https://doi.org/10.17221/77/2024-CJFS

Comparative evaluation of high pressure processing and thermal pasteurisation on phytochemicals, microbial and sensorial attributes of sweet cherry (*Prunus avium* L.) juice

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Citation: Ahmad T., Shahbaz H.M., Saeed K., Iqbal S., Rehman H. (2024): Comparative evaluation of high pressure processing and thermal pasteurisation on phytochemicals, microbial and sensorial attributes of sweet cherry (*Prunus avium* L.) juice. Czech J. Food Sci., 42: 405–414.

Abstract: Sweet cherry juice rich in phenols and anthocyanins is highly perishable and typically undergo thermal pasteurisation, which can diminish its nutritional composition. High pressure processing (HPP), a non-thermal technique using pressure to inactivate the microbes while preserving nutrients, offers a more effective alternative for extending the shelf life of fruit juice. Accordingly, present study evaluated comparative impact of high pressure processing and thermal pasteurisation on phytochemicals, antioxidant activity, microbial and sensory attributes of cherry juice during storage. For study, cherry juice subjected to two different HPP levels (400 and 600 MPa) for 5 min and thermal pasteurisation (95 °C) for 30 s, followed by storage (60 days at 4 °C). Results showed HPP and thermal pasteurisation had significant impact ($P < 0.05$) on phenolics, flavonoids, and antioxidants compared to control, however, thermally pasteurised juice showed rapid deterioration compared to HPP juice, whereas anthocyanin and cyanidin-3-glucoside levels remarkably different in both groups. Microbial findings revealed safety of HPP pasteurisation juice with shelf life (45 days) however, better sensory acceptability for HPP treated juice. In nutshell, HPP pasteurisation is pragmatic approach for enhancing shelf life with better nutrients for cherry juice and findings useful for beverage industry and health professionals.

Keywords: non-thermal; phytonutrients; shelf life; consumer acceptability; microbial safety

Since last decade, need for novel processing technologies to improve and maintain food products quality, especially fresh juices and beverages increased. High pressure processing (HPP) emerged as non-thermal technique utilising hydrostatic pressures (100–1 000 MPa) to inactivate pathogenic microbes and maintain sensory attributes for fruit juices (Tenuta et al. 2023). Sweet cherry, known as (*Prunus avium* L.), is highly coveted fruit owing to its organoleptic attributes like taste, softness, aroma, nutritional value, and health benefits (Di Matteo et al. 2017;

The authors are grateful to the Technology Development Fund Program (Grant No. TDF02-116) of Higher Education Commission (HEC), Islamabad, Pakistan for funding the research work.

https://doi.org/10.17221/77/2024-CJFS

Gonçalves et al. 2019). It is also reported sweet cherry consumption improve human health and believed to offer benefits in combating diabetes, cancer, inflammatory, and cardiovascular diseases (Mahmoud et al. 2022). The health benefits of sweet cherry are associated with the presence of high content of phenolics, flavonoids, and anthocyanin compounds. Additionally, sweet cherry is hailed as superfood owing its low-calories, nutrient-dense and rich source of antioxidants notably anthocyanins like cyanidin-3-glucoside and cyanidin-3-rutinoside (Szpadzik et al. 2022). These compounds mainly responsible for antioxidant activity and possess capacity 4 times higher than vitamin E and surpass effectiveness of vitamin C in human health promotion (van der Werf et al. 2018). Pakistan produces over 8 000 metric tons of cherries annually for the year 2023. However, due to inadequate infrastructure, longer distances from major markets, and the fruit's short shelf life around 1–2 days, much of the fruit spoils in local markets. Cherry being perishable fruit processed into purees and juices to improve shelf life. However, to maintain juice safety and quality, thermal pasteurisation is used which results loss of nutrients (Mandha et al. 2023). Additionally, in conventional processing, Maillard reactions, ascorbic acid oxidation occur which adversely affect organoleptic and sensory attributes of juices. Thus innovative processing technologies like HPP used to preserve nutrients and enhance shelf life of juices (Kathuria and Thakur 2023). Although heat treatments highly effective in eliminating microbes, they can diminish nutritional and sensory attributes of products (Garcia-Parra et al. 2017). Therefore, alternative technologies are in effect, with special consideration given to high pressure processing with relatively low temperatures compared to conventional thermal methods (Waghmare 2024). HPP can inactivate pathogens and spoilage microbes but cannot affect covalently bonded molecules so physiochemical properties of food remain unchanged so product remain fresh and nutritious compared to conventional processing (Queirós et al. 2015; Sehrawat et al. 2021).

Although HPP is globally recognised non-thermal treatment but limited literature available on effect of HPP on organoleptic properties and phytonutrients of sweet cherry juice so present study conducted to investigate effect of HPP in comparison to thermal pasteurisation on phytochemicals (anthocyanins, flavonoids), antioxidant [2,2-diphenyl-1-picrylhydrazyl (DPPH)], microbial and sensory attributes using indigenous cherry at storage intervals.

MATERIAL AND METHODS

The present study conducted to assess impact of thermal and HPP pasteurisation on phytochemicals, microbial aspects, and sensory parameters of cherry juice.

Research material and chemicals. Cherry fruit (*Prunus avium* L.), purchased at maturity from Gilgit-Baltistan transported in commercial packaging to university laboratory. Folin-Ciocaltue reagent, sodium carbonate, DPPH, sodium hydroxide, and gallic acid purchased from Merck (Germany). Aluminum chloride ($6H_2O$) from CHEMIZ (UK), quercetin from Targetmol (USA) whereas, plate count agar from Merck and rose Bengal agar from HIMEDIA (India) were purchased.

Juice extraction. Before processing of juice for pasteurisation, cherry fruit (*Prunus avium* L.), stems and pits of removed and sterile juice extractor (Cold Press, JE-B03B MIUI; MIUI Smart Home Appliances, China) used for juice extraction and 100% pure cherry juice was collected in the sterile vacuum (500 mL flexible pouches) without adding sugar and preservatives by following the procedure of Ekanem and Ekanem (2019). After the juice extraction, samples were subjected to different treatments which were selected considering literature review for the preservation potential of HPP, microbial safety and cherry juice shelf life as well as thermal treatment (commercial conditions) as per plan mentioned in Table 1.

Thermal treatment of juice. Cherry juice subjected to thermal pasteurisation using water bath (WNB 14; Memmert GmbH + Co. KG, Germany) temperature set (95 °C for 30 s) following the procedure of Saeeduddin et al. (2015). Afterwards, juice samples transferred to ice bath for cooling, storage for study analysis.

Table 1. Study plan of cherry juice subjected to thermal and HPP treatments

Treatments	Description
T_0	control in which sweet cherry juice is not subjected to any treatment
T_1	sweet cherry juice subjected to HPP treatment at 400 MPa for 5 min
T_2	sweet cherry juice subjected to HPP treatment at 600 MPa for 5 min
T_3	sweet cherry juice subjected to thermal treatment at 95 °C for 30 s

HPP – high pressure processing

https://doi.org/10.17221/77/2024-CJFS

High pressure processing. After extraction followed by packaging of juice, subjected to non-thermal processing using HPP unit (HPP L2-600/2; Tianjin Huatai-Senmiao Bioengineering Technology Co., Ltd., China), equipped with jackets contain water for pressure medium, deploying two levels 400 MPa and 600 MPa for 5 min following protocol as mentioned by Gouvea et al. (2020).

Analysis of juice subjected to thermal and high pressure processing treatments. After the application of processing treatments to cherry juices, placed at 4 °C for storage (0, 15th, 30th, 45th, and 60th day) and subjected to analysis as mentioned below.

Total phenolics. Total phenolics of juices were determined using Folin-Ciocalteu method following the procedure of Singleton et al. (1999). Cherry juice mixed with reagents, incubated, and absorbance was at 760 nm and total phenolics content (TPC) estimated in mg GAE·mL^{-1}.

Total flavonoids. Total flavonoids were determined using colourimetric assay as discussed by Saeed et al. (2013). First of all, 0.5 mL juice added to reagents and incubated for 30 min at room temperature. Afterwards, absorption taken at 510 nm, and concentration expressed as quercetin in mg·mL^{-1} of juice.

Antioxidant capacity. Cherry juice scavenging free radicals' activity was assessed using the DPPH assay by following the method of Brand-Williams et al. (1995). Accordingly, 100 µL of cherry juice containing 290 µL of DPPH solution (0.004% in methanol) was added, followed by test tubes shaking, left in the dark for 30 min, and measured absorbance at 517 nm. The percentage inhabitation of DPPH was estimated by using Equation 1.

$$\%\ inhibition = \frac{A_{DPPH} - A_{JUICE}}{A_{DPPH}} \times 100 \quad (1)$$

where: A_{DPPH} – absorption value of DPPH blank; A_{JUICE} – absorption value measured for cherry juice samples.

Total anthocyanins level. Total anthocyanins estimated using pH differential method, in which juice was used at pH (1 and 4.5) using two buffer solutions by following protocol of Giusti and Wrolstad (2001). Afterwards, solutions prepared using potassium chloride and sodium acetate buffer. After incubation for 15 min, absorbance taken at 510 nm and 700 nm for buffers 1 and 2, respectively, and total anthocyanins determined.

Anthocyanin determination. Cyanidin-3-O-glucoside determined using high pressure liquid chromatography using autosampler (Agilent 1100; Agilent Scientific Instruments, USA) by following the procedure of Sang et al. (2017). Then, for analysis, stationary phase using C-18 column (250 mm × 4.6 mm), with 10 particle sizes and mobile phase containing mixture of ethanol and 0.25 mol·L^{-1} tartaric acid aqueous solution at 20 : 80 (*v*/*v*). Fresh cherry juice mixed with mobile phase in ratio (50 : 50) and centrifuged at 4 000 rpm (revolutions per minute) for 10 min afterwards, supernatant filtered through syringe filter (0.22 µm) followed by samples injected for analysis.

Microbiological analysis. Juices samples subjected to microbial analysis for safety assessment and shelf-life testing. For total plate count, serial dilution made and poured onto agar plates: for total plate count, nutrient agar at 37 °C for 48 h and rose Bengal agar (HIMEDIA, India) for yeast and molds at 30 °C for 72 h. Colonies were counted by using the colony counter (CC-J2; Jintan Rongjin Medical Equipment Co., Ltd., China) by following the procedure of Usaga et al. (2021).

Sensory evaluation analysis. Sensory evaluation (taste, aroma, colour, and overall acceptability) of juices done using 9-point hedonic scale by adopting protocol of Liu et al. (2016).

Statistical analysis. Collected data analysed using SPSS (version 21), and data represented as mean ± standard deviation (SD) with significance ($P < 0.05$). Descriptive statistic and one-way analyses (ANOVA) were also employed by following the guidelines of Han et al. (2022).

RESULTS

The present study conducted to assess impact of processing techniques including thermal and HPP, on phytochemicals, microbial and sensory analysis of cherry juice.

Phytochemicals of juices. Results (Table 2) reported T_2 (600 MPa HPP) has the highest total phenolics, total flavonoids, and free radical scavenging activity, reported as 76.95 ± 3.42 mg·(100 mL)$^{-1}$, 44.62 ± 3.10 mg·(100 mL)$^{-1}$, and 62.81 ± 2.61%, respectively at the start of storage, whereas the lowest values reported in T_3 (90 °C for 5 min) as 62.24 ± 3.71 mg·(100 mL)$^{-1}$, 31.51 ± 4.81 mg·(100 mL)$^{-1}$, and 30.81 ± 2.31% for said traits that were decreased to 61.62 ± 3.31 mg·(100 mL)$^{-1}$ and 50.17 ± 3.32 mg·(100 mL)$^{-1}$ for total phenolics content, 36.12 ± 0.41 mg·(100 mL)$^{-1}$ and 27.02 ± 1.36 mg·(100 mL)$^{-1}$ for total flavonoids, 25.27 ± 1.41% and 19.32 ± 1.51% for free radical scavenging activity in T_2 and T_3, correspondingly at storage termination (60 days). T_2 significantly outperformed T_0 and T_3 in preserving total flavonoids, and overall storage has a declining effect on phytochemicals profile irrespective of treatments.

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Table 2. Total phenolics of cherry juice subjected to thermal and high pressure processing

Parameters	Day	Study groups				*P*-value
		T_0	T_1	T_2	T_3	
Total phenolics [mg·(100 mL)$^{-1}$]	0	66.22^{A} ± 1.32	71.12^{A} ± 2.42	76.95 ± 3.42	62.24^{A} ± 3.71	0.102
	15	61.73^{AB} ± 1.01	71.73^{A} ± 2.12	71.21 ± 3.21	56.82^{B} ± 2.82	0.096
	30	51.21^{bBC} ± 6.43	67.21^{aA} ± 1.61	69.45^{a} ± 8.71	55.81^{ab} ± 0.81	0.003*
	45	57.72^{bAB} ± 6.61	65.75^{abA} ± 4.41	69.74^{a} ± 2.01	54.22^{b} ± 8.82	0.006*
	60	45.84^{cC} ± 2.80	54.74^{abB} ± 5.72	61.62^{a} ± 3.31	50.17^{bc} ± 3.32	0.009*
	P-value	0.016*	0.012*	0.129	0.420	–
Total flavonoids [mg·(100 mL)$^{-1}$]	0	42.02^{aA} ± 2.10	38.12^{ab} ± 5.31	44.62^{a} ± 3.10	31.51^{b} ± 4.81	0.018*
	15	34.94^{B} ± 1.71	40.54 ± 1.62	39.21 ± 6.81	31.32 ± 4.02	0.223
	30	29.34^{bBC} ± 1.06	36.81^{a} ± 3.51	39.42^{a} ± 3.52	30.32^{b} ± 0.71	0.003*
	45	28.30^{bBC} ± 1.82	34.62^{a} ± 1.62	37.17^{a} ± 1.71	28.81^{b} ± 1.42	0.000*
	60	25.20^{cC} ± 3.21	31.91^{b} ± 1.54	36.12^{a} ± 0.41	27.02^{c} ± 1.36	0.000*
	P-value	0.001*	0.055	0.132	0.364	–
Free radical scavenging activity (%)	0	59.61^{aA} ± 3.41	61.92^{aA} ± 1.82	62.81^{aA} ± 2.61	30.81^{bA} ± 2.31	0.000*
	15	38.52^{bB} ± 3.72	48.51^{aB} ± 3.93	46.14^{aB} ± 1.82	26.02^{cB} ± 1.06	0.002*
	30	33.91^{bC} ± 1.72	40.06^{aC} ± 1.31	43.23^{aB} ± 2.31	28.51^{cAB} ± 3.31	0.000*
	45	22.22^{bD} ± 1.51	32.92^{aD} ± 1.32	35.42^{aC} ± 2.06	17.12^{cC} ± 0.62	0.000*
	60	16.12^{cE} ± 0.62	18.51^{bE} ± 0.81	25.27^{aD} ± 1.41	19.32^{bC} ± 1.51	0.000*
	P-value	0.000*	0.000*	0.000*	0.000*	–

*Said parameters are statistically significant differences for treatments and storage intervals; $^{a–c}$small superscript letters showed statistical difference in rows; $^{A–D}$capital letters in each column indicate significant different group for each group separately ($P < 0.05$); data are expressed as means ± SD (standard deviation); T0 – control in which sweet cherry juice is not subjected to any treatment; T1 – sweet cherry juice subjected to HPP treatment at 400 MPa for 5 min; T2 – sweet cherry juice subjected to HPP treatment at 600 MPa for 5 min; T3 – sweet cherry juice subjected to thermal treatment at 95 °C for 30 s; HPP – high pressure processing

Anthocyanins in sweet cherry juice. Results (Figure 1) for total anthocyanins reported highest the value in T_2 as 26.80 ± 1.42 mg·(100 mL)$^{-1}$, followed by T_0 [26.03 ± 3.31 mg·(100 mL)$^{-1}$] and lowest in T_3 [22.72 ± 0.72 mg·(100 mL)$^{-1}$] at study initiation, that were decreased to 14.41 ± 3.15, 9.32 ± 1.21, and 9.13 ± 1.62 mg·(100 mL)$^{-1}$, correspondingly at the termination of storage. Similarly, the concentration of anthocyanin (cyanidin-3-glucoside) in cherry juice subjected to HPP and heat treatments showed a significant difference ($P < 0.05$) as reported in Figure 2. A declining trend noted during storage and significant reduction in cyanidin-3-glucoside in control T_0 [22.06 ± 0.21 mg·(100 mL)$^{-1}$] and heat treatment T_3 [17.92 ± 0.54 mg·(100 mL)$^{-1}$] compared to T_2 [27.42 ± 0.42 mg·(100 mL)$^{-1}$].

The results (Table 3) reported total plate count, yeast, and mold in cherry juice treated with HPP and heat pasteurisation indicated at day 0, total plate count load was (1.0×10^2) CFU·mL^{-1} in T_0, whereas yeast and mold not present in control and treatment groups (CFU – colony-forming unit). After 45 days, these values increased for TPC (2.0×10^{10}), yeast (2.0×10^7), and mold (1.84×10^3) log CFU·mL^{-1} compared to heat-treated and high pressure processing. T_2 results comparable to those of thermal group, as it successfully inhibited TPC, yeast, and mold count upto 45th day of trial. Moreover, mold was absent in T_2 and T_3 groups throughout study intervals. Nevertheless, results by HPP and thermally pasteurised samples were more promising.

Sensory evaluation. Organoleptic qualities encompassing taste, flavour, colour, and overall acceptability of sweet cherry juice, remained satisfactory throughout storage, with exception in control (T_0) and thermal (T_3). Results indicated noticeable deterioration for colour and taste after 30th storage day and was a significant disparity for acceptance and taste of thermally treated juice at onset compared to HPP-treated and control juice. Regarding taste, highest score attributed T_2 (8.66 ± 0.53), followed by T_1 (8.61 ± 0.44), while lowest in T_3 (5.15 ± 0.12). However, these scores declined to 7.83 ± 0.16 and 7.12 ± 0.12 for T_2 and T_1, respectively, whereas T_3 experienced more significant decrease 3.32 ± 0.82 by termination of experiment (Table 4).

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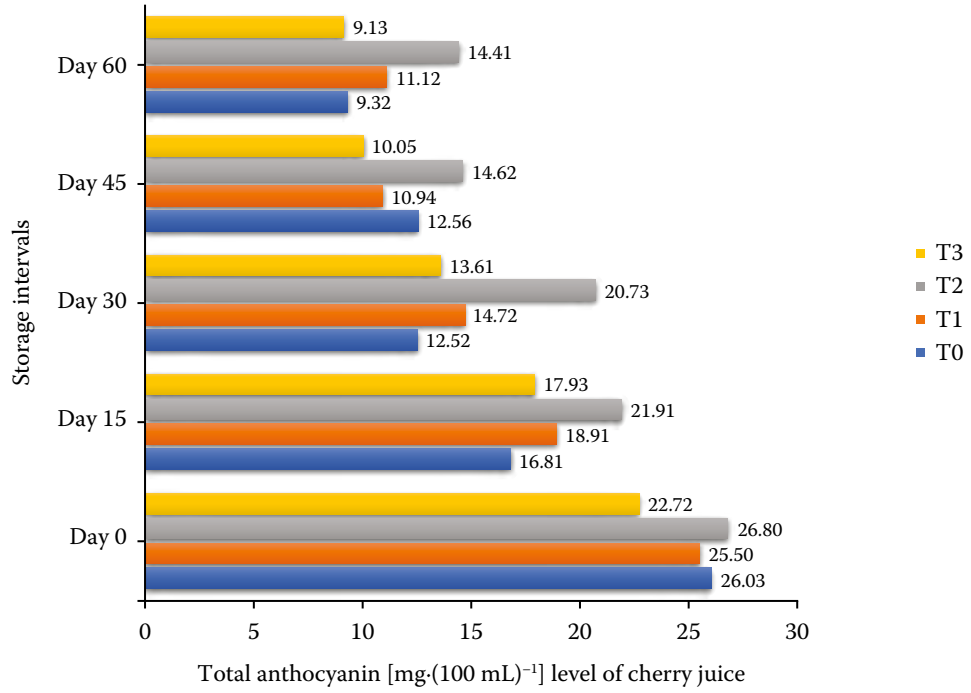

Figure 1. Total anthocyanin [mg·(100 mL)$^{-1}$] of sweet cherry juice subjected to high pressure processing and thermal treatment stored at (4 °C) for 60 days

T0 – control in which sweet cherry juice is not subjected to any treatment; T1 – sweet cherry juice subjected to HPP treatment at 400 MPa for 5 min; T2 – sweet cherry juice subjected to HPP treatment at 600 MPa for 5 min; T3 – sweet cherry juice subjected to thermal treatment at 95 °C for 30 s; HPP – high pressure processing

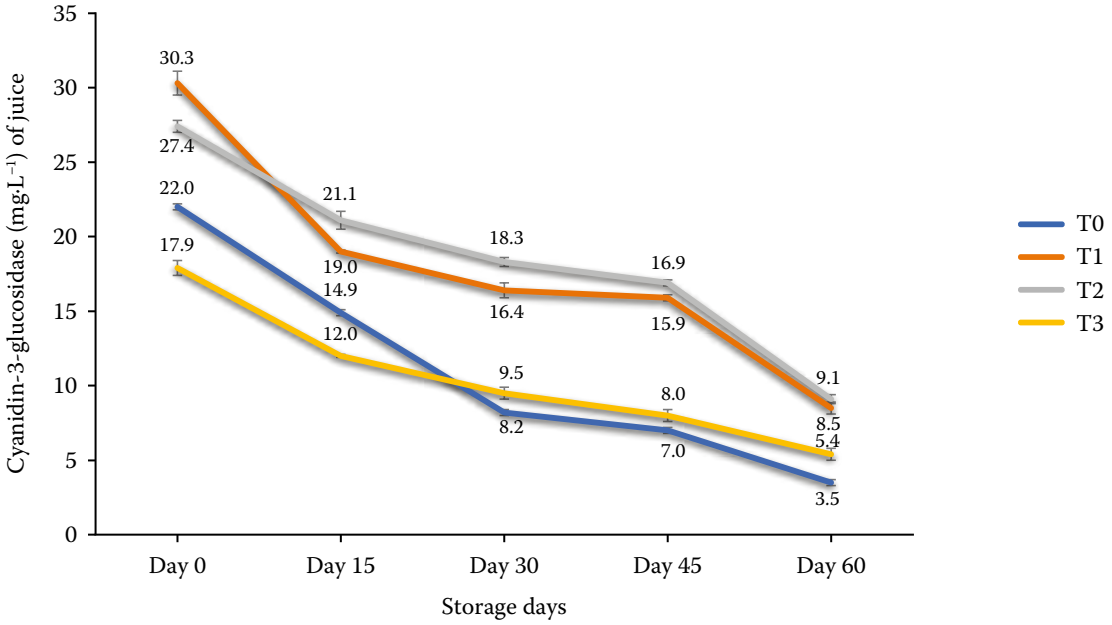

Figure 2. Cyanidin-3-glucosidase (mg·L^{-1}) of sweet cherry juice subjected to high pressure processing and thermal treatment stored at (4 °C) for 60 days

T0 – control in which sweet cherry juice is not subjected to any treatment; T1 – sweet cherry juice subjected to HPP treatment at 400 MPa for 5 min; T2 – sweet cherry juice subjected to HPP treatment at 600 MPa for 5 min; T3 – sweet cherry juice subjected to thermal treatment at 95 °C for 30 s; HPP – high pressure processing

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Table 3. Microbiological analysis of sweet cherry juice subjected to high pressure and thermal processing stored (4 °C)

Parameters	Treatments	Storage intervals (days)				
		0	15	30	45	60
Total plate count	T_0	1.01×10^2	1.51×10^4	1.81×10^8	2.01×10^{10}	2.17×10^{12}
	T_1	ND	ND	1.10×10^2	1.53×10^4	1.78×10^7
	T_2	ND	ND	ND	ND	1.74×10^5
	T_3	ND	ND	ND	ND	1.01×10^2
Yeast	T_0	ND	1.54×10^2	1.57×10^6	2.01×10^7	2.20×10^{10}
	T_1	ND	ND	ND	1.22×10^2	1.93×10^4
	T_2	ND	ND	ND	ND	1.62×10^2
	T_3	ND	ND	ND	ND	ND
Mold count	T_0	ND	ND	1.47×10^2	1.84×10^3	2.60×10^5
	T_1	ND	ND	ND	ND	1.57×10^3
	T_2	ND	ND	ND	ND	ND
	T_3	ND	ND	ND	ND	ND

Data are expressed as mean; ND – not detected (below the detection limit: 1 log CFU·mL^{-1}); CFU – colony-forming unit; T0 – control in which sweet cherry juice is not subjected to any treatment; T1 – sweet cherry juice subjected to HPP treatment at 400 MPa for 5 min; T2 – sweet cherry juice subjected to HPP treatment at 600 MPa for 5 min; T3 – sweet cherry juice subjected to thermal treatment at 95 °C for 30 s; HPP – high pressure processing

Table 4. Sensory evaluation of cherry juice subjected to thermal and high pressure processing processing

Parameters	Treatments	0	15	30	45	60	*P*-value
Taste	T_0	$8.60^{aA} \pm 0.31$	$7.22^{bB} \pm 0.32$	$6.51^{cC} \pm 0.82$	$5.52^{bD} \pm 1.21$	$5.03^{dA} \pm 0.25$	0.000*
	T_1	$8.61^{aA} \pm 0.44$	$8.11^{abB} \pm 1.31$	$7.61^{bC} \pm 0.21$	$7.12^{aD} \pm 0.12$	$6.92^{eB} \pm 0.18$	0.001*
	T_2	$8.66^{aA} \pm 0.53$	$8.58^{aAB} \pm 0.43$	$8.22^{aB} \pm 0.16$	$7.83^{aC} \pm 0.16$	$7.53^{eC} \pm 0.08$	0.000*
	T_3	$5.15^{bA} \pm 0.12$	$5.06^{cB} \pm 0.74$	$4.71^{dC} \pm 0.12$	$3.32^{bD} \pm 0.82$	$3.10^{dD} \pm 0.12$	0.000*
	P-value	0.000*	0.000*	0.000*	0.000*	0.002*	–
Aroma	T_0	$8.72^{aA} \pm 0.22$	$7.60^{bA} \pm 0.32$	$7.06^{bB} \pm 0.25$	$4.62^{bC} \pm 0.12$	$4.35^{eA} \pm 0.10$	0.000*
	T_1	$8.94^{aA} \pm 0.15$	$8.60^{abA} \pm 0.41$	$8.51^{aA} \pm 0.12$	$7.72^{aB} \pm 0.16$	$6.95^{eB} \pm 0.22$	0.003*
	T_2	$8.71^{aA} \pm 0.51$	$8.23^{aB} \pm 0.16$	$8.32^{aB} \pm 0.24$	$8.06^{aC} \pm 0.12$	$7.61^{eC} \pm 0.14$	0.017*
	T_3	$5.32^{bA} \pm 0.14$	$5.62^{cB} \pm 0.18$	$5.34^{cB} \pm 0.16$	$4.81^{bC} \pm 0.44$	$4.74^{dD} \pm 0.06$	0.009*
	P-value	0.000*	0.000*	0.000*	0.000*	0.001*	–
Colour	T_0	$8.54^{aA} \pm 0.42$	$8.34^{bB} \pm 0.31$	$8.06^{cB} \pm 0.12$	$7.90^{cC} \pm 0.20$	$7.41^{eA} \pm 0.39$	0.000*
	T_1	$8.71^{aA} \pm 0.10$	$8.25^{abA} \pm 0.34$	$8.02^{bAB} \pm 0.12$	$8.12^{bB} \pm 0.12$	$7.77^{dAB} \pm 0.32$	0.002*
	T_2	$8.63^{aA} \pm 0.12$	$8.42^{aA} \pm 0.26$	$8.12^{aA} \pm 0.14$	$8.16^{aB} \pm 0.26$	$8.33^{abB} \pm 0.62$	0.001*
	T_3	$5.36^{bA} \pm 0.46$	$5.16^{cB} \pm 0.28$	$4.04^{dB} \pm 0.12$	$4.02^{dC} \pm 0.17$	$4.07^{cC} \pm 0.19$	0.001*
	P-value	0.000*	0.000*	0.000*	0.000*	0.004*	–
OAA	T_0	$8.84^{aA} \pm 0.21$	$8.34^{cAB} \pm 0.15$	$7.88^{cB} \pm 0.21$	$6.32^{bC} \pm 0.11$	$6.07^{eA} \pm 0.21$	0.000*
	T_1	$8.91^{aA} \pm 0.13$	$8.61^{bA} \pm 0.21$	$8.47^{bAB} \pm 0.16$	$8.04^{aB} \pm 0.12$	$7.92^{dA} \pm 0.42$	0.002*
	T_2	$8.67^{aA} \pm 0.25$	$8.22^{aAB} \pm 0.15$	$8.34^{aB} \pm 0.14$	$8.09^{aC} \pm 0.16$	$8.02^{cB} \pm 0.47$	0.000*
	T_3	$7.12^{bA} \pm 0.15$	$6.95^{dA} \pm 0.15$	$6.76^{dB} \pm 0.07$	$6.25^{bC} \pm 0.21$	$5.72^{dC} \pm 0.28$	0.001*
	P-value	0.001*	0.000*	0.001*	0.004*	0.002*	–

*Said parameters are statistically significant differences for treatments and storage intervals; $^{a–d}$small superscript letters in each column represent significant different groups at each interval separately; $^{A–C}$capital superscript letters in each row represent significant different intervals in each group separately; data are expressed as mean ± SD (standard deviation); OAA – overall acceptability; T0 – control in which sweet cherry juice is not subjected to any treatment; T1 – sweet cherry juice subjected to HPP treatment at 400 MPa for 5 min; T2 – sweet cherry juice subjected to HPP treatment at 600 MPa for 5 min; T3 – sweet cherry juice subjected to thermal treatment at 95 °C for 30 s; HPP – high pressure processing

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Overall, sensory attributes of HPP-treated cherry juice stood out compared to thermal treatment.

DISCUSSION

The nutritional analysis of processed foods allows us to determine values of vital nutrients present, which ultimately influence consumer health. Non-thermal processing techniques offer advantages over traditional thermal methods, such as reduced energy consumption, preservation of sensory and nutritional qualities. thus, non-thermal processing techniques are gaining popularity in food processing, especially juices and beverages for consumers. These nutritional compounds in cherries are considered optimal for human health (Nunes et al. 2021). Our study results supported by Hayaloglu and Demir (2015), who conducted study to assess antioxidant activity and physiochemical properties of sweet cherry, reported total phenolic contents ranged 58.31–115.41 mg·(100 g)$^{-1}$, which is comparable with our study finding reporting total phenols at 66–76.9 mg·(100 mL)$^{-1}$. A similar trend reported in pomegranate's fermented juice treated by HPP comparison to thermal treatment (Chen et al. 2013; Ma et al. 2019), increased phenolic contents attributed to increased extractability of phytonutrients by HPP (Lou et al. 2022). Similarly, another study reported that high pressure processing of vegetable baby puree enhanced total phenolic content, showing better performance than controls (Javed et al. 2023).

Sweet cherry is rich source of flavonoids like quercetin, which possess antioxidant and anti-inflammatory potential. Jang et al. (2018) also reported quercetin as primary flavanol in sweet cherry and level in cherry depends on agronomic practices and climatic conditions. Additionally, Tahir Mahmood et al. (2013) reported that total flavonoids in sweet cherry fruit ranged from 36.6–51.8 mg·(100 g)$^{-1}$. Comparable results reported in current investigation in which of flavonoids concentration in sweet cherry juice ranged 38.1–44.6 mg·(100 mL)$^{-1}$. Our results align with Vieira et al. (2018), who also observed increased retention of total flavonoids in HPP treated orange juice compared to thermal. Our findings of antioxidant assays are consistent with Rios-Corripio et al. (2024), who documented antioxidant activity of fresh black cherry juice processed at 400 MPa (for 10 min) and 600 MPa (for 5 min) was higher than thermal and fermented processing. Moreover, Hassanpour et al. (2011) assessed antioxidant capacity of sweet cherry and revealed that inhibition% ranged from 38–82%. This effect was due to the documented ability of high pressure processing to maintain antioxidants, which contributes significantly to the overall antioxidant activity of juice that is degraded by thermal pasteurisation.

Anthocyanins naturally occurring glycosylated pigmented compounds classified within phenolic and flavonoid groups. Our study reported anthocyanin ranged 227–268 mg·L^{-1} at baseline, and these findings align with Jakobek et al. (2007), who reported 256 mg·L^{-1} anthocyanins in cherry juice. A study assessed effect of HPP and thermal sterilisation revealed higher anthocyanin in HPP-treated cherry juice compared to thermal (Peng et al. 2018). Furthermore, studies reported anthocyanins better preserved in strawberry juice treated with HPP during storage compared to puree (Aaby et al. 2018). Our study revealed cyanidin-3-glucoside in cherry juice ranged from 17.9–30.3 mg·L^{-1} after processing, cyanidin-3-glucoside concentration decreased up to 40.9% in post thermal group and increased in HPP-processed juice, with maximum retention in HPP 600 MPa cherry juice. A comparable pattern documented by Garcia-Parra et al. (2017). Findings of investigation are comparable with Ballistreri et al. (2013), who found 0.55–34.84 mg·(100 g)$^{-1}$ of cyanidin-3-glucoside concentration in sweet cherry. On other hand Queirós et al. (2015) reported 8% increase in anthocyanin contents of HPP treated cherry juice.

Ensuring microbial safety of juices essential to prevent foodborne illnesses from pathogenic microorganisms, contaminate products. Our study suggested HPP and thermal pasteurisation decreased initial microbial load and reduced TPC, yeast, and mold to undetectable levels (< 1 log CFU·mL^{-1}). These finding also supported by literature, which documented favourable outcomes under HPP treatments. Results suggested HPP is effective in inactivation microorganisms in red fruit pomegranate (Ma et al. 2019). Only HPP treated cherry juice at 600 MPa showed comparable efficacy to thermal for inhibiting microbial growth, sustaining inhibition until storage (45th day). These findings align with results of (Queirós et al. 2015), HPP efficiently reduce microbial load in fruit juice (Wu et al. 2021). The microbial inactivation owing to HPP treatments occurs due to disruption of cell membrane integrity, inactivation of key enzymes, damage to DNA strands, and the irreversible denaturation of proteins (Kultur et al. 2017). Additionally, another study results are also aligned with Ricardo et al. (2022), who reported 500 MPa for 10 min prolonged the shelf life of juices by 52 days by suppressing the growth of microbes

https://doi.org/10.17221/77/2024-CJFS

(Ferreira et al. 2022). Moreover, sensory properties more refined in HPP compared to thermally pasteurisation as it uses pressure to deactivate microbes at low temperature. Sensory results showed lower score for control (T_0) and thermal (T_3) groups of cherry juice than HPP groups, which is consistent with findings of Liu et al. (2016), who indicated HPP-treated cherry and fresh cucumber juice exhibited superior quality in aroma, taste and colour compared to thermally processed juice.

CONCLUSION

Our study showed HPP and thermal treatments effective in reducing microbial load up to 45th storage day compared to control whereas, significant reduction for flavonoids, anthocyanins cyanidin-3-glucoside and antioxidant observed after thermal pasteurisation of juice compared to control and HPP processing. Additionally, HPP 600 MPa most efficient in retaining phenols, flavonoids and antioxidant potential of juice compared to thermal due to which not only bioactive profile of juice maintained along with better sensory attributes than thermal group. Findings provide valuable insights for juice industry for application of HPP for preserving nutrients, phytochemicals and better consumer acceptability to develop safe, health and nutritious juices for better health.

Acknowledgement. The authors are highly grateful to the Department of Food Science and Human Nutrition, University of Veterinary and Animal Sciences, Lahore, Pakistan for providing facilities to complete the research work.

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Received: April 30, 2024
Accepted: October 15, 2024
Published online: November 15, 2024