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RESEARCH ARTICLE

Application of Image Analysis Technique in Coagulation of Milk for *Paneer* Manufacturing

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Abstract: This study was aimed to investigate the coagulation process of *Paneer* manufacturing and to determine the optimal conditions for its production using image analysis techniques. *Paneer*, a traditional coagulated dairy product, is widely recognized and valued for their nutrition and easy to use. The whey images were captured and analyzed at different levels of agitator speed (20, 30 and 40 RPM) and coagulation temperatures (70, 75 and 80°C), and the *L*, a*,* and *b** values of each sample were evaluated using Adobe Photoshop software. The *a** value was specifically used to assess the greenish colour of the sample image, which is an important indicator of complete coagulation of milk. The results revealed that the optimal coagulation conditions were 70°C coagulation temperature, 40 RPM agitator speed and 140 s coagulation time with *a** value of -5.39. These findings suggest that image processing may be an effective tool for monitoring and standardizing the coagulation process of milk for *Paneer* manufacturing. By using this technique, the quality and consistency of *Paneer* may be improved, and human intervention in the production process may also be minimized.

Keywords: *Paneer*; Coagulation; Image; Software; Temperature

Introduction

In recent years, the food industry has been witnessing a significant growth in the use of image analysis techniques for quality control and inspection of various food products (Mollazade et al. 2012). The applications of these techniques have not only facilitated assessment of food quality and safety but also led to the development of novel and innovative food products (Brosnan and Sun, 2004). Among the many applications of image analysis techniques in the food industry, colour analysis is one of the most important and widely used techniques (Ogawa and Adachi, 2014). The colour of food products is an essential factor that influences consumer perception, acceptance, and purchasing decisions (Ares and Deliza, 2010). Therefore, the accurate and reliable measurement of food colour is crucial for ensuring the quality and consistency of food products.

In the dairy industry, colour analysis is of utmost importance, especially for products such as milk, *paneer, yogurt, ghee* and *butter* (Kamthania et al. 2014). In context to *Paneer*, colour is influenced by several factors viz. breed of the animal, the stage of lactation, the processing method, and the storage conditions (Chandan, 2007). The colour of *Paneer* can provide important information regarding product quality, freshness, and the presence of defects (Prajapati et al. 2021). Traditional methods for measuring the colour of dairy products involve visual assessment by human experts, which can be subjective and prone to error (Revilla et al. 2016). In recent years, the use of image analysis techniques for colour analysis of dairy products has become increasingly popular.

Image analysis techniques for colour analysis of dairy products can be broadly classified into two categories, namely, colorimetric and image processing techniques. Colorimetric techniques involve the measurement of the colour of dairy products using colorimeters or spectrophotometers (Minz and Saini, 2021). These instruments measure the intensity of light reflected from the surface of the dairy product and provide colour information in terms of colour space coordinates, such as CIELAB, CIELUV, and CIEXYZ. The colour information can then be used to calculate various colour parameters, such as hue, chroma, and lightness.

The image processing techniques involve the analysis of digital images of dairy products captured using digital cameras or scanners. Image processing techniques can provide more detailed and comprehensive colour information compared to colorimetric techniques (Cabaret et al. 2007). Image processing techniques involve several steps, including image acquisition, image

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segmentation, feature extraction, and classification. In the image acquisition step, digital-images of dairy products are captured using a digital camera or scanner. In the image segmentation step, the dairy product in the image is isolated from the background using various image processing algorithms (Poursaberi et al. 2010). In the final step, colour features such as *L*, a*,* and *b** values can be used to assess the product quality.

L, a*,* and *b** values are colour space coordinates that are commonly used in colorimetry for colour analysis of dairy products, including *Paneer* (Leon et al. 2006). *L** represents the lightness or brightness of the colour (0 being black and 100 being white), *a** axis represents the red-green axis (positive values indicating redness and negative values indicating greenness). The *b** axis represents the yellow-blue axis, with positive values indicating yellowness and negative values indicating blueness.

In the context of *Paneer* manufacturing, the coagulation of milk and whey separation is important step. The colour of whey is a decisive factor about completion of milk coagulation process. Generally the colour of whey is greenish after milk coagulation such as greenish color (Pranita et al. 2015; Baba et al. 2016; Chaudhari et al. 2022), greenish whey from cow's cheese (El Zubeir and Jabreel, 2008) and greenish whey from bovine milk cheese (Baig et al. 2022). This allows for a more objective assessment of the colour of whey, rather than relying on subjective assessments made by human experts (Yam and Papadakis, 2004). So, objective of the present investigation is determination of colour values of whey using image processing technique to provide a quantitative assessment of the colour of the whey for milk coagulation stage.

Material and Methods

Raw Material

Standardized buffalo milk (6% Fat and 9% SNF) was collected from the Experimental Dairy, ICAR-NDRI, Karnal, Haryana, India.

Experimental setup and procedure

The experimental set up (Fig. 1) consists of cylindrical coagulation tank with paddle agitator, image acquisition system (lighting system, digital camera) and a computer with installed Adobe Photoshop software (version 7.0). The coagulation tank was insulated with glass-wool insulation to minimize heat loss from it.

Image acquisition

Lighting system

To obtain accurate colour images of food samples, it is crucial to use appropriate lighting because the colour of the food samples depends on the spectrum of light reflected from it. To standardize the spectral power distribution of the light source, the CIE has established standard illuminants that are identified by their colour temperatures. In food research, the most commonly used standard illuminants are A (2856K), C (6774K), D_{65} (6500K), and D (7500K), with C, D_{65}, and D being designed to imitate different variations of daylight (Sharma, 2018). To capture the colour accurately, the camera lens axis and the lighting source axis should be at an angle of about 45^0, as this angle produces the diffuse reflection responsible for the colour. Additionally, the light intensity should be uniform across the food sample, which can be achieved by experimenting with lighting arrangements, such as altering the distance between the light source and the food sample, taking pictures in a dark room, and verifying the results with a light meter (Yam and Papadakis, 2004).

Digital camera

The images were captured using Ravtron web camera (Full HD 1920 × 1080 pixels) which was integrated to the coagulation tank (Fig.1).

Colour image processing

Adobe Photoshop software (version 7.0) was employed to evaluate the values of *L*, a*,* and *b**. It has various tools that can be applied to analyse the colour of food samples. It has abundant features for editing images and its ability to analyse colour in comparison to more expensive colour analysis softwares. Additionally, it provides more advanced capabilities for managing and producing consistent colours than the other graphics software. A computer (Intel Core-i3, 4GB RAM, 1TB hard disk) was used to operate the software. This software is widely accessible in numerous laboratories and receives strong support from both the manufacturer and users (Yam and Papadakis, 2004).

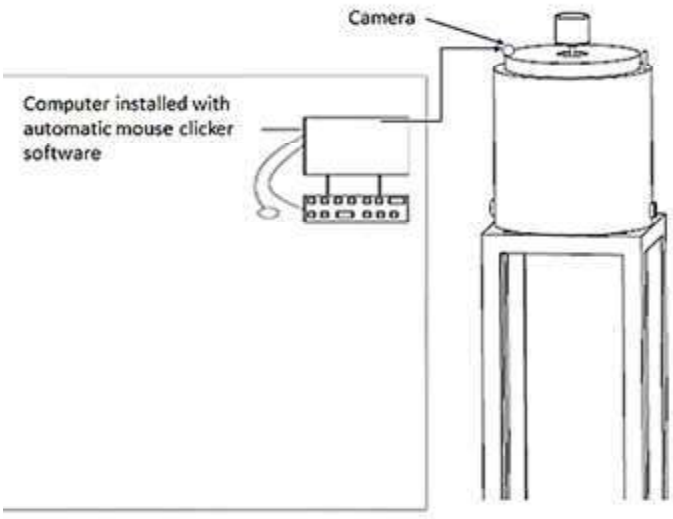

Fig.1 Experimental set up for image capturing

For quantitative analysis, *L*, a*,* and *b** values were utilized because these values are not device-dependent and encompass a broader range than RGB and CMYK. The Adobe Photoshop software can exhibit *L*, a*,* and *b** values, as well as RGB and CMYK values, in the Info Palette and Histogram Window. The Histogram method was applied (Shahraki et al. 2014) to assess the *L**, *a**, and *b** distribution of the samples. The Histogram Window presents the data (average, standard deviation, median, percentage, etc.) of the colour value (*L*) for a chosen area in the coagulation image. The Histogram Window can also provide the data for two other colour values (*a* and *b*) by selecting them from the Channel drop-down menu. Obtaining the average color of a sample or its any part is effortless using the Histogram Window (Afshari-Jouybari and Farahnaky, 2011). The *L, a* and *b* values displayed in the Histogram Window are not standardized colour values. However, they can be transformed to *L**, *a**, and *b** values by using following standard formulaes (Yam and Papadakis, 2004).

$$L^* = \left[\frac{L}{255}\right] \times 100 \quad (1)$$

$$a^* = \left[\frac{240a}{255}\right] - 120 \quad (2)$$

$$b^* = \left[\frac{240b}{255}\right] - 120 \quad (3)$$

The chroma value and hue angle were calculated from the *L*, a** and *b** values (Barnwal et al. 2015; Pathare et al. 2013):

$$Chroma\ value = \sqrt{\left(a^{*2} + b^{*2}\right)} \quad (4)$$

$$Hue\ angle\ (^\circ) = \left(\frac{180}{\pi}\right) \times \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (5)$$

Whiteness index (WI) was calculated by using following standard relation (Barnwal et al. 2015; Pathare et al. 2013; Wasnik et al. 2017):

$$WI = 100 - \sqrt{\left(100 - L^{*2}\right) + a^{*2} + b^{*2}} \quad (6)$$

Yellowness Index was computed by following equation (Pathare et al. 2013; Wasnik et al. 2017):

$$YI = \frac{142.86 \times b^*}{L^*} \quad (7)$$

Equations (1) to (7) were used to describe the colour change of whey during coagulation of milk for *paneer* manufacturing.

Experimentation and Analysis

Paneer was prepared in the laboratory using the standard method (Aneja et al. 2002) for application of image analysis technique in coagulation of milk for *Paneer* Manufacturing. Initially, preliminary trials were conducted to determine the range of agitator speed that could be applied during the experiments. Three different agitator speeds (20, 30 and 40 RPM) and three different coagulation temperatures (70, 75 and 80 °C) were selected after the preliminary trials. The various images were captured from dosing of coagulant to till complete separation of whey from coagulum. The images were captured at 5 s interval during milk coagulation for 2.5 minutes. The each sample image was analysed for *L*, a** and *b** values by importing the image in the Adobe Photoshop software.

The colour of whey, obtained during *paneer* manufacturing, is a crucial factor about end point of milk coagulation process. Normally, the colour of whey is greenish after milk coagulation such as greenish color (Pranita et al. 2015; Baba et al. 2016; Chaudhari et al. 2022), greenish whey from cow's cheese (El Zubeir and Jabreel, 2008) and greenish whey from bovine milk cheese (Baig et al. 2022). So, *a** values were used to assess the greenish colour of the whey during coagulation.

For comparison of the variation in several sets of data, it is generally desirable to use a measure of relative variation i.e. the coefficient of variation (CV, %) or relative standard deviation (RSD, %). The CV (%) or RSD (%) may be computed as (Johnson, 2005; Rao, 2018):

$$RSD\ (\%) = \frac{\sigma}{\bar{x}} \times 100 \quad (8)$$

The mean or arithmetic mean ($\bar{x}$), and standard deviation (σ) can be calculated as (Johnson, 2005):

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (9)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}} \quad (10)$$

Where, x_i and n are i-th data number of data in respective colour attribute column.

The mean deviation (M.D.) may be computed as (Murthy 2013):

$$M.D. = \frac{\sum_{i=1}^{n} (x_i - \bar{x})}{n}$$

Microsoft Excel-2013 software was used for regression analysis and graphs preparation.

Results and Discussion

The various captured images at 5 second interval were analysed and processed in Adobe Photoshop software (version 7.0) software for *a** values. Table 1 shows the effect of agitation speed or agitator speed and the desirable coagulation temperature on *L**, *a**, and *b** values whereas Table 2 represents the effect of agitation speed and the desirable coagulation temperature on hue angle (°), chroma value, yellowness index (YI) and whiteness index (WI). Reliability reproducibility was obtained with a RSD from 0.063 to 0.933 % i.e. lower than 1 %. The mean deviation was ranged from 0.005 to 0.160. The mean deviation (0.005 to 0.160) and RSD (0.063 to 0.933 %) show that the precision of colour attributes (*L*, a*, b*,* hue angle, chroma value, yellowness index and whiteness index) of whey are favourable for various combination of process parameters i.e. coagulation temperature, agitation speed and coagulation time (Tables 1-2). The different coagulation time (range: 140-185 s) was observed for different combinations of coagulation temperature and agitator speed.

It was reported that the colour of whey is greenish after milk coagulation (Pranita et al. 2015; Baba et al. 2016; Chaudhari et al. 2022), greenish whey from cow's cheese (El Zubeir and Jabreel, 2008) and greenish whey from bovine milk cheese (Baig et al. 2022). Therefore, the second order (quadratic) was established through regression analysis (Table 3) which may be used for prediction of coagulation time for desired coagulation of milk for *paneer* manufacturing using desirable *a**-values (-5.393 to -5.289). Second order (quadratic) equations and R^2 values of *a** values in terms of coagulation time at three different agitator speeds (20, 30 and 40 RPM) and three different coagulation temperature (70, 75 and 80 °C) were determined. It was observed that the R^2 values for the different agitator speeds (20, 30 and 40 RPM) and three different coagulation temperatures (70, 75 and 80 °C) were higher and closer to 1.0, which indicates a good fit to the model (Anup et al. 2019).

Table 1: Effect of agitation speed and coagulation temperature on *L**, *a** and *b** values of whey

Coagulation Temperature, °C	Agitation speed (RPM)	Coagulation time (seconds)	*L** value	*a** value	*b** value
	40	140	62.584	-5.393	9.585
70	30	160	62.596	-5.384	9.618
	20	180	62.635	-5.318	9.750
	40	150	62.603	-5.384	9.592
75	30	170	62.568	-5.374	9.675
	20	190	62.674	-5.289	9.769
	40	145	62.670	-5.355	9.878
80	30	165	62.580	-5.342	9.675
	20	185	62.643	-5.319	9.731
M.D.			0.034	0.030	0.076
RSD (%)			0.063	0.678	0.983

Table 2: Effect of agitation speed and coagulation temperature on hue angle (p), chroma value, yellowness index and whiteness index of whey

Coagulation Temperature, °C	Agitation speed (RPM)	Coagulation time (seconds)	Hue Angle (°)	Chroma Value	Yellowness index	Whiteness index
	40	140	-60.628	10.998	21.880	86.008
70	30	160	-60.753	11.022	21.951	85.989
	20	180	-61.382	11.106	22.238	85.926
	40	150	-60.687	11.000	21.889	86.008
75	30	170	-60.942	11.067	22.091	85.952
	20	190	-61.561	11.109	22.268	85.927
	40	145	-61.529	11.236	22.517	85.826
80	30	165	-61.087	11.056	22.086	85.965
	20	185	-61.331	11.090	22.192	85.939
M.D.			0.005	0.053	0.160	0.039
RSD (%)			0.598	0.664	0.933	0.065

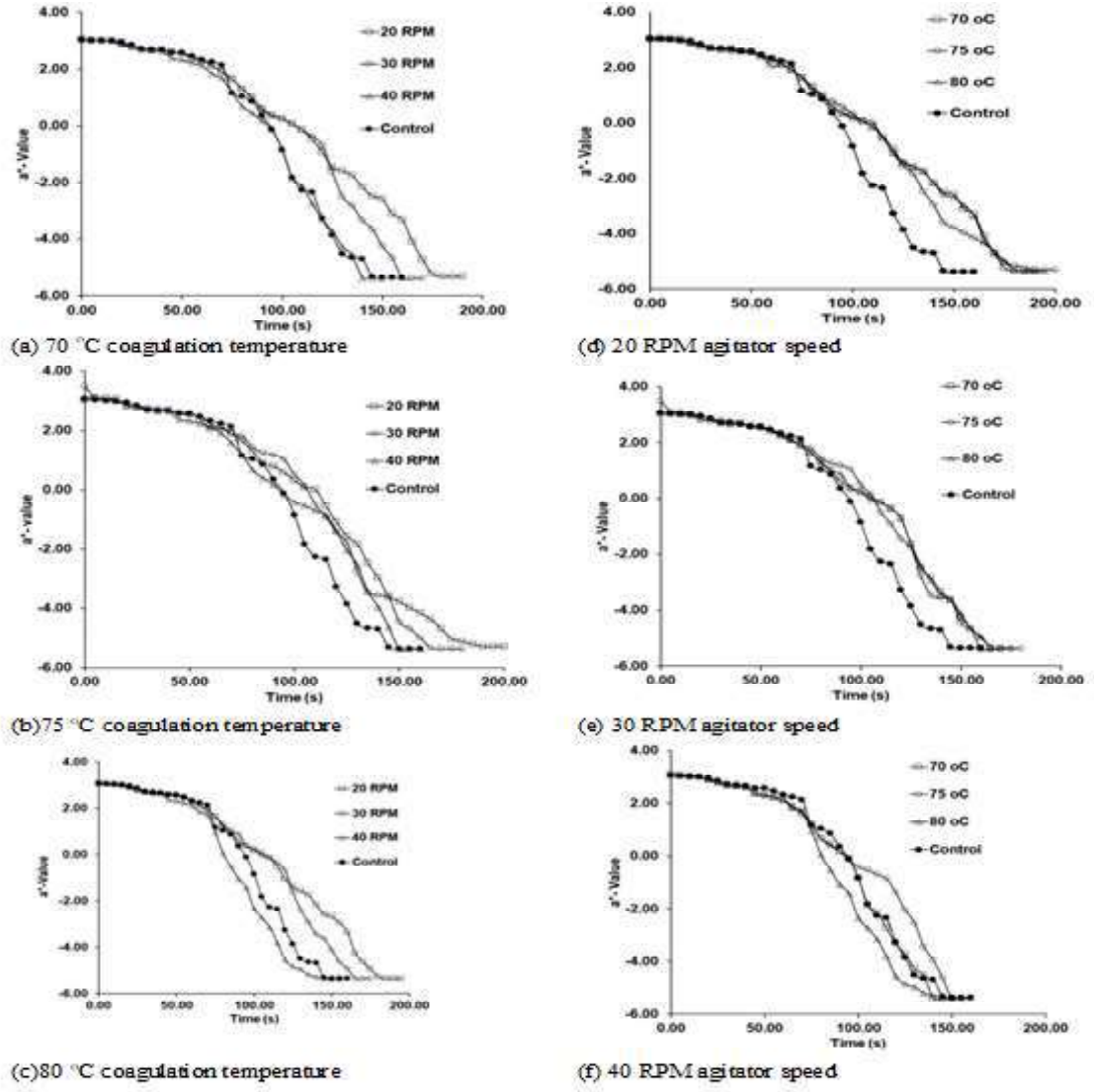

Fig. 2 Changes in a*-values of whey with coagulation time at (a) 70 °C (b) 75 °C (c) 80 °C (d) 20 RPM (e) 30 RPM (f) 40 RPM

Table 3: Second order (quadratic) equations and R^2 – values of *a**-values of whey in terms of coagulation time at different coagulation temperatures and agitator speeds

Coagulation temperature °C	Agitator speed, RPM	Regression equation	R^2	RMSE (%)
70	20	$y = -0.0002x^2 - 0.0068x + 3.2031$	0.9937	0.2970
	30	$y = -0.0004x^2 + 0.0103x + 2.906$	0.9920	0.5309
	40	$y = -0.0005x^2 + 0.008x + 3.0307$	0.9888	0.3801
75	20	$y = -0.0002x^2 - 0.0195x + 3.5449$	0.9758	1.9222
	30	$y = -0.0003x^2 - 0.0026x + 3.3035$	0.9816	0.2296
	40	$y = -0.0004x^2 + 0.0049x + 3.0091$	0.9917	0.1742
80	20	$y = -0.0002x^2 - 0.0106x + 3.2844$	0.9917	0.1568
	30	$y = -0.0003x^2 + 0.0055x + 3.0019$	0.9891	0.4005
	40	$y = -0.0003x^2 - 0.0225x + 3.6332$	0.9563	0.2893

Note: y = *a**-value; x = time (s)

Figures 2 (a-c) demonstrate the influence of agitator speed (RPM) at different coagulation temperatures (70 °C, 75 °C and 80 °C) on *a** values of the samples. The results indicated that coagulation occurred more rapidly at 40 RPM (140 s) than at 30 RPM (160 s) and 20 RPM (180 s) at 70 °C. Figures 2 (d-f) represent the effect of coagulation temperatures (°C) at different agitator speeds (20 RPM, 30 RPM and 40 RPM) on *a** values of the samples. Similarly, at 75 °C and 80 °C, the coagulation process was more rapid at 40

RPM than at 30 and 20 RPM. In all three cases, there was a steady decline in *a** value during the first 60 seconds of coagulation, followed by a sudden drop in *a** value, indicating the formation and separation of whey. The *a** value was found to be related to the agitator speed, with a more negative *a** value indicating optimal greenish whey separation at higher agitation speeds. Overall, these findings suggest that the optimal conditions for coagulating milk for *Paneer* involve a careful balance of agitation speed and coagulation temperature to promote efficient coagulation and whey separation.

Conclusion

From this study, it was found that the desirable *a**-values were -5.393 to -5.289 for whey separation for complete coagulation of milk for *paneer* manufacturing. The optimal coagulation conditions were achieved with a coagulation temperature of 70°C, an agitator speed of 40 RPM for 140 s, and *a** value of -5.39.

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