

Influence of in-package microwave treatment and geometry on selected characteristics of *Paneer*

Bhavesh B Chavhan, P Barnwal*, P N Raju and A K Singh

Received: 21 July 2022 / Accepted: 20 December 2022 / Published online: 20 April 2023
© Indian Dairy Association (India) 2023

Abstract: In this paper, the influence of in-package microwave treatment and geometry (cylinder and cube) of *paneer* on its colour, texture and sensory characteristics was investigated. The freshly prepared *paneer* was moulded into cylinder and cube shapes with the help of moulds and packed in polypropylene pack. This packed *paneer* was exposed to different level of microwave power (270, 360 and 450W) for varying time (10, 20 and 30s) and evaluated for colour, texture and sensory attributes of the *paneer*. It was observed that microwave power and exposure time had significant effect on colour, texture and sensory quality of both cylinder and cube shaped *paneer*. It was observed that all important quality and properties of *paneer* viz. whiteness index, hardness, flavour and overall acceptability were higher in cube shaped *paneer* than that of cylinder shaped *paneer*. Therefore, it may be recommended that for in-package microwave treatment, a cube shaped *paneer* may be used over cylindrical shape.

Keywords: Colour, Microwave power, *Paneer*, Sensory, Texture

Introduction

Paneer, a south-Asian variety of soft cheese, is obtained by acid and heat coagulation of milk. It is popular throughout south-Asia and used in raw form or in preparation of several varieties of culinary dishes and snacks. Day by day, the production of *paneer* is spreading throughout the world. The ability of *paneer* to be deep fried is one of the important features that have led to its wider acceptance and a favourite for making snacks, such as *pakor*as or fried *paneer chunks* (Aneja, 2007). Good quality *paneer* is characterized by a marble white colour, sweetish, mildly acidic taste, nutty flavour, spongy body and closely knit smooth texture. It is a rich source of protein available at a comparatively lower cost and forms an important source of animal protein for vegetarians. In addition to its high protein content and digestibility, the biological value of protein in *paneer* is in the range of 80 to 86 (Shrivastava and Goyal, 2007).

Paneer is a valuable source of fat, vitamins and minerals like calcium and phosphorus. It has a reasonably long shelf life under refrigeration. The production of *paneer* has been largely confined to the unorganised dairy sector which employs traditional, inefficient methods of manufacture. Due to the ever growing demand for *paneer*, researchers were encouraged to develop new techniques for the manufacture of *paneer*. Researchers recommended varied processing conditions for the preparation of varieties of *paneer* using different types of milk.

Microwaves are electromagnetic waves whose frequency and wavelength varies from 300 MHz to 300 GHz and 1mm to 1m, respectively. Generally, domestic microwave appliances operate at a frequency of 2.45 GHz, whereas industrial microwave systems operate at frequencies of 915 MHz and 2.45 GHz (Giese, 1992). 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. There are many factors which affect the microwave heating and its heat distribution and the most important of them are the dielectric properties and penetration depth.

ICAR- National Dairy Research Institute (Deemed University),
Karnal – 132 001, Haryana, India

P Barnwal (✉)
Dairy Engineering Division,
ICAR-National Dairy Research Institute (Deemed University),
Karnal-132 001, Haryana, INDIA
Phone: +91-184-2259419(O), +91-8397833349 (M)
Fax : +91-184-2250042
Email: pbarnwal@rediffmail.com, pbndri@gmail.com

There are various applications of microwaves in dairy industry e.g. microwave heating of yoghurt (Turgut, 2016), microwave drying of *paneer* (Singh and Rai, 2004), cultured milk products (Sarkar, 2006), milk pasteurization (Kumar, 2009), continuous microwave processing of *paneer* (Karthikeyan et al. 2011), microwave stretching of mozzarella cheese (Kishor et al. 2015) and soya fortified *paneer* (Uprit and Mishra, 2004) etc. Badola et al. (2017) studies the combined effect of herbal essential oil and in-package microwave thermization treatment on shelf life of burfi and reported that microwave power level of 10% and treatment exposure time of 60s had statistically significant ($p < 0.05$) effect on microbial counts together with non-significant ($p > 0.05$) effect on sensory scores.

The flavour and colour of a food product have significant impacts on consumer

acceptability and two of the challenges with microwave food products are (i) it is often difficult to achieve the desired flavour that matches products prepared in a conventional oven or by frying and (ii) to get the browning that the consumer expects. There are some reactions that do not occur when foods are heated in the microwave oven and this is part of what contributes to the lack of flavour and colour development. The typical browning which occurs when foods are heated by conventional means produces not only the desired brown pigments but also produces a variety of desirable flavours.

The effects of geometries (size and shape) of food materials on microwave heating have been reported by some researchers in published literature (Vilayannur et al. 1998; Basak et al. 2014; Hossan et al. 2010; Zhang et al. 2018). The physical size and shape of foods affect the temperature distribution within the food. Vilayannur et al. (1998) studied temperature and moisture distributions in different geometries i.e. brick-shaped, cylinder-shaped and hexagonal prism-shaped products. Hossan et al. (2010) analysed microwave heating for cylindrical shaped objects. The temperature distributions within the body were represented as a function of cylinder length, radius, heat transfer coefficient, and microwave frequency. Basak et al. (2014) analysed the effect of shapes for microwave-assisted food processing of 2D samples. Zhang et al. (2018) studied numerical simulation of shape effect, which was assessed by microwave power absorption capability and temperature distribution uniformity in a single sample heated in a domestic microwave oven. In microwave processing, various shapes e.g. sphere, cube, cylinder, ellipsoid, and cuboid of potato samples on microwave power absorption capability and temperature distribution uniformity before the internal hot spots reach the phase transition temperature were investigated (Zhang et al. 2018).

Therefore, in view of the above, an effort was made to investigate the influence of in-package microwave treatment and geometry

(cylinder and cube) of *paneer* on its colour, texture and sensory characteristics.

Materials and Methods

Fresh pooled buffalo milk was received from the Experimental Dairy, ICAR-National Dairy Research Institute, Karnal, Haryana, India. Two type of moulds (cylindrical- 2.1 cm dia \times 3 cm height; cubic - 2.1 cm side) were used for moulding the *paneer* into cylindrical and cubical shapes. Stainless steel was used in fabrication of the moulds. Both moulds provide constant mass (11g). Polypropylene microwavable safe packaging materials were procured from M/s Krishna Plastic and Packaging Material, New Delhi. A convection microwave oven (make - IFB; model- 30FRC2; power supply - 230V~50Hz; rated microwave output - 900W; operation frequency - 2450MHz; oven capacity - 30 Litres and cooking uniformity -turntable system) was used for in-package microwave treatment.

Preparation of *Paneer* sample

Paneer was prepared using standard batch method of manufacture (Aneja, 2007) as shown in Fig.1. The prepared *paneer* was cut into desired shape using mould, immersed in chilled water (4°C) and packaged in selected packaging material and storage (4 \pm 1°C).

Freshly prepared *Paneer* was moulded with the help of stainless steel (SS) cylinder/cube mould into cylinder / cube shapes having constant mass 11g. It was then packed in polypropylene pack (410 μ m) under atmospheric condition and subjected to in-package microwave treatment.

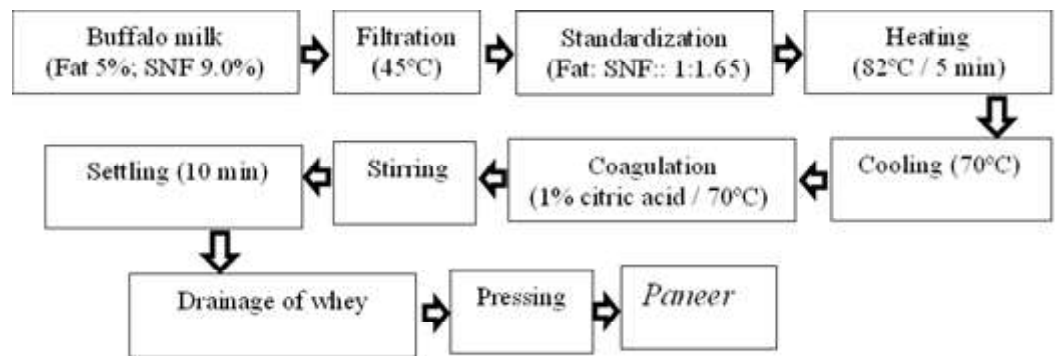
Selection of microwave power level and exposure time for in-packaged *Paneer*

The microwave power level and exposure time was selected based on preliminary trials for the in-packaged *paneer* treatment. The microwave treatment involved subjecting the in-packaged product to three microwave power levels (270, 360 and 450W) and exposure times (10, 20 and 30s) in the convection microwave oven.

Colour Measurement

Whole *paneer* (cubic or cylindrical form) was shredded with the help of a grater (mesh size of grater) and analysed for colour measurement. Colour values (L^* , a^* , b^*) of the *Paneer* samples were determined by using a Colour Measuring System (Labscan, XE, Hunter Lab. Inc., USA). Before colour measurement, the instrument was calibrated with a standard black glass and white glass tiles as specified by the manufactures (Barnwal et al. 2014). Data were obtained from software in terms of L^* {lightness, range: 0 (black) to 100 (white)}, a^* {redness; range: +60 (red) to -60 (green)} and b^* {yellowness, range: +60 (yellow) to -60 (blue)}.

Fig.1 Process flow chart for the manufacture of *Paneer*



Whiteness index (*WI*) of the *Paneer* samples was calculated by using following standard relation (Srinivasa et al. 2017).

$$WI = 100 - \sqrt{(100 - L^*)^2 + a^{*2} + b^{*2}} \quad (1)$$

The chroma value, hue angle and browning index (*BI*) were calculated by using standard relations (Barnwal et al. 2015; Gupta et al. 2011) and used to describe the color change due to shape and in-package microwave treatment of *paneer* samples:

$$Chroma = \sqrt{a^{*2} + b^{*2}} \quad (2)$$

$$Hue \text{ angle} = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (3)$$

$$BI = \left[\frac{100 \times (x - 0.31)}{0.17} \right] \quad (4)$$

$$\text{Where, } x = \frac{(a^* + 1.75 \times L^*)}{(5.645 \times L^* + a^* - 3.012 \times b^*)}$$

Sensory evaluation

The 9-point Hedonic scale (9 for ‘liked extremely’ and 1 for ‘disliked extremely’) was used for the determination of sensory attributes of the in-packaged microwave treated *Paneer* by discriminative and communicative judges selected based on the discriminative test of sensory evaluation. They evaluated the product for various sensory parameters e.g. colour and appearance, body and texture, flavour and overall acceptability.

Texture Profile Analysis (TPA)

Textural attributes of *Paneer* samples were determined by using a texture analyser (TA-XT2i, Stable Micro System Ltd., Surrey, England) equipped with a 25 kg load cell and calibrated with 5kg standard dead weight (Meena et al. 2014). Compression probe

(P-75) was used to compress the whole sample (cube/cylinder) up to 80 percent of its original height (80 percent of its strain), using a double compression test. Before starting the test, the probe (P-75) was calibrated to a distance of 50 mm. The constant probe speed (pre-test speed: 2 mm/sec; speed during test: 1mm/sec; post-test speed: 2mm/sec) were used throughout the study. Sample (cylinder: 2.1 cm dia × 3 cm height, cube: 2.1 cm side) was placed on the platform. Probe was positioned centrally over the sample surface and allowed to compress the product. All the tests were conducted at about temperature of sample maintained at 25±1°C. The force distance compression curve was obtained to estimate the hardness, springiness, cohesiveness, gumminess, chewiness and adhesiveness.

Statistical analysis

The data collected during experimental trials is expressed as mean ± standard deviation for three independent samples, calculated using Microsoft excel software. The data obtained during the present investigation is subjected to the one way analysis of variance (ANOVA) using SPSS version 23 software of M/s IBM Corporation.

Results and Discussion

The one way analysis of variance (ANOVA) for different selected characteristics i.e. colour, texture and sensory characteristics of in-package microwave treated geometry (cylinder and cube) of *paneer* samples are presented in Tables 1-4.

Colour attributes of the in-package microwave treated *Paneer*

Table 1 represents the colour attributes (*L**, *a**, *b**) of in-package microwave treated *paneer* (cylinder and cube geometries) under different microwave power and exposure time. For cylindrical shaped *paneer*, *L**, *a** and *b** these attributes are highly significant (p<0.001) with microwave power, exposure time and their interactions (Table 1).

For cylindrical *paneer* sample, *L**-value ranged from 79.23±0.39 (270W, 20s) to 80.43±0.14 (450W, 10s) whereas for cubical *paneer* sample, it ranged from 80.88±0.46 (450W, 10s) to 82.13±0.10 (270W, 10s). In case of cylindrical *paneer* sample, *a**-value ranged from

-2.60±0.06 (270W, 30 s) to -2.32±0.09 (450W, 20s) and for cubical *paneer* sample, it ranged from -2.49±0.40 (270W, 30s) to -2.06±0.07 (270W, 10 s). The *a**-value was statistically similar for all microwave power at 20 sec microwave exposer time for both shape.

For cylindrical shaped *paneer* samples, the maximum and minimum values of *b**-value were 13.12±0.34 (270W, 30s) and 11.58±0.06 (450W, 20s), respectively. The *b**-value for cubical shaped *paneer* sample ranged from 8.81±0.09 (360W, 20s) to 10.34±0.43 (270W, 30s.) The *b**-value was statistically different for all microwave power at 20 sec.

Colour derivatives of the in-package microwave treated Paneer

Colour derivatives (whiteness index, *WI*; Chroma; hue angle, brownness index, *BI*) of in-package microwave treated *paneer* (cylindrical and cubic geometry) are presented in Table 2 under different microwave power and different microwave exposure

time. These colour derivatives was highly significant ($p < 0.001$) with microwave power (Table 2). The whiteness index of *paneer* (cylinder shape) was ranged from 75.39±0.07 (360W, 20 s) to 76.78±0.13 (450W, 10 s) and for the *paneer* (cube shape); it ranged from 78.14±0.15 (270W, 30s) to 78.97±0.05 (450W, 30s). So it was observed that the whiteness index was more in cube shaped *paneer* than cylindrical (Campanone and Zaritzky, 2005). It was investigated that for cube shaped sample most of the microwave energy was concentrated at the centre. The chroma value of both shaped *paneer* was significant ($p < 0.001$) with microwave power and microwave exposure time. Chroma value was maximum and minimum as 13.37±0.03 and 11.81±0.37, respectively for cylinder shaped *paneer*, whereas it was maximum and minimum as 10.65±0.32 and 9.10±0.11, respectively for cube shaped *paneer*.

The parameter hue angle presented negative sign denotes that the perceived colour was less bluish/more yellowish than inherent colour, positive sign denote opposite. The hue angle value of (cylinder) shaped and (cube) was almost similar for all microwave

Table 1 ANOVA for Colour attributes of different geometry and in-package microwave treated *Paneer*

Microwave Power (W) ↓	Exposure Time (s) →	Colour attributes		
		10	20	30
	Geometry			
			<i>L</i> *	
270	Cylinder	80.02±0.01 ^{ab}	79.23±0.39 ^{bB}	79.91±0.18 ^{aA}
	Cube	82.13±0.10 ^{aA}	81.39±0.05 ^{bA}	80.92±0.01 ^{cB}
360	Cylinder	80.06±0.03 ^{ab}	80.08±0.09 ^{aA}	80.16±0.16 ^{aA}
	Cube	81.72±0.17 ^{ba}	82.13±0.02 ^{aA}	81.46±0.02 ^{ba}
450	Cylinder	80.43±0.14 ^{aA}	79.94±0.07 ^{ba}	80.21±0.07 ^{aA}
	Cube	80.88±0.46 ^{ab}	81.01±1.13 ^{aA}	81.40±0.10 ^{aA}
			<i>a</i> *	
270	Cylinder	-2.58±0.00 ^{ac}	-2.55±0.04 ^{ab}	-2.60±0.06 ^{ab}
	Cube	-2.06±0.07 ^{aA}	-2.42±0.03 ^{aA}	-2.49±0.40 ^{aA}
360	Cylinder	-2.43±0.02 ^{ab}	-2.34±0.08 ^{aA}	-2.37±0.03 ^{aA}
	Cube	-2.30±0.06 ^{ab}	2.28±0.01 ^{aA}	-2.30±0.01 ^{aA}
450	Cylinder	-2.38±0.01 ^{abA}	-2.32±0.09 ^{aA}	-2.49±0.05 ^{baB}
	Cube	-2.20±0.10 ^{abAB}	-2.46±0.10 ^{ba}	-2.33±0.05 ^{abA}
			<i>b</i> *	
270	Cylinder	12.52±0.14 ^{ba}	12.76±0.29 ^{abA}	13.12±0.34 ^{aA}
	Cube	9.50±0.11 ^{ba}	9.64±0.05 ^{ba}	10.34±0.43 ^{aA}
360	Cylinder	12.79±0.05 ^{aA}	12.45±0.03 ^{aA}	12.46±0.17 ^{ab}
	Cube	9.06±0.07 ^{ba}	8.81±0.09 ^{cb}	9.66±0.11 ^{ab}
450	Cylinder	12.26±0.07 ^{aA}	11.58±0.06 ^{ba}	12.19±0.37 ^{ac}
	Cube	9.63±0.18 ^{aA}	9.49±0.03 ^{aA}	9.52±0.08 ^{ab}
F- value		Power	Time	Power × Time
<i>L</i> *	Cylinder	19.52***	15.66***	5.12**
	Cube	5.72*	1.43 ^{NS}	3.99**
<i>a</i> *	Cylinder	36.04***	5.87**	2.33 ^{NS}
	Cube	0.13 ^{NS}	4.49*	2.33 ^{NS}
<i>b</i> *	Cylinder	24.87***	4.52*	4.53**
	Cube	30.77***	23.18***	7.63***

Note: Data presented as Mean ± SD values ; ^{abc}Means within column (microwave power) and ^{ABC}Means within a row (exposure time); the same superscript is not significantly different; NS non-significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; $n = 3$

power and time. There was non-significant effect observed in both power and time. The *BI* value was statistically same for all microwave power at 10 sec.

BI value was ranged from 13.09±0.42 (450W, 20s) to 15.04±0.06 (270W, 30s) for cylinder shaped *paneer* and in case of cube shaped *paneer*, it was ranged from 9.01±0.03 (360W, 20s) to 11.04±0.97 (270W, 30s). The *BI* value higher in cylinder shaped *paneer* than cube.

It was shown that, under different microwave power and microwave exposure time, the Textural characteristics hardness, springiness, cohesiveness, gumminess, chewiness and resilience of *in-packaged microwave treated paneer* were presented in Table 3. The hardness, cohesiveness, gumminess, springiness and resilience properties were significant ($p < 0.05$) with reference to power values of microwave treatments, where the properties like chewiness, cohesiveness, springiness and resilience were non-significant with time for cylinder shaped *paneer*. In case of

Table 2 ANOVA for Colour derivatives of different geometry and in-package microwave treated *Paneer*

Microwave Power (W) ↓	Geometry	Exposure Time (s) →		
		10	20	30
Colour derivatives				
Whiteness Index (WI)				
270	<i>Cylinder</i>	76.26±0.07 ^{ab}	75.49±0.44 ^{bb}	75.86±0.08 ^{abB}
	<i>Cube</i>	79.65±0.08 ^{aa}	78.90±0.04 ^{ba}	78.14±0.15 ^{cb}
360	<i>Cylinder</i>	76.18±0.23 ^{ab}	75.39±0.07 ^{aa}	75.45±0.05 ^{aa}
	<i>Cube</i>	79.47±0.11 ^{ba}	78.94±0.07 ^{aa}	78.96±0.18 ^{ca}
450	<i>Cylinder</i>	76.78±0.13 ^{aa}	76.71±0.19 ^{aa}	76.62±0.03 ^{aa}
	<i>Cube</i>	78.48±0.37 ^{ab}	78.62±1.00 ^{aa}	78.97±0.05 ^{aa}
Chroma				
270	<i>Cylinder</i>	12.78±0.14 ^{ba}	13.01±0.28 ^{abA}	13.37±0.03 ^{aa}
	<i>Cube</i>	9.72±0.12 ^{ba}	9.93±0.06 ^{ba}	10.65±0.32 ^{aa}
360	<i>Cylinder</i>	13.01±0.49 ^{aa}	12.67±0.01 ^{aa}	12.69±0.16 ^{ab}
	<i>Cube</i>	9.35±0.08 ^{bb}	9.10±0.11 ^{bb}	9.99±0.11 ^{ab}
450	<i>Cylinder</i>	12.49±0.07 ^{aa}	11.81±0.37 ^{bb}	12.44±0.06 ^{ab}
	<i>Cube</i>	9.88±0.18 ^{aa}	9.81±0.05 ^{aa}	9.80±0.09 ^{ab}
Hue angle				
270	<i>Cylinder</i>	-1.36±0.00 ^{aa}	-1.37±0.00 ^{aa}	-1.37±0.00 ^{abB}
	<i>Cube</i>	-1.35±0.00 ^{ab}	-1.32±0.00 ^{aa}	-1.33±0.04 ^{aa}
360	<i>Cylinder</i>	-1.38±0.00 ^{ab}	-1.38±0.00 ^{aa}	-1.38±0.00 ^{ab}
	<i>Cube</i>	-1.32±0.00 ^{abA}	-1.31±0.00 ^{aa}	-1.33±0.00 ^{ba}
450	<i>Cylinder</i>	-1.37±0.00 ^{abB}	-1.37±0.00 ^{abA}	-1.36±0.00 ^{aa}
	<i>Cube</i>	-1.34±0.01 ^{bb}	-1.31±0.00 ^{aa}	-1.33±0.00 ^{abA}
Brownness Index (BI)				
270	<i>Cylinder</i>	14.17±0.21 ^{ba}	14.70±0.51 ^{abA}	15.04±0.06 ^{aa}
	<i>Cube</i>	10.13±0.09 ^{aa}	10.08±0.04 ^{aa}	11.04±0.97 ^{aa}
360	<i>Cylinder</i>	14.69±0.72 ^{aa}	14.29±0.11 ^{aa}	14.26±0.22 ^{ab}
	<i>Cube</i>	09.36±0.06 ^{bb}	9.01±0.03 ^{cb}	10.24±0.15 ^{aa}
450	<i>Cylinder</i>	13.91±0.09 ^{aa}	13.09±0.42 ^{bb}	13.58±0.03 ^{ac}
	<i>Cube</i>	10.34±0.25 ^{aa}	9.89±0.23 ^{aa}	10.00±0.05 ^{aa}
F- value		Power	Time	Power × Time
WI	<i>Cylinder</i>	39.51***	2.65 ^{NS}	5.71**
	<i>Cube</i>	10.31***	5.15*	6.98***
Chromo	<i>Cylinder</i>	26.19***	4.89*	4.58**
	<i>Cube</i>	40.55***	31.88***	11.25***
Hue angle	<i>Cylinder</i>	14.35***	0.23 ^{NS}	2.44 ^{NS}
	<i>Cube</i>	1.36 ^{NS}	3.87*	1.21 ^{NS}
BI	<i>Cylinder</i>	22.86***	2.00 ^{NS}	4.43**
	<i>Cube</i>	14.60***	10.52***	3.46*

Note: Data presented as Mean ± SD values (n=3). ^{abc}Means within column (power) and ^{ABC}Means within a row (time) the same superscript is not significantly different, NS non-significant, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; n=3

Table 3 One way ANOVA for textural properties of Microwave in-package treated *Paneer* at different Power and Time

Microwave Power (W)	Geometry	Exposure Time (s)		
		10	20	30
Textural properties				
Hardness				
270	<i>Cylinder</i>	5.40±1.68 ^{aA}	6.81±1.29 ^{aA}	6.10±0.75 ^{aA}
	<i>Cube</i>	8.97±2.27 ^{aA}	5.74±1.01 ^{aAB}	8.15±0.63 ^{aA}
360	<i>Cylinder</i>	3.07±0.97 ^{ba}	5.94±0.48 ^{abAB}	5.43±0.32 ^{aAB}
	<i>Cube</i>	7.22±0.90 ^{aA}	4.30±0.10 ^{bb}	5.20±0.46 ^{bb}
450	<i>Cylinder</i>	4.99±0.75 ^{aA}	4.56±0.22 ^{ab}	4.31±0.25 ^{ab}
	<i>Cube</i>	5.46±0.43 ^{aA}	7.98±1.18 ^{aA}	7.98±1.18 ^{aAB}
Gumminess				
270	<i>Cylinder</i>	3.82±1.18 ^{aA}	4.90±0.85 ^{aA}	4.45±0.54 ^{aA}
	<i>Cube</i>	8.97±2.27 ^{aA}	5.74±1.01 ^{aAB}	8.35±0.50 ^{aA}
360	<i>Cylinder</i>	2.36±0.76 ^{ba}	4.27±0.40 ^{aA}	4.01±0.21 ^{aAB}
	<i>Cube</i>	7.22±0.90 ^{aA}	4.29±0.10 ^{bb}	5.20±0.46 ^{bb}
450	<i>Cylinder</i>	3.51±0.60 ^{aA}	3.60±0.30 ^{aA}	3.25±0.20 ^{ab}
	<i>Cube</i>	5.47±0.42 ^{aA}	7.99±1.18 ^{aA}	7.99±1.18 ^{aAB}
Chewiness				
270	<i>Cylinder</i>	0.57±0.02 ^{aA}	0.60±0.01 ^{aA}	0.62±0.04 ^{aA}
	<i>Cube</i>	4.28±2.14 ^{aA}	1.42±0.22 ^{aAB}	2.18±0.08 ^{aA}
360	<i>Cylinder</i>	0.20±0.15 ^{ba}	0.53±0.07 ^{aA}	0.52±0.11 ^{aAB}
	<i>Cube</i>	1.80±0.38 ^{aAB}	0.68±0.20 ^{bb}	1.31±0.05 ^{abA}
450	<i>Cylinder</i>	0.46±0.08 ^{aA}	0.40±0.00 ^{aA}	0.36±0.35 ^{ab}
	<i>Cube</i>	0.70±0.05 ^{ab}	1.93±0.55 ^{aA}	1.93±0.55 ^{aA}
Cohesiveness				
270	<i>Cylinder</i>	0.70±0.00 ^{ab}	0.71±0.01 ^{aA}	0.72±0.03 ^{aA}
	<i>Cube</i>	1.00±0.00 ^{aA}	1.00±0.00 ^{aA}	0.99±0.08 ^{aA}
360	<i>Cylinder</i>	0.76±0.02 ^{aA}	0.71±0.01 ^{ba}	0.73±0.00 ^{abA}
	<i>Cube</i>	1.00±0.00 ^{aA}	1.00±0.00 ^{aA}	1.00±0.00 ^{aA}
450	<i>Cylinder</i>	0.70±0.01 ^{bb}	0.73±0.02 ^{abA}	0.75±0.01 ^{aA}
	<i>Cube</i>	1.00±0.00 ^{aA}	1.00±0.00 ^{aA}	1.00±0.00 ^{aA}
Springiness				
270	<i>Cylinder</i>	0.14±0.01 ^{aA}	0.11±0.01 ^{aA}	0.14±0.01 ^{aA}
	<i>Cube</i>	0.22±0.14 ^{aA}	0.24±0.02 ^{ba}	0.25±0.00 ^{abA}
360	<i>Cylinder</i>	0.07±0.04 ^{aA}	0.12±0.01 ^{aA}	0.12±0.02 ^{aA}
	<i>Cube</i>	0.24±0.02 ^{aAB}	0.26±0.04 ^{bb}	0.25±0.03 ^{aA}
450	<i>Cylinder</i>	0.13±0.01 ^{aA}	0.10±0.01 ^{aA}	0.10±0.01 ^{aA}
	<i>Cube</i>	0.48±0.10 ^{ab}	0.35±0.01 ^{aA}	0.35±0.01 ^{aA}
Resilience				
270	<i>Cylinder</i>	0.39±0.01 ^{aA}	0.40±0.01 ^{aA}	0.38±0.02 ^{ab}
	<i>Cube</i>	0.16±0.04 ^{bb}	0.33±0.00 ^{ab}	0.34±0.01 ^{aA}
360	<i>Cylinder</i>	0.45±0.05 ^{aA}	0.40±0.00 ^{aA}	0.42±0.00 ^{aA}
	<i>Cube</i>	0.34±0.01 ^{aA}	0.33±0.50 ^{aA}	0.35±0.14 ^{aA}
450	<i>Cylinder</i>	0.39±0.01 ^{ba}	0.40±0.04 ^{abA}	0.46±0.01 ^{aA}
	<i>Cube</i>	0.35±0.02 ^{aA}	0.35±0.01 ^{aAB}	0.35±0.01 ^{aA}
F- value		Power	Time	Power × Time
Hardness	<i>Cylinder</i>	7.44*	4.83*	3.24*
	<i>Cube</i>	6.42**	2.52NS	5.46**
Gumminess	<i>Cylinder</i>	5.78*	5.87*	2.13NS
	<i>Cube</i>	6.85**	2.69NS	5.56**
Chewiness	<i>Cylinder</i>	6.32**	1.82NS	2.70NS

Cohesiveness	<i>Cube</i>	7.26**	2.90NS	5.52**
	<i>Cylinder</i>	3.70*	1.19NS	4.89**
Springiness	<i>Cube</i>	1.65NS	1.45NS	1.08NS
	<i>Cylinder</i>	3.69*	0.71NS	3.96*
Resilience	<i>Cube</i>	9.56***	2.35NS	6.89*
	<i>Cylinder</i>	4.08*	1.23NS	3.89*
	<i>Cube</i>	32.31***	18.08***	14.06***

Note: Data presented as Mean ± SD values (n=3). ^{abc}Means within column (power) and ^{ABC}Means within a row (time) the same superscript is not significantly different, NS non-significant, *p<0.05, **p<0.01, ***p<0.001; n=3

Table 4 One way ANOVA for sensory evaluation of Microwave in-package treated *Paneer* at different Power and Time

Microwave Power (W) ↓	Exposure Time (s) →	10	20	30
	Geometry	Sensory attributes		
		Flavour		
270	<i>Cylinder</i>	48.33±0.57 ^{abA}	49.66±0.57 ^{aA}	47.66±0.57 ^{bA}
	<i>Cube</i>	46.67±2.30 ^{aA}	47.67±0.57 ^{aA}	47.67±0.57 ^{aA}
360	<i>Cylinder</i>	40.33±0.57 ^{aB}	39.33±0.57 ^{aC}	40.33±0.57 ^{aC}
	<i>Cube</i>	47.33±0.57 ^{aA}	47.33±0.57 ^{aA}	46.67±1.58 ^{aA}
450	<i>Cylinder</i>	40.33±0.57 ^{bB}	44.66±0.57 ^{aB}	42.33±0.57 ^{bB}
	<i>Cube</i>	47.00±0.00 ^{aA}	46.67±0.57 ^{aA}	46.33±0.57 ^{aA}
		Body & Texture		
270	<i>Cylinder</i>	30.00±0.00 ^{bA}	32.00±0.00 ^{aA}	31.66±0.57 ^{aA}
	<i>Cube</i>	33.67±0.57 ^{aA}	34.67±0.57 ^{aA}	34.67±0.57 ^{aA}
360	<i>Cylinder</i>	29.33±0.57 ^{aA}	29.66±0.57 ^{aB}	25.66±0.57 ^{bB}
	<i>Cube</i>	34.33±0.57 ^{aA}	34.33±0.57 ^{aA}	35.00±0.57 ^{aA}
450	<i>Cylinder</i>	26.33±0.57 ^{aB}	27.66±0.57 ^{aC}	27.00±1.00 ^{aB}
	<i>Cube</i>	34.33±0.57 ^{aA}	34.00±0.00 ^{aA}	34.33±0.57 ^{aA}
		Colour & Appearance		
270	<i>Cylinder</i>	9.33±0.57 ^{aA}	9.33±0.57 ^{aA}	09.66±0.57 ^{aA}
	<i>Cube</i>	09.67±0.57 ^{aA}	10.00±0.00 ^{aA}	09.67±0.57 ^{aA}
360	<i>Cylinder</i>	8.33±0.57 ^{aAB}	7.66±0.57 ^{abB}	06.00±1.00 ^{bB}
	<i>Cube</i>	10.00±0.00 ^{aA}	10.00±0.00 ^{aA}	10.00±0.00 ^{aA}
450	<i>Cylinder</i>	7.00±1.00 ^{aB}	7.33±0.57 ^{aB}	07.33±0.57 ^{aB}
	<i>Cube</i>	09.67±0.57 ^{aA}	10.00±0.00 ^{aA}	09.67±0.57 ^{aA}
		Overall acceptability		
270	<i>Cylinder</i>	92.66±0.57 ^{bA}	96.99±0.00 ^{aA}	93.98±1.00 ^{bA}
	<i>Cube</i>	94.68±2.30 ^{aA}	97.34±1.14 ^{aA}	97.01±1.00 ^{aA}
360	<i>Cylinder</i>	83.99±1.00 ^{aB}	81.65±1.71 ^{aC}	76.99±2.00 ^{bC}
	<i>Cube</i>	96.33±1.15 ^{aA}	96.33±0.57 ^{aA}	96.34±2.72 ^{aA}
450	<i>Cylinder</i>	78.66±1.14 ^{aC}	84.65±0.57 ^{aB}	81.66±2.14 ^{bB}
	<i>Cube</i>	96.00±1.00 ^{aA}	95.34±0.57 ^{aA}	95.00±2.28 ^{aA}
	F- value	Power	Time	Power × Time
Flavour	<i>Cylinder</i>	524.33***	17.33***	18.66***
	<i>Cube</i>	0.96 ^{NS}	0.24 ^{NS}	0.70 ^{NS}
Body & Texture	<i>Cylinder</i>	127.44***	20.11***	19.27***
	<i>Cube</i>	1.00 ^{NS}	2.71 ^{NS}	1.64*
Colour & Appearance	<i>Cylinder</i>	29.30***	1.61 ^{NS}	3.92 ^{NS}
	<i>Cube</i>	1.00 ^{NS}	1.00 ^{NS}	0.25 ^{NS}
Overall acceptability	<i>Cylinder</i>	19.41***	1.58 ^{NS}	2.64*
	<i>Cube</i>	11.37***	1.80 ^{NS}	1.60 ^{NS}

Note: Data presented as Mean ± SD values (n=3). ^{abc}Means within column (power) and ^{ABC}Means within a row (time) the same superscript is not significantly different, NS non-significant, *p<0.05, **p<0.01, ***p<0.001; n=3

cube shaped *paneer* the hardness, gumminess and chewiness were significant ($p < 0.01$), springiness and resilience were highly significant ($p < 0.001$) and cohesiveness was non-significant with time and it was also observed that all properties were non-significant with time.

The hardness ranged from 3.07 ± 0.97 (360 W, 10s) to 6.81 ± 1.29 N (270 W, 20 s) for cylinder shaped *paneer* whereas in case of cube shaped *paneer*, it was ranged from 4.30 ± 0.10 (360 W, 20 s) to 8.97 ± 2.27 (270 W, 10 s). So in both shaped *paneer* it was observed that hardness (N) decreased significantly as microwave power increased with respect at time. This may be due to softening of product, coupled with fusion and vapour/ moisture exudation (Badola et al. 2017). The hardness was statistically par with each other for all microwave power and time in both shaped *paneer*. The average values of cylinder shaped *paneer*, hardness, gumminess, springiness and chewiness was decreased significantly with increasing microwave power and time whereas cohesiveness and resilience were increases shown in Table 3. In case of cube shaped *paneer* the textural property such as springiness and resilience were increase with increasing microwave power and time and it ranged from 0.22 ± 0.14 (270W, 10sec) to 0.48 ± 0.10 (450 W 10 s), 0.16 ± 0.04 (270W, 10sec) to 0.35 ± 0.01 (450W, 30sec) respectively. The cohesiveness was shows the constant value for all microwave power and time i.e. 1.00 ± 0.00 .

Sensory characteristics of in-package microwave treated *paneer*

Sensory characteristics of in-package microwave treated *paneer* are represented as values in Table 4. The flavour score was highly significant ($p < 0.001$) with microwave power, time and their interaction for cylinder shaped *paneer* and for cube shape it was observed non-significant effect with power, time and their interaction, The flavour values ranged from 39.33 ± 0.57 (360W, 20 s) to 49.66 ± 0.57 (270W, 20 s) for cylinder shape *paneer* and for cube shape *paneer*, it ranged 46.33 ± 0.57 (450W, 30s) to 47.67 ± 0.57 .

The Body and texture was also follow similar trends like flavour. The body and texture values was ranged from 25.66 ± 0.57 (360W, 30s) to 32.00 ± 0.00 (270W, 20s) for cylinder shaped *paneer* and for cube shaped *paneer*, it ranged from 33.67 ± 0.57 (270W, 10s) to 35.00 ± 0.57 (360W, 30 s).

The colour and appearance values of cylinder shaped *paneer* were highly significant with power and non-significant with time and their interaction and for cubed shaped *paneer* there was non-significant effect with power, time and their interaction. The colour and appearance values were ranged from 6.00 ± 1.00 (360 W, 30 s) to 09.66 ± 0.57 (270W, 30 s) for cylinder shaped *paneer* and in case of cube shaped *paneer*, it ranged from 09.67 ± 0.57 (450W, 10 s) to 10.00 ± 0.00 (360W, 10s). The sensory score for overall acceptability presented a highly significant ($p < 0.001$) for microwave power and non-significant for time in both shaped.

The overall acceptability values for cylinder shaped *paneer* ranged from 76.99 ± 1.00 (360W, 30s) to 96.99 ± 0.00 (270W, 20s) and that of cube shaped *paneer* it was ranged from 94.68 ± 2.30 (270W, 10s) to 97.34 ± 1.14 (270 W, 20 s).

From overall acceptability it was observed that as microwave power and time was increased the score was also increase in both shaped *paneer*.

Conclusions

The product *paneer* (cylinder and cube shaped) was packed in polypropylene subjected to the microwave treatment at different power (270, 360 and 450W) and exposed for different time (10, 20 and 30s). It was observed that all properties which seem to be important with the point of view of quality of *paneer* such as whiteness index, hardness, flavour and overall acceptability were in higher in cube shaped *paneer* than those in cylinder shaped. Thus it could be concluded that for in-package microwave treatment a cube shaped *paneer* can be use over cylindrical shape. The overall acceptability values for cylinder shaped *paneer* ranged from 76.99 ± 1.00 (360W, 30s) to 96.99 ± 0.00 (270W, 20s) and that of cube shaped *paneer* it was ranged from 94.68 ± 2.30 (270W, 10s) to 97.34 ± 1.14 (270 W, 20s).

Acknowledgement

The first author gratefully acknowledges the Institute Fellowship offered by ICAR-NDRI (Deemed University), Karnal to support this research work.

References

- Aneja RP (2007) East-West fusion of dairy products. In: Dairy India Yearbook, Gupta S (Ed.) A Dairy India Publication, New Delhi. 6: 51-53
- Badola R, Panjagari NR, Singh RRB, Singh AK, Prasad WG (2017) Combined effect of herbal essential oil and in-package microwave thermization treatment on shelf life of *burfi*. Indian J Dairy Sci 70: 674-682
- Barnwal P, Mohite AM, Singh KK, Kumar P (2014) Selected physico-mechanical characteristics of cryogenic and ambient ground turmeric. Int Agrophys 28: 111-117
- Barnwal P, Singh KK, Sharma A, Choudhary AK, Saxena SN (2015) Influence of pin and hammer mill on grinding characteristics, thermal and antioxidant properties of coriander powder. J Food Sci Technol 52: 7783-7794
- Basak T, Panda S, Srirama S, Bhattacharya M (2014) Analysis on effect of shapes for microwave-assisted food processing of 2D samples. International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics
- Campanone LA, Zaritzky NE (2005) Mathematical analysis of microwave heating process. J Food Eng 69: 359-368
- Giese J (1992) Advances in microwave food processing. Food Technology (Chicago) 46: 118-123

- Gupta RK, Kumar P, Sharma A, Patil RT (2011) Color kinetics of aonla shreds with amalgamated blanching during drying. *Int J Food Prop* 14: 1232-1240
- Hossan MR, Byun D, Dutta P (2010) Analysis of microwave heating for cylindrical shaped objects. *Int J Heat Mass Transfer* 53: 5129-5138
- Karthikeyan S, Venkateshaiah BV, Tulasidas TN, Achoth L, Rao KJ, Krishnappa (2011) Process optimization for continuous microwave processing of *paneer*. *Dairy Foods Int* 1: 47-52
- Kishor K, Singh A, Singh A, Kandpal M, Rout S (2015) Effect of microwave stretching on quality attributes of *mozzarella cheese*. *Int J Curr Microbiol App Sci* 4: 572-581
- Kumar D (2009) Performance evaluation of microwave heating system for milk pasteurization. *Curr Adv Agric Sci* 1: 121-122
- Meena GS, Gupta VK, Khetra Y, Raghu HV, Khurna S (2014) Characterization of market *Kheer mohan*. *Indian J Dairy Sci* 67: 380-386
- Sarkar S (2006) Shelf-life extension of cultured milk products. *Nutrition & Food Science* 36(1): 24-31
- Shrivastava S, Goyal GK (2007) Preparation of *paneer*—A Review. *Indian J Dairy Sci* 60:377–388
- Singh S, Rai T (2004) Process optimization for diffusion process and microwave drying of *paneer*. *J Food Sci Technol (Mysore)* 41: 487-491
- Srinivasa K, Barnwal P, Pritpal S (2017) Selected physical, colour and textural characteristics of market *Rasogolla*. *Indian J Dairy Sci* 70: 155-161
- Turgut T (2016) The effect of microwave heating on the some quality properties and shelf life of *yoghurt*. *Kafkas Univ Vet Fak Derg* 22: 809-814
- Uprit S, Mishra HN (2004) Microwave heating and its effect on keeping quality of soya fortified *paneer*. *Egypt J Dairy Sci* 32: 269-276
- Vilayannur RS, Puri VM, Anantheswaran RC (1998) Size and shape effect on nonuniformity of temperature and moisture distributions in microwave heated food materials: Part II experimental validation. *J Food Process Eng* 21: 235-248
- Zhang Z, Su T, Zhang S (2018) Shape effect on the temperature field during microwave heating process. *J Food Quality* 2018: 1-24