Egyptian J. Desert Res., **73**, No. 2, 573-591 (2023)

VALORIZATION OF RED BEETROOT VALUE CHAIN THROUGH AGRO-FOOD PROCESSING

Amira M. Shokry
Agro-Industrial Unit, Department of Plant Production, Desert Research Center, Cairo, Egypt
E-mail: amerashoukry@gmail.com

Beetroot is highly nutritious vegetable crop, which is a perishable commodity due to its high moisture content. Thence, development of products could be highly advantageous in red beetroot value chain valorization. For this purpose, jam with 0.5% (RJC5) and 0.1% (RJC1) cinnamon powder, puree with 1% thyme (RPT) and 1% mint (RPM) leaves powder, also, raw pickle (RRG) and boiled pickle (BRG) with garlic were processed from red beetroot. A control treatment (RJC, RPC, RRC and BRC) without any additive from jam, puree, raw pickle and boiled pickle, respectively, was also processed. Consistency and phenolic and flavonoids were determined for red beetroot jam and puree treatments. Vitamin C and DPPH activity were determined for jam, puree and pickle treatments, where hardness was determined for pickle treatments. Sensory evaluation was conducted for both jam and pickle treatments. For the sensory attributes of red beetroot puree treatments, tahina salad was prepared by adding puree treatments as an additive. Results showed that, adding cinnamon did not affect the RJ consistency, where consistency of both RPT and RPM treatments were higher than the RPC treatment. vitamin C content was enhanced for RJC5, RJC1, RPT and RRG treatments. Regarding the DPPH activity determination, RJC, RPM, RRG, BRG and BRC demonstrate significantly high DPPH values. RRC and RRG treatments manifest a perfect hardness when compared with BRC and BRG treatments. For sensory evaluation, the RRG treatment recorded an excellent taste, texture and flavor sensory parameters, where the RJC, RJC5 and tahina salad with RPC treatment exhibit a good overall acceptability score.

Keywords: Agro-Food processing**,** cinnamon, jam, mint, pickle, puree, red beetroot, thyme, value chain

INTRODUCTION

A ‘value chain’ in agriculture identifies the set of activities, which bring a basic agricultural product from production in the field to final consumption, where at each stage value is added to the product. The agro-food processing considered to be a way supporting valorization of the crop value chain where it reduces the postharvest crop losing rate, link producers with the markets and achieve customer needs, therefore, valorize the crop value chain. In the same time, at the latest years, there was a big interest about differentiation healthy food products, which improve health benefit (Stolzenbach et al., 2013).

Red beetroot (*Beta vulgaris* L.) which belong to the Chenopodiaceae family and known as red beetroot, beet, garden beet, table beet is a traditional vegetable in many parts of the world. Today, beetroot is regularly consumed as part of the normal diet (Liliana and Oana-Viorela, 2020).

Red beetroot has a great health benefit, which is important for the development and growth of human body, it contains large amounts of bioactive and nutritional compounds such as carbohydrates, fibers, vitamins, minerals and betalains, it could be used as a source of natural pigments (Dhiman et al., 2021, Kusznierewicz et al., 2021 and Trishitman et al., 2021). Beetroot considered to be a premium dietary supplement as it is rich in phytochemical compounds (carotenoids, phenolic acids, ascorbic acid) which shown pharmacological applications and used in traditional medicine for hundreds of years to treat constipation, gut and joint pain (Hamedi and Honarvar, 2019) and due to its anti-anemic, lipid and blood pressure-lowering effects (Dhiman et al., 2021), also, its extracts exhibit antihypertensive and hypoglycemic activity as well as excellent antioxidant activity (Babarykin et al., 2019).

Jam, pickle and puree is the most food preservation process that could be suitable to be applied under home conditions or small-scale food production system, so, it could support women and stockholders. The aim of this study is to valorize the value chain of red beetroot through developing of red beetroot food products to enhance the availability of red beetroot throughout the year to the consumer, reduce post-harvest losses and raise the added value of the red beetroot.

MATERIALS AND METHODS

The fresh red beet root, cinnamon bark powder, thyme leaves powder, mint leaves powder, garlic, tahina, citric acid, salt and sugar were purchased from local markets, Giza, Egypt. The vegetal parts from red beetroot were removed and washed to remove residues of sand or dirt then packed in polyethylene bags and stored in a refrigerator at 4ºC, until processing.

1. Processing of Red Beetroot Jam

The red beetroot jam (RJ) was processed according to Sindumathi and Amutha (2014), where the washed red beetroot was peeled and grated using a kitchen processor. The grated red beetroot was then put into an open stainless-steel pan and a required amount of sugar (55%) was added and heated continuously under low flame. When the total soluble solids (TSS) reached 60° Brix, citric acid (0.6%) was added and stirred continuously. Heating was stopped when the TSS reached 67- 68° Brix. The mixture was hot filled into 300 ml previously sterilized glass jars and the jars were inverted to ensure sterilization of the vertical space then they had left to cool under ambient temperature. The prepared jam was stored at a refrigerated temperature (4 ±2°C) until analysis. Two treatments of the red beetroot jam were processed by adding 0.5% (RJC5) and 1% (RJC1) of cinnamon powder. A control red beetroot jam treatment (RJC) was processed without any additive.

2. Processing of Red Beetroot Puree

Washed red beetroot was cut into cubes and soaked in water and boiled for 10 minutes, then cooled to room temperature. The cooled red beetroot cubes were blended using a kitchen blender to obtain a fine puree paste as described by Guldiken et al. (2016). Two treatments of red beetroot puree (RP) were processed by adding 1% thyme (RPT) and 1% mint (RPM) leaves powder while a control treatment (RPC) was processed without any additives. Dried glass jars were filled with the RP treatments, covered and sterilized at 121°C for 30 minutes (Talcott and Howard, 1999) in stainless steel pressure cooker. RP treatment jars were cooled to room temperature and then stored refrigerated at a temperature of 4±2°C until analysis.

3. Processing of Red Beetroot Pickle

Washed red beetroot was cut into small, homogeneous slices using a slicer (approx. thickness 5 mm). Red beetroot sliced pieces were divided into two groups, the first group (RR) was pickled directly in the raw state while the second group (BR) was boiled for five minutes and cooled to room temperature before pickling. Samples from two groups were distributed into clean dried glass jar. Minced garlic cloves (1%) were added to both groups (RRG and BRG), while the control treatment of both groups was processed without minced garlic (RRC and BRC), for both groups, respectively. Each jar was filled with a salty brine (120 g NaCl /L of water) to obtain an overall salt concentration of 5–6% in the end-product (Srivastava and Singh, 2016).

4. Analytical Methods

The fresh red beet root sample was analyzed for moisture, ash, total fiber, total protein and ether extract according to A.O.A.C. (2005). Total carbohydrate was calculated by difference. For the RJ and RP treatments, consistency and phenolic and flavonoid compounds were determined as follows:

Consistency was measured using viscometer, V60002, FFUNGILAB, Spain (Spindle R7) 20 rpm, torque was 100% maintained at the Food Safety and Quality Control laboratory (FSQC), Faculty of Agriculture, Cairo University.

Phenolic and flavonoid compounds were determined by using high performance liquid chromatography (HPLC) analysis according to Agilent Application Note (2014). Instrument Condition was: agilent1260 infinity HPLC Series (Agilent, USA), equipped with quaternary pump, the column used: aKinetex®1.7 µm EVO C150 mm x 4.6 mm (Phenomenex, USA), operated at 30℃. The separation was achieved using a ternary linear elution gradient with (A) HPLC grade water 0.1% trifluoro acetic acid (TFA), (B) acetonitrile, (c) methanol. Flow rate was 1 ml /min. The injected volume was 20 µL. Detection: variable wavelength detector (VWD) set at 280 nm.

For the RJ, RP, RR and BR treatments, vitamin C and DPPH were determined as follows:

Vitamin C was estimated according to Baja and Kaur (1981) where 5 g of each sample were extracted with 100 ml of oxalic acid – EDTA solution. The extract was filtered through a filter paper and then centrifuged. A 5 ml aliquot was then transferred into a 25 ml calibrated flask and mixed with other reagents (0.5 ml of metaphosphoric acid – acetic acid solution and 1 ml of 5% V/V sulphuric acid), followed by 2 ml of ammonium molybdate reagent. After 15 minutes the absorbance was measure at 760 nm against a reagent blank.

DPPH radical scavenging activity was estimated as described by Brand-Williams et al. (1995). Concentrations ranging from 0.1, 0.2 and 0.4 mg/ml were prepared with methanol from each sample. The extract (100 µl) and DPPH radical (100 µl, 0.2 mM) was dissolved in methanol. The mixture was stirred and left to stand for 15 minutes in the dark, then the absorbance was measured at 517 nm against a control which carried out using 2 ml DPPH solution without the test sample. The DPPH free radical scavenging ability was subsequently calculated as follows:

DPPH scavenging ability (%) = $(A_c - A_t)/A_c \times 100$.

Where Ac: absorbance of control

At: absorbance of samples

5. Hardness of The Red Beetroot Pickle Treatments

Hardness (N) was measured using Instron Universal Testing Machine (Model 2519-105, USA) at Research Park (CURP), Faculty of Agriculture, Cairo University. Six replicates from each sample were taken. The machine test speed was 200 mm/min and hardness (N) was recorded electronically.

6. Sensory Evaluation

The RJ, RR and BR treatments were analyzed for their sensory profiles. For that, several attributes (color, texture, taste, flavour and overall acceptability) were evaluated. Whilst the sensory attributes of RP treatments were evaluated by estimate the color, texture, taste, flavour and overall acceptability of tahina salad processed using the RP treatments. Each of these attributes was rated on a hedonic scale ranging from 1 to 10, where the number 1 corresponded to the lower limit (less intense, less pleasurable), 5 corresponded to the middle limit (middle intense, middle pleasurable) and 10 corresponded to the higher limit (very intense, very pleasurable) according to Guine et al. (2016).

7. Statistical Analysis

The data obtained were subjected to statistical analysis of variance (ANOVA). All analyses were performed in triplicate. All tests were conducted at the 5% significant level according to Armonk (2011).

RESULTS AND DISCUSSION

1. Gross Chemical Analysis of Red Beet Root

Red beetroot considered to be a good source of human important nutrient. The chemical composition of red beetroot varies based on the cultivar. Sawicki et al. (2016) mentioned that the disposition of nutritional components in red beetroot differs based on the plant's anatomical portion (leaves, stem, root, peel).

Table (1) illustrates that red beetroot contained a high content of total carbohydrates (8.8%), crude fiber (3.2%), crude protein (1.2%) and a small amount of ether extract (0.2%), which made it a good choice of nutrient source in weight loss diet. Moisture and total ash contents found to be 86.1% and 0.5%, respectively. Moftah et al. (2023) reported the same results for moisture, carbohydrate and total protein contents expect the total fiber content that was significantly lower (1.9%). Bangar et al. (2022) registered that the ash and total fiber of red beet root were 1.08% and 2.8%, respectively. The results are approaching with USDA (2020), which illustrated that, raw red beetroot contains 87.58%, 1.61%, 0.17% and 9.59% moisture, protein, total lipid and carbohydrate, respectively. Guldiken et al. (2016) mentioned that moisture of fresh red beetroot was 87%. Differences in nutritional values attributed to the properties of the soil and other environmental conditions (Abdo et al., 2020).

Table (1). Gross chemical composition of raw red beet root (fresh weight basis).

Gross Constitutes	(%)
Moisture	86.1
Total ash	0.5
Crude fiber	3.2
Crude protein	1.2
Ether extract	0.2
Total carbohydrates	8.8

2. Consistency of Red Beetroot Jam and Puree Treatments

The consistency measurement is an important guidance to the product development (Shahnawaz and Shiekh, 2011). Consistency is related to non-Newtonian or semi solid fluids with suspended particles and long chain soluble molecules and is measured practically by distribution or flow of the product. The United States' standards define the consistency of semi solid products as their ability of holding the liquid section in suspension (Gould, 1983).

Fig. (1) shows the consistency values of both RJ and RP treatments. It was found that, for the RJ treatments, the highest consistency value was obtained with the RJC1 treatment followed by RJC then RJC5 treatments. The results are in accordance with Salama et al. (2019), who illustrated that, the consistency of gurma melon jam with 1% cinnamon was more than the consistency of gurma melon jam with 0.5% cinnamon.

Whereas the RPT and RPM treatments demonstrated a highly increment consistency value in comparison with the RPC treatment. Barrette et al. (1998) published that the consistency depends mainly on the insoluble solids to total soluble solids ratio. Nada et al. (2016) also clarified that, the apparent viscosity decreases as temperature increased for all strawberry puree jam samples studied.

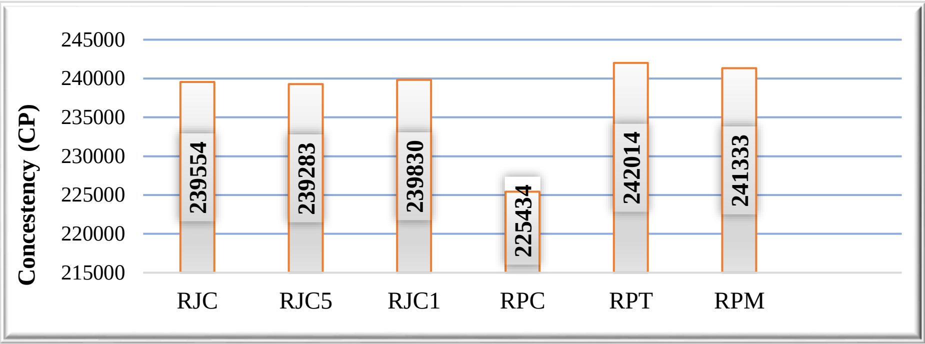

Fig. (1). Consistency of red beetroot jam and puree treatments.
(RJC) control red beetroot jam, (RJC5) red beetroot jam with 0.5% cinnamon, (RJC1) red beetroot jam with 1% cinnamon, (RPC) control red beetroot puree, (RPT) red beetroot puree and (RPM) red beetroot puree.

3. Phenolic and Flavonoid Compounds of Red Beetroot Jam and Puree Treatments

A histrionic HPLC chromatogram peaks of RJ and RP treatments were shown in Table (2), Fig. (2a and 2b), respectively. Data in Table (2) and peaks in Fig. (2a) manifest that, vanillic acid, syringic acid and *o*-cumaric were identify in RJC, RJC5 and RJC1 treatments. Syringic acid (7.791 mg/kg) and *o*-cumaric (0.637 mg/kg) were enhanced in RJC1 treatment as compared with RJC and RJC5 treatments. On the other hand, hesperidin (1.116 mg/kg), resveratrol (2.504 mg/kg) and kaempferol (15.713 mg/kg) were improved in RJC1 treatment as compared with hesperidin (0.805 mg/kg), resveratrol (2.182 mg/kg) and kaempferol (11.978 mg/kg) for RJC treatment. Likewise, *p*-hydroxybenzoic acid (12.581 mg/kg), chlorogenic acid (2.337 mg/kg) and *p*-cumaric acid (0.671 mg/kg) were improved in RJC5 treatment as compared with *p*-hydroxybenzoic (5.462 mg/kg), chlorogenic acid (0.643 mg/kg) and *p*-cumaric acid (0.235 mg/kg) for RJC treatment. Catechin and ferulic were only identify in RJC5 and RJC1 treatments, where RJC5 treatment found to have (10.827 mg/kg and 2.235 mg/kg) more than those identify in RJC1 treatment (1.936 mg/kg and 0.890 mg/kg), respectively. Moreover, RJC5 treatment was distinguished by gallic acid (12.235 mg/kg) and apigenin (1.242 mg/kg) which were not identified in RJC and RJC1 treatments.

Table (2). Phenolic and flavonoid compounds of red beetroot jam and puree treatments.

Phenolic and flavonoids compounds	**(%)**					
	RJC	**RJC5**	**RJC1**	**RPC**	**RPT**	**RPM**
***P*-hydroxybenzoic acid**	5.462	12.581	------	1.199	------	1.334
Chlorogenic acid	0.643	2.337	------	1.755	3.048	1.183
Vanillic acid	1.081	0.508	0.685	------	1.604	3.741
Syringic acid	1.608	1.065	7.791	0.314	0.459	------
***P*-cumaric acid**	0.235	0.671	------	119.698	------	------
Rutin	0.568	------	0.598	------	0.681	------
***O*-cumaric acid**	0.101	0.131	0.637	------	0.458	0.458
Hesperidin	0.805	------	1.116	0.726	5.097	24.588
Resveratrol	2.182	------	2.504	------	------	4.288
Kaempferol	11.978	------	15.713	19.951	4.223	6.380
Gallic acid	------	12.235	------	------	------	------
Catechin	------	10.827	1.936	5.437	3.475	1.640
Caffeic acid	------	0.260	0.745	7.160	7.499	8.617
Ferulic acid	------	2.235	0.890	------	------	5.056
Apigenin	------	1.242	------	------	------	0.119
Quercetin	------	------	------	------	2.919	------
Rosemarinic acid	------	------	------	------	------	2.181
Myricetin	------	------	------	------	------	0.718

(RJC) control red beetroot jam, (RJC5) red beetroot jam with 0.5% cinnamon, (RJC1) red beetroot jam with 1% cinnamon, (RPC) control red beetroot puree, (RPT) red beetroot puree with 1% thyme and (RPM) red beetroot puree with 1% mint.

Likewise, data in Table (2) and peaks in Fig. (2b) represent the HPLC chromatogram of RP treatments which shows that, catechin, chlorogenic acid, caffeic acid, hesperidin and kaempferol were identify in the RP treatments but with a different concentration. The highest catechin (5.437 mg/kg) and kaempferol (19.951 mg/kg) concentrations were observed with the RPC treatment followed by RPT (3.475 mg/kg) and RPM (1.640 mg/kg) treatments for the catechin concentration but followed by RPM (6.380 mg/kg) and RPT (4.223 mg/kg) treatments for kaempferol concentration, respectively.

The highest chlorogenic acid concentration (3.048 mg/kg) was observed with RPT treatment while the highest caffeic acid concentration (8.617 mg/kg) was observed with RPM treatment. Hesperidin concentration found to be decreased in RPC treatment (0.726 mg/kg) followed by RPT (5.097 mg/kg) and RPM (24.588 mg/kg) treatments, respectively. Moreover, vanillic acid and *o*-cumaric acid were identified in the RPT treatment (1.604 mg/kg and 0.808 mg/kg) and RPM treatment (3.741 mg/kg and 0.458 mg/kg), respectively.

Also Fig. (2b) shows that, the RPM treatment was uniqueness with some compounds that not found in the other RP treatments which was ferulic acid, resveratrol, rosemarinic acid, myricetin, apigenin with 5.056 mg/kg, 4.288 mg/kg, 2.181 mg/kg, 0.718 mg/kg and 0.119 mg/kg concentrations, respectively, while RPT treatments was particularly had quercetin (2.919 mg/kg) and rutin (0.681 mg/kg). *P*-cumaric acid (119.698 mg/kg) was only identified in the RPC treatment.

Tahira et al. (2011) reported that mint contains rosmarinic acid and caffeic acid as a major phenolic acid and, ferulic acid in a considerable concentration. Ravichandran et al. (2012) clarified that cinnamic acid, vanillic and caffeic acid was found in red beet extracts and stated that, concentrations of phenolic acid vary depending on treatments. Baião et al. (2017) reported in a review that red beetroot contains caffeic acid, *p*-cumaric acid, *p*-hydroxybenzoic acid, syringic acid and vanillic acid. Nieto (2020) reviewed the quercetin, syringic acid, caffeic acid, hesperidin and kaempferol as the main phenolic acids and flavonoid components in thyme plant.

4. Vitamin C of Red Beetroot Jam, Puree and Pickle Treatments

Vitamin C is one of the most antioxidant effective factors in food. Temperature and duration of thermal processing impacts vitamin C content (Nemzer et al., 2011, Njoku et al., 2011, Paciull et al., 2016 and Pavlović et al., 2017). Therefore, vitamin C content of RJ, RP, RR and BR treatments were evaluated. Data of vitamin C are presented in Fig. (3). There was a significant difference in vitamin C content for both RJ and RP treatments. A highly significant increment in vitamin C content was recorded for RJC5 and RJC1 treatments in comparison with the RJC treatments. The results obtained

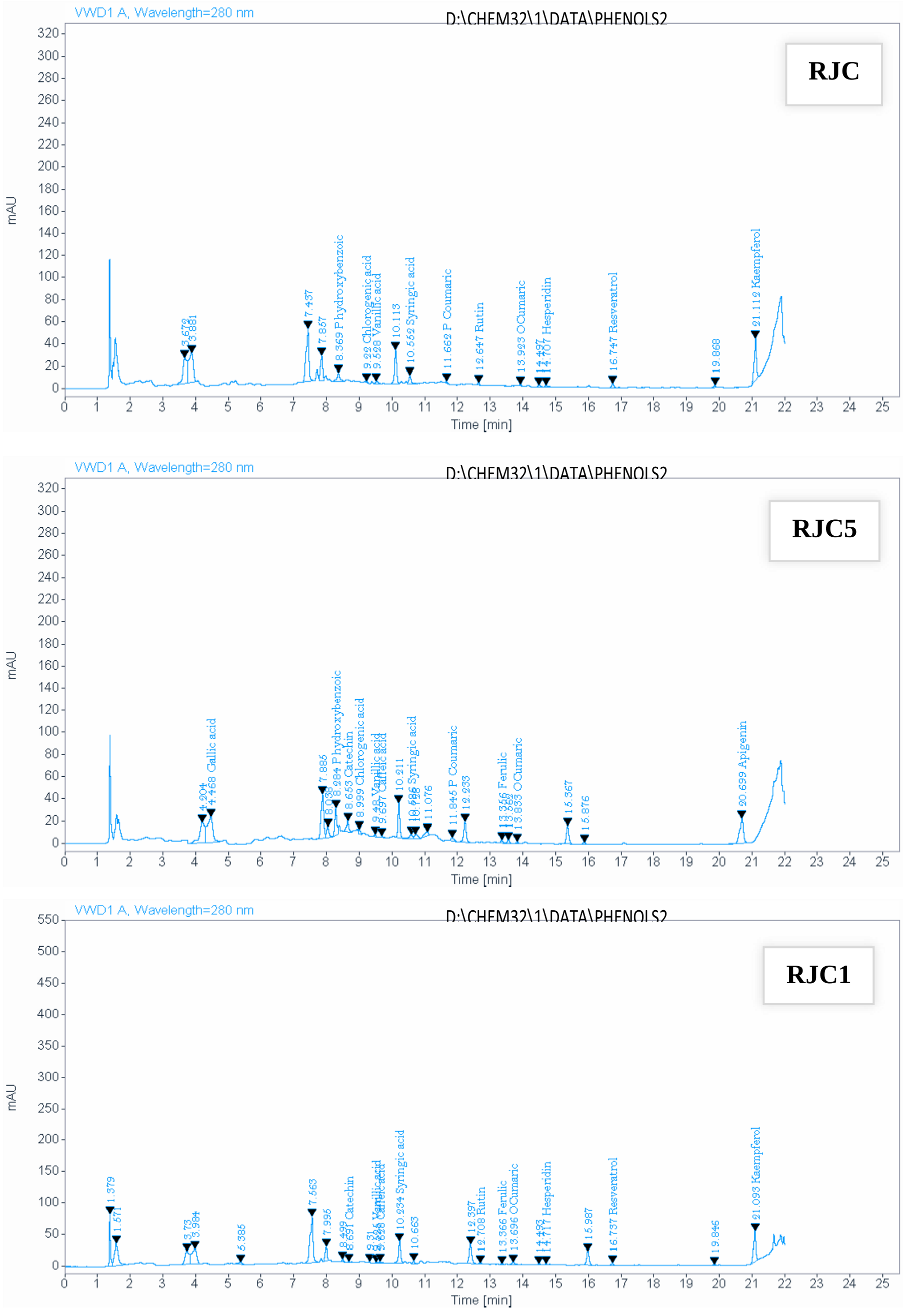

Fig. (2a). HPLC chromatogram obtained for red beetroot jam treatments.

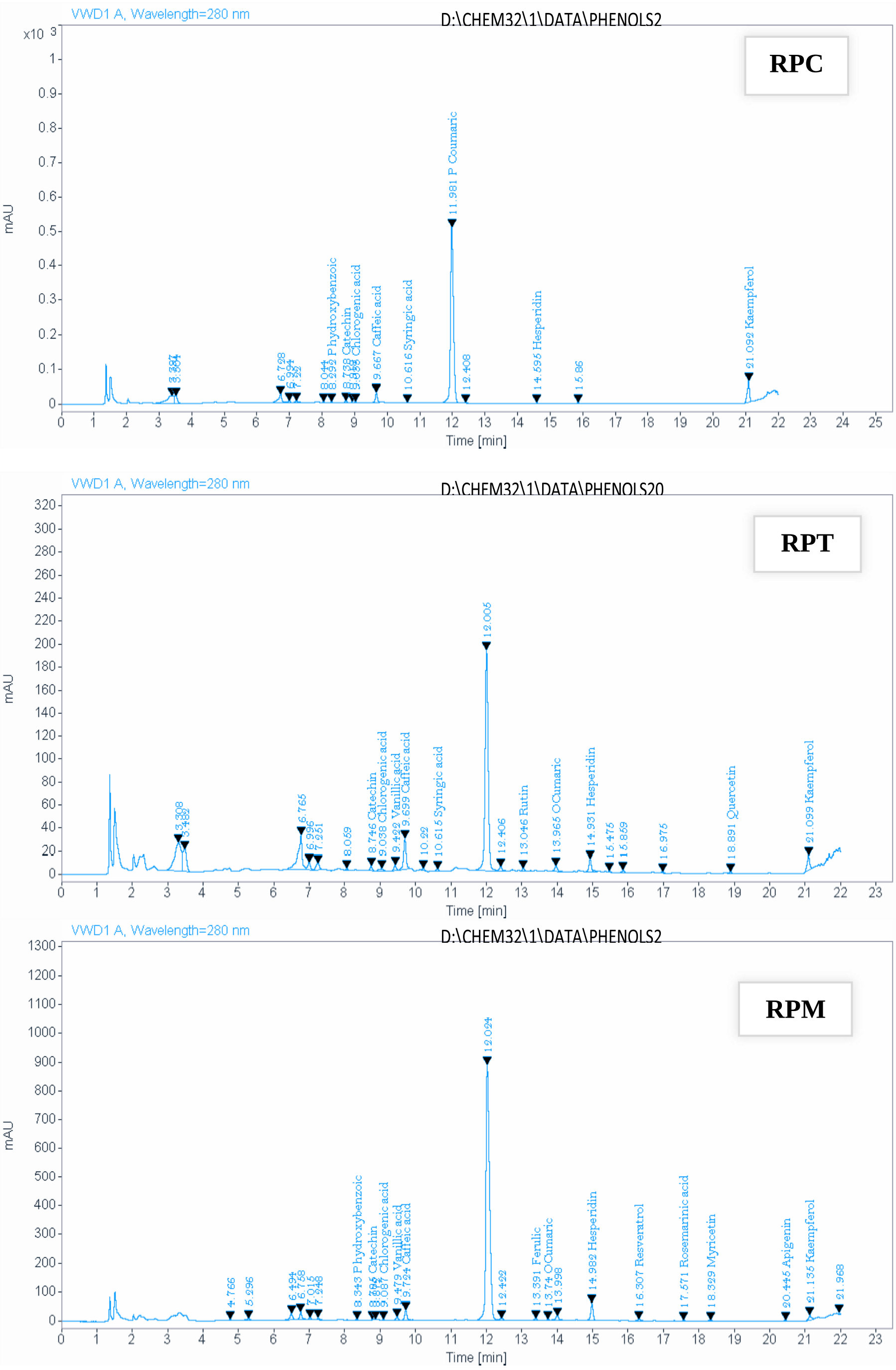

Fig. (2b). HPLC chromatogram obtained for red beetroot puree treatments.

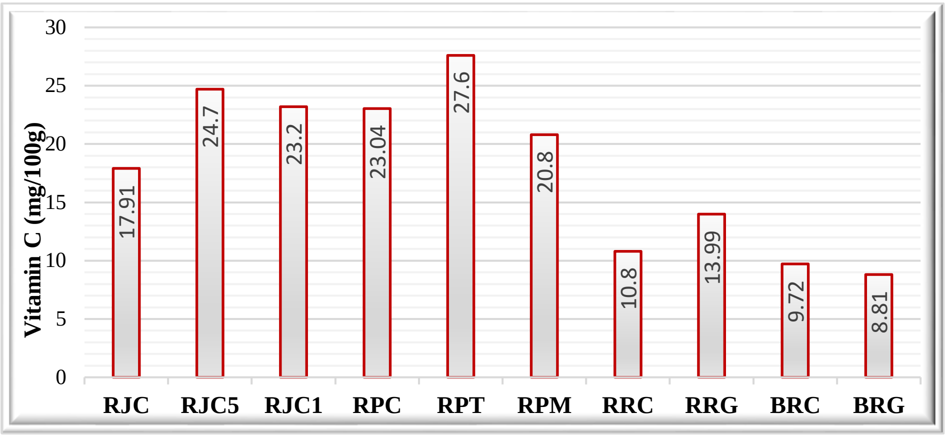

Fig. (3). Vitamin C content of red beetroot jam, puree and pickle red beetroot treatments.

(RJC) control red beetroot jam, (RJC5) red beetroot jam with 0.5% cinnamon, (RJC1) red beetroot jam with 1% cinnamon, (RPC) control red beetroot puree, (RPT) red beetroot puree with 1% thyme and (RPM) red beetroot puree with 1% mint, (RRC) control raw red beetroot pickle, (RRG) raw red beetroot pickle with 1% garlic, (BRC) control boiled red beetroot pickle and (BRG) boiled red beetroot pickle with 1% garlic.

are in agreement with Byarushengo et al. (2014), who announced that cinnamon essential oil can compensate the loss happened in vitamin C during pineapple jam process. Also, Shokry et al. (2018) observed that, using cinnamon and clove fortify the loss in vitamin C content in pomegranate jam.

On the other side, the RPT treatment possesses a significant highly vitamin C content, counter to the RPM treatment which recorded a significant lower vitamin C content than RPC treatment. wherefore, adding thyme found to be more powerful in supporting vitamin C loss in RP processing more than the mint addition. The same trend of thyme and mint effect was observed by Rehman et al. (2019), who reported a significant increase in ascorbic acid content for apple jam treated with thyme compared with apple jam treated with mint and clarified that, a deficiency in ascorbic acid was occurred with an increase in the percentage of mint added to the apple jam.

Fig. (3) clarifies that vitamin C content of the RR treatments is significantly higher as compared with the BR treatments. Furthermore, for the RR treatments, the RRG treatment recorded a significantly higher vitamin C content more than RRC treatment at variance the BRG treatment which scored a slightly lower vitamin C content than the BRC treatment. So, adding garlic did not support the degradation in vitamin C content that occurred as a result of the heat treatment. The results of the BR treatments are slightly in accordance with Srivastava and Singh (2016), who found that vitamin C content in boiled RR was 8.85 mg/100 g, also mention that vitamin C content for the fresh beetroot was 7.95 mg/100 g. The loss in vitamin C content may be due to effect of temperature during thermal processing (Uckiah et al., 2009 and Rehman et al., 2019).

5. DPPH Radical Scavenging Activity of Red Beetroot Jam, Puree and Pickle Treatments

Antioxidant activity of RJ, RP, RR and BR treatments were estimated by DPPH free radical scavenging activity determination. DPPH is a stable free radical that reduced in the presence of antioxidants, resulting in color changing from purple to yellow (Do et al., 2014). Data in Table (3) reveal the DPPH values of RJ, RP, RR and BR treatments. The highest significant value of DPPH was found with the RJC treatment followed by RJC5 then RJC1 treatments, whilst the RPM treatment possessed a significant increment in DPPH value followed by RPT then RPC treatments.

Table (3). DPPH radical scavenging activity of red beetroot jam, puree and pickle treatments.

Red beetroot treatments	**DPPH of red beetroot treatments (%)**		
	0.1%	**0.2%**	**0.4%**
RJC	18.46^{b}	25.84^{c}	52.68a
RJC5	22.15^{a}	32.55^{a}	39.93^{b}
RJC1	22.15^{a}	28.52^{b}	36.24^{c}
RPC	2.35^{c}	7.38^{c}	24.83^{c}
RPT	6.04^{b}	28.86^{b}	32.84^{b}
RPM	9.40^{a}	33.89^{a}	42.62^{a}
RRC	2.24^{d}	4.14^{d}	12.78^{d}
RRG	4.15^{c}	7.35^{c}	21.90^{c}
BRC	7.35^{b}	10.54^{b}	31.31^{b}
BRG	16.29^{a}	21.73^{a}	38.04^{a}

(RJC) control red beetroot jam, (RJC5) red beetroot jam with 0.5% cinnamon, (RJC1) red beetroot jam with 1% cinnamon, (RPC) control red beetroot puree, (RPT) red beetroot puree with 1% thyme and (RPM) red beetroot puree with 1% mint, (RRC) control raw red beetroot pickle, (RRG) raw red beetroot pickle with 1% garlic, (BRC) control boiled red beetroot pickle and (BRG) boiled red beetroot pickle with 1% garlic.
Means sharing the same letter in the same column (between treatments in each product) are not significantly different at $p \geq 0.05$.

Moreover, the finding of the present study displays that adding garlic significantly enhanced the DPPH value when compared with the control sample of both RR and BR treatments, this is because garlic had the strongest antioxidant capacity as reported by Sayin and Alkan (2015). Sawicki and Wiczkowski (2018) reported that, there is a decrement in the rate of betalains loss during boiling and fermentation of the unpeeled red beet and so the unpeel step for the red beetroot enhances the DPPH percent as well as the antioxidant effect.

6. Hardness of Red Beetroot Pickle Treatments

Pickle texture and the changes happened during processing are a key of importance to determine because it affect the consumer acceptance (Farahnaky et al., 2012). Hardness of the the RR and BR treatments were evaluated at zero time, 30 days and 60 days of pickling. Fig. (4) clarifies that, the hardness of the RRC and RRG treatments were significantly more than the BRC and BRG treatments. Also, it was noticed that, adding garlic to the RR and BR affected the pickle hardness, where it was found that, the hardness of RRG and BRG treatments were significantly lower than the RRC and BRC treatments all over the 60 days.

Rahman et al. (2022) observed more than 50% reduction in hardness of blanched nutmeg pickle whereas the time of the blanching time increase the hardness decrease and reported that this may be happened due to the tissue softening under high temperature. Badwaik et al. (2016) reported that, the turgor pressure increases within the cell structure during the blanching treatments which forces the cell membrane against the cell wall and cause a loss in fruit texture. Rahman et al. (2014) informed that the presence of enzymes responsible for hydrolyzed plant tissues might be affect the decrement in pickle hardness.

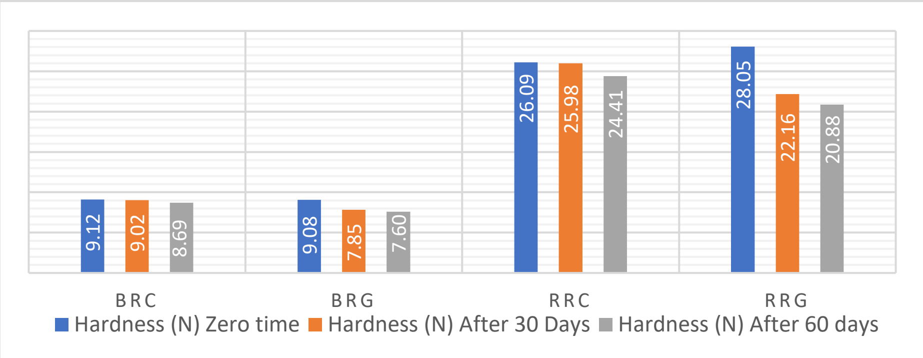

Fig. (4). Hardness of red beetroot pickle treatments during storage.
(RRC) control raw red beetroot pickle, (RRG) raw red beetroot pickle with 1% garlic, (BRC) control boiled red beetroot pickle and (BRG) boiled red beetroot pickle with 1% garlic.

7. Sensory Evaluation of Red Beetroot Jam, Puree and Pickle Treatments

Sensory evaluation used to assess the product quality and consumer expectations about the product. Data in Table (4) represent the sensory evaluation of all red beetroot treatments. For RJ treatments, it was noticed that there were no significant differences between RJC and RJC5 treatments for color, texture, flavour and overall acceptability, but significantly differences in taste. The RJC1 treatment was significantly lower in flavour and overall acceptability when compared with RJC and RJC5 treatments. For taste parameter, RJC5 and RJC1 treatments found to have a slightly significant lower taste as compared with RJC treatment.

For the sensory evaluation of RP treatments, which was evaluated by adding the RP treatments to tahina salad, the mean lower significant sensory parameters scores were observed with the RPM treatments, where the RPC was significantly higher than the RPT treatments, where taste, texture and overall acceptability of the RPC treatment was significantly higher than the RPT treatment.

Furthermore, RRG treatments found to have the highest significant taste, texture and flavour scores, followed by RRC treatments for texture parameter and BRC treatment for taste and flavour parameters.

Table (4). Sensory evaluation of red beetroot jam, puree and pickle treatments.

Red beetroot treatments	**Sensory parameters of red beetroot treatments**				
	Color	**Taste**	**Texture**	**Flavour**	**Overall acceptability**
RJC	9.5^{a}	8.5^{a}	7.5^{a}	9.3^{a}	9.0^{a}
RJC5	9.5^{a}	8.0^{b}	7.3^{a}	9.3^{a}	9.0^{a}
RJC1	9.5^{a}	7.8^{b}	7.3^{a}	8.5^{b}	8.5^{b}
RPC	9.5^{a}	9.8^{a}	9.0^{a}	9.5^{a}	9.8^{a}
RPT	9.3^{a}	8.5^{b}	8.5^{b}	9.3^{a}	9.3^{b}
RPM	8.8^{b}	8.0^{c}	8.0^{c}	8.5^{b}	8.5^{c}
RRC	8.3^{b}	6.0^{c}	8.0^{b}	6.6^{c}	6.5^{b}
RRG	9.0^{a}	8.5^{a}	8.3^{a}	8.5^{a}	8.0^{a}
BRC	9.0^{a}	7.3^{b}	7.5^{c}	7.8^{b}	8.0^{a}
BRG	8.3^{b}	6.3^{c}	7.3^{c}	6.3^{c}	6.5^{b}

(RJC) control red beetroot jam, (RJC5) red beetroot jam with 0.5% cinnamon, (RJC1) red beetroot jam with 1% cinnamon, (RPC) control red beetroot puree, (RPT) red beetroot puree with 1% thyme and (RPM) red beetroot puree with 1% mint, (RRC) control raw red beetroot pickle, (RRG) raw red beetroot pickle with 1% garlic, (BRC) control boiled red beetroot pickle and (BRG) boiled red beetroot pickle with 1% garlic.
Means sharing the same letter in the same column (between treatment of each product) are not significantly different at $p \geq 0.05$.

CONCLUSION

The present study revealed that, using cinnamon with RJ, thyme and mint leaves powder with RP exhibit a good DPPH activity with an excellent content of polyphenol and flavonoid compounds beside the acceptable consistency. Also, adding cinnamon and thyme support vitamin C content for both RJ and RP treatments, respectively. RR treatments state an excellent vitamin C and hardness properties and possess a good DPPH value as compared with boiling BR treatments. Furthermore, adding garlic reinforcement vitamin C content for the RRG treatment and DPPH value of RRG and BRG treatments but affected both RR and BR treatments hardness. Regarding the sensory evaluation, the highest overall acceptability was found with RJC, RJC5, RRG and BRC treatments, whilst the tahina salad contained RPC treatment scored a high overall acceptability followed by tahina salad contained RPT treatment then tahina salad contained RPM treatment. Generally, preserving red beetroot through agri-food processing reduced post-harvest loss and supports the red beetroot value chain with a recommendation of more analysis that should be done in order to provide a safety product.

REFERENCES

Abdo, E., S. El-Sohaimy, O. Shaltout, A. Abdalla and A. Zeitoun (2020). Nutritional evaluation of beetroots (*Beta vulgaris* L.) and its potential application in a functional beverage. Plants, 9: 1752-1768.

Agilent Application Note (2014). Publication number 5991-3801EN. Available online at: https://www.agilent.com/cs/library/applications/5991-3801EN.pdf.

A.O.A.C. (2005). In: ‘Association of Official Analytical Chemistry’. Official Methods of Analysis. 18th Ed. Washington DC, USA.

Armonk, N.Y. (2011). IBM SPSS statistics for windows. Version 20.0. IBM crop.

Babarykin, D., G. Smirnova, I. Pundinsh, S. Vasiljeva, G. Krumina and V. Agejchenko (2019). Red Beet (*Beta vulgaris*) impact on human health. Journal of Biosciences and Medicines, 7: 61-79.

Badwaik, L.S., G. Gautam and S.C. Deka (2016). Influence of blanching on antioxidant, nutritional and physical properties of bamboo shoot. J. Agric. Sci., 10 (3): 140–150.

Baião, D.S., C.D.F. Silva, L.P. Gomes, D.V. da Silva, A. Carolina N.T.F. Correa, P.R. Pereira, E.M. Del Aguila and V.M.F. Paschoalin (2017). Polyphenols from root, tubercles and grains cropped in Brazil: Chemical and nutritional characterization and their effects on human health and diseases. Nutrients, 9: 1044-1072.

Baja, K.L. and G. Kaur (1981). Spectrophotometric determination of L-ascorbic acid in vegetables and fruits. Analyst, 106: 117-120.

Bangar, S.P., S. Arashdeep, CH. Vandana, SH. Nitya and J.M. Lorenzo (2022). Beetroot as a novel ingredient for its versatile food applications. Critical Reviews in Food Science and Nutrition 25: 1-25.

Barrette, D.M., E. Garcia and J.E. Wayne (1998). Textural modification of processing tomatoes. Critical Reviews in Food Science and Nutrition, 38 (3): 173–258.

Brand-Williams, W., M.E. Cuvelier and C. Berset (1995). Use of free-radical method to evaluate antioxidant activity. LWT Food Sci. Technol., 28: 25-30.

Byarushengo, D., R. Minja and A. Temu (2014). Lemongrass and cinnamon essential oils as vitamin C preservatives and flavour enhancers in jam. Tanzania Journal of Engineering and Technology, (TJET), 35 (1): 46-53.

Dhiman, A., R. Suhag, D.S. Chauhan, D. Thakur, S. Chikara and P.K. Prabhakar (2021). Status of beetroot processing and processed products: Thermal and emerging technologies intervention. Trends in Food Science and Technology, 114: 443-458.

Do, Q.D., A.E. Ngkawijaya, P.L. Tran-Nguyen, L.H. Huynh, F.E. Soetaredjo, S. Ismadji and Y.H. Ju (2014). Effect of extraction solvent on total phenol content, total flavonoid content, and antioxidant activity of *Limnophila aromatica*. J. Food Drug Anal., 22: 296–302.

Farahnaky, A., R. Azizi and M. Gavahian (2012). Accelerated texture softening of some root vegetables by Ohmic heating. J. Food Eng., 113: 275–280.

Gould, A.W. (1983). In: 'Tomato Production, Processing and Quality Evaluation' (2nd ed.). West Port, CT: AVI Publishing.

Guine, R.P.F., A.R.F. Roque, F. Gonalves and P.M.R. Correia (2016). Development of an innovative jam based on beetroot. Journal of Food Science Research, 1 (2): 49-53.

Guldiken, B., G. Toydemir, K.N. Memis, S. Okur, D. Boyacioglu and E. Capanoglu (2016). Home-processed red beetroot (*Beta vulgaris* L.) products: Changes in antioxidant properties and bio accessibility. Int. J. Mol. Sci., 17: 858- 870.

Hamedi, S. and M. Honarvar (2019). *Beta vulgaris*—A mini-review of traditional uses in iran, phyto-chemistry and pharmacology. Current Drug Discovery Technologies, 16 (1): 74-81.

Kusznierewicz, B., M. Mróz, I. Koss-Mikołajczyk and J. Namieśnik (2021). Comparative evaluation of different methods for determining phytochemicals and antioxidant activity in products containing betalains – verification of beetroot samples. Food Chem., 362: 130-132.

Liliana, C. and N. Oana-Viorela (2020). Red beetroot: Composition and health effects - A Review. J. Nutri. Med. Diet Care, 6: (1): DOI: 10.23937/2572-3278.1510043

Moftah, R.F., R.M. Hamdy and M.A. El-Geddawy (2023). Red beetroots - a potential dietary supplement in the management of hypercholesterolemia. International Journal of Agricultural Sciences, 5 (1): 169-176.

Nada, Y.I., M.F. Abd El-Salam, H.I. Khalil and M.A. El Nono (2016). Rheological properties of strawberry puree jam. Misr J. Ag. Eng., 33 (2): 527–544.

Nemzer, B., Z. Pietrzkowski, A. Spórna, P. Stalica, W. Thresher, T. Michałowski and S. Wybraniec (2011). Betalainic and nutritional profiles of pigment-enriched red beet root (*Beta vulgaris* L.) dried extracts. Food Chemistry, 127: 42-53.

Nieto, G. (2020). A Review on applications and uses of thymus in the food industry. Plants, 9: 961-989.

Njoku, P.C., A.A. Ayuk and C.V. Okoye (2011). Temperature effects on vitamin C content in citrus fruits. Pakistan Journal of Nutrition, 10 (12): 1168-1169.

Paciull, M., I.G. Medina-Meza, E. Chiavaro and G.V. Barbosa-Canovas (2016). Impact of thermal and high-pressure processing on quality parameters of beetroot (*Beta vulgaris* L.). LWT- Food Science and Technology, 68: 98-104.

Pavlović, R., J. Mladenović, N. Pavlović, M. Zdravković, D. Jošić and J. Zdravković (2017). Antioxidant nutritional quality and the effect of thermal treatments on selected processing tomato lines. ACTA Scientiarum Polonorum Horticulture, 16 (3): 119- 128.

Rahman, A., M.S. Kayshar, M. Saifullah and M.B. Uddin (2014). Evaluation of quality status and detection of adulterants in selected commercial pickles and chutneys based on consumer attitude and laboratory analysis. Journal of the Bangladesh Agricultural University, 12 (1): 203–209.

Rahman, N., K. Mahmood, H. Kamilah, S. Sulaiman, M. Ibrahim and F. Ariffin (2022). Effects of blanching and pickling process on the alcohol acyltransferase (AAT) activity, myristicin content and quality parameters of pickled nutmeg (*Myristica fragrans*). Journal of Food Science and Technology, 59: 542–551.

Ravichandran, K., A.R. Ahmed, D. Knorr and I. Smetanska (2012). The effect of different processing methods on phenolic acid content and antioxidant activity of red beet. Food Research International, 48: 16–20.

Rehman, A.U., R. Tahira, S. Naheed and M.A. Randhawa (2019). Value addition of apple jam with thyme and mint. J. Agric. Res., 57 (1): 39-44.

Salama, I., S. Abo-Elmaaty, A. Sulieman and M. Abdel-Hady (2019). Innovation of jam from groum melon pulp as untraditional source. Zagazig J. Agric. Res., 46 (2): 419-429.

Sawicki, T. and W. Wiczkowski (2018). The effects of boiling and fermentation on betalain profiles and antioxidant capacities of red beetroot products. Food Chemistry, 259: 292-303.

Sawicki, T., N. Bączek, W. Wiczkowski (2016). Betalain profile, content and antioxidant capacity of red beetroot dependent on the genotype and root part. Journal of Functional Foods, 27: 249-261.

Sayin, K. and S.B. Alkan (2015). The effect of pickling on total phenolic contents and antioxidant activity of 10 vegetables. Journal of Food and Health Science, 1 (3): 135-141.

Shahnawaz, M. and S.A. Shiekh (2011). Analysis of viscosity of jamun fruit juice, squash and jam at different compositions to ensure the suitability of processing applications. International Journal of Plant Physiology and Biochemistry, 3 (5): 89-94.

Shokry, A.M., K.R. Makpoul and A.A. Ibraheem (2018). Pomegranate jam and sauce quality assessment as value-added products and their effects on filled biscuits sensory properties. Middle East Journal of Agriculture Research, 7: 1492-1502.

Sindumathi, G. and G.S. Amutha (2014). Processing and quality evaluation of coconut-based jam. IOSR J. Env. Sci., Toxicol. Food Technol., 8 (1): 10-14.

Srivastava, S. and K. Singh (2016). Changes occur on nutritional value of beetroot (*Beta vulgaris*) after pickling. Current Research in Nutrition and Food Science, 4 (3): 217-221.

Stolzenbach, S., W.L.P. Bredie and D.V. Byrne (2013). Consumer concepts in new product development of local foods: Traditional versus novel honeys. Food Research International, 52 (1): 144-152.

Tahira, R., M. Naeemullah, F. Akbar and M.S. Masood (2011). Major phenolic acids of local and exotic mint germplasm grown in Islamabad. Pak. J. Bot., 43: 143-146.

Talcott, S.T. and L.R. Howard (1999). Chemical and sensory quality of processed carrot puree as influenced by stress-induced phenolic compounds. J. Agric. Food Chem., 47 (4): 1362-1366.

Trishitman, D., S.N. Pradeep and K.R. Navin (2021). Concentration of beetroot juice colorant (betalains) by forward osmosis and its comparison with thermal processing. LWT, 145: 111522.

Uckiah, A., D. Goburdhun and A. Ruggoo (2009). Vitamin C content during processing and storage of pineapple. Nutrition and Food Science, 39 (4): 398-412.

USDA (2020). Beets, raw. Available online at: https://fdc.nal.usda.gov/fdc-app.html#/food-details/1103338/nutrients.

تثمين سلسلة القيمة للبنجر الأحمر من خلال التصنيع الزراعي الغذائي

أميرة محمد شكري رياض
وحدة التصنيع الزراعي، قسم الإنتاج النباتي، مركز بحوث الصحراء، القاهرة، مصر

يعتبر البنجر الأحمر (الشمندر) محصول ذو قيمة غذائية عالية إلا أنه سريع التلف بسبب ارتفاع محتواه من الرطوبة. ومن ثم، فإن تطوير منتجات منه يمكن أن يدعم تثمين سلسلة القيمة للبنجر الأحمر. ولهذا الغرض، فقد تم تصنيع مربى البنجر الأحمر بإضافة ٠.٥٪ (RJC5) و٠.١٪ (RJC1) مسحوق القرفة، بيوريه البنجر الأحمر بإضافة ١٪ من مسحوق أوراق الزعتر (RPT) و١٪ من مسحوق أوراق النعناع (RPM). كذلك تم تصنيع مخلل البنجر الأحمر الخام (RRG) ومخلل البنجر الأحمر المسلوق (BRG) مع الثوم. تم أيضًا تصنيع عينة كونترول من كل من المربي (RJC) والبيوريه (RPC) والمخلل الخام (RRC) والمخلل المسلوق (BRC) بدون أي مادة مضافة. تم تقدير القوام لكل من معاملات المربى والبيوريه وتقدير فيتامين C و نشاط الـ DPPH لكل من المربى، البيوريه والمخلل، بينما تم قياس الصلابة لمخلل البنجر الأحمر. تم إجراء التقييم الحسي لكل من معاملتي المربى والمخلل، أما بالنسبة لمعاملات البيوريه فقد تم تحضير سلطة الطحينة بإضافة معاملات البيوريه كمواد مضافة لتقييم الصفات الحسية لمعاملات بيوريه البنجر الأحمر. أظهرت النتائج أن إضافة القرفة إلى معاملات RJ لم تؤثر على قوام المربى، على العكس من ذلك، بالنسبة لمعاملات RP فقد تأثر القوام بإضافة الزعتر والنعناع، حيث كان تماسك معاملتي RPT وRPM أعلى من معاملة الـ RPC. أظهرت معاملات RJC5، RJC1، RPT وRRG احتوائهم على محتوى جيد جدًا من فيتامين C. فيما يتعلق بقياس نشاط الـDPPH، أظهرت كل من RJC، RPM، RRG، BRG وBRC قيم DPPH عالية بشكل ملحوظ. أيضًا وجد أن معاملات RRC وRRG أظهرت درجة صلابة جيدة بالمقارنة مع معاملات الـBRC وBRG. بالنسبة للتقييم الحسي، وجد أن معاملة الـ RRG سجلت أعلى قيمة لكل من الطعم، الملمس والنكهة، في حين أظهرت معاملات الـ RJC، RJC5 والطحينة المضاف لها معاملة الـ RPC أعلى قبول عام.