Modelling and Kinetic Study of Novel and Sustainable Microwave-Assisted Dehydration of Sugarcane Juice

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ABSTRACT

Sugarcane juice is one of the delicious drinks with a better nutritional profile and high perishability too. Keeping in view the nutritional composition, it is direly needed to extend its shelf life to assist better transportation and storage. Reduction in water contents is one of the ways to enhance the keeping quality of such kind of foods. In this current research project, optimization of the process parameters was done for the concentration of sugarcane juice. Purposely, microwaves were applied at variable powers i.e. 30-100W. For the optimization of power-time combination, central composite statistical design (CCD) was applied. Overall, power of the microwaves is a major determinant of the evaporation i.e. processing time was reduced with the increase in powers. The results of response surface methodology (RSM) showed sugarcane juice concentration to 75-degree brix at 100W power in 15 minutes. The energy consumption was found to had been reduced 1.3 times as compared to other power ranges. Furthermore, the sensorial characteristics and antioxidant activity were better retained using microwave processing. Hence, 100W power of microwaves was found most energy-efficient for the concentration of the juice. Both, the cost and processing time was reduced using microwave processing, proving it a sustainable tool to concentrate the juices.

Keywords: modelling, kinetics, sugarcane, microwave, sustainability, dehydration, brix

INTRODUCTION

Sugarcane, botanically known as *Saccharum officinarum* is one of the major bumper crops of Pakistan. As a result of milling of sugarcanes, high-sugar juice is obtained which is used for the manufacturing of white crystalline sugar and alcohol. The byproducts of milling process are straws and bagasse, widely burned as fuel for various industries [1]. The major portion of sugarcane juice is water *i.e.* 75-85%. The second major portion consists of non-reducing sugars like sucrose (10-21%). Small amount of reducing sugars like glucose and fructose is also present *i.e.*0.3-3%. Amongst some of the other components, 0.2-0.6% inorganic substituents, 0.5-1% organic matter and same percentage of nitrogenous compounds are present [2]. The major purpose of sugarcane cultivation is the production of sucrose (table sugar). However, at a smaller scale sugarcane juice is also used for the manufacturing of traditional brown sugar, also known as jaggery and gurr or shakkar, more traditionally. Numerous byproducts like bagasse and molasses are produced during the juice clarification and concentration process for white sugar production. These byproducts are used in many of the other industries including plastics, chemical's making, ethanol production and animal's feed etc. [3]. The presence of various biologically active components makes sugarcane juice a health booster natural drink. Though, it has very limited shelf life owing to higher enzyme and microbial activities. Thus, the dire need is to preserve this natural hub of functional components to make it available throughout the year and maintain the bioactivity of the mentioned constituents [4].

Presently, some novel techniques including spray drying or separation through membranes are being trialed as substitutes of conventional preservation processes like evaporation and crystallization etc. [5,6]. Though, microwave has not been yet investigated for concentration of sugarcane juice. The uniqueness of this method is the rapid heating of materials without effecting the bioactivity of functional components. Keeping in view the mentioned facts, the current research project was focused on the concentration of liquid through application of microwave (MW). Even though application of microwaves has been studies for replacing conventional dehydration methods for fruits and vegetables, but to our understanding it has not been tested for concentration or evaporation of juices [7].

Keeping in view the above-mentioned facts, microwave was applied for the concentration of sugarcane juice. Furthermore, the concentrated juice can be constituted again as a drink or can be used directly as in ingredient in the formulation of different other products. Another expectation was that the concentrated product would be healthier than refined table sugar, owing to have bioactive components. So, the outcomes of current study would be at par for the application of sugarcane juice concentration at industrial level, along with other juices. Hence, there is need to explore how evaporation goes on as a function of microwave power and time.

MATERIALS AND METHODS

Juice extraction from sugarcane

A lab scale crusher was used to crush and extract the juice from small-cut sugarcane pieces. Extraction of juice was followed by filtarion through muslin cloth. In this way, the straw and miscellaneous impurities were separated. Storage of filtered juice was done at 4^oC.

Sugarcane juice concentartion through microwave

A microwave oven (Orient, Pak) was used for the concentration of sugarcane juice. The maximum capacity of the oven was 23 litters. 200 ml of the juice samples in glass beaker were placed and heated in the oven at variable microwave powers *i.e.* 30-100 watts to achieve the final concentration 75^o Brix. Airtight glass jars were opted to pack the final concentrate, later that was stored at 4^oC to put under further analyses.

Evaporation rate

Through evaporation process, the samples were weighed periodically after an intervel of every 3 minutes. The evaporation rate (ER) was calculated using following mathematical expression;

$$\mathrm{ER} = \frac{\mathrm{W_t} - \mathrm{W_{t+dt}}}{\Delta \mathrm{t}}$$

ER, the evaporation rate is expressed in gram water per 100 grams per minutes (g water/100g.min).

Δt is the evaporation time (in minutes).

W_t and W_{t+dt} were the moisture content at t time and t+dt, correspondingly [7].

Moisture ratio (MR)

Moisture removed from the juice samples was determined as a function of moisture ratio (MR) by using the equation mentioned below;

$$\mathrm{MR} = \frac{\mathrm{M_t} - \mathrm{M_e}}{\mathrm{M_o} - \mathrm{M_e}}$$

Here, M_e and M_t are the moisture contents at the time zero and t, respectively. While, M_e shows the moisture contents at equilibrium [8]. Various models as explained by [7,9,10] were used for the comparison with evaporation curve.

The diffusivity coefficient was determined by using the obtained experimental data. Fick's law of diffusion was used in this regard. Due to unsteadiness of dehydration process during the diffusion, Fick's law can be mentioned as;

$$\text{MR} = \frac{M_t - M_e}{M_o - M_e} = \frac{8}{\pi^2} \exp\left(\frac{-\pi^2 Dt}{4L^2}\right)$$

Here, D can be explained as effective diffusion coefficient, with unit m^2/s. while, L is showing the half thickness in meters, of imagined slab of sugarcane juice [10]. The slope, depicted by symbol α, can be determined by using mathematical expression given below;

$$\alpha = \frac{-\pi^2 \text{D}}{4L^2}$$

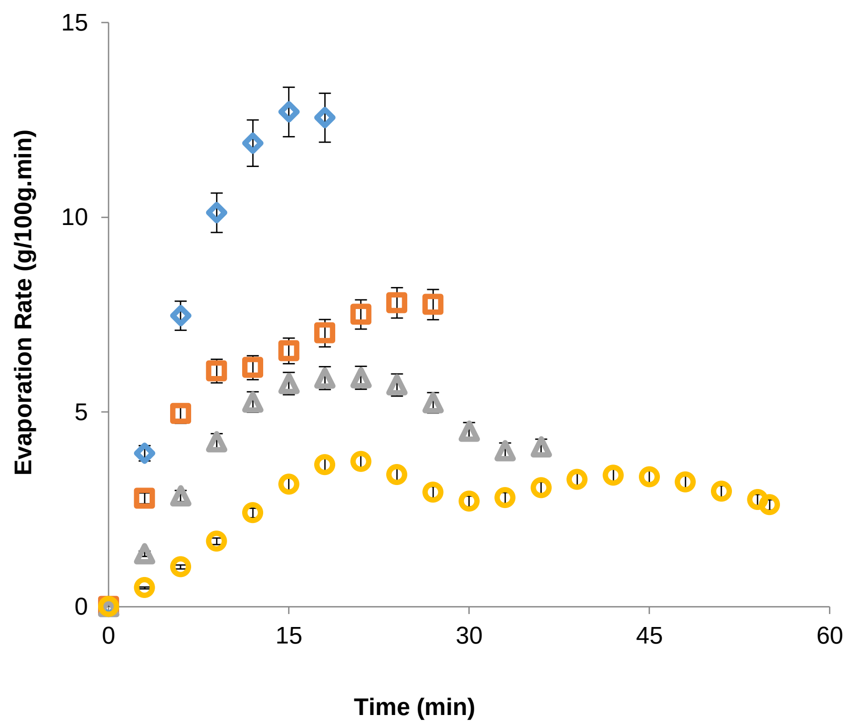
Some of the further performed analysis are mentioned below;

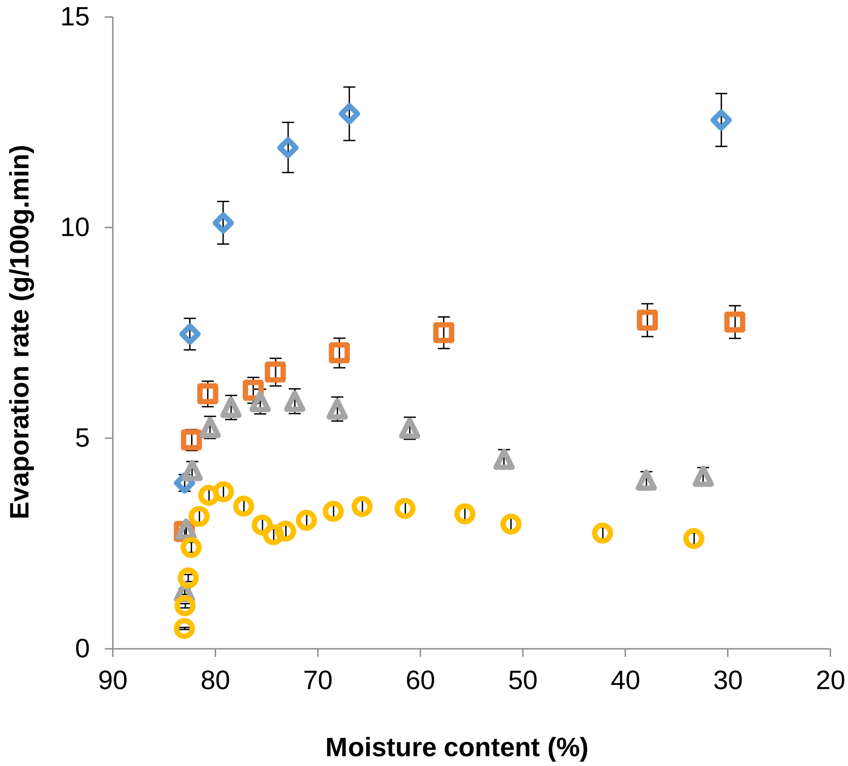
- *Solubility Index*
- *Free radical scavenging activity (DPPH)*
- *Energy Consumption*

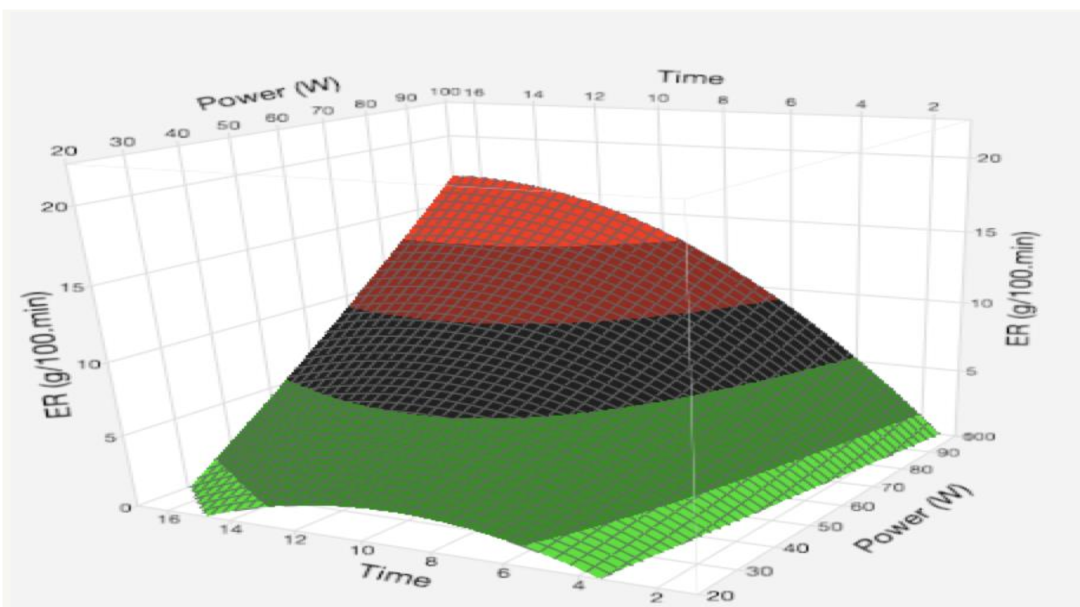
Statistical analysis

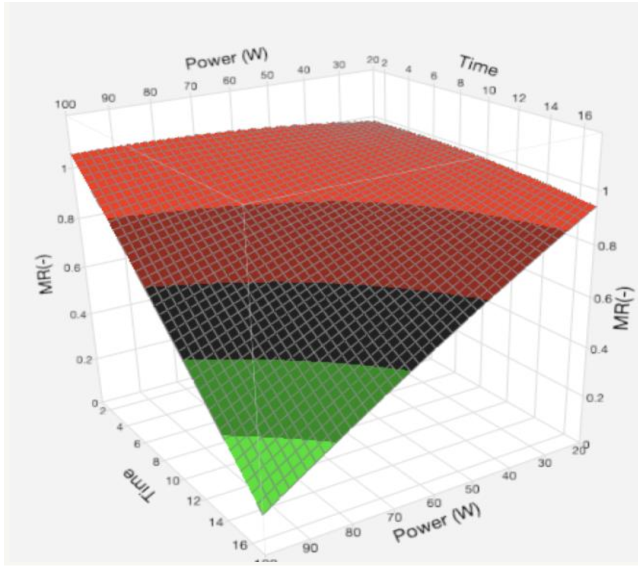
All the experimental values were obtained in triplicate. The final outcomes were statistically analyzed by the application of appropriate model.

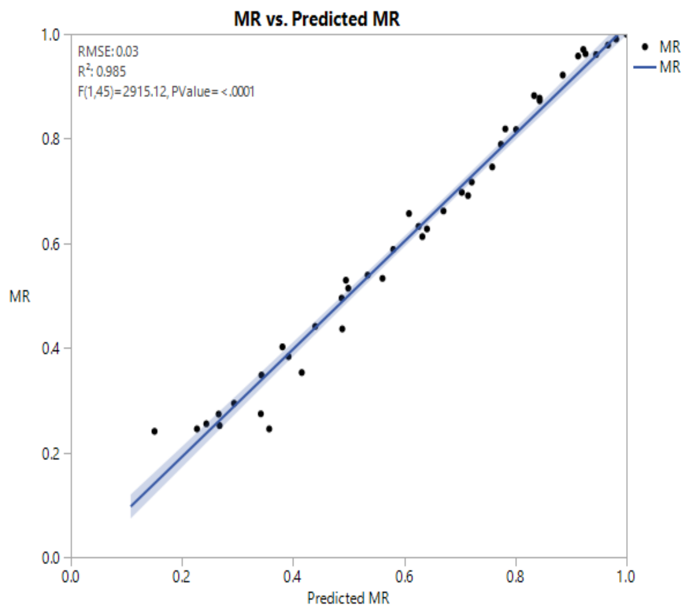
RESULTS AND DISCUSSION

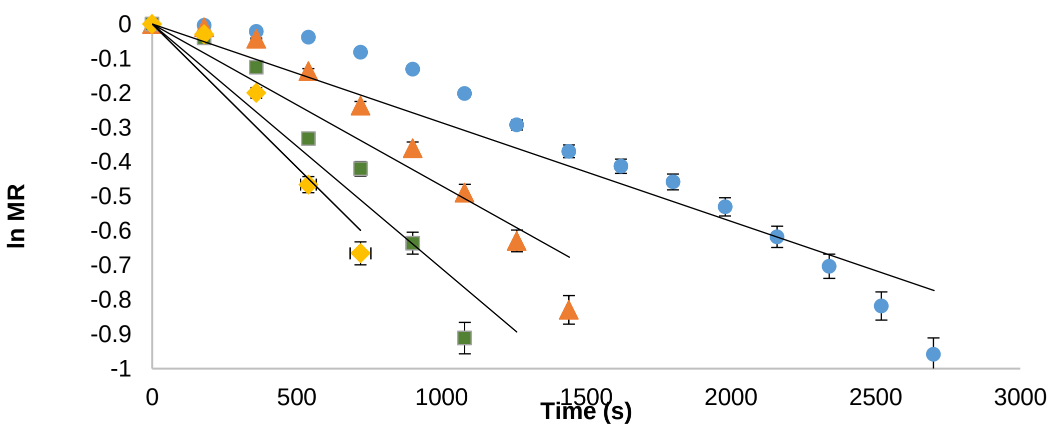



15
10
5
0
Evaporation rate (g/100g.min)
90
80
70
60
50
40
30
20
Moisture content (%)


Power (W)
Time
ER (g/100.min)
Time
Power (W)
ER (g/100.min)


Power (W)
Time
MR(-)
Time
Power (W)
MR(-)


MR vs. Predicted MR
RMSE: 0.03
R²: 0.985
F(1,45)=2915.12, PValue=<.0001
MR
MR
MR
Predicted MR


ln MR
Time (s)

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