Continuous Microwave Processing and Preservation of Acidic and Non Acidic Juice Blends

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Abstract

Continuous microwave processing system is one of the pasteurization/sterilization techniques that offer good potential for high quality, reduced process times and energy as compared with conventional techniques. The overall goal of these studies was to process and preserve the fruit and vegetable juices through continuous flow of microwave heating system. Two categories of 10 blends were prepared and processed through continuous – flow of microwave heating system (2kW) at 250 ml/min, using specially designed applicator in cubical cavity. The objectives of this work are to study the effects of Microwave heating on juice properties viz., optical properties, Chemical and biochemical and characteristics like sensory, nutritional, protein and vitamins. The effect of microwave heating on rate of pasteurization/sterilization, the effect of microwave power and shelf life of juices. Storage of one year studies showed that all blends were found to have insignificant variation and equivalent to fresh juice. Continuous MW pasteurization (45 l/hr)/sterilization (30 l/hr) was developed using experimental parameters .Specific Energy consumption was 0.160 KW-hr/kg and energy cost for 1kg of blend juice processing was 1.12 INR compare to the conventional cost approx. 4.9 INR (1kWh=7.00INR).Energy saved during MW Heating is approx. 337 % and processing time was reduced about 3 times compared to conventional, indicating increase in the production of processed juice. The above continuous MW processing have reduced the cost, energy, manpower and space compared to conventional, high pressure processing and plasma technique.

Keywords- Continuous microwave processing, Pasteurization, Sterilization, Specific energy consumption.
1. Introduction
Traditionally, pasteurization of juices is carried out under continuous high temperature short-time (HTST) heating using heat exchangers (tubular/plate) followed by a brief period of holding followed by subsequent cooling, again in heat exchangers and packaging, usually under aseptic conditions. A common problem encountered in the Continuous HTST pasteurization processes is the contact surface fouling and nutrient loss caused by the exposure of fluids to high surface temperatures. Fruit juices were not recognized as vehicles for food borne illnesses; however, there have been certain pathogens associated with food borne illnesses in fruit juices (Besser et al., 1993; Centres for Disease Control and Prevention (CDC), 1997).

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 2450 MHz 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 (Ahsen Rayman and Taner Bysal, 2011). Microwave (MW) heating is another electrical method that provides inactivation of enzymes and microorganisms quickly rather than the traditional heating methods.

Inactivation of microorganisms and reduction of quality attributes are both highly dependent on time-temperature treatments during pasteurization, so optimization of this process is crucial in obtaining a safe and high-quality product. Because of the potential benefits of delivering reduced thermal exposure to inactivate pathogenic microorganisms while maintaining high quality, continuous-flow microwave pasteurization systems have created much interest in the beverage industry and thus has been investigated for various beverages such as apple juice (Tajchakavit, Ramaswamy, & Fustier, 1998; Canumir, Celis, deBruijn & Vidal, 2002), milk (Knutson, Marth & Wagner, 1988; Kudra, VandeVoort, Raghavan, & Ramaswamy, 1991; Villamiel, Lopez-Fandino, Corzo, Martinez-Castro & Olano, 1996) and orange juice (Nikdel, Chen, Parish, MacKellar & Friedrich, 1993; Tajchakavit & Ramaswamy, 1995). While many investigations on microwave pasteurization have focused on microbial inactivation in acidic juices, very little work has been conducted on nutrient retention and product parameters of non-acidic juices processed through a continuous – flow microwave pasteurization system. Until recently, microwave heating has not been used for sterilization as successfully as for pasteurization (Buffler, 1993). The presence of hot and cold spots has been a major concern due to the ability of C. botulinum to grow readily in a non-acidic anaerobic condition.

 Blanching is an important step in the industrial processing of fruits and vegetables. It consists of a thermal process that can be performed by immersing vegetables in hot water (88-99°C, the most common method), hot and boiling solutions containing acids and/or salts, steam, or microwaves. The efficiency of the
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blanching process is usually based on the inactivation of one of the heat resistant enzymes: peroxidase or polyphenol oxidase (Arroqui et al., 2002). Microwave blanching of fruits and vegetables is still limited. Some of the advantages compared with conventional heating methods include speed of operation and no additional water required.

The aim of this research was (1) to design a industrial scale continuous flow microwave pasteurization system for non acidic juice blends and to characterize the following process parameters viz., optical properties, Chemical and biochemical and characteristics like sensory, nutritional, protein and vitamins, energy studies and shelf life of juices.

2. Materials and Methods

2.1 Material
Carrot (Daucus carota), Beetroot (Beta vulgaris), Bittergourd (Momordica charantia), Bottlegourd (Lagenaria siceraria), Cucumber (Cucumis sativus), Pomegranate (Punica granatum), Jamun (Syzygium cumin), Muskmelon (Cucumis melo), Papaya (Carica papaya), Banana (Musa acuminata) Mango (Mangifera indica) Grape (Vitis vinefera) were procured from local local producer washed and peeled and were stored in a walk-in cooler at +4 °Cand 92.4% humidity for a maximum of 24 h before processing into juice.

2.2 Microwave Blanching
All the materials were thoroughly washed, wiped with ethanol to avoid surface contamination and peeled. The low acid containing fruits and vegetables namely Carrot ,Beetroot , Bittergourd, Bottle gourd, Cucumber, Muskmelon , Papaya and Banana were subjected to microwave blanching at 3 W/gm for cleansing of the product, the decreasing of the initial microbial load and inactivation of flavor spoiling enzymes prior to the extraction of juices.

2.3 Preparation of juice blends
Two categories of 10 blends were totally prepared by extracting and blending the juices from fruits and vegetables according to the as in Table 1. Most of the blends was adjusted to 14° brix and some of them were prepared according to commercial formulations. pH was naturally adjusted by mixing acidic and non acidic juices which ranged from 3.9 -4.5.

Table 1: Ratios of Fruit and Vegetable based blends

<table>
<thead>
<tr>
<th>Fruit Based Blends</th>
<th>Ratio</th>
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<tbody>
<tr>
<td>1 Pomegranate :carrot</td>
<td>5:3</td>
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<tr>
<td>2 Beet root Jamun</td>
<td>4:6</td>
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<tr>
<td>3 Musk Melon :Grape</td>
<td>4:6</td>
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<tr>
<td>4 Papaya:Grape</td>
<td>4:6</td>
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<tr>
<td>5 Papaya:Banana:Grape</td>
<td>3:1:6</td>
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</table>
2.4 Processing of juice blends by Continuous Microwave heating system.

Fig.1 explains the steps required for the process of continuous flow microwave sterilization system. The juice blends were passed through specially designed helical spherical applicator (350 ml). The applicator was made from Pyrex glass tubing centrally located within the cubical cavity connected to microwave heating system (2KW-2450 MHz, Model- PTF2620, Enerzi Microwave systems Pvt. Ltd, Belgaum, Karnataka, India). The magnetron connects to the oven cavity using WR-304 waveguide components. A stainless steel reservoir (40 L capacity) was used to feed the liquid to the system. The sample was pumped at flow rate 250ml/min through a calibrated variable speed metering pump. The input power level was given as 1.8 KW, and fiber optic probes (Neoptix model No: REFLEX-4) were used to measure time temperature data. Processed juices were collected aseptically into pre cooled sterile glass bottles (figure 5) at the exit of the microwave cavity.

![Flow chart of processing of juices by continuous flow microwave sterilization system](image)

**Washing and Peeling**

Vegetables/Fruits were exposed to MW heating system at 60-70°C (blanching) at 900 Watts.

**Extraction of Pulp and juice by basket press**

Vegetable or Fruit based blends were prepared

**Homogenization**

Continuous Heating of juice in MW heating system

**Holding tank**

Continuous bottling of juice

**Product kept for storage studies**

**Figure 1**: Flow chart of processing of juices by continuous flow microwave sterilization system

2.5 Measurement of time-temperature profiles and engineering properties.

Water was run through the system long enough to purge out what was previously present in the system, then the data-logger and microwave ovens were turned on. The
system was run for 10 min after establishing steady-state condition indicated by a constant outlet temperature. During microwave heating, inlet and outlet temperatures were recorded every 2 seconds. Heating characteristics associating different system parameters were evaluated. The water to be run through the microwave was kept in a controlled temperature environment for achieving the desired initial temperature. The average residence time of heated water was determined by dividing the sample volume by the steady state volumetric flow rate. Heating rate was calculated according to

\[ HR = \frac{T_o - T_i}{\Delta t} \]  

Where HR is heating rate (°C/s); \( T_o \) is outlet temperature (°C); \( T_i \) is inlet temperature (°C); \( \Delta t \) is residence time in microwave.

2.6 Storage analysis of blends.
Proximate and quality analysis carried as follows: total titrable acidity, anthocyanin estimation, sugars (reducing & total Invert sugars), moisture, total Ash were determined according to S.Ranganna (1986). The colour (L*, a*, b*) values were measured using Hunter Lab Colorflex colorimeter. Total soluble matter (Brix) of juices was measured with a refractometer at 20 °C (Assoc. of Official Analytical Chemists (AOAC) 1995). The pH and electrical conductivity was determined with Hanna model HI 3512 pH meter (Hanna Equipment’s (India)). Total Plate count of bacteria and fungi, Enterobacteria was calculated by plating on nutrient agar and Potato Dextrose Agar and Maconkey Agar respectively (Himedia Laboratories, Mumbai). The shelf life of juice blends were studied for a period of 10 months.

2.7 Sensory analysis.
Acceptance testing was used to determine how much each sample was liked based on a 9-point hedonic scale for a set of attributes, where 9 was the highest intensity and 0 was none. Water was provided to the panellists for rinsing their palate between samples. All evaluations were made in sensory booths at room temperature.

3. Result and Discussion
3.1 Effect of microwave blanching
The effect of microwave blanching was studied in carrot and beetroot by assaying the activity of Pectin methyl Esterase (PME) and polyphenol oxidase (PPO) respectively. PME activity was measured by titration method described by S.Ranganna (1986). PPO was monitored Spectrophotometrically at 425 nm, according to the method described by Campos et al. (1996). It was observed MW Heating effect for PME activity reduced from 9.83 to 1.87 against conventional method at 3.61(µmol/min/mL). It was observed MW Heating effect for PPO activity reduced from 0.0602 to 0.0177 against conventional method at 0.0410(min⁻¹). In parallel to our results, Tajchakavit and Ramaswamy (1997) found PME inactivation in orange juice was significantly faster in the MW heating than with conventional thermal heating and decimal reduction.
times were determined for PME in MW heating as: \( D_{60} = 7.37 \) s (\( z = 13.4 \) °C); and in thermal heating: \( D_{60} = 154 \) s (\( z = 17.6 \) °C).

### 3.2 Effect of microwave heating

The processed juice blend (0 days) was compared with the fresh juice blend with respect to following parameters.

#### 3.2.1 Physico-Chemical properties

pH, Acidity, TSS, Total sugar content, Color values, Anthocyanin pigment, Total ash and mineral content were evaluated in the both fresh and processed samples (Table 2). All the samples showed an insignificant variation when compared to the fresh sample.

**Table 2**: Physico chemical analysis of juice blends for fresh, processed (initial and final) samples

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Blend A</th>
<th>Blend B</th>
<th>Blend C</th>
<th>Blend D</th>
<th>Blend E</th>
<th>Blend F</th>
<th>Blend G</th>
<th>Blend H</th>
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<td>Acidity</td>
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</tbody>
</table>

\( ^*C \)- Fresh Juice blend, I- MW processed (0 days), F- MW processed 180 days, -- present in trace amounts

#### 3.2.2 Microbial Inactivation

Samples were inoculated by the method of serial dilution followed by pour plate technique. The total colony count for both fungi and bacteria for 10 blends were evaluated A total 3 log reduction was observed in the case of bacteria and fungi. Enterobacteriaceae was found to be totally absent in all processed sample.

#### 3.3.3 Heating characteristics

The heating period was less than 6 min and exit temperature of pomegranate and carrot blend juice was 95°C after MW heating. The temperature 121°C was maintained for 20 – 30 sec. Figure 3 shows the average time and temperature curve of the studied non acidic juice blends by MW heating.
Exit time temperature profiles for both water and juice obtained by pumping liquid through the microwave heating system at a flow rate of 250 ml/min showed typical lag periods prior to achieving steady state. The non linearity in time temperature data during early phase of heating (figure 4) can be easily explained by the heat sink contributed by the coil and environment within the cavity as detailed in Kudra et al (1991). Temperature profiles observed for the exit temperatures during heating of both water and non acidic blend juice were similar.

**Figure 2:** Microwave sterilization of non-acidic blend juice: Time temperature curve

**Figure 3:** MW Heating curves for Helical-Spherical as a function of flow rate(250ml)

### 3.3 Calculation of engineering properties.

The energy absorbed by the water can be calculated by the following formula.

\[ Q = m \cdot C \cdot \Delta T \]  

Where, \( Q \) is Quantity of Heat (Released or Absorbed). Joules, calories, \( m \) is Mass (grams) of substance being heated, cooled or changing state, \( C \) = Specific Heat Capacity (J/g°C; cal), \( \Delta T \) = Difference in Temperature.(\( \Delta T^\circ C \); or \( \Delta T^\circ F \)).

The specific energy (KW – hr/kg) consumed was calculated as the ratio of Total energy consumed (KW – hr/kg) and feed (kg/hr). The total energy was taken by sum of the MW energy and feed pump against the power factor.
Thermal conductivity, Thermal Diffusivity, Density and Specific Heat was calculated according to the model described by Choi and Okos (1986). The evaluated values were tabulated (Table 3). The dielectric properties of juices which were calculated according to the method described by Sipahioglu and Barringer (2003) are shown in Table 4.

**Table 3:** Comparison of engineering parameters for fresh and processed juice blends

<table>
<thead>
<tr>
<th>Properties</th>
<th>Blend 1</th>
<th>Blend 2</th>
<th>Blend 3</th>
<th>Blend 4</th>
<th>Blend 5</th>
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<th>Blend 7</th>
<th>Blend 8</th>
<th>Blend 9</th>
<th>Blend 10</th>
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<tbody>
<tr>
<td>Specific Density (g/mL)</td>
<td>103</td>
<td>102</td>
<td>103</td>
<td>104</td>
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<td>102</td>
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<tr>
<td>Specific Heat (kJ/kgK)</td>
<td>2.92</td>
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<td>Thermal Conductivity (W/mK)</td>
<td>0.35</td>
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<tr>
<td>Thermal Diffusivity (m/s)</td>
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*C- Fresh Juice blend, _I- MW processed 0 days

**Table 4:** Dielectric properties of Fresh and processed juice samples

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<th>Month 1</th>
<th>Month 2</th>
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3.4 Preservation and sensory studies.

The samples were tested at an interval of one month up to 180 days. Storage analysis of the juice blends are shown in Table 2. After heat treatments, the acidity values were found to be same for all. The effect of storage on a* and b* values of carrot juices was found to be statistically significant (P ≤ 0.05). Thermal treatments decreased the a* values, and during storage, the a* values increased. Rivas and others (2006) determined acidity values in blended orange–carrot juice that had been produced by PEF (25 kV/cm; 330 μs), conventional pasteurization, and in the control, 0.626%, and 0.599%, 0.568%, respectively. They found an increase in acidity values of PEF-treated and thermally pasteurized samples. Calcium content showed an insignificant variation during 6 months of storage period. Total sugar content decreased slightly when compared with the fresh sample.
4. Conclusion
Given the physical design of the system, volume capacity and volumetric flow rates, the application of microwave energy for the sterilization of non acidic juice blends. Specially designed applicator (helical-Spherical) used for processing of blend juice to reach process temp of 121°C at flow rate of 250ml/min with power density 4.73W/g to destroy all molds, bacteria, yeast, E.coli. Exit temperatures of non acidic blend juice under continuous flow microwave heating conditions were found to be a function of product flow rate, internal volumetric capacity and initial temperature. This system gives 68.75% efficiency of conversion of electrical to thermal energy and power absorbed was found to be 1100 Watts. Thermal conductivity was reduced during MW Heating approximately by 10.3%. It was observed that PPO and PME activity was highly reduced in all vegetables and fruits followed by Microwave Blanching at 3 W/gm. Specific Energy consumption was 0.160 KW-hr/kg. Energy cost for 1kg of blend juice processing was 1.12 INR compare to the conventional cost approx. 4.9 INR (1kWh=7.00INR). 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 coils would narrow the residence time distribution thus proving it to be a feasible thermal process.

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References


