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RESEARCH ARTICLE

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Sensorial, textural, and nutritional attributes of coconut sugar and cocoa solids based "bean-to-bar" dark chocolate

Shameena Beegum P.P[1] | Ravi Pandiselvam[1] | Ramesh S.V.[1] | Sugatha P[1] | Arifa Nooh[1] | Neenu S[2] | Alka Gupta[2] | Eldho Varghese[3] | D. Balasubramanian[4] | Elain S. Apshara[5] | Musuvadi Ramarathinam Manikantan[1] | Kukkehalli Balachandra Hebbar[1]

[1]Physiology, Biochemistry & Post Harvest Technology, ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala, India

[2]Crop Production, ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala, India

[3]Fishery Resources Assessment, ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala, India

[4]Post Harvest Technology & Farm Machinery & Power, ICAR- Directorate of Cashew Research, Puttur, Karnataka, India

[5]ICAR- Regional Station, Karnataka, India

Correspondence
Shameena Beegum P.P, Kukkehalli Balachandra Hebbar and Musuvadi Ramarathinam Manikantan, Physiology, Biochemistry & Post Harvest Technology, ICAR-Central Plantation Crops Research Institute, Kasaragod, 671124, Kerala, India.
Email: shameena.pht@gmail.com, balakbh65@gmail.com and manicpcri@gmail.com

Abstract

The impacts of cocoa solids and coconut sugar on the sensory perception of bean-to-bar dark chocolate were investigated with mixture design using response surface methodology. The maximum and minimum levels of cocoa nib, cocoa butter, and coconut sugar for the preparation of chocolate were 35–50%, 15–30%, and 20–35%, respectively. A suitable mathematical model was used to evaluate each response. Maximum and minimum levels of components caused a poor sensory acceptance of the resultant dark chocolate. The optimum level of independent variables, for the best set of responses, was 44.7% cocoa nib, 25.2% cocoa butter, and 30.2% coconut sugar, with a hedonic score of 8.28 for appearance, 8.64 for mouth feel, 8.71 for texture, 8.68 for taste, and 8.51 for overall acceptability, at a desirability of 0.86. The minimum time for grinding the chocolate mix was 24 hour, which was evident from the microscopic analysis of the chocolate mix. The optimized chocolate (70% dark) per 100 g constitutes 1.06 g moisture, 50.09 g crude fat, 10.37 g crude protein, 35.90 g carbohydrates, and 2.55 g ash content. The L, a, b values indicated a darker color and was stable under ambient condition with a hardness value of 59.52 N, which significantly decreased to 16.23 N within 10 min at ambient temperature (30 ± 2°C). The addition of coconut sugar along with cocoa solids incorporates polyphenols, flavonoids, antioxidant potential, and minerals into bean-to-bar dark chocolate and hence offers a commercial value and health potential for stakeholders.

KEYWORDS

bean-to-bar dark chocolate, cocoa solids, coconut sugar, sensory perception

1 | INTRODUCTION

Craft chocolates are made of raw cocoa (*Theobroma cacao* L.) beans, generally processed on a small scale, with a strong emphasis on the inherent flavor of the beans. Hence, "bean-to-bar" signifies that the craft chocolate makers exercise complete control over the origin of their products starting from the fermented and dried beans to the finished chocolate bar and it directly benefits the farming community. These chocolates are generally made using well fermented, dried cocoa beans, and sugar with or without cocoa butter. They are marketed as dark chocolates with cocoa content ranging from 60 to 99%. Consumption of dark chocolate is associated with potential health benefits owing to its rich polyphenols specifically flavonoids and antioxidant activities of cocoa beans (Cinquanta et al., 2016).

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Cocoa mass is the ground form of cocoa nibs or kernels and is the prime ingredients for dark chocolate preparation. Cocoa butter imparts stability to the product. Sugar acts as a sweetening agent, adds bulkiness to the product, acts as a preservative, and has a direct impact on the texture of finished chocolate (Afoakwa et al., 2008b). The demand for healthier chocolates with more cocoa solids and natural sweeteners is increasing progressively due to concerns about health, food, and lifestyle. More than one in 10 adults (537 million) in the world are now living with diabetes and the scenario in India is one in 12 (74.2 million), which is likely to increase to 643 million and 124.8 million in 2045, respectively (IDF, 2021). Thus, food with a low glycemic index (GI) is the need of the hour.

Sucrose in the form of refined sugar is one of the major ingredients in confectioneries such as chocolates. Health issues related to high sugar levels and calories are a major concern which has resulted in an increased demand for sugar-free or natural and healthy sugar-based food products. Shanthamma, Priyanka, Priyanga, Moses, and Anandharamakrishnan (2021) developed milk chocolates with natural sugar substitutes such as sorbitol, fructooligosaccharide (FOS), inulin, xylitol, and palm sugar. Similarly, Furlán et al. (2017) studied the effects of developing sugar-free white chocolate using stevia and sucralose as sweeteners. Gómez-Fernández et al. (2021) studied the significant effect of low-calorie sweeteners such as polydextrose, inulin, and so forth, on the dark chocolate formulation. Though artificial sweeteners have zero calorific value and low GI, the results of in vivo studies revealed their carcinogenic effects (Maluly et al., 2020) which in turn led to the use of natural sweeteners. These concerns led to the demand for natural sweeteners with low GI in confectionaries including dark chocolate. Lately, chocolate production with palm sugar has emerged as a healthy alternative source with multiple health benefits due to the low GI of natural sugars. Major sources of natural sugar are palm sugar from palmyra sap and coconut sugar from coconut sap. Saputro et al. (2016) attempted to make dark chocolate with palm sugar.

Coconut sugar, obtained by concentrating coconut inflorescence sap, has become a popular healthy alternative sweetener. Hebbar et al. (2015) have developed a process protocol for the production of coconut sugar from fresh inflorescence sap (*Kalparasa*®). The characterization of biochemical and functional qualities revealed that total phenolics, flavonoids, and antioxidant activity in 100 g coconut sugar has 47.2 Gallic Acid Equivalent (mg GAE), 4.76 Catechin Equivalent (mg CE), 22.9 Ascorbic Acid Equivalents Antioxidant Capacity (mg AEAC), respectively (Hebbar et al., 2020). It is also rich in amino acids and minerals. Replacing refined sugar with natural coconut sugar enriched with nutrients from dark chocolate is a healthier approach that is beneficial for diabetes patients. However, it should not adversely affect the sensory appeal of the chocolate. Hence, optimization of variables is necessary before manufacturing a marketable bean-to-bar chocolate with natural and healthy raw materials. In this direction, only few research studies on the effect of natural sugars especially coconut sugar on dark chocolate are carried out. In addition, the optimization of ingredients is a must for formulating chocolates. Therefore, the present investigation is envisaged to study the impact of ingredients like coconut sugar on bean-to-bar dark chocolate by optimizing the quantum of cocoa nibs, cocoa butter, and coconut sugar based on sensory perception and also to compare its functional and mineral composition with that of the raw cocoa beans, roasted beans, and the nibs.

2 | MATERIALS AND METHODS

2.1 | Raw materials

Cocoa beans that were well fermented and dried were packaged in low-density polyethylene pouches and stored at room temperature until further use. Cocoa butter was purchased from the Central Arecanut and Cocoa Marketing and Processing Co-operative Limited, at Puttur, Karnataka, India. Coconut sugar was prepared from *kalparasa*® (coconut inflorescence sap) by concentrating in an open pan cooker at 90–115°C for 3–3.5 h followed by drying at 55–60°C to get a moisture content of less than 1.7%.

2.2 | Roasting and winnowing

The roasting temperature was fixed at 130°C for 20 min based on the preliminary experiment conducted in an open ball batch roaster (7 kg capacity per batch, Advanced Motor Care, Chennai, Tamil Nadu, India). Roasted beans were cooled down to 35–40°C and processed into nibs after bean-breaking and winnowing using a bean breaker (10 kg/h, Advanced Motor Care, Chennai, Tamil Nadu, India) and winnower (Double Wind Powered, 10 kg/h, Advanced Motor Care, Chennai, Tamil Nadu, India).

2.3 | Grinding, refining, tempering, molding, demoulding, and packaging

Various chocolate formulations containing cocoa nibs, cocoa butter, and coconut sugar were ground using a tilting chocolate refiner (model No. 508, Premier, Chennai, India), which can operate continuously for more than 72 h. After gradually adding nibs, the top lock knob was turned to apply pressure to the nibs. After a few hours of refining, when the nibs turned shiny in appearance, cocoa butter and coconut sugar were added part by part, and the process of refining was continued for 24 h. The knob was loosened for an hour before taking out the samples so that the acetic acid present in it would volatilize. Soy lecithin (emulsifier at 0.4%) was added half an hour before taking out. The mix was then tempered at the pre-standardized temperature combinations (45–27–33°C), followed by molding in polycarbonate molds. It was tapped gently onto the workspace to release air bubbles and the excess chocolate was scraped off from the top of the mold using a spatula and kept in the refrigerator at 10–14°C for 45 min to harden. After demouding, it was covered using food grade aluminium foil, packed in a paper box and stored under refrigerator till further use.

TABLE 1 Limit and constraints in the selected variables and model

Low limit		Constraint		High limit
35.000	≤	A: Cocoa nib	≤	50.000
15.000	≤	B: Cocoa butter	≤	30.000
20.000	≤	C: Coconut sugar	≤	35.000
		A + B + C	=	100.000

2.4 | Impact of cocoa nibs, cocoa butter, and coconut sugar on chocolate formulation

2.4.1 | Optimization study: Experimental design and statistical analysis

Response surface methodology (RSM) using Mixture Design was followed to optimize the quantum of selected components such as cocoa nib (A), cocoa butter (B), and coconut sugar (C). The optimal (custom) design available in the mixture design was used for the test as the sum of all the ingredients should be 100% as visualized in Table 1. It is a flexible design structure to accommodate model's categorical factors and irregular (constrained) regions. Based on the preliminary experiments on bean-to-bar chocolate and the survey on existing bean-to-bar dark chocolate recipes available from various brands in market, the constraints of cocoa nib, cocoa butter, and coconut sugar were fixed at 35–50, 15–30, and 20–35%, respectively (Table 1). Sensory attributes including appearance, mouth feel, texture, taste, and overall acceptability (OA) were selected as the responses. Three components represent 100% of the total formulation, that is, cocoa nib (A) + cocoa butter (B) + coconut sugar (C) = 100%. The constraint and component ranges are as follows.

Table 2 shows the experimental design in terms of actual components. An optimal mixture design with 14 runs (including two center points) was generated for experimentation. The model used for establishing a relationship between the response and the input variables is in the form:

$$Y = \beta_1 A + \beta_2 B + \beta_3 C + \beta_{12} AB + \beta_{13} AC + \beta_{23} BC + e \quad (1)$$

where Y represents sensory attributes (response variable). A, B, and C refer to the levels of independent factors being evaluated [viz., A = cocoa nib (%), B = cocoa butter (%), and C = coconut sugar (%)]. β_i (linear coefficient) and β_{ij} (interaction coefficient) [$i < j = 1, 2,$ and 3] are the parameters of the model to be estimated. The error term "e" is assumed to follow normal distribution of independent and identical distributions characterized with zero mean and constant variance. The suitability of the developed model was tested by calculating the coefficient of determination (*R2*), adjusted R^2, and predicted *R2*. Analysis of variance (ANOVA) was used to assess the statistical significance of the model, and the significance of the estimated regression equation was tested using a *t*-test at $p < .05$. Numerical optimization was used for the simultaneous optimization of multiple responses. Design generation and analysis were performed using Stat-Ease software (Design-Expert 12.0, licensed to ICAR-CMFRI).

Data pertaining to biochemical, functional, and nutritional characterization of the optimized chocolate sample and raw cocoa beans were analyzed with completely randomized design (CRD) using SAS software.

2.4.2 | Sensory evaluation

Nine-point hedonic test was followed for sensory evaluation. Forty semi-trained panelists of different age groups, including the elderly group (25–60 years of age) and kids (6–17 years of age), were selected for sensory evaluation. The sensory panel consists of all the heads of the divisions (team recommended by the Director of the Institute) and selected members among the scientists, technical, supporting staff, and students of the Institute with good sensory perception (non-smokers, frequent chocolate consumers, and those who were screened based on the preliminary sensory evaluation tests). The consent for testing the samples was obtained before the test. The kids and teenagers were selected from schools functioning with the financial support of the Institute based on their sensory perception. Parental approval was obtained for the sensory evaluation. In addition, the parents of children below 16 were present in the sensory lab before doing the sensory evaluation. The participants were given samples by rearranging the order and giving three digit codes, three times a day around 11:30 a.m., 2:30 p.m., and 3:30 p.m.

Sensory briefing and evaluation

The sensory panelists were briefed about the nature of the product, product combinations, hedonic scale to determine the degree of acceptability of the product, sensory score card, the order of likeness, and the evaluation of sensory attributes. Panelists were asked to judge the 14 types of chocolate in terms of appearance, aroma, taste, texture, mouth feel, and OA. The children were briefed in detail about the test in their respective mother tongues as well as in English language. The score for the attributes of each sample was based on the agreed numbers on the 9-point hedonic scale (1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = liked extremely). One chocolate bar (30 g) was presented for evaluation.

The samples were served in the Agro Processing Complex of the Institute, where the chocolates were stored under refrigeration. There is a temporary sensory booth arrangement in the complex for routine sensory analysis for all the products developed through research. A separate arrangement was provided for the kids and teenagers. Samples were served in the cabins (single room) of the heads of the divisions. The availability of proper light was ensured in all the places. After ensuring seat, neutralizer (water), sample codes on the table, and sensory briefing, samples were taken from storage about 5 min before the analysis. All samples were evaluated at room temperature (30 ± 2°C). Temperature, humidity, and light of all the rooms were ensured to be the same.

TABLE 2 Outline of the experimental design matrix and observed values of response variables

Run	A	B	C	Appearance	Mouth feel	Texture	Taste	Overall acceptability
1	42.5	30	27.5	7.96	8.40	8.51	8.45	8.50
2	47.5	20	32.5	8.31	8.80	8.87	8.89	8.44
3	47.5	27.5	25	7.76	8.54	8.61	8.44	8.22
4	40	27.5	32.5	8.22	8.12	8.26	7.88	8.10
5	42.5	22.5	35	8.03	8.22	8.31	8.15	8.32
6	45	25	30	8.14	8.87	8.90	8.84	8.80
7	50	22.5	27.5	8.10	7.87	7.91	7.71	8.60
8	50	15	35	7.43	7.67	7.73	7.63	8.45
9	50	30	20	7.10	7.40	7.59	6.91	7.90
10	35	30	35	6.80	7.90	8.06	6.56	8.40
11	50	30	20	7.17	7.31	7.42	7.10	7.80
12	50	15	35	7.97	7.53	7.62	7.33	8.50
13	42.5	30	27.5	7.89	8.47	8.56	8.32	8.60
14	35	30	35	6.96	7.82	7.92	6.89	8.48

Note: A: cocoa nib, B: cocoa butter; C: coconut sugar. Values are mean score. Scores were based on a 9-point hedonic scale (with 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = liked extremely.

The panelists were asked to taste one sample at a time by placing it on the tongue and allowing it to slowly melt while touching it to the hard palate (to judge the mouth feel). It was suggested that the product should move through the entire mouth. Then allow it to be in mouth for at least 10 s to judge the texture and taste. Appearance of the samples was judged in terms of perfectness in shape and color (dark brown). Mouth feel was judged based on the behavior of the samples in the mouth with attributes such as sticky or melting, wherein stickiness is considered as a negative attribute and melting a positive attribute. Texture was evaluated in terms of smoothness or hardness, where smoothness was a positive attribute and hardness was a negative feature. Taste was analyzed with respect to bitterness or acidic nature, where bitterness was the positive attribute. After finishing one product, panelists were asked to sip water during an intermission of 1 min between two samples in order to neutralize the carryover effect of the previous sample. The time given for each set was 12–15 min. The test was carried out at room temperature (30 ± 2°C) within 5-10 min of being removed from storage.

2.5 | Standardization of grinding time of the optimized sample based on the particle size (microstructure)

To find out the optimum grinding time, optimized combination of cocoa nib, cocoa butter, and coconut sugar were ground using a tilting-type wet grinder, and samples were withdrawn from the grinding mass to evaluate the particle size at 6-h intervals starting from 6, 12, 18, 24, 30, 36, and 42 h. The samples were processed as per the method followed by Tan and Balasubramanian (2017) by mixing and homogenizing the mass (0.25 g) with isopropyl alcohol (5 ml;99% pure) using a vortex (Spinix, Tarsons, India) for 10 sec. Slides were prepared for microscopic observation by placing two drops of the homogenized solution on a clean glass slide (Himedia, India) using a micropipette (Accupipet, Tarsons, India) fitted with a wide orifice tip. The solution was covered slowly with a cover glass so as to avoid the trapping of any air bubbles within. The slides were then observed under a compound upright microscope (Eclipse Ni-U, Nikon, Japan). The microscope had a C-mount camera, DS-Ri1, equipped with a 5.9 megapixel CMOS image sensor, and the magnification of the objective lens and eyepiece were ×60 and ×10, respectively. Microscopy images were acquired at different random points of the sample surface spread and analyzed using NIS-Elements L imaging software.

2.6 | Proximate composition of the optimized chocolate

Moisture (gravimetric), crude fat (soxhlet method), crude protein (Kjeldahl method), total carbohydrates (difference method), and total ash content were estimated following standard procedures (AACC, 2000).

2.7 | Color and textural measurements

The surface color of optimized dark chocolate was measured using Hunter lab Color Flex (Model 45/O-L, USA. The parameters such as L*, a*, and b* were measured.

The breaking strength (N) or hardness of the dark chocolate was measured by using a TA – XT plus texture analyzer. Peak force at break was documented and means values were noted. A needle-shaped probe was used with a diameter of 25 mm. The test was performed as per the method followed by Saputro et al. (2016) with slight modification. The test conditions were as follows: pretest speed of 1.50 mm/s, test speed of 2.0 mm/s, posttest speed of 10 mm/s, distance of 5 mm, time of 30 s, and trigger force of 25 g. The chocolate sample was held at room temperature (30 ± 2°C) and the change in hardness was measured at different portion of the same bar at every 1-min interval up to 10 min.

2.8 | Comparison of functional quality of the optimized chocolate sample with raw cocoa beans, roasted cocoa beans, and cocoa nibs

The defatted chocolate sample was extracted using 70% acetone (acetone:water at 70:30 v/v), acidified acetone (70%, 1.2 M HCl), 80% ethanol (ethanol:water, at 80:20 v/v), and acidified ethanol (80%, 1.2 M HCl) as per Singleton, Orthofer, and Lamuela-Ranventos (1999) with slight modification.

Then, 0.5 g of defatted sample was mixed with 5 ml of selected solvent and vortexed for 30 min in a SPINIX vortex shaker at 40 Hz, followed by 15 min centrifugation at 10,000 rpm at 24°C. The supernatant of two extractions was pooled together (10 ml) and the samples were collected for estimation of polyphenol. The best solvent was selected based on maximum extraction efficiency.

2.8.1 | Estimation of polyphenols

Extract of 0.1 ml was made up to 5 ml with deionized water, followed by addition of 0.05 ml of freshly prepared Folin-Ciocalteu reagent (FCR: water, 1:1 v/v) and incubated for 3 min before it was vortexed for 1 min which was followed by addition of 0.5 ml 20% sodium carbonate (freshly prepared). A UV-Visible spectrophotometer (P/N 204-04550, SHIMADZ UV-160A, Shimadzu, Tokyo, Japan) was used to measure absorbance at 700 nm, 45 min after keeping the sample under room temperature against 0.1 ml of 70% acidified acetone as blank and the result was expressed as mg of gallic acid equivalent per 100 g sample.

2.8.2 | Flavonoid estimation

Total flavonoid content was determined according to Zhishen, Mengcheng, and Jianming (1999) with slight modification. The best extraction medium obtained from the polyphenol estimation was selected for estimating flavonoids and antioxidant activity. 0.1 ml extract was made up to 10 ml with distilled water. At time zero, 5% sodium nitrite (0.3 ml) was added, followed by 10% aluminium chloride (0.3 ml) at 5 min, and 1 M sodium hydroxide (2 ml) at 11 min. The pink color developed was measured at a 510 nm against 0.1 ml 70% acidified acetone as blank and results were expressed as mg of quercetin equivalent (QE).

2.8.3 | Antioxidant activity

Assay for 2,2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH): Extract of 0.1 ml was made up to 1 ml with distilled water, followed by the addition of 2 ml of DPPH reagent. It was kept in dark for 30 min and the absorbance was measured at 517 nm against methanol as blank. DPPH was calculated using the formula:

$$\text{DPPH ACTIVITY }\% = (\text{absorbance of control} - \text{absorbance of sample} / \text{absorbance of control}) \times 100 \tag{2}$$

where the absorbance of control should be less than 2)

Assay for ferric reducing ability of plasma (FRAP): FRAP was followed as per Benzie and Strain (1996). Extract of 0.01–0.1 ml was made up to 1 ml with distilled water, followed by addition of 2 ml of FRAP reagent and the absorbance was read at 593 nm against distilled water as blank along with the reagent after 30 min of incubation under the dark and the result was expressed in terms of Trolox Equivalent (TE).

2.9 | Comparison of mineral elements of the optimized chocolate sample with raw cocoa beans, roasted cocoa beans, and cocoa nibs

Elemental analysis of chocolate samples was carried out by the wet digestion method according to AOAC (2006). Estimation of total amounts of phosphorus, potassium, calcium, magnesium, sulfur, iron, zinc, copper, manganese, and boron were made in the diacid digested samples (nitric-perchloric acids in a 9:4 ratio). Total phosphorus was determined by the vanado-molybdic yellow color method using a UV–Visible spectrophotometer (Shimadzu UV-1601 model). Total sodium and potassium by flame photometer (Elico Model CL 378), total sulfur by tubidimetric method using a UV-Visible spectrophotometer, and calcium and magnesium by the versenate titration method. Total iron, zinc, copper, and manganese were estimated by an Atomic Absorption Spectrophotometer (Thermoscientific iCE 3000 series).

3 | RESULTS AND DISCUSSION

As per the experimental plan, 14 runs with the level of independent variables such as cocoa nib, cocoa butter, and coconut sugar were attained through RSM and mean score obtained on the sensory attributes are presented in Table 2. Three-dimensional surface plots were drawn to portray the major and interactive effects of the independent variables, on the dependent variables. Standard estimate obtained for the interactions are furnished in Table S1.

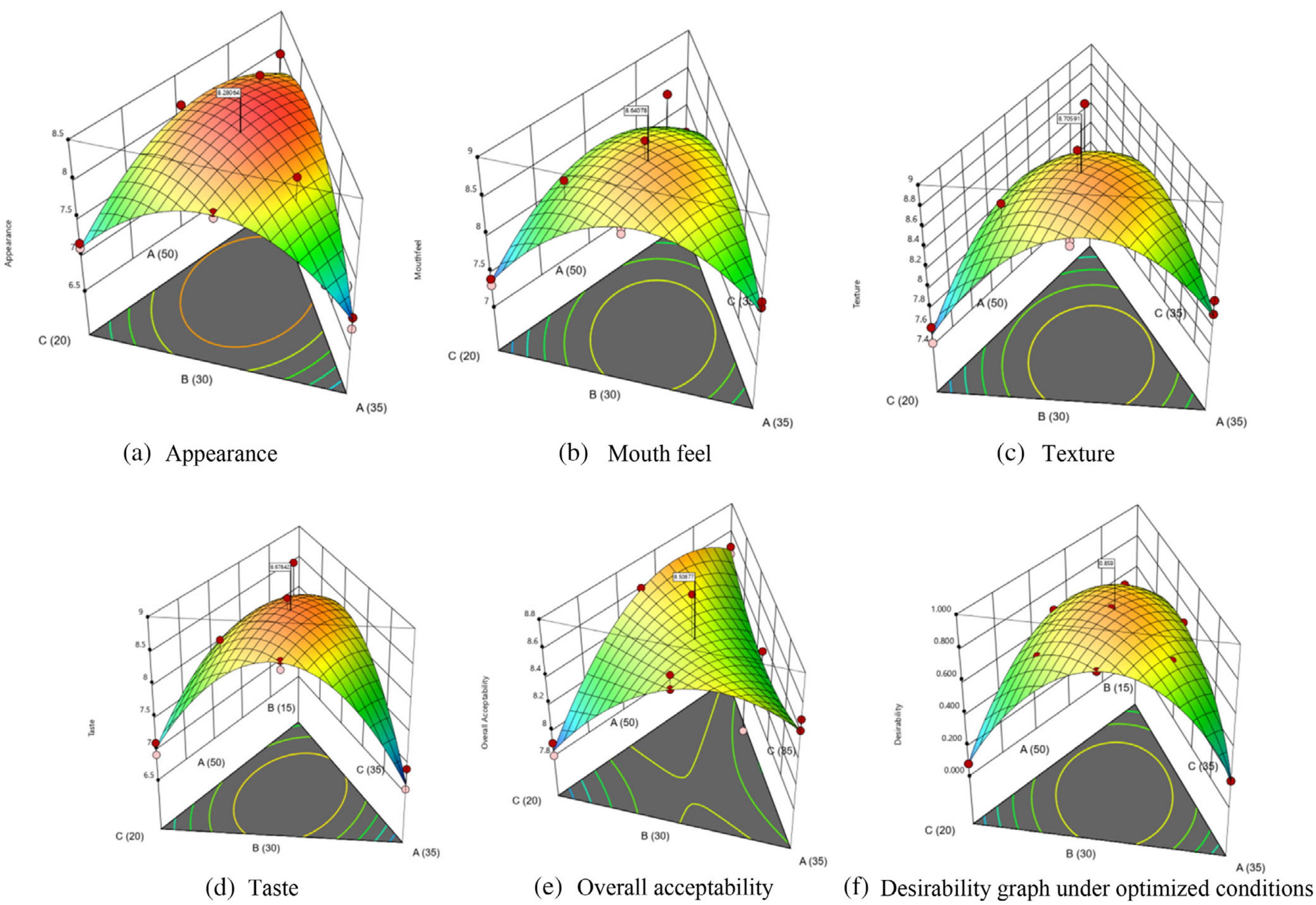
3.1 | Effect of component on appearance

The appearance of different chocolate formulations was judged based on their shape and color. A good chocolate must have a glossy

TABLE 3 ANOVA of the polynomial models of the various responses

ANOVA	Appearance	Mouthfeel	Texture	Taste	Overall acceptability
Model *F* value	14.21	6.42	6.12	14.43	4.44
Model *p* value	0.000835***	0.01**	0.012**	0.0008***	0.03*
Linear mixture (*F* value)	6.92**	1.195^{ns}	1.42^{ns}	1.98^{ns}	4.60*
AB (*F* value)	15.67**	5.91 *	6.03*	17.24**	1.17^{ns}
AC(*F* value)	28.99**	15.31**	14.55**	41.09***	6.48*
BC (*F* value)	9.45**	6.88*	5.69*	7.04*	5.80*
R^2	0.899	0.801	0.793	0.90	0.74
Adj-R^2	0.835	0.68	0.66	0.84	0.569
Predicted R^2	0.69	0.10	0.04	0.57	0.48
Adeq. Precision	10.07	6.77	6.45	10.23	6.32
CV%	2.68	3.55	3.44	3.90	2.167
Mean	7.70	8.07	8.16	7.79	8.37
SD	0.21	0.29	0.28	0.304	0.18

Note: *$p < .05$, **$p < .01$, and ***$p < .001$.
Abbreviations: ANOVA, analysis of variance; ns, nonsignificant.



(a) Appearance (b) Mouth feel (c) Texture (d) Taste (e) Overall acceptability (f) Desirability graph under optimized conditions

FIGURE 1 3D Response surface graph obtained for the varying levels of independent variables on responses

appearance and a light-to-dark brown color (Afaoakwa, 2010). The color of chocolates is mainly influenced by its composition and processing methods. The scores obtained for the appearance of different chocolate samples ranged from 6.80 to 8.31. As the ratings were more than 5 (neither like nor dislike), the treatments were proved to be acceptable in terms of their perfection in shape and color (dark brown). The score also indicated that the chocolates were well tempered, as the appearance is an indicator of well-tempered chocolates or if there had been an initiation of fat or sugar bloom.

With regard to the ANOVA, the model was found highly significant (Table 3) with a high R^2 value (.899). The magnitudes of the coefficients for the mixtures indicated that the cocoa nib level could impart dark chocolate with a higher likeness than cocoa butter and coconut sugar. Both the linear and interaction effects of the variables were significant ($p < .05$). Adequate precision, which is a measure used to evaluate the predictive ability of the fitted model was greater than 4.

It is evident from the 3D surface graph (Figure 1a) that the effect of all three components was parabolic, that is, an increasing trend was followed by a peak and then a decline in the appearance. However, Rad, Pirouzian, Konar, Toker, and Polat (2019) reported that sucrose influences color and results in higher sensory acceptance for appearance as compared to alternate sweeteners. Similarly, increasing the proportion of butter resulted in higher appearance score than nib, sugar, and milk (Kissiedu, Agbenorhevi, & Datsomor, 2020). Coconut sugar is a product obtained through Maillard reaction, and hence, it has a darker (yellowish to golden brown) color than refined sugar. In addition, reducing sugar, proteins, and amino acids present in coconut sugar induce Maillard reaction while grinding, refining, and tempering leading to intensify the darker color. Chocolate formulations with higher proportion of coconut sugar (35%) showed darker in color than those with lesser (20%) proportion. Philip, Ohene, and Dewettinck (2014) observed darker color of chocolates due to the addition of alternate sweeteners than refined sugar. Likewise, the more cocoa nib, the darker the color would be. The pale yellowish color of cocoa butter provided a lighter color to chocolates. An optimal level of cocoa butter is needed to improve the appearance and taste of chocolate and increase the stability of chocolate against bloom formation (Halim, Selamat, Mirhosseini, & Hussain, 2019). It is understood that the perfect blend or balance of cocoa nib, cocoa butter, and coconut sugar is necessary to get the chocolate in a good shape and color. The surface graph also reveals that the range of minimal and maximal levels of ingredients selected in the experiment is ideal. The linear and interaction equation in terms of actual components obtained for appearance is as follows:

$$\text{Appearance} = -0.29A - 0.45B - 0.45C + 0.01AB + 0.02AC + 0.01BC \quad (3)$$

3.2 | Effect of component on mouth feel

Mouth feel is a measure of smoothness, stickiness, grittiness, and melting behavior. It is a critical sensory attribute. Sensory score for mouth feel was varied from 7.31 (like moderately) to 8.87 (like very much). The model was significant ($p < .01$) with R^2 of .80. Coefficient in the pure mixture indicated that cocoa nib resulted in chocolate with a higher likeness for mouth feel than cocoa butter and coconut sugar. Interaction effect of cocoa nib*coconut sugar had a comparatively higher likeness.

The parabolic response surface graph revealed the relationship between the factors (Figure 1b). Increasing concentrations of the ingredients had a negative effect on the mouth feel of the chocolates. Among the factors, cocoa butter has more influence on the mouth feel, as chocolate made of cocoa beans and sugar only results in a gritty texture (Beckett, 2009). It is apparent that the maximum and minimum levels of these components are negatively affecting the mouth feel of chocolates. Nevertheless, the incorporation of natural palm-based sugar influences the chocolate mouth feel and aroma (Saputro et al., 2016). In addition, the distinct color and flavor of coconut sugar resulting from the Maillard reaction while heating the inflorescence sap, could positively influence the chocolate aroma. The main effects of cocoa nib, cocoa butter, and coconut sugar were found to be negatively correlated with mouth feel, while the linear effects were positively correlated. It was reported that chocolate having low cocoa solids in the form of cocoa nib and cocoa butter (65%) melted and provided a creamy texture. The chocolate with relatively higher cocoa solids (75%) was exemplified by having a dry, mealy, and sticky mouth feel (Thamke, Durschmid, & Rohm, 2009). Kissiedu et al. (2020) obtained a higher mouth feel with increased butter and a lower mouth feel with an increased sugar level. Cocoa butter is the continuous phase of dark chocolates, composed of monounsaturated triacylglycerols that provide chocolates with a smooth texture, glossy appearance, and desirable sensory attributes (Chen et al., 2022). The results of mouth feel also show the necessity of an optimum mixture of all the components. The linear and interaction equation in terms of actual components obtained for mouth feel is as follows:

$$\text{Mouth feel} = -0.27A - 0.39B - 0.51C + 0.01AB + 0.02AC + 0.01BC. \quad (4)$$

3.3 | Effect of component on texture

Texture is another important parameter of chocolate quality, evaluated in terms of smoothness or hardness. The type of fat and type of sugar used mostly affect the texture, apart from the processing conditions. For a smooth textured chocolate, a minimum refining time of 24 h should be provided (Beckett, 2009). The minimum and maximum scores obtained for texture was 7.42 (like moderately) and 8.90 (like very much) respectively, which showed that all the formulations were liked satisfactorily. The model was significant ($p < .01$). Cocoa nib produced dark chocolate with a higher likeness to texture than the rest of the components. Similarly, the interaction effect for cocoa nibs*coconut sugar indicated a higher likeness for texture ($p < .01$) as observed in the case of mouth feel. The 3D surface graph for the texture behaved similar to that of the mouth feel (Figure 1c). A maximum score was obtained for the combination of 45% cocoa nibs, 30% coconut sugar, and 25% cocoa butter. The acceptability was found to decrease as the concentration of cocoa butter increased. In addition, a positive effect of coconut sugar was observed. According to Full, Reddy, Dimick, and Ziegler (1996), solid fat content increases the chocolate's hardness. The higher sugar content in chocolate results in a gritty texture (Beckett, 2009). The texture of the chocolate is affected not only by the differences in particle density but also by other factors, namely, particle size distribution, moisture content, and sugar composition. Afoakwa, Paterson, Fowler, and Ryan (2008) observed that increasing fat from 25 to 35% gave significant reductions in specific surface area in dark chocolate. Besides, generally, up to 40–45% of sugar is added in dark chocolates. In chocolate, solid particles such as sugar and cocoa nib are dispersed in a cocoa butter fat matrix. The fat crystal network formed during the production of chocolate had an impact on the final quality. Hence, the optimum level of solid particles in the formulation is necessary (Kalic et al., 2018). Harder texture at maximum level of cocoa nib, cocoa butter, and coconut sugar might be due to the formation of strong sugar networks due to the hygroscopic nature of coconut sugar, also due to the presence of reducing and non-reducing sugars in it that require higher penetration force. A similar finding was observed by Sethupathy, Suriyamoorthy, Moses, and Chinnaswamy (2020). In addition, incorporation of palm sugars exhibit lower densities than sucrose which result in increased particle interactions leading to harder texture in chocolate than those with refined sugar (Saputro et al., 2016). The linear and interaction equation in terms of actual components obtained for texture is given below,

$$\text{Texture} = -0.27\text{A} - 0.36\text{B} - 0.46\text{C} + 0.01\text{AB} + 0.02\text{AC} + 0.01\text{BC}. \quad (5)$$

3.4 | Effect of component on taste

Taste is one of the critical determinants of chocolate acceptance. It critically analyses whether the chocolate is bitter, acidic, or salty. The score for different formulations ranged from 6.56 (35% cocoa nibs, 20% cocoa butter, and 32.5% coconut sugar) to 8.89 (47.5% cocoa nibs, 30% cocoa butter and 35% coconut sugar). Level of cocoa nib and cocoa butter had a higher likeness to taste than coconut sugar. The interaction between cocoa nib*coconut sugar was deemed highly significant ($p < .001$). The model was significant with R^2 of .90. Ingredient composition influences chocolate taste more than processing parameters (Kissiedu et al., 2020). The 3D surface graph suggested that as the proportion of cocoa nib and coconut sugar increased, there was an increase in the taste, which was vice versa in the case of cocoa butter. It clearly indicates the influence of three factors on taste (Figure 1d). However, the maximum level of components resulted in a negative effect. The caramelized taste of coconut sugar also influenced the taste. Besides, the particle size of the components can significantly influence the taste of chocolate, as reported by Philip et al. (2014). The linear and interaction equations in terms of real and actual components obtained for taste are given below.

The final equation in terms of actual components.

$$\text{Taste} = 0.59\text{A} - 0.59\text{B} - 0.79\text{C} + 0.02\text{AB} + 0.03\text{AC} + 0.01\text{BC} \quad (6)$$

As stated above, cocoa nib and coconut sugar are crucial to getting the perfect taste of the chocolates. The cocoa nib between 40 and 45% was highly acceptable, and when the concentration was at its maximum level, that is, 50%, the taste of the product was considerably reduced. A similar effect was seen with coconut sugar. A higher level of coconut sugar might lead to Maillard reaction, which results in an intense caramel-like taste and flavor. A perfectly balanced amount of ingredients is required to achieve the perfect taste for the product.

3.5 | Effect of component on overall acceptability (OA)

Overall acceptability, the most important attribute in sensory evaluation, was found to range from 7.80 (like moderately) to 8.80 (like very much). ANOVA for the model suggested that it was significant ($p < .05$) with a high R^2 value (0.90). Coconut sugar produced a dark chocolate with a higher likeness for OA than other factors. Cocoa nib and cocoa butter together had more influence on the OA than the other two mixture combinations. Guinard and Mazzucchelli (1999) observed faster melting in chocolate with the addition of high cocoa butter. In addition, samples characterized by relatively less sugar and low-fat were connected with viscous, mouth coating fatty/oily, cocoa, and darker notes. The role of butter is to suspend and lubricate sugar particles. Besides taste and other parameters, natural sugar influences the aroma and flavor of chocolate which was supported by Saputro et al. (2016). Result of the present study also shows that balance mixture of each component is necessary to get a perfect sensory perception (Figure 1e). The linear and interaction equation in terms of actual components obtained for OA is given below,

$$\text{OA} = 0.086\text{A} + 0.12\text{B} - 0.31\text{C} - 0.003\text{AB} + 0.007\text{AC} + 0.008\text{BC} \quad (7)$$

3.6 | Optimization and validation

The optimization criteria and the predicted values for each response are furnished in Table 4. The best combinations of process variables for the best set of response properties were 44.7% cocoa nibs, 25.2% cocoa butter, and 30.2% coconut sugar. The responses (sensory scores) calculated at optimal extraction conditions consisted of a hedonic score of 8.28 for appearance, 8.64 for mouth feel, 8.71 for texture, 8.68 for taste, and 8.51 for OA, which are evident from the response surface graphs with a desirability of 0.86 (Figure 1f). The predicted responses were validated with three replications and the result (Table 4) showed the closeness of the values.

3.7 | Standardization of grinding time of the optimized sample based on the particle size (microstructure)

Many larger aggregates were observed in the samples ground for 6 h (Figure 2) whereas comparatively few large spherical particles could be seen in samples that were ground for 12 and 18 h. Thereafter,

TABLE 4 Optimization criteria and predicted values for responses

Variables	Goal	Lower limit	Upper limit	Predicted mean	Data mean	95% TI low	95% TI high	Observed mean
A–A	Is in range	35	50					
B–B	Is in range	15	30					
C–C	Is in range	20	35					
Appearance	Maximize	6.8	8.31	8.28	8.81	7.19	9.37	8.02
Mouth feel	Maximize	7.31	8.87	8.64	9.37	7.13	10.16	8.7
Texture	Maximize	7.42	8.9	8.71	9.42	7.22	10.19	8.75
Taste	Maximize	6.56	8.89	8.68	9.45	7.073	10.28	8.8
Overall acceptability	Maximize	7.8	8.8	8.51	8.97	7.55	9.47	8.72

Note: A: Cocoa nib, B: cocoa butter, C: coconut sugar.
Abbreviation: TI: tolerance interval.

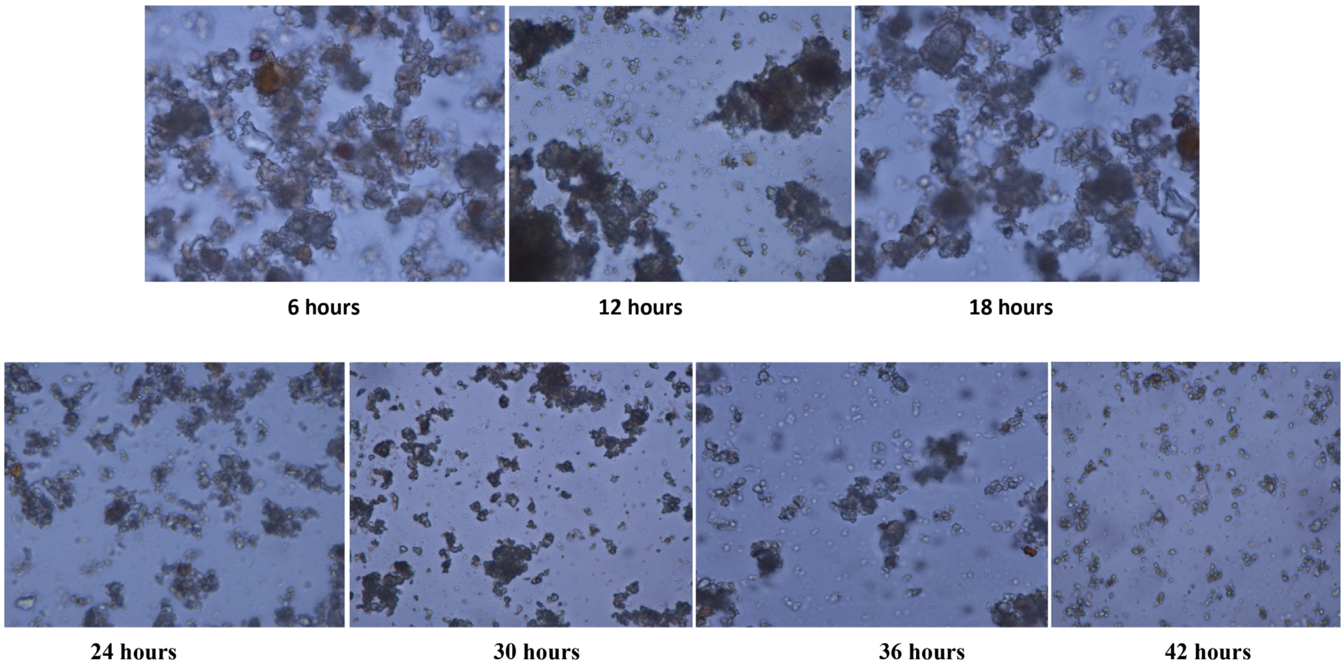


FIGURE 2 Microscopic analysis of the optimized chocolate over time

irregular small pieces of cocoa solids and sugar particles and their clusters were observed in samples ground for 24 h and beyond. The chocolate particles got crushed evenly between the stone of the grinder resulting in reduced particle size. Change of spherical cocoa particles into small flat pieces during refining was reported by Tan and Balasubramanian (2017). It took at least 24 h to get finer-sized particles which was reduced further at 42 h. Hence, a minimum of 24 h was necessary to get a smooth textured chocolate with the tilting chocolate wet grinding machine.

3.8 | Proximate composition of the optimized chocolate

Dark chocolate shall contain, on a dry matter basis, not less than 35% total cocoa solids, of which not less than 18% shall be cocoa butter and not less than 14% fat-free cocoa solids (Codex, 2016). Optimized chocolate sample had a mean moisture content of 1.06% (Table 5) which is in accordance with the earlier report of 70% dark chocolate (Melo et al., 2020). The fat percentage of chocolate mainly depends on the fat content of cocoa beans used and the added cocoa butter. Protein content is also in agreeable with that of earlier findings (Melo et al., 2020). The higher texture reading revealed that the chocolates were harder as they were measured after taking out from the refrigerated storage. In addition, increase in particle volume fraction due to lower density of coconut sugar (in comparison with sucrose) might contribute in increased particle interactions which ultimately resulted in harder chocolate. However, it gradually reduced ($p < .01$) over time when kept at outside (Figure S1). Hardness value reduced to 18.22 N and 16.23 N at 5 min and 10 min respectively. Conversely, the reading of seventh and eighth minute was nonsignificant ($p > .05$). Similar trend was observed for hardness observed at ninth and tenth minute. It is ideal to keep under refrigerated storage to get proper texture. Saputro et al. (2016) reported textural hardness between 12 and 15 N

TABLE 5 Proximate composition of optimized chocolate

Proximate composition	Quantity (g/100 g)		
Moisture	1.06 ± 0.46		
Crude fat	50.09 ± 1.11		
Crude protein	10.37 ± 0.01		
Total carbohydrates	35.90 ± 0.45		
Ash	2.55 ± 0.82		
Hardness (N)	59.52 ± 4.87		
Color values	L*	a*	b*
	25.71 ± 0.2	6.23 ± 0.36	6.25 ± 0.57

Note: Values are mean of three replication ± *SD*.

for palm-based chocolates. In general, bean-to-bar chocolate melts at tropical ambient temperatures.

Color is one of the important visual attributes that define the appearance of chocolate besides the external features like gloss, shape, surface, and smoothness or roughness. The dark chocolate had a L* value of 25.71 indicating its color toward black/dark. (Table 5). Chocolates with fine particles (18–25 μm) are characterized with more particle-particle interactions and, thus, emerge from light to dark brown and are saturated, compared to chocolates with coarse particles. Maillard reaction between the coconut sugar and cocoa amino acid did not result in extreme dark color to the chocolate. Similar result was observed by Saputro et al. (2016).

3.9 | Functional characterization of the optimized sample

3.9.1 | Standardization of extraction condition

Different solvents with different pH levels and varying degrees of polarity were used to get maximum extraction of phenolics from the chocolate samples. Total polyphenol content (TPC) for four different extraction media involving 70% acetone (acidified and non acidified) and 80% ethanol (acidified and non acidified) ranged from 341.17 mg to 480.64 mg GAE/100 g. The statistical analysis showed significant difference ($p < .01$) between ethanol and acetone with acidification and nonacidification with a coefficient of variation of 2.44%. Higher extraction was observed in aqueous solvents with acidification, and among acetone and ethanol, acetone was better solvent to extract the TPC. Similar observation was reported by Arivalagan et al. (2018) during the extraction of polyphenols from coconut testa. Acidified acetone could extract maximum polyphenols from the sample (480.64[a] mg GAE/100 g) followed by acetone (448.63[b] mg GAE/100 g, acidified ethanol (367.24[c] mg GAE/100 g), and the least was for ethanol (341.17[d] mg GAE/100 g; data not shown in table form). Złotek, Mikulska, Nagajek, and Świecaa (2016) and Sulaiman, Sajak, Ooi, Supriatno, and Seow (2011) reported the efficacy of acetone than methanol in extracting polyphenols from basil leaves and vegetables, respectively.

3.9.2 | Comparison of polyphenols and antioxidants of the optimized chocolate sample with raw cocoa beans, roasted cocoa beans, and cocoa nibs

There is a significant loss of polyphenols especially flavonoids during roasting process (Table 6). Raw cocoa bean has the highest polyphenols, flavonoids, and antioxidant activity, which considerably reduced after roasting which was in accordance with Urbańska et al. (2021). However, it was improved slightly in nibs as it was in concentrated form in nibs after the removal of shell. Since, the proportion of cocoa nibs in chocolate formulation was 45%, the bioactive components were the least among others. Amudhan and Apshara (2015) evaluated exotic clones at CPCRI, India, in which the bioactive compounds ranged from 81.4 to 142.3 mg/g polyphenols. Further, Urbańska & Kowalska (2019) reported a broad range of polyphenol content (996–3,787 mg GAE/100 g) in roasted and unroasted cocoa beans from worldwide collections. In raw beans, polyphenol content over 6,000 mg/100 g of product was documented whereas roasted beans derived from the same production cycle exhibited relatively very little polyphenols (1,050 mg/100 g of the product) (Salvador et al., 2019). Polyphenols in dark and milk and white chocolate were 578, 160 and 126 mg/100 g, respectively (Meng, Mhd Jalil, & Ismail, 2009).

The flavonoids present in the dark chocolates are catechin, epicatechin, cyanidin, quercetin, and so forth. (Afaoakwa, 2010). Flavonoids in raw beans, roasted beans, nibs, and 70% dark chocolate vary from 1,130.03 to 583.24 mg QE/100 g ($p < .01$; Table 6). Reduction of flavonoids during roasting is clearly evident from our experiment. However, the flavonoid quantity in nib was higher than that of roasted beans which could be due to the increased proportion of nibs after removing shell. Nonetheless, 583.24 mg flavonoids is comparatively higher than that of apple, onion or wine, and foods known for their high amount of phenolic compounds. Meng et al. (2009) found even 28 mg CE/100 g of defatted dark chocolate. Dark chocolate contains as high as 951 mg of cocoa flavonoids (Afaoakwa, 2010).

Similarly, approximately 90.75–96.81% of antioxidant activity was observed in dark chocolates (Urbanska & Kowalska, 2019). Antioxidant activity in raw beans, roasted beans, nibs, and 70% dark chocolate in terms of DPPH and FRAP assays were 94.21% (DPPH), 90.98%, 91.56%, and 89.45% and 1,230.48 mg, 865.97 mg, 1043.14 mg and 445.03 mg/100 g, respectively (Table 6). In DPPH assay, no significant difference was observed between the roasted beans and nibs. The antioxidant potential among different exotic cocoa clones was in the range of 66.6–98.8% (Amudhan & Apshara, 2015).

3.10 | Comparison of mineral profile of the optimized chocolate sample with raw cocoa beans, roasted cocoa beans, and cocoa nibs

Optimized dark chocolate and preprocessed cocoa beans showed significant differences (Table 7) for the mineral composition. The composition of minerals in raw cocoa beans was in accordance with the

TABLE 6 Comparison of polyphenols and antioxidants of the optimized chocolate sample with raw cocoa beans, roasted cocoa beans, and cocoa nibs

	Total phenolics (mg GAE/100 g)***	Total Flavanoids *** (mg QE/100 g)***	Antioxidant activity	
			DPPH*** (%)	FRAP*** (mg TE/100 g dark chocolate)
Raw cocoa beans	1,195.47 ± 25.25[a]	1,129.52 ± 3.90[a]	94.19 ± 0.09a	1,230.48 ± 3.39[a]
Roasted cocoa beans	1,087.99 ± 23.12[c]	930.65 ± 6.13[c]	90.99 ± 0.20b	865.97 ± 54.61[c]
Broken beans/ nibs	1,150.69 ± 22.18[b]	1,110.67 ± 6.55[b]	91.56 ± 0.47b	1,043.14 ± 49.45[b]
70% dark chocolate with cocoa liquor, cocoa butter, and coconut sugar	590.85 ± 5.00[d]	583.71 ± 8.02 [d]	89.43 ± 0.62c	445.03 ± 3.62[d]
CV	1.98	0.67	0.44	4.12

Note: *$p < .05$, **$p < .01$ and ***$p < .001$. Mean values not sharing the same letters (a,b,c,d) differes significantly ($p < 0.05$).
Abbreviations: DPPH, 2,2-diphenyl-1-picryl-hydrazyl-hydrate; FRAP, ferric reducing ability of plasma; ns, nonsignificant; GAE, Gallic acid equivalent; QE, quercetin equivalent; TE, Trolox Equivalent.

TABLE 7 Comparison of mineral content in the optimized chocolate sample with raw cocoa beans, roasted cocoa beans, and cocoa nibs

	Total P*** (mg/100 g)	Total K*** (mg/100 g)	Na*** (mg/100 g)	Total mg*** (mg/100 g)	Ca*** (mg/100 g)	S*** (mg/100 g)	Fe*** (mg/100 g)	Mn*** (mg/100 g)	Zn*** (mg/100 g)	Cu*** (mg/100 g)
Raw cocoa beans	765.625[a]	1,352.5[a]	1,101.3[a]	530.0[a]	180.00[a]	265.00[a]	10.89603[b]	6.051250[a]	6.88765[a]	4.77900[a]
Roasted cocoa beans	705.000[b]	1,050.0[b]	950.0[b]	504.5[a]	135.00[a]	240.00[a]	8.00900[d]	6.142000[a]	7.28925[a]	4.23375[b]
Broken beans/ nibs	575.000[c]	800.0[c]	850.0[b]	345.0[b]	135.00[a]	165.25[b]	9.81575[c]	4.429275[b]	5.93325[b]	4.38375[b]
70% dark chocolate with cocoa liquor, cocoa butter, and coconut sugar	400.000[d]	850.0[c]	750.0[c]	235.0[c]	90.25[b]	115.00[c]	13.04575[a]	3.332750[c]	5.02800[c]	2.73605[c]
CV	2.48	4.96	6.84	4.76	21.32	6.31	3.43	3.92	3.67	4.39

Note: * $p < .05$, ** $p < .01$ and *** $p < .001$. Mean values not sharing the same letters (a,b,c,d) differes significantly ($p < 0.05$).
Abbreviation: ns, nonsignificant.

earlier reports (Afoakwa, Quao, Takrama, Budu, & Saalia, 2013). Processes such as roasting and shelling did not affect sodium, calcium, and copper ($p > .05$) content in cocoa beans unlike all the other minerals. Chocolate had the lowest mineral content than raw, roasted beans, and nibs except for potassium and iron. Cocoa beans in any form were found to be rich in potassium (1.35% and 1.05% in raw and roasted beans, respectively). Nibs and dark chocolate had similar potassium values because the coconut sugar present in chocolate might have contributed. Coconut sugar contains 202 mg nitrogen, 79 mg phosphorous, 1,030 mg potassium, 6 mg calcium, 29 mg magnesium, 30 μg boron, 2,100 μg zinc, 130 μg manganese, 2,190 μg iron, and 230 μg copper/100 g dry weight, respectively (Hebbar et al., 2015), which is higher than those present in cane sugar. Besides, almost all essential amino acids required for protein synthesis is present in coconut sugar, and is rich in vitamins. Iron, magnesium, and zinc present in coconut sugar are approximately two, four, and ten folds higher than that of unrefined cane sugar. As per EU Regulation (EU No 1169/2011), nutrient reference values recommended for adults (mg/day) are 800 mg Ca, 375 mg Mg, 700 mg P, 2,000 mg K, 1 mg Cu, 14 mg Fe, 10 mg Zn, and 10 mg Mn (Cinquanta et al., 2016). It is apparent that 96% of the daily requirement of F, 42.5% of K, and 11% of Ca can be met from the optimized dark chocolate (per 100 g). Raw beans to 70% chocolate were found to be a strong source for Mg (530 mg-235 mg/100 g, respectively), and the values were similar to whole-meal bread and potatoes. Cocoa contains 4–5 folds higher Mg than peas, white wheat, corn, and rice (Sager, 2012).

4 | CONCLUSION

Dark chocolate is manufactured with cocoa nib, cocoa butter, and sugar. Sensory perception is the critical qualitative criteria affecting the consumer acceptability of chocolate. Substitution of sucrose in dark chocolate with natural and healthy sweeteners has great potential these days. In the present study, coconut sugar is used as the source of sweetener. The impact of cocoa nib, cocoa butter, and coconut sugar with respect to the sensory attributes was studied. Variable levels of ingredients were evaluated and the result of the response surface methodology revealed that a global optimum existed in the result and a single optimum was obtained for each response. Maximum and minimum levels of cocoa nib (35 and 50%), cocoa butter (15 and 30%), and coconut sugar (20 and 35%) negatively influenced the appearance, mouth feel, texture, taste, and overall sensory acceptability. The caramelized color of coconut sugar and its gritty texture affected the OA. Moreover, the interaction between cocoa nib and coconut sugar had a significant influence on the chocolate formulations. Bean-to-bar dark chocolate at the optimum level of 44.7% cocoa nib, 25.2% cocoa butter, and 30.2% coconut sugar, resulted in a maximum response in sensory attributes. In addition, the presence of coconut sugar significantly contributed to the enhanced quality of dark chocolate with respect to its functional qualities and mineral content.

AUTHOR CONTRIBUTIONS

Shameena Beegum P.P: Conceptualization (equal); investigation (lead); methodology (equal); software (supporting); validation (lead); writing – original draft (lead). **Ravi Pandiselvam:** Data curation (equal); methodology (equal); writing – review and editing (equal). **Ramesh S.V.:** Data curation (equal); methodology (lead); writing – review and editing (lead). **Sugatha P:** Formal analysis (equal); methodology (lead); resources (equal). **Arifa Nooh:** Data curation (equal); formal analysis (equal); investigation (equal); resources (equal). **Neenu S:** Formal analysis (lead); methodology (lead). **Alka Gupta:** Methodology (equal). **Eldho Varghese:** Software (lead); validation (equal). **D. Balasubramanian:** Data curation (equal); formal analysis (equal). **Elain S. Apshara:** Conceptualization (equal); methodology (equal); resources (equal). **Musuvadi Ramarathinam Manikantan:** Conceptualization (equal); supervision (equal); visualization (equal). **Kukkehalli Balachandra Hebbar:** supervision (equal).

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ETHICAL STATEMENTS

Conflict of Interest: The authors declare that no known competing interests will influence the work reported in this article.

DATA AVAILABILITY STATEMENT

I confirm that my article contains a Data Availability Statement even if no data is available (list of sample statements) unless my article type does not require one.

ORCID

Shameena Beegum P.P https://orcid.org/0000-0003-4391-2643
Ravi Pandiselvam https://orcid.org/0000-0003-0996-8328
Ramesh S.V. https://orcid.org/0000-0002-2107-360X
Alka Gupta https://orcid.org/0000-0002-7877-4466

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