Utilization of whey for formulation of whey jamun juice ice pops with antidiabetic potential

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Abstract
Whey utilization has been a subject of much research, as it has a very high biological oxygen demand (BOD) and must be treated prior to disposal. Several strategies, such as isolation of whey proteins, bioconversions of lactose to ethanol, and methane production, have aimed at reducing the organic load for reducing the BOD levels. In order to enhance the utilization of whey, a novel approach for formulating a functional food was employed. Whey was blended with jamun juice to prepare whey jamun ice pops (WJP) by the use of freezing technology (−20°C) with the addition of small amounts of citric acid as preservative as well as for enhancing taste and nonnutritive sugar (sucralose). The formulation containing 59.7 ml of jamun pulp juice, 40.11 ml of whey, 0.06 g of citric acid, and 0.13 g of sucralose, which ranked best among all combinations, was selected. The formulation was analyzed for physicochemical parameters, total polyphenols, total flavonoids, and sensory acceptability. WJP was found to have 78% DPPH (2,2-diphenyl-1-picrylhydrazyl) inhibition (antioxidant activity), 7.89 mg GAE/ml of total polyphenols, 4.58 QE mg/ml of total flavonoids, 0.7% (v/v expressed as citric acid) titrable acidity, pH 4.3, TSS 12°Brix, 14.3 mg/100 ml vitamin C, and 6% reducing sugar. In the present study, in vitro antidiabetic activity showed inhibition of α-amylase activity by 60%, and in vivo activity tested in albino rats revealed that the final product helped in regulating the blood glucose in the body.

KEYWORDS
antidiabetic, food upcycling, jamun/Indian blackberry, polyphenols, whey

1 | INTRODUCTION

Whey is the translucent liquid left after milk is acid treated (with lemon juice or citric acid) and strained. The liquid comprises about half of total solids of milk, of which mainly are various important constituents like whey proteins, milk sugar (lactose), salts, and other water-soluble vitamins. The whey also consists of various essential nutrients which are of importance to the human body in addition to the other nutrients. Nearly 3 MT (metric ton) of this essential nutrient-rich whey is formed from various dairy industries in India (Jindal et al., 2004). According to the Water Pollution Research Laboratory, the biological oxygen demand (BOD) of whey is 38,000–46,000 ppm, and sometimes this value goes up by 76,000 ppm despite the fact that the allowable limit is 200 ppm for the normal domestic sewage (Shukla et al., 2004).
In order to tackle with the disposal of liquid whey from various dairy outlets and to decrease the pollution in the environment, it must be given prior treatment, or it may further be processed to gain the beneficial and marketable products (Mishra, 2008). Additionally, research suggests that the liquid whey can be a rich source of various nutrients comprising both the organic and inorganic nutrients, which could prove useful to the set of population, having extra calorie burning jobs such as sportspersons, athletes, gym going people, and folks involved in alike works (Gupte & Nair, 2010; Mudgil & Barak, 2019).

Jamun (Syzygium cumini) also called as “Indian blackberry” accounts to stand at the second place for the phytonutrients rich fruit (15.4%) in the world (Sagrawat, 2006).

The nutrient-rich fruit possesses several health benefits, including various noncommunicable diseases, among them the more specific one being diabetes, for which it has been used since ages as a traditional medicine (D’Mello et al., 2000; Manganaris et al., 2014; Paul & Das, 2018). In addition, the jamun fruit’s significance lies in the fact that because of its rich phytochemical profile, it has potential to overcome serious diseases such as neurological problems, antidiabetic, heart-related problems, and cancerous tumors, which are gaining attention globally (Patil et al., 2012).

The jamun fruit has been reported to possess antioxidant and free radical scavenging activities, antibacterial, antifungal, antidiabetic, and anti-inflammatory properties (Sharma et al., 2012). Jamun possesses attractive color, astringent taste, appreciable mineral, and vitamin content. Although jamun fruit is seasonal, perishable, and underutilized, it carries a great potential to be taken up as a raw material for postharvest processing and development of functional food carrying disease-prevention ability besides the basic function of supplying nutrients (Sehwag & Das, 2015).

The approaching demands from the urbanized section of the population makes it compulsory to the research and development sector of the various food industries to merge the various staple and underutilized food products to make the novel food products that are beneficial for human health and feasible from the economic point of view as well. Thus, the various secondary products from the various food manufacturing units in combination with the other energy rich foods can prove a better source of nutrition.

Whole contour of this Indian blackberry contributes its richness in terms of its excellent source of various natural containing pigments and bioactive components. Edible ices along with other whey-based beverage foodstuffs could be capable as well as gainful carrier of phytochemicals resulting from the fruit. In vision of the many curative and beneficial properties of this Indian blackberry and because of its less availability in the market throughout the year, an effort has been made in this study to formulate whey-based jamun ice pops with possible therapeutic effects. As both jamun juice and whey are highly perishable, production of ice pops by blending the jamun juice and whey liquid is more advantageous because at freezing temperature shelf life can be enhanced, overall product stability gets increased, and nutrient value is retained. The formulation was optimized based on the maximum polyphenolic content and highest sensory score for enhancing the nutritional and functional properties of the blend of jamun juice and whey. The phytonutrient/polyphenols have been reported to have antidiabetic and antihyperlipidemic effect. So, the formulation optimization is based on maximum polyphenolic content, which will correspond to the maximum antidiabetic effect.

2 | METHODS

2.1 | Procurement of raw material

Fresh Jamun fruit was purchased from a local fruit market of New Delhi, India. The fruit was washed, cleaned, deseeded, and then juice was extracted in a laboratory juicer. The juice was pasteurized and stored at 4°C for further use.

2.2 | Preparation of whey

For the preparation of whey, toned milk (Amul, India) with 3% fat and 8.5% SNF was curdled by the addition of 1%–2% citric acid solution with constant stirring with glass rod; it resulted in the formation of coagulum of milk protein (casein). The liquid (whey) thus obtained was collected by the filtration, subsequently cooled, and stored at 4°C for further use.

2.3 | Formulation of whey-based jamun ice pops

Jamun juice, whey, citric acid, and sucralose were the main ingredients used in the formulation of the whey jamun ice pops (WJP). The ingredients varied—jamun juice 20–50 ml, whey 50–80 ml, citric acid 0.01–0.1 g, and sucralose 0.14–0.29 g—in the formulation as per the mixture design. Sucralose is a nonnutritive sweetener, and its use is meant to enhance the taste of the final product. The levels were selected based on preliminary sensory trials for acceptability of WJP. The blended contents were filled into cone shaped molds of 100 ml and were kept under freezing condition at temperature of about –20°C for 4 h and used for further analysis.

2.4 | Nutritional analysis

The raw materials and developed formulation of WJP were analyzed for nutritional information using the methods as per Association of Analytical Chemists (AOAC, 1990). The titrable acidity of whey and jamun was measured as percentage lactic and citric acid, respectively, against the 0.1 N NaOH. The percentage of the fat was calculated by Gerber’s centrifuge method as explained by the BIS (1997). The vitamin C percentage in the juice was measured by titration method with 2, 6-dichlorophenol-indophenol dye solution. The whey, jamun juice, and WJP formulation were freeze dried, and the powder obtained was used for further analysis (Paul & Das, 2018).
2.4.1 | Moisture content

In the preweighed dried Petri plates, 10 ml of sample was taken and placed in a hot air oven for 24 h at 130°C, then cooled in a desiccator and weighed again (AOAC, 1990). The difference in weight was taken as the percentage of moisture.

2.4.2 | Ash content

To estimate the ash present in the sample, 3 ml of the sample was measured in the silica dish and then placed in the muffle furnace for 2 h at 500°C. The silica dishes containing ash were placed in desiccators for cooling, and weight was taken for the final calculations as per AOAC’s (1990) protocol.

2.4.3 | Crude protein

For the estimation of the crude protein of the jamun juice and whey, Kjeldahl method was followed as explained by AOAC (2006). According to the protocol, the protein analysis was done in three phases: digestion, distillation, and titration. To carry out the digestion, 10 ml of sample was mixed with 10 ml concentrated sulfuric acid followed by the addition of potassium sulfate and copper sulfate in the ratio of 10:1. The mixture was then heated at temperature between 350 and 380°C to carry out the faster and efficient digestion process. After the completion of digestion, the sample was cooled to room temperature and then shifted to distillation section. Alkali (40% NaOH) was added during distillation, thereby converting ammonium ions to ammonia gas. The ammonia gas formed was then absorbed into a 4% boric acid solution. Finally, the titration was done to determine the amount of nitrogen in the condensate flask with a standard solution of 0.1 N HCl solution in the presence of mixed indicators, namely methyl red and bromocresol green.

2.4.4 | Crude fiber content

The crude fiber of the final product was done as per the AOAC (2006): 2 g of fat free sample was taken in the thimble, first the acid digestion (1.25% H2SO4 for 45 min) carried out, followed by the alkali wash (1.25% NaOH for 45 min). The sample was then filtered and washed with distilled water. Afterward, the water was vacuum evaporated and the crucibles were dried in a hot air oven. The residue left was weighed and kept in the muffle furnace for 3 h at 450–550°C till the whitish ash was left, placed in the desiccator for cooling, and the final weight was taken. The result was expressed as percentage crude fiber.

2.5 | Determination of total phenols

The total phenolic content (TPC) in the WJP formulations and jamun juice was estimated using the Folin-Ciocalteu’s reagent (Waterhouse, 2002). Note that 20 μl of each juice sample was mixed with 1.58 ml of water and 100 μl of the Folin-Ciocalteau reagent. After 10 min, 300 μl of the sodium carbonate solution was added and the mixture was shaken. The solution was allowed to stand at 20°C for 2 h and the absorbance of each solution was determined at 765 nm against the blank. The results were expressed as mg Gallic acid equivalents (GAE)/ml. All the samples were analyzed in triplicates.

2.6 | Determination of total flavonoids

The total flavonoids content was determined using the method described by Arnous et al. (2001). Note that 1 ml of methanolic extract was mixed with 0.3 ml NaNO2 (5%), and after 5 min, 0.6 ml of AlCl3 (10%) was added to the mixer. After 5 min, 2 ml of NaOH (4.3%) was added and the absorbance was observed at 517 nm, and the results were expressed as mg Quercetin (QE)/L. All the samples were analyzed in triplicates.

For making the methanolic extract, we took approximately an amount of 5–10 ml of our optimized whey jamun mixture extracted with 20 ml of methanol (80%) and was mixed further for about 30–60 s and was kept overnight at room temperature, followed by centrifugation (8000rpm). The sample was then filtered through Whatman No. 1 filter paper in a Buchner funnel. The filtered solution was evaporated under vacuum in a rotator at 40°C and then dissolved in the respective solvent.

2.7 | Determination of antioxidant potential by DPPH radical scavenging method

The antioxidant activity of the developed product (WJP) was measured using the DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical scavenging method with slight modifications as described by Brand Williams et al. (1995). Note that 0.1 ml of methanolic extract of whey-based jamun mixture and jamun juice was mixed with 2.9 ml of DPPH solution (0.1 mM). The mixture was well mixed and placed in the dark for 1 h. The reduction in absorbance at 517 nm was recorded with an spectrophotometer (Inkarp Pvt Ltd) as percentage inhibition (% I) of DPPH.

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\% I = \left(1 - \frac{AS}{AC}\right) \times 100
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where I is DPPH inhibition %, AC is absorbance of control sample (at 0 h), and AS is absorbance of test (after 1 h).

2.8 | Determination of in vitro α-amylase inhibitory activity

The liquid sample (100 μl) was added to (100 μl) of 0.02 mol/L sodium phosphate buffer (pH 6.9) and 10 μl α-amylase solution (4.5 units/ml/min). After 10 min, 100 μl of 1% starch solution was added
and incubated at 25°C for 30 min, and the reaction mixture was terminated by the addition of 1.0 ml dinitrosalicylic acid reagent (1 g 3,5-dinitrosalicylic acid in a solution containing 20 ml of 2 mol/L NaOH, 50 ml distilled water, and 30 g Rochelle salt). The reagents along with the salt were dissolved in 100 ml distilled water. The reaction mixture tubes were then prewarmed in a water bath for 5 min (100°C), and then cooled down (25°C). The tubes after cooling containing the reaction mixture were diluted with distilled water (up to 10 times), and the absorbance was recorded at 540 nm (Sathiavelu et al., 2013).

2.9 | Determination of antidiabetic activity by overall glucose tolerance test

To investigate the hypoglycemic effects of optimized whey based jamun ice popsicle (WJP) and Jamun seed extract (JSE), 18 male albino rats (2–3 months old), weighing about 180–200 g, were obtained after ethical approval (Approval no: 173/GO/RE/BI/S/2000) from the Institutional Animal Ethics Committee, Jamia Hamdard, New Delhi. The rats were divided into three groups for overall glucose tolerance test as per the standard method (Islam et al., 2009). During the experiment, the animals were starved overnight; baseline glucose level was measured using a glucometer (ACCU-CHEK, Roche Diabetes Care). The experiment was preceded further by the oral intervention of the aqueous extracts of jamun seeds and whey jamun optimized mixture twice a day for 2 weeks in groups 2 and 3, while group 1 received glucose (1 mg/kg of body weight) along with the normal diet. After 2 weeks of intervention with the optimized formulation, the serum blood glucose levels were measured by collecting blood sample from the tail vein at 0, 15, 30, 60, and 120 min. The results were compared, and a graph was plotted between time and blood glucose levels using STAT software (Zhang et al., 2002).

2.10 | Determination of sensory appropriateness

To determine the overall sensory acceptability of the WJP, 30 semi-trained consumer panelists comprising both genders, in the age group 18–40 years, from the Department of Food Technology, Jamia Hamdard, New Delhi were invited to evaluate WJP for sensory properties. The samples were rated by the panelists on the 9-point hedonic scale (9 indicated the highest and 1 lowest numeric score) on the basis of various sensory parameters such as color, taste, appearance, and overall acceptability.

2.11 | Statistical analysis

Data obtained for the various parameters were expressed as mean ± SDs of at least three replications. The results were statistically evaluated by ANOVA (Minitab 14) with a confidence level of 0.95.

### TABLE 1 Proximate composition of whey and jamun Juice

| Parameter                      | Whey     | Jamun Pulp |
|--------------------------------|----------|------------|
| Moisture (%)                   | 93       | 79–80      |
| Protein (%)                    | 0.45 ± 0.03 | 0.65 ± 0.03 |
| Ash (%)                        | 1.2 ± 0.08 | 1.03 ± 0.08 |
| Fat (%)                        | 0.19 ± 0.02 | 0.18 ± 0.02 |
| SNF (%)                        | 5.6      | ND         |
| Acidity                        | 0.16     | 0.8 ± 0.01 |
| Reducing sugar (%)             | ND       | 6.88 ± 0.35 |
| Ascorbic acid (mg/100 g)       | ND       | 29.78 ± 2.17 |
| α-amylase inhibitory activity (%) | ND   | 71 ± 0.22   |
| T SS (°Brix)                   | ND       | 14.85 ± 1.47 |
| pH                             | 6.3      | 3.87 ± 0.01 |

### TABLE 2 Proximate composition of whey jamun ice pops (WJP)

| Constituent               | Content |
|---------------------------|---------|
| Moisture                  | 92%     |
| Protein                   | 0.44%   |
| Fat                       | 0.2%    |
| Ash                       | 1.3%    |
| Crude fiber               | 0.42%   |
| Reducing sugar            | 6%      |
| Acidity (% citric acid)   | 0.7%    |
| pH                        | 4.3     |
| TSS °Brix                 | 12      |
| Total polyphenols         | 7.89 mg GAE/ml |
| Total flavonoids          | 4.58 mg QE/ml |
| DPPH (% inhibition)       | 78      |
| α-amylase inhibitory activity (%) | 60 |
| Vitamin C (mg/100 ml)     | 14.3    |

3 | RESULTS AND DISCUSSION

3.1 | Proximate composition of raw material

The proximate estimation of the whey and jamun pulp for the principle components such as titrable acidity, pH, fat, vitamin C, moisture, ash, crude protein, crude fiber, and total soluble solid content was done and presented in Table 1. Table 2 shows the proximate estimation of the above components of whey jamun ice pop, and other constituents like total phenols, flavonoids, reducing sugars, DPPH (% inhibition), and α-amylase inhibitory activity (%) were also analyzed. The energy value of the optimized run was found to be 316 ± 2.07 kJ/100 ml.
3.2 Optimization of formulation

The final optimized run based on the maximum polyphenolic content and highest sensory score was selected and analyzed for the overall proximate composition. The parameters for the final optimized run had significant amounts of jamun juice (29.7 ml) and whey liquid (30.04 ml). Desirable amounts of nonnutritive sweetener sucralose (0.13 g) and citric acid (0.06) as stabilizer were also used.

3.3 Characterization of optimized WJP

The final optimized formulation after its proximate analysis showed a very potent antioxidant property. Along with that jamun pulp being a potent antidiabetic (Achrekar et al., 1991), significant amounts of vitamin C (14.3 mg/100 mL) were present in the WJP, and the results were in consonance with the findings of Sehwag and Das (2016) who reported 28.3 mg/100 g of vitamin C in the jamun pulp. The results are presented in Table 2, and the proximate analysis indicating the moisture content, total soluble solids (TSS), crude protein, crude fat, ash and pH of the WJP were found around 80%, 12 °Brix, 0.40%, 0.2%, 1.4%, and 4.3, respectively. These proximate results were in consonance with the results of Sartaj Ali et al. (2013) in their biochemical analysis of jamun fruit. The results were also in line with Priyanka et al. (2015) in the formulation of beverage made from whey and guava and using jamun with different fruit juices.

3.4 Total phenolic content of optimized run of WJP

From Figure 1, it was observed that the TPC content of the freshly made WJP was 7.89 mg GAE/ml. Shahnawaz et al. (2009) have reported TPC content of 11.41 mg GAE/g in jamun pulp, which is in similar lines with our findings as the amount of jamun juice used in WJP was 50%. Rufino et al. (2011) also reported 11.17 ± 67.1 mg GAE/ml of total phenols in the fresh Jamun juice. During the storage, a decrease in total phenolic content of WJP mixture was observed, and TPC content of 7.13, 6.43, and 5.96 mg GAE/ml was observed at the end of the first, second, and third week, respectively. A decreasing trend of the TPC was also reported by Kopjar and Pilizota (2009) in stored jamun juice. The decrease in phenolic content during storage period might be attributed to the oxidation of phenolic compounds due to their volatile nature (Kapoor & Ranote, 2016; Ranganna, 1986).

3.5 Total flavonoids content of the optimized run of WJP

As shown in Figure 2, total flavonoid content in WJP was found to be about 4.58 mg QE/mL. During the storage period of 3 weeks, the total flavonoid content decreased gradually. The TFC at the end of 7, 14, and 21 days was found to be 4.27, 3.98, and 3.56 mg QE/mL, respectively. Sundararajan et al. (2016) have reported total flavonoid content of 5.34 mg QE/mL in Jamun squash. Our findings are also in accordance with the results of Mohamed et al. (2013), who have reported TFC in methanolic extract of Jamun was 6.22 mg QE/g of dry sample. In the present study, we have used a blend of whey and jamun juice that is the reason the results are on the lower side in comparison to the previous studies. The decrease in the TFC is attributed to the process of oxidation of flavonoids during storage.

3.6 DPPH activity (% inhibition) of the optimized run of WJP

The presence of the bioactive compounds in the jamun juice is responsible for the antioxidant potential of the jamun. The antioxidant activity DPPH (% inhibition) of freshly prepared WJP was found to be 78%. Antioxidant activity is mostly due to the phenolic and flavonoid compounds present in jamun juice (De Bona et al., 2016; Hossain et al., 2016). Some other authors also reported that the antioxidant effect is mainly due to radical scavenging activity of phenolic compounds such as flavonoids, polyphenols, tannins, and phenolic terpenes present in the jamun juice (Matsukawa et al., 1997; Rahman & Moon, 2007). Besides this, the presence of vitamin C in jamun juice also contributes
to antioxidant activity. Further, the storage period of 3 weeks resulted in the slight decrease (2%-10%) of the antioxidant activity of the WJP as shown in Figure 3. Randhawa et al. (2018) have also reported a decrease in antioxidant activity of jamun drink during storage. In another study by Kapoor and Ranote (2016), a decrease in antioxidant activity has been reported in pear jamun juice during storage. Dudonne et al. (2009) have reported that antioxidant activity has a positive correlation with phenolic compounds, thus the decrease in antioxidant activity may be linked to decrease in phenolic compounds during storage. Another reason for decrease in antioxidant activity during storage may be attributed to possible oxidation of antioxidant components (Socorro et al., 2010).

3.7 Sensory evaluation

Sensory evaluation of the formulated whey jamun ice pops has a greater impact over the mindset of consumer for the preference of food. The mean panel score obtained from the sensory analysis showed that the final formulation of WJP possessed highest score (more than 50% of acceptance or at least 5 points) in all the parameters. The overall mean score for sensory properties like color, taste, appearance, and overall acceptability was found to be 6.85, 6.44, 6.71, and 6.14, respectively, on a 9-hedonic scale (9: like extremely, 1: dislike extremely), as shown in Figure 4. Due to less awareness of the product, which is presented in the form of ice pops, it did not receive a high score on the hedonic scales; however, the mean sensory scores were above 6 which indicated that the product was in the acceptable range. Consumer acceptance often increases when they are made aware of the functional aspects and health benefits. Therefore, with more information about the health benefits of whey jamun ice popsicles, its acceptability may increase, especially among those with diabetic ailment.

3.8 \( \alpha \)-Amylase inhibition activity of WJP

From the in vitro study carried out for jamun seeds, jamun juice, and WJP, it was observed that the jamun seeds exhibited greater \( \alpha \)-amylase inhibition activity, followed by jamun juice and WJP. The \( \alpha \)-amylase activity of jamun seeds and jamun juice was about 78% and 71%, while WJP showed 60% of \( \alpha \)-amylase activity; this result is in consonance with the results of Sehwag and Das (2016); in their work for the formulation of the whole jamun based functional confection in which they reported to have 55% of \( \alpha \)-amylase inhibition activity; however, another study by Gaanappriya et al. (2013) has reported 40% of inhibition in probiotic jamun juice. Another study by Sathiavelu et al. (2013) has reported 71.17% inhibition activity in \textit{Eugenia jambolana}. The phytochemicals such as gallic acid and catechin possessed by the jamun juice exhibit a number of health benefits including antidiabetic effect through the inhibition of \( \alpha \)-amylase activity (Gajera et al., 2017; Shivashankara et al., 2013).

3.9 In vivo result of whey jamun optimized mixture and jamun seeds

Statistical analysis of responses from blood glucose levels showed significant deviations due to therapeutic formulation being given at different time intervals. From Figure 5, it can be seen that levels of blood glucose are significantly lower in the therapeutic group compared to the control group.
glucose (mg/dL) were being regulated when the rats were being orally fed for 2 weeks with jamun seed extract and whey jamun optimized mixture. The mean values for blood glucose levels in normal and hyperglycemic animals are presented in Table 3. The mean blood glucose level of groups 1, 2, and 3 at 0 min was recorded to be 110.5 ± 3.065, 106.75 ± 3.351, and 108 ± 1.291 mg/dL, respectively. After 60 min of oral intervention, the mean glucose levels elevated to 270.5 ± 2.630, 240.25 ± 1.652, and 262 ± 1.633 mg/dL in groups 1, 2, and 3, respectively. At the end of 120 min, a decreasing trend in mean blood glucose levels was observed; in the hyperglycemic group, the decrease was less 177.75 ± 2.462 mg/dL; however, there was a significant reduction in the jamun seed extract diet group 121 ± 1.683 mg/dL and in the whey jamun mixture diet group 139.25 ± 1.377 mg/dL. From the results of this study, it may be concluded that aqueous extract of jamun seeds possesses the highest glucose reducing activity, while whey jamun optimized mixture also resulted in glucose reduction to significant levels. The study by Raza et al. (2017) in evaluation of jamun fruit and seed extract against hyperglycemia also supports the outcomes of our in vivo study. Some earlier studies conducted also demonstrate that the oral intervention of aqueous extract of jamun pulp led to considerable reduction in blood glucose level (Rekha et al., 2008; Saravanan & Pari, 2008; Farhana and Swarnomon, 2012).

4 | CONCLUSION

The main focus of the study was to develop an industrial and scientific approach that utilizes “whey,” the by-product of dairy industry, and the underutilized crop “jamun” for the formulation of ice popsicles. Moreover, jamun is an anthocyanin and phytonutrient rich fruit and whey is a proven source of proteins and inorganic nutrients. The present study discovered various beneficial effects of jamun juice, which was incorporated into whey liquid. The special effects comprised better quality characteristics (physicochemical and sensory properties), enhanced phytonutrient profile, and improved storage stability. The underutilized jamun can thus be used as a natural bioactive source for formulation of functional products. The optimized product revealed the therapeutic effect (antidiabetic) and thus the product formulated thereof has multifold health benefits and improved sensory qualities. Because of jamun fruit being highly perishable and whey being high in BOD, thus adding cost to its safe disposal, therefore a product made thereof can be important from the economical point of view adding to their profitability and consumption. The future possibility lies in blending of underutilized crop jamun fruit with whey liquid or concentrate to meet the nutritional requirements of the most vulnerable population group such as infants, school age children, adolescents, pregnant, and lactating mothers in developing countries like India.

**CONFLICT OF INTEREST**

The authors confirm that they have no conflict of interest to declare for this publication.

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**TABLE 3** In vivo result of whey jamun optimized mixture and jamun seeds

| Time (min) | Normal group Mean ± SD | Jamun seed extract Mean ± SD | Whey jamun optimized mixture Mean ± SD |
|-----------|------------------------|-------------------------------|--------------------------------------|
| 0         | 110.5 ± 3.065          | 106.75 ± 3.351*               | 108 ± 1.291*                         |
| 15        | 222.25 ± 3.172         | 180 ± 3.488*                  | 206 ± 1.958*                         |
| 30        | 237.75 ± 2.658         | 194 ± 2.739                   | 200 ± 2.198                          |
| 60        | 270.5 ± 2.630          | 240.25 ± 1.652*               | 262 ± 1.633*                         |
| 120       | 177.75 ± 2.462         | 121 ± 1.683*                  | 139.25 ± 1.377*                      |

Means of SD for n = 3. The experimental values within columns that have star superscript are significantly different (p < 0.05) according to Turkey Kramer multiple test range.
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