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Influence of low pressure cold plasma on cooking and textural properties of brown rice

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ABSTRACT

The aim of this research is to study the effect of low pressure cold plasma on the cooking and textural properties of brown rice at two different power levels (40 and 50 W) and different treatment times (5 and 10 min). Cold plasma processing of foods is an emerging non thermal technology mainly used to change surface properties of substrates and microbial inactivation. Proximate composition, cooking properties and textural characteristics of plasma processed brown rice were investigated. SEM, contact angle and surface energy analysis were done to study the changes in surface morphology of plasma treated rice. It was observed that after the plasma treatment the cooking time was reduced significantly from 29.1 min to 21.1 min with respect to plasma power and time of treatment. The increase in degree of gelatinization of the cooked samples supported the decrease in cooking time. The water uptake was increased from 2.2 to 2.36 g/g after the treatment. Textural parameters showed there is decrease in hardness from 40.47 N to 30.09 N and chewiness. The extent of plasma treatment was observed as decrease in contact angle and increase in surface energy, making surface more hydrophilic and thus rice grains absorbs more water resulting in lesser cooking time. Based on the results it can be concluded that plasma application can significantly change cooking and textural properties.

Industrial relevance: The present work is suitable for the instant rice production industries. This technology can be used by the industries designing rice cooker. This can also be used by the countries for cooking rice, where resources are scarcity.

1. Introduction

Plasma is a state of matter which consists of electrons, ions, free radicals, positive and atoms in free and excited state and large number of unionised neutral molecules. Cold plasma processing has been used for sterilization, functionalization, inactivation of enzymes, altering the hydrophilic/hydrophobic properties, etching or deposition of thin films etc. (Misra, Tiwari, Raghavarao, & Cullen, 2011; Misra et al., 2014; Pankaj, Misra, & Cullen, 2013; Surowsky, Fischer, Schlueter, & Knorr, 2013; Pankaj et al., 2014; Thirumdas, Sarangapani, & Annapure, 2015a; Sarangapani, Yamuna, Thirumdas, Annapure, & Deshmuk, 2015; Sarangapani, Thirumdas, Ajinkya, Annapure, & Deshmuk, 2016). There are different types of plasma systems available, of those barrel and parallel plate plasma systems are widely used. Etching is surface phenomenon where the surface is etched by the ionized gas and the etched materials are volatilized and is removed by vacuum system. The reactive ion etching system is a type of glow discharge method generally used to increase the effective surface area of the material at the microscopic scale enhancing the surface energy. In the plasma etching system the substrate/specimen is placed on live electrode usually operates at reduced pressure and there is bombardment of reactive species (Manos & Flamm, 1989). Murakami, Niemi, Gans, O'Connell, and Graham (2013); Laroussi (2009) reported that air plasma is the sources for reactive oxygen-based and nitrogen-based species, such as O, O^{*}_2, O_3, OH, NO, NO_2 etc. The density of charged species in low pressure glow discharge is around 10^8–10^{13} cm^3 (Schutze et al., 1998; Ward, Jung, Hinojosa, & Benerito, 1978). Several researchers have reported that the cooking and textural properties of the rice can be altered using non thermal processing techniques like ultrasound, gamma irradiation, etc. (Cui, Pan, Yue, Atungulu, & Berrios, 2010; Sabularse, Liuzzo, Rao, & Grodner, 1991; Sung, 2005). However, use of plasma processing to improve properties of food grains are not explored much except a few reports (Chen, 2014; Chen, Chen, & Chang, 2012; Thirumdas, Deshmukh, & Annapure, 2015b).

Rice (*Oryza sativa* L.) is the staple foods for nearly half of the world's population and third leading cereal in production. The consumption of brown rice is decreased across the world due to its dark colour, hard texture, chewiness and prolonged cooking time. The presence of bran layer around the rice kernel makes it unpalatable. Due to this people started to consume milled white rice with wide range of degree of milling. Milling operations with wide range resulted in loss of nutritional

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profile of brown rice because most of the nutrients are present in bran layer and germ of the kernel (Puri, Dhillon, & Sodhi, 2014). The complete milling operation reduces 80% of thiamine (vitamin B1), 67% of vitamin B3, 90% of vitamin B6, half of the phosphorous and manganese, 60% iron and all other essential fatty acids (Babu, Subhasree, Bhakyaraj, & Vidhyalakshmi, 2009).

The nutritional profile of brown rice is high and contains specific phenolic compounds particularly ferulic acid and diferulates. Rice bran is a rich source of oryzanols, which are groups of steryl ferulate esters. During the milling operation most of the phenolic compounds are lost along with bran layer (Tian, Nakamura, & Kayahara, 2004). Cooking is the most important processing steps to provide desirable texture in rice grains. The rice grains are boiled in limited or excess amount of water for cooking. Due to increase in health consciousness, people started to consume brown rice. Though much work has been done on the cooking and physicochemical properties of brown rice, investigation of the effect of cold plasma on the cooking and textural properties of brown rice along with other physico-chemical properties needs to be studied systematically. Therefore, in the present investigation we have reported the effect of cold plasma on the above said properties as a function of applied power and treatment time.

2. Materials & methods

Brown rice was used for analysis which is procured from local market. All required chemicals were procured from S.D. fine chemicals and Hi-Media laboratories (Mumbai), India. All chemicals and reagents used were of analytical reagent grade (purity 99.99%).

2.1. 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 and it is placed in air conditioned room at 24 °C. A schematic diagram of the bell jar type plasma reactor used in the present study is given in Fig. 1. 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. Initially, the system was evacuated to 0.05 mbar using Edward's rotary vacuum pump to remove adsorbed gases or water vapours from the surface of the brown rice. Atmospheric air (temperature 24 ± 1 °C) 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. The output voltage of the plasma system was calculated using high voltage probe (SEW PD-28 model, attenuation ratio- 1:1000) at the given working pressure. The voltage at 40 W and 50 W was observed to be 1500 V and 1750 V respectively. The relative humidity (RH) of air used was 45.3 ± 0.3% was measured using humidity measuring meter. The brown rice (10 g) was kept in petri plate and placed between the two electrodes. The sample treated in triplicates and was performed on the same day. The temperature of brown rice was 24 °C before treatment as the sample was kept in the same air conditioned room. In the present investigation, we have used low pressure / temperature plasma and hence the brown rice temperature is not changed much after the plasma treatment. The samples were treated at two different power levels 40 watt and 50 watt at different time intervals and samples were designated as untreated / control sample (vacuum applied without plasma treatment), sample 1 (40 W 5 min), sample 2 (40 W 10 min), sample 3 (50 W 5 min), sample 4 (50 W 10 min).

2.2. Proximate composition of plasma treated brown rice

Moisture, fat, protein, and ash content were determined using (AOAC, 2010) methods. Carbohydrate content was determined by difference.

2.3. Cooking parameters of plasma treated brown rice

Cooking time, water uptake and cooking loss were determined as per the procedure given by Chen et al. (2012). The elongation in length and width of plasma treated rice after cooking was determined by dividing cooked by uncooked rice kernels.

2.4. Degree of gelatinization

The degree of gelatinization was determined using the procedure described by Birch and Priestley (1973). The cold plasma treated samples were cooked for 25 min at three different temperatures 80, 90 and 100 °C in excess water.

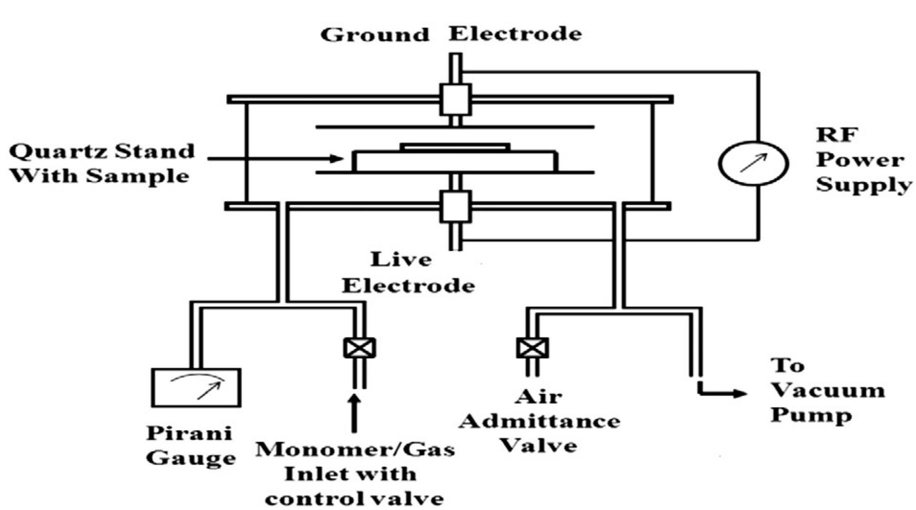

Fig. 1. Schematic diagram of bell jar type plasma parallel reactor.