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*Original Research Article*

# Studies on Microbial Destruction and Quality Characteristics in Beetroot -Jamun Juice by Continous Microwave Heating System

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**The continuous microwave processing system is one of the pasteurization techniques that offer good potential for high quality, reduced processing time and energy as compared with conventional techniques. Beetroot is one of the most consumed root vegetable worldwide due to its nutritional value. Jamun fruit has been reported to possess anti-inflammatory, antibacterial, anti-diabetic and anti-diarrheal effects. The blend of beet-root and jamun juice is a formulated health drink and the overall goal of this study was to process and preserve this blend juice through a continuous flow of microwave heating system with value addition. The objectives of this work are to study the effects of microwave heating on juice properties viz., physical-chemical, sensory, microbial count and engineering parameters during a storage period of 180 days. Storage studies showed that MW treatment caused insignificant variation in acidity and pH, slight increase in bacterial count. Continuous Microwave pasteurization system (15 l/hr) was developed using optimized experimental parameters. The achieved reduction of specific energy requirements of originally 0.7 kW-h per litre to 0.142 kW-h per litre makes the presented concept a process option which is highly energy efficient and can be easily integrated into existing food processing operations.**

**Key words:** Microwave processing, conventional process, beet-root jamun juice, nutritional characteristics and specific energy.

## INTRODUCTION

Microwave heating refers to the use of electromagnetic waves of certain frequencies to generate heat in a material (Metaxas and Meredith 1983).Typically, microwave food processing uses the 2 frequencies of 2450 and 915 MHz of these two, the 2450MHz frequency is used for home ovens, and both are used in industrial heating. For protecting nutritional and sensory quality characteristics of foods during processing, new techniques, such as electrical methods, are improved as alternatives to traditional methods. They aim to inactivate enzymes and kill microorganisms in a short time rather than thermal processes while minimizing quality losses. Microwave (MW) heating is another electrical method that provides inactivation of microorganisms quickly rather than the traditional heating methods(AhsenRayman and TanerBysal, 2011). MW heating can be used in the food industry for blanching, cooking, pasteurization, preheating, and drying. Recent studies show that MW heating also provides the transfer of functional components to a product (Canumir and others 2002; Gerard and Roberts 2004).In conventional heating methods, material is heated by conduction or convection. These are relatively slow methods as foods are good heat insulators. The surface is the hottest area of the product and the centre the coolest. When a microwaveable product is to be developed the fundamental mechanisms of microwave heating and the interaction of microwaves with materials should be understood, although the technology is difficult (Buffler, 1993; James, 1993). During microwave processing, microwave energy penetrates through the material. Some of the energy absorbed by the material and converted to heat, which in turn raises the temperature of the material such that the interior parts of the material are hotter than its surface, since the surface loses more heat to the surroundings (Das and others 2009). This characteristic has the potential to heat large sections of the material uniformly Advantages of microwave processing over conventional heating include , rapid volumetric heating, less energy usage than conventional energy forms due to higher energy densities and instantaneous control, (Clayton, 1999) Reduced

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environmental pollution due to increased energy efficiencies and clean transfer of energy to product being heated.

Diabetes mellitus [DM] is a metabolic disorder of the endocrine system. The disease occurs worldwide and its incidence is increasing rapidly in most parts of the world. Cardiovascular disease (CVD) is a major complication of diabetes and the leading cause of early death among people with diabetes. Beetroot(Beta vulgaris)belongs to Amaranthaceae family. Beetroots are a rich source of potent antioxidants and nutrients, including magnesium, sodium, potassium and vitamin C, and betaine, which is important for cardiovascular health. Research published in the American Heart Association journal Hypertension showed drinking 500 ml of beet-root juice led to a reduction in blood pressure within one hour.
Jamun fruit (Syzygiumcumini) belongs to Myrtaceae family. The barks, leaves and seeds extracts of jamun have been reported to possess anti-inflammatory (Chandhuri et al. 1990), antibacterial (Bhuiyan et al., 1996) and antidiarrheal effects (Indira and Mohan, 1992).The blend of beet-root and jamun juice is a formulated health drink. But the effects of microwave (MW) heating on natural jamun and beet-root blended juice during storage have not yet been investigated in detail. For this reason in our study, MW heating was used as an alternative to traditional conventional method in jamun and beetroot blended juice. Furthermore, during 6 months of storage at room temperature (RT), the change in quality characteristics (pH, total soluble matter, total titrable acidity, color values, reducing sugars, total sugars and minerals) engineering properties of foods (thermal conductivity, viscosity, density, specific heat, thermal death time), the effect of microwave power (energy studies) and microbial count was estimated with MW and conventionally processed lots.

## Materials and Methods

### Materials

Jamun (SyzygiumcuminiL.) and Beetroot (Beta vulgaris L.) were used as the raw material in this study. Jamun and beet-root were purchased from a local producer washed and peeled and were stored in a walk-in cooler at +4 ◦Cbefore processing into juice.

### Processing methods

Beetroots procured from the market were thoroughly washed and peeled. Beetroot is made into Cylinder and blanched in the microwave at power levels 2W/gm. Beetroot & jamun juice was extracted by using basket press. The pH value was adjusted to 4.2with the addition of jamun juice to the beet-root juice for the long period of storage. After adjusting pH values, the juices were pasteurized traditionally by conventional method and also with the specially designed microwave (MW) heating applicator. Physical, chemical and microbial analysis was conducted after production and also during a 6-months storage period.

### Conventional method

In conventional method beetroot and jamun blended juice were pasteurized at 95-100$^{o}$C and filled in glass bottle kept at room temp. The following procedure was followed:-

- The juice was taken on a vessel and heated on the gas stove until it was boiled.
- The sterilized bottle was filled with hot juices and capped by using capping machine.

### MW application- Continuous-flow microwave heating system

A modified MW heating system (Enerzi Microwave Systemspvt.ltd, Belgaum) with 2450 MHz (2kw microwave power) operated at 1800 W was used to accommodate the continuous-flow microwave heating of fluid. A stainless steel container (25 liters) was used to feed juice to a calibrated variable speed metering pump, which circulated liquid through the helical-spherical applicator centrally located in the MW heating as shown in figure 1. Inlet and outlet temperatures were continuously monitored by fibre optic temperature probes (-50˚C to 250˚C Reflex Make, Canada). The data were collected for the helical-spherical applicator with juice holding at 94$^{o}$C for particular times and filled into the sterilized glass bottles.

### Methods of analysis

Parameters of microwave (MW) and conventional methods of blended beetroot and jamun juice were analysed as described below.
The pH was determined with a Hanna model HI 3512 pH meter (Hanna Equipment's (India) Pvt.Ltd, Navi Mumbai).Total soluble matter (TSS) was measured in (˚Brix) of juices was measured with a refractometer at 20 ◦C (Assoc. of Official Analytical Chemists [AOAC] 1995).Total titrable acidity, reducing sugars, minerals and moisture was measured using the methods described by Ranganna (1986).The colour ($L*$, $a*$, $b*$) values of the juice were measured with a HunterLabColorflex colorimeter (Hunter Associates Laboratory, Reston, Va., U.S.A.) and total colour differences ($\Delta E$) were calculated according to control group.

For the microbial counts, samples were serially diluted and pour plated in acidified potato dextrose agar (PDA)for mold and yeast counts, MacConkey agar for E.coli and Enteric bacteria, nutrient agar for bacteria (less fastidious detect viable natural microorganisms in beetroot jamun juice blend, the total plate count method was used (Liu et al., 2013). Untreated and treated samples were serially diluted with sterile 0.85% NaCl solution, and 1.0mL of each dilution was plated into duplicate plates of appropriate agar. Nutrient agar (Himedia Laboratories, Mumbai) was used for counting total aerobic bacteria (TAB) after incubation at 37 °C for 48 ± 2 h. Potato dextrose agar agar (Himedia Laboratories, Mumbai) was used for counting the viable yeasts and molds (Y & M) after incubation at 27 °C for 72 ± 2 h. After incubation, the colonies were counted. Log N/N0 was calculated to determine the inactivation effect, where N0 is the number of viable microorganisms of initial microorganisms in the untreated sample, and N was the corresponding viable number of microorganisms after treatment. The samples were analyzed for a storage period of 6 months. All the samples were taken in triplicate.

### Sensory evaluation

Beetroot jamun juice blend was tested by an untrained panel consisting of 10 laboratory members. The judges were asked to rate the juice 0-9 (with 0 indicating a strong rejection and 9 indicating a strong acceptance) on a hedonic scale, and then were asked to comment their impression on appearance, color, flavor, sweetness and overall acceptability.

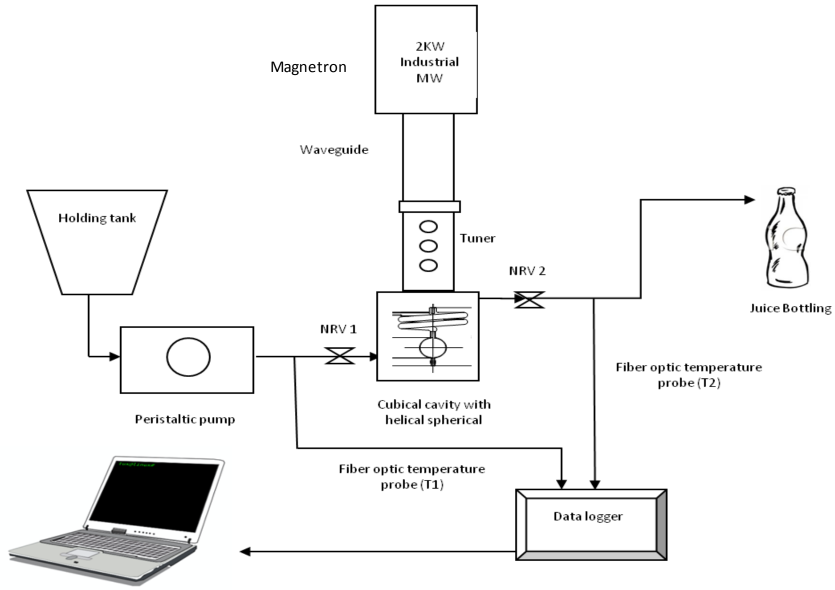


**Fig 1:** Continuous Microwave Heating system with specially designed applicator

**Table 1:** Effect of MW and Conventional treatments on different parameters of juice

| Properties | Control | Microwave treated juice | | Conventional treated juice | |
|---|---|---|---|---|---|
| | | 0 days | 180 days | 0 days | 180 days |
| **pH** | 4.21±0.01 | 4.23±0.01 | 4.18±0.02 | 4.23±0.01 | 4.17±0.02 |
| **°brix** | 9.2±0.1 | 9.6±0.1 | 9.1±0.15 | 9.3±0.12 | 9.2±0.2 |
| **%acidity** | 0.424±0.05 | 0.448±0.04 | 0.49±0.03 | 0.423±0.02 | 0.48±0.03 |
| **%moisture** | 92.20±0.01 | 91.30±0.01 | 90.6±0.01 | 89.83±0.01 | 89.6±0.01 |
| **%sugars** | | | | | |
| Reducing sugars | 3.254±0.1 | 4.93±0.3 | 4.64±0.4 | 4.38±0.2 | 3.76±0.5 |
| Invert Sugars | 5.351±0.2 | 7.565±0.3 | 7.12±0.2 | 6.506±0.1 | 5.43±0.3 |
| Total sugars | 5.246±0.1 | 7.433±0.1 | 7.08±0.5 | 6.39±0.2 | 6.02±0.4 |
| **Colour** | | | | | |
| L* | 24.17 | 24.24 | 23.96 | 24.38 | 24.03 |
| a* | 1.74 | 2.46 | 3.35 | 2.85 | 2.32 |
| b* | -0.13 | -0.08 | -0.02 | 0.01 | -0.11 |
| **Total ash (%)** | 0.472 | 0.54 | 0.62 | 0.59 | 0.59 |

**Table 2:** Microbiological analysis of beetroot Jamun juice

| Storage duration | Conventional | | MW | |
|---|---|---|---|---|
| | TAB ($log_{10}N$) | Y&M ($log_{10}N$) | TAB ($log_{10}N$) | Y&M ($log_{10}N$) |
| Control | 3.44±0.03 | 2.98±0.03 | 3.44±0.03 | 2.98±0.03 |
| MW | | | | |
| 0 days | 1.00±0.09 | 0 | 0 | 0 |
| 30 days | 1.07±0.09 | 0 | 0 | 0 |
| 60 days | 1.17±0.06 | 0 | 0 | 0 |
| 90 days | 1.30±0.01 | 0 | 1.17±0.03 | 0 |
| 120 days | 1.60±0.07 | 0 | 1.30±0.01 | 0 |
| 150 days | 1.61±0.05 | 0 | 1.47±0.05 | 0 |
| 180 days | 1.62±0.08 | 0.69±0.02 | 1.39±0.01 | 0 |

Conventional- thermally treated beetroot jamun juice

MW-microwave processed beetroot jamun blend juice

TAB,total aerobic bacteria

Y&M,yeasts and molds

All data were the means ± SD, n=3

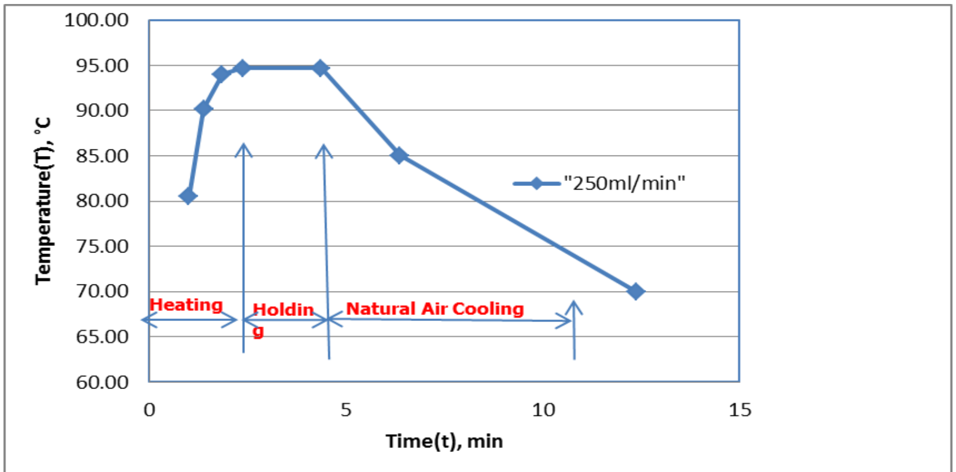


**Figure 2:Time vs Temperature , Heating and cooling curve for continous flow microwave (MW) heated blend juice**

**Table 3:** Engineering properties for beetroot- jamun blend juice

| Properties | Control | MW | Conventional |
|---|---|---|---|
| **Thermal properties** | | | |
| Specific heat(KJ/Kg˚K) | 3.789 | 3.759 | 3.782 |
| Density(kg/$m^3$) | 1.048 | 1.053 | 1.049 |
| Electricalconductivity(µS/cm) At 25.2˚C | 10102.3 | 10700 | 12320 |
| Thermal conductivity(W/m˚K) | 0.574 | 0.572 | 0.574 |

### Engineering properties

Thermal conductivity, Thermal diffusivity, density and Specific Heat were calculated according to the model described by Choi and Okos (1986).The specific energy of continuous MW heating is calculated as shown in Eqn.1

$$\text{Specific Energy (kW-hr/l)} = \frac{\text{Total Energy Consumed (kW)}}{\text{Feed (l/hr)}} \quad (1)$$

The specific energy (kW–hr/l) consumed was calculated as the ratio of total energy consumed (kW-hr/l) and feed (l/hr).The total energy was taken from the sum of the MW energy and feed pump against the power factor.

## Result and Discussion

### Physico-chemical properties

With regard to pH, both treatments (MW heating and conventional method) produced a non-significant increase (P>0.05) in the pH of the juice (Table 1). There was no variation of the pH with storage time, except for the conventionally treated sample, where a decrease (P<0.05) appeared in the last weeks of storage at room temperature, owing to the beginning of microbiological spoilage of the juice (Table 2). Various authors have studied the storage effect on the pH of fruit juices. Souci, Fachmann, and Kraut (1986), Kaanane, Kane, and Labuza (1988), and Martı´n,Solanes, Bota, and Sancho (1995)did not observe variations in pH during storage of MW pasteurized orange juice.

Microorganisms cause fruit juice spoilage by fermentation of sugars, and can thereforechange the ˚Brix. The TSS content of the MW heated and conventional samples increased (P<0.05) with each of the treatments (Table 1).Effect of microwave heating on total sugars of blend juice was studied and compared with conventional method samples shows a slight change in the stored samples.

The fresh jamun and beetroot blend and MW treated grouphad acidity values of 0.424% and 0.448%, respectively. After MW treatment, the transfer of ions to vegetable juice increased the acidity. Titrable acidity values of other groups are shown in (Table 1). After heat treatments, the acidity values were found to be 0.448% and 0.423% for theMWand conventional method respectively. In the 3rd month of storage, acidity values were higher. It is thought that pectin degradation of galacturonic acid causes an increase in acidity. Different heat treatments on acidity values were not statistically significant (P >0.05). With regard to storage, MW treated and conventional method showed an increase in total acidity (P<0.05) after 20 weeks of storage related to the decrease found in pH, possibly owing to the onset of fermentation.

Based on L∗, a∗ and b∗values compared to the fresh blend group were similar in samples after MW and conventional method thermal treatments. Colour changes during storage can result from the storage conditions such as temperature. In addition, the effect of storage on a∗andb∗values of juices was found to be statistically significant (P ≤ 0.05). Thermal treatments decreased the a∗values, and during storage, the a∗values increased. The decrease in b∗values during storage was related to the decrease in betalaine content. Choi and others (2001) studied orange juice processed by traditional methods (90 ◦C, 90 s) and found an increase in b∗ values after 7 weeks of storage.

### Microbial count

The inactivation of the TAB and Y&M in beetroot jamun juice by microwave heating is illustrated in Table 2. The initial counts of TAB and Y&M in untreated (control) juice were 3.44 log10 CFU/ml. After conventional and MW treatment, the TAB count and the Y&M count were significantly reduced. The total plate counts were reduced by 2.44 log10 CFU/ml and 3.44 log10 CFU/ml respectively, indicating that MW treatments at 2kW had a high bactericidal effect. The total Y & M count was reduced by 2.98 log10 CFU/ml for both conventional as well as MW treatments. Koutchama, Le Bail and Ramaswamy (2001) reported that microbial destruction occurs much faster under microwave heating than under thermal heating suggesting some enhanced effects associated with microwave heating. The TAB count was increased only by 0.62 log10 CFU/ml and 1.39 log10 CFU/ml respectively for conventional and MW after 6 months of storage period. The Y&M count was increased only by 0.39 log10 CFU/ml for conventional and MW treated sample showed no colonies after a storage period. On the basis of preliminary research, MW treatment not only achieved inactivation of microbes, but also prolonged juice storage time and maintained nutritional values and sensory characteristics. Therefore, the optimized flow rate (ml/min) and holding times are sufficient to produce muskmelon blend juice with good hygienic standard TAB. Similar results were reported in kava juice (Abdullah et al,2013), apple juice (Tajchakavit, Ramaswamy& Fustier, 1998), orange juice (Nikdel , Chen, Parish, MacKellar, & Friedrich 1993), indicating that MW treatment is effective in reducing the TAB in different fruit products. Inactivation of aerobic bacteria by MW treatment is thought to be the result of protein denaturation and aggregation in cytoplasm indicated by dark spots and the leakage of nucleic acids (Sun woo, et al., 2000). Based on previous microbiological results, the analysis of quality attributes was focused on the effects of MW processing with helical spherical applicator at a power level of 1.8 kW and 250 ml/min flow rate.

**Sensory evaluation**

The average score of taste panelists was 6 for all the sensory attributes of muskmelon blend. The panel has identified the strong beetroot flavor which masked the jamun juice and was rated as moderately acidic. The colour remained a positive point for the blend, as was the appearance. The juices were slightly viscous, which was a positive point for 7 of the judges. The retention of a red colour can be explained by the early inactivation of oxidases. Due to the blanching done prior processing, enzymes were inactivated in fruits leading to cell decompartimentalization. The main oxidizing enzyme in fruits, polyphenol oxidase is fairly resistant to thermal inactivation. This early enzyme inactivation might also play a role in the perceived flavor , with absence for example of lipoxygenase reaction products. As MW blanching was rapid, because the fruits and their vulnerable compounds such as ascorbic acid andanthocyanins were only exposed for a short duration to high temperature.

**Engineering properties**

The time temperature curve showing heating, holding and cooling periods was obtained for beetroot jamun blend juice (figure 2).Thermal Death Time (TDT) of blended juice during MW heating was 3.32min ($D_{94.7}$ =3.32min) with a total heating and cooling time was 12.36min.The Z value reflects the temperature dependence of the reaction.It is defined as the temperature change required to change the D value by factor of 10.Thermal conductivity, specific heat, density was found to be same with control.Viscosity of blended juice was not changed during MW Heating and conventional heating, recorded at 100rpm is 1.41CPs.The efficiency of the MW system and applicator was estimated by the power absorption , which was found to be 58.33 % and 65.62% respectively. The power absorption is calculated by the following Eqn.2

$$\text{Power absorbed } (P_{abs}) = m_1 \times C_p \times \Delta T \quad .. (2)$$

Where, $m_1$= mass flow rate (ml/min), $C_p$=Specific heat (KJ/Kg˚K), ΔT= Temperature difference ($T_o$-$T_i$).
As shown in table 3, the specific heat, density and thermal conductivity were found to be similar for control, conventional and MW treated samples .These parameters were useful to design the MW heating system. Electrical conductivity was rather high in conventional when compared with the MW treated sample.

## Conclusion

The reduced cost of pasteurization is clearly advantageous for the proposed microwave process method in terms of time and energy. The quality characteristics and engineering properties of the beetroot jamun blend juice were evaluated after the application of microwave energy for pasteurization.Specially designed applicator was used for processing of blend juice to reach process temperatures of 95oC at a flow rate of 250ml/min to destroy TAB and Y& M. pH and acidity remained constant during storage whereas total sugars increased immediately after processing but gradually decreased during storage. The color change was found to be insignificant during storage compared to the fresh blend juice value in both MW and conventional treated samples. Exit temperatures of non acidic blend juice under continuous flow microwave heating conditions were found to be a function of product flow rate, and initial temperature.Specially designed applicator was used for processing of blend juice to reach process temperature of 95˚C at a flow rate of 250ml/min with power density 4.73W/g to destroy all bacteria, yeast and moulds.The system gave 61.2% efficiency of conversion of electrical to thermal energy and power absorbed was found to be 1050 Watts.Thermal conductivity was increased during MW Heating approximately by 14 %. The specific energy required for processing 15 l/hr was found to be 0.142 kW-hr. One major factor in designing a continuous flow microwave sterilization system is to insure the fluid is obtaining uniform thermal energy. The large cavity oven showed to produce uniform heating throughout the cavity and the use of helical spherical applicator would narrow the residence time distribution thus proving it to be a feasible thermal process.

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