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Effect of ultrasound-assisted Osmo and convective air drying on quality of potato slices

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Abstract
Potato slices were subjected to ultra sonication by using ultra probe sonicator at different ultrasound powers such as 130.87, 95.84, 75.44 and 54.26 W and at different treatment times such as 1, 5, 10, 15 min. Sonicated potato slices were subjected to osmotic dehydration at 10% salt concentration for 90 min immersion time and at 50 °C solution temperature and then dried in a convective air dryer at 65 °C at air velocity of 0.04 m/s. The quality of dried potato slices were determined by measuring physical and chemical properties. Lowest final moisture content (5.66% d.b.), highest rehydration ratio (3.25), bulk density (150.31 kg/m^3) and carbohydrates content (58.33 g/100 g) and lowest shrinkage (63.16%) and browning (0.054) were observed in the potato slices treated under 130.87 W and 15 min treatment time compared to all other samples. Final moisture content, Rehydration ratio, bulk density, shrinkage, carbohydrate content and browning of control (osmo air dried) sample was 8.08% (d.b.), 2.32, 145.8 kg/m^3, 68.35%, 57.99 g/100 g and 0.063, respectively. Finally, it was concluded that the quality of ultrasound treated samples observed better compared to control sample.

Keywords: osmotic dehydration, Rehydration ratio, bulk density, shrinkage, carbohydrate content, browning

1. Introduction

Potatoes are highly nutritious vegetable containing high energy, dietary fiber, biologically active photochemicals, vitamins, and minerals which offer great benefit for use as functional food ingredient [1]. In 2017, more than 19 million hectares of potatoes were harvested worldwide. China is the biggest producer of potatoes worldwide, with about one-third of the world's potatoes produced in China and India. According to FAO estimates, in 2019, 370 million metric tons of potatoes were produced worldwide, a substantial increase from 333.6 million tons in 2010 [2]. Potato is not only grown for immediate household human consumption, but, it is more raw material for the food processing industry. Currently, the growth of this industry has increased mainly due to the increase in the urban population, the diversification of diets and lifestyles that have less time for preparing the foods with fresh agricultural produce. For different human consumption purposes, the dehydration process of potatoes can produce two types of products, namely, dehydrated vegetable and snack food. This may require different pre-treatment methods, which could have an important influence on the final quality of the products.

In developing countries about 3% to 14% of potato products are wasted [3]. Drying the agricultural produce reduces the waste. Drying food, namely, fruits and vegetables is used to increase quality of the agricultural produce and it is also used as one of the important processes in food industry, although it has adverse effects as change of color, stiffness of texture and reduction of quality on final product [4]. To improve quality of potato products, some methods like osmosis and blanching before drying are used by researchers and their effects on qualitative properties of dried products are investigated [4]. Osmotic pre-treatment, being an energy efficient technology, is a good pre-process for drying the fruits [5].

Osmotic dehydration is a process to eliminate a part of water of plant and animal products by submerging it in hypertonic solution and the required driving force for transfer of water from food material to osmotic solution is the difference between osmotic pressure of hypertonic solution and food material and can be used as an independent stage or in combination with other processes such as drying by air, freezing, frying, microwave, canning, etc. [6]. Dehydration process by osmotic method leads to reduction of shrinkage of final air dried product compared to the samples dried directly under hot air without osmotic pretreatment [4].

In this study, ultrasound pre-treatment is used before osmotic dehydration which enhances the mass transfer during osmotic dehydration and also air drying because of cavitation effect caused by ultrasound waves. Ultrasound waves create rapid expansion and contractions in cell structure of the material as similar to compression and releasing of a sponge and creates micro-channels for easy mass transfer and water can exit from the solid material during drying by hot air. Ultrasound-assisted osmotic drying is of great commercial importance of less damaged food and is dried with low humidity because of creating spongy structure [7]. Many research works are done on the ultrasonic osmo air driying of different fruits and vegetables, but, limited research data are available on the potato slices with combinations of different power levels and treatment. Hence, the present study was undertaken to improve the quality of potato slices by determining shrinkage, rehydration ratio, bulk density, browning and carbohydrate content of the osmo dried potatoes treated with ultrasound and without ultrasound (control).

2. Material and Methods

2.1 Raw Materials

Matured potatoes of local variety (cv. Kufri Chandramukhi) were procured from the local market of Bapatla, Guntur Dist, Andhra pradesh. Potatoes were washed with tap water and peeled manually with peeler. Peeled potatoes were cut into 1 mm thickness using a manual operated potato slicer.

2.2 Blanching

Potato slices were dipped in 1% sodium metabisulphite solution to reduce non- enzymatic browning and then blanching was done at 80 ºC for 3 min. After blanching, the potato slices were removed from 1% sodium metabisulphite solution and immediately cooled by dipping in cold water for 3 min. The slices were removed from cool water and wiped with tissue paper to remove water adhering to the slices. The initial moisture content of the potato slices was 84.7% w.b. (553.6% d.b.).

2.3 Ultrasound treatment

The blanched potato slices were subjected to ultra sonication by using ultra probe sonicator (Model: DP120, Make: Dakshin, Mumbai). For sonication of potato slices, the distilled water to product ratio was maintained as 3:1 i.e. 150 g of potato slices were dipped in 450 mL water. Temperature of water during the sonication was 30±3 °C. The sonication was done at different power levels such as 130.87, 95.84, 75.44 and 54.26 W and at different treatment times such as 1, 5, 10, 15 min in a continuation mode of operation. After sonication, the potato slices were removed from water, drained, then gently remove adhering water with blotting paper and weighed. After that, the potato slices were subjected to osmotic dehydration at 10% salt solution for 90 min immersion time and at 50 °C solution temperature. For each experiment, the solution to sample ratio of 5:1 means 100g of ultrasonic pretreated potato slices in 500mL osmotic solution was maintained and agitated with a stirrer (Make: REMI Model: RQ 121/D, Mumbai) at a speed of 300 rpm to improve mass transfer and to maintain the uniform solution temperature. After osmotic dehydration, 50 g of the potato slices were dried in a food dehydrator (Model: EZIDRI Ultra FD1000;, Hydraflow Industries Ltd., New Zealand) at 65 °C and at air velocity of 0.04 m/s for 10 h. The quality of dried potato slices were determined by measuring physical, chemical and microbial properties with three replications.

2.4 Physical and chemical properties

2.4.1 Moisture content

Moisture content of potato slices was determined by standard oven method [8]. Approximately five grams of the sample was spread evenly over the previously dried and weighed moisture box with lid. Moisture box + lid along with sample was placed in a hot air oven (M.B. Instruments, Delhi) maintained at 103±2 °C and dried for 24 h. After drying, box with lid closed was removed, cooled in a desiccator and weighed. Three replications of the sample were taken for drying to obtain accurate results. Moisture content was expressed as per cent on dry basis.

$$\text{Moisture content (\% d.b.)} = \frac{W_1 - W_2}{W_2 - W} \times 100$$

where,
W = Wesight of empty box, g
W_1 = Weight of box with material before drying, g
W_2 = Weight of box with dried material, g

2.4.2 Shrinkage

Shrinkage, which occurred during ultrasonic pretreated osmo+air drying as a result of water evaporation, was evaluated by determination of the relative volume of dried material. The shrinkage ratio of dried sample was measured with initial and dried volume of the slices. Same potato slices before and after drying were used for this determination. The initial (fresh) and ultrasonic pretreated osmo + air dried volume of the slices were measured by using mutivolume pycnometer (Model: MVP 1305; Micromerities, USA). Shrinkage of potato slices at the end of drying process was calculated using the following equation [9]:

$$\text{Shrinkage,\%} = \left(1 - \frac{V}{V_0}\right) \times 100$$

where,
V_0 and V denote the initial and dried volume of the slices, respectively.

2.4.3 Rehydration ratio

Rehydration ratio was evaluated by soaking known weight of ultrasonic pretreated osmo + air dried sample in sufficient volume of distilled water in a glass beaker at 40 °C and maintained in a water bath. This process was continued upto 30 min after that the sample weight became constant [9]. Rehydration ratio (RR) was computed as follows:

$$\text{Rehydration ratio, RR} = \frac{W_r}{W_d}$$

where,
W_r = Weight of rehydrated sample, g
W_d = Weight of dried sample used for rehydration, g

2.4.4 Bulk density

Bulk density of ultrasonic pretreated osmo + air dried potato slices was measured by gently filling them in a 25 mL in a measuring cylinder of 250 mL and taking the weight using a digital balance (Essae-Teraoka Pvt. Ltd., Bangalore, AJ-220E) with 0.001 g accuracy. Weight of the filled samples divided by the volume of the container gave the bulk density (kg/m^3) of the samples [8].

2.4.5 Carbohydrate content
Total carbohydrate content of ultrasonic pretreated osmo + air dried potato slices was measured by using anthrone method [10].

Amount of carbohydrates present in 100 mg of the sample (g/100 g) = $\frac{\text{mg of glucose}}{\text{Volume of the sample}}$ x 100

2.4.6 Browning
Exactly 5 g of ultrasonic pretreated osmo + air dried potato powder sample made by motor and pestle was soaked in 100 mL of 60% alcohol for 12 h and filtered with 125 mm whatman filter paper. Absorbance of the filtrate was recorded by spectrophotometer (Model: 2202; Systronics, India) at 440 nm using alcohol as blank and expressed as optical density (OD) [11].

3. Results and Discussion
3.1 Moisture content
Effect of ultrasonic pretreated osmo + air dried potato slices treated under different ultrasound powers and treatment times on moisture content is shown in Fig. 1. The moisture content of ultrasonic pretreated osmo + air dried potato slices varied from 5.66% to 6.52% (d.b.). The lowest moisture content of 5.66% (d.b) was observed in ultrasonic pretreated osmo + air dried potato slices treated with ultrasound power of 130.87 W and treatment time of 15 min and highest moisture content (6.52% (d.b.)) was observed in ultrasound power of 54.26 W and treatment time of 1 min. Moisture content observed in control (osmo + air dried) sample was 8.08% (d.b.). The moisture content of samples decreased significantly (p<0.05) with increase in ultrasound power levels and treatment time. The moisture content of the samples after ultrasonic pretreatment and after osmotic dehydration of the ultrasonic pretreated samples are given in Table 1.

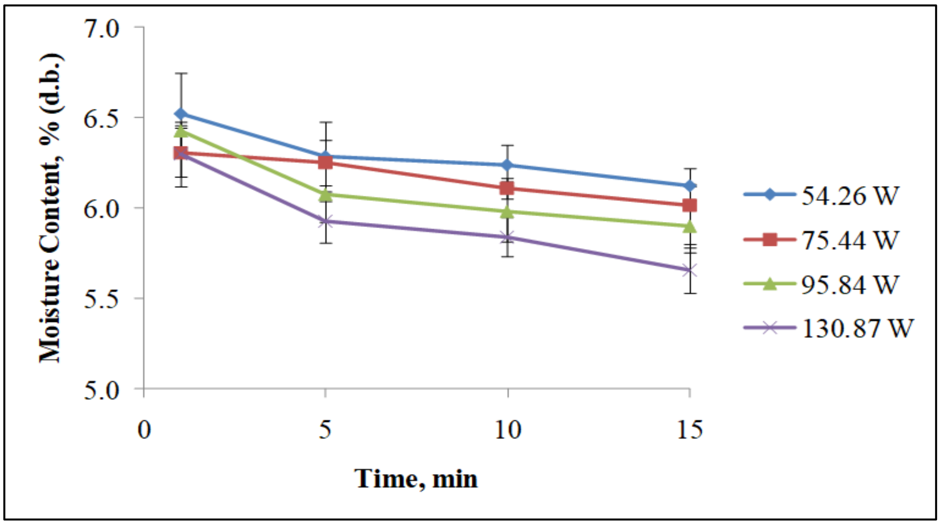

Fig 1: Variation of moisture content of potato slices after air drying with ultrasound treatment time at different ultrasound powers

Table 1: Moisture contents of the potato slices after ultrasonic pretreatment and after osmotic dehydration of ultrasonic pretreated potato slices

Power, W	Moisture Content (% d.b.)							
	Ultrasound				Osmotic Dehydration			
	Ultrasound Treatment Time				Ultrasound Treatment Time			
	1 min	5 min	10 min	15 min	1 min	5 min	10 min	15 min
54.26	552.00	547.87	545.68	544.98	328.51	327.89	325.14	327.19
75.44	551.60	547.39	543.47	542.62	327.89	320.61	320.48	316.73
95.84	550.87	544.31	539.74	537.57	324.25	315.92	310.01	303.54
130.87	548.61	541.07	537.33	534.38	321.06	308.03	305.89	298.60

3.2 Shrinkage
Effect of ultrasonic pretreated osmo + air dried potato slices treated under different ultrasound powers and treatment times on shrinkage is shown in Fig. 2. The shrinkage of ultrasonic pretreated osmo + air dried potato slices varied from 59.9% to 69.1%. The lowest shrinkage of 63.2% was observed in ultrasonic pretreated osmo + air dried potato slices treated with ultrasound power 130.87 W and treatment time of 15 min and highest shrinkage (69.2%) was observed in ultrasound power 54.26 W and treatment time 1 min. Shrinkage observed in control (osmo + air dried) sample was 68.3%. The shrinkage of samples decreased significantly (p<0.05) with increase in ultrasound power levels and not significantly with treatment time. Reduction in shrinkage of the samples with ultrasonic pretreatment can be due to the formation of microscopic channels that develop a spongy structure in the texture. These channels in turn facilitate moisture loss and cell damage to the capillary tubes [12, 13]. High ultrasonic time accelerate the water removal rate and do not allow the product to deform [12, 13]. These results are similar to the results obtained by Kaveh *et al.* [14] and they reported that with the increase of duration of ultrasonic application to blackberry the amount of shrinkage reduced.

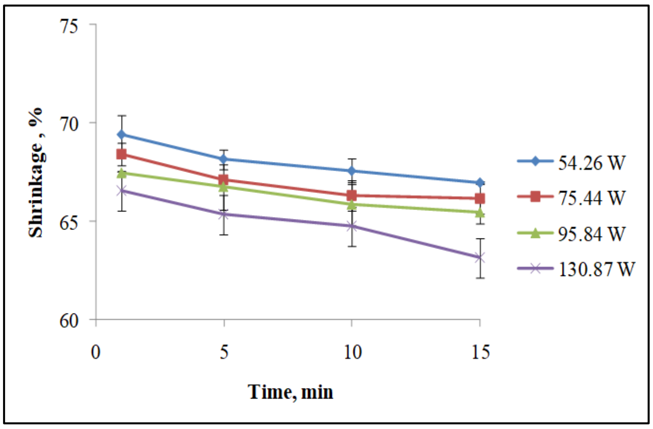

Fig 2: Variation of shrinkage of potato slices after air drying with ultrasound treatment time at different ultrasound powers

3.3 Rehydration ratio

Effect of ultrasonic pretreated osmo + air dried potato slices treated under different ultrasound powers and treatment times on rehydration ratio is shown in Fig. 3. The rehydration ratio of dried potato slices varied from 2.3 to 3.2. The lowest rehydration ratio of 2.3 was observed for ultrasonic pretreated osmo + air dried potato slices treated with ultrasound power of 54.26 W and treatment time 1 min and highest rehydration ratio (3.2) was observed for ultrasound power of 130.87 W and ultrasound treatment time of 15 min. Rehydration ratio of control (osmo + air dried) sample was 2.3. The rehydration ratio increased significantly ($p<0.05$) with an increase in ultrasound power levels and treatment time. The ultrasonic pretreatment improved the rehydration ability of dry products due to the damage of the cell wall caused by ultrasonic waves, resulted in serious surface tissue collapse, enhanced water penetration into the cell, and finally resulted in improved rehydration ratio.

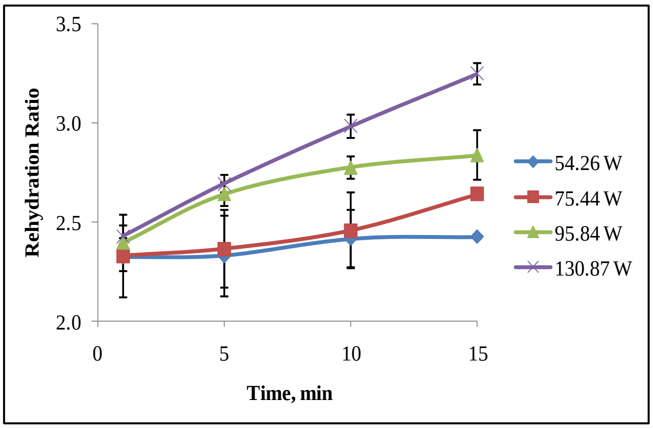

Fig 3: Variation of rehydration ratio of potato slices after air drying with ultrasound treatment time at different ultrasound powers

3.4 Bulk density

Effect of ultrasonic pretreated osmo + air dried potato slices treated under different ultrasound power levels and treatment times on bulk density is shown in Fig. 4. The bulk density of ultrasonic pretreated osmo + air dried potato slices varied from 148.56 to 150.31 kg/m^3. The lowest bulk density of 148.56 kg/m^3 was observed in ultrasonic pretreated osmo + air dried potato slices treated with ultrasound power 54.26 W and treatment time of 1 min and highest bulk density of 150.31 kg/m^3 was observed in ultrasound power 130.87 W and treatment time of 15 min. Bulk density of control (osmo + air dried) sample was 145.8 kg/m^3. The bulk density increased significantly ($p<0.05$) with increase in ultrasound voltage levels and treatment time.

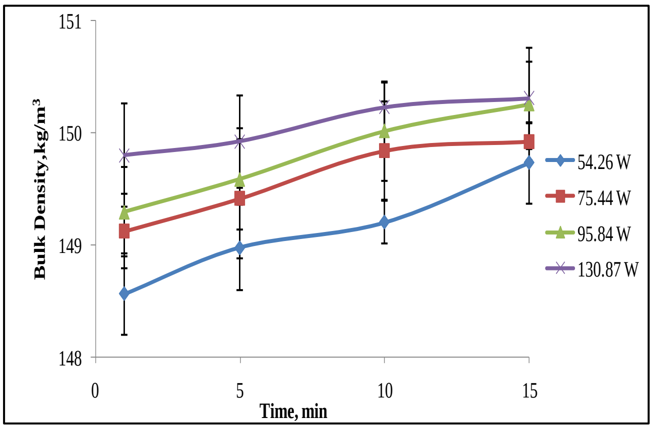

Fig 4: Variation of bulk density of potato slices after air drying with ultrasound treatment time at different ultrasound powers

3.5 Browning

Effect of ultrasonic pretreated osmo + air dried potato slices treated under different ultrasound powers and treatment times on browning is shown in Fig. 5. Browning is expressed in terms of absorbance (OD). The OD of ultrasonic pretreated osmo + air dried potato slices varied from 0.054 to 0.061. The lowest OD (0.054) was observed in dried potato slices treated with ultrasound power 130.87 W and treatment time of 15 min and highest OD of 0.061 was observed in ultrasound power 54.26 W and treatment time of 1 min. The OD decreased significantly ($p<0.05$) with increasing ultrasound power levels and treatment time. Application of ultrasound reduced the browning values in comparison with that of the control (osmo + air dried) (0.063). The reduction in browning values in the ultrasonic pre-treated osmo + air dried samples shows that the rate of brown pigment formation reduced with ultrasound application. Cavitation and heat generated by ultrasound can create free radicals that can inactivate enzymes [15].

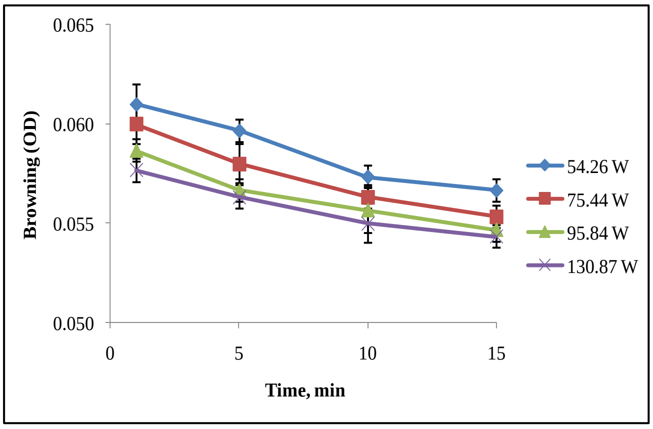

Fig 5: Variation of browning of potato slices after air drying with ultrasound treatment time at different ultrasound powers

3.6 Carbohydrate content

Effect of ultrasonic pretreated osmo + air dried potato slices treated under different ultrasound powers and treatment times on carbohydrate content are shown in Fig. 6. The carbohydrate content of ultrasonic pretreated osmo air dried potato slices varied from 53.21 to 58.33 g/100 g. The lowest carbohydrate content of 53.21 g/100 g was observed in ultrasonic pretreated osmo + air dried potato slices treated with ultrasound power 54.26 W and treatment time of 1 min and highest carbohydrate content of 58.33 g/100 g was observed in ultrasound power 130.87 W and treatment time of 15 min. Carbohydrate content of control (osmo + air dried) sample was 51.16 g/100 g. The carbohydrate content increased significantly (p<0.05) with increase in ultrasound power levels and treatment time.

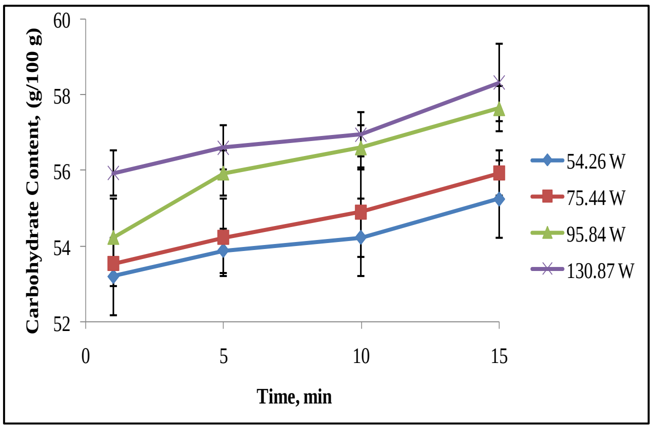

Fig 6: Variation of carbohydrate content of potato slices after air drying with ultrasound treatment time at different ultrasound powers

4. Conclusion

Effect of combination of ultrasound and osmotic dehydration treatment before air drying improved the quality of the potato slices by reducing final moisture content, shrinkage, browning and improving the rehydration ratio, bulk density and carbohydrate content compared to control (osmo + air dried). Highest rehydration ratio, bulk density and carbohydrates content and lowest final moisture content, shrinkage and browning were observed in the ultrasonic pretreated osmo air dried potato slices treated under ultrasonic power 130.87 W and 15 min treatment time compared to all samples treated with ultrasound powers 95.84, 75.44 and 54.26 W and treatment time 1, 5, 10 and 15 min and also control (osmo air dried) sample. Finally, it was concluded that the quality of ultrasound treated samples observed better compared to control sample.

5. Author Contributions

N. Vinoda contributed to the investigation, data collection and analysis of the data and writing the manuscript; Bitra V.S.P. planned the experiments, supervised the work, data and manuscript correction; Edukondalu L. supervised the experimental work; Vimala Beera and V. Srinivasa Rao gave the suggestions.

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