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(Original Article)

Influence of Different Extraction Techniques on Yield and Quality of Plums Juices

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Abstract

Two plums cultivars (Red 'Centerose' and Yellow 'Yabany Zahaby') were used to produce juice. Several treatments were conducted on plums before juice extraction, including freezing, enzymatic hydrolysis (pectinase), microwave, and steaming (hot water vapor). The obtained plums juices were analyzed for physical and chemical properties. The results showed that addition of 250 mg of pectinase/ 100g plums increased the juice yield to 78.24% and 76.67% for the red and yellow plums, respectively. Also, microwave heating for 20 s and steaming for 60 min enhanced the juice yield for both red and yellow plums. Furthermore, pectinase addition to plums before juice extraction improved nutritional and antioxidant properties of obtained plum juice. Besides, ascorbic acid content in obtained red and yellow plums juices after enzymatic treatment recorded 62.49 and 48.94 mg/ 100 ml, respectively. On the other hand, red and yellow juices obtained after steam treatment had significantly higher values of phenolics, flavonoids and antioxidant activity, when compared to all other treatments. The results indicate that combined freezing treatment with pectinase addition facilitate the production of a nutritious clear juice, which promote its usage for food and beverage applications.

Keywords: *Plums juice, Enzymatic treatment, Microwaves, Steam, Antioxidant activity.*

Introduction

Plum *(Prunus salicina* L.) belongs to the *Rosaceae* family, which comprises a wide range of flavors (from sour to sweet) and colors (black, red, purple, and yellow) (Birwal *et al.,*2017). The average production of plums and sloes in Egypt recorded 17882.51 tonnes in 2021 (FAO, 2023). Plums are a seasonal fruit that are not only delicious but also useful. Clinical studies have demonstrated that drinking plum juice helps to maintain blood levels of insulin and glucose, which may lower anxiety and neophobia and reduce the risk of heart disease. It also controls heart rate and blood pressure (Birwal *et al.,* 2017).

Plums are an important food in our diet because of their nutritional significance. The beneficial substances phenolic acids, anthocyanins, and carotenoids are abundant in plums. Additionally, due to their high content of pectin, organic acids (citric and malic), sugars (sucrose, glucose, and fructose), tannins, aromatic compounds, and enzymes, plums offer low calories and a

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relatively high nutritional value (Nakatani *et al.,* 2000; Ertekina *et al.,* 2006; Birwal *et al.*,2017).

In spite of the fact that most plums are consumed fresh around the world, they can also be processed by drying, canning, and making beverages (Stacewicz-Sapuntzakis *et al*., 2001; Somogai, 2005; Blazek, 2007). Due to the high content of pectic polysaccharides, which created challenging technical issues in the pressing operation during juice extraction, one of the challenges in manufacturing plum juices is the poor juice yield (Zbrzeniak *et al.,* 2015). To solve this problem, pretreatment, clarification, and thermal treatments are necessary steps during fruit processing into juice. According to several research (Chang *et al.,* 1994; Will and Dietrich, 2006), the pretreatment of plums with enzymes may have a negative impact on the juice's quality (as complete degradation of pectin produce cloudy juices).

Furthermore, ascorbic acid, anthocyanins, and phenolics may be negatively impacted by the thermal treatment applied on fruit juice. However, due to its effectiveness in inactivating or destroying microorganisms or human pathogens, as well as prolonging the product's shelf life, this treatment is still commonly utilised (Wang *et al.,* 2014). Therefore, this study was designed to examine several techniques, including freezing, enzymatic hydrolysis, microwave heating, and steaming to improve plum juice extraction yield. Additionally, effect of these treatments on quality characteristics of the obtained juice was evaluated.

Materials and Methods

Materials

Red plums 'Centerose' and yellow plums 'Yabany Zahaby' cultivars *(Prunus salicina* L.) were brought from local market, Assiut, Egypt. Whereas all chemicals in this study are of analytical grade and were purchased from EL-Gomhouria for Trading Chemicals and Drugs Co., Assiut, Egypt. Pectinase, 2,2-Diphenyl-1-picrylhydrazyl (DPPH), Folin-Ciocalteu reagent, and gallic acid were purchased from Sigma-Aldrich Chime, Germany.

Methods

Extraction of juice

Plum fruits were chosen randomly and washed. Some of these fruits were extracted directly using the Multi-press Automatic Juice Extractor (Braun, Germany), and the juice obtained from fresh red and yellow plums coded with RC and YC, respectively. Other plums fruits were frozen at -20 °C, and the frozen fruits were divided into sections and treated before juice extraction with different treatments and then it had pasteurization (80 °C for 3 min) for processed juices. Juices yield after these treatments were coded as shown in Table 1.

Table 1. Codes of juice samples

Sample code	Treatment
RC	Control juice extracted from red plums without any pretreatment.
RF	Plum juice extracted from frozen red plums after thawing.
RE50	Plum juice extracted from frozen red plums after thawing and treatment with 50 mg pectinase /100g fruit at 50 ºC for 1h before extracting the juice.
RE250	Plum juice extracted from frozen red plums after thawing and treatment with 250 mg pectinase / 100g fruit at 50 ºC for 1h before extracting the juice.
RM20	Plum juice extracted from frozen red plums after thawing and treatment with microwaves 2450 MH for 20 s before extracting the juice.
RM30	Plum juice extracted from frozen red plums after thawing and treatment with microwaves 2450 MH for 30 s before extracting the juice.
RM40	Plum juice extracted from frozen red plums after thawing and treatment with microwaves 2450 MH for 40 s before extracting the juice.
RS20	Plum juice extracted from frozen red plums after thawing and treatment with steam for 20 min before extracting the juice.
RS40	Plum juice extracted from frozen red plums after thawing and treatment with steam for 40 min before extracting the juice.
RS60	Plum juice extracted from frozen red plums after thawing and treatment with steam for 60 min before extracting the juice.
YC	Control juice extracted from yellow plums without any pretreatment.
YF	Plum juice extracted from frozen yellow plums after thawing.
YE50	Plum juice extracted from frozen yellow plums after thawing and treatment with 50mg pectinase / 100g fruit at 50 ºC for 1h before extracting the juice.
YE250	Plum juice extracted from frozen yellow plums after thawing and treatment with 250mg pectinase / 100g fruit at 50º C for 1h before extracting the juice.
YM20	Plum juice extracted from frozen yellow plums after thawing and treatment with microwaves 2450 MH for 20 s before extracting the juice.
YM30	Plum juice extracted from frozen yellow plums after thawing and treatment with microwaves 2450 MH for 30 s before extracting the juice.
YM40	Plum juice extracted from frozen yellow plums after thawing and treatment with microwaves 2450 MH for 40 s before extracting the juice.
YS20	Plum juice extracted from frozen yellow plums after thawing and treatment with steam for 20 min before extracting the juice.
YS40	Plum juice extracted from frozen yellow plums after thawing and treatment with steam for 40 min before extracting the juice.
YS60	Plum juice extracted from frozen yellow plums after thawing and treatment with steam for 60 min before extracting the juice.

Analytical methods

Physical properties

The pH value (which was measured by pH meter (Hanna Instruments, Padova, Italy), total soluble solids (TSS), and total titratable acidity (TTA) contents were determined according to AOAC (2005), while TSS/TAA values reflect maturity or ripeness index. Furthermore, the juice clarity was estimated by measuring absorbance at 660 nm (Cai *et al.,*2020). Viscosity of plum juice was measured using an Ostwald Capillary tube and the values were expressed as flow time (sec.) at 25 °C. The viscosity was calculated by the following equation:

$$\frac{\eta_s}{\eta_w} = \frac{p_{s*}\, t_s}{p_{w*}\, t_w}$$

where η_s=viscosity of sample, η_w=viscosity of water, p_s=density of sample, t_s=flow time of sample (sec.), p_w=density of water, t_w=flow time of water (sec.)

Chemical composition

Ash, and reducing sugars of plum juice were determined as described in the AOAC (2005). Pectin content was detected according to the methods described by Mauri (2020) and Abd Rashida *et al.* (2016) with some modification. The means of triplicate were reported for each sample.

Lycopene determination

The lycopene was determined from the filtered solution by reading the absorbance using a UV-Visible spectrophotometer at 472 nm. The lycopene content was calculated according to Laleye *et al.* (2010) by the following formula:

$$\text{Lycopene (mg/ 100 g)} = \frac{3.1206 \times \text{absorbance} \times \text{volume} \times \text{dilution}}{\text{Weight of sample (g)} \times 1000} \times 100$$

Determination of β- Carotene and vitamin A

The content of β-carotene in the plum juice was extracted with hexane and acetone (2:1), and sample extract was determined spectrophotometrically at 460 nm. (Hasan *et al.,* 2019). Whereas vitamin A calculated as international unit (IU) according to the following formula: 0.6µg of β-carotene= 1 IU of vitamin A (Khoo *et al.,* 2011).

Ascorbic acid (Vitamin C)

Ascorbic acid was determined according to the method described by Ruck (1963), and the results were expressed as mg/100 ml.

Anthocyanin content

The total anthocyanins content in plums juices was determined by the pH differential method according to Giusti and Wrolstad (2001). The absorbance of diluted sample was calculated according to the following formula.

$$A = (A\lambda\, vis - max - A700)pH1.0 - (A\lambda\, vis - max - A700)\, pH4.5$$

The monomeric anthocyanin pigment concentration was calculated by using the following formula:

$$(mg/liter) = (A\ x\ MW\ x\ DF\ x\ 1000)\ /\ (\varepsilon\ x\ 1)$$

Where MW is molecular weight of cyanidin-3-glucoside = 449.2, DF is the dilution factor and ε= 26,900.

Whereas color density was calculated according to the following formula:

$$\text{Color density} = [(\text{A420 nm} - \text{A700nm}) + (\text{A}\lambda\text{ vis} - \text{max} - \text{A700nm})]\ \text{x DF}$$

Furthermore, the Polymeric color and polymeric color percentage of the bisulfite-bleached sample were calculated as follows.

$$Polymeric\ color\ = [(A420\ nm\ -\ A700nm) + (A\lambda\ vis - max\ -\ A700nm)]\ x\ DF$$

$$Percent\ polymeric\ color\ =\ (polymeric\ color/\ Color\ density)\ x\ 100$$

Total phenolics, total flavonoids, and antioxidant activity

Total phenolics: The total phenolics content of samples was determined using Folin-Ciocâlteu colorimetric method (Singleton *et al.,* 1999), with some modifications as in Gao *et al.* (2002), it was determined in the juices and the results were expressed as milligram of gallic acid equivalents/100 g sample (mg GAE/ 100 g sample).

Total flavonoids: The aluminium chloride colorimetric assay was used for flavonoids determination as described by Marinova *et al*. (2005). Total flavonoids content was expressed as milligram catechin equivalents/ 100 g sample (mg CE/ 100g sample).

Antioxidant activity: Antioxidant activity of juice samples was determined by DPPH method according to Garcia *et al.* (2012) with some modifications. Plum juice was added to DPPH (0.002%), then the mixture was incubated for 100 min at room temperature and absorbance was measured using UV-Vis spectrophotometer at 517 nm. The blank for measurement was made by methanol. The inhibition percentage of the DPPH radical was calculated according to the formula:

I % = [(AB - AS)/AB] x 100

Where I=DPPH inhibition %, AB=absorbance of control sample, AS = absorbance of a tested sample at the end of the reaction. Each assay was carried out in triplicate.

Statistical analysis

Analysis of variance and significant differences among means of the obtained data were tested by using SPSS software (version 16.0 for Windows, SPSS Inc., Chicago, IL). Analysis of Variance (ANOVA) was completed using Duncan's multiple comparison for mean difference testing according to (Steel and Torrie, 1980).

Results and Discussion

Juice yield

Data in Fig. 1 illustrated the effect of different treatments on juice yield of red and yellow plums. The data showed that freezing treatment of the plum fruits before juice extraction (samples RF and YF) increased the yield non-significantly ($p > 0.05$) in the two cultivars under investigation (from 46.57 to 54.75 % in red plums, and from 46.55 to 48.99% in yellow plums). This increase could be attributed to the effect of freezing process on destroying the internal structure of plums fruits, and thus might be responsible for a better diffusion of water (Albagnac *et al.,* 2002).

Effect of pectinase addition on juice yield is shown in Fig.1. Data showed that addition of pectinase caused a significant ($p < 0.05$) increase in juice yield in the two cultivars, while increase the dosage of pectinase to 250 mg/ 100g of red plums recorded the highest yield (78.24%). These findings are consistent with those obtained by previous study (Chang *et al.,* 1994), they found that juice yield of red plum variety increased from 25 to 79% after addition pectinase, which was close to this study. Furthermore, freezing and defrosting of plum fruit as a pretreatment process before enzymes addition have the potential to break down cell walls, which making it easier for pectic enzymes to penetrate cells (Zbrzeniak *et al.,* 2015). In another study, Olawuyi *et al.* (2021) found that the addition of pectinase enzyme (0.2%) to plum fruit (*Prunus salicina L.)* on 45°C, raised the juice yield from 72.27% (in control) to 81.03 %.

Using microwave treatment for 20 s before juice extraction caused an increase in juice yield from 46.57 to 54.52% and from 46.55 to 61.95% in red and yellow plums, respectively (Fig.1). Meanwhile, the increase of the time of microwave treatment to 60 s caused a decrease in juice yield. This decrease could be attributed to the behaviors of plum flesh in the microwave, as it foamed, and gave some liquid upon heating that flowed through skin gaps, besides more water vapor was formed faster and escaped in the gas phase, contributing to decrease of juice yields (Cendres *et al.,* 2011).

The effect of thermal treatment with steam for 40 and 60 min caused an increase in the juice yield in the two cultivars, while sample YS60 recorded the highest yield (Fig.1); as steam extraction enhances extraction and extend the shelf life of fruit juice (Ide *et al.,* 2021). The values of juice yield obtained after using steam (for 1 h) during extraction of grape juice recorded 534 mL/ Kg (53.4%) (Mendes Lopes *et al.,* 2016), which was lower than our results. Whereas Arias *et al.* (2022) found that using short steam blanching during extraction of purple passion fruit caused non-significant ($p>0.05$) increase in the yields of purées obtained.

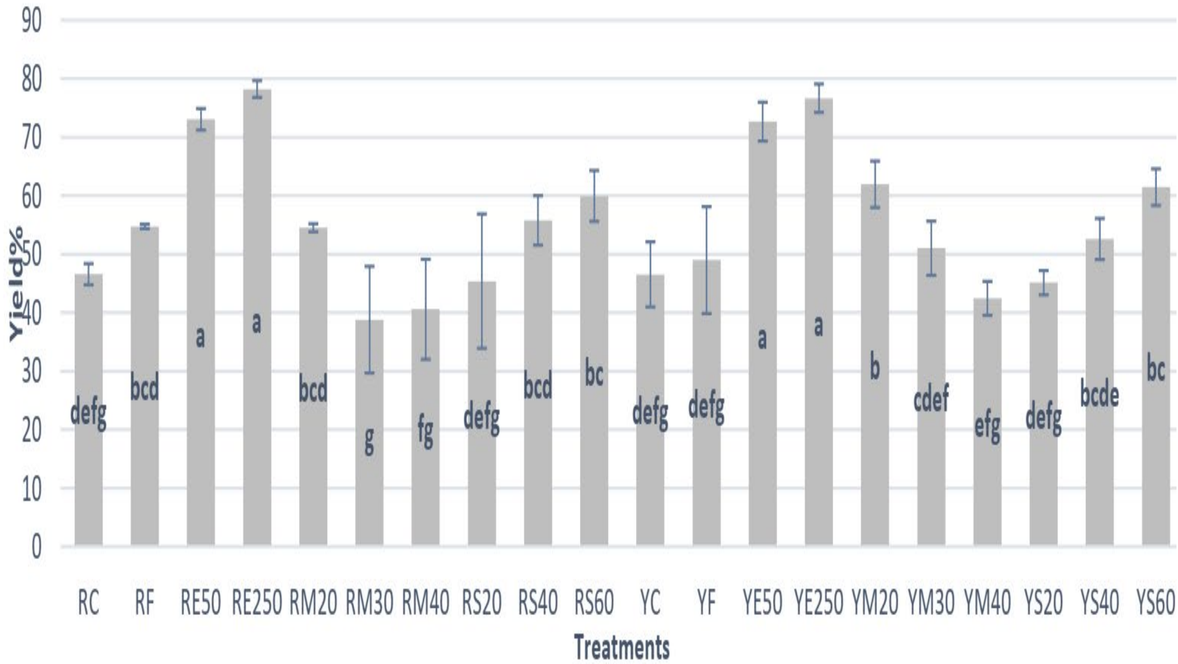

Fig.1.Plums juices yield before and after different treatments on plums fruits.
RC. control juice extracted from red plums (R)without any pretreatment; RF: Plum juice extracted from frozen R; RE50: Plum juice extracted after addition 50 mg pectinase/100g R; RE250: Plum juice extracted after addition 250 mg pectinase/100g R; RM20: Plum juice extracted after treated R with microwaves (M) for 20s.; RM30: Plum juice extracted after treated R with M for 30s.; RM40: Plum juice extracted after treated R with M for 40s.; RS20: Plum juice extracted after treated R with steam (S) for 20 min.; RS40: Plum juice extracted after treated R with S for 40 min.; RS60: Plum juice extracted after treated R with S for 60 min.; YC: control juice extracted from yellow plums (Y) without any pretreatment; YF: Plum juice extracted from frozen Y; YE50: Plum juice extracted after addition 50mg pectinase /100g Y; YE250: Plum juice extracted after addition 250mg pectinase/100g Y; YM20: Plum juice extracted after treated Y with microwaves (M) for 20s.; YM30: Plum juice extracted after treated Y with M for 30s.; YM40: Plum juice extracted after treated Y with M for 40s.; YS20: Plum juice extracted after treated Y with steam (S) for 20 min.; YS40: Plum juice extracted after treated Y with S for 40 min.; YS60: Plum juice extracted after treated Y with S for 60 min.; $^{a-g}$Means ±SD (standard deviation) with different small letters in columns differ significantly at $p<0.05$.

According to the data obtained in Fig.1, the highest juice yield percentages were chosen in each treatment to compare juice quality between these treatments.

Physical properties

Table 2 shows pH values of plums juices obtained from different treatments. Data showed that control plums juices recorded 3.44 and 3.23 in samples RC and YC, respectively. Meanwhile Will and Dietrich (2006) found that pH values ranged between 3.36 and 3.53 in plum (*Prunus domestica*) juices from different cultivars, which were close to our findings. Furthermore, pectinase addition to plums before juice extraction caused a decrease in pH value in extracted red plum juice (Table 2), due to the production of galacturonic acid after enzyme treatment, likewise Olawuyi *et al.* (2021) noticed a decrease in pH value of extracted plum juice after enzyme pretreatment. Whereas non-significant ($p > 0.05$) difference in pH value was found in extracted juices from yellow plum after the same treatment, when compared to the control. However, microwave and steam treatments caused an increase in pH values; and sample RS60 (steam treatment) recorded the highest pH value (3.56±0.007). Likewise, Abdulsalam and Jibia (2019) found an increase in pH values with the increase in pasteurization temperature.

The total soluble solids (TSS) content varied between 11.45 and 11.95% in juice samples extracted from fresh red and yellow plums, respectively (Table 2). Values are closed to those obtained by Wang *et al.* (2014), as they found TSS values of plums of 4 cultivars ranged between 10.3 and 12.1%. All treatments applied on red plums in this study enhanced TSS, and this imply the increase in their acceptability to consumers. Furthermore, the data showed that steam treatment increased TSS value in red plums (as sample RS0 recorded the highest value). Different trend was observed in yellow plums, as steam treatment caused a decline in TSS value, due to the incorporation of water into the juice after the steam extraction method, which caused the decrease in TSS levels (Yamamoto *et al.,* 2015).

Data in Table 2 showed that fresh juices recorded the highest total titratable acidity (TTA) values (0.445 and 0.488 in red and yellow plums, respectively). Whereas Ionica *et al.* (2013) reported that the titratable acidity of twelve plums varied between 0.34 and 0.77 g malic acid/100 g fresh matter, which are in accordance with this study.

Ripeness index (TSS/TTA ratio) in fresh juices obtained from red and yellow plums recorded 25.72 and 24.47, respectively (Table 2). Whereas all treatments applied on plums fruits before juice extraction caused an increase in TSS/ TTA values, especially with microwave treatment, while steam treatment of red plums before juice extraction produced a juice with the highest TSS/TTA ratio (61.72±2.860), when compared to the control. The increase in TSS/ TTA ratio refers to the enhancement effect on quality and flavor of juices extracted (Fellers,1991; Chang *et al.,* 1994)

Data in Table 2 showed that viscosity of fresh juices obtained from red and yellow plums recorded 61.06 and 42.49 cP. (mPa.s), respectively. Higher values were reported by Will *et al.* (2008), they referred to the viscosity of typical cloudy juices ranged between 95 and 134 mPas. Furthermore, the obtained data showed that freezing treatment of plums affected significantly ($p<0.05$) and decreased viscosity values of the obtained juices, when compared to control. Whereas enzyme treatment recorded the lowest viscosity, due to the hydrolytic action of enzymes on the pectic materials present in the juice; and hydrolyzing of soluble polysaccharides responsible for high viscosity (Cheryan and Alvarez, 1995), which weakened its ability to retain water, and release of free water into the juice. Likewise, other studies referred to pectinase ability to decrease viscosity of fruit juices (Chang *et al.,* 1994; Arsad *et al.,* 2015). Furthermore, steam treatment of plum fruits before juice extraction increased viscosity and recorded the highest values in red and yellow plums juices (118.91 and 99.84 cP.).

Clarity of fresh juices obtained from fresh red and yellow plums (samples RC and YC in Table 2) recorded 0.102 and 0.206 %, respectively. Freezing treatment of plum fruits before juice extraction increased clarity non significantly ($p > 0.05$) in the two types of plums (RF and YF), when compared with the control. Furthermore, enzymatic treatment led to an increase in the clarity of juice, while sample YE250 recorded the highest value (98.63). Enzymatic treatment increased the rate of clarification by exposing part of the positively charged protein beneath thus reducing electrostatic repulsion between cloud particles which caused these particles to aggregate into larger particles and eventually settled out (Sin *et al.,* 2006). The thermal treatments by microwave or steam did not differ significantly, when compared with the control. Our findings are in agreement with (Cendres *et al.,* 2012).

Table 2. Physical properties of plums juices after different pretreatments on plums fruits.

Cultivar	Treatments*	PH	TSS	TTA	TSS/TTA ratio	Viscosity (cP)	Clarity
Red	RC	3.44^{cd}±0.01	11.45^{d}±0.07	0.445^{b}±0.01	25.72^{d}±0.67	61.06^{c}±0.93	0.102^{c}±0.001
	RF	3.46^{c}±0.007	12^{c}±0.00	0.247^{d}±0.008	48.61^{b}±1.67	4.84^{g}±0.08	0.176^{c}±0.009
	RE250	3.34^{e}±0.007	12.55^{b}±0.07	0.252^{d}±0.004	49.80^{b}±0.56	1.03^{h}±0.005	62.12^{b}±1.26
	RM20	3.53^{b}±0.01	12.5^{b}±0.00	0.208^{e}±0.01	60.16^{a}±2.86	11.95^{e}±0.17	0.270^{c}±0.01
	RS60	3.56^{a}±0.007	16^{a}±0.00	0.259^{cd}±0.01	61.72^{a}±2.86	118.91^{a}±0.30	0.318^{c}±0.01
Yellow	YC	3.23^{h}±0.01	11.95^{c}±0.07	0.488^{a}±0.003	24.47^{d}±0.007	42.49^{d}±0.18	0.206^{c}±0.005
	YF	3.26^{g}±0.01	12.45^{b}±0.07	0.276^{c}±0.007	45.11^{b}±0.981	5.48^{g}±0.12	0.401^{c}±0.002
	YE250	3.23^{h}±0.007	11.1^{e}±0.14	0.243^{d}±0.01	45.89^{b}±3.66	0.97^{h}±0.003	98.63^{a} ±0.51
	YM20	3.45^{cd}±0.00	10.05^{f}±0.07	0.212^{e}±0.004	47.53^{b}±1.129	9.62^{f}±0.11	0.385^{c}±0.008
	YS60	3.30^{f}±0.007	9.75^{g}±0.35	0.248^{d}±0.008	39.27^{c}±2.652	99.84^{b}±0.42	0.239^{c}±0.006

Samples codes as shown in footnote of Fig. 1; TSS: Total soluble solids; TTA: Total titratable acidity; cp: centipoise; $^{a-h}$Means ±SD (standard deviation) with different small letters in the same column differ significantly at $p<0.05$.

Chemical properties of plum juice

The data in Table 3 showed that the ash content increased significantly ($p < 0.05$) with enzymatic treatment in the two plums cultivars. Reducing sugars contents also increased significantly ($p < 0.05$) with enzymatic treatment, and the red plum juice (RE250) recorded the highest value. Enzymatic treatments caused a degradation of cell wall polysaccharides and produced higher content of sugars (Lieu and Le*,* 2010). Additionally, there was a correlation between the rise in sugar content and the juice extraction yield (Olawuyi *et al.,* 2021); and similar trend was found in this work.

The effect of different treatments on pectin content of plum juices is given in Table 3. The steam treatment increased pectin content (from 8.5 to 13.5ml in red plums juice and from 7.75 to 14.25ml in yellow plums juice). Our results are in a good agreement with Arias *et al.* (2022), as they noticed that the soluble pectin percentage increased (from 1.3 to 4.66%) after raising the steam blanching holding time from 90 to 110 s in obtained purées.

Table 3. Chemical composition of plums juice without and with pretreatments on plums fruits.

Cultivar	Treatments*	Ash%	Reducing sugar (g/100g)	Pectin (ml)
Red	RC	1.89^{bc}±0.06	5.90^{de}±0.16	8.5^{b}±0.70
	RF	1.74^{bc}±0.33	5.56^{e}±0.50	7.25^{bc}±1.06
	RE250	2.58^{a}±0.05	8.56^{a}±0.05	-
	RM20	2.13^{ab}±0.01	7.18^{bc}±0.23	7.4^{bc}±0.56
	RS60	2.16^{ab}±0.03	7.43^{b}±0.15	13.5^{a}±0.70
Yellow	YC	1.47^{c}±0.05	5.51^{e}±0.15	7.75^{bc}±0.35
	YF	1.76^{bc}±0.01	4.51^{f}±0.26	6.2^{cd}±0.99
	YE250	2.15^{ab}±0.09	6.54^{cd}±0.19	-
	YM20	2.44^{a}±0.02	6.87^{bc}±0.20	4.75^{d}±1.06
	YS60	2.54^{a}±0.48	5.90^{de}±0.59	14.25^{a}±0.35

*Samples codes as shown in footnote of Fig. 1; $^{a-f}$Means ±SD (standard deviation) with different small letters in the same column differ significantly at p<0.05.

Lycopene, beta-carotene, vitamin A, and vitamin C contents

Data in Table 4 showed that the lycopene content in juices extracted from fresh red and yellow plums recorded 5.65 and 3.21 mg/ 100 ml, respectively. Whereas addition of pectinase to red plums before extraction caused an increase in lycopene content (9.95 mg/ 100 ml) in the obtained juice. Zuorro *et al.* (2011) reported that pectinase enzyme increased lycopene quantity. Furthermore, yellow plums showed different trend.

The data in this study revealed that fresh yellow plum juice recorded higher content of beta-carotene (0.107 mg/ 100 g) and vitamin A (64.05 IU) than red plum juice. It was clear that freezing, enzymatic and microwave treatments enhanced beta-carotene and vitamin A contents significantly ($p < 0.05$). Likewise, Prokopov *et al.* (2017) found that pectinase addition improved beta-carotene value. Besides, the steam treatment decreased beta-carotene and vitamin A content in obtained juices (Table 4). Our findings are consistent with that of Chen *et al.* (1995), they found that vitamin A content decreased as heating temperature and time increased.

Nonsignificant differences were found between red and yellow plum juices in their content of ascorbic acid (samples RC and YC). While all applied treatments in this study enhanced ascorbic acid content, and the obtained juices after enzymatic treatment recorded the highest value (Table 4), due to additional release into the juice by mechanical breakage of the cell wall by enzyme (Wang *et al.,* 2019). On contrary of our results, Olawuyi *et al.* (2021), noticed that enzyme-treated decreased ascorbic acid content in juice samples from 9.61 to 7.36 mg/100ml.

Table 4. Lycopene, beta-carotene, vitamin A and ascorbic acid in plums juices without and with pretreatments.

Cultivar	Treatments*	Lycopene (mg/100ml)	Beta-carotene (mg/100ml)	Vitamin A (IU)**	Ascorbic acid (mg/100ml)
Red	RC	5.65^{b}±0.14	0.094^{fg}±0.001	56.34^{fg}±1.18	32.18^{g}±0.53
	RF	4.31^{c}±0.34	0.393^{b}±0.01	235.74^{b}±6.87	45.81^{d}±0.66
	RE250	9.95^{a}±0.31	0.467^{a}±0.005	280.11^{a}±2.93	62.49^{a}±0.77
	RM20	1.73^{ef}±0.09	0.207^{d}±0.002	124.26^{d}±1.78	54.35^{b}±1.04
	RS60	2.94^{d}±0.15	0.076^{g}±0.001	45.9^{g}±1.18	53.23^{b}±1.22
Yellow	YC	3.21^{d}±0.45	0.107^{f}±0.006	64.05^{f}±4.03	33.22^{g}±0.36
	YF	2.04^{e}±0.06	0.449^{a}±0.01	269.48^{a}±8.51	37.71^{f}±0.74
	YE250	0.2006^{g}±0.08	0.354^{c}±0.01	212.1^{c}±10.27	48.94^{c}±0.10
	YM20	1.34^{f}±0.12	0.145^{e}±0.01	86.97^{e}±6.15	36.62^{f}±0.81
	YS60	2.12^{e}±0.11	0.036^{h}±0.001	21.75^{h}±0.72	40.00^{e}±0.50

*Samples codes as shown in footnote of Fig. 1; **IU: International unit; $^{a-h}$Means ±SD (standard deviation) with different small letters in the same column differ significantly at $p<0.05$.

Anthocyanin

The results in Table 5 showed anthocyanins content in plum juices, and red plums juice (RC) recorded higher content of monomeric anthocyanin pigment (67.96 mg/L) than yellow plums juice (YC). Anthocyanins are the pigments that give plums their purple-reddish color and released from the skins to give red plum juice its color (Will and Dietrich, 2006). Data revealed that the steam treatment enhanced anthocyanins content in red plum juice. Different trend was noticed in yellow plums juice. Anthocyanins degradation could be attributed to high polyphenol oxidase activity (Zbrzeźniak *et al.,* 2015). Moreover, changes in temperature, light, oxygen, and pH cause quickly deterioration of anthocyanins (Tiwari *et al.,* 2010; Oancea and Oprean, 2011).

Table 5. Anthocyanin in plums juices obtained without and with pretreatments.

Cultivar	Treatments*	Monomeric anthocyanin pigment (mg/liter)	Color density	Polymeric color	% Polymeric color
Red	RC	67.96^{b}±2.12	3.31^{b}±0.27	2.76^{bc}±0.14	83.73^{ab}±11.34
	RF	35.90^{c}±2.36	4.09^{a}±0.08	3.61^{a}±0.17	88.12^{ab}±2.44
	RE250	63.87^{b}±9.09	3.24^{b}±0.10	2.43^{c}±0.34	74.97^{bc}±8.25
	RM20	23.21^{d}±2.36	3.23^{b}±0.08	2.99^{b}±0.10	92.61^{a}±0.57
	RS60	87.91^{a}±10.74	1.84^{d}±0.06	1.19^{d}±0.13	64.65^{c}±4.99
Yellow	YC	34.39^{c}±3.07	1.01^{e}±0.11	0.260^{e}±0.05	25.68^{d}±2.65
	YF	6.59^{e}±0.59	1.11^{e}±0.10	0.415^{e}±0.13	37.11^{d}±8.58
	YE250	6.59^{e}±0.11	1.13^{e}±0.09	0.948^{d}±0.07	83.89^{ab}±12.89
	YM20	10.09^{e}±2.23	2.55^{c}±0.25	2.46^{c}±0.29	96.57^{a}±1.83
	YS60	6.85^{e}±0.47	1.24^{e}±0.14	1.14^{d}±0.07	92.36^{a}±4.59

*Samples codes as shown in footnote of Fig. 1; $^{a-e}$Means ±SD (standard deviation) with different small letters in the same column differ significantly at $p<0.05$

Total phenolics, flavonoids contents and antioxidant activity

Table 6 shows that phenolics content in control juices obtained from red and yellow plums recorded 79.99 and 51.42 mg GAE /100ml, respectively. Furthermore, pectinase addition to plums before juice extraction had a positive effect on phenolics content of the obtained juice. By degrading of the cell wall polysaccharides by the enzymes action, the release of such phenolics can be accelerated (Pinelo and Meyer, 2008). Olawuyi *et al.* (2021) reported similar outcomes in terms of the influence of enzymes addition on increasing phenolic content, as they found that total phenolics content increased after using enzymes before juice extraction (from 37.70 to 63.81 mg GAE/100ml). Moreover, using microwave treatment in this study before juice extraction liberated the majority of the polyphenols in plums. Besides, the steam treatment increased phenolics content and recorded the highest value (282.72 and 199.43mg GAE /100ml) in red and yellow plums juices, due to the effect of heating process on rupturing cellular membranes, which could raise the content of polyphenolics (Cohen *et al.,* 2001). Likewise, Dini *et al.* (2013) found that steamed pumpkin had a higher total phenolic content than raw or boiling pumpkin.

Data in the same Table 6 showed that total flavonoids were 12.84 and 4.07 mg CE/100ml in fresh red and yellow plums juices, respectively. Whereas pectinase addition enhanced flavonoids content in the obtained juice. Likewise, Olawuyi *et al.* (2021) found that total flavonoids increased after enzymatic treatment from 199.08 to 215.39 mg rutin /100ml. Moreover, data in this study showed that the steam treatment increased total flavonoids content.

On the other hand, data in Table 6 showed that enzymatic treatment increased antioxidant activity significantly ($p<0.05$) in the obtained plum juices, when compared to control. This is in the same line with Olawuyi *et al.* (2021). Whereas steam treatment caused an increase in antioxidant activity to its highest level (87.53% in red plums juice and 83.98% in yellow plums juice). This increase could be attributed to the effect of heating process, as the internal expansion of water vapor forms microchannels that can dissolve cell walls and allow the extraction of antioxidant, while the steam softens the fruit's exterior (Arias *et al.,*2022).

Table 6. Phenolics, flavonoids content and antioxidant activity in plums juices obtained without and with different pretreatments.

Cultivar	Treatments*	Phenolics (mg GAE /100 ml)	Flavonoids (mg CE/100 ml)	Antioxidant activity%
Red	RC	$79.99^{g}\pm0.83$	$12.84^{cd}\pm4.24$	$67.24^{d}\pm1.01$
	RF	$59.13^{h}\pm0.84$	$13.18^{cd}\pm4.42$	$64.94^{e}\pm0.10$
	RE250	$148.24^{c}\pm0.49$	$17.66^{c}\pm0.29$	$70.01^{c}\pm1.27$
	RM20	$144.92^{d}\pm0.48$	$17.28^{c}\pm0.67$	$67.69^{d}\pm0.43$
	RS60	$282.72^{a}\pm0.57$	$35.42^{a}\pm1.37$	$87.53^{a}\pm1.35$
Yellow	YC	$51.42^{i}\pm0.85$	$4.07^{e}\pm0.12$	$60.62^{f}\pm0.60$
	YF	$22.67^{j}\pm1.25$	$2.48^{e}\pm0.31$	$56.07^{g}\pm1.43$
	YE250	$106.32^{e}\pm1.37$	$12.73^{cd}\pm0.52$	$64.78^{e}\pm0.80$
	YM20	$90.71^{f}\pm0.73$	$11.74^{c}\pm0.60$	$63.89^{e}\pm0.71$
	YS60	$199.43^{b}\pm0.83$	$25.12^{b}\pm1.30$	$83.98^{b}\pm1.38$

*Samples codes as shown in footnote of Fig. 1; a-j Means ±SD (standard deviation) with different small letters in the same column differ significantly at $p<0.05$

Conclusion

From the obtained results, it could be concluded that using different treatments before extraction of plum juice enhanced juice yield. Moreover, enzymatic treatment with pectinase (250 mg/100g) recorded the highest yield. Furthermore, steam treatment on plums was better than microwave treatment in juice yield. Concerning quality characteristics of juice obtained after pectinase treatment, data shows that this treatment improved the clarity, maturity index, ash, reducing sugars, lycopene, vitamins (A and C), phenolics content, and antioxidant activity. Moreover, steam treatment exhibits better values of phenolics, flavonoids, and antioxidant activity than microwave treatment.

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تأثير تقنيات الاستخلاص المختلفة على إنتاجية وجودة عصائر البرقوق

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الملخص

تم استخدام صنفين من البرقوق (الأحمر "سنتروزي" والأصفر " اليابانى الذهبي ") لإنتاج العصير ، وأُجريت عدة معاملات على البرقوق قبل استخراج العصير، والتي تشمل التجميد واستخدام الإنزيم (البكتينيز) والميكروويف والبخار (بخار الماء الساخن). تم تقييم الخواص الفيزيائية والكيميائية لعصائر البرقوق التي تم الحصول عليها بعد الاستخلاص. أظهرت النتائج أن إضافة 250 ملجم من البكتينيز/ 100 جم من البرقوق أدى إلى زيادة إنتاجية العصير إلى 78.24٪ و76.67٪ في البرقوق الأحمر والأصفر، على التوالي. أيضاً المعاملة بالميكروويف لمدة 20 ثانية والمعاملة بالبخار لمدة 60 دقيقة أدت إلى زيادة نسبة إنتاجية العصير في البرقوق الأحمر والأصفر. علاوة على ذلك، فإن إضافة إنزيم البكتينيز إلى البرقوق قبل الاستخلاص أدى إلى تحسين الخصائص الغذائية ومضادات الأكسدة للعصير الناتج . كما ان محتوى حامض الاسكوربيك في العصير الناتج بعد المعاملة الإنزيمية سجل 62.94 و48.94 مللجم/ 100 مل في عصير البرقوق الأحمر والأصفر على التوالي. على الجانب الآخر ان عصائر البرقوق الناتجة بعد المعاملة بالبخار لثمار البرقوق سجلت محتوى أعلى من المواد الفينولية والفلافونودية وكذلك سجلت قيم مرتفعة كمضادات للأكسدة، وذلك بالمقارنة مع جميع المعاملات محل الدراسة. وتشير النتائج إلى أن الجمع بين المعاملة بالتجميد مع إضافة البكتينيز أمكنت من إنتاج عصير صافٍ ذو قيمة غذائية عالية، مما يشجع على استخدامه في تطبيقات الأطعمة والمشروبات.

الكلمات المفتاحية: *عصير البرقوق، المعاملة الإنزيمية، المايكرويف، البخار، نشاط مضادات الأكسدة.*