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Gagan Dip
Department of Food Science and Technology, Punjab Agricultural University, Ludhiana, Punjab, India

Poonam Aggarwal
Department of Food Science and Technology, Punjab Agricultural University, Ludhiana, Punjab, India

Corresponding Author:
Poonam Aggarwal
Department of Food Science and Technology, Punjab Agricultural University, Ludhiana, Punjab, India

Development of plum juice concentrate blended carbonated beverages

Gagan Dip and Poonam Aggarwal

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Abstract
Carbonated beverages infused with fruit flavors are valuable source of vital nutrients, including vitamins, minerals, and various beneficial bioactive compounds. Plums considered as delectable and nutritious addition to fruit based carbonated drinks, providing rich display of essential vitamins, minerals, and potent antioxidants. Their inclusion not only enhances beverage's flavor but also contributes to its health promoting qualities. Plums are furthermore valuable dietary fiber source. Plum juice was obtained through a screw type extraction process and afterward concentrated to a range of 13.62 to 68.60 degrees Brix. Carbonated beverage infused with plum juice concentrate blend was formed and established according to criteria about both biochemical and sensory attributes. For the formulation of carbonated plum beverage, several concentrations of plum fruit concentrate, i.e., 5%, 7.5%, and 10%, were employed in combination with sugar syrup and chilled carbonated water. These variations in concentrate levels were incorporated to fine-tune the beverage's flavor and characteristics. The results indicate that use of 7.5% plum juice concentrate in the carbonated beverage formulation yielded greater sensory quality while retaining a significant quantity of biochemical attributes.

Keywords: Anthocyanins, antioxidant activity, CIE color value, juice extraction

1. Introduction
Fruits are an essential constituent of nutritious diet. Including fruits in diet is important for enhancing overall health. Fruits are key factor in reducing risk of several diseases, such as heart disease, stroke, and cancer. Their nutritional content and natural compounds play substantial role in providing health benefits (Topp *et al*., 2012) [10]. Global production of fruits has been increasing in recent years and Global consumption of fruit juice has also been increasing in recent years. Fruit juice can be a convenient way to consume fruits. Plums are rich in bioactive compounds, including anthocyanin's, phenolic acids, flavanols, organic acids, vitamin A, B, C & K and minerals (Birwal *et al*., 2017) [4]. Carbonated soft drinks are well known for their capability to satisfy thirst and deliver refreshing experience. Given growing demand for soft drinks, there is an opportunity to take advantage of on this trend by creating fruit juice based beverages enriched with added nutrients. Consumers are progressively aware of connection between their dietary adoptions and overall health, making such products mostly attractive. Carbonated fruit juice based beverages represent an innovative idea that offers not only nutritional benefits of fruit but also integrates natural pigments and flavors, enhanced by sparkle of carbonation (Masoumi *et al*., 2018) [8]. Carbonation of fruit juices boosts beverage's taste, aroma, and extends its shelf life. Use of gas flushing, namely carbon dioxide, represents practical substitute method for extending shelf life of fruit juice (Abu-Reidah, 2020) [1]. This method effectively delays growth of microorganisms in plum juice. The primary objective of this research is to develop a plum based carbonated beverage and explore its physicochemical and phytochemical characteristics.

2. Materials and Methods
2.1 Raw Materials
Ripe Indian plum fruits, characterized by their consistent size and color, were procured from local fruits and vegetable markets in Ludhiana, India. The fruits underwent a thorough examination to detect any signs of damage or infestation. Subsequently, they were rinsed using distilled water to eliminate any traces of dirt or pesticide residues. After this step, the process of juice extraction was initiated.

2.2 Juice extraction
The plum was precisely diced into small pieces using a stainless-steel knife. We used screw-type juice extractor to ensure a highly efficient juice extraction process, minimizing the presence of any remaining pulp. This juice extraction sequence was repeated three times with the extractor. Subsequently, the juice was refined through the use of a muslin cloth filter to elevate its overall quality.

2.3 Preparation method for carbonated plum juice beverage
The necessary amount of syrup, created by mixing plum juice with changing concentrations. Sugar syrup was included to attain the desired sugar concentration of 15°Brix. Plum juice was homogenized and pasteurized by regulating the temperature to 85 ± 2 ºC and maintaining it for 2 minutes, after which it was quickly cooled. The juice is concentrated in rotary vacuum evaporator @ 40 ºC till the total soluble solids content reach to 70 ± 0.5 ºB. These carbonated plum juice beverage trials were prepared by, the post-mix carbonation technique was used, following the approach detailed by Arora and Aggarwal (2020) [3]. There are 3 distinct formulations were developed, each incorporating varying proportions of plum juice concentrate, specifically 5.0%, 7.5%, and 10%. The sugar syrup, maintained at 80 ºB, remained constant at 10% in all formulations. The remaining mixture consisted of chilled carbonated water at 3-6 ºC. After that bottles were immediately cooled to 0-4 ºC. Addition of carbonated water and properly sealed with cork. Then boiled the bottles in boiling water bath for 20 minutes then immediate cooling is done.

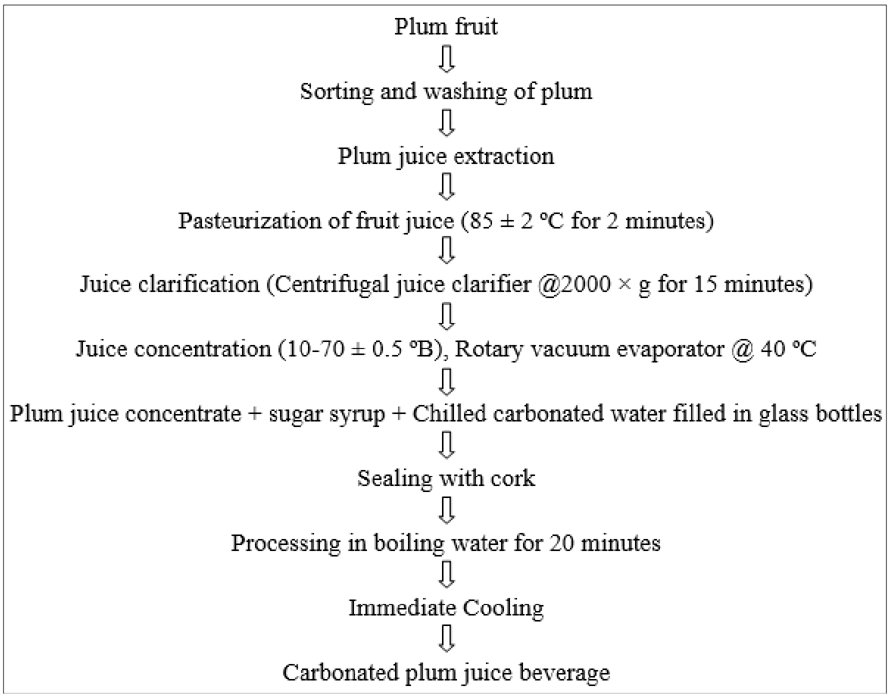

Fig 1: Flow diagram of carbonated plum juice beverage

2.4 Estimation of physicochemical characteristics
The examination of the plum juice samples involved key measurements. To analyze the plum juice samples, we used a hand refractometer from Erma, Japan, to measure the Total Soluble Solids (TSS) content. To measure Titratable Acidity in plum juice, a standardized sodium hydroxide solution is gradually added to the sample, with phenolphthalein serving as an indicator. The endpoint is reached when the solution changes color from acidic to slightly alkaline. The Titratable Acidity is then calculated in terms of malic acid equivalents based on the volume and concentration of the sodium hydroxide solution added (Ranganna, 2005) [9]. Additionally, the pH of the samples was determined using a pH meter from (Mettler Toledo, India). The recorded pH values offer valuable insights into chemical properties of the plum juice. During analysis of plum juice samples, two key characteristics were determined by Ranganna's (2005) [9] methods: Carbon Dioxide (CO_2) gas volume and Total Solids content. For CO_2 gas volume measurement, a known sample volume was sealed and shaken to release dissolved CO_2, with released gas volume quantified (Arora and Aggarwal., 2009) [3]. Total Solids content was measured by precisely weighing juice samples, heating it to remove moisture, and calculating weight difference before and after drying. The carbon dioxide (CO_2) content in plum juice samples was assessed using AOAC method (2019) [2], with outcomes expressed in milligrams per 100 milliliters (mg/100ml). The procedure involved taking known volume of juice samples and sealing it in specific container. The dissolved CO_2 gas was then released into the container's headspace through agitation or standing. The released CO_2 was accurately measured. Color characteristics, specifically L* (lightness), a* (redness to greenness), and b* (yellowness to blueness), were evaluated using Hunter Color Lab equipment, specifically the Ultra Scan from Hunter Lab in the USA. The Hunter Color Lab equipment is renowned for its precision in color analysis. L* values typically range from 0 to 100, where higher values indicate greater lightness. a* values denote the color's position on the red to green scale, with positive values representing redness and negative values indicating greenness. Meanwhile, b* values measure the yellowness to blueness, with positive values suggesting yellowness and negative values indicating blueness.

2.5 Estimation of phytochemical characteristics

The determination of ascorbic acid content in the plum juice sample involved a standard titrimetric method, employing a 2,6-Dichlorophenol indophenol dye solution. To begin, a carefully measured volume of the plum juice was placed in a suitable container. A solution of 2,6-Dichlorophenol indophenol dye, typically of known concentration and initially blue in color, was prepared. This dye solution was gradually introduced into the plum juice sample while stirring, causing a color change from blue to colorless as it reacted with the ascorbic acid. The titration continued until the blue color vanished, marking the endpoint, and the volume of dye solution used was recorded. By leveraging the known concentration of the dye solution, the ascorbic acid concentration in the plum juice could be accurately calculated outlined by (Kaur *et al*. in 2022) [5]. he determination of anthocyanins, as per the AOAC methods (2019) [2], involves specific steps. Firstly, a known volume of the plum juice sample is mixed with acidified methanol to extract the anthocyanin compounds. After an incubation period, the extract's absorbance is measured at specific wavelengths using a spectrophotometer. Anthocyanin content is then calculated based on these absorbance readings, generally expressed as milligrams of anthocyanin per 100 milliliters of plum juice (Kaur *et al*. in 2022) [5]. To evaluate total phenols in plum juice, Folin-Ciocalteu reagent method was employed, comprising several key steps. Firstly, exact volume of juice sample was accurately measured. Afterward, phenolic compounds were extracted from sample using a suitable solvent. The extracted sample was then mixed with Folin-Ciocalteu reagent, leading to color change that signified oxidation of phenolic compounds. This color change was quantified using a spectrophotometer, and total phenolic content was calculated based on absorbance readings and a standard curve, typically expressed as milligrams of gallic acid equivalents (GAE) per 100 milliliters (mg GAE/100 ml) of plum juice (Kaur *et al*. in 2022) [6]. To assess antioxidant activity, particularly DPPH free radical scavenging activity in plum juice, following method was employed. First, DPPH solution with specific concentration was prepared. A known volume of plum juice sample was then mixed with DPPH solution. The mixture was incubated in dark to allow antioxidants in juice to scavenge DPPH radicals, resulting in reduction in solution's purple color. After incubation, decrease in absorbance was measured spectrophotometrically, and antioxidant activity was calculated as a percentage of DPPH scavenged by the plum juice (Kaur *et al*. in 2022) [6].

2.6 Sensory evaluation

Sensory evaluation, using 9-point hedonic scale is commonly employed approach for the assessment of subjective sensory attributes of a product, on all sides of aspects like taste, appearance, aroma, and texture. In this method, a panel of trained or untrained individuals rates the product's attributes on a scale ranging from 1 (extremely disliked) to 9 (extremely liked), with 5 typically representing a neutral point or no preference (Lusk *et al*., 2015) [7]. The scores assigned by the 30 panel members provide valuable data about the overall acceptance and liking of the product. The cooled beverage, served at a temperature of 4-6 °C, was evaluated based on measures appearance, mouthfeel, flavor, and overall acceptability, were taken into consideration as part of evaluation.

2.7 Statistical analysis

All analysis for the study were performed in triplicates. The difference among the means were tested by one-way ANOVA, at 95% CI ($p<0.05$), using statistical software SPSS version 25.

3. Results and Discussion

3.1 Quality parameters of plum juice and plum juice concentrate

The quality comparison between Plum Juice and Plum Juice concentrate across various physicochemical and color coordinate parameters are as shown in (Table 1). The "$p<0.05$" notation suggests that the differences observed are statistically significant. In terms of physicochemical attributes, the total soluble solids (ºB) and total solids (%) are notably higher in the Plum Juice concentrate compared to Plum Juice, indicating a substantial concentration of solids during the conversion process. This higher concentration contributes to the increased thickness and sweetness of the concentrate. Conversely, the pH is slightly lower in the concentrate, which could be attributed to the concentration process. The acidity percentage is significantly elevated in the Plum Juice concentrate, possibly due to the concentration of acids during the processing. Furthermore, color coordinates, the L* value (indicative of lightness) is higher in the concentrate, suggesting that the concentrate appears lighter in color compared to the regular juice. The a* value (representing red to green spectrum) is lower in concentrate, indicating shift towards greenness. Additionally, the b* value (denoting yellowness to blueness) is lower in concentrate, indicating a shift towards blueness. The results shows that Plum Juice concentrate is particularly different from the Plum Juice in terms of various properties, including sweetness, acidity, and color attributes. The concentration process, as evident in higher total solids and increased acidity, significantly impacts final product's characteristics. The changes in color coordinates suggest a shift in visual appearance of concentrate towards lighter and less red and yellow tones. However, when assessing importance of these distinctions, it's crucial to take into account particular context and consumer preferences. For instance, concentrate might be preferred for its intensified sweetness and thickness, while original juice could be favored for its lighter color and lower acidity. The Plum Juice exhibits significantly higher ascorbic acid content at 65.72 mg/100 ml compared to concentrate's 36.22 mg/100 ml. This suggests that Plum Juice is a richer source of vitamin C, which is well known for its antioxidant properties and health benefits. Although difference is relatively small, Plum Juice has slightly higher anthocyanin content at 8.5 mg/100 ml compared to concentrate's 7.52 mg/100 ml. Anthocyanins are natural pigments with potential antioxidant and health-promoting effects. Total phenols in the Plum Juice are significantly lower at 230.32 mg GAE/100 ml compared to the concentrate's much higher content of 752.80 mg GAE/100 ml. Total phenols are often associated with antioxidant activity and potential health benefits, with the concentrate containing significantly more of these compounds. The Plum Juice exhibits considerably lower antioxidant activity at 27.04 µmol TE/100 ml compared to the concentrate's notably higher value of 135.12 µmol

TE/100 ml. This result aligns with the higher content of total phenols in the concentrate, as phenolic compounds are known for their antioxidant properties. Carbon dioxide (CO_2) amount in carbonated drinks were determined at 482.66 milligrams per 100 milliliters, and volume of CO_2 gas was analyzed to be 2.18 cubic meters similar results reported by (Arora and Aggarwal, 2009) [3].

The (Table 2) displays formulations (F1, F2, F3) of a beverage with varying plum juice concentrate and constant sugar syrup i.e., 15%. Formulation F2, containing 7.5 units of plum juice concentrate and 177.5 ml of chilled carbonated water, exhibited the highest sensory scores, particularly in color, mouthfeel, flavor, and overall acceptability. This indicates that a moderate increase in plum juice concentrate, along with precise carbonated water quantities, significantly improved sensory characteristics. Overall, Formulation F2 is the most favored choice, with subtle adjustments in ingredients playing a vital role in shaping the beverage's sensory attributes, warranting further study for commercial application.

Table 1: Quality attributes of fresh plum juice and concentrate

Parameters	Plum Juice	Plum Juice concentrate	$p<0.05$
Physicochemical			
Total Soluble Solids (ºB)	13.63 ± 0.26	68.6 ± 1.64	S
Total solids (%)	9.26 ± 0.51	70.23 ± 2.78	S
pH	4.12 ± 0.08	3.58 ± 0.06	S
Acidity (%)	0.98 ± 0.03	5.14 ± 0.21	S
Color coordinates			
L*	30.12 ± 0.13	36.22 ± 0.15	S
a*	3.43 ± 0.08	1.31 ± 0.05	S
b*	1.03 ± 0.02	-1.27 ± 0.14	S
Phytochemical			
Ascorbic acid (mg/100 ml)	65.72 ± 1.43	36.22 ± 1.35	S
Anthocyanins (mg/100 ml)	8.5 ± 0.06	7.52 ± 0.38	S
Total phenols (mg GAE/100 ml)	230.32 ± 8.02	752.80 ± 26.48	S
Antioxidant activity (µmol TE/ 100 ml)	27.04 ± 0.84	135.12 ± 2.36	S

Results are expressed as mean ± standard deviation, n = 3

GAE: Gallic acid equivalent; TE: Trolox equivalent; S: Significant ($p<0.05$) difference among columns

Table 2: Sensory evaluation of carbonated plum juice beverage

Ingredients	Formulations		
	F_1	F_2	F_3
Plum Juice concentrate	5	7.5	10
Sugar syrup	15	15	15
Chilled carbonated water (ml)	180	177.5	175
Sensory characteristics			
Color	7.55 ± 0.32^{b}	8.72 ± 0.62^{a}	7.52 ± 0.35^{b}
Mouthfeel	7.59 ± 0.28^{b}	8.54 ± 0.86^{a}	7.30 ± 0.56^{b}
Flavor	7.52 ± 0.42^{b}	7.87 ± 0.42^{a}	7.62 ± 0.45^{ab}
Overall Acceptability	7.43 ± 0.63^{b}	8.58 ± 0.21^{a}	7.45 ± 0.36^{b}

Results are expressed as mean ± standard deviation, n = 30

Different letters in superscript indicates significant ($p<0.05$) difference between columns

4. Conclusion

Carbonated beverages, widely consumed globally, are experiencing continuous growth and hold paramount importance in the worldwide industry. This sector serves as a significant foundation within the larger industry. In response to the changing dynamics of this expanding market, companies are at the forefront of creating new flavors, with a strong emphasis on enhancing consumer well-being. The carbonated beverage's nutritional characteristics were enhanced through the addition of 7.5% plum juice concentrate. This enhances nutritional composition of carbonated beverage with different bioactive compounds. Fruits based carbonated drinks can attract the consumer.

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