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Microwave vs conventional popping system: A comparative evaluation for maize popping

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Abstract

Microwave popping has vast and substitute technology in the field of food popping process over the conventional popping process for food grains such as maize, rice, sorghum etc. Basically, microwave processing is being performed by electromagnetic radiations with a microwave frequency of approximately 2,450 megahertz (MHz) and the main principle behind the food heating is dielectric heating which is absorbed by food material which have moisture content as a one component. This is the only one food processing operation which transfers the energy from inside to outside of the food items due to its volumetric heating rather than conventional heating source which transfers heat from outside to inside with temperature gradient and heat loss (based on conduction principle). In this article, studies on comparative analysis of popping characteristics were extensively done for poppable variety of maize grains using microwave radiation as heat source and existing conduction principle. Popping is a simultaneous starch gelatinization and HTST expansion process. This study aimed at providing brief knowledge on popping characteristics of maize grains such as popping yield and volume expansion ratio for obtaining high popping characteristics in best suitable method. It was found that popping characteristics (such as popping yield-85.62% to 90% mean of 87.81% and Volume Expansion Ratio - 6 to 8 folds) of American maize as compare to batch type of popping machine with popping yield-62% to 75% mean of 68.50 % and Volume Expansion Ratio – 5 to 6 folds). These results were highest in microwave popping with less input of electric energy.

Keywords: maize, popping method, popping characteristics

Introduction

Microwave heating has vast applications in the field of food processing over a period of several decades. The applications of microwave heating in food processing include drying, pasteurization, sterilization, thawing, tempering, baking of food materials etc. (Gupta & Wong, 2007; Metaxas & Meredith, 1983) [8, 17]. Microwave heating has gained popularity in food processing due to its ability to achieve high heating rates, significant reduction in cooking time, more uniform heating, safe handling, ease of operation and low maintenance (Salazar-Gonzalez, San Martin-Gonzalez, Lopez-Malo, & Sosa-Morales, 2012; Zhang, Tang, Mujumdar, & Wang, 2006) [21, 26]. Moreover, microwave heating might change flavor and nutritional qualities of food in a lesser extent as opposed to conventional heating during cooking or reheating process (Vadivambal & Jayas, 2010) [27]. Microwaves are electromagnetic waves whose frequency varies within 300 MHz to 300 GHz. Domestic microwave appliances operate generally at a frequency of 2.45 GHz, while industrial microwave systems operate at frequencies of 915 MHz and 2.45 GHz (Datta & Anantheswaran, 2000) [5]. Magnetron is a main and important unit in all type of microwave food heating applications with magnet in its mounting box. The horizontal plates of it form a heat sink, cooled by airflow from a fan. The magnetic field is produced by two powerful ring magnets, the lower of which is just visible. Almost all modern microwave applicators in home, magnetrons are of similar layout and appearance. Microwave processing uses microwave radiation to heat food. Electromagnetic (EM) radiation exists over a range of wavelengths, where shorter wavelengths (such as x-rays and gamma rays) have higher energy than longer wavelengths (such as radio waves). On the electromagnetic spectrum, microwaves fall between radio and infrared waves.

Microwaves are a form of electromagnetic radiation and are on the low energy end of the energy spectrum, second to radio waves. The waves are generated by something called a magnetron – something found within every microwave processing machines.

Magnetrons produce an electromagnetic field with a microwave frequency of approximately 2,450 megahertz (MHz), which is the equivalent to 2.4 gigahertz (GHz). Microwaves produced within the microwave processing space cause dielectric heating – they bounce around the inside of the machine and are absorbed by whatever is placed in that. In order for something to heat in a microwave machines, water must be present within the substance. If water is not present, heating will not occur and it would remain cool. The reason for this is that water molecules within the food vibrate at an incredible speed, creating molecular friction which is responsible for the heating of the food. The structure of the water molecules are torn apart and vigorously deformed. This is much different than any other method of cooking, as other methods such as convection ovens heat up food by transferring heat conventionally from the outside inward.

Microwave heating is caused by the ability of the materials to absorb microwave energy and convert it into heat. Microwave heating of food materials mainly occurs due to dipolar and ionic mechanisms. The presence of moisture or water causes dielectric heating due to the dipolar nature of water. When an oscillating electric field is incident on the water molecules, the permanently polarized dipolar molecules try to realign in the direction of the electric field. Due to the high frequency the electric field, this realignment occurs at a million times per second and causes internal friction of molecules resulting in the volumetric heating of the material. Microwave heating might also occur due to the oscillatory migration of ions in the food which generates heat in the presence of a high frequency oscillating electric field (Datta & Davidson, 2000) [6]. Microwaves are in fact radiation. They are classified as non-ionizing radiation – radiation which can change the position of atoms but is not strong enough to alter their structure, composition, or properties. Even though non-ionizing radiation is not strong enough to alter the structure of atoms, it is still able to cause physical alterations. A clear example of how non-ionizing radiation can harm you is the damage caused to your skin and eyes caused by the sun. When you use microwave cooking, you are exposing yourself to microwave radiation. Other forms of ionizing radiation are visible light, ultraviolet and infrared waves, and waves emitted from televisions, cell phones, and electric blankets. Today we live in a technologically advanced world. We could label the time we live in as the "technology age" as well as the "radiation age". We are currently bombarded with radiation from almost everything around us: radio towers, televisions, cell phones, microwave ovens, computers, satellites, broadcast antennas, and so much more.

Traditionally, popping is being done in small and large scale by organized and unorganized sector in the cooking pan of batch type popping machine which was heated by using electric heater with the conduction mode of heat transfer to the cereal grains. Since, this mode of heat transfer is directly proportional to temperature gradient with the thickness of the wall. Heat is passed through the physical contact by the receiving of the energy from adjacent heated atoms. Hence, Temperature control of this heater was set at the same level during popping so that heat loss may be negligible and pan was covered with the lid during processing of the grains to leaving the grains outside the heated pan. The heating was continued until complete popping took place. Till today, organized sector uses only batch type operation for popping of cereals grains (Sharma *et al*. 2015) [23].

The use of microwave energy in food processing has evolved and now is an established phenomenon as a source of clean thermal energy and has a promising potential of cooking, tempering, drying, heating, baking, blanching, popping and puffing processes (Buffler 1993; Roussy and Pearce, 1995) [4, 20]. Microwave popcorn is a very popular snack worldwide and this technology has also been used to pop and puff other cereal grains. Moisture is the driving force in microwave expansion of starchy grains. During microwave heating, glassy starch simultaneously lose moisture and expand (Boischot *et al*., 2003; Ernoult *et al*., 2002) [3, 7]. Degree of gelatinization and moisture content of the starchy grains were two of the most important factors in determining the shape, expansion bulk volume, density and popping efficiency of the microwave products (Lee *et al*., 2000) [15]. During microwave expansion of cereal grains, the microwave energy heats the product through the vibrational energy imparted on moisture. Upon heating, moisture generates the superheated steam necessary for expansion, which accumulates at the nuclei in the glassy matrix, creating a locally high pressure. As cereal matrix undergoes a phase transition from glassy to rubbery state, it starts to yield under high superheated steam pressure and expansion takes place. As moisture is lost from the matrix, and upon cessation of microwave heating, the matrix cools down and reverts to the glassy state and the final structure sets. Microwave process parameters such as microwave power level, microwave power density and residence time are major factors deciding the popping quality of the cereals in domestic microwave oven (Singh and Singh 1999; Moisont and Nakrugsa 2009; Sweley *et al*., 2011; Joshi *et al*., 2014b; Sharma *et al*., 2014) [24, 19, 16, 25, 22].

The snack food is one of the most important areas of the food industry. Designing snack foods today can be a complex process to meet changing consumers taste and expectations and elusive search for something unique that also appeals to a wide variety of people. Most snack manufacturers use some form of existing technology such as batch type popping machine for popping the food grains to prepare snack products. Therefore, popping using advance technologies i.e. microwave oven method are processes, which can produce better popping characteristics as compare to conventional method of popping i.e. batch type popping machine. As a simplest, inexpensive and quickest traditional method of dry heat application in conventional method of popping for preparation of popped food formulations and ready-to-eat snacks products, popping has been practiced since hundreds of years.

Popping of cereals has been practiced since hundreds of years. Popping is a type of starch cookery, where grains are exposed to high temperature for short time. Popping is a process in which kernels are heated until internal moisture expands and pops out through the outer shell of the kernel (Arkhipov *et al., 2005*) [1]. Superheated vapor is produced inside the grains by instantaneous heating, which cooks the grain and expands the endosperm while escaping with great force through the micro pores of the grain structure. Most of the water in the kernel is superheated at the moment of popping and provides driving force for expanding the kernel once pericarp ruptures. Hoseney *et al., 1983* [11] proposed that during the popping of popcorn the pericarp acts as a pressure vessel and popping occurs at about 177°C, which is equivalent to a pressure of 135psi inside the kernel. Popping imparts acceptable taste and desirable aroma to the product. Popped grain being a pre-cooked ready-to-eat material can be used in snack foods, specialty foods and as a base for development of supplementary foods. Convenient snack foods like popcorn, popped and puffed rice, popped sorghum, popped wheat roasted and puffed soybean and other legumes are very popular not only in Indian subcontinent, but also worldwide (Anderson, 1971; Jaybhaye *et al.*, 2014) [1, 12]. Generally, cereal grains are popped with conventional method such as hot air, hot sand, frying in hot oil, batch type popping machine and microwave heating methods. To avoid the limitations of conventional popping methods, electromagnetic waves such as microwaves are used now-a-days, which provides better energy efficiency in very short time. Microwave energy is worldwide used for producing popcorn.

Though a wide range of cereals are used for popping; only few of them pop well. The reason for this may be the factors which influence popping qualities of cereals, such as season, varietal difference, grain characters i.e. bran content, bran thickness, moisture content, type of endosperm, physical characters of grains and also the method of popping (Hoke *et al.*, 2005; Mirza *et al.*, 2014; Joshi *et al.*, 2014a) [10, 19, 13]. Initial micro pore size, popping temperature, surface tension, yield stress and rupture stress are some other factors that influence the popping characteristics of the grains (Henry *et al., 1995*) [09]. This paper presents a comparative analysis of popping characteristics from two various methods of popping of maize grains, so as to understand the concept and principle mechanisms of popping methods, to analyze the factors which are influencing better popping yield with minimum time and energy requirement, in response to high and greater volume expansion ratio.

Materials and methods

Sample preparation

Commercially variety of maize (American corn) was procured from local market, Ludhiana, Punjab, India for conducting investigation on popping. For conducting popping experiments, 100 maize grains (without adding salt and oil) were taken from the conditioned samples of moisture content of 11, 13 and 15% wb. after adding the calculated amount of distilled water in weighed samples because in this range only quality were good. The initial moisture content of the maize was 11 % wb. The final moisture content of the sample was measured with hot air oven at 105ºC for 6 h. Then popping was performed for 3, 4 and 5 min of popping time by conventional as well as microwave oven method. In microwave oven method, IFB make microwave oven of 900 W (Capacity: 30 L) microwave power was chosen. The popping trails with microwave oven were conducted at 60, 80 and100% power level. The grains samples were put in glass beaker and covered with aluminum foil with two or three hole in that for escaping the steam during popping. In conventional method, (PRIMEX make batch type popping machine) the cooking pan was heated by using electric energy. The temperature was set at 200ºC during popping and lid was covered during the experiments. The heating was continued with the 3, 4 and 5 min. Then, popping characteristics such as popping yield and volume expansion ratio were calculated with the following equations and comparative analysis of popping quality was done:

Popping yield (%): Popping yield is the ratio of total weight of popped maize to the sum of total weight of popped and unpopped grains (%).

$$\text{Popping Yield}(\%) = \frac{\text{Total weight of popped corns}}{\text{Total weight of popped corns} + \text{Total weight of unpopped corns}} x100$$

Volume expansion ratio: Volume expansion ratio is the ratio of total popped volume (mL) to that of volume of raw kernels (mL) and expressed as mL.

$$Volume\ Expansion\ Ratio = \frac{Vf}{Vi}$$

Results and Discussion

Effect of conventional method of popping on popping characteristics

Effect of moisture content and time on quality parameters viz. popping yield and volume expansion ratio of maize popped using conventional method has been presented in Fig.1 (a) and (b). Popping yield varied from 47.29 to 71.80 percent and volume expansion ratio varied 4.75 to 7.17 at different moisture levels and time. The popping yield and volume expansion ratio increased as the moisture content increased from 11 to 13% moisture level, and then decreased with further increase of moisture to 15%. The popping yield and volume expansion ratio increased as the time increased from 3 to 5 min of popping. These results agreed with findings of *Metzger et al., 1989* [18]. The maximum popping was obtained 71.80% from moisture content of 13% for 5 min of popping, because it had the highest flake size. The reason behind this was when moisture content was increase up to optimum level then water was the only one factor which increases the popping characteristics in maize after that the phase of material was changed from glassy state to rubbery state and starch becomes softer, so it decreased the popping quality. With this, popping characteristics were increased with increase time due to pressure development inside the kernel.

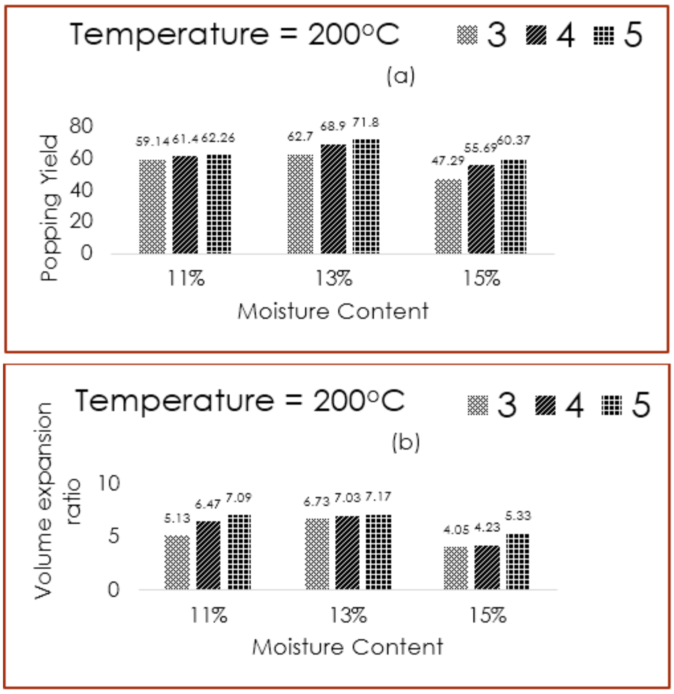

Fig 1: Effect of moisture content and popping time on popping characteristics by conventional method of popping

Effect of microwave oven method of popping on popping characteristics

Effect of power, moisture content and time on quality parameters viz. popping yield and volume expansion ratio of maize popped using microwave oven has been presented in Fig.2 and Fig. 3. In this method of popping, the popping yield was 10.78 to 89.71 % and volume expansion ratio was 1.01 to 9.57. Initially up to 13 % moisture content and 80 % power level the popping characteristics were increased then further increasing the moisture content and power level the popping quality was decreased sharply due to burning of the particles in the microwave. The popping quality was increased with increase the time of popping in this method. The maximum popping was obtained 89.71 % at 13 % moisture content for 5 min. The reason behind this was that, with the time, we increase the microwave power then high power and increased time burns the food products and it produced reverse effect on popcorn quality.

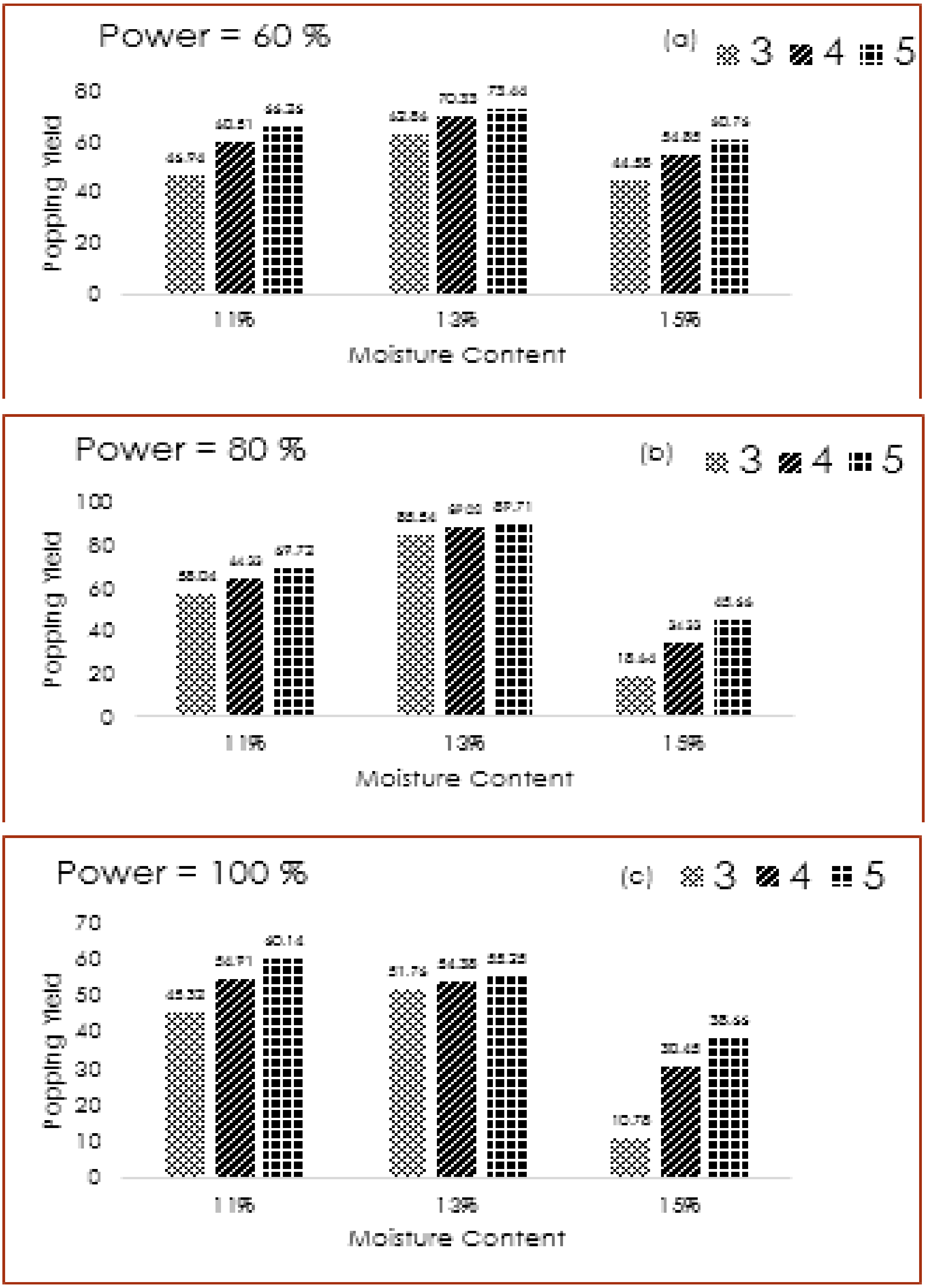

Fig 2: Effect of moisture content and popping time on popping yield by microwave oven method of popping at different microwave power level; (a) at 60% (b) 80% (c) 100%

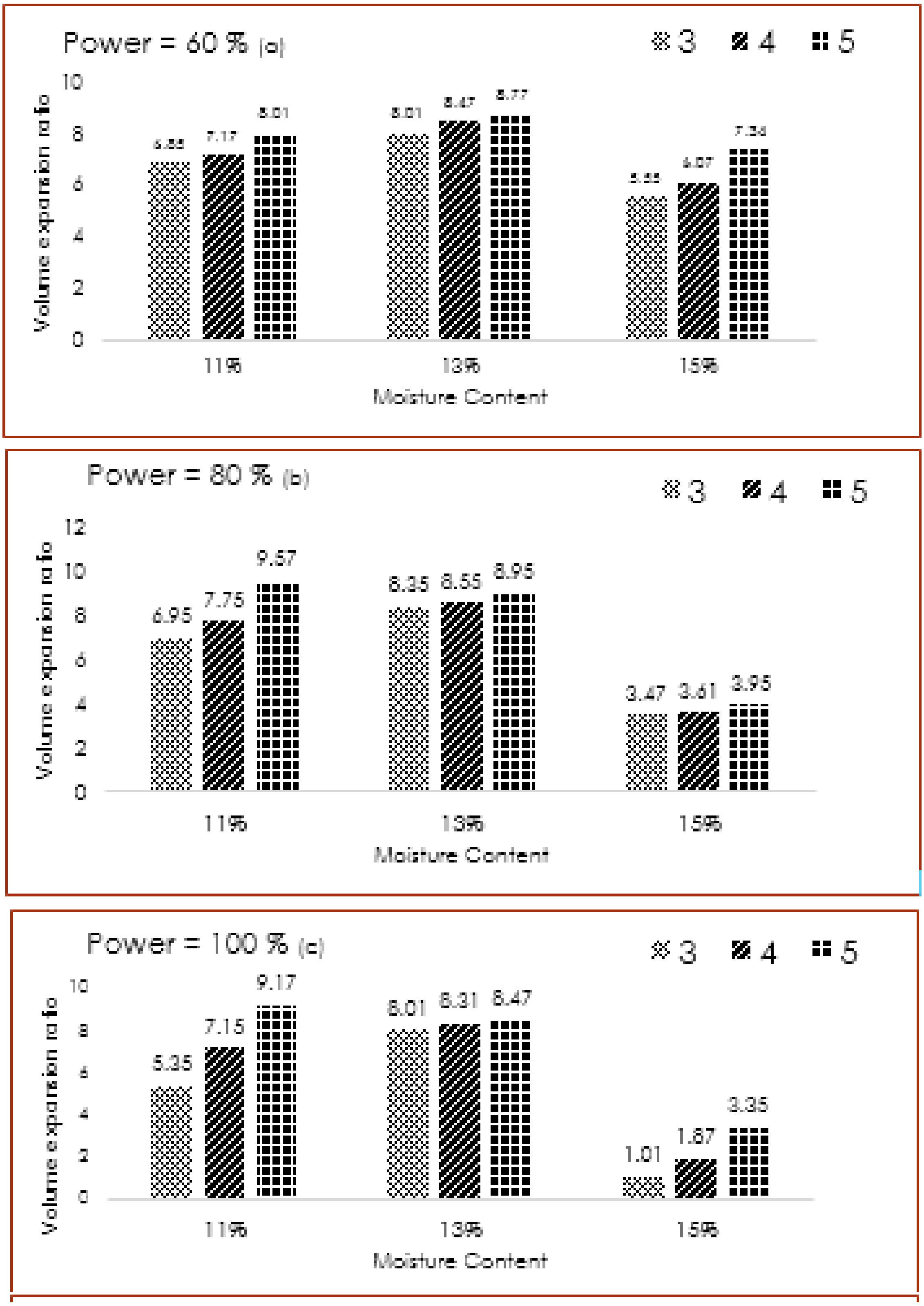

Fig 3: Effect of moisture content and popping time on volume expansion ratio by microwave oven method of popping at different microwave power level; (a) at 60% (b) 80% (c) 100%

Conclusion

The comparative results showed that microwave method of popping was better to produce popcorn as compare to existing conventional method of popping. With this also, microwave method gives increased 20% more popping characteristics than conventional method. In microwave method, the first pop was done at 60 sec and popping completed at 150 sec rather than 100 sec and 240 sec, respectively in conventional method of popping. This analysis showed that microwave method saves more than 30% labour as well as processing time for making popcorn as compare to conventional popping method. Therefore, microwave food processing is the only one innovative and substitute technology for food sector, which can replace the existing heating applications in food industries.

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