# MICROENCAPSULATION OF ULTRASOUND EXTRACTED JAMUN JUICE BY SPRAY DRYING

**By**

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# CHAPTER V

## SUMMARY AND CONCLUSION

Jamun (*Syzygium cuminii*) is an under-utilized fruit tree from Indian subcontinent. It belongs to the family of myrtaceae. Jambul, black palm, java palm, and Indian blackberry are the common names of jamun. Jamun holds significant therapeutic value due to its rich content of phytochemicals, minerals, and vitamins. It exhibits proven pharmacological properties in animal systems, including hypoglycaemic, anti-inflammatory, antimicrobial, antioxidant, antidiarrheal, analgesic, astringent, and gastro-protective effects. Studies on the use of jamun for managing diabetes have also demonstrated positive results. Jamun is used to produce a variety of processed food items, including juice, wine, muffins, and frozen yogurt. The fruit pulp is utilized in the preparation of squash, instant drink mixes, cakes, dairy products, chapattis, and flatbreads. Rich in anthocyanins, jamun serves as a natural colorant, preservative, and flavour enhancer in the food industry.

Jamun processing primarily involves two methods viz. juice extraction and drying of juice. Though jamun contains 80% pulp, juice extraction using conventional methods remains challenging. To enhance both yield and nutritional quality, improved extraction techniques are essential. Commonly used methods include hand squeezing, mechanical extraction, enzymatic extraction and ultrasound assisted extraction. Among these, ultrasound assisted extraction stands out as a promising "green technology" for juice extraction. Various drying methods are available for liquids, including drum drying, freeze drying, and spray drying. The goal of drying is to achieve higher yield and produce high-quality powder. Among these methods, spray drying is considered one of the best methods for powder production. Combining ultrasonic technology with spray drying can further enhance both the yield and quality of the powder.

The research work entitled “Microencapsulation of ultrasound extracted jamun juice by spray drying” was conducted with the following objectives: i) To optimize the operating parameters for ultrasound assisted extraction of jamun juice ii) To optimize the concentration of feed solution and operating parameters for spray drying of jamun juice iii) To conduct the storage studies of optimally produced jamun juice powder

The fresh jamun fruits were procured from KCAEFT Instruction Farm, Tavanur, Malappuram district, Kerala. The fruits were washed properly with clear water and surface drying was done. Prior to any processing and handling of fruits, engineering and physicochemical properties are important. This will give the complete understanding about the fruit. The engineering and physicochemical properties of jamun fruits were determined based on the standard procedures. The properties include, axial dimensions, shape index, geometric mean diameter, arithmetic mean diameter, aspect ratio, elongation ratio, sphericity, surface area, volume, bulk density, true density, porosity, colour, pulp content, seed content, juice content, firmness, coefficient of friction, moisture, pH, TSS, acidity, specific gravity, colour, TPC, TAC and ascorbic acid, respectively. The seeds were then removed from the fruits and the pulp was blended using a blender. The blended pulp was packed under LDPE pouches (80-micron thickness) and stored in deep freezer at -18°C till the conduct of the experiment.

Two technologies viz. ultrasound assisted extraction of jamun pulp and spray drying of jamun juice were included in the current study to extract jamun juice effectively and produce quality powder. The process parameters of ultrasound (US) assisted extraction of jamun juice were optimized based on the quality parameters of extracted juice. Response surface methodology was used for the optimization. Three levels of treatment temperature (10,20,30°C) and exposure time (30,60,90 mins) were selected for extraction and the responses selected were yield, pH, TSS, acidity, total phenolic content, total anthocyanin content and antioxidant activity. Central composite design was framed for the experimental design. The solid-liquid ratio was fixed as 2:1 based on the preliminary studies conducted and from the review of previous studies. For spray drying, Box- Behnken design was selected as the experimental design with process variables of inlet air temperature (140,150,160°C), feed rate (8,10,12 rpm) and carrier concentration (15,20,25%). The responses selected were powder yield, moisture content, water activity, bulk density, tapped bulk density, wettability, dispersibility, solubility, total anthocyanin content and total colour difference. The process parameters of spray drying were optimized based on the quality attributes of spray dried sample.

The characteristic studies were carried out to understand the qualities of optimised US assisted extraction of jamun juice and spray dried jamun juice powder.

For the characterization of spray dried powder, SEM analysis, FTIR analysis and encapsulation efficiency were also determined.

The optimised jamun juice powder was packed in two different packaging materials viz. aluminium laminated pouches and metalized polyester and the storage studies were conducted under room temperature (25±5 ℃) for the duration of 90 days. Further, the samples were analysed continuously on a 30 days interval to examine the variations in different quality parameters of jamun powder. Further, sensory evaluation was performed on the reconstituted spray dried powder samples. Additionally, the cost economic studies were conducted and the benefit cost ratio and payback period were calculated.

**The results of the above experiments are summarized as following:**

The engineering properties of jamun fruit such as axial dimensions, shape index, geometric mean diameter, arithmetic mean diameter, aspect ratio, elongation ratio, sphericity, surface area, volume, bulk density, true density, porosity, colour(L*,a*,b*), pulp content, seed content, juice content, firmness, coefficient of friction (stainless steel, plywood, cardboard, glass) were found to be 22.22 mm, 21.93mm, 20.99 mm, 0.96, 21.04 mm, 21.72 mm, 0.98, 0.95, 0.947, 1427$mm^2$ ,7.28 $mm^3$, 0.67 g/$cm^3$, 1 g/$cm^3$, 32.48, 13.13, 3.83, -3.6, 79.20%, 17.23%, 50.20%, 0.98 Kg/$cm^2$, 1.25, 1.28, 1.56, 1.98, respectively. Additionally, the physicochemical properties of jamun fruit juice such as moisture, pH, TSS, acidity, specific gravity, colour (L*, a*, b*), TPC, TAC, AA and ascorbic acid were measured to be 85.33%, 3.12, 13.14ºBrix, 0.81, 0.9, 17.43, 25.57, 8.57, 256.76 mg/100ml, 1284.14 mg/100ml, 86 % DPPH and 16 mg/100 ml, respectively. Physicochemical properties of wall material and feed solution were also determined.

The ultrasound-assisted extraction (US) of jamun juice was optimized using Response Surface Methodology (RSM) with a central composite design. The optimized process conditions for ultrasound assisted extraction were found to be treatment temperature 30°C, 60 minutes exposure time, and a solid-liquid ratio of 2:1, with a desirability of 0.825. The quality parameters of the optimized US extracted jamun juice, including juice yield, pH, titratable acidity, total soluble solids (TSS), total phenolic

content, total anthocyanin content, and antioxidant activity, were found to be 81.33%, 3.08, 0.81, 6ºBrix, 147.21 mg/100ml, 1227.37 mg/100ml, and 94.54%, respectively.

The spray drying of ultrasound-extracted jamun juice was optimized using Response Surface Methodology (RSM) with a Box-Behnken design. The optimized spray drying conditions were found to be 160°C inlet temperature, 21% carrier concentration (3:1 MD:GA), and a 10rpm feed rate, with a desirability of 0.706. The lowest moisture content and water activity were observed at the maximum inlet air temperature of 160°C. The quality attributes of the optimized jamun juice powder, including powder yield, moisture content, water activity, pH, total soluble solids (TSS), bulk density, tap bulk density, wettability, dispersibility, solubility, total anthocyanin content, total phenolic content, antioxidant activity, and total colour difference, were found to be 65%, 3.9%, 0.29, 3.3, 10ºBrix, 0.29 g/cm$^3$, 0.43 g/cm$^3$, 71%, 92%, 96%, 690 mg/100ml, 95 mg/100ml, 95%, and 46, respectively. The proximate composition of optimized jamun juice powder including energy, carbohydrate, total sugar, protein, total fat, total ash and fibre were found to be 354.76kcal, 81.1%,24.56%, 4.9%, 1.5%, 1.2% and 0.3%, respectively.

The physicochemical properties of the optimized ultrasound extracted spray dried jamun powder demonstrated its storage stability, flowability, and reconstitution ability. The bioactive compounds highlight the phytonutritional potential of the powder. The proximate analysis results reveal the nutritional potential of the spray-dried jamun juice powder. SEM analysis shows that ultrasound treatment significantly alters the powder sample compared to untreated powder. The treatment reduces the average particle size, resulting in more uniform dispersion and an increased number of smaller particles. Additionally, SEM images of the ultrasound treated sample reveal a smoother surface and altered morphologies, such as the formation of fine particles due to the cavitation effect. FTIR analysis confirms that the optimized powder contains important phenolic groups, as indicated by the presence of various bonds in the spectrum. The encapsulation efficiency of anthocyanin was achieved as 96% which shows the good encapsulation effect.

The optimised sample received a satisfactory sensory score of 7.85 for overall acceptability when taking into account the reconstituted samples. The optimized US

treated spray dried reconstituted sample showed nearly identical sensory properties to the control sample in every aspect. Both US treated and non-treated samples had similar score for overall acceptability. This reveal that US treatment does not changed the sensory characteristics of jamun juice in terms of sensory attributes. Compared to control, the optimized samples slightly loss the score in colour and appearance, due to the presence of carrier materials.

The optimized US pre-treated spray dried jamun juice powder was packed in aluminium laminated pouches and metalized polyester pouches. Compared to laminated aluminium, metalized polyester gave more protection in terms of moisture content and water activity at ambient conditions for 3 months. The production cost of one kilogram of spray dried jamun juice powder was estimated to be Rs.2372/-. The benefit-cost ratio of the US extracted jamun juice powder by spray drying was found to be 1.1:1 with payback period of 2.84 years.

**Following conclusions were derived based on the findings:**

- The quality of spray dried jamun juice powder was improved by ultrasound pre-treatment.
- Ultrasound assisted extraction of jamun juice significantly increased the juice yield and quality parameters of juice when compared to conventional extraction methods.
- Pre-treatments viz. US treatment temperature and exposure time increases the quality of juice
- Ultrasound (US) treatment at a temperature of 30°C, an exposure time of 60 minutes, and a solid-to-liquid ratio of 2:1 resulted in the maximum yield and improved juice quality.
- Spray drying of jamun juice, following ultrasound pre-treatment, produced high-quality powder at a temperature of 160°C, a carrier concentration of 21% and a feed rate of 10 rpm.
- Optimized ultrasound pre-treated spray dried jamun juice powder showed good quality in terms of physical, chemical, biological and nutritional aspects.
- The SEM images of US treated spray dried powder having fine particles with lesser diameter.

- FTIR analysis revealed the presence of phenolic compounds in the optimized powder, with the ultrasound-treated sample exhibiting higher peaks compared to the non-treated sample.
- The sensory and nutritional parameters of the optimized jamun juice powder were within the acceptable limits as recommended by FSSAI.
- The benefit cost ratio and payback period of the US extracted jamun juice spray drying were estimated at 1.1:1 and 2.84 years, respectively.

**Scope of future works**

- Explore the impact of additional variables in ultrasound assisted extraction viz. ultrasound frequency, power intensity etc.
- Investigate the use of more carrier agents like whey protein, chitosan, novel biopolymers to optimize the spray-dried powder's quality, stability and nutritional properties.
- Evaluate innovative packaging materials viz. biodegradable films, multilayer laminates and advanced packaging methods like intelligent packaging to improve storage stability.
- Conduct long-term storage studies under different environmental conditions viz. temperature and humidity to understand the degradation kinetics of the powder.
- Investigate the potential of the encapsulated jamun powder as a functional ingredient in food products like beverages, desserts, nutraceuticals etc.
- Instead of a batch-type ultrasound system, a continuous ultrasound chamber can be designed and developed to enhance the efficiency and scalability of the process.