more other phenolic groups. These compounds primarily play important roles in growth, reproduction, protection against diseases, sensory characteristics and color of fruits and vegetables [17]. Phenolic compounds are found in vacuoles in free forms or attached to cell wall components such as pectin, hemicellulose and lignin. Ultrasound destroys the cell wall and consequently releases phenolic compounds [18]. Decreases in phenol contents with increasing heat could be attributed to decomposition of lignin and further releases of phenols [19]. Results of ANOVA test (Table 2) and comparison of tested and predicted results in the grape juice samples treated by ultrasound under various conditions of power, temperature and time are presented in Table 3. As seen in Table 3, no significant differences were seen between the tested and predicted phenol contents of the treated grape juices under various conditions. However, various levels of power, temperature and time were used when ultrasonication significantly affected the total phenol contents of the grape juices.

Results indicated that total phenol content in grape juices treated by ultrasound decreased significantly ($p \leq 0.05$) by increasing power from 10 to 200 W, temperature from 0 to 60 °C and time from 2 to 10 min. The maximum total phenol content (15.95 mg l^{-1}) was seen in grape juice samples treated at 10 W for 6 min at 0 °C. The minimum total phenol content (11.15 mg l^{-1}) was observed at 200 W for 6 min at 60 °C. However, degradation rate of phenolic compounds was less than that in thermal pasteurization and their contents in ultrasonicated samples were higher than those in control pasteurized at 90 °C for 30 s. Similarly, Tavakoli et al. investigated effects of ultrasound on quality characteristics of carrot juice, showing that contents of phenolic compounds in carrot juices decreased with increases in ultrasonic power, temperature and time due to the synergistic interactions of power and time [1].

3.2. Total Phenolic Compounds

Table 2. Results from ANOVA of total phenol, anthocyanin and total microbial count of the samples under ultrasonication

Source of variation	Total phenol (mg l^{-1})		Anthocyanin (µg l^{-1})		Total Count (CFU ml^{-1})	
	P-value	F-value	P-value	F-value	P-value	F-value
Regression constant	0.000	49.84	0.000	40.89	0.000	141.90
Linear effects	0.000	138.64	0.000	112.55	0.000	367.00
Power (a)	0.000	342.43	0.000	282.72	0.000	913.96
Temperature (b)	0.000	65.25	0.001	50.46	0.000	175.50
Time (c)	0.035	8.25	0.017	9.45	0.019	11.54
Square effects	0.013	10.62	0.003	28.25	0.000	52.47
Power × Power (a^2)	0.003	31.04	0.882	40.97	0.000	157.21
Temperature × Temperature (b^2)	0.979	0.00	0.585	0.02	0.613	0.29
Time × Time (C^2)	0.719	0.14	0.608	0.34	0.363	1.00
Interactions	0.851	0.26	0.608	0.67	0.038	6.23
Power × Temperature (a × b)	0.659	0.17	0.342	1.10	0.008	18.69
Power × Time (a × c)	0.800	0.07	0.409	0.81	1.00	0.00
Temperature × Time (b × c)	0.496	0.54	0.782	0.09	1.00	0.00
R^2	98.90%		98.66%		99.61%	

Table 3. Comparison between the tested and predicted phenol and anthocyanin contents and total microbial counts of the grape juice samples treated by ultrasound at various conditions of power, temperature and time

Treatment	Anthocyanin tested (µg l^{-1})	Anthocyanin predicted (µg l^{-1})	Total phenol tested (mg l^{-1})	Total phenol predicted (mg l^{-1})	Total count tested (CFU ml^{-1})	Total count predicted (CFU ml^{-1})
1	0.48	0.48	12.66	12.70	6	5.67
2	0.74	0.71	14.59	14.44	17	16.75
3	0.80	0.80	15.69	15.53	26	25.38
4	0.46	0.48	12.28	12.43	4	4.25
5	0.82	0.84	15.95	16.11	30	31.00
6	0.36	0.39	11.68	11.69	0	0.38
7	0.40	0.43	11.74	12.05	2	2.88
8	0.48	0.48	12.70	12.70	5	5.67
9	0.34	0.34	11.27	11.42	0	0.62
10	0.48	0.48	12.76	12.70	6	5.68
11	0.58	0.55	13.35	13.05	11	10.12
12	0.30	0.28	11.15	10.99	0	-1.00
13	0.78	0.78	14.77	14.91	23	22.88
14	0.64	0.61	13.81	13.80	13	12.62
15	0.42	0.42	12.04	11.90	3	3.12

In a study by Hooshyar et al., it was shown that contents of phenolic compounds decreased significantly with increases in ultrasound, temperature and time [20]. Saeeduddin et al., investigated quality characteristics of pear juices treated by ultrasound (750 W for 10 min at 25, 45 and 65 °C) and industrial (65 and 95 °C for 10 and 2 min, respectively) methods. They reported that total phenol decreased by ultrasound in all treatments. They stated that treatment by ultrasound at 65 °C for 10 min yielded the highest phenolic content [21]. In a study by Radziejewska-Kubzdela et al., effects of thermal treatment (80 °C for 5 min) and ultrasound (frequency, 20 kHz; amplitude, 70%; power, 140 W; time, 10 min) on bioactive compounds of *Berberis amurensis* water juices were investigated, resulting in a better protection of phenols under ultrasonication [22].

3.2.1. Single Optimization for Total Phenol Content

Single optimization conditions for the total phenol content (mg l^{-1}) of the grape juice treatments by ultrasound at various levels of power, temperature and time are present in Figure 1. Single optimization conditions to achieve the maximum phenol content (16.47 mg l^{-1}) with 100% desirability were predicted as 0 °C, 2 min and 10 W.

3.3. Anthocyanin

Anthocyanins are the most important pigments in flavonoids. They are often found in colored foods such as strawberries, apples, cherries, raspberries, oranges, grapes, figs, mangoes, pomegranates, red cabbage and sweet potatoes [15]. Anthocyanins are highly unstable and can degrade during the processes, losing their biologically active characteristics during processing, high temperature, light, oxygen and presence of enzymes and metal ions [23,24]. Anthocyanins (flavonoid compounds) are easily degraded by heat, changing color acceptability of the juices. Their degradation by temperature is due to oxidation and covalent bond breakage. The rate of degradation increases by increases in temperature. Heating intensity and duration include major effects on the stability of anthocyanins [25]. Indeed, opening the pyrylium loop and formation of chalcone are significant events occurred during destruction of anthocyanins [12]. Tested and predicted anthocyanin contents of the grape juices treated by ultrasound at various levels of power, temperature and time are present in Table 3. As seen in the table, no significant differences were reported between the tested and predicted anthocyanin contents. Although, various levels of power, temperature and time significantly affected anthocyanin contents of the grape juices. In addition, anthocyanin contents in grape juices treated by ultrasound decreased significantly ($p \leq 0.05$) by increases in ultrasonic power from 10 to 200 W, temperature from 0 to 60 °C and time from 2 to 10 min. Similarly, Hooshyar et al. assessed effects of ultrasound on the characteristics of cherry juices; through which, contents of anthocyanin compounds decreased significantly with increases in ultrasound, temperature and time [20]. The maximum anthocyanin content (0.82 µg ml^{-1}) was seen in samples treated at 10 W for 6 min at 0 °C and the minimum anthocyanin content (0.03 µg ml^{-1}) was observed in samples treated at 200 W for 6 min at 60 °C (Table 3).

3.3.1. Single Optimization for Anthocyanin

Single optimization condition for anthocyanin contents (µg ml^{-1}) in grape juices treated by ultrasound at various levels of power, temperature and time are demonstrated in Figure 2. The optimal condition to achieve the maximum anthocyanin content (0.87 µg ml^{-1}) with 100% desirability was predicted at 10 W, 0 °C and 2 min.

3.4. Total Microbial Count

Thermal sonication treatment accelerates inactivation of microbes in juices. Microbial destruction is affected by ultrasound power, processing time, treatment temperature, volume of the processed juice and juice composition.

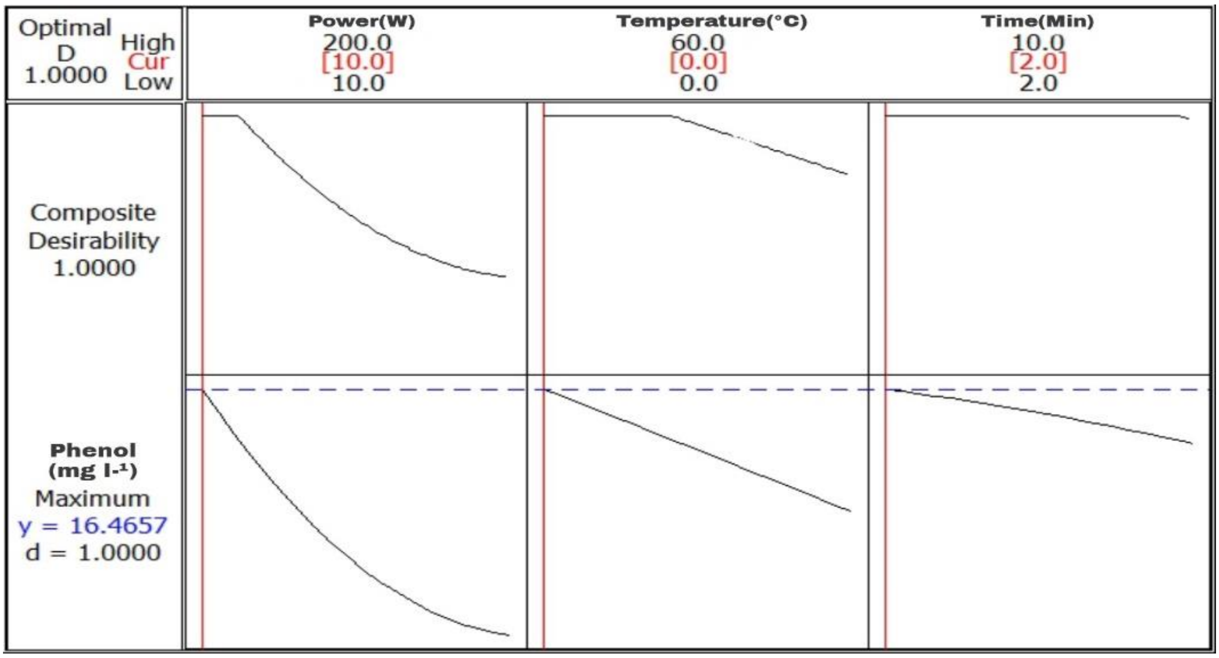

Figure 1. Single optimization conditions for the total phenol content (mg l^{-1}) of the grape juices treated by ultrasound

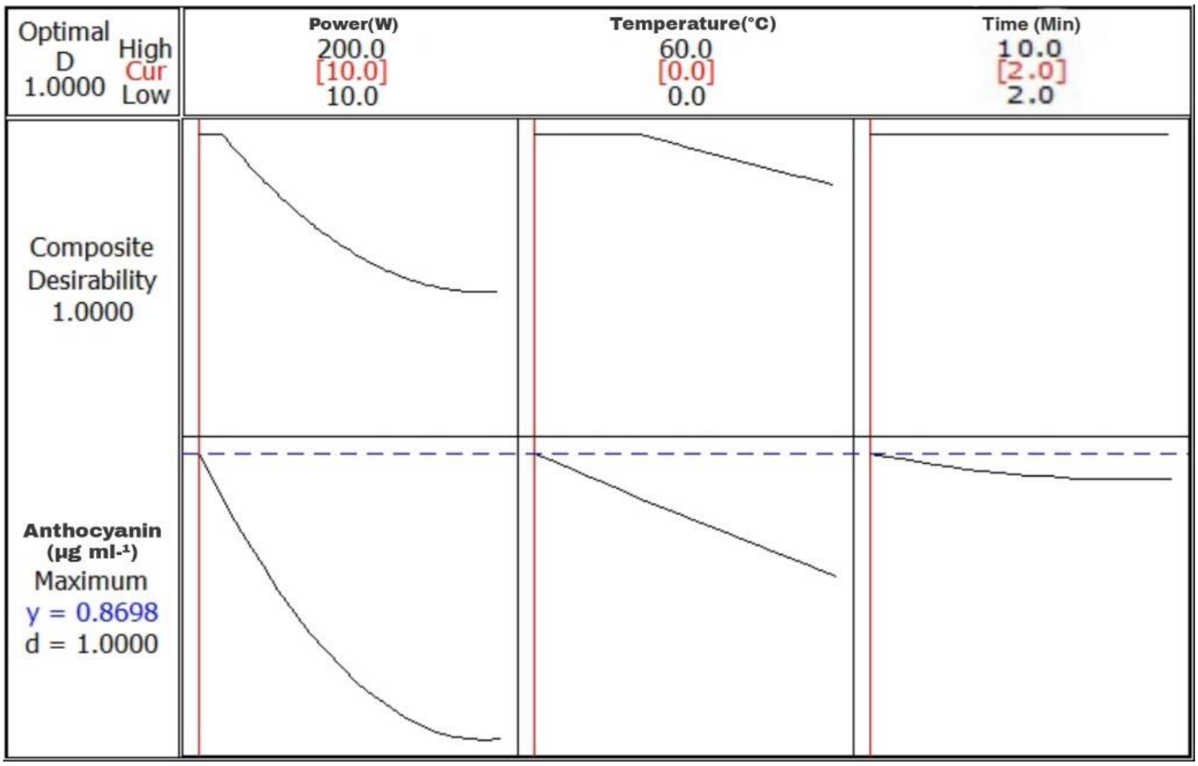

Figure 2. Single optimization conditions for the anthocyanin content (µg ml^{-1}) of the grape juice treated by ultrasound

Microorganisms do not respond to ultrasound treatment in similar ways. Microbes are killed by ultrasound treatment due to thinning of their cell membrane, local heat generation, increased pressure and production of free radicals [26]. Moreover, physical stresses caused by ultrasonic cavitation and collapse of bubbles produced in the process are the major mechanisms responsible for the inactivation of microbes. Hydrophobic surface of the microbial cell wall helps destroy cavitation bubbles formed during ultrasonication, leading to severe damages to the cell wall [27,28]. Tested and predicted total counts of the grape juices treated by ultrasound under various conditions of power, temperature and time are demonstrated in Table 3. Based on the table, no significant differences were seen between the tested and predicted total counts. Although, various levels of power, temperature and time variously affected the total counts in grape juices treated by ultrasound. Total counts in the grape juices decreased significantly ($p \leq 0.05$) with increases power from 10 to 200

W, temperature from 0 to 60 °C and time from 2 to 10 min. The maximum total count of the grape juice samples treated by ultrasound (30 CFU ml^{-1}) was observed at 10 W, 0 °C, time 6 min and the minimum total count (0 CFU ml^{-1}) was seen at 200 W, 30 °C and 10 min; as for the controls. This indicated the appropriateness of ultrasonication for the grape juice treatment. Based on the Iranian National Standard No. 3414, total count of the fruit juices must be less than 1 CFU ml^{-1} [29]. As seen in Figure 3, the optimal conditions for the grape juices treated by ultrasound with 100% desirability (total count of 0 CFU ml^{-1}) could be achieved at power of 200 W, temperature of 60 °C and time of 10 min. Saeeduddin et al. investigated the quality characteristics of pear juices treated by ultrasound (750 W for 10 min at 25, 45 and 65 °C) and industrial (65 and 95 °C for 10 and 2 min, respectively) methods. They reported that the microorganisms were completely inactivated by thermal pasteurization at 95 °C. Treatment by ultrasound at 750 W for 10 min at 65 °C led to the best results [21]; similar to the current results (Figure 3)

3.4.1. Single Optimization for Total Microbial Count

Single optimization conditions for total count of microorganisms (CFU ml^{-1}) in grape juices treated by ultrasound under various power, temperature and time are present in Figure 3. To achieve 0 CFU ml^{-1} with 100% desirability, the predicted condition included 200 W, 60 °C and 10 min.

3.5. Multiple Optimization for Treatment of Grape Juice by Ultrasonication

The optimized conditions by considering total phenol, anthocyanin and total microbial count of the grape juices treated by ultrasound at a similar time is provided in Figure 4. To achieve the maximum phenols (11.60 mg l^{-1}) and anthocyanin (0.37 µg ml^{-1}) and the minimum microbial load (0 CFU ml^{-1}) in the ultrasonicated samples with 81.94% desirability, treatment was predicted at 144.34 W, 60 °C and 2 min.

3.6. Optimal treatment by Ultrasound versus Thermal Pasteurization

Table 4 shows comparison of the optimum sample treated by ultrasound with the control thermally pasteurized at 90 °C for 30 s. In general, no significant differences were reported between the microbial loads of the grape juices pasteurized by the two methods, while bioactive compounds of the samples treated by ultrasound were higher than those of the other samples. Therefore, ultrasonicated samples were preferred to the samples pasteurized at 90 °C for 30 s in their quality characteristics. Dubrovic et al. investigated effects of ultrasound and pasteurization on the anthocyanin contents of strawberries. They showed that anthocyanin contents decreased by pasteurization due to the high temperature, compared to untreated juices [30].

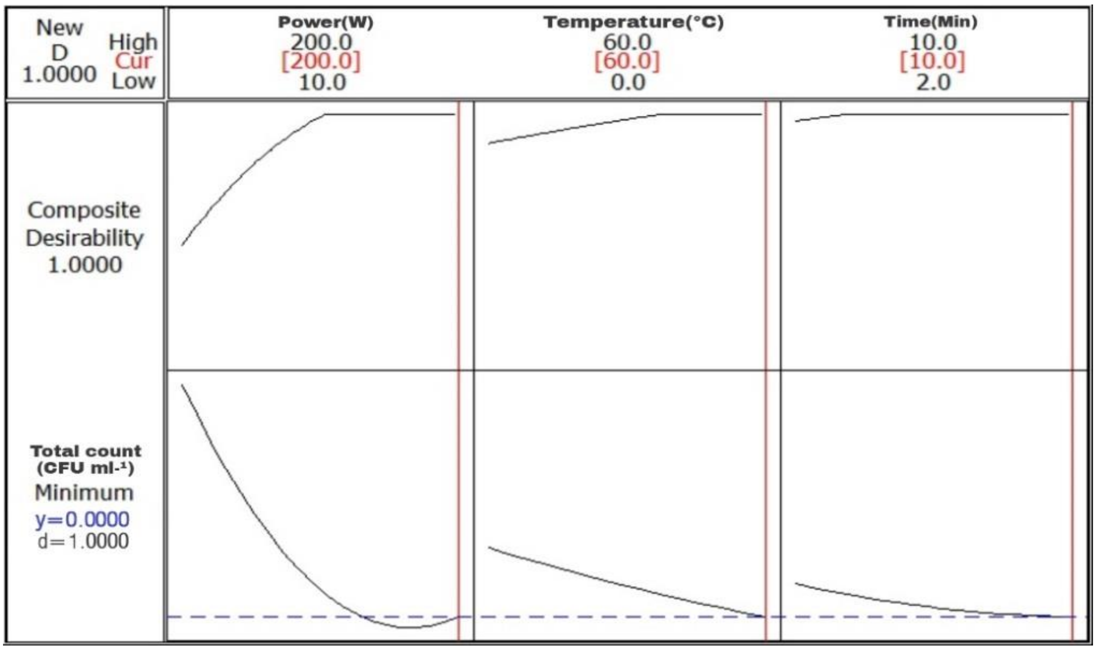

Figure 3. Single optimization conditions for the total microbial count (CFU ml^{-1}) of the grape juice treated by ultrasound

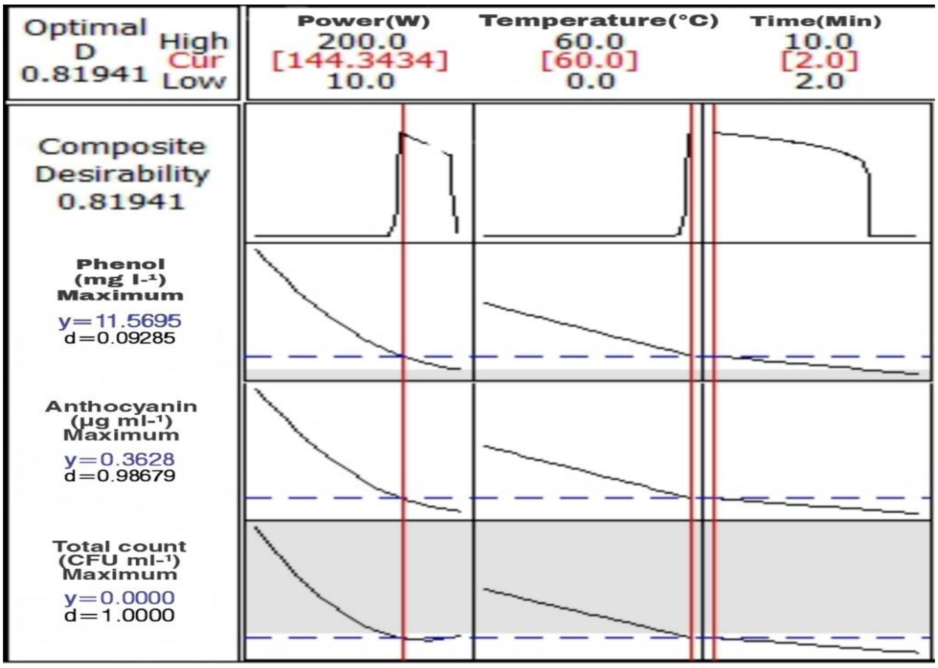

Figure 4. Multiple optimization of phenol (mg l^{-1}) and anthocyanin (µg ml^{-1}) contents and total microbial count (CFU ml^{-1}) of the grape juice samples treated by ultrasound

Table 4. Comparison of the sample pasteurized at 90 °C (control) with the sample treated by ultrasound under optimum condition (60 °C, 2 min, 144.34 W)

Test	Optimum ultrasound	Pasteurization (90 °C for 30 s)
Total phenol (mg l^{-1})	13.63 ±0.11^{A}	10.84 ±0.10^{B}
Anthocyanin (µg l^{-1})	0.37 ±0.02^{A}	0.13 ±0.01^{B}
Total microbial count (CFU ml^{-1})	0.00 ±0.00^{A}	0.00 ±0.00^{A}

*Different uppercase letters indicate significant differences (p≤0.05) in the rows.

4. Conclusion

The current study was carried out to assess and compare contents of the phenols and anthocyanins and microbial counts of the red-grape juices treated by ultrasound and thermal processes. Various levels of variables, including ultrasound power from 10 to 200 W, temperature from 0 to 60 °C and time from 2 to 10 min, were studied. Based on the results, quantities of total phenol and anthocyanin and microbial counts in grape juices treated by ultrasound decreased significantly (p≤0.05) by increases in power, temperature and time. Moreover, further bioactive compounds of phenols and anthocyanins were preserved in ultrasonicated grape juices with the minimum microbial loads under optimized conditions, compared to the controls.

5. Acknowledgements

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6. Conflict of Interest

The authors report no conflicts of interest.

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مقایسه بار میکروبی و ترکیبات زیست‌فعال در نمونه‌های آب انگور تیمار شده با فراصوت و پاستوریزه شده حرارتی

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چکیده

سابقه و هدف: پاستوریزه‌کردن یکی از پرکاربردترین روش‌ها در کاهش بار میکروبی در آب‌میوه ها می‌باشد. متأسفانه، دمای بالا باعث از بین رفتن آنتوسیانین‌ها و ترکیبات پلی فنولی می‌شود. وضعیت تغذیه‌ای و کیفیت آب میوه‌ها می‌تواند با استفاده از سایر روش‌های آلودگی‌زدایی مانند فرآیند فراصوت بهبود یابد. این مطالعه به‌منظور بررسی اثرات امواج فراصوت بر محتوای ترکیبات زیست‌فعال و بار میکروبی نمونه‌های آب انگور قرمز انجام شد. نتایج به‌دست آمده در شرایط بهینه فراصوت با نتایج نمونه‌های پاستوریزه حرارت‌دیده مقایسه شد.

مواد و روش ها: اثر سه متغیر زمان فراصوت (۲، ۶ و ۱۰ دقیقه)، دمای فراصوت (۰، ۳۰ و ۶۰ درجه سلسیوس) و قدرت فراصوت (۱۰، ۱۰۵ و ۲۰۰ وات) بر میزان کل ترکیبات فنولی، آنتوسیانین و شمارش کلی میکروبی آب انگور قرمز مطالعه شد. طراحی آزمون با روش سطح پاسخ (طراحی باکس بنکن) انجام و بهینه‌سازی یافته ها انجام شد. کیفیت نمونه‌های بهینه شده با نمونه کنترل پاستوریزه‌شده در ۹۰ درجه سلسیوس به مدت ۳۰ ثانیه مقایسه شد. میزان کل ترکیبات فنولی، آنتوسیانین و شمارش کلی میکروبی به‌ترتیب با روش‌های فولین-سیوکالتیو، اسپکتروفتومتری و شمارش کلی پرگنه‌ها[۱] تعیین شدند.

یافته‌ها و نتیجه‌گیری: بیشینه ترکیبات فنولی و آنتوسیانین و کمینه بار میکروبی در دمای ۶۰ °C ، زمان ۲ دقیقه و قدرت فراصوت ۱۴۴/۳۴ وات به‌دست آمد. نتایج نشان داد میزان فنول کل و آنتوسیانین نمونه تیمار شده با فراصوت در شرایط بهینه به‌صورت معنی‌داری بیشتر از نمونه پاستوریزه شده با حرارت بود. اختلاف معنی‌داری بین میزان شمارش کلی دو نمونه تیمار فراصوت و پاستوریزاسیون حرارتی مشاهده نگردید. نتایج نشان داد با بهینه‌سازی تیمار فراصوت می‌توان ترکیبات زیست‌فعال بیشتری نظیر فنول‌ها و آنتوسیانین‌ها را در آب انگور در مقایسه با فرایند حرارتی حفظ کرد. به‌علاوه، با بهینه سازی شرایط تیمار فراصوت می‌توان به ایمنی مشابه با پاستوریزاسیون حرارتی دست یافت.

تعارض منافع: نویسندگان اعلام می‌کنند که هیچ نوع تعارض منافعی مرتبط با انتشار این مقاله ندارند.

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واژگان کلیدی
- آنتوسیانین
- پاستوریزاسیون
- ترکیبات فنولی
- فراصوت

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