

## RESEARCH ARTICLE

# Impact of microwave treatment on paneer: A study of image analysis and quality

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**Abstract:** The image processing technique was employed to analyze microwave-treated paneer samples. These samples were prepared through the standard heat-coagulation process of milk to produce paneer. A microprocessor-controlled semi-automatic pressing technique was utilized for paneer pressing, and its textural parameters were assessed using image-analysis methods. Microwave heating was introduced to extend the shelf-life of the paneer. Subsequently, paneer samples were placed in a 50 mm diameter dish and scanned using a Canon scan Mark II 9000F scanner to analyze colour parameters. The structure visible in the images was evaluated both before and after microwave treatment. It was observed that longer durations of microwave heating affected the browning index, while shorter exposures did not significantly enhance shelf life. The microbial quality shelf-life of microwave-heated paneer samples was extended by up to 15 additional days compared to control samples.

**Keywords:** Paneer, Semi-automatic Pressing, Microwave treatment, Image analysis, Shelf-life

## Introduction

Paneer is one of the most nutrient rich and delicious milk products consumed worldwide. It is highly perishable because of its composition and unit operations involved in its preparation. Paneer is used for the preparation of variety of tasty, healthy and

nutritious dishes and snacks in India. Preparation method of chhana or paneer involves heat-acid coagulation of cow or buffalo or standardized milk at about 85 to 90 C temperature then followed by pressing of the coagulum for a specified duration (5 to 15 minutes) in a mechanical or hydraulic or an automated press (Chitranayak et al. 2017a; Chitranayak et al. 2021). Ammu et al. (2020) had reviewed and reported about the improvement in overall paneer quality by application of mechanization method in paneer and chhana production. The effect of milk composition and milking season on quality characteristics of chhana was reported by Chakraborty et al. (2021). The effect of heating technique on the solid amount present in chhana recovered from cow and buffalo milks was studied and reported by Choudhary et al. (1998). Khan SU and Pal MA (2011) had reviewed on the various methods of paneer production and Kulshreshtha et al. (1987) and Arvind et al. (2019) had studied on the quality of paneer related to pressing conditions.

Thermal treatments of food and dairy products, such as heating, drying, sterilization, pasteurization etc. can be chosen on the

## Nomenclature

2-D	two-dimensional
$C_p$	specific heat
$d$	penetration depth
$E$	applied microwave field strength (V/cm)
Exp	exponential
$f$	frequency of the applied microwaves (Hertz)
GHz	Giga Hertz
$h$	surface heat transfer coefficient ( $W/m^2K$ )
$K$	thermal conductivity ( $W/m K$ )
$K'$	constant, for expressing the heating in desired

	temperature and time
MW	microwaves
$P_D$	power dissipation ( $W/m^3$ )
SNF	solid not fat
$\tan \delta$	loss tangent
TPC	total plate count
Y & M	yeast and mold
$\epsilon'$	relative dielectric constant
$\epsilon''$	dielectric loss factor of the material under observation
$\rho$	density ( $kg/m^3$ )
$\alpha$	attenuation factor

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basis of level of temperature required and the intended purpose (Aref et al. 1972). Heat treatment of milk is essential to destroy the pathogenic as well as spoilage microorganisms. It also denaturates whey proteins, reduces solubility of colloidal calcium phosphate, thus co-precipitating them along with the casein upon acidification of milk. These constituents increase the yield of curd, which are otherwise lost in whey (Rose and Tessier 1959; Fox and Morrissey 1977; Brule et al. 1978; Walstra and Jenness 1983). Heat treatment at 90 °C for 10–15 min was necessary to achieve desired yield (Muller et al. 1967). However, the application of thermal treatment produces some changes which may be desired, such as the softening of the texture, protein coagulation and aromatic components formation in addition to inactivation of pathogens present in the products. The heating technique by the application of microwaves could be successful in the products having high and intermediate moisture contents, since the water molecules present in the moisture are polar in nature. Therefore, the dairy and food products with higher moisture content, fat and sugar have great affinity to the applied high frequency microwaves to heat the sample instantaneously in a uniform way. The application of microwave treatment method has various field of dairy and food processing such as drying, pasteurization, cooking and increasing the shelf life of the food materials for their longer preservation (Chandrasekaran et al. 2013). In comparison to the methods of conventional heating, microwave treatment have many advantages such as, high volume handling capacity, uniform and instant distribution of heat energy throughout the food particles which would yield products with higher qualities in terms of texture, taste, flavour, nutrition, and the overall increased production (Venkatesh, and Raghavan, 2004; Ahmed and Ramaswamy, 2007). Microwave heating is useful in controlling microbial growth in food and dairy products and also a fast technique for heating cooked food items. Moreover, the microwave heating technique changes the taste, nutrition, colour of dairy products much less than the other heating methods during cooking foods or reheating process of the pre-cooked food products. The prospects of microwave processing in dairy industry need to be investigated extensively. When employed this technology to Indian dairy products, due concern is to be given to the shelf-stability of products as well as quality changes.

Paneer is highly prone to contamination by different microorganisms as it contains high moisture content, in the range of 45 to 65 percent. The growth of microorganisms such as, yeasts and molds, and pathogens such as, *Salmonella sp.*, *Staphylococcus aureus*, *E-coli* and *Listeria monocytogenes*, which spoil paneer and deteriorate its physiochemical attributes, taste, colour and flavor. *Listeria monocytogenes*, a food pathogen, development in paneer sample by PCR method was conducted by Ashwani et al. (2012). A research work on *Escherichia coli* O157:H7 and *Listeria monocytogenes* detection in different kinds of milk products was reported by Singh et al. (2009). Rani et al. (2014) worked on the preparation method of ready-to-serve low

cholesterol masala paneer, its storage condition and the microbial quality. Kaur et al. (2013) worked and reported on the analysis of microbial quality, of food items kept in household at refrigerated condition. The highest quality of paneer remains intact for about one-day at ambient temperature and for about six to seven days under refrigerated temperature in the range of 4 to 6 °C and the spoilage of paneer is mainly due to the bacterial action, which can be controlled by applying good manufacturing practices and different heat treatment methods (Chitranayak et al. 2017b). Many researchers have been regularly working to extend the shelf life of paneer, including the application of microwaves.

Image processing is the technique which uses many complicated mathematical operations to process different captured images of food product or any other sample by using the processing of signal. In this technique digital photography or an optical scanner can be used for capturing or importing the images of the sample under test or sample to be analyzed. Further, the images captured from the optical scanner or by a digital camera have to be analyzed for later processing and finally the result will be produced based the final analysis of the images produced. For normal printouts, the analog image processing may be used, but for higher analysis of images digital technique and method has to be applied, which is done with the help of software and computers. For conducting the image analysis of the prepared paneer samples, the digital images of control and microwave heat energy treated paneer samples were captured as reported by Russ (1975). Giardina and Dougherty (1988) also worked and reported on the morphological methods in image and signal processing.

In the present study, microwave heating, which is being applied for heating of foods including paneer at every household in urban and semi-urban society, was applied with an intention to enhance microbial quality and shelf-life of paneer. Further, image analysis of the microwave treated and control samples of paneer were conducted. Therefore, the present work is conducted to know the effect of microwave treatment on paneer quality.

## Materials and methods

### Procurement of milk

Cow milk was procured from cattle yard of SRS of ICAR-NDRI, Bengaluru.

### Preparation of paneer

The self-explanatory process flow chart for paneer preparation is given in Fig.1. For the continuous production of paneer, the performance of an impact type device was reported by Das S and Das H (2009).

**Microwave treatment**

The microwave heating technique was applied over paneer sample for the enhancement of its shelf life and microbial quality. Paneer samples were exposed to microwave for 40 seconds ( $M_{40}$ ) and 60 seconds ( $M_{60}$ ). Untreated paneer samples were kept as control (C).

**Physico-chemical quality analysis**

Physico-chemical analysis of microwave-treated paneer involves studying the changes in its physical and chemical properties after microwave treatment.

**Moisture content**

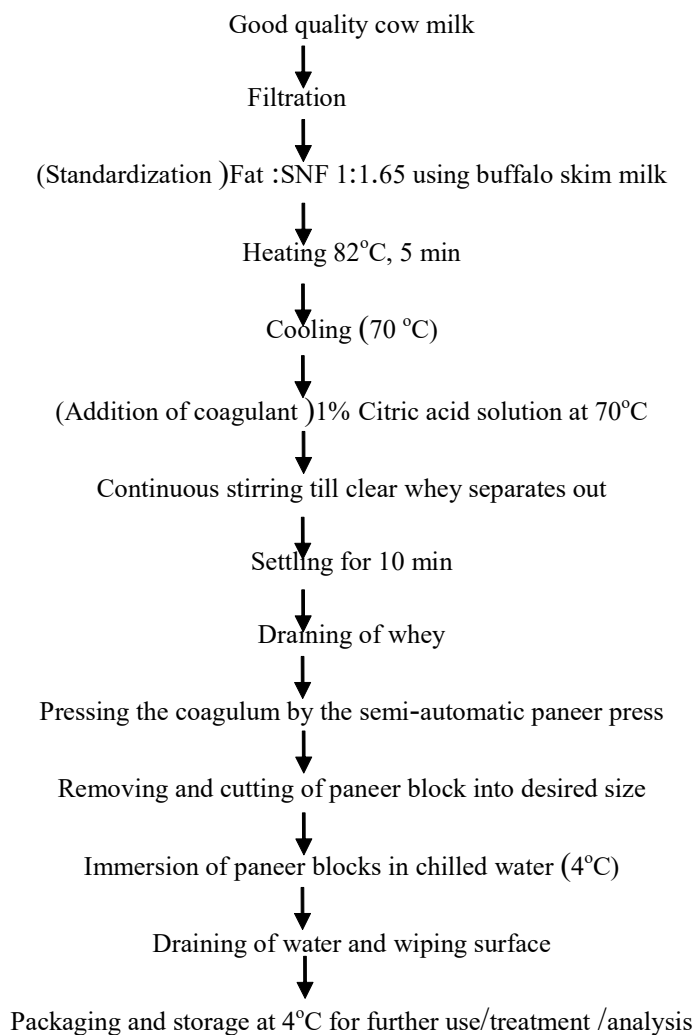
The moisture content of the paneer was determined by gravimetric method (AOAC, 2005). The moisture content of the

paneer should not be > 70% (Chitranyak et al. 2017a). Microwaving can affect the moisture content which has significant impact on the paneer’s consistency, shelf life, and texture. Increased evaporation can lead to drier paneer, while insufficient evaporation might result in soggy texture.

**Density & porosity estimation**

For measuring porosity of paneer, 1.5cm\*1.5cm\*1.5cm ( $V_0=3.375\text{cm}^3$ ) paneer cubes were taken. Its initial weight was recorded ( $M_0$ ). Paneer cubes were soaked in distilled water for overnight and kept in the refrigerator. Thereafter wiped the surface of the sample and taken the final weight ( $M_1$ ).

Porosity of paneer cube was calculated by using formula.



**Fig. 1** Flow diagram for manufacture of paneer by semi-automatic paneer press

$$\text{Porosity} = \frac{(M1 - M0)}{V0} \times \text{density of water}$$

### Instrumental texture profile analysis (TPA) of paneer

Microwave treatment may cause the paneer to become either softer or harder, which could affect its culinary applications and consumer acceptance. TPA tests were performed using texture analyzers of stable micro system equipped with 5kg load cell. The analyzer is linked to a computer that recorded the via a software program exponent 32. Experiments were carried out by compression test that generated plot of force (g) vs. time (s), from which texture values were obtained. A cylindrical probe (P/75) was used to compress 2cm\*2cm\*2cm paneer samples. The speed of the probe was fixed at 5mm/s during the test, compression & relaxation of the samples will take place. During the testing, the samples were held manually against the base plate.

### Image acquisition

For the image analysis of the paneer samples prepared the sample was placed in the 50 mm diameter petri dish over a Canon scan Mark II 9000F scanner to get the image of the paneer. The set of images of paneer samples scanned were saved in a different folder for the analysis of its fractal dimension, pixel intensity, colour, skeletal analysis and particle analysis. Image analysis is actually the determination of structure of paneer samples before and after the microwave heating treatment. There are two parameters of the paneer samples analyzed using Image Analysis and they are, Colour Parameter and Textural Parameter.

### Image analysis

Each sample had net quantity of 250 g, out of which 6 samples of area 2.5 cm<sup>2</sup> were cleanly cut without any protrudes in all four sides of paneer. Out of the 6 pieces taken in every sample, 3 were

microwave heated at 40 seconds and the other 3 were microwave heated at 60 seconds. Then the sample was placed in the 50 mm diameter petri dish over a Canon scan Mark II 9000F scanner to get the image of the paneer for image analysis. The structure of the image was analyzed before and after the microwave treatment for comparing both the control and the microwave treated pieces. Image analysis and the analysis of the colour parameters of the paneer samples prepared using the automated press were done. Color parameters of the paneer samples were analyzed using the Adobe Photoshop software; where,

‘L’ is the lightness ranging from 0 to 100 (the minimum value of 0 is for black and the maximum value of 100 is for white). ‘a’ is the chromatic component whose value ranging from -120 to +120 (the minimum value of -120 is for the colour green and the maximum value of +120 is for the colour red); ‘b’ (Chromatic component) ranging from -120 to +120 (the minimum value of -120 is for the colour blue and the maximum value of +120 is for the colour yellow).

The “L, a and b” values obtained from the scanned images were used for the evaluation of L\*; a\*; b\*; and further the values of hue; chroma; yellowness index; whiteness index; browning index were determined as per the equations and formula given in the Table 1. Hue defines the pure colour in terms of green, red and blue. This is used to determine a certain colour. Chroma is the quality that distinguishes a strong colour from a weak colour. Yellowness Index (YI) is the number evaluated on the basis of data obtained from spectrophotometer which describes kind of changes in colour of the product from white or clear towards yellow. The test of yellowness index is used for evaluating the colour variations in a product or test sample produced by actual or stimulated exposure at outdoor. Whiteness Index (WI) gives the measurement that correlates the visual ratings of whiteness for certain white and near white surfaces. Browning Index (BI) of the sample is used to find the browning appearance or effect on

**Table 1** Image parameters and corresponding Formulae

Image parameters	Equations or Formula
Lightness	$L^* = \frac{L}{255} \times 100$
Chromatic component	$a^* = \frac{(240 \times a)}{255} - 120$
Chromatic component	$b^* = \frac{(240 \times b)}{255} - 120$
Hue	$\tan^{-1} \frac{b^*}{a^*}$
Chroma	$\sqrt[2]{a^{*2} + b^{*2}}$
Change in colour	$\sqrt{(ax - ao)^2 + (bx - bo)^2 + (cx - co)^2}$
Browning index	$\frac{(m - 0.31) \times 100}{0.172}$
Yellowness index	$m = \frac{(a + 175L)}{5.645L + a - 3.012b}$
Whiteness index	$\frac{b^*}{L^*} \times 142.86$
	$100 - (\sqrt{(100 - L^*)^2 + a^{*2} + b^{*2}})$

the sample surface, which indicates the browning index. Image parameters and corresponding formulae were shown in Table 1.

## Results and Discussion

### Physico-chemical analysis of microwave treated and control paneer samples

Moisture content, density and porosity of microwave treated and control paneer samples were analyzed. Moisture content of microwave treated paneer samples was observed to be increased with its storage period (from 0<sup>th</sup> day to 12<sup>th</sup> day). Whereas moisture content of control paneer samples showed an initial increase and thereafter a decreasing trend with storage period (from 0<sup>th</sup> day to 20<sup>th</sup> day). There was no significant difference in density of microwave treated paneer samples and some random deviation was observed in the density values of control samples with storage. Kumar et al. (2014) mentioned that the moisture content in paneer varies between 50.72 to 56.99 % prepared from cow and buffalo milk with fat content ranging from 3.5 to 6%. The initial moisture content of the paneer and the rate at which moisture evaporates are critical in the microwave heating process. The behavior of water in the paneer is dependent on its phase (liquid water vs. solid ice) and the amount of free water present. Further, the variations in pressure and time have a significant impact on the moisture levels in paneer. This suggests that both factors must be carefully controlled to achieve desired results. The study observed that varying the duration of microwave application did not significantly affect the moisture content, structural integrity, or texture of the paneer. This could imply that once a certain threshold of heating is reached, additional microwave exposure might not lead to substantial changes. According to Khan and Pal (2011), paneer made from buffalo milk typically contains between 51–54% moisture. This benchmark is useful for understanding the typical moisture range in paneer. In summary, while microwave heating can influence the moisture content and characteristics of paneer, the duration and specific pressure conditions need to be optimized. The typical moisture content range for paneer from buffalo milk is well-established, but practical outcomes depend on controlling microwave parameters effectively.

Porosity values of microwave treated samples were less compared to its control sample. There was no trend observed in the values of porosity with storage period for both microwave treated and control samples.

### Texture profile analysis of microwave treated and control paneer samples

Texture profile analysis of microwave treated and control paneer samples were done. Hardness, Adhessiveness, Springiness, Resilience, Cohesiveness, Gumminess and Chewiness values were obtained. Hardness values of both microwave treated and control samples were showed a decreasing trend with storage period. Microwave treated sample was harder than control samples. Springiness and chewiness values of both microwave treated and control samples exhibited an increasing trend with storage period. The increase in chewiness was also reported by Dongare et al. (2019), Singh et al. (2014) and Shashikumar and Puranik (2012)

### Image analysis of microwave treated and control paneer samples

The samples of paneer cubes prepared were treated with microwaves and then their digital images were analyzed. Digital Images of control paneer sample, digital images of 40 Second-Microwave heat energy treated paneer sample and the digital images of 60 Second-Microwave heat energy treated paneer sample has been depicted in Fig.2. The values of hue of the sample paneer defined the pure colour in terms of green, red and blue (Table 3). Chroma values distinguished between the strong colour zones of the paneer sample from the weak colour zone. The results and the data obtained from the spectrophotometer explain the yellowness index, change in colour of the product under test from white or clear towards yellow. The change found in the value of whiteness index actually gives the measurement that correlates visual ratings of whiteness for the near white surface of the paneer and the certain white surface of the paneer sample. The WI of control and microwave treated paneer samples were at par with the findings of Barnwal et al. (2023). The ability of food products for the absorption of microwaves and convert the energy of microwaves into heat depends on their dielectric

**Table 2** Physico-chemical analysis of microwave treated and control paneer samples

Days	Treated			Control		
	Moisture (%) wet basis	Density (g/cc)	Porosity (%)	Moisture(%) wet basis(	Density (g/cc)	Porosity (%)
0 <sup>th</sup> day	51.10	1.2053	7.722	47.2059	1.1426	19.93
4 <sup>th</sup> day	54.27	1.121	3.7	48.6847	1.4202	10.21
8 <sup>th</sup> day	55.72	1.2096	4.1013	51.1723	-	-
12 <sup>th</sup> day	56.7253	1.2073	4.6873	54.2753	-	-
16 <sup>th</sup> day	-	-	-	44.1482	0.5637	5.2951
20 <sup>th</sup> day	-	-	-	42.3762	0.9848	9.7259

property. The heating by microwave takes place because of the dipolar rotation and ionic polarization mechanism (Li et al. 2019).

Pant et al. (1993) analyzed the texture profile attributes of paneer prepared from tofu and milk after deep-fat frying and before frying by conventional heating method. The observation made for the microwave treated paneer samples that the variation in the value of the browning index is large for higher duration of microwave exposure, which finds the effect of more browning of the paneer

sample. This may happen due the application of microwave heating of the sample for 40 and 60 seconds, which indicated the rise in the value of browning index from -0.56 to 36.85 after the microwave treatment of 40 seconds and it further increased to 104.61 for 60 seconds of microwave application as given in the table below. Similar pattern was observed for the yellowness index of the paneer sample. Browning and yellowness both for the paneer sample increased with the exposure of microwave

**Fig.2** Digital Images of control and microwave treated paneer samples



(a) Control sample, PC1

(b) Digital Images of 40 Second-Microwave heat energy, operated at 2450 MHz frequency, treated paneer sample-PM1

(c) Digital Images of 60 Second-Microwave heat energy treated paneer sample, PM1, Source operated at 2450 MHz frequency

**Table 3** Texture profile analysis of microwave treated and control paneer samples

Sample	Parameters	Days of interval		
		0 <sup>th</sup> day	8 <sup>th</sup> day	20 <sup>th</sup> day
Control	Hardness	82.3480	19.4613	42.2288
	Adhessiveness	-2.7665	-0.5194	-1.3670
	Springiness	0.6764	0.8441	0.9071
	Resilience	0.2200	0.2877	0.2872
	Cohessiveness	0.3654	0.6274	0.6438
	Gumminess	30.0899	12.2100	27.1893
	Chewiness	20.3528	10.3064	24.6634
Treated	Hardness	103.556	-	56.6989
	Adhessiveness	-0.9285	-	-1.4996
	Springiness	0.7527	-	0.9267
	Resilience	0.1781	-	0.2689
	Cohessiveness	0.3147	-	0.5455
	Gumminess	32.589	-	30.9315
	Chewiness	24.5297	-	28.6642

Means in column with the same letters do not differ significantly ( $p < 0.05$ )

Control: Untreated paneer sample, M40: Microwave treated paneer sample for 40 second, M60: Microwave treated paneer sample for 60 second

**Table 4** Effect of microwave treatment on CIE L\*, a\*, b\* and ΔE

Treatment	CIE L*	CIE a*	CIE b*	ΔE
CONTROL	84.50±0.68 <sup>a</sup>	2.53±0.11 <sup>a</sup>	16.72±0.82 <sup>a</sup>	48.87±0.50 <sup>a</sup>
M40	84.12±1.56 <sup>a</sup>	1.96±0.14 <sup>b</sup>	17.38±1.00 <sup>a</sup>	48.27±1.62 <sup>a</sup>
M60	84.50±0.44 <sup>a</sup>	2.58±0.15 <sup>a</sup>	16.53±0.63 <sup>a</sup>	34.95±0.7 <sup>b</sup>

**Table 5** Effect of microwave treatment on hue, chroma, BI, YI and WI

Treatment	Hue	Chroma	BI	YI	WI
CONTROL	81.38±0.43 <sup>a</sup>	16.91±0.81 <sup>a</sup>	23.51±1.03 <sup>a</sup>	28.25±1.18 <sup>a</sup>	77.05±0.26 <sup>a</sup>
M40	83.57±0.46 <sup>b</sup>	17.49±1.00 <sup>a</sup>	24.11±1.83 <sup>a</sup>	29.54±2.04 <sup>a</sup>	76.36±1.61 <sup>a</sup>
M60	81.15±0.27 <sup>a</sup>	16.73±0.64 <sup>a</sup>	23.29±0.89 <sup>a</sup>	27.94±0.92 <sup>a</sup>	77.18±0.18 <sup>a</sup>

Means in column with the same letters do not differ significantly ( $p < 0.05$ )

energy. Apart from these three important colour, indices, the yeast and mold count of paneer samples prepared was also undertaken for control and microwave treated samples. It was found that the microbial growth was much less in the microwave treated paneer samples in comparison to control samples after 24, 48, 72 and 96 hours. However, the detailed study on microbial growth and total plate count was conducted and discussed in another related research work. The results given in the tables' showed that the exposure of microwaves over the paneer samples for 40 seconds found to be optimum. Statistical analysis was carried out for the image data obtained using multivariate analysis with LSD post doc test to compare means. It was found that the microwave treatment of a domestic microwave appliances used in home appliances operated at 2450 MHz frequency on paneer had significant ( $p < 0.05$ ) effect on CIE a\*, hue and ΔE (Table 2).

## Conclusion

On the basis of the experimental data of image analysis and microbial analysis obtained for the microwave exposure over the paneer samples, it was observed that the up-keeping quality of microwave treated paneer was improved. On the basis of the values obtained for image parameters for paneer samples based on standard equation, the statistical analysis was carried using multivariate analysis with LSD post doc test to compare means. It was found that the microwave treatment of paneer had significant effect on CIE a\*, hue and ΔE. The samples with 60 seconds exposure of domestic microwave appliances, normally used in home appliances operate at 2450 MHz frequency have shown higher amount of changes in colour parameters, as shown in the tables than 40 second and control samples of paneer. Therefore, it can be concluded that the duration of 40 second exposure of microwaves energy over the paneer samples could be optimum for its shelf life improvement, without compromising much of its colour, taste and appearance. Moreover, it can be

stated that microwave technology is a successful technology for the processing of food without compromising its quality.

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