6.1 INTRODUCTION

Rice (Oryza sativa L.) is a principal and leading staple cereal food in many parts of the world next to wheat (Ghadge and Prasad, 2012). China, India, Bangladesh, Indonesia, Vietnam, Thailand, Myanmar, Japan, and the Philippines are the important world rice-producing countries. One-fifth of the total world rice production is contributed by India from the cultivated crop area of 43.40 million hectares (FAOSTAT, 2017). China and India contribute more than half of world production of rice whereas more than ninety percent of world rice production is being fulfilled by these Asian countries. Rice being rich in carbohydrate fulfills the major daily energy needs and more than half of the world’s population is observed to use rice as a source of nourishment (Bhatia et al., 2009a; Prasad et al., 2010b).

Dry heat expanded snacks as puffed rice is obtained from the pre-conditioned milled parboiled rice. Puffed rice is used extensively as breakfast and snacks food item. Puffed rice as a common food ingredient is also observed to be used in popular street food such as bhel puri. It is offered in most of the temples and gurudwaras as holy food item prasad. The puffed rice flour has also been found to be utilized as ingredients for desserts, sweets, baby foods, crackers, stews, soups, noodles, and puddings. During the process of dry heat puffing, rice starch gelatinizes and a portion of this is retrograded and damaged, which ultimately converts part of it to resistant starch. The formed fraction of resistant starch is nutritionally significant as dietary fiber in helping the bowel movement and reducing constipation and
irritable bowel syndrome (Yue and Waring, 1998), as it escapes unaltered during digestion in the gastro-intestinal tract serve as periodic for gut micro-flora to ferment and produce short-chain fatty acids in improving the gut health. Further, rice as gluten-free food provides added benefit and provides a suitable alternative of wheat in the breakfast item especially suitable for the celiac subjects (Prasad et al., 2010b).

Edible coating with chocolate and sweetener of puffed rice may thus find larger acceptability as breakfast food item on comparing with corn flakes, which provides zein, an incomplete protein. To make the coated product more nutritional and functional, jaggery may be used as a source of sweetener. Jaggery in the diet is recommended to exterminate many physiological disorders and promotes longevity (Rao et al., 2007). Chocolate is rich in antioxidants, flavonoids and other important secondary metabolites thus suggested to consume for beneficial health effects (Fishera and Hollenbergb, 2005).

Coating materials being semisolid in nature and the consistency of coating materials thus may be controlled with the addition of suitable hydrocolloids. Guar gum (Cyamopsis tetragonoloba) is a water-soluble polysaccharide used as a stabilizer and binding agent in various food products (Morris, 1990). Addition of it adds benefits of dietary fiber and reduces the laxative requirement with helping the persons suffering from irritable bowel syndrome (Greenberg and Sellman, 1998; Slavin and Greenberg, 2003). Prevalence of Iron deficiency is the most common nutritional inadequacy leading to the cause of anemia or impaired mental development in nearly one-third of the world’s population. Supplementation with ferrous sulfate (FeSO₄) in coating material further improves the iron content of the coated product. Being, more than half of the world’s population uses rice as staple food, coating with such a combination may act as an important vehicle to solve the associated
nutritional problem through the development of widely acceptable ready-to-eat (RTE) breakfast and snacks food items.

6.2 MATERIALS AND METHOD

The puffed rice developed in the current study was prepared from the selected intermediate amylose content Indica, medium grain size and coarse rice variety Gurjari procured from Anand Agricultural University (Gujarat). The nutritional enhancement of puffed rice was achieved by coating (chocolate based) the product with different ingredients to form chocolate coated puffed rice (CCPR).

6.2.1 Preparation of chocolate coated puffed rice

The different coating materials taken as independent variables for optimization of product development based on the central composite rotatable design of response surface methodology (RSM) were chocolate and jaggery with fixed ingredient combinations (Table 6.1). The selection range of coating materials viz. jaggery and chocolate where adjusted from 3.10 to 22.90g and 17.31 to 35.69g, respectively whereas the other ingredients i.e. skim milk powder, guar gum and the FeSO₄ powder was kept constant at 1.0 %, 0.5%, and 43.33 mg/100g respectively (Mridula and Pooja, 2014; US-FDA, 2017).

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Code</th>
<th>Levels in coded form</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>-1.414</td>
</tr>
<tr>
<td>Jaggery, g</td>
<td>X₁</td>
<td>3.10</td>
</tr>
<tr>
<td>Chocolate, g</td>
<td>X₂</td>
<td>17.31</td>
</tr>
</tbody>
</table>
The coating mixture was prepared by dissolving the coating ingredients in 20ml distilled water that was further employed for coating the puffed rice in a laboratory scale continuous coating machine equipped with a hot air blower and stainless steel continuous rotating coating pan. About one hundred gram of puffed rice sample was taken in each experimental run into the rotating pan and occasionally sprayed with the coating mixture until each and every individual entity of puffed rice got perfectly coated with the mixture. In order to expedite and enhance the coating process temperature of air used in the partial drying of the coating layer was kept at 70±2°C and speed of coating pan where fixed 60 rpm/min for 10 minutes. After visual satisfaction of coating process, the sample was transferred from coating pan into hot air oven (50±2°C) for 2 hrs. The standard method of (A.O.A.C., 2002) was utilized for evaluation of moisture content within coated samples.

6.2.2 Physical characteristics

Dimensional parameters i.e. length, breadth and thickness were determined using a dial-type vernier caliper (Mitutoyo Corporation, Japan) with least count of 0.01 mm . The different dimensions were further taken as the basis for calculation of different dimensional characteristics like surface area, geometric mean diameter ($D_e$), sphericity, etc (Singh and Prasad, 2013).

$$D_e = (LBT)^{1/3}$$

(6.1)

Where L= length, B= breadth, and T= thickness

The different coated samples were examined for thousand kernel weight (TKW) by randomly selecting coated puffed rice grains and weighing them on an electronic balance (Ishida Co. Ltd., Japan) having an accuracy of about 0.001 g.
Bulk density ($\rho_b$) of the coated puffed rice kernels is the ratio between its mass and total volume, and was calculated by pouring the coated sample into an empty 100 ml graduated cylinder tapped few times and observed for reading (Jian and Bal, 1997).

6.2.3 Chemical characteristics

The standard procedures of AOAC were used for determination of chemical composition (moisture, ash, protein and crude fiber) of CCPR. Carbohydrate content of samples was determined by the differential method and wet digestion method was used to determine the mineral content of the sample (A.O.A.C., 2002). The free fatty acid content was estimated using standard method (Ranganna, 2000).

6.2.4 Fourier Transform Infra-red Spectroscopy (FTIR)

10 mg of samples were mixed with 50 mg of potassium bromide in a mortar and pestle for preparation of thin pallets that are examined for infra-red absorption spectra using FTIR Spectrometer (Shimadzu, Tokyo, Japan), pre-calibrated with the potassium bromide (KBr) and deuterated triglycine sulfate (DTGS) detector. The spectra of different samples were observed at a resolution of 2 cm$^{-1}$ and intensity range of 4000-400 cm$^{-1}$.

6.2.5 Functional characteristics

The modified method of Ainsworth, (2007) was used for estimation of total phenolic activity of the puffed rice and CCPR. A 0.5 ml sample extract was mixed with 2ml of FCR (Folin- Ciocalteu reagent) diluted with de-ionized water (1:10) in a test tube. The mixture was neutralized with 4 ml of 7.5% (w/v) sodium carbonate solution and kept in place for 30 min with occasional shaking to help in the development of the uniform colored solution. The solution was recorded for absorbance at 765 nm wave length using a spectrophotometer
(711-SNV) and gallic acid was used as a standard to draw the calibration curve employed in the determination of the total phenolic content of samples.

6.2.5.1 Milk Absorption capacity (MAC)

Milk absorption capacity (MAC) was estimated by separating the centrifuged residue after evaporation after discarding the supernatant (Stojceska et al., 2008). The left out residue was weighed and calculated for MAC (Eq. 6.2).

\[
WAI \ (g / g) = \frac{\text{Weight of gel}}{\text{Dry weight of sample}}
\]  

(6.2)

6.2.6 Textural characteristics

Hardness is defined as the maximum peak value observed in the force-time graph that further corresponds to the appearance of the first crack in the sample. The equipment utilized for hardness measurement of coated puffed rice was a TA-XT2 Texture Analyzer (Stable Microsystems, Surrey, UK), which was equipped with a load cell 50 kg and probe P5 with 5 mm diameter. Time versus compression force program was set and a single coated puffed rice kernel was compressed in each run along the thickness with a test speed of 2 mm/sec, post speed 10 mm/sec, 80% strain and 5 g of trigger force (Stojceska et al., 2008).

6.2.7 Optical characteristics

The color of CCPR sample was estimated by Hunter Lab Chroma meter (Konica Minolta Sensing, Inc., Model No.CR-400, Japan). The values of L, a and b values were noted directly from the colorimeter and following mathematical relationship was used to calculate the color difference (\(\Delta E\))

\[
\Delta E = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2}
\]  

(6.3)

Where L represents the lightness (0 for black to 100 for white)
a represents redness [red (+) to green (-)] and

b represents yellowness [yellow (+) to blue (-)].

6.2.8 Morphological characteristics

Morphological properties of CCPR were viewed with the help of Scanning electron microscope (Jeol JSM-6510LV, Tokyo, Japan). Double-sided conductive tape was used to keep the samples on different aluminum stubs followed by gold coating and transferred to an instrument running at high vacuum to get the different micrographs at several magnifications.

6.2.9 Sensory characteristics

The nine point hedonic scale was used to carry out a sensory evaluation of the CCPR (Ranganna, 2000) and instructions were provided to the panelists both in verbal and non-verbal form before they reach any decision (Imad et al., 1999). The parameters evaluated in the sensory analysis were sensory texture, sensory color, sensory texture and overall acceptability (Meilgaard et al., 2006). The test was conducted in the laboratory with semi trained panelists recruited from the staff and students of Sant Longowal Institute of Engineering and Technology, Longowal campus. The nine-point hedonic scale was used to evaluate the sensory analysis, in which 9 represents ‘like extremely’ and 1 represents ‘dislike extremely’ (Watts et al., 1989). The statistical and computational methods were used for the analysis of average mean values of scores for each attribute.

6.2.10 Experimental design and optimization

Response surface methodology (RSM) was used for experimental design and analysis with experiments conducted according to central composite rotatable design (CCRD) having two independent variables (k=2) i.e. Jaggery and dark chocolate (chocolate) at five different levels (Prasad and Nath, 2002a). The experimental combinations are presented both in coded
and un-coded form of independent variables (Table 6.1). A total of 13 experimental combinations were explored possessing 4 factorial experimental points, four axial points and 5 central point experiments (Table 6.2). Total number of experimental combinations = $2^k + 2\times k +$ central point experiment. Five different Levels for each experiment in coded form are, - $\alpha$, -1, 0, +1, +$\alpha$. Where, $\alpha = (2)^{k/4} = (2)^{1/2} = 1.414$.

The range of coating materials (jaggery and chocolate) was decided as per the literature survey and preliminary experimental trails. The lowest and highest selected values for jaggery was set to 3.10 g and 22.90 g while as for chocolate the levels were fixed to 17.31 g and 35.69 g, respectively. The effect of varying the jaggery and chocolate on the dependent variables were observed and analyzed statistically using Stat-Ease software (Stat-Ease, version 6.01, Stat-Ease Inc., MN).

The second order polynomial equation (Eq. 6.4) was fitted to the experimental data of dependent variables in order to observe the effects of selected independent variables.

$$Y = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \sum_{j=i+1}^{n} \beta_{ij} x_i x_j + \sum_{i=1}^{n} \beta_{ii} x_i^2$$  \hspace{1cm} (6.4)

Where, $\beta_0$ is the value of the fitted response at the centre point of the design, $\beta_i$, $\beta_{ij}$, and $\beta_{ii}$ are the linear, interaction and quadratic regression coefficients; $Y$, the dependent variable, $x$ as independent variable, $x_i$ represents the coded form of independent variables ($x_1$ as jaggery and $x_2$ as chocolate).

The independent variables of coating materials jaggery and chocolate were optimized numerically. The independent variables were reserved in range while the responses were fixed either in range, maximized and minimized based on the desired characteristics for developing highly acceptable CCPR. Multiple response optimizations as a tool were applied for obtaining the best combination of independent variables based on the selected response.
variables conditions as sensory scores for all the attributes as maximum with hardness in the final product as a minimum (Prasad, 2009; Prasad and Nath, 2002a).

6.2.11 Statistical analysis

One-way analysis of variance (ANOVA) was used to assess data using SPSS 16.0 software. Values are expressed as a mean ± standard deviation and critical differences were used to show the significant differences among the samples at the significance level of p ≤ 0.05 (Singh and Prasad, 2013).

6.3 RESULTS AND DISCUSSION

6.3.1 Development of chocolate coated puffed rice

Puffed rice is a pre-cooked, expanded, shelf stable ready-to-use an intermediate food product commonly used as breakfast snacks. It is a common ready-to-eat food item consumed after seasoning or directly with the addition of milk and curd. The milk absorption characteristics of puffed rice play an important role in the breakfast food item commercially acceptable (Kumar and Prasad, 2017). Under present investigation, efforts have been made to develop the functional chocolate coated puffed rice (CCPR). Statistical optimization approach of CCRD was adopted. Effect of jaggery (3.10 to 22.90g) and chocolate (17.31 to 35.69g) were observed on physical, textural, functional optical and sensory characteristics in order to optimize the CCFR. Levels of skim milk powder (1.0%), guar gum (0.5%), and ferrous sulfate (43.33 mg/100g) were considered as constant.

6.3.2 Physical characteristics

As a dimensional parameter of physical characteristics, length, breadth, and thickness of chocolate coated puffed rice (CCPR) ranged from 13.60mm to 14.97mm, 4.52mm to 5.64mm and 4.28mm to 5.14mm, respectively upon using different concentrations of jaggery
and chocolate in the coating material (Table 6.2). The dimensional parameters of obtained CCPR (Fig. 6.1) were regressed and the response surface for these parameters as a function of coating material formulation is shown (Fig. 6.2). The highest values of dimensional parameters were observed when the maximum amount of jaggery (22.90g) was used for the coating process. The magnitude and sign of regression coefficient of jaggery and chocolate showed a significant ($p \leq 0.01$) positive effect on dimensional properties of CCPR (Table 6.3). The values of length, breadth, and thickness as dependent on the amount of jaggery and chocolate may be obtained through the developed full quadratic model (Eq. 6.5-6.7).
Table 6.2 Physical, textural, functional and optical sensory characteristics as affected by the levels of jaggery and chocolate

<table>
<thead>
<tr>
<th>Exp. No.</th>
<th>Jaggery</th>
<th>Chocolate</th>
<th>L (mm)</th>
<th>B (mm)</th>
<th>T (mm)</th>
<th>GMD (mm)</th>
<th>SA (mm²)</th>
<th>TKW (g)</th>
<th>BD (kg/cm³)</th>
<th>HD (N)</th>
<th>MAC (g/g)</th>
<th>DE</th>
<th>Colour</th>
<th>Texture</th>
<th>Taste</th>
<th>OAA</th>
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<td>-1</td>
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<td>7.23</td>
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<td>31.20</td>
<td>101.65</td>
<td>27.06</td>
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<td>160.51</td>
<td>34.60</td>
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</tr>
</tbody>
</table>

*L-Length, B-Breadth, T-Thickness, GMD-Geometric mean dimension, SA-Surface area, TKW-Thousand kernel weight, BD- Bulk density, HD-Hardness, MAC-Milk absorption capacity, DE-Color difference, OAA-Overall acceptability*
Table 6.3 Regression coefficients of fitted models with statistical parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>L (mm)</th>
<th>B (mm)</th>
<th>T (mm)</th>
<th>GMD (mm)</th>
<th>SA (mm$^2$)</th>
<th>TKW (g)</th>
<th>BD (kg/cm$^3$)</th>
<th>HD (N)</th>
<th>MAC (g/g)</th>
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<th>Colour</th>
<th>Texture</th>
<th>Taste</th>
<th>OAA</th>
</tr>
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<tbody>
<tr>
<td>$X_1$</td>
<td>0.262**</td>
<td>0.241***</td>
<td>0.239***</td>
<td>0.217***</td>
<td>9.570***</td>
<td>1.349***</td>
<td>4.837***</td>
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<td>0.165***</td>
<td>-0.068***</td>
<td>-0.248***</td>
</tr>
<tr>
<td>$X_2$</td>
<td>0.105ns</td>
<td>0.113*</td>
<td>0.073ns</td>
<td>0.080**</td>
<td>3.187**</td>
<td>1.244**</td>
<td>6.604**</td>
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<td>-0.415**</td>
<td>4.760***</td>
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<td>-0.159*</td>
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</tr>
<tr>
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<td>-0.114**</td>
<td>-5.053**</td>
<td>-1.04ns</td>
<td>-1.532**</td>
<td>3.083</td>
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<td>0.004**</td>
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<tr>
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<td>0.081**</td>
<td>0.021ns</td>
<td>0.006ns</td>
<td>-0.277ns</td>
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<td>4.792***</td>
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<td>-0.128ns</td>
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<td>0.025</td>
<td>0.024</td>
<td>0.006</td>
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<td>0.022</td>
<td>0.021</td>
<td>0.006</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.183</td>
<td>0.103</td>
<td>0.094</td>
<td>0.057</td>
<td>2.734</td>
<td>0.771</td>
<td>1.319</td>
<td>2.384</td>
<td>0.135</td>
<td>0.741</td>
<td>0.094</td>
<td>0.119</td>
<td>0.119</td>
<td>0.062</td>
</tr>
</tbody>
</table>

L-Length, B-Breadth, T-Thickness, GMD-Geometric mean dimension, SA-Surface area, TKW-Thousand kernel weight, BD- Bulk density, HD-Hardness, MAC-Milk absorption capacity, DE-Color difference, OAA-Overall acceptability
Level of significance***p<0.01%, **p<0.05%, * p< 0.1%, ns non-significant
Figure 6.1 Coated puffed rice as dependent on variable jaggery and chocolate combinations
Figure 6.2 Physical and textural responses as affected by the levels of jaggery and chocolate
Length=14.49+0.26A+0.10B-0.092AB+0.067A^2-0.30B^2 \quad (6.5)

Breadth=5.42+0.24A+0.11B-0.20AB-0.081A^2-0.23B^2 \quad (6.6)

Thickness=4.70+0.24A+0.073B-0.045AB+0.021A^2-0.920B^2 \quad (6.7)

Where, A is the amount of jaggery and B is the amount of chocolate.

The quadratic models of dimensional parameters fixed well with the observed data as the coefficient of multiple determinations ($R^2$) of 0.759, 0.889 and 0.815, and adequate precision of 7.378, 10.902 and 8.293 for length, breadth and thickness, respectively (Table 6.3).

The geometric mean diameter (GMD) of CCPR varied from 6.56 to 7.34mm for samples coated with varying concentrations of coating materials (Table 6.2). The higher value of GMD was noted when the maximum amount of jaggery (22.90g) was present in the coating material whereas the least value was observed upon using a lower amount of jaggery (6.00g). The higher concentration of coating materials resulted in the formation of a thicker coating material that upon surface deposition of puffed rice formed a comparatively thicker layer thereby increasing dimensional characteristics, which may be correlated with the TKW. Adhesion of sodium chloride and its effect on coating was demonstrated (Kuntz, 1994). The magnitude and sign of regression coefficient for jaggery and chocolate showed a significant (p≤0.01) effect on the geometric mean diameter of CCPR (Table 6.2). Model parameters, coefficients, constant with statistical findings are presented in Table 6.2. The value of geometric mean diameter as dependent on the amount of jaggery and chocolate is presented by following equation (Eq. 6.8).

\[ \text{GMD}=7.06+0.22A+0.080B-0.11AB-6.433A^2-0.093B^2 \] \quad (6.8)
The surface area of CCPR was ranged from 135.26 to 169.16 mm$^2$ (Table 6.1). The trend is shown by surface area in accordance with the observed dimensional characteristics with a higher concentration of coating material resulting in the formation of a comparatively larger surface area whereas the lower concentration functioned vice versa. The response surface plot for the surface area as a function of chocolate and jaggery (Fig. 6.2) and the following relationship was developed (Eq. 6.9) with the significance of independent variables (Table 6.3).

$$SA=156.84+9.57A+3.19B-5.05AB-0.28A^2-3.99B^2$$  \hspace{1cm} (6.9)

The quadratic model fitted well with observed data having a high coefficient of multiple determinations values ($R^2 = 0.914$). The geometric mean diameter and surface area of CCPR showed a direct relationship with the amount of coating material used. The effect of surface area on coated popcorn was reported (Miller and Barringer, 2002).

Thousand kernel weight (TKW) gives a measure of individual kernel size and it ranged from 27.15 to 34.60 g for coated samples (Table 6.1). TKW of grains was found directly proportional to the concentration of coating materials and was found to be highest at higher levels of coating ingredients and lowest at lower values of coating ingredients (Fig. 6.2). The densities of used ingredients of coating materials has enhanced the TKW of CCPR (Beckett, 2011; Patil and Anekar). Effect of independent variables on TKW is clear from the following relation (Eq. 6.10).

$$TKW=30.76+1.35A+1.24B-0.10AB+0.37A^2-0.18B^2$$  \hspace{1cm} (6.10)

The bulk density of CCPR varied from 87.44 to 114.27 kg/m$^3$ upon coating with different concentrations of coating materials (Table 6.1). The response surface plot related to bulk density as a function of jaggery and chocolate are presented (Fig. 6.2). The values of
bulk density were found highest when 6.00g of jaggery and 20.00g of chocolate were used as a coating material. The relationship developed with independent variables including the significance of terms (Eq. 6.11) for the developed model is presented (Table 6.2).

\[
BD=109.21+4.84A+6.60B-1.53AB-4.80A^2-2.18B^2
\]  
(6.11)

The higher side of R² with a numeric value of 0.970 indicating the suitability of the model for predicting the bulk density of CCPR. The applied dry heat puffing has resulted in decreased BD (Kumar et al., 2016; Kumar and Prasad, 2017) and further, coating of puffed rice has resulted in enhanced TKW and thus increased the BD of CCFR (Okafor and Usman, 2015).

6.3.3 Functional and textural characteristics

The milk absorption capacity (MAC) of different puffed rice samples coated with varying levels of coating ingredients was found in the range of 1.20 to 3.6 g/g (Table 6.2). MAC of CCPR was highest when the concentration of coating materials contained 6.00g of jaggery and 22.00 g of chocolate as coating mixture. The response surface plot for MAC as a function of chocolate and jaggery are shown in Fig. 6.3 and following relationship was developed with independent variables (Eq. 6.12).

\[
MAC=2.07-0.58A-0.42B+0.41AB-0.021A^2-0.13B^2
\]  
(6.12)

The quadratic model fitted well with observed data as portrayed by a high R² as 0.953. Coating materials contained jaggery, dark chocolate and guar gum, which has created a smooth layer on the surface and filled the gap and void spaces of puffed rice and thus reduced the MAC and enhanced the milk absorption time (Chassagne-Berces et al., 2011).

Hardness is the maximum force required for compressing or deforming a product during deformation curves and the values varied from 11.80 to 32.38 N for CCPR (Table
6.2). The magnitude of regression coefficient for coating materials (jaggery and chocolate) showed a significant (p≤0.01) effect on the hardness of CCPR (Table 6.3). The maximum hardness of CCPR was found in samples coated with coating ingredients containing 13.00g of jaggery and 17.31g of chocolate. The value of higher R² as 0.881) indicates the suitability of the model for predicting the bulk density of CCPR. Model parameters, coefficients, constant with statistical findings are presented (Table 6.3). The value of hardness as dependent on the amount of jaggery and chocolate is presented in equation (Eq. 6.13).

\[
\text{Hardness}=15.04+2.46A-3.14B+3.08AB+4.79A^2+6.22B^2
\]  

(6.13)

The surface cementing of void space or cracks of roasted flaked rice on coating (Fig 6) has resulted in the enhanced level of hardness in CCPR (Torres-Martinez et al., 2007).

6.3.4 Color difference (DE)

The values of color difference (DE) ranged from 34.50 to 52.28 for different samples coated with varying amounts of chocolate and jaggery (Table 6.2). The values of DE were found highest when highest amount of 22.90 g jaggery was used with 26.50g of chocolate in the coating mixtures. The minimum DE was noticed when chocolate was used at the minimum level in the coating material. The response plots for CD as a function of coating materials i.e. chocolate and jaggery is shown in Fig. 6.3 and the effect of independent variables on the color difference clear from the following relation (Eq. 6.14).

\[
\text{DE}=46.79+3.38A+4.76B-0.14AB+0.51A^2-2.56B^2
\]  

(6.14)

The quadratic model fitted well with the observed data as high level of R² as 0.978 was obtained (Table 6.2). Increase in the DE may be attributed to the addition of dark compound of coating material on the surface of CCFR (Košutić et al., 2016).

Figure 6.3 Functional, optical and sensory responses as affected by the levels of jaggery and chocolate
6.3.5 Sensory characteristics

The sensory characteristics of CCPR samples were found to have significant variations and the values of sensory color, texture and taste ranged from 7.02 to 8.48, 7.02 to 8.62 and 7.54 to 8.69, respectively (Table 6.2). The sensory color had the lowest value when the highest quantity of jaggery (22.90g) was used whereas the samples coated with assumed an optimum level of coating ingredients scored the highest values for sensory scores due to panelists fondness towards the mentioned sample. The magnitude of regression coefficient for coating materials (jaggery and chocolate) showed with their significance values (p≤0.01) on sensory properties of CCPR (Table 6.3).

Model parameters, coefficients, and constants with statistical findings are presented in Table 6.3. The sensory properties such as sensory color, texture, and taste (Fig 3) depended on the amount of jaggery and chocolate as presented through equations (Eq. 6.15-6.17).

\[
\text{Sensory Color} = 8.31 - 0.097A - 0.079B + 3.846AB - 0.62A^2 - 0.13B^2
\]  
\[\text{(6.15)}\]

\[
\text{Sensory Texture} = 8.40 + 0.16A + 0.14B - 0.29AB - 0.49A^2 - 0.34B^2
\]  
\[\text{(6.16)}\]

\[
\text{Sensory Taste} = 8.54 - 0.068A - 0.16B + 0.038AB - 0.38A^2 - 0.32B^2
\]  
\[\text{(6.17)}\]

The sensory texture of CCPR was found lowest (7.02) when lower levels of jaggery (6.00 g) and chocolate (20.00 g) were used. Texture plays an important role on acceptability of CCPR (Trevisan and Arêas, 2012). The minimum value of sensory taste was noticed upon using 33.00 g of chocolate and 6.00g of jaggery as coating material whereas the values of sensory taste were highest at assumed optimum levels of coating materials. The possible reasons for not preferring highest and lowest values of chocolate in different samples may be due to bitter aftertaste provided at a higher concentration of chocolate whereas the lower concentrations haven’t satisfied the perception of panelists.
6.3.6 Overall acceptability

The overall acceptability (OAA) values of CCPR varied from 7.09 to 8.55 (Table 6.2). The maximum value of OAA was found at the assumed optimum level when 13.00g of jaggery and 26.50g of chocolate was used as coating materials whereas minimum value of OAA was observed when a higher amount of coating ingredients were used in the coating process. The coefficient of multiple determinations ($R^2$) was the high indicated suitability of the model for predicting the OAA of CCPR. The value of OAA as dependent on the amount of jaggery and is presented through the following mathematical relationship (Eq. 6.18).

$$OAA = 8.45 - 0.25A - 0.036B - 0.066AB - 0.34A^2 - 0.64B^2$$  \hspace{1cm} (6.18)

6.3.7 Optimization and characterization of chocolate coated roasted flaked rice

In the optimization process two coating materials i.e. levels of jaggery and chocolate were considered as independent variables. Design- expert software (Design- expert 7.0.0-version Stat-Ease Inc., Minneapolis, USA) was used for obtaining the optimized combinations in the numerical and graphical approach of multi-response optimization. According to requisite characteristics in either of the optimization process of the final product, the lower and higher range of these ingredients was set along with the responses i.e. length, breadth, thickness, GMD, SA, TKW, BD, MAC, and DE set in-range whereas sensory colour, texture, taste and overall acceptability were kept maximum and hardness of the final product was set to a minimum. The range of coating materials used for optimization was 3.10 to 22.90 g of jaggery and 17.31 to 35.69 g of chocolate. After analyzing the responses the optimum level of independent variables as jaggery, 12.29g (-0.10) and chocolate, 26.66g (0.03) in the coating material were found to be the best combination (Fig. 6.4).
Figure 6.4 Superimposed counter plots for sensory and textural responses as affected by the levels of jaggery and chocolate.
The suitable higher acceptability of CCPR could be prepared with the various combinations of graphical optimization technique (Fig. 6.4) depending on the choice of different parameters (Badwaik et al., 2012). The obtained theoretical results for the physical, textural, functional optical and sensory characteristics were confirmed by preparing the CCPR of a numerically optimized combination of jaggery and chocolate in the coating material while characterizing the developed highly acceptable ready-to-eat functional food product.

Evident differences in physical, chemical, textural, functional, optical and sensory characteristics were observed on comparing the developed puffed rice with the optimized chocolate coated puffed rice (CCPR).

6.3.7.1 Physical characteristics

The dimensional parameters of physical characteristics on the application of the coating on puffed rice have found to affect positively. Length increased from 14.19±0.05 to 14.25±0.72mm whereas the breadth and thickness varied from 4.90±0.03 to 5.42±0.25mm and 4.23±0.34 to 4.76±0.06mm, respectively (Table 6.4). The enhancement in dimensional characteristics is due to the adherence of the coating ingredients in form of an additional layer on the puffed rice. The variation as provided by coating process over the basic dimensions also affected the surface area, geometric mean diameter (GMD) and other derived dimensional characteristics. The GMD increased from 6.65±0.18 to 7.16±0.22mm and surface area from 138.88±7.64 to 161.21±1.37mm².

The thousand kernel weight and bulk density as the important gravimetric parameters of physical characteristics increased from 22.28±0.16 to 30.58±0.31g and 82.46±5.02 to 109.93±0.28 kg/m³, respectively after coating application.
Table 6.4 Comparative physical, textural, functional, optical and sensory properties of uncoated and coated puffed rice

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Uncoated</th>
<th>Coated</th>
</tr>
</thead>
<tbody>
<tr>
<td>L (mm)</td>
<td>14.19±0.05</td>
<td>14.46</td>
</tr>
<tr>
<td>B (mm)</td>
<td>4.90±0.03</td>
<td>5.40</td>
</tr>
<tr>
<td>T (mm)</td>
<td>4.23±0.34</td>
<td>4.67</td>
</tr>
<tr>
<td>GMD (mm)</td>
<td>6.65±0.18</td>
<td>7.04</td>
</tr>
<tr>
<td>SA (mm²)</td>
<td>138.88±7.64</td>
<td>155.96</td>
</tr>
<tr>
<td>TKW (g)</td>
<td>22.28±0.16</td>
<td>30.66</td>
</tr>
<tr>
<td>BD (kg/m³)</td>
<td>82.46±5.02</td>
<td>108.84</td>
</tr>
<tr>
<td>HD (N)</td>
<td>19.78±1.22</td>
<td>14.76</td>
</tr>
<tr>
<td>MAC (g/g)</td>
<td>3.27±0.41</td>
<td>2.12</td>
</tr>
<tr>
<td>DE</td>
<td>42.37±0.36</td>
<td>46.57</td>
</tr>
<tr>
<td>Color</td>
<td>8.26±0.12</td>
<td>8.31</td>
</tr>
<tr>
<td>Texture</td>
<td>7.67±0.11</td>
<td>8.38</td>
</tr>
<tr>
<td>Taste</td>
<td>7.69±0.09</td>
<td>8.54</td>
</tr>
<tr>
<td>OAA</td>
<td>7.56±0.08</td>
<td>8.47</td>
</tr>
</tbody>
</table>

Values are represented as mean ± standard deviation, L-Length, B-breadth, T-thickness, GMD-geometric mean dimension, SA-surface area, TKW-thousand kernel weight, BD-bulk density, HD-hardness, MAC-milk absorption capacity, DE-color difference, OAA-Overall acceptability
6.3.7.2 Chemical characteristics

The chemical composition of the puffed rice and CCPR is presented in Table 6.5. The chemical composition of puffed rice samples notably changed after their coating process. The moisture content of puffed rice increased after coating from 5.94±0.07 to 6.90±0.27%, and the reason might be the characteristics of bound moisture in the coating ingredients. The presence of good fat in coating ingredients enhances the overall fat content of CCPR from 1.14±0.06 to 3.67±0.39%. The protein and ash content of puffed rice incremented from 6.23±0.25 to 8.18±0.17% and 1.35±0.21 to 1.61±0.45%, respectively. The carbohydrate levels in puffed rice and CCPR was 82.38±0.63% and 77.88±0.52% whereas the energy values ranged from 403.07±1.85 to 377.27±2.43kCal, respectively. The mineral content of coated puffed rice was much higher than puffed rice and the obvious reasons are the presence of appreciable amounts of minerals in coating materials. The values (mg/100g) of minerals such as iron, calcium, sodium, and potassium enhanced from 1.66±0.19 to 29.17±0.17, 18.23±0.50 to 61.93±0.24, 5.56±0.26 to 18.90±0.56 and 210.67±5.69 to 465.72±6.09, respectively upon coating process.
Table 6.5 Comparative chemical characteristics of uncoated and coated puffed rice

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Puffed rice</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uncoated</td>
<td>Coated</td>
<td></td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>5.94±0.07</td>
<td>6.90±0.27</td>
<td></td>
</tr>
<tr>
<td>Crude fat (%)</td>
<td>1.14±0.06</td>
<td>3.67±0.39</td>
<td></td>
</tr>
<tr>
<td>Crude fiber (%)</td>
<td>1.77±0.11</td>
<td>1.75±0.19</td>
<td></td>
</tr>
<tr>
<td>Protein (%)</td>
<td>6.23±0.25</td>
<td>8.18±0.17</td>
<td></td>
</tr>
<tr>
<td>Total ash (%)</td>
<td>1.35±0.21</td>
<td>1.61±0.45</td>
<td></td>
</tr>
<tr>
<td>Carbohydrate (%)</td>
<td>82.38±0.63</td>
<td>77.88±0.52</td>
<td></td>
</tr>
<tr>
<td>Energy (kcal/100g)</td>
<td>403.07±1.85</td>
<td>377.27±2.43</td>
<td></td>
</tr>
<tr>
<td>Iron (mg/100g)</td>
<td>1.66±0.19</td>
<td>29.17±0.17</td>
<td></td>
</tr>
<tr>
<td>Calcium (mg/100g)</td>
<td>18.23±0.50</td>
<td>61.93±0.24</td>
<td></td>
</tr>
<tr>
<td>Sodium (mg/100g)</td>
<td>5.56±0.26</td>
<td>18.90±0.56</td>
<td></td>
</tr>
<tr>
<td>Potassium (mg/100g)</td>
<td>210.67±5.69</td>
<td>465.72±6.09</td>
<td></td>
</tr>
<tr>
<td>Total polyphenol (mg GAE/100g)</td>
<td>2.89±0.41</td>
<td>96.62±1.34</td>
<td></td>
</tr>
<tr>
<td>Free fatty acid (%)</td>
<td>0.13±0.01</td>
<td>0.16±0.04</td>
<td></td>
</tr>
</tbody>
</table>

Values are represented as mean ± standard deviation
6.3.7.3 Fourier Transform Infra-red Spectroscopy (FTIR)

Infrared (IR) absorption spectrum confirms and corresponds to the absorption bands of various functional groups such as alcohols, aldehydes, esters, ketones, etc. present in the food sample (Fig. 6.5). The spectra of puffed rice bands at 920.12 cm\(^{-1}\) and 996.23 cm\(^{-1}\) corresponds to the presence of functional group –C–O and –C=O. The spectra of puffed rice and CCPR hadn’t any major differences in absorption bands ranging from 996.23 cm\(^{-1}\) to 1414.72 cm\(^{-1}\) bands. The band range of 1642.37–1748.37 cm\(^{-1}\) shows the existence of fatty acids in puffed and CCPR with similar results also reported (Gangidi et al., 2002). The absorption band observed at wave number indicate the symmetrical and asymmetrical –CH\(_2\)– stretching band, while the band at 3015 cm\(^{-1}\) to 3000 cm\(^{-1}\) wave number were linked to –O–H bond stretching in CCPR. The band shifts visualized in puffed rice to CCPR were 2400 cm\(^{-1}\) to 2359.20 cm\(^{-1}\), 2853.59 cm\(^{-1}\) to 2840.16 cm\(^{-1}\) and 3000 cm\(^{-1}\) to 3015 cm\(^{-1}\) wave number after the coating process. The spectrum of characteristics bands compared to puffed rice showed that there wasn’t any major difference found except for the band stretching (Dutta and Mahanta, 2012).

6.3.7.4 Textural, functional and optical characteristics

The process of the coating has not much affected the hardness values for the optimized CCPR and was found to decrease from 19.78±1.22 to 15.71±1.94N (Table 6.4), this may be attributed to the increased moisture content of coated product from 5.94 to 6.90%.

The MAC of the puffed rice and optimized CCPR was found to decrease from 3.27±0.41 to 2.27±0.21g/g (Table 6.4). The decrease in MAC may be attributed to the packing of cracks and pores of puffed rice with the coating materials (Fig. 6.6). It was also
found that on coating the milk absorption time for the loss of crispness was extended to more than one and half of the time taken by the uncoated puffed rice.

![Figure 6.5 FTIR spectra of uncoated and coated puffed rice](image)

**Figure 6.5 FTIR spectra of uncoated and coated puffed rice**

The coating process of puffed rice also resulted in elevating the levels of total polyphenols from 87.89±1.41 to 96.62±1.34mg GAE/100g, due to phenolics present in the chocolate. The free fatty acid content showed a slight increase from 0.13±0.01 to 0.16±0.04% after application of coating ingredients (Table 6.5). The Resistant starch content (2.55±0.11%) of puffed rice further contributes towards functionality as dietary fiber.

The utmost change was observed in the color difference, which was 42.37±0.36 for the puffed rice and 46.33±0.76 for CCPR. The obvious reasons can be attributed to a different color of the coating material that reduces the lightness values (Table 6.4).
6.3.7.5 Morphological characteristics

The morphological characteristics of puffed and CCPR had a visible difference as depicted (Fig. 6.6). The coating of puffed rice resulted in smoothening of its irregular surface by filling of coating material in the cracks and grooves that existed on the surface of the puffed rice. The irregular surface of puffed rice is formed during its development by differential expansion of endosperm leading to the formation of surface furrows and grooves on the surface that get sealed and filled up by coating materials (Naruenartwongsakul et al., 2008; Vallons et al., 2011).

6.3.7.6 Sensory characteristics

The sensory characteristics also showed notable differences after coating application with sensory color and texture changing from 8.26±0.12 to 8.21±0.09 and 7.67±0.11 to 8.34±0.11 for puffed rice and CCPR, respectively. The reason might be due to the fact that panelists liked the chocolate and jaggery coated puffed rice (Solís-Morales et al., 2009). Likewise, the sensory taste values increased from 7.69±0.09 to 8.50±0.04 for CCPR while as the overall acceptability values changed from 7.56±0.08 to 8.42±0.09 after coating application as (Table 6.4). Higher values of all the sensory attributes for the developed CCPR may find the place among the highly acceptable ready-to-eat breakfast food item.
Figure 6.6 Photograph from rough rice to coated puffed rice with micrograph depicting the differences from uncoated to coated puffed rice.
6.4 CONCLUSION

In the present study, it is concluded that physicochemical and sensory characteristics of the developed product changed on the coating. Puffed rice is ready to eat food products and after application of coating ingredients, it improves the nutritional and sensory characteristics of products. A combination of 12.29g jaggery and 26.66g chocolate was found most desirable for the development of chocolate coated puffed rice (CCPR). In chocolate coated puffed rice overall acceptability score was found highest (8.55) and optimized product also found the similar value of overall acceptability (8.42). The coating materials increased sensory characteristics such as color, texture and taste and total polyphenol and milk absorption time. The coated product is unique in taste as well as nutritional characteristics. The product thus may be used as snacks and ready to eat functional breakfast food. Higher values of all the sensory attributes for the developed CCPR may find the place among the highly acceptable ready-to-eat breakfast food items and also be a suitable food alternative for celiac subjects being developed food as gluten-free.