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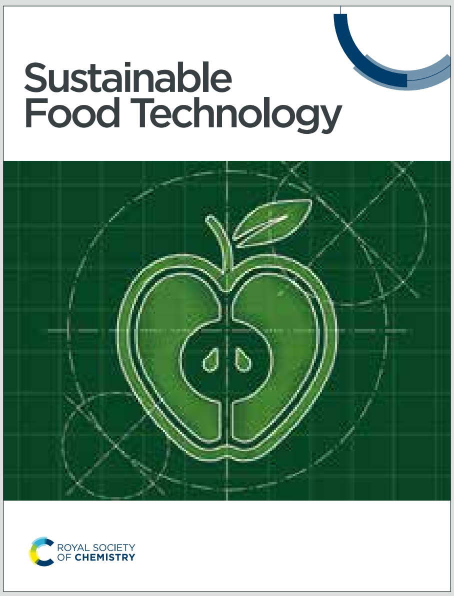

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Sustainability Spotlight Statement:

Sustainability spotlight: This study supports sustainability by upcycling of rosehip waste into ash gourd candy which directly contributes to SDG 12: Responsible Consumption and Production, which emphasizes sustainable resource utilization and waste reduction along with SDG 2: Zero Hunger by enhancing the nutritional quality of foods through optimised blanching and increased phytochemicals. The strategy focuses on process optimization and waste valorisation to promote circular bioeconomy and sustainable production systems.

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Valorisation of Rosehip Waste for Functional Enhancement of Ash Gourd Candy: physicochemical, bioactive, molecular and structural characterization

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Abstract

The study investigates blanching duration optimization in ash gourd candy production and the utilization of rosehip waste as a functional ingredient to develop value-added confectionery as an approach to sustainable waste valorisation. Optimization of blanching duration showed improved phytochemicals retention, while structural analysis of blanched samples indicated higher porosity, which may have facilitated the penetration of rosehip phytochemicals into the candy. The enhanced functionality of candies may have been the result of blanching optimization and incorporation of rosehip powder and extract during osmotic dehydration. Rosehip waste increased phytochemical and antimicrobial activities while retaining acceptability scores (>7 on a 9-point scale), with highest scores observed for 2.5 % powder and 5 % extract in optimised (2.5 min) blanched samples. FT-IR spectra show the presence of functional groups, and ranking analysis indicate that blanching duration primarily affected the colour and texture, whereas rosehip waste incorporation had greater effect on taste and flavour. Principal component analysis (PCA) was applied to assess the influence of formulation and processing parameters on the quality characteristics of the developed product. These findings demonstrate the potential of rosehip waste upcycling to reduce food processing waste and produce value-added functional confectionery products while retaining satisfactory sensory quality.

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1. Introduction

Traditional confectionery products are generally made with white sugar using processed food ingredients. The high prevalence of sugar consumption has an adverse effect on health such as obesity, cardiovascular diseases, diabetes, etc [1,2]. As a result, the food industries are looking for new solutions to develop healthy products. Several recent studies have shown that confectionery products incorporated with other natural ingredients can have health-promoting benefits [3]. Watermelon candy has been prepared incorporating different concentrations of orange waste to enhance its nutritional value, jelly candies prepared with grape juice as a source of anthocyanins, shows that candies fortified with natural ingredients can be a potential source of functional ingredients [4,5]. Moreover, natural confectionery products have high demand in the market due to their high nutrition and taste acceptability [5].

The Cucurbitaceae family includes many vine species with abundant health benefits. Among the various gourds, ash gourd (*Benincasa hispida*) has been well known since historical times for its therapeutic and nutritional value[6]. It contains carbohydrates, dietary fiber, protein, minerals (such as zinc, iron, calcium etc.) along with phytochemicals (astilbin, naringenin, catechin, isovitexin, alnusenol etc.)[6,7], however, during processing (such as blanching, dehydration) significant changes in their nutritional quality may occur. During candy production, a complex array of chemical reactions take place, especially during blanching, which plays a pivotal role in determining the product quality attributes (nutritional value, antioxidant activity, and sensory characteristics) of processed foods[8]. It is mainly done to inactivate enzymes such as polyphenol oxidases and peroxidases which cause off flavour and undesirable color changes. It also helps in reducing the surface microbial load, softening the plant tissues to enhance their palatability and expelling the air, removing the waxy layer from fruit surfaces etc[9]. However,

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blanching causes destruction of heat labile nutrients and leaching of water-soluble compounds therefore reducing the nutritional value and antioxidant potential of the product. Despite of causing maximum nutritional losses hot water blanching is the most widely used method due to ease of operation and cost effectiveness. Attempts have been made by several researchers to minimise these losses by adjusting the time and temperature of the treatment [10,11].

Rosa genus belonging to the Rosaceae family bears pseudo-fruit known as rosehips are found in the Middle East, Europe, North America, and Asia. There are around 25 wild varieties and some commercial varieties grown in this region. Rosehips are underutilized fruits with an abundance of phytochemicals containing phenolic acids, flavonoids, fruit acids (mainly ascorbic acid, citric acid and malic acid), vitamins (mainly vitamin C), sugars, and carotenoids[12]. Pharmacological studies have shown that rosehips have anti-obesity, anti-inflammatory, antinociceptive, antioxidant, ulcerogenic, anti-diabetic, and anti-cancerous effects [13]. The rosehip extract has been found effective in protecting the kidney against oxidative stress [14] and can act as a pain reliever in rheumatoid arthritis and osteoarthritis [15].

However, processing of rosehips into value-added products such as jam, puree, marmalade generates around 30 % of the solid waste mainly in the form of seed and husk known as 'fluff'[16]. This residue is generally discarded or utilized as a low-value resource, such as heating fuel or fertilizer [17]. In alignment with the principles of a circular economy, it is essential to explore efficient strategies for waste valorisation. Researchers have reported innovative approaches for the utilization of rosehip waste. [18] Produced fibre- and bioactive compounds enriched waffle cones by incorporating rosehip waste. Biobased food packaging material using rosehip residue as a major component (74 %) along with starch and polylactic acid is a novel attempt to reduce waste in food industry [17]. Such valorisation strategies not only minimize waste

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generation but also contribute to the achievement of Sustainable Development Goal 12: Responsible Consumption and Production, which emphasizes sustainable resource utilization and waste reduction [19].

Enrichment of food products with functional components has been commonly used in order to enhance their pro-health properties. Food products with elevated levels of antioxidants are in high demand because of their roles in the maintenance and enhancement of health and protection against many diseases [20]. Therefore, in order to enhance the nutritional value of ash gourd candy additional fruit powder or extract which enhances the nutritional value of the candies without affecting consumer acceptability can be done. White chocolate containing rosehip extract has been prepared to enhance antioxidant potential of white chocolate [21]. Therefore, rosehip in the form of powder or extract can be used in other confectionery products to enrich them with bioactive compounds.

Previous studies have evaluated the effect of blanching time on ash gourd candy enriched with citrus peel polyphenols using vacuum impregnation method [22], however, the incorporation of functional ingredients during the osmotic dehydration step which is the commonly employed technique in small-scale industries generally associated with ash gourd candy production, remains largely unexplored. Furthermore, despite the rich bioactive profile of rosehips, its utilization in confectionery products as functional ingredient requires further investigation. Therefore, the present study aims to optimize blanching duration to maximize phytochemical retention for ash gourd candy while enhancing its nutritional and functional qualities through incorporation of rosehip powder or extract during osmotic dehydration, which may support sustainable waste valorisation and circular resource utilization.

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2. Materials and Methods

2.1 Preparation of materials

Ash gourds (variety PAG-3) were collected from the Regional Research Station, Ballowal Saunkhri (Shahid Bhagat Singh Nagar), Punjab Agricultural University, Ludhiana, Punjab, 141004, India. Good quality ash gourd was selected for the preparation of candy. Washing and cleaning of ash gourd was done thoroughly. Peeling of ash gourd was done by hand peeler and seeds were removed manually. The ash gourd pieces were cut into pieces of length 4±0.5 cm and width 2±0.5 cm. To make the ash gourd firm during processing, the pieces were pricked and immersed in lime water for 2 hours and further washed with water. The 70 ºBrix sugar syrup was prepared by adding 2.34 kg sugar in 1L of water [23]. Rosehips of Hybrid T (*Rosa* x *hybrida*) were washed, dried, sliced and seeds were removed, followed by drying at 55 ºC in hot air cabinet drier (Frederick Herbert-Design, Bombay, India) until constant weight and finally ground to powder (RP). Rosehip extract (RE) was prepared using the above dried rosehips employing ultrasonication as per the standard protocol outlined by [24]. The chemicals used in the study were of analytical grades and water used is distilled water.

2.2 Blanching

The ash gourd pieces were further treated with 100 ppm potassium metabisulphite (KMS) and 200 ppm ascorbic acid for two minutes after that blanching was done at 85±3 ºC for 0, 2.5, 5 min and samples were allowed to cool immediately in cold water.

2.3 Osmosis and drying of candy

The main process in the preparation of candy is osmotic dehydration. The sugar syrup was prepared by adding 2.34 kg sugar in 1L water with continuous heating until the TSS (Total soluble solids) of sugar solution reached 70 ºBrix, followed by filtration in 2-fold muslin cloth [25].

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The blanched samples were dipped into prepared sugar syrup at room temperature 25±2 °C. Raw rosehips contain hairy fibres called achenes, due to which it's direct incorporation into the sugar syrup was not preferred, therefore, converting raw rosehips into powder or its extraction were the only possible methods for incorporation into the sugar syrup. The rosehip powder (RP) was obtained upon hot air cabinet tray drying at 55 ºC and rosehip acidulated water extract (RE) was obtained upon ultrasound assisted extraction (Power: 300 W, time: 30 min, solid-liquid ratio: 1:15, pH: 5.5) as per previous study[24]. In this sugar syrup RP concentration at 0, 2.5, 5 % or RE concentration at 0, 5, 10 % was added. After each day, the TSS of the osmotic solution was maintained at its initial TSS (70 ºBrix) by preparing a syrup of 70 ºBrix and adding it to each treatment solution according to its TSS. This method for maintaining the initial TSS was more suitable as compared to boiling which would have destroyed the heat labile phytochemicals of rosehips. There was no additional decline in the TSS of the osmotic solution once equilibrium was attained. After complete osmotic dehydration, the candies were placed in a hot air cabinet tray drier for 24 hours at 55±2 ºC.

2.4 Physicochemical analysis

The prepared ash gourd candies supplemented with RP or RE were analyzed for different physicochemical parameters such as water activity, total soluble solids, color and texture. Water activity was measured by a water activity meter (PREAQUA LAB, Water activity analyzer, SN: PRE000197). A hand refractometer of various ranges was used to measure the total soluble solids (ºBrix) of the prepared solution from ash gourd candy in ºBrix. The color of rosehips was measured using the Colorimeter (Hunter Lab) with a D 65 illuminant. The color was evaluated by determining L (0-100, dark to light), a∗ (±, green/red), and b∗ (±, blue/yellow) values [25]. The texture profile analysis was performed using a TA-XT texture analyzer (Stable Micro Systems,

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Model TA-HDi, UK) using a cylindrical probe (50 mm) was used to evaluate the texture of candies in terms of hardness (N), springiness (mm), cohesiveness, gumminess (N) and chewiness (J). Pre-test speed was 0.5 mm/s, the post-test speed was 0.5 mm/s, distance between probe and sample was 10 mm, trigger force was 10 g, and the time between two penetrations was 4 sec.

2.5 Phytochemical analysis

2.5.1 Preparation of extract

The candy (1g) and 50 ml methanol (80 %) are added and refluxed using an extraction unit for 4 hr as described by [26] with certain modifications. The extracts obtained were subjected to further centrifugation (Sorvall ST 16R, Thermo Fisher Scientific, Germany) at 10,000 rpm for 10 min. The supernatant obtained from centrifugation was collected and stored in 50 ml centrifuge tubes at 4±1 °C until further analysis.

2.5.2. Phytochemical Analysis

2.5.2.1 Total phenolic content (TPC)

The total phenolic content (TPC) of the candy samples was determined using the Folin-Ciocalteu (FC) reagent. Extract (0.1 ml) was mixed with 2.5 ml of 1 mol FC reagent and 2 ml of sodium carbonate (20 %, w/v), followed by volume makeup of 5 ml with distilled water. After incubation for 2 h, the absorbance was noted at 760 nm and the results were expressed as mg gallic acid equivalent (GAE)/100 g) [27]. The total phenolic content was calculated using the equation $y= 0.0782x – 0.0546$ ($R^2 = 0.9954$).

2.5.2.2 Total flavonoid content (TFC)

Total flavonoid content (TFC) was determined using method described by [22]. Aliquot (0.1 ml) was mixed with 1.5 ml methanol (80 %), 0.1 ml aluminium chloride (10 %), 0.1 ml

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potassium acetate (1 M), and 2.7 ml distilled water. The absorbance was immediately taken at 415 nm and results were expressed as mg quercetin equivalent (QE)/100 g. The total flavonoid content was calculated using the equation y= 0.0096x – 0.0134 (R^2 = 0.9987).

2.5.3 Antioxidant Activity

2.5.3.1 DPPH (2,2-diphenyl-1-picryl hydrazyl) assay

To determine the free radical antioxidant activity by DPPH method, extract (0.1 ml) was taken to which 1 ml Tris buffer was added to maintain a suitable pH [28,29] of the reaction medium along with 2 ml methanol solubilized DPPH reagent, followed by incubation for 30 min and the absorbance was noted at 517 nm [30]. The results were expressed as percent inhibition as compared to control.

% DPPH scavenging = (Ac – As)/Ac *100

Where, Ac and As are absorbance of control and sample, respectively.

2.5.3.2 Ferric reducing antioxidant power (FRAP) assay

The ability of extracts to reduce Fe^{3+} -TPTZ to a blue-coloured Fe^{2+} -TPTZ in FRAP method as described by [27]. FRAP reagent was prepared by mixing stock solutions, 10 mM 2,4,6-tri(2-pyridyl)-1,3,5-triazine (TPTZ) stock solution, 300 mM acetate buffer (pH 3.6), and 20 mM Ferric chloride solution in the ratio 1:10:1. Extract (0.2 ml) was mixed with 4.5 ml FRAP reagent and distilled water was added to make the volume. The absorbance was determined at 593 nm and results were expressed as mmol ferric chloride equivalent /g. FRAP antioxidant activity was calculated using the equation y= 0.097x – 0.0243 (R^2 = 0.9955).

2.5.3.3 Metal chelation activity (MCA)

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The Fe^{2+} chelating activity of the samples was determined by measuring the formation of the complex Fe^{2+}-ferrozine according to [31]. Aliquot (1 ml) is mixed with 1 ml (0.1mM) ferrous chloride and 1 ml (0.25 mM) ferrozine and kept at room temperature for 15 minutes of incubation. The readings are recorded at absorbance of 562 nm and results were expressed as µmol ferric chloride equivalent /g. MCA antioxidant activity was calculated using the equation y= 18.9x – 33.2 (R^2 = 0.9997).

2.6 Antidiabetic activity/*In vitro* α-amylase inhibition assay

The inhibition of the samples to inhibit the activity of alpha-amylase was determined according to [32] with slight modifications. Aliquot (1 ml) in 0.02 M sodium phosphate buffer of pH 6.9 were added to (0.5 mg/ml) alpha amylase and incubated at 25 °C for 10 min. Then, 1 ml (1 %) starch solution prepared in phosphate buffer is added. Incubation of reaction mixture was done at 25 °C for 10 min, to the reaction mixture 1 ml dinitrosalicylic acid (DNSA) reagent is added to stop the reaction [33]. The reaction mixture was further incubated in boiling water bath at room temperature for 5 minutes. Dilution of reaction mixture is done using 10 ml distilled water. Solution with 100 % enzyme activity was taken as control [34]. The results were recorded at 540 nm and reported as percent inhibition as compared to control.

% Antidiabetic Activity = (Ac – As)/ Ac x 100

Where, Ac and As are absorbance of control and sample, respectively.

2.7 Antimicrobial activity

The antimicrobial activity of water extracts (1 g in 50 ml distilled water) from ash gourd candy supplemented with RP or RE for *E. coli, B. cereus, C. perfringens, L. mesenteroides* and *P. cartovorum* by using agar well diffusion method [35 36]. The extracts were diluted with distilled water to 5 mg/mL, and 100 µL of the resulting extract was added to each well. Microbial

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suspensions were standardized to approximately 10^8 CFU/mL before spreading onto the agar plates. Controls were kept for each bacterial strain where the sample was replaced with distilled water. All the experiments were performed in triplicate, and the results were expressed as the diameter of the inhibition zone (mm).

2.8 Sensory analysis

Prior consent (verbal) has been taken from the semi-trained panellist to participate in the sensory analysis of the ash gourd candies. Scores on a 9-point hedonic scale based on appearance, color, taste, texture were evaluated to draw the overall acceptability of ash gourd candy supplemented with RP or RE by 20 judges (9 males and 11 females, 21–33 years old). It is further submitted that the permission to conduct a human sensory panel study is not a requirement of our institution. All these semi-trained panelists given their prior informed consent before participating in the sensory evaluation. Sensory evaluation was performed at 26 ± 2°C.

2.9 FTIR (Fourier transform infrared spectroscopy)

The ash gourd candies supplemented with RP or RE were tested for FTIR spectra using an Agilent Cary 630 FTIR spectrometer. All the samples were evaluated at room temperature, and the spectra were collected in the 4000-400 cm^{-1} wave number range [37].

2.10 Structural analysis

The microstructure of ash gourd candy (control samples) were determined with SEM (JEOL, JSM-6510 LV, Tokyo, Japan) in order to study the effect of blanching. Samples were mounted on aluminium stubs and coated with gold for 4 min.

2.11 Statistical analysis

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The data obtained was analyzed using SPSS 16.0 software. All the measurements were calculated in triplicate (n=3). One-way ANOVA with Duncan's Multiple Range Test (DMRT) as post-hoc analysis was used to carry out statistical analysis. Statistical differences were carried out at $p \leq 0.05$. Ranking analysis was conducted using MS-Excel to determine the major factors (powder concentrations, extract concentrations, and blanching time) affecting the overall acceptability of the ash gourd candy.

2.12 PCA analysis

Principle components analysis (PCA) was conducted using a R software (version 4.5.3) using software packages-factoextra, pca3d, FactoMineR and psych, to determine the effect of phytochemical and sensory parameters on the preparation of the rosehip incorporated ash gourd candy. Data scaling methods include, for variable preprocessing step Z-score standardization method to prepare data for PCA and for final index normalization step min-max scaling method was used to convert PCA scores to 0-1 index.

3 Results and discussion

3.1 Effect of blanching time on the physicochemical parameters, phytochemical, and overall acceptability of ash gourd candy

3.1.1 Effect on physicochemical parameters

The effect of blanching conditions (control, 2.5, 5 min) on the physicochemical parameters such as water activity, total soluble solids (TSS), color, and texture of ash gourd candies supplemented with RP or RE is shown in Table 1. Water activity is an important physico-chemical attribute determining the quality and stability of the product as it affects the enzymatic activity and

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microbial activity of the product. Water activity was significantly (p≤0.05) affected by the different blanching time given to the ash gourd candy as shown in Table 1. The water activity of ash gourd candies varied from 0.34±0.01 to 0.42±0.02. With the increase in blanching time from 0 to 5 min, there is a decrease in the water activity of the candies irrespective to the type of candy. This could be due to the breakdown of the cell membrane during blanching [38] which would increase the removal of water from the plant tissues during drying, hence the respective samples have low water activity as shown in Table 1. The results were in accordance with the findings of [39], who found that the resultant product possessed lower water activity when blanched due to alteration in the cell wall and membrane of persimmon slices. The blanching duration affected the TSS of ash gourd candies with TSS ranging from 60.20±2.31 to 68.50±2.73 °B (Table 1). With the increase in the blanching time from 0 to 5 min, a significant (p≤0.05) increase in the TSS was observed for all the samples. This could be related to two major factors the first one is due to the softening of the tissues which enhances the rate of sugar transfer during osmosis and another one could be the loss of moisture which increases the uptake of sugar during osmosis [40].

In general, blanching significantly affects the color and texture of products. As expected, the L, a* and b* values reveal the significant (p≤0.05) effect of blanching on the color of ash gourd candies supplemented with RP or RE. The L (lightness) value varied from 57.12±1.08 to 60.46±2.50, a* (redness or yellowness) varied from 1.27±0.04 to 2.50±0.04 and b* (blueness or greenness) values varied from 3.18±0.09 to 4.89±0.02 of the ash gourd candy as presented in Table 1. With the increase in blanching from 0 to 5 min the product became lighter in color resulting in an increase in L value whereas the a* and b* values for ash gourd candy samples decreased from 0 to 5 min. The increase in the L value and decrease in the a* and b* values indicate the increase in the transparency of the tissues with increase in blanching time [41]. The decrease in a* value may also be

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due to the loss of entrapped air in the plant tissues with blanching which increases with increase in blanching duration [42]. Inactivation of enzymes such as polyphenol oxidase (PPO) may also contribute to the overall color changes of the plant tissue [43]. The decrease in b* value is seen from 0 to 2.5 min, however, there is increase from 2.5 min to 5 min which may be due to browning enzymes which would have not been completely inactivated during the blanching treatment. Regarding the effect on texture, the hardness of ash gourd candies varied from 21.35±0.11 to 24.91±0.44 N. The hardness of the candies decreased with increase in blanching time from 0 (24.91 N) to 5 min (21.35 N) as shown in Table 1. This is due to the softening of the tissues by degrading the cell wall polysaccharides which further increases with increase in blanching time due higher disintegration and further heat penetration from outside to inside. The results are consistent with the results of [39] who reported decrease in the hardness of the persimmon samples as a result of blanching. The firmness of fruits and vegetables is attributed to the presence of pectin substances and turgor pressure. However, during blanching the pectin gets decomposed causing a decrease in the turgor pressure and softening of tissues[44]. Springiness is another important texture parameter, it is the measure of the texture recovered by the food during the time from the end of the first bite and the start of the second bite [45]. The springiness values for candies increased with an increase in blanching from 0 (6.94 mm) to 5 min (12.25 mm). High springiness values indicate the requirement of high mastication energy [46]. Cohesiveness and gumminess were also increased with an increase in blanching from 0 to 5 min. The cohesiveness and gumminess varied from 0.47 to 0.68 and 14.51 to 11.70, respectively. Chewiness is the required energy to masticate a solid food to a form that is ready for swallowing and is related to the primary parameters of springiness, cohesiveness, and hardness[47]. The chewiness of candies varied from 81.25 to 177.84 J and increased with blanching time which may be due to the retained structure of the plant tissue even at higher blanching

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durations. Complete inactivation of pectin degrading enzymes and improper heat penetration inside the plant tissue could have resulted in increased chewiness of ash gourd candy.

3.1.2 Effect on bioactive parameters

The effect of blanching on the phytochemicals of ash gourd candies supplemented with RP or RE was determined in terms of total phenolic, flavonoids content, antioxidant activity and antidiabetic activity as summarized in Table 2. Blanching of the ash gourd candy resulted in the retention of bioactive compounds. As shown in Table 2 control samples had lower amounts of TPC (66.7 mg/100g) and TFC (31.4 mg/100g). In 2.5 min blanched samples, antioxidant activity was higher than 0 min samples due to the release of bound bioactive compounds. When the plant matrix was blanched for 2.5 min, opening up of the structure led to the release of phytochemicals which were embedded in the unblanched sample and could also be due to the oxidation of phenolics and flavonoids during enzymatic reactions in unblanched samples [48]. In comparison to 5 min blanched samples, samples blanched for 2.5 min show maximum retention of bioactive compounds. The degradation of phenolics and flavonoids could be attributed to the loss of hydrophilic and thermosensitive compounds during long-duration blanching treatment (5 min). The results are in accordance with the results of[49], who studied the effect of different conventional blanching temperature-time combinations on the bottle gourd juice and reported that with an increase in blanching temperature phytochemicals increased till 4-5 min due to the enhanced skin permeability caused by the heat treatment. However, with further increase in temperature-time combination, the phytochemicals decreased due to the high temperature causing their degradation.

As expected, similar results were observed for antioxidant activity. The antioxidant activity of ash gourd candy was determined using DPPH, FRAP and MCA methods. The antioxidant activity values of ash gourd candies ranged from 18.55 to 21.65 % (DPPH), 0.56 to 1.12 mmol/g

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(FRAP) and 15.86 to 17.22 µmol/g (MCA) as given in Table 2. Ash gourd candy samples blanched for 2.5 min possessed highest antioxidant activity (DPPH (21.65 %), FRAP (1.12 mmol/g), MCA (17.22 µmol/g)) as compared to 0 ((DPPH (18.55 %), FRAP (0.56 mmol/g), MCA (15.86 µmol/g)) and 5 min (DPPH (19.46 %), FRAP (0.95 mmol/g), MCA (16.01 µmol/g)) blanched samples. The enhanced total phenolic content during blanching from 0 to 2.5 min may be due to the release of bound phytochemicals which got released upon tissue disintegration. The inactivation of PPO enzyme during blanching may have led to the retention of higher phenolic compounds leading to increased antioxidant activity [43]. However, further increase in blanching duration from 2.5 min to 5 min causes heat induced degradation of phytochemicals due to their heat labile nature and leaching losses leading to lower antioxidant activity [50]. [51] observed similar results and concluded that blanching of pomegranate for 3 min showed highest antioxidant activity. The antioxidant potential of blanched control samples is due to the presence of ash gourd phytochemicals such as catechin, cucurbitacin, β-sitosterol, naringenin etc. [52]

The functioning of the α-amylase enzyme is inhibited by certain compounds that inhibit the absorption of dietary starch in the body therefore preventing blood glucose levels from increasing. The range for α-amylase inhibition activity for ash gourd candy blanched for different durations varied from 7.55 to 9.25 % as shown in Table 2. With the increase in blanching time from 0 to 2.5 min their antidiabetic activity increased, however, with a further increase in blanching time from 2.5 to 5 min a decrease in antidiabetic activity was observed. The maximum antidiabetic activity is shown by 2.5 min blanched samples due to the retention of maximum phytochemicals. However, with a further increase in blanching time from 2.5 to 5 min, there was leaching of the polyphenols causing decrease in antidiabetic activity of the samples [53]. The results are consistent with [54] who

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observed α amylase activity in *Adansonia digitata* leaves to be higher in blanched samples as compared to raw; [52] reported that ash gourd has potential against diabetes mellitus.

3.1.3 Effect on overall acceptability

The overall acceptability of ash gourd candies supplemented with RP or RE and blanched for different durations was analyzed on the basis of sensory analysis. Significant ($p \leq 0.05$) difference was observed on the color and appearance, texture and mouthfeel, flavor, taste and overall acceptability of different ash gourd candies. Samples blanched for 2.5 min showed the highest values for color and appearance (8.40±0.06), texture and mouthfeel (8.20±0.06), flavor (8.10±0.07), taste (8.50±0.06) and overall acceptability (8.30±0.05). The range analysis (Table 3) showed that blanching was the major contributing factor for color and texture among other factors. This could be due to the softening of the tissues during blanching and allowing higher penetration of the RP or RE in the ash gourd candies giving an attractive appearance. Blanching affects the texture and mouthfeel as it causes softening of the tissues giving better chewability as compared to unblanched candy. No off-flavor was recorded by the panelists in any of the candy samples.

3.2 Effect of rosehip powder (RP) and rosehip extract (RE) on the physicochemical parameters, phytochemical, antimicrobial activity and overall acceptability of ash gourd candy

3.2.1 Effect on physicochemical parameters

The new developed food product must meet the consumer expectations. The effect of RP or RE supplementation on the physico-chemical parameters that describe the acceptability of product is presented in Table 1. The water activity of ash gourd candies supplemented with RP or RE varied from 0.32±0.02 to 0.41±0.01. The lowest water activity was observed in RP based ash gourd

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candies as compared to RE. With increase in the concentration of RP from 2.5 (0.37±0.01) to 5 % (0.35±0.01) the water activity decreased which is due to the water adsorption capacity of the RP which binds the water therefore lowering the water activity [55]. With increase in the concentration of extract from 5 to 10 % irrespective to blanching time, the water activity increased which could have been due to the dilution of the sugar syrup due to the addition of RE. The TSS of ash gourd candies supplemented with RP or RE varied from 60.30±2.49 to 68.50±2.03 °B. The addition of RP or RE did not significantly affect the TSS of ash gourd candies irrespective to the concentration of powder or extract.

The color and texture of candy had significant effect on the acceptability of the food product. In this study, the color of ash gourd candies significantly influenced by the supplementation of RP or RE. The L value of ash gourd candies supplemented with RP or RE from 33.27 to 57.06. With increase in the concentration of RP or RE from 2.5 (40.23) to 5 % (38.64), and 5 (57.06) to 10 % (53.90), respectively, the L value decreased indicates the dark color of candies. The L value was higher for RE based ash gourd candies as compared to RP based ash gourd candies for 2.5 min blanching time. The a* values of RP or RE based ash gourd candies varied from 1.76 to 3.00. The ash gourd candies containing RP or RE, there is increase in a* value as the color of the powder and extract significantly contribute to the a* values. With increase in the concentration of RP or RE the a* values for both RP or RE based ash gourd candies increased. The b* value of candies shows the blueness or greenness in the color. The b* values of RP or RE based ash gourd candies varied from 3.23 to 4.92. The b* values for ash gourd candies supplemented with RP or RE also increased with the increase in the concentration of the powder or extract. With increase in the concentration of RP from 2.5 % (3.87 at 2.5 min blanching time) to 5 % (4.15 at 2.5 min blanching time) and RE from 5 % (3.56 at 2.5 min blanching time) to 10 % (3.77 at 2.5 min

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blanching time), the b* value decreased. The a* and b* values of RE based candies was lower as compared to the RP based ash gourd candies at 2.5 min blanching time. The darkening of the color ash gourd candies supplemented with RP or RE with increase in the concentration of powder or extract is due to the more penetration of the powder particles or the extract into the plant matrix.

As discussed earlier, texture is the major factor contributing to acceptability of product. The hardness of the ash gourd candies supplemented with RP or RE varied from 20.78 to 25.61 N. The hardness of RP based ash gourd candies (23.66 N) was considerably higher as compared to the RE based ash gourd candies (23.18 N) and control samples (23.13 N) at 2.5 min blanching duration. This may be due to the presence of particles of RP in candies which make them hard due to the water binding activity of powders [55]. The texture of the candy is highly dependent on the interaction of various constituents and structural elements at both microscopic and macroscopic levels [56]. The particle size of the powder affects the ability of fibres and proteins to absorb water which affects the chewing behaviour of the candy [56]. With increase in the concentration of RP or RE in the sugars syrup no significant ($p \leq 0.05$) effect was observed on the hardness values of the candies. The springiness values for RP or RE based ash gourd candies varied from 6.64 to 13.71 mm. As shown in Table 1, with increase in the concentration of RP from 2.5 (8.55 mm at 2.5 min blanching time) to 5 % (9.83 mm at 2.5 min blanching time) and extract from 5 (8.28 mm at 2.5 min blanching time) to 10 % (9.94 mm at 2.5 min blanching time) the springiness values increased as compared to control (8.23 mm at 2.5 min blanching time). The cohesiveness and gumminess of RP or RE-based ash gourd candies varied from 0.49±0.01 to 0.72±0.02 and 11.70±0.25 to 15.69±0.02 N, respectively. Chewiness is the required energy to masticate a solid food to a form that is ready for swallowing and is related to the primary parameters of springiness, cohesiveness, and hardness[47]. The chewiness of candies varied from 83.23±2.55 to 215.09±9.30 J. As shown in the Table 1, with

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increase in the concentration of powder or extract from 2.5 % (109.24 J) to 5 % (132.68 J) and 5 % (105.6 J) to 10 % (133.98 J) respectively for 2.5 min blanched samples, there was an increase in the values of chewiness.

3.2.2 Effect on bioactive parameters

The ash gourd candies developed with the addition of RP or RE had an increased bioactive compound as shown in Table 2. The bioactive composition of RP or RE based ash gourd candies was determined in terms of total phenolic and flavonoid content. The total phenolic and flavonoids content values ranged from 83.1 to 165.4 mg/100g and 41.2 to 108.4 mg/100g, respectively. Among RP and RE based ash gourd candy blanched for 2.5 min, the increase in the total phenolic and flavonoids content was more in case of powder (63.3 and 22.1 %, respectively) as compared to extract (42.7 and 13.6 %, respectively) this is because powder contains high amount of phytochemicals as compared to extract, therefore contributing more phytochemicals to the ash gourd candy. This is because powder is a concentrated form of plant bioactive compounds whereas during extract preparation, heat treatment leads to the destruction of heat labile compounds this shortcoming is the basis of different extraction techniques that have been developed for efficient extraction of bioactive compounds from their solid/powder form [57].

The antioxidant activity of RP or RE based ash gourd candies was determined in terms of DPPH radical scavenging activity, FRAP and MCA. The antioxidant activity values of RP and RE based ash gourd candies ranged from 24.55±0.22 to 32.14±1.01 % (DPPH), from 1.38±0.05 to 3.98±0.03 mmol/g (FRAP) and 19.50±0.47 to 21.07±0.26 µmol/g (MCA). With increase in the concentration of RP from control to 2.5 % for ash gourd candies blanched for 2.5 min, the antioxidant activity increased by 38.2 % (DPPH), 198.2 % (FRAP) and 19.8 % (MCA). With

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further increase in the concentration of powder from 2.5 to 5 %, the antioxidant activity also increased by 7.3 % (DPPH), 39.38 % (FRAP) and 2.1 % (MCA). The results are consistent with [58] who studied the antioxidant properties of date jam by incorporating pomegranate peel powder at different levels (0-6 %) and observed that with increase in pomegranate peel concentration antioxidant activity of jam increased. Similarly, the antioxidant activity of RE based ash gourd candies also increased with increase in the concentration of RE. As compared to control when the concentration of extract increased from 0 to 5 %, the antioxidant activity of RE based candy samples increased by 31.6 % (DPPH), 38.4 % (FRAP) and 15.5 % (MCA). With further increase in RE concentration from 5 to 10 %, the antioxidant activity increased by 2.6 % (DPPH), 36.1 % (FRAP) and 0.5 % (MCA). However, the increase in the antioxidant activity was higher for the RP based candy samples as compared to RE based candy samples. Among RP and RE based ash gourd candies blanched for 2.5 min, the increase in antioxidant activity was more in samples containing 2.5 % RP as compared to 5 % RE based ash gourd candies as shown in Table 2. These results indicated that RP or RE to be a potential ingredient for the development of healthy food products. [40] also observed the same trend in antioxidant activity of ginger candy incorporated with beet root extract at different concentrations (0-10 %). The antioxidant activity of RP or RE samples is due to the presence of abundant polyphenols (myricetin, rutin, catechin, quercetin, vanillic acid, syringic acid, gallic acid, ellagic acid, protocatechuic acid) [59].

The antidiabetic activity of ash gourd candies supplemented with RP or RE varied from 10.98 to 14.54 %. The highest antidiabetic activity was recorded for the samples containing 5 % RP (14.54 %) and 10 % RE (14.22 %) blanched for 2.5 min. The antidiabetic activity of RP and RE based ash gourd candy samples increased with the addition of 2.5 % powder and 5 % extract as compared to control by 51.5 and 50.4 %, respectively. With increase in the concentration of

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powder from 2.5 to 5 % and extract from 5 to 10 %, the antidiabetic activity increased by 3.7 and 2.2 % respectively for 2.5 min blanched samples. The maximum increase in the antidiabetic activity was recorded for samples containing 2.5 % RP (51.5 %) as compared to 5 % RE (50.4 %) for 2.5 min blanched samples.

3.2.3 Antimicrobial activity

The antimicrobial activity of ash gourd candies supplemented with RP or RE was determined against *E. coli, B. cereus, C. perfringens, L. mesenteroides* and *P. cartovorum* as zone of inhibition (mm). It was found that the effect of blanching and addition of RP or RE had significant ($p \leq 0.05$) effect on the antimicrobial activity of candies (Table 4). Against all the microorganisms, samples blanched for 2.5 min were most effective in suppressing their growth as compared to 5 min blanched samples and unblanched samples as shown in Table 4. Among different concentrations of powder and extract, the samples containing 5 % RP showed maximum inhibition against all the microbes. The maximum inhibition against *E. coli*, *B. cereus*, *C. perfringens*, *L. mesenteroides* and *P. cartovorum* was shown by 5 % RP (16, 23, 25, 26 and 21 mm, respectively) and lowest was shown by control sample (4, 8, 10, 14 and 5 mm, respectively). The results verify that the candies blanched for 2.5 min containing 5 % RP retains the highest amount of phytochemicals which inhibit the microorganisms with highest zone of inhibition. Antibacterial activity of rosehips is due to the presence of polyphenols especially flavanols and ellagitannins [60,61].

3.2.4 Effect on overall acceptability

The supplementation of RP and RE enhanced the acceptability of candy. The ranking analysis (Table 3) has shown that the concentration of powder showed the highest effect on the flavor, taste and overall acceptability of the ash gourd candy. The RP was more effective in

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imparting the characteristic taste and flavor to candy as compared to RE. The highest flavor (8.40±0.08), taste (8.45±0.07) and overall acceptability (8.23±0.06) was recorded at 2.5 % RP concentration. The reason for the high overall acceptability of the RE samples as compared to control could be the enhanced nutritional quality of the RE samples as attributed by the color and appearance of the samples (brown) as compared to control (white). Incorporation of RP and RE to the candies masked the sweetness of the candies with a little sour taste giving a new taste to the candies. Blanching also had effect on the texture of the candies, however its contribution in determining the overall acceptability was less as compared to rosehip incorporation (Table 3).

3.3 Molecular characterization

The FTIR spectra of ash gourd candies supplemented with RP or RE and blanched for different time durations is given in Fig 1. The FTIR spectra of control candies blanched for 0, 2.5 and 5 min (Fig 1a); all the candies blanched for 2.5 min (Fig 1b) and optimised candies blanched for 2.5 min (Fig 1c) were compared to determine the qualitative effect of blanching and changes in the functional groups of candy samples incorporated with different concentrations of RE and RP. The peaks in the range of 1000 to 1250 cm^{-1} corresponds to phenols and peaks in the range of 3000 to 3500 cm^{-1} corresponds to O-H stretching which is present in water and carboxylic acid [62]. The absorption peak at 1600 cm^{-1} representing C=C group and peaks in the wavelength 1150-1010 cm^{-1} showing presence of C-O group, the presence of these groups is characteristic of catechins and have also been reported by [24,60]. The infrared spectra revealed the presence of different functional groups, suggesting that supplementation with RP and RE in combination with blanching treatment influenced the chemical characteristics of ash gourd candy. It is clear from the spectra (Fig 1a) that 2.5 min blanched samples retained more bioactive compounds than

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samples blanched for 5 min. In 2.5 min blanched samples containing RP and RE, additional functional groups between 1000 and 1300 cm^{-1} indicates the presence of phenolic groups [63]as compared to control (Fig 1b). It is also clear from the spectra shown in Fig 1c, that candies containing 5 % RP and 10 % RE had no difference in the presence of functional groups and the mode of application and concentrations did not affect the qualitative functionality of the product [40].

3.4 Structural characterization

The structural analysis was conducted to study the effect of blanching on the microstructure. Alteration in the microstructure of blanched ash gourd candies is clearly visible from Fig. 2 as compared to the control ash gourd candy which shows intact matrix and even cell structure. The thermal energy produced in the plant matrix due to the blanching would have altered the tissue structure causing it to soften, accompanied by cell wall disintegration and formation of cracks and pores [41]. As compared to the unblanched samples, blanched samples possessed uneven and denser surface with porous structure. The SEM images (Fig. 2) of 2.5 min blanched samples indicate that heat treatment may have led to the release of bound phytochemicals contributing to the enhanced antioxidant activity. However, blanching for 5 min would have caused softening of the tissues to the extent of forming highly irregular surface and opening of the plant matrix which may have resulted in the loss of phytochemicals due to leaching[64].

3.5 PCA analysis

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The 2-D biplots further help in understanding the distribution, clustering, and relationships among treatments and response variables. The biplot for RP treatments (Fig 3a) shows grouping of phytochemical parameters (such as antioxidant activity, TPC and related parameters) are associated with the 2.5 min blanched samples containing 5 % RP, as these samples are positioned in the direction of these variable vectors. In contrast, sensory attributes (including overall acceptability) show strong association with the 2.5 min blanched samples containing 2.5 % RP, suggesting higher consumer preference at this blanching duration and rosehip concentration. The biplot explains 81.56 % of the total variance, indicating a good representation of the dataset.

For RE treatments (Fig. 3b), the biplot reveals that phytochemical properties, particularly antioxidant and antidiabetic activities, are closely associated with the 2.5 min blanched samples containing 10 % RE, as these samples lie along the direction of the respective variable loadings. Meanwhile, sensory attributes are more closely aligned with the 2.5 min blanched samples containing 5 % RE, indicating better overall acceptability for this treatment. The cumulative variance explained by the first two principal components is 86.54 %, reflecting a strong model fit.

Overall, the blanching duration 2.5 min appears to be optimal across both RP and RE treatments as also supported by statistical analysis; balancing enhanced phytochemical properties and desirable sensory characteristics, while control samples (C) are generally positioned away from these favourable attribute vectors, indicating comparatively lower functional and sensory performance.

4. Conclusion

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By supplementation of rosehip in ash gourd candy, it was possible to enhance the bioactive compounds of the confectionery product. In addition, RP or RE incorporation enhanced the acceptability of ash gourd candies. The quality parameters of ash gourd candy were significantly ($p \leq 0.05$) affected by the blanching conditions. The SEM analysis indicates the visible effect of blanching on the structure of ash gourd candy. The FTIR spectra shows the presence of functional groups and antimicrobial results verified the quantitative analysis indicating that candies blanched for 2.5 min containing 5 % RP and 10 % RE are most suitable in terms of phytochemical potential. Sensory evaluation identified 2.5 min blanched candy supplemented with 2.5 % RP and 5 % RE as the most preferred samples. The PCA analysis was helpful in the optimization of samples. The current study shows that the potential of RP or RE to be supplemented to candy for the improvement of nutritional value while maintaining the consumer acceptability. This research demonstrates the potential of valorising waste from rosehip industry and provides valuable information for designing the best conditions for the retention and enhancement of bioactive potential of ash gourd candy, therefore, promoting circular bioeconomy, sustainable production systems and contributing to SDG 2 and 12. However, future studies should assess the phytochemical profile using advance techniques such as HPLC and LC–MS in order to identify and characterize individual phenolic compounds responsible for the observed functional properties along with evaluating the storage stability, microbial quality and shelf-life to determine the practical applicability and commercial viability of the developed candy.

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Data Availability: The data supporting the results of this study are included in the manuscript. Product figures and tables for eigenvalues and loading values, are provided in the supplementary information.

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DOI: 10.1039/D6FB00107F

References

1. N. G. H. I. Kavithani, I. Wickramasinghe and S. M. T. A Maralanda, Impact of sugar replacement by non-centrifugal cane-sugar on physicochemical, antioxidant, and phenolic content of confectionery product, *Food Chem. Adv.*, 2024, 4, 100604.

2. E. Pineda, M. Gressier, D. Li, T. Brown, S. Mounsey, J. Olney and F. Sassi, Effectiveness and policy implications of health taxes on foods high in fat, salt, and sugar, *Food Policy*, 2024, 123, 102599.

3. H. B. Rashmi and P. S. Negi, Upcycling Surinam cherry and spine gourd fruit waste: development of anthelmintic jelly candies using fruit extracts, *J. Food Sci. Technol.*, 2024, 61, 1905-1918.

4. Y. P. de Oliveira Nishiyama-Hortense, M. J. de Paula Rossi, V. D. Shimizu-Marin, N. S. Janzantti, S. Gómez-Alonso, R. Da-Silva and E. S. Lago-Vanzela, Jelly candy enriched with BRS Violeta grape juice: Anthocyanin retention and sensory evaluation, *Future Foods*, 2022, 6, 100179.

5. V. Marinelli, A. Lucera, A. L. Incoronato, L. Morcavallo, M. A. Del Nobile and A. Conte. Strategies for fortified sustainable food: The case of watermelon-based candy, *J. Food Sci. Technol.*, 2021, 58, 894-901.

6. B. Bhushan, V. Nanda and N. Jindal, Strategies for processing and valorization of ash gourd byproducts: A comprehensive review, *Food Chem.*, 2025, 473, 143040.

7. P. Gupta, S. Chikkala and P. Kundu, Ash gourd and its applications in the food, pharmacological and biomedical industries, *Int. J. Veg. Sci.*, 2021, 27, 44-53.

8. Y. Bouhile, Y. Guo, B. Wu, J. Dai, C. Song, Z. Pan and H. Ma, Research progress in the application of infrared blanching in fruit and vegetable drying process, *Compr. Rev. Food Sci. Food Saf.*, 2025, *24*, e70103.

View Article Online
DOI: 10.1039/D6FB00107F

9. B. Wu, Y. Ma, Y. Guo, M. Zielinska, K. Gao, C. Song, *et al.*, Research progress in the application of catalytic infrared technology in fruit and vegetable processing, *Compr. Rev. Food Sci. Food Saf.*, 2024, 23, e13291.

10. B. Zhang, Z. Qiu, R. Zhao, Z. Zheng, X. Lu and X. Qiao, Effect of blanching and freezing on the physical properties, bioactive compounds, and microstructure of garlic (Allium sativum L.), *J. Food Sci.*, 2021 *86*, 31-39.

11. V. Sicari, R. Romeo, M. Leporini, T. M., Pellicanò, R., Tundis and M. R. Loizzo, Comparison of traditional hot water and vacuum assisted blanching methods on the physico-chemical quality parameters and antioxidant activity of zucchini (Cucurbita pepo L.) slices, *J. Food Meas. Charact.,* 2022, 16, 281-294.

12. D. Č. Dabić Zagorac, M. M. Fotirić Akšić, V. Glavnik, U. M. Gašić, I. Vovk, Ž. L. Tešić, and M. M. Natić, Establishing the chromatographic fingerprints of flavan-3-ols and proanthocyanidins from rose hip (Rosa sp.) species., *J. Sep. Sci.*, 2020, 43, 1431-1439.

13. A. Kumar, A. Sahal, P. Kumari, I. Hussain, R. Gupta, S. Chaudhary, *et al*., Rosehip (Rosa canina L.): Nutritional Profile, Bioactive Compounds, Extraction, and Applications, *Food Humanit.*, 2025, 100936.

14. H. Sadeghi, E. Karimizadeh, H. Sadeghi, E. Panahi kokhdan, M. Mansourian, K. Abbaszadeh-Goudarzi, *et al*., Protective Effects of Hydroalcoholic Extract of Rosa canina Fruit on Vancomycin-Induced Nephrotoxicity in Rats*, J. Toxicol, 2021*, 5525714.

15. O. R. Negrean, A. C. Farcas, S. A. Nemes, D. E. Cic and S. A. Socaci, Recent advances and insights into the bioactive properties and applications of Rosa canina L. and its by-products, *Heliyon*, 2024, *10*.

View Article Online
DOI: 10.1039/D6FB00107F

16. A. R. Borşa, F. Ranga, M. Fogarasi, A. Borşa, D. C. Vodnar, and C. A. Semeniuc, Valorisation of rosehip waste into a food ingredient–Focus on its colour, carotenoid content, and techno-functional properties, *Appl. Food Res*., 2025, 5, 100999.

17. Y. Monroy, F. Versino, M. A. García and S. Rivero, Ecological packaging: Reuse and recycling of rosehip waste to obtain biobased multilayer starch-based material and PLA for food trays, *Foods*, 2025, 14, 1843.

18. A. R. Borşa, A. Păucean, M. Fogarasi, F. Ranga, A. Borșa, A. E. Tanislav, *et al*., Utilisation of rosehip waste powder as a functional ingredient to enrich waffle cones with fibres, polyphenols, and carotenoids, *Foods*, 2025, 14, 90.

19. A. Lemaire and S. Limbourg, How can food loss and waste management achieve sustainable development goals?, *J. Cleaner Prod.*, 2019, 234, 1221-1234.

20. A. Vignesh, T. C. Amal, A. Sarvalingam and K. Vasanth, Food chemistry advances, *Food Chemistry Advances*, 2024, 5, 100749.

21. Z. Didar, Characterization of white chocolate enriched with co-encapsulated Lactobacillus acidophilus (La-5) and rose hip shell fruit extract: Characterization, probiotic viability during storage, and in vitro gastrointestinal digestion, *Food Sci. Nutr.*, 2024, 12, 890-906.

22. J. Nishad, A. Joshi, S. Sethi, S. G. Rudra, E. Varghese, N. Shankhwar *et al*., Functionalization of ash gourd: Infusion of citrus peel polyphenols through vacuum impregnation, *Food Biosci.*, 2022, 50, 102095.

23. S. Singh, U. Kumar and A. Rai, Process optimization for the manufacture of angoori petha, *J. Food Sci. Technol*., 2014, 51, 892-899.

View Article Online
DOI: 10.1039/D6FB00107F

24. A. Saini, V. Kumar, R. Kaur, S. Kumar, N. Gautam and S. Janghu, Conventional and non-conventional approaches for the extraction of rosehip phytocompounds and its bioactive, structural and antimicrobial characterization, *J. Food Meas. Charact.,* 2024, 18, 2834-2845.

25. Aoac, *Official methods of analysis*, Association of Official Analytical Chemists., Washington D.C., 18th edn., 2017.

26. Z. He, W. Xia, Q. Liu and J. Chen, Identification of a new phenolic compound from Chinese olive (Canarium album L.) fruit, *Eur. Food Res. Technol.*, 2009, 228, 339-343.

27. S. Muzzaffar, W. N. Baba, N. Nazir, F. A. Masoodi, M. M. Bhat and R. Bazaz, Effect of storage on physicochemical, microbial and antioxidant properties of pumpkin (Cucurbita moschata) candy, *Cogent Food Agric*., 2016, 2, 1163650.

28. F. Abderrahim, S. M. Arribas, M. C. Gonzalez and L. Condezo-Hoyos, Rapid high-throughput assay to assess scavenging capacity index using DPPH, *Food Chem*., 2013, 141, 788-794.

29. K. Pyrzynska and A. Pękal, Application of free radical diphenylpicrylhydrazyl (DPPH) to estimate the antioxidant capacity of food samples, *Anal. Methods*, 2013, 5, 4288-4295.

30. H. R. de Moraes Barros, T. A. P. de Castro Ferreira and M. I. Genovese, Antioxidant capacity and mineral content of pulp and peel from commercial cultivars of citrus from Brazil, *Food chem.,* 2012, 134, 1892-1898.

31. L. L. Canabady-Rochelle, C. Harscoat-Schiavo, V. Kessler, A. Aymes, F. Fournier and J. M. Girardet, Determination of reducing power and metal chelating ability of antioxidant peptides: Revisited methods., *Food Chem.*,2015, 183, 129-135.

32. J. N. Lalpara, M. D. Vachhani, S. D. Hadiyal, S. Goswami and G. G. Dubal, Synthesis and in vitro antidiabetic screening of novel dihydropyrimidine derivatives, *Russ. J. Org. Chem.*, 2021, 57, 241-246.

View Article Online
DOI: 10.1039/D6FB00107F

33. A. Gupta, R. Kumar and A. K. Pandey, Antioxidant and antidiabetic activities of Terminalia bellirica fruit in alloxan induced diabetic rats, *S. Afr. J. Bot.*, 2020, 130, 308-315.

34. H. Ali, P. J. Houghton and A. Soumyanath, α-Amylase inhibitory activity of some Malaysian plants used to treat diabetes; with particular reference to Phyllanthus amarus, *J. Ethnopharmacol.*, 2006, 107, 449-455.

35. I. E. Cock and S. Mohanty, Evaluation of the antibacterial activity and toxicity of Terminalia ferdinandia fruit extracts, *Pharmacogn. J*, 2011, 3, 72-79.

36. C. Perez, Antibiotic assay by agar-well diffusion method, *Acta Biol Med Exp*, 1990, 15, 113-115.

37. R. Kaur, V. Kumar, P. Aggarwal and G. Singh, Valorization of citrus residue for the development of phytochemical enriched candy: textural, bioactive, molecular, and structural characterization, *Biomass Convers. Biorefin*., 2025, 15, 2805-2816.

38. M. Tapia-Salazar, I. G. Arévalo-Rivera, M. Maldonado-Muñiz, L. E. Garcia-Amezquita, M. G. Nieto-López, D. Ricque-Marie, *et al*., The dietary fiber profile, total polyphenol content, functionality of Silvetia compressa and Ecklonia arborea, and modifications induced by high hydrostatic pressure treatments, *Food Bioprocess Technol,* 2019, 12, 512-523.

39. T. Oshima, K. Kato and T. Imaizumi, Effects of blanching on drying characteristics, quality, and pectin nanostructures of dried cut-persimmons, *Lwt*, 2021, *143*, 111094.

40. V. Kumar, R. Kushwaha, A. Goyal, B. Tanwar and J. Kaur, Process optimization for the preparation of antioxidant rich ginger candy using beetroot pomace extract, *Food Chem.*, 2018,*245*, 168-177.

41. R. Chandel, V. Kumar, R. Kaur, S. Kumar, M. S. Gill, R. Sharma, et al., Functionality enhancement of osmo-dried sand pear cubes using different sweeteners: quality, bioactive, textural, molecular, and structural characterization*, J. Food Meas. Charact.*, 2023, 17, 3709-3721.

View Article Online
DOI: 10.1039/D6FB00107F

42. M. Tang, H. Sun, Z. Zhang, J. Zhao, J. Cao, K. Thakur and S. He, Evaluation of hot water and microwave blanching on qualities and sensory characteristics of water dropwort (Oenanthe javanica DC.), *J. Food Process. Preserv.*, 2019, 43, e14104.

43. S. Mandliya, J. Majumdar, S. Misra, M. Pattnaik and H. N. Mishra, Evaluation of dry microwave and hot water blanching on physicochemical, textural, functional and organoleptic properties of Indian gooseberry (Phyllanthus emblica), *J. Food Meas. Charact.*, 2023, 17, 2881-2891.

44. M. Warner, B. L. Thiel and A. M. Donald, The elasticity and failure of fluid-filled cellular solids: theory and experiment, *Proc. Natl. Acad. Sci. U. S. A.*, 2000, 97, 1370-1375.

45. A. J. Rosenthal, Texture profile analysis–how important are the parameters?, *J. Texture Stud.*, 2010, 41, 672-684.

46. M. Shafiur Rahman and A. I. Al-Mahrouqi, Instrumental texture profile analysis of gelatin gel extracted from grouper skin and commercial (bovine and porcine) gelatin gels, *Int. J. Food Sci. Nutr.*, 2009, 60, 229-242.

47. A. S. Szczesniak, Texture is a sensory property, *Food Qual. Prefer*., 2002, 13, 215-225.

48. A. Sulaiman, M. J. Soo, M. Farid and F. V. Silva, Thermosonication for polyphenoloxidase inactivation in fruits: Modeling the ultrasound and thermal kinetics in pear, apple and strawberry purees at different temperatures, *J. Food Eng.*, 2015, 165, 133-140.

49. S. Bhat, C. S. Saini and H. K. Sharma, Changes in total phenolic content and color of bottle gourd (Lagenaria siceraria) juice upon conventional and ohmic blanching, *Food Sci. Biotechnol*., 2017, 26, 29-36.

50. T. V. L. Nguyen, T. Y. N. Tran, D. T. Lam, L. G. Bach and D. C. Nguyen, Effects of microwave blanching conditions on the quality of green asparagus (Asparagus officinalis L.) butt segment, *Food Science & Nutrition*, 2019, 7, 3513-3519.

View Article Online
DOI: 10.1039/D6FB00107F

51. T. P. Magangana, N. P. Makunga, O. Amos Fawole and U. L. Opara, Effect of solvent extraction and blanching pre-treatment on phytochemical, antioxidant properties, enzyme inactivation and antibacterial activities of 'Wonderful'pomegranate peel extracts, *Processes*, 2021, 9, 1012.

52. B. Das Gupta, A. Kar, S. Singha, S. Gayen, S. Jana, N. Sharma, et al., Metabolite Profiling and Integrated Network Pharmacology Based Mechanism of Benincasa hispida (Thunb.) Cogn. Fruit Against Non-insulin-Dependent Diabetes Mellitus, *Phytochem. Anal.*, 2025, 36, 884-895.

53. M. Oboh, L. Govender, M. Siwela and B. N. Mkhwanazi, Anti-diabetic potential of plant-based pentacyclic triterpene derivatives: Progress made to improve efficacy and bioavailability, *Molecules*, 2021, 26, 7243.

54. E. A. Irondi, J. K. Akintunde, S. O. Agboola, A. A. Boligon and M. L. Athayde, Blanching influences the phenolics composition, antioxidant activity, and inhibitory effect of Adansonia digitata leaves extract on α-amylase, α-glucosidase, and aldose reductase, *Food Sci. Nutr.*, 2017, 5, 233-242.

55. E. Sánchez-Zapata, J. Fernández-López, M. Peñaranda, E. Fuentes-Zaragoza, E. Sendra, E. Sayas and J. A. Pérez-Alvarez, Technological properties of date paste obtained from date by-products and its effect on the quality of a cooked meat product, *Food Res. Int.*, 2011, 44, 2401-2407.

56. A. Periche, A. Heredia, I. Escriche, A. Andrés and M. L. Castelló, Optical, mechanical and sensory properties of based-isomaltulose gummy confections, *Food Biosci.,* 2014, 7, 37-44.

57. I. I. Muhamad, N. D. Hassan, S. N. Mamat, N. M. Nawi, W. A. Rashid and N. A. Tan, Extraction technologies and solvents of phytocompounds from plant materials: physicochemical characterization and identification of ingredients and bioactive compounds from plant extract using various instrumentations, in *Ingredients Extraction by Physicochemical Methods in Food*, Academic Press, 2017, pp. 523–560.

View Article Online
DOI: 10.1039/D6FB00107F

58. S. A. Ali, N. K. Alqahtani, T. M. Alnemr and S. M. Saleh, Pomegranate peel powder for the sustainable development of a novel date jam: Texture profile, color parameters, microstructure features, antioxidant activity, and sensory properties, *LWT*, 2025, 217, 117403.

59. S. Jiménez, N. Jiménez-Moreno, A. Luquin, M. Laguna, M. J. Rodríguez-Yoldi and C. Ancín-Azpilicueta, Chemical composition of rosehips from different Rosa species: An alternative source of antioxidants for the food industry, *Food Additives & Contaminants: Part A*, 2017, 34, 1121-1130.

60. M. M. Alves, C. Batista, D. Mil-Homens, L. Grenho, M. H. Fernandes and C. F. Santos, Enhanced antibacterial activity of Rosehip extract-functionalized Mg (OH) 2 nanoparticles: An in vitro and in vivo study*, Colloids Surf., B*, 2022, *217*, 112643.

61. J. Milala, L. Piekarska-Radzik, M. Sójka, R. Klewicki, B. Matysiak and E. Klewicka, Rosa spp. extracts as a factor that limits the growth of Staphylococcus spp. bacteria, a food contaminant, *Molecules*, 2021, 26, 4590.

62. S. R. Gade, M. Meghwa, P. K. Prabhakar and A. M. Giuffrè, A comparative study on the nutritional, antioxidant, thermal, morphological and diffraction properties of selected cucurbit seeds, *Agronomy*, 2022, 12, 2242.

63. A. A. Jovanović, B. Balanč, P. M. Petrović, M. Volić, D. Micić, J. Živković and K. P. Šavikin, Design and characterization of liposomal-based carriers for the encapsulation of rosa canina fruit extract: in vitro gastrointestinal release behavior, *Plants*, 2024, 13, 2608.

64. J. Wang, Y. Chen, H. Wang, S. Wang, Z. Lin, L. Zhao and H. Xu, Ethanol and blanching pretreatments change the moisture transfer and physicochemical properties of apple slices via microstructure and cell-wall polysaccharides nanostructure modification, *Food Chem.*, 2022, *381*, 132274.

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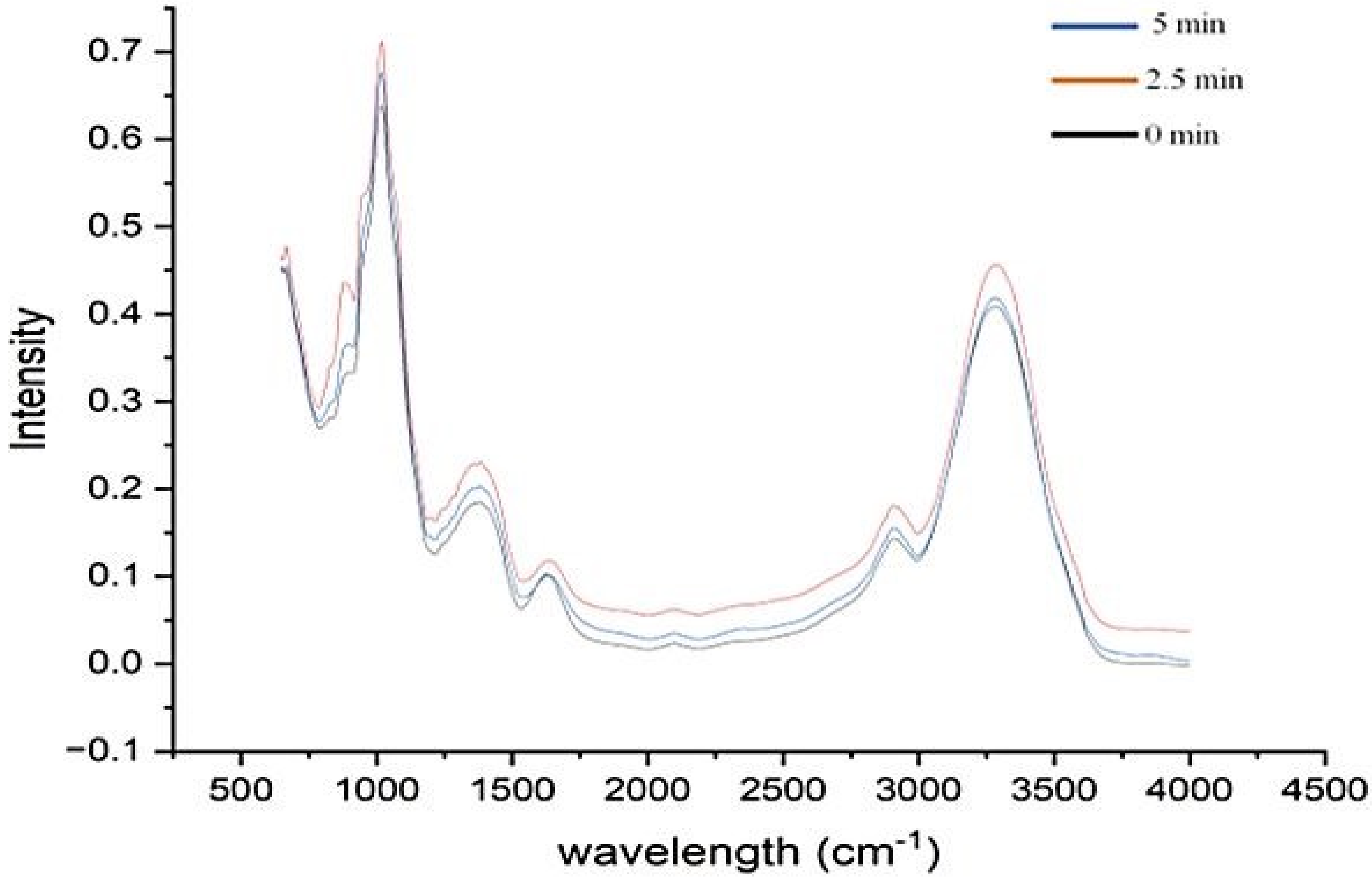
DOI: 10.1039/D6FB00107F

(a)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2.5 min
0 min
Intensity
wavelength (cm-1)
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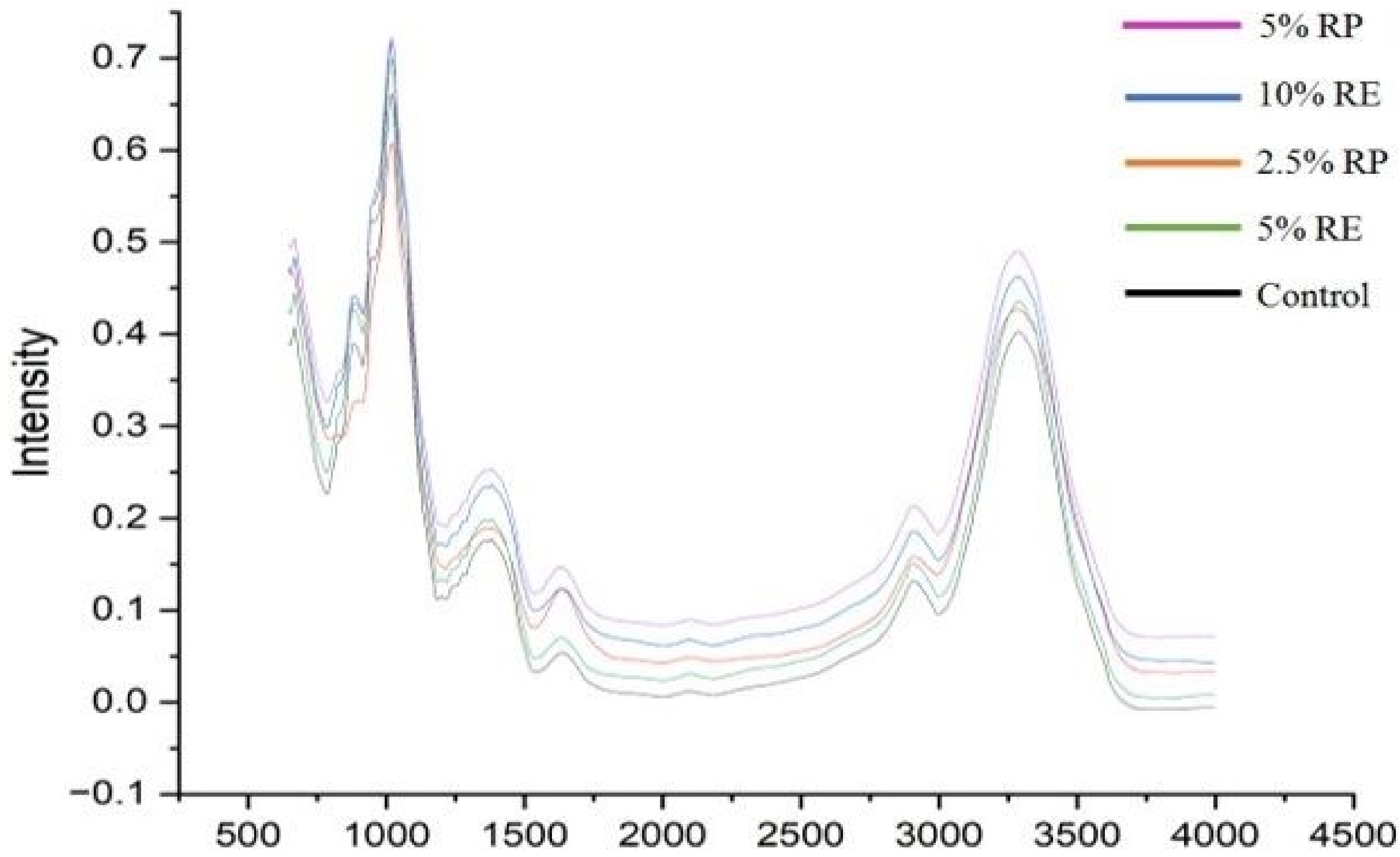
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
500
1000
1500
2000
2500
3000
3500
4000
4500

(b)


5% RP
10% RE
2.5% RP
5% RE
Control
Intensity
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
500
1000
1500
2000
2500
3000
3500
4000
4500

(c)

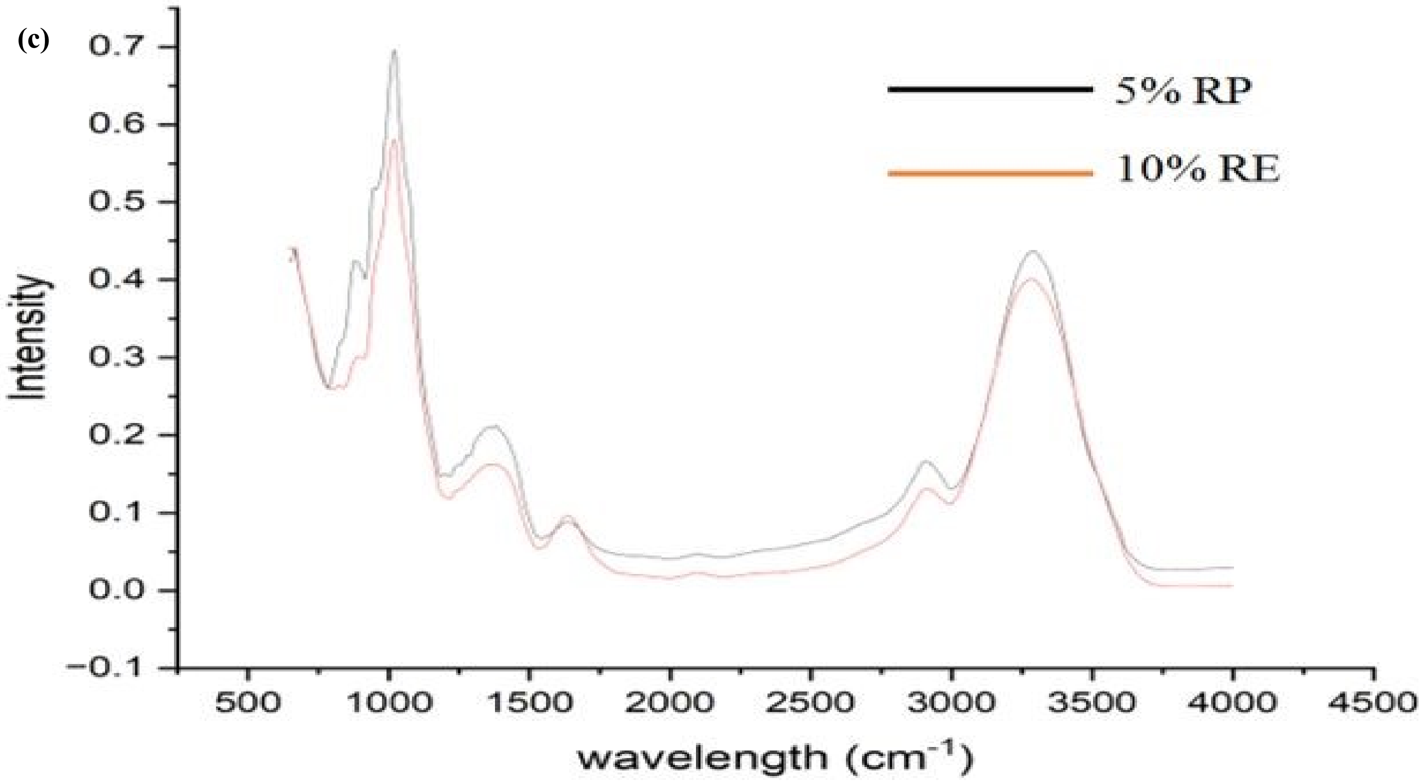


Fig. 1: FTIR characterization of ash gourd candies (a) control samples blanched for 0, 2.5 and 5 min (b) candies supplemented with rosehip powder (RP) and rosehip extract (RE) blanched for 2.5 min (c) optimized ash gourd candies supplemented with rosehip powder (RP) and rosehip extract (RE) blanched for 2.5 min

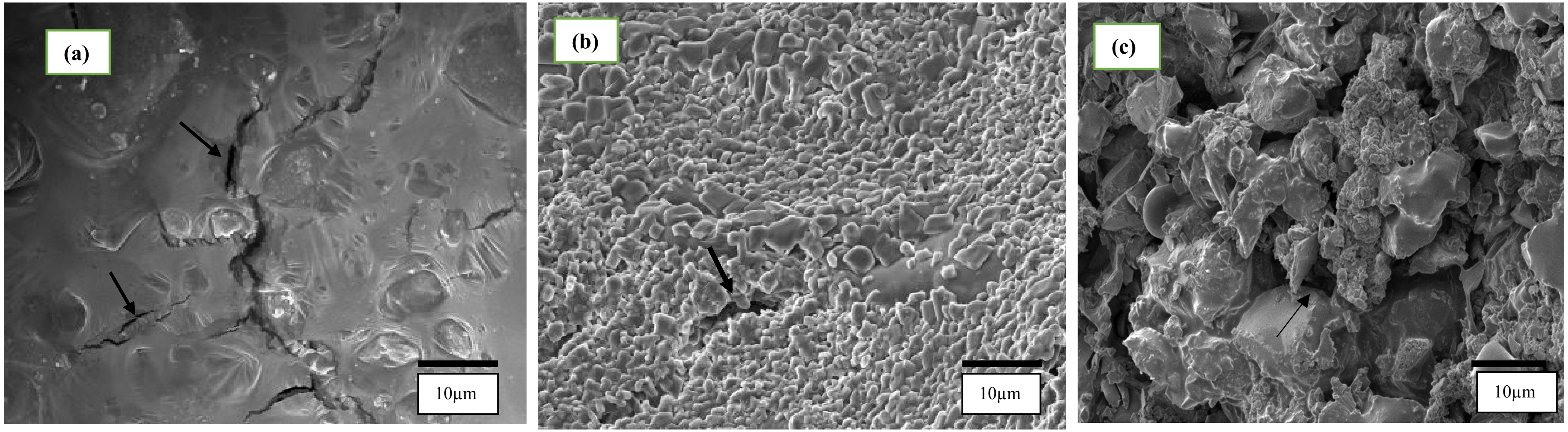
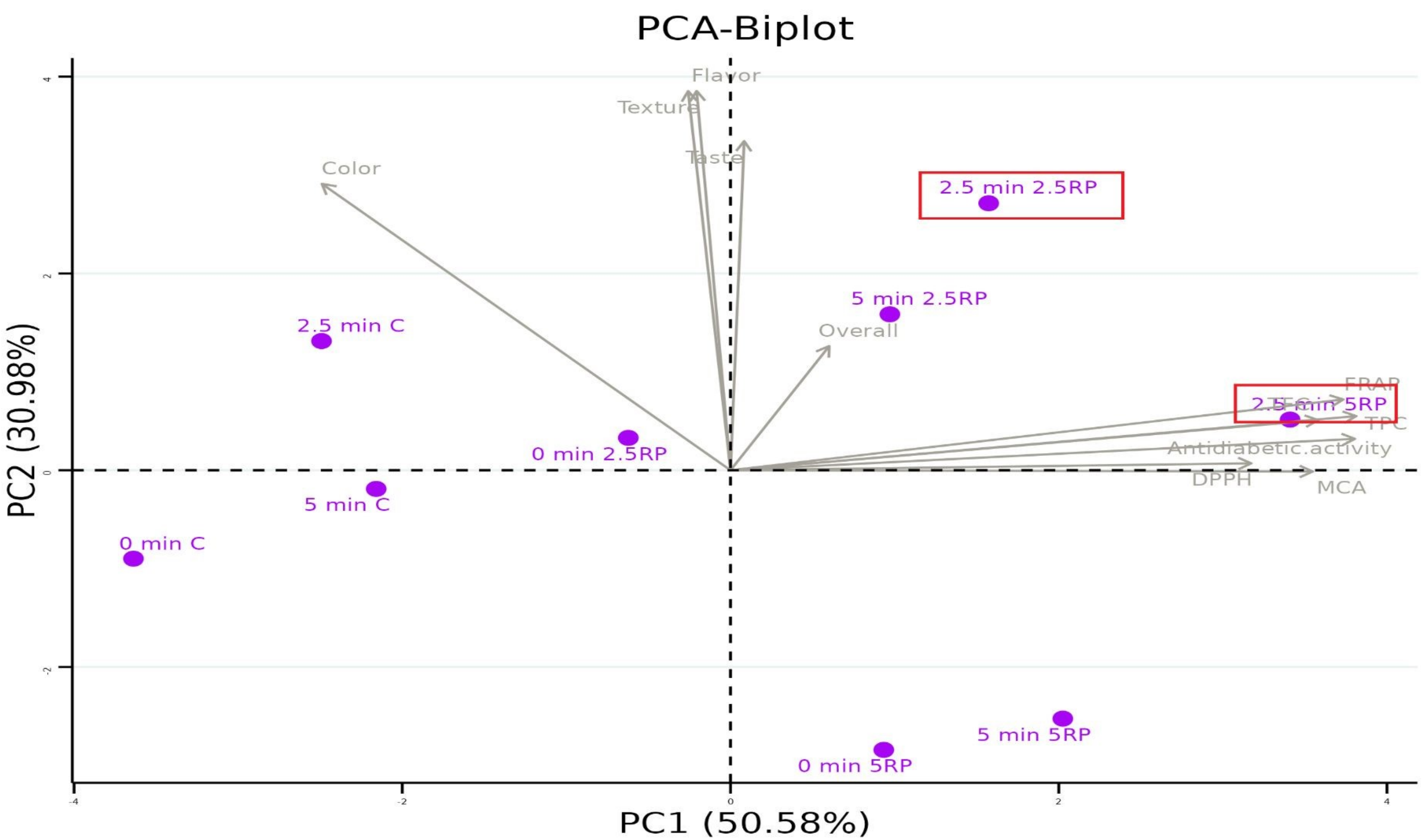


Fig 2: Structural characterization of control ash gourd candies at different blanching time (a) 0 min (b) 2.5 min, (c) 5 min at × 500 magnification

(a)


PCA-Biplot
PC2 (30.98%)
PC1 (50.58%)
4
2
0
-2
-4
-2
0
2
4
Flavor
Texture
Taste
Color
Overall
FRAP
TPC
Antidiabetic.activity
DPPH
MCA
2.5 min 2.5RP
5 min 2.5RP
2.5 min C
0 min 2.5RP
5 min C
0 min C
2.5 min 5RP
5 min 5RP
0 min 5RP

(b)

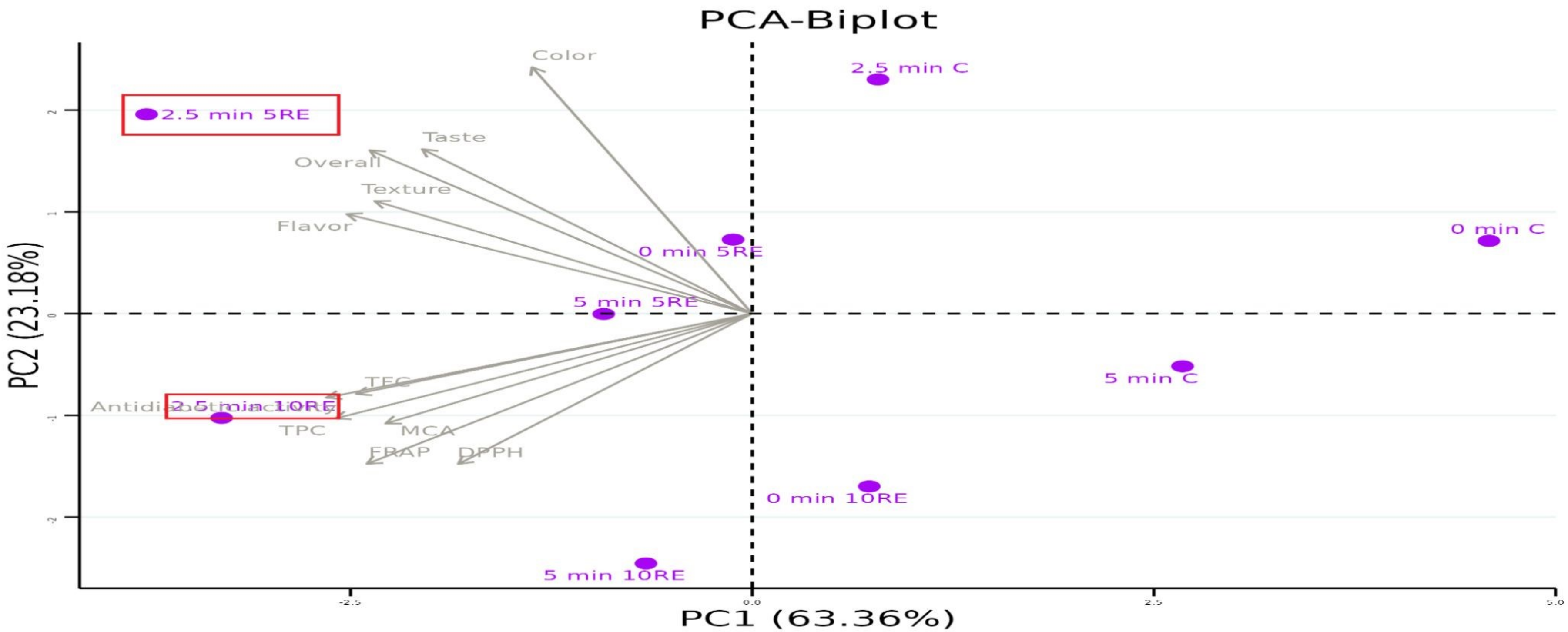


Fig 3: PCA analysis of phytochemical and sensory parameters affecting the rosehip incorporated ash gourd candy preparation (a) biplot for RP treatments and (b) biplot for RE treatments blanched for 0, 2.5 and 5 min. Legend for variables:Control (C), RP (rosehip powder), RE (rosehip extract), Total Phenolic Content (TPC), Total Flavenoid Content (TFC), DPPH (2,2-diphenyl-1-picryl hydrazyl), Ferric reducing antioxidant power (FRAP), Metal chelation activity (MCA).

Table 1: Physicochemical properties of ash gourd candy supplemented with rosehip powder (RP) and rosehip extract (RE)

Blanching time	0 min					2.5 min					5 min				
Sample	**Control**	**RP**		**RE**		**Control**	**RP**		**RE**		**Control**	**RP**		**RE**	
Concentration		**2.5%**	**5%**	**5%**	**10%**		**2.5%**	**5%**	**5%**	**10%**		**2.5%**	**5%**	**5%**	**10%**
Water activity	0.42±0.02^{aA}	0.39±0.01^{bcA}	0.38±0.01^{cdA}	0.41±0.01^{aA}	0.40±0.01^{bA}	0.37±0.02^{bcB}	0.37±0.01^{abB}	0.35±0.01^{cdB}	0.36±0.01^{bcB}	0.39±0.02^{aB}	0.34±0.01^{aC}	0.33±0.01^{abC}	0.34±0.01^{aC}	0.32±0.02^{bcC}	0.34±0.02^{aC}
TSS (°B)	60.20±1.29^{aC}	60.30±2.49^{aC}	61.70±0.55^{aC}	60.30±2.38^{aC}	61.40±0.16^{aC}	64.19±0.46^{aB}	66.00±1.25^{aB}	65.10±0.64^{aB}	65.40±0.58^{aB}	65.80±2.31^{aB}	68.30±2.11^{aA}	68.50±2.03^{aA}	68.00±1.65^{aA}	67.70±0.24^{aA}	67.00±2.95^{aA}
Color															
L	57.12±1.08^{aA}	41.32±0.92^{cA}	40.00±0.50^{cA}	56.12±2.42^{abA}	54.55±0.24^{bA}	60.34±2.55^{aA}	40.23±0.46^{dB}	38.64±1.36^{dA}	57.06±1.09^{bA}	53.90±0.77^{cA}	60.46±2.50^{aA}	36.51±1.41^{dC}	33.27±0.36^{eB}	56.05±0.35^{bA}	52.13±1.03^{cA}
a*	2.50±0.04^{abA}	2.48±0.05^{abcA}	2.60±0.11^{aB}	2.35±0.02^{cA}	2.37±0.08^{bcA}	1.55±0.06^{dB}	2.18±0.07^{aB}	2.25±0.06^{aC}	1.76±0.07^{cC}	1.87±0.02^{bC}	1.27±0.04^{eC}	2.41±0.10^{bA}	3.00±0.01^{aA}	2.08±0.04^{dB}	2.26±0.03^{cC}
b*	4.89±0.02^{aA}	4.27±0.12^{bB}	4.92±0.15^{aA}	3.23±0.04^{dC}	3.76±0.12^{cB}	3.18±0.09^{dC}	3.87±0.06^{bC}	4.15±0.06^{aB}	3.56±0.02^{cB}	3.77±0.09^{bB}	3.87±0.12^{dB}	4.76±0.02^{aA}	4.87±0.13^{aA}	4.21±0.02^{cA}	4.42±0.03^{bA}
Texture															
Hardness (N)	24.91±0.44^{aA}	25.57±0.16^{aA}	25.61±0.01^{aA}	25.01±0.81^{aA}	25.03±0.76^{aA}	23.13±0.91^{aB}	23.66±0.74^{aB}	23.68±0.25^{aB}	23.18±1.02^{aB}	23.23±0.41^{aB}	21.35±0.11^{abC}	20.78±0.88^{bC}	21.78±0.48^{aC}	21.42±0.09^{abC}	21.50±0.13^{abC}
Springiness (mm)	6.94±0.20^{bA}	6.64±0.07^{cA}	7.24±0.22^{bA}	7.06±0.14^{bA}	7.89±0.08^{aA}	8.23±0.06^{bB}	8.55±0.04^{bB}	9.83±0.05^{aB}	8.28±0.04^{bB}	9.94±0.44^{aB}	12.25±0.01^{cC}	12.96±0.02^{bC}	13.71±0.06^{aC}	13.49±0.07^{aC}	12.72±0.35^{bC}
Cohesiveness	0.47±0.01^{cA}	0.49±0.01^{cA}	0.53±0.01^{aA}	0.49±0.01^{cA}	0.51±0.01^{bA}	0.56±0.01^{abcB}	0.54±0.00^{cB}	0.56±0.01^{abB}	0.55±0.02^{bcB}	0.58±0.01^{aB}	0.68±0.02^{bC}	0.70±0.00^{abC}	0.72±0.02^{aC}	0.69±0.01^{abC}	0.71±0.01^{abC}
Gumminess (N)	11.70±0.25^{cC}	12.53±0.02^{bB}	13.57±0.48^{aB}	12.25±0.02^{bcB}	12.76±0.52^{bB}	12.95±0.41^{abB}	12.77±0.23^{bB}	13.49±0.06^{aB}	12.75±0.11^{bB}	13.47±0.43^{aB}	14.51±0.08^{cA}	14.54±0.60^{cA}	15.69±0.02^{aA}	14.78±0.12^{bcA}	15.26±0.24^{abA}
Chewiness (J)	81.25±2.02^{cC}	83.23±2.55^{bcC}	98.27±1.68^{aC}	86.52±3.03^{bC}	100.72±2.17^{aC}	106.60±4.32^{bB}	109.24±3.58^{aB}	132.68±3.58^{aB}	105.6±2.09^{bB}	133.98±4.35^{aB}	177.84±5.28^{cA}	188.52±4.85^{bA}	215.09±9.30^{aA}	199.38±7.38^{bA}	194.17±4.20^{bA}

Mean value ± standard deviation of three replicates; small letters (a, b, c…) within row show a significant difference between different candy samples at a specific blanching time, capital letters (A, B, C…) within row show a significant difference between the different blanching time for specific sample.

Table 2: Phytochemical properties of ash gourd candy supplemented with rosehip powder (RP) and rosehip extract (RE)

Blanching time	0 min					2.5 min					5 min				
Sample	Control	RP		RE		Control	RP		RE		Control	RP		RE	
Concentration		2.5%	5 %	5 %	10%		2.5%	5%	5%	10%		2.5%	5%	5%	10%
TPC (mg/100g)	56.7± 2.04^{aC}	90.7± 2.01^{cC}	117.1± 1.93^{eC}	83.1± 1.04^{bC}	99.5± 3.11^{dC}	75.1± 6.04^{aA}	139.0± 3.07^{cA}	165.4± 7.91^{eA}	121.5± 3.32^{bA}	147.9± 2.74^{dA}	65.9± 2.31^{aB}	119.9± 2.04^{cdB}	122.6± 1.27^{dB}	102.3± 2.45^{bB}	118.7± 2.10^{cB}
TFC (mg/100g)	21.4± 1.31^{aC}	44.1± 1.11^{cC}	57.2± 1.73^{eC}	41.2± 1.17^{bC}	50.9± 1.74^{dC}	53.0± 1.02^{aA}	76.9± 2.11^{cA}	108.4± 4.57^{eA}	71.6± 1.15^{bA}	102.3± 3.61^{dA}	41.1± 1.44^{aB}	61.3± 1.90^{bB}	81.9± 2.91^{dB}	51.2± 1.52^{aB}	71.7± 3.64^{cB}
DPPH (%)	8.55± 0.50^{aB}	24.55± 0.22^{bC}	26.35± 1.16^{dC}	23.82± 0.94^{bC}	25.30± 0.38^{cdB}	11.65± 0.87^{aA}	29.93± 1.08^{cA}	32.14± 1.30^{dA}	28.50± 0.36^{bA}	29.23± 1.13^{bcA}	9.46± 0.37^{aB}	27.21± 0.51^{cB}	29.28± 0.55^{eB}	26.59± 0.03^{bB}	28.17± 0.25^{dA}
FRAP (mmol/g)	0.56± 0.02^{aC}	1.38± 0.05^{cC}	1.93± 0.01^{eC}	1.31± 0.03^{bC}	1.61± 0.03^{dC}	1.12± 0.03^{aA}	3.34± 0.14^{dA}	3.98± 0.15^{eA}	1.55± 0.01^{bA}	2.11± 0.07^{cA}	0.95± 0.01^{aB}	2.97± 0.02^{dB}	3.25± 0.12^{eB}	1.48± 0.01^{bB}	1.92± 0.07^{cB}
MCA (µmol/g)	5.86± 0.24^{aB}	19.50± 0.47^{bcA}	19.89± 0.43^{dA}	19.20± 0.07^{bA}	19.56± 0.42^{cdC}	7.22± 0.74^{aA}	20.64± 0.44^{bcA}	21.07± 0.49^{cA}	19.89± 0.80^{bA}	20.04± 0.66^{bcA}	6.01± 0.24^{aB}	20.03± 0.81^{bcA}	20.56± 0.26^{cA}	19.65± 0.17^{bA}	19.88± 0.85^{bcB}
Antidiabetic activity (%)	7.55± 0.26^{aC}	10.98± 0.30^{bC}	12.78± 0.25^{dB}	11.92± 0.11^{cC}	12.35± 0.21^{dC}	9.25± 0.29^{aA}	14.01± 0.55^{bA}	14.54± 0.42^{bA}	13.92± 0.60^{bA}	14.22± 0.39^{bA}	8.12± 0.28^{aB}	12.25± 0.13^{bB}	13.05± 0.15^{eB}	12.65± 0.10^{cB}	13.01± 0.26^{dB}

Mean value ± standard deviation of three replicates; small letters (a, b, c…) within row show significant difference between different candy samples at specific blanching time, capital letters (A, B, C…) within row show significant difference between different blanching time for specific sample; TPC: total phenolic content; TFC: total flavonoid content; DPPH: 2,2-diphenyl-1-picrylhydrazyl; FRAP: Ferric reducing power assay; MCA: Metal chelating activity.

Table 3: Sensory analysis of ash gourd candy supplemented with rosehip powder (RP) and rosehip extract (RE)

Blanching Time			Color and appearance	Texture and mouthfeel	Flavor	Taste	Overall
0 min	**Control**		8.10±0.05^{Ba}	7.90±0.05^{Ba}	7.50±0.05^{Cc}	8.10±0.05^{Cb}	7.90±0.06^{Bb}
	RP	**2.5%**	7.80±0.06^{Bd}	7.70±0.04^{Bb}	7.85±0.08^{Ca}	8.00±0.06^{Cd}	7.84±0.04^{Bb}
		5%	7.70±0.05^{Be}	7.50±0.06^{Bc}	7.10±0.09^{Cd}	7.00±0.05^{Ce}	7.33±0.07^{Bc}
	RE	**5%**	8.00±0.03^{Bb}	7.85±0.05^{Ba}	7.90±0.05^{Ca}	8.40±0.07^{Ca}	8.04±0.08^{Ba}
		10%	7.90±0.05^{Bc}	7.70±0.07^{Bb}	7.65±0.10^{Cb}	8.05±0.06^{Cc}	7.83±0.06^{Bb}
2.5 min	**Control**		8.40±0.06^{Aa}	8.20±0.06^{Aa}	8.10±0.07^{Ac}	8.50±0.06^{Ab}	8.30±0.05^{Ab}
	RP	**2.5%**	8.10±0.04^{Ad}	7.95±0.07^{Ac}	8.40±0.08^{Ab}	8.45±0.07^{Ac}	8.23±0.06^{Ab}
		5%	7.90±0.05^{Ae}	7.70±0.06^{Ad}	7.80±0.07^{Ad}	7.20±0.10^{Ad}	7.65±0.07^{Ad}
	RE	**5%**	8.30±0.02^{Ab}	8.10±0.05^{Ab}	8.60±0.10^{Aa}	8.70±0.05^{Aa}	8.43±0.05^{Aa}
		10%	8.20±0.04^{Ac}	8.00±0.06^{Ac}	8.15±0.05^{Ac}	8.30±0.09^{Ac}	8.16±0.06^{Ac}
5 min	**Control**		8.00±0.04^{Ca}	7.80±0.05^{Ba}	7.70±0.10^{Bc}	8.25±0.05^{Bb}	7.94±0.04^{Bb}
	RP	**2.5%**	7.72±0.03^{Bc}	7.60±0.05^{Cb}	8.10±0.09^{Ba}	8.05±0.07^{Bc}	7.87±0.07^{Bc}
		5%	7.50±0.05^{Cd}	7.30±0.06^{Cc}	7.20±0.07^{Bd}	7.10±0.08^{Bd}	7.28±0.05^{Bd}
	RE	**5%**	7.90±0.03^{Cb}	7.75±0.07^{Ba}	8.05±0.06^{Ba}	8.50±0.06^{Ba}	8.05±0.05^{Ba}
		10%	7.80±0.04^{Cc}	7.65±0.05^{Bb}	7.90±0.05^{Bb}	8.15±0.04^{Bc}	7.88±0.06^{Bc}
Factor	**Level**	**Values**					
A (Powder)	2.50%	K_{A1}	7.87	7.75	8.12	8.17	7.98
	5%	K_{A2}	7.70	7.50	7.37	7.10	7.42
		$\mathbf{R_A}$	**0.17**	**0.25**	**0.75**	**1.07**	**0.56**

B (Extract)	5%	K_{B1}	8.07	7.90	8.18	8.53	8.17
	10%	K_{B2}	7.97	7.78	7.90	8.17	7.95
		$\mathbf{R_B}$	**0.10**	**0.12**	**0.28**	**0.37**	**0.22**
C (Blanching time)	0 min	K_{C1}	7.90	7.73	7.60	7.91	7.79
	2.5 min	K_{C2}	8.18	7.99	8.21	8.23	8.15
	5 min	K_{C3}	7.78	7.62	7.79	8.01	7.80
		$\mathbf{R_C}$	**0.40**	**0.26**	**0.61**	**0.32**	**0.37**
Rank			C>A>B	C>A>B	A>C>B	A>B>C	A>C>B
Major contributing factor			Factor C	Factor C	Factor A	Factor A	Factor A

Mean value ± standard deviation of three replicates; small letters (a, b, c…) within row show significant difference between different candy samples at a specific blanching time, capital letters (A, B, C…) within row show a significant difference between the different blanching time for specific sample. Factor A, B, C and D represents the effect of rosehip powder, rosehip extract, and blanching time, respectively. R_A, R_B, R_C, R_D were the differences between the highest and lowest values of Kij (average value of the respective parameter, i= A,B,C, and j= 1,2,…3) of each sensory parameter.

Table 4: Antimicrobial activity of ash gourd candy supplemented with rosehip powder (RP) and rosehip extract (RE)

Blanching time	0 min					2.5 min					5 min				
Sample / Concentration	Control	RP		RE		Control	RP		RE		Control	RP		RE	
		2.5%	5%	5%	10%		2.5%	5%	5%	10%		2.5%	5%	5%	10%
Microorganisms	**Zone of inhibition (mm)**														
E. coli	4±0.78^{a}	7±0.92^{c}	11±1.16^{e}	6±0.85^{b}	8±1.04^{d}	6±0.73^{a}	10±1.11^{b}	16±1.88^{c}	9±0.96^{b}	13±1.43^{c}	5±0.81^{a}	9±1.02^{bc}	13±1.25^{d}	7±0.89^{ab}	10±1.12^{c}
B. cereus	8±0.95^{a}	14±1.37^{c}	19±2.08^{d}	12±1.18^{b}	16±1.74^{cd}	12±1.06^{a}	17±1.82^{bc}	23±2.24^{d}	14±1.21^{b}	18±1.93^{c}	10±0.98^{a}	16±1.69^{bc}	20±2.11^{c}	13±1.15^{b}	17±1.84^{c}
C. perfringens	10±1.84^{a}	15±1.92^{bc}	18±2.05^{c}	14±1.27^{b}	16±1.78^{bc}	13±1.66^{a}	18±1.95^{bc}	25±2.31^{c}	17±1.74^{ab}	20±2.08^{b}	11±1.72^{a}	16±1.83^{b}	21±2.16^{c}	15±1.24^{b}	18±1.58^{b}
L. mesenteroides	14±1.76^{a}	17±1.91^{ab}	21±2.14^{c}	16±1.68^{ab}	19±1.97^{bc}	17±1.72^{a}	22±1.36^{b}	26±2.28^{c}	19±1.88^{a}	24±2.15^{bc}	15±1.81^{a}	19±1.92^{b}	23±2.06^{c}	18±1.75^{ab}	21±2.03^{bc}
P. cartovorum	5±0.82^{a}	10±1.18^{b}	14±1.29^{c}	8±0.91^{b}	10±1.12^{b}	8±0.86^{a}	16±1.24^{c}	21±2.17^{d}	11±1.03^{b}	14±1.35^{c}	6±0.79^{a}	14±1.27^{c}	17±1.58^{d}	10±0.97^{b}	12±1.18^{bc}

Mean value ± standard deviation of three replicates; small letters (a, b, c…) within the row show significant difference between different candy samples at a specific blanching time.

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Data Availability:

The data supporting the results of this study are included in the manuscript. Product figures and tables for eigenvalues and loading values are provided in the supplementary information.