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Effect of low temperature plasma processing on physicochemical properties and cooking quality of basmati rice

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ABSTRACT

Low temperature plasma processing is a novel technology used for surface modification in other fields, now drawn considerable interest in food processing sector. In the present study efforts were made to reduce the cooking time of basmati rice using the low temperature plasma. It was observed that after the plasma treatment the cooking time was reduced from 20 min to 13 min with a significant increase in water uptake with respect to increase in plasma power and time of treatment. Water uptake kinetics revealed that the decrease in rate constant (k) in the plasma treated samples showed faster cooking rate. Textural parameters showed that there is a decrease in hardness and stickiness. The extent of plasma treatment was observed as a decrease in contact angle and an increase in surface energy, making surface more hydrophilic and thus rice grains absorb more water with lesser cooking time. Hence plasma treatment can be used to improve cooking quality of basmati rice.
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1. Introduction

Plasma is referred to as the fourth state of matter consisting of excited atoms or molecules, ions, electrons, UV–Visible radiations and neutrals (Deshmukh & Bhat, 2011). The term 'Plasma' was first employed by Lewi Tonks and Irving Langmuir to define this fourth state of matter which is partially or fully ionized state of gas. The change of phase from solid to liquid and further to gas occurs as we increase the energy input likewise increasing the energy input beyond a certain level in the gaseous state causing ionization of gas molecules which yields the plasma state (Luo, Angelo, & Merlino, 1998). Plasma is a gas of which a fraction of its constituents are no longer electrically neutral. Instead, the atoms/molecules are ionized, that is, they have lost (or gained) one or more electrons and moreover free electrons are also present in the plasma.

Rice is the staple food for nearly half of the world's population and second leading cereal in production. Asia produces nearly about 90% of world total production of rice. Cooking is the most important processing step to provide desirable texture in rice grains. It involves heat and mass (water) transfer. Juliano and Perez (1986) reported that change in reaction mechanism of cooking in tropical rice occurs at 90 °C instead of 100–110 °C for milled japonica rice. Chakkaravarthi, Lakshmi, Subramaniana, and Hegde (2008) reported that the logarithmic ratio of moisture uptake during cooking and time taken for cooking proved that the cooking rate follows first order chemical equation. The rice grains are boiled in limited or excess amount of water for cooking. The starch of milled rice grains absorbs moisture and swells during cooking due to its gelatinization (Yadav & Jindal, 2007).

Plasma processing has been used for sterilization, etching and deposition of thin films (Bhat, Upadhyay, Deshmukh, & Gupta, 2003; Deshmukh & Shetty, 2007a; Jahid & Han, 2014; Pankaj et al., 2014). Air plasma are excellent sources of reactive oxygen-based and nitrogen-based species, such as O, O^*_2, O_3, OH, NO, and NO_2 (Laroussi, 2009). Schutze, Jeong, Babayan, Park, and Selwyn (1998) reported that the density of charged species in low pressure plasma discharge is around 10^8–10^{13} cm^{-3}. Recently, plasma technology is used in inactivation of enzymes like peroxidases, polyphenoloxidase (Pankaj, Misra, & Cullen, 2013; Surowsky, Fischer, Schlueter, & Knorr, 2013), spreadability of oil on biscuits (Misra et al., 2014), as the novel and innovative technology. It can also be used to increase the surface energy of the materials so that the affinity with water is enhanced (Deshmukh & Shetty, 2007b). The etching and the increase in surface energy (enhanced hydrophilicity) of rice grains could be useful to reduce cooking time. Thirumdas, Sarangapani, and Annapure (2015) in his review reported that there are several fields in food processing sector where cold plasma can be successfully applicable. In addition, the cross-linking of starch by glow discharge plasma has been reported (Zou, Liu, & Eliasson, 2004).

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Chen, Chen, and Chang (2012) have used DC glow discharge plasma treatment to improve the cooking properties of brown rice, where it was observed that the water absorption of rice was increased after the treatment and resulted in reduction in cooking time.

In the present investigation the effect of low pressure low temperature plasma on the cooking and textural properties of basmati rice has been studied along with the physicochemical properties and other parameters which are essential in determining the quality of the basmati rice with increase in time and power of plasma treatment.

2. Materials and methods

2.1. Materials

Basmati rice was procured from local market of Mumbai city. All required chemicals were procured from S.D. fine chemical and Hi-Media Mumbai, India. All the chemicals and reagents used were of analytical grade.

2.2. Plasma apparatus

Plasma reactor made of a glass tube having thickness 4 mm, height 120 mm and internal diameter 300 mm was used for this purpose. The reactor has top and base plate made of stainless steel. The electrodes were connected through the Wilson seals on these plates. The base plate has ports to connect gas/monomer reservoir, pirani gauge, vacuum pump, air admittance valve etc. The diameter of the two parallel electrodes was 20 cm and distance between the electrodes was kept constant (3 cm) in all the experiments. Rice samples were uniformly spread on the mesh kept on a glass stand between the two electrodes as shown in Fig. 1. Initially, the system was evacuated to 0.02 mbar using Edward's rotary vacuum pump to remove adsorbed gases or water vapours from the surface of the rice grains. The untreated sample was also kept in vacuum before characterization. Atmospheric air was used as gas for plasma generation and the working pressure was then adjusted to 0.15 mbar using mass flow controller. Electrodes were capacitively coupled to Radio Frequency (RF) power supply having frequency 13.56 MHz. The matching network was adjusted to get stable glow discharge. Basmati rice was subjected to air plasma treatment at two different power levels and for different durations and samples stored in vacuum desiccators till further analysis. The samples were named as mentioned in (Table 1).

Table 1
Nomenclature of samples with respect to plasma power and treatment time used for the experiments.

Nomenclature of sample	Power of plasma (W)	Treatment time (min)
Control/untreated	Nil	Nil
Sample 1	30	5
Sample 2	30	10
Sample 3	40	5
Sample 4	40	10

2.3. Proximate composition of basmati rice before and after plasma treatment

Moisture, fat, protein, and ash, was determined using (AOAC, 2010) methods. Carbohydrate content was determined by difference. Amylose content was determined by using procedure Ong and Blanshard (1995).

2.4. Effect of plasma treatment on cooking properties

2.4.1. Cooking time

Basmati rice (2 g) samples were taken in a test tube and cooked in 20 ml distilled water in a boiling water bath. The cooking time was determined by removing a few kernels at different time intervals during cooking and pressing them between two glass plates until no white core was left as per procedure given by Chen et al. (2012).

2.4.2. Water uptake of basmati rice

Rice samples (2 g) were cooked in test tube containing 20 ml distilled water for a cooking time in a boiling water bath. After cooking excess water was drained off and contents were transferred on filter paper to remove surface water. The cooked samples were then weighed accurately and the water uptake ratio was calculated as per procedure given by Singh, Kaur, Singh, and Singh (2005).

2.4.3. Cooking loss

Rice samples (2 g) in 20 ml distilled water were cooked for minimum cooking time in a boiling water bath. The gruels were transferred

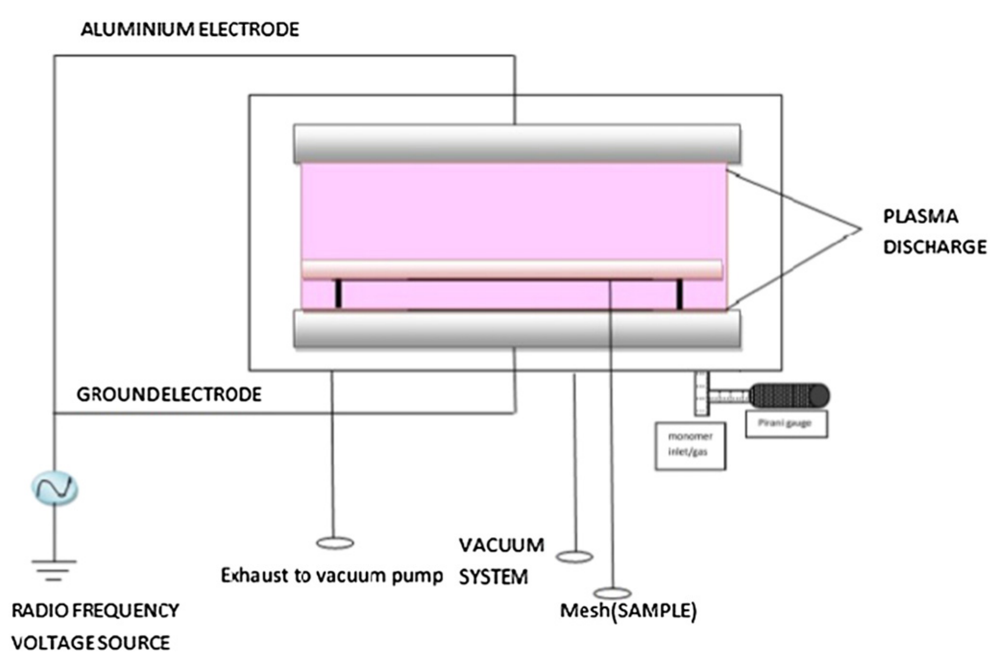

Fig. 1. Schematic diagram of low temperature plasma apparatus.

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