International Journal of Food Science and Nutrition
www.foodsciencejournal.com
ISSN: 2455-4898
Received: 24-01-2025, Accepted: 25-02-2025, Published: 15-03-2025
Volume 10, Issue 2, 2025, Page No. 12-22

Assessment of sensory properties of optimized wheat- white yam composite cookies using response surface methodology

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Abstract
Effect of optimization of dough thickness and baking temperatures on the sensory properties of optimized cookies from wheat-white yam flour using Response Surface Methodology (RSM) was evaluated. The experimental design was done using Central composite rotatable design (CCRD) that generated 13 runs for the cookie samples. The process variables were dough thickness (mm) and baking temperature (ºC). The individual flours used for the cookies were formulated using wheat flour and white yam flour at (90%:10%). *Uziza* seed (*Piper guineense*) flour was used as a flavoring agent and *Moringa oleifera* seed flour for enrichment. The cookies were produced by creaming of margarine and sugar, mixing of the base raw materials wheat-white yam flour at (90%:10%), *uziza* seed flour was used as a flavoring agent and moringa seed flour for enrichment to form a dough, shaping at different dough thickness and baking temperatures, 5 mm and 200ºC,4 mm and 165ºC,4 mm and 200ºC, 2.5 mm and130ºC, 2.5 mm and 200ºC, 4 mm and 130ºC, 5.5 mm and 165ºC, 2.5 mm and 165ºC, 5.5 mm and 130ºC, WFC 3 mm and 180ºC (Control), depanning, cooling and packaging. Cookies were evaluated for sensory properties using a 9 - point Hedonic of extremely (9), like very much (8), like moderately (7), like slightly (6), neither like nor dislike (5), dislike slightly (4), dislike moderately (3), dislike very much (2) and dislike extremely (1) with thirty trained panelists. Data obtained was analyzed using statistical analysis of variance (ANOVA) with the mean values separated by Duncan's multiple range tests at 0.05% level of significance. Appearance of the cookies samples analyzed ranged from 5.80 for sample WYC_4 (2.5 mm dough thickness baked) to 8.86 for sample WYC_2 (4 mm dough thickness baked at 165ºC). Taste of the samples ranged from 6.01 for cookie sample WYC_6 (4 mm dough thickness baked at 130ºC) to 8.90 for sample WYC_2 (4 mm dough thickness baked at 165ºC). Aroma of the samples ranged from 6.33 for sample WYC_6 (4 mm dough thickness baked at 130ºC) to 8.96 for sample WYC_2 (4 mm dough thickness baked at 165ºC).Crispiness ranged from 6.23 for sample WYC_5 (2.5 mm dough thickness baked at 200ºC) to 8.90 for sample WYC_2 (4 mm dough thickness baked at 165ºC) and overall acceptability sensory scores ranged from 6.57 for sample WYC_5 (2.5 mm dough thickness baked at 200ºC) to 8.93 for sample WYC_2 (4 mm dough thickness baked at 165ºC).Sensory properties optimization result of the cookies revealed that 4.0 mm dough thickness and 165ºC baking temperature produced quality cookie with appearance score 8.86, taste score 8.90, aroma score 8.96, crispiness score 8.9 and overall acceptability score of 8.93 with the highest desirability function of 1.0 which could be recommended for cookies manufacturers and may serve to reduce high dependence on wheat flour, reduce gluten content and improve the economy of farmers involved in white yam production.

Keywords: Optimization, Dough thickness, Baking temperature, sensory properties

Introduction

Cookies, as a carbohydrate-based snack have relatively low phyto-chemical and nutritional value except if it is enriched with foods rich in phytochemicals (Lasekan and Akintola, 2021). Cookies are food products that have been baked to relatively low moisture content and softer than biscuit (Okaka, 2009) [16]. According to Adeleke, (2021), it could easily be produced with composite flour than bread because it requires little or no leavening before baking. Mc Watter *et al.* (2021) [15] stated that cookies have wide consumption, extended shelf-life, and good eating quality. It has been observed that cookies are commonly eaten by both adult and children (Kure *et al.*, 2022). The increasing demand for cookies by all ages has necessitated the need to utilize it as a vehicle for improving nutrient density of foods for the consumers. However, the policy of 10% inclusion of cassava flour in wheat-baked foods has limited the use of other flours in composite flour formulation (Okaka, 2009) [16]. The major ingredients for cookies are flour, fat, sugar, salt and water. It is produced by mixing various ingredients like flour, sugar, milk, flavouring agents, chemical additives, fat, sweeteners and water to form dough (Ekpo, 2017). These were mixed together with other minor ingredients (baking powder, skimmed milk, emulsifier and sodium meta-bisulphite) to form dough containing a gluten network. According to Akinwande *et al.*, (2021) [4], soft wheat flour has been the major ingredient used in the production of cookies and other pastry products, but they can also be made with non-wheat flours such as white yam flour, sorghum, maize, pearl millet, plantain, acha grain, bambara-nuts flours etc. Composite flour is desirable in this regard because it improves the physical, sensory and nutritional value of food products, such as confectionary products, especially when blended (Yahaya, 2021) [20]. In fact, cookies have been suggested for better use for composite flour than bread due to their low leavening attributes, ready-to-eat form, wide consumption, relatively long shelf life, and good eating quality (Bala and Riar, 2015).

Cookies could be flat and crisp, and may be sweetened or unsweetened, according to preference (Adeleke, 2021) [2, 3]. Cookies can be made from hard dough e.g. crackers; hard sweet dough e.g. rich tea and short or soft dough e.g. short bread and short cake (Lasekan and Akintola, 2021). The dough formed, unlike bread, is not allowed to ferment, and then it is baked in the oven (Adeleke, 2021) [2, 3]. Cookies could be baked in the primitive or modern oven, but the fundamental ingredient is wheat flour (Ekop, 2017) [8]. Research had shown that cookies are baked from wheat that has the unique ability to form a cohesive gluten network when mixed with water (Bala and Riar, 2015). This simple discovery set the stage for the development of many yeast breads, pastries, cakes, cookies and other baked products that are so popular today (Udensi and Okoronkwo, 2008) [18].

Cookies and other baked food products are important items belonging to the class of food that are sold in ready to serve form (Kure *et al* 2022). Cookies are of good value, contributing valuable quantities of iron, calcium, protein, calorie, fibre and some of the B-vitamins (Ukaegbu, 2021) [19]. They are one of the most popular bakery products made from cereals that are consumed by nearly all the people in the world (Femor, 2023). It had been established that cookies are produced from palatable dough that is transformed into appertizing product through the application of heat in the oven (Kure *et al*., 2022). Sometimes, bakery products are used as vehicles for the incorporation of different nutritionally rich ingredients (Sudha *et al.*, 2007) [17]. Although various flavourants are used in cookies production, the use of *uziza* seed would confer additional benefits as natural flavourants with rich phytochemical properties. Finally, this study evaluated the effect of optimization of dough thickness and baking temperatures on the sensory properties of optimized cookies from wheat-white yam flour using Response Surface Methodology (RSM).

Materials and methods

Sources of Materials

Wheat flour (*Triticum aestivum*), yam tuber (*Dioscorea rotundata*) was purchased from yam dealers in Eke-Awka market and *Moringa oleifera* seed, *uziza* seeds (*Piper guinneese*) were purchased from Relief market along Egbu road in Owerri Metropolis of Imo State. Other ingredients such as Dangote granulated sugar city of manufacture Ikeja, Derich baking powder city of manufacture Nanhai foshan, China, and RICCI margarine city of manufacture Afenni Indonesia for Okoti Enterprise Nigeria Limited, milk and eggs were purchased from Eke-Awka market in Anambra State Nigeria. The reagents and equipment used were of analytical grade.

Confirmation of the food raw materials

The raw materials wheat flour (*Triticum aestivum*), raw yam tubers (*Dioscorea rotundata*), *Moringa oleifera* seed, *Uziza* seeds (*Piper guinneese*) were taken to Department of Crop Science in the Faculty of Agriculture, Nnamdi Azikiwe University, Awka for identification and confirmation by a botanist.

Sample Production

Production of white yam flour

Two kilogram (2kg) of matured white yam tubers (*Dioscorea rotundata*) was processed into flour using (Ezike, 2020) [10] with slight modification. The wholesome white yam tubers were processed by peeling using stainless steel table knife, washing, slicing to 2 Mm thickness, and then soaked in water containing 1% sodium metabisulphite for 5min to inactivate the enzyme phenolase that could cause enzymic browning in the white yam tuber. The sliced white yam was drained and oven dried at 70ºC for 6 h using a thermostatic electric oven (Model (DHG-9101-05A) with working size of 350 mm and temperature range of 50to 300ºC. The oven dried sliced yam samples were milled using an attrition mill (Model 368 Corona) and sieved using 250 mm mesh sieve to produce white yam flour.

Production of *Moringa oleifera* seed flour

The method of Enwere *et al.,* (2021) [9] was used. One kilogram of dried *moringa* seeds w be sorted, dehulled and further oven dried at 50ºC for 3 h using a thermostatic electric Oven Model (DHG-9101-05A) with working size of 350 mm, temperature range of 50 to 300ºC. It was milled using attrition mill (Model, 264 Corona) and sieved using a (muslin cloth) 250nm sieve mesh size to obtain *Moringa* seed flour.

Production of *Uziza* seed flour (*Piper guineense*)

The method of Lamaison and Carnet (2010) [14] with slight modification was used. Five hundred grammes (500 g) of dried *uziza* seed (*Piper guineense*) were processed by sorting, milling into fine particles flour using Attrition mill (Model, 264 Corona). The milled *piper guineense* was sieved using 250 nm sieve mesh size to obtain *uziza* seed flour.

Experimental Design (by Design Expert version 12)

The experiment was designed using Central Composite Rotatable Design (CCRD) that generated 13 runs.

Table 1: Design key of experiment for the variables

Process variables	Unit	-α	-1	0	+1	+α
Dough thickness	mm	2.5	3	4	5	5.5
Baking temperature	(ºC)	130	150	165	180	200

Dough thickness (mm) = 2.5 to 5.5 mm
Baking temperature (ºC) = 130ºC to 200ºC

Table 2: Design of experiment of the variables

Run	Factor 1 A:(Dough thickness) (mm)	Factor 2 B: Baking temperature (ºC)
1	5	200
2	4	165
3	4	200
4	4	165
5	4	165
6	5.5	130
7	2.5	200
8	4	130
9	5.5	165
10	4	165
11	5.5	165
12	2.5	130
13	2.5	200

Table 3: Recipe for Cookies Production

Recipe	Quantity
Wheat flour	340 g
White yam flour	40 g
Moringa seed flour	20 g
Uziza seed flour	2 g
Sugar	100 g
Margarine	120 g
Salt	0.5 g
Egg	1 piece
Baking powder	2 g
Water	200 ml

Production of cookies

Cookies were produced with slight modification using the method of Cookery (2018) [7]. Wheat flour, white yam flour and *moringa* seed flour was formulated as stated in Table 3. The formulated recipe was mixed with sugar, *uziza* seed flour, margarine, baking powder, salt and water was added and mixed to form dough and shaped into varying cookies thickness and baked at the designed temperatures in Table 3. The dough was rolled on a floured board using rolling pin. It was cut according to the varying desired thicknesses and baked according to the designed baking temperatures using a thermostatic Electric Oven Model (DHG-9101-05A) with working size of 350 mm and temperature range of 50 to 300ºC. A control sample was produced with 100% wheat flour to serve as control. The baked cookies were brought out from the oven, cooled, packaged in an airtight cellophine and labeled before carrying out sensory evaluation using structured questionnaire using a 9- point Hedonic scale.

Sensory Evaluation

Sensory evaluation of the cookie samples was carried out according to the method described Ihekoronye and Ngoddy (1985) [13]. A panel of twenty panelists consisting of students and members of Staff of Food Science and Technology Department, Nnamdi Azikiwe University, Awka, Anambra State were chosen based on their familiarity and experience with the cookie samples for sensory evaluation. The samples produced were presented randomly in coded form in white ceramic saucer plates to the panelists. The panelists were provided with portable water to rinse their mouth in between the evaluations. However, a questionnaire describing the sensory properties (appearance, taste, aroma, crispiness and overall acceptability) of the cookies was given to each panelist. The sensory properties were rated on a 9-point Hedonic scale in which the degree to which each sample was rated were like extremely (9), like very much (8), like moderately (7), like slightly (6), neither like nor dislike (5), dislike slightly (4), dislike moderately (3), dislike very much (2) and dislike extremely (1).

Statistical analysis

The mean of all parameters obtained from the analysis of cookies samples was examined for significance ($p \leq 0.05$) by analysis of variance (ANOVA) and all data obtained was subjected to One-way Analysis of Variance using SPSS software version 23 (Statistical Package for Service solution).

Optimization procedure

Numerical optimization was performed using Design Expert software version 12 of Response Surface Methodology. Multiple responses were optimized simultaneously through the use of desirability function that combines all the response into one measurement. The method finds operating conditions (combination of independent variables) that maximize the desirability function. The constraints were set to get the value of a variable for an optimum response (a minimum and maximum level was provided for each variable included). Optimization helped to find the optimal dough thickness and baking temperatures to yield the best sensory properties for the optimized cookie and desirability.

Results and Discussion

Sensory properties of cookies samples from blends of wheat-yam flour baked at different dough thickness and baking temperatures

The results of the sensory evaluation are as presented in Table 4. The parameters evaluated were appearance, taste, aroma, crispiness and overall acceptability. The result of the sensory evaluation of the samples from blends of wheat-yam flour enriched with *Moringa oleifera seed flour* and flavoured with *uziza* seed flour evaluated, showed that sensory score for the appearance of the cookies samples ranged from 5.80 for sample WYC_4 (2.5 mm dough thickness baked) to 8.86 for sample WYC_2 (4 mm dough thickness baked at 165ºC).The panelists score revealed that the appearance of the cookies samples was significantly different ($p \leq 0.05$). The appearance of a food sample is an important sensory attribute a food product must possess because of its influence on a consumer acceptability of food products (Falola, 2012) [11].

The sensory score for the taste of the samples ranged from6.01 for cookie sample WYC_6 (4 mm dough thickness baked at 130ºC) to 8.90 for sample $W4C_2$ (4 mm dough thickness baked at 165ºC). The sample WYC_2 (4 mm dough thickness baked at 165ºC) had the highest value in terms of the taste which could be attributed to the panelist’s likeness with the taste of cookie produced at 4mm dough thickness baked at 165ºC. Also according to (Ayodele, 2003) [5] sweetening agents helps in improving the taste of baked food samples including the production variables of the cookies such as the dough thickness and baking temperatures. Taste is the degree of sweetness, bitterness sourness and saltiness of a food product. The sensory score for the aroma of the samples ranged from 6.33 for sample WYC_6 (4 mm dough thickness baked at 130ºC) to 8.96 for sample WYC_2 (4 mm dough thickness baked at 165ºC). The aromas of the samples were significantly different ($p \leq 0.05$). The aroma of the samples was highest in sampleWYC_2 (4 mm dough thickness baked at 165ºC) followed by sample WYC_3 (4 mm dough thickness baked at 200ºC) with the value 7.96. Each sensory attributes was rated on a 9-point hedonic scale in which the degree to which each sample was rated as like extremely (9), like very much (8), like moderately (7), like slightly (6), neither like nor dislike (5), dislike slightly (4), dislike moderately (3), dislike very much (2) and dislike extremely (1).

The crispiness scores as evaluated by the panelists for the samples ranged from 6.23 for sample WYC_5 (2.5 mm dough thickness baked at 200ºC) to 8.90 for sample WYC_2 (4 mm dough thickness baked at 165ºC). The sample WYC_2 (4 mm dough thickness baked at 165ºC) had the highest value in terms of crispiness, followed by sample WYC_3 (4 mm dough thickness baked at 200ºC). While sample WYC_5 (2.5 mm dough thickness baked at 200 ºC) had the least value in terms of crispiness. The crispiness of the samples was significantly different ($p \leq 0.05$). The crispiness of food product is a measure of the degree of softness and hardness of a food product.

The overall acceptability of the samples evaluated showed that the cookies overall acceptability sensory scores ranged from 6.57 for sample WYC_5 (2.5 mm dough thickness baked at 200ºC) to 8.93 for sample WYC_2 (4 mm dough thickness baked at 165ºC). The high sensory properties of the sample WYC_2 (4 mm dough thickness baked at 165ºC) could be attributed to its high value based on the 9- point hedonic of sample WYC_2 in terms of appearance, taste, aroma, crispiness and overall acceptability. Also the sample WYC_2 (4 mm dough thickness baked at 165ºC) was significantly different ($p \leq 0.05$) compared to other samples analyzed and thus could be described as most acceptable.

Table 4: Sensory properties of cookies from blends wheat-yam flour baked at different dough thickness and baking temperatures

Samples	Appearance	Taste	Aroma	Crispiness	Overall acceptability
WYC_1	$6.80^{cd} \pm 0.88$	$7.00^{cd} \pm 0.69$	$7.16^{cd} \pm 0.74$	$7.36^{bcd} \pm 0.88$	$7.33^{cd} \pm 0.88$
WYC_2	$8.86^{a} \pm 0.34$	$8.90^{a} \pm 0.30$	$8.96^{a} \pm 0.81$	$8.90^{a} \pm 0.31$	$8.93^{a} \pm 0.25$
WYC_3	$8.00^{b} \pm 0.45$	$7.90^{b} \pm 0.69$	$7.96^{b} \pm 0.76$	$8.00^{b} \pm 0.69$	$8.13^{b} \pm 0.57$
WYC_4	$5.80^{e} \pm 0.73$	$6.02^{g} \pm 0.78$	$6.40^{e} \pm 0.89$	$6.73^{def} \pm 1.01$	$6.70^{de} \pm 1.02$
WYC_5	$6.20^{de} \pm 0.84$	$6.21^{ef} \pm 0.92$	$6.50^{ef} \pm 1.04$	$6.57^{f} \pm 1.17$	$6.57^{e} \pm 0.93$
WYC_6	$6.46^{cde} \pm 1.04$	$6.01^{g} \pm 0.94$	$6.33^{e} \pm 0.84$	$6.30^{ef} \pm 1.17$	$6.73^{de} \pm 1.08$
WYC_7	$6.97^{c} \pm 0.71$	$6.90^{cd} \pm 0.94$	$6.83^{ef} \pm 0.79$	$6.93^{ef} \pm 0.69$	$7.06^{cde} \pm 0.91$
WYC_8	$6.80^{cd} \pm 0.84$	$6.50^{def} \pm 0.89$	$6.43^{e} \pm 0.81$	$6.60^{ef} \pm 0.85$	$7.06^{cde} \pm 0.98$
WYC_9	$6.67^{cd} \pm 0.62$	$6.80^{de} \pm 0.74$	$6.70^{ef} \pm 0.76$	$7.00^{cde} \pm 0.78$	$6.86^{cde} \pm 0.76$
WFC	$7.67^{b} \pm 0.60$	$7.50^{bc} \pm 0.81$	$7.60^{bc} \pm 0.98$	$7.65^{bc} \pm 0.98$	$7.52^{bc} \pm 0.98$
LSD	0.203068	0.20406	0.203068	0.230666	0.20304

Values are mean ± standard deviation of triplicate determinations. Values in the same column bearing different superscripts differed significantly ($p \leq 0.05$).

Key

Sample WYC_1= 5 mm dough thickness baked at 200ºC
Sample WYC_2= 4 mm dough thickness baked at 165ºC
Sample WYC_3= 4 mm dough thickness baked at 200ºC
Sample WYC_4= 2.5 mm dough thickness baked at 130ºC
Sample WYC_5= 2.5 mm dough thickness baked at 200ºC
Sample WYC_6= 4 mm dough thickness baked at 130ºC
Sample WYC_7= 5.5 mm dough thickness baked at 165ºC
Sample WYC_8= 2.5 mm dough thickness baked at 165ºC
Sample WYC_9= 5.5 mm dough thickness baked at 130ºC
Sample WFC= 3 mm dough thickness baked at 180 ºC (Control)

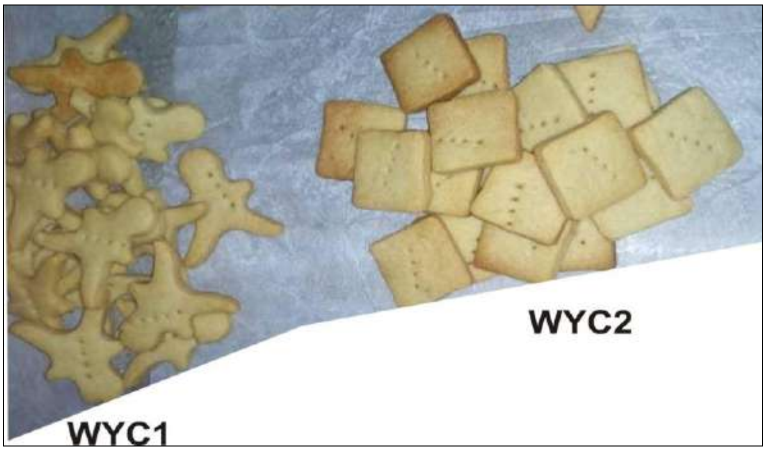


Plate 1
Sample WYC_1= 5 mm dough thickness baked at 200ºC Cookie
Sample WYC_2= 4 mm dough thickness baked at 165ºC Cookie

Plate 2
Sample WYC_3= 4 mm dough thickness baked at 200ºC Cookie
Sample WYC_4= 2.5 mm dough thickness baked at 130ºC Cookie

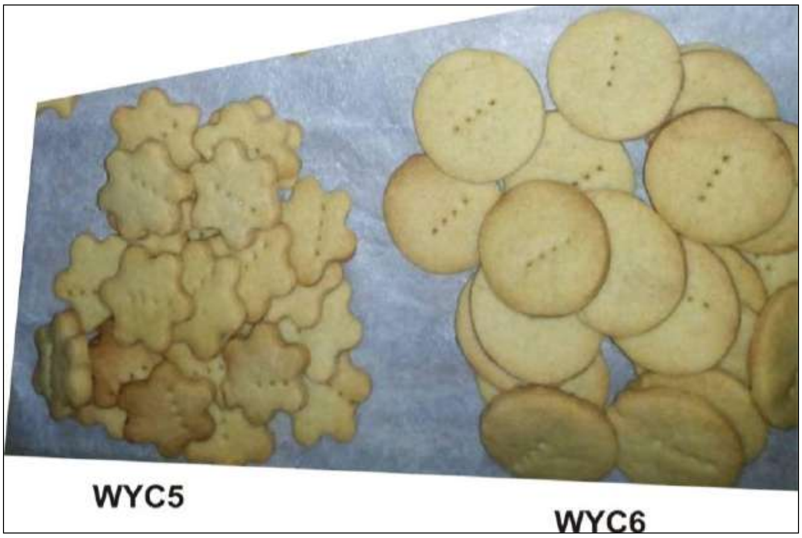


Plate 3
Sample WYC_5= 2.5 mm dough thickness baked at 200ºC Cookie
Sample WYC_6= 4 mm dough thickness baked at 130ºC Cookie

Plate 4
Sample WYC_7= 5.5 mm dough thickness baked at 165ºC Cookie
Sample WYC_8= 2.5 mm dough thickness baked at 165ºC Cookie

Plate 5: Sample WYC_9 = 5.5 mm dough thickness baked at 130ºC Cookie

Model Fitting of Central Composite Rotatable Design (CCRD) on the effect of dough thickness and baking temperatures on the sensory properties of cookies from wheat-white yam flour

The ANOVA values for model fitting of sensory properties of cookies are shown in Table 5

Table 5: ANOVA Values of Central Composite Rotatable Design, Quadratic Models of Sensory properties of cookies

Sensory Properties	Std. Dev	Mean	C.V (%)	Press	R^2	Adj. R^2	Predic R^2	Adeq Prec.	P. Value	P –Lack of Fit	Significant Model
Appearance	0.472	7.35	6.42	32.07	0.906	0.838	-0.936	10.07	0.00018 (Significant)	0.0001 (Significant)	Quadratic
Taste	0.643	7.35	8.74	55.8	0.83	0.707	-2.264	6.97	0.00129 Significant	0.062 Significant	Quadratic
Aroma	0.582	7.47	7.79	43.11	0.842	0.728	1.883	43.11	0.0101 Significant	0.072 Significant	Quadratic
Crispiness	.671	7.49	8.89	58.12	0.781	0.63	-3.067	5.548	.00286 (Significant)	0.0001 Significant	Quadratic
Overall Acceptability	0.488	7.59	6.42	31.95	0.864	0.760	-1.608	7.60	0.0001 (Significant	0.001 Significant	Quadratic

Model is adequate when $p \leq 0.05$, lack of fit ($p \leq 0.05$), Adjusted R^2 ($\geq 60\%$)

The result obtained from the Table 5 of sensory properties of the cookies on appearance showed that quadratic model was suggested. The quadratic model showed a significant lack of fitness ($p \leq 0.0001$). The Adjusted-R^2 was (0.838) which was 84%. The probability of the p- value for the quadratic model was significant ($p \leq 0.0001$) making appearance of the cookies fit into the model. The Coefficient of Variation (CV) value was 6.42 which indicate the data was not tightly clustered around the mean 7.35 and there is a lot of spread in data indicating that the data was not very predictable. This could be due to some factors such as natural variability of ingredients, human element in the production process or environment conditions. In the food industry highly processed food like potato chips a coefficient of variation (CV) up to 20% might be acceptable. However a co-efficient of variation (CV) around 5 - 10% would be considered ideal for cookies.

Regression equation for prediction was obtained for cookies appearance (C_A)

C_A = 0kn.0404A + 0.16665B -0.2569AB – 1.53A^2 – 1.2429B^2 (Eq 1)

The mathematical model for the appearance content of the cookies (C_A) was presented in equation (1) above. The dough thickness (A) had a positive coefficient value of (+0.0404), baking temperature (B) has a positive coefficient of (+0.1665). The combination of the two independent variables dough thickness and baking temperature (AB) gave a negative coefficient value of (-0.2569), while the squared dough thickness (A^2) had a negative coefficient -1.53 and squared baking temperature (B^2) had a negative coefficient value of -1.24. The equation (1) revealed that the dough thickness (A) and baking temperature (B) was antagonistic to the cookies appearance. The 3D-surface contour plot model of cookies appearance (C_A) as shown in Fig. 1

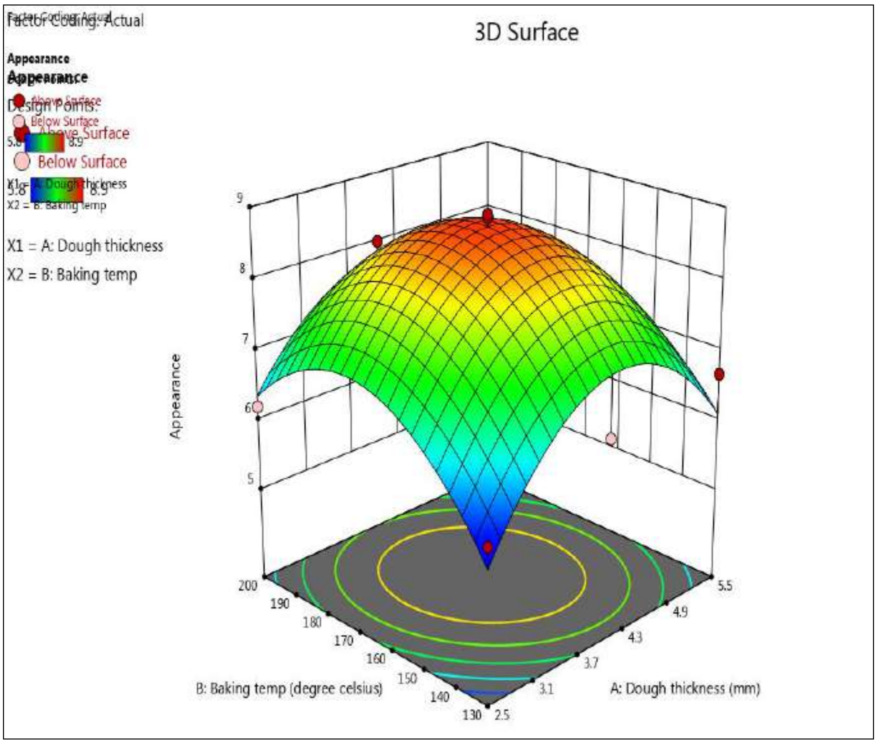
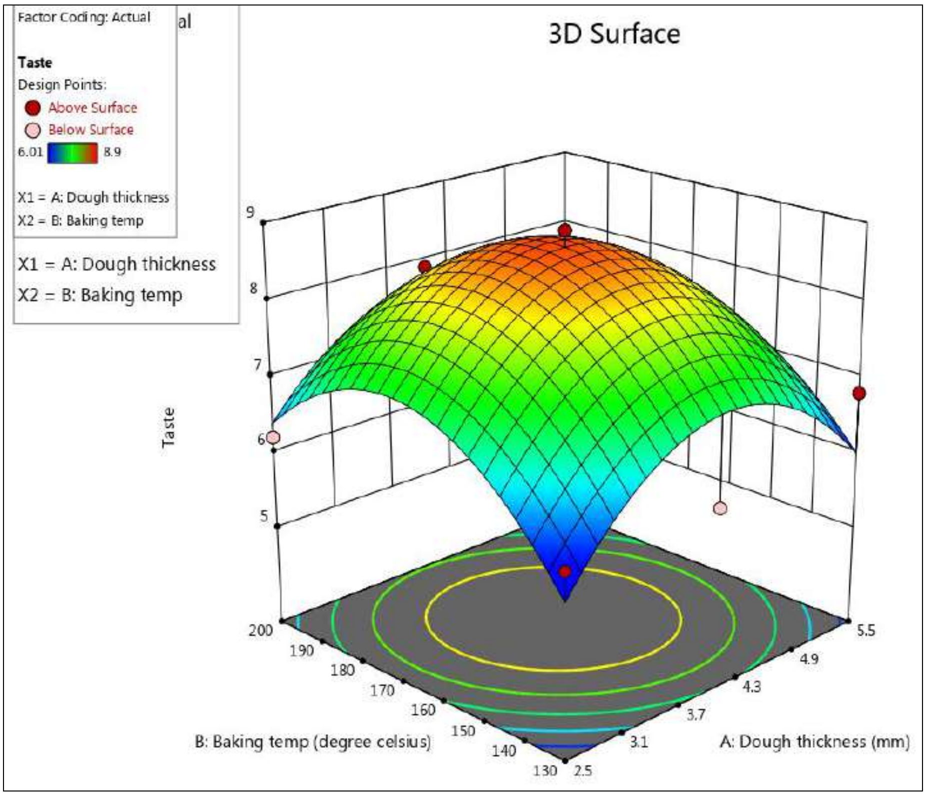


Fig 1: 3D-Surface contour plot on the effect of dough thickness (mm) and baking temperature (°C) on the cookies appearance



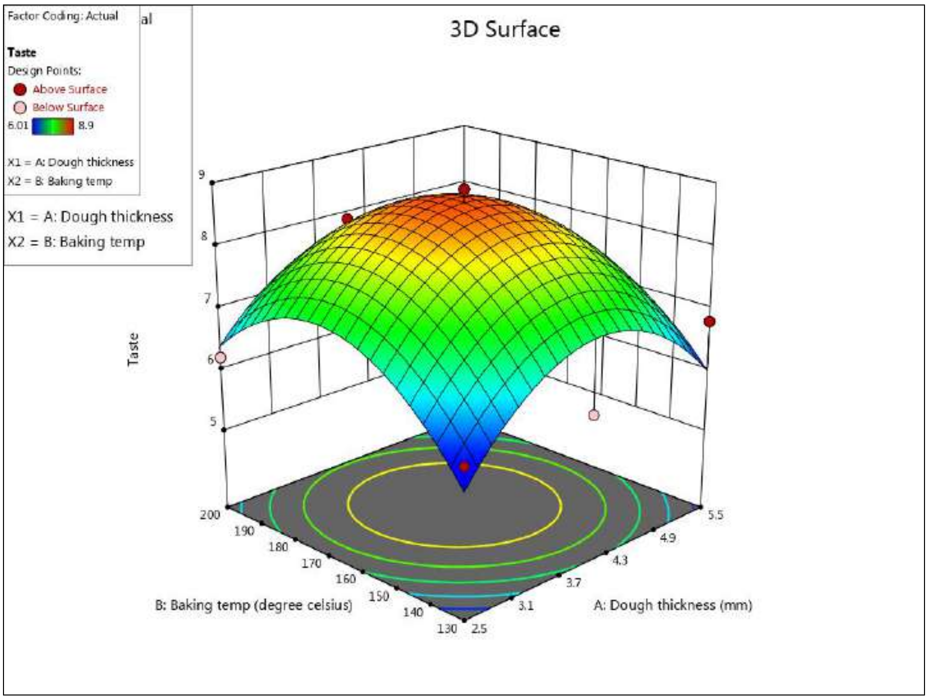


Fig 2: 3D-Surface contour plot on the effect of dough

From the 3D-Surface contour graph increase in dough thickness and baking temperature led to a corresponding increase in the appearance of the cookies. The effect of the two independent variables dough thickness and baking temperature significantly ($p \leq 0.001$) influenced the cookies appearance. The equation was fitted as the adjusted - R^2 value was high 84%. Also as the baking temperature increased from 130 to 180ºC and dough thickness from 2.5 to 5.5 mm the cookies appearance increased from 6.0 to 8.0. According to the sensory evaluation questionnaire, 9- point hedonic scale used by the panelists for sensory evaluation of the cookies revealed that 8.0 was like very much.

Taste of cookies on sensory properties, quadratic model was suggested. The quadratic model showed an insignificant lack of fitness ($p \geq 0.062$). The Adjusted-R^2 was (0.707) which is 71%. The probability of the (p -value) for the quadratic model was significant ($p \leq 0.0001$) making taste of the cookies fit into the model. The Coefficient of Variation (CV) value was 0.7070 which is 71% and indicates that data was not tightly clustered around the mean

7.35 and there was a lot of spread in data indicating that the data was not very predictable. This could be due to some factors such as natural variability of ingredients, human element in the production process or environment conditions. In the food industry highly processed food like potato chips a coefficient of variation (CV) up to 20% might be acceptable. However a co-efficient of variation (CV) around 5-10% would be considered ideal for cookies.

Regression equation for prediction was obtained for cookies taste (C_{Ta})

C_{Ta}= Cookies taste

$C_{Ta} = 0.04145A + 0.2139B - 0.1620AB - 1.37A^2 - 1.2829B^2$ (Eq 2)

The mathematical model for the cookies taste (C_{Ta}) is presented in equation (19) above. The dough thickness (A) had a positive coefficient value of (+0.04145) baking temperature (B) has a positive coefficient of (+0.2139). The combination of the two independent variables dough thickness and baking temperature (AB) gave a negative coefficient value of (-0.1620), while the squared dough thickness (A^2) had a negative coefficient -1.37 and squared baking temperature (B^2) had a negative coefficient value of -1.28. The equation (2) revealed that the dough thickness (A) and baking temperature (B) will not be antagonistic to the cookies taste and their increase will improve the taste of the cookies.

The 3D-surface contour plot model of cookies taste (C_T) is shown in Fig. 3 below.

thickness (mm) and baking temperature (ºC) on the cookies taste From the 3D-Surface contour graph increase in dough thickness and baking temperature led to a corresponding increase in the taste of the cookies. The independent variables dough thickness and baking temperature significantly ($p \leq 0.001$) influenced the cookies taste positively. As the dough thickness from 2.5 to 5.5 mm, taste of the cookies increased from 6.0 to 7.2. However, as the baking temperature of the cookies increased from 130ºC to 200ºC, taste of the cookies increased from 5.0 to 6.0. The graph showed that increase in dough thickness significantly increased taste of the cookies more significantly ($p \leq 0.05$).

From the ANOVA Table 5 on sensory properties of cookies, quadratic model was suggested for the cookies aroma. The quadratic model showed an insignificant lack of fitness ($p \geq 0.072$). The Adjusted-R^2 was (0.728) which is 73%. The probability of the (p - value) for the quadratic model was significant ($p \leq 0.0101$) making aroma of the cookies fit into the model. The Coefficient of Variation (CV) value was 7.79 which indicate that data was not tightly clustered around the mean 7.49 and there was a lot of spread in data indicating that the data was not very predictable. This could be due to some factors such as natural variability of ingredients, human element in the production process or environment conditions. In the food industry highly processed food like potato chips a coefficient of variation (CV) up to 20% might be acceptable. However a co-efficient of variation (CV) around 5-10% would be considered ideal for cookies.

Regression equation for prediction was obtained for cookies aroma (C_{Aro})

C_{aro}= Cookies Aroma

$C_{Aro} = -0.1468A + 0.1985B - 0.0936AB - 1.37A^2 - 1.17B$ (Eq 3)

The mathematical model for the cookies aroma (C_{Aro}) is presented in equation (3). The dough thickness (A) had a negative coefficient value of (-0.1468), baking temperature (B) has a positive coefficient of (+0.1985). The combination of the two independent variables dough thickness and baking temperature (AB) gave a negative coefficient value of (-0.0936), while the squared dough thickness (A^2) had a negative coefficient -1.37 and squared baking temperature (B^2) had a negative coefficient value of -1.178. The equation (3) revealed that increase in dough thickness (A) was antagonistic to the cookies aroma and increase in baking temperature will improve or increase the aroma of the cookies.

The 3D-surface contour plot model of cookies aroma (C_{aro}) is shown in Fig.3

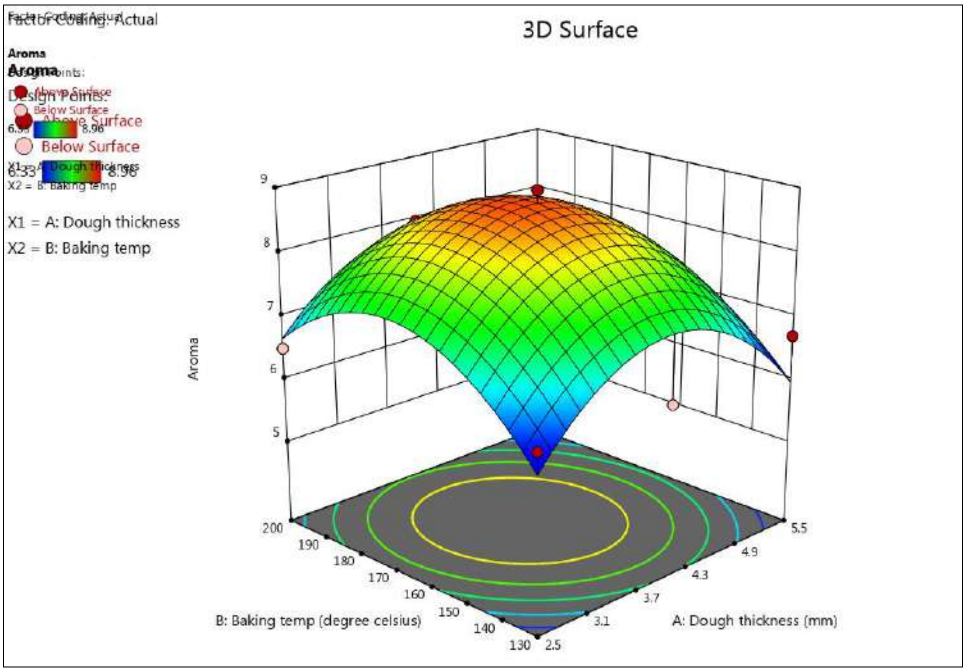


Fig 3: 3D-Surface contour plot on the effect of dough thickness (mm) and baking temperature (ºC) on the cookies aroma.

The 3D-Surface contour plots for the model of the cookies aroma as shown in Fig 3, suggests that increase in baking temperature led to a corresponding positive increase in the aroma from 5.0 to 8.0. However, as the baking temperature of the cookies increased from 130ºC to 200ºC, aroma of the cookies increased from 6.5 to 8.0. The graph showed that increase in dough thickness both significantly increased energy value of the cookies positively.

From the Table 5 on sensory properties of cookies, quadratic model was suggested for the cookies crispiness. The quadratic model showed significant lack of fitness ($p \leq 0.001$). The Adjusted-R^2 was (0.6255) which is 63%. The probability of the (p- value) for the quadratic model was significant ($p \leq 0.0101$) making crispiness of the cookies fit into the model. The Coefficient of Variation (CV) value was 8.96 which indicate that data was not tightly clustered around the mean 7.49 and there is a lot of spread in data indicating that the data was not very predictable. This could be due to some factors such as natural variability of ingredients, human element in the production process or environment conditions. In the food industry highly processed food like potato chips a coefficient of variation (CV) up to 20% might be acceptable. However a co efficient of variation (CV) around 5-10% would be considered ideal for cookies.

Regression equation for prediction was obtained for cookies crispiness (C_{Cris})

C_{Cris} = Cookies crispiness

$C_{Cris} = -0.1468A + 0.1138B + 0.0778AB - 1.28A^2 - 1.04B^2$ (Eq 4)

The mathematical model for the cookies crispiness (C_{Cris}) is presented in equation (4) above. The dough thickness (A) had a negative coefficient value of (-0.0164), baking temperature (B) has a positive coefficient of (+0.1138). The combination of the two independent variables dough thickness and baking temperature (AB) gave a positive coefficient value of (+0.0778), while the squared dough thickness (A^2) had a negative coefficient -1.28 and squared baking temperature (B^2) had a negative coefficient value of -1.04. The equation (21) revealed that increase in dough thickness (A) will be antagonistic to the cookies crispiness, indicating that increase in dough thickness could lead to decrease in cookies crispiness and increase in baking temperature will improve or increase the crispiness of the cookies.

The 3D-surface contour plot model of cookies crispiness (Cris) as shown in Fig. 4

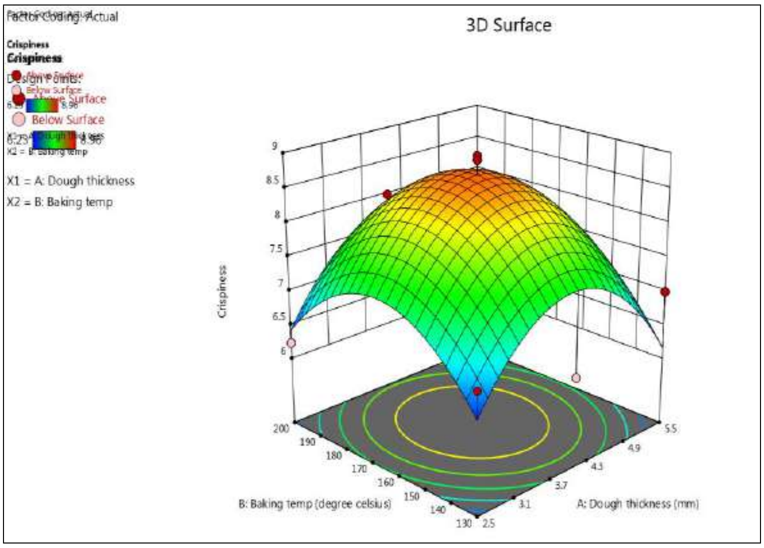


Fig 4: 3D-Surface contour plot on the effect of dough thickness (mm) and baking temperature (ºC) on the cookies crispiness**.**

indicates that increase in dough thickness led to a significant increase in the crispiness of the cookies and as the dough thickness increases cookies crispiness decreases cookies crispiness from 7.0 to 6.2, while increase in baking temperature from 130ºC to 200ºC, the cookies crispiness increased from 6.2 to 8.2. The implication of it could be that as the baking temperature increased the cookies becomes crispier and as the dough thickness increased the cookies becomes less crispy.

A regression coefficient of sensory on overall acceptability of cookies was suggested. The quadratic model showed significant lack of fitness ($p \leq 0.001$). The Adjusted-R^2 was (0.7670) which is 77%. The probability of the (p-value) for the quadratic model was significant ($p \leq 0.0101$) making overall acceptability of the cookies fit into the model. The Coefficient of Variation (CV) value was 6.42 which indicated that data was not tightly clustered around the mean 7.59 and there was a lot of spread in data indicating that the data was not very predictable. The variation could be due to changes in processing conditions, human and instrumental factors in the process of production of the cookies. In the food industry highly processed food like potato chips a coefficient of variation (CV) up to 20% might be acceptable. However a co-efficient of variation (CV) around 5-10% would be considered ideal for cookies.

Regression equation for prediction was obtained for cookies overall acceptability (C_{OA})

C_{OA} = Cookies overall acceptability

$C_{OA} = -0.0894A + 0.1410B - 0.0083AB - 1.30A^2 - 0.09997B^2$ (Eq 5)

The mathematical model for the cookies overall acceptability (C_{OA}) is presented in equation (5). The dough thickness (A) had a negative coefficient value of (-0.0894), baking temperature (B) has a positive coefficient of (+0.1410B^2). The combination of the two independent variables dough thickness and baking temperature (AB) gave a negative coefficient value of (-0.0083), while the squared dough thickness (A^2) had a negative coefficient -1.30 and squared baking temperature (B^2) had a negative coefficient value of -0.0999. The equation (5) revealed that only the baking temperature influenced the overall acceptability of the cookies.

The 3D-surface contour plot model of cookies Overall acceptability (C_{OA}) as shown in Fig. 5.

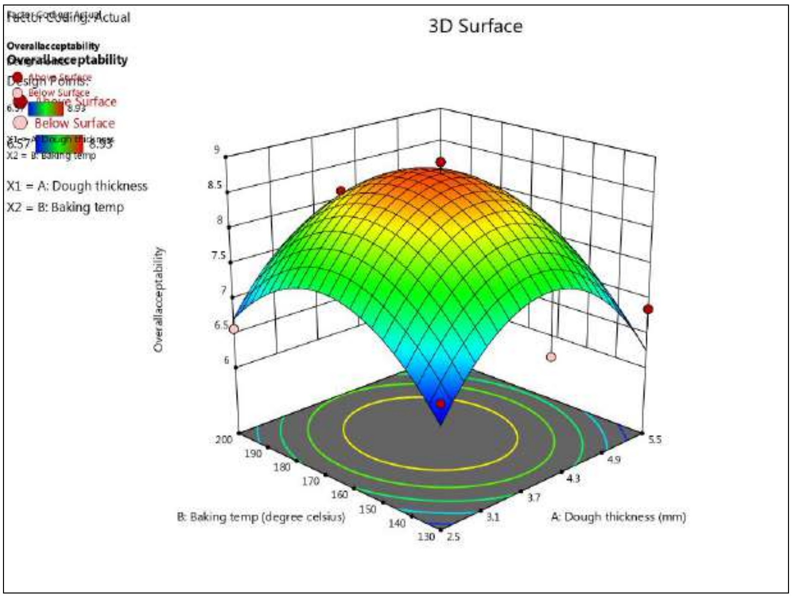


Fig 5: 3D-Surface contour plot on the effect of dough thickness (mm) and baking temperature (°C) on the cookies overall acceptability

From the 3D-Surface contour graph as the baking temperature increased from 130 to 200°C overall acceptability of the cookies increased from 6.57 to 8.93 which is approximately 9.0 (extremely liked) judging with the sensory questionnaire hedonic scale. As the dough thickness of cookies increased from 2.5 mm to 5.5 mm the overall acceptability of the cookies increased from 6.0 to 6.8.

Table 6: Constraints of sensory properties of process variables of the cookies

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A:Dough thickness	is in range	2.5	5.5	1	1	3
B:Baking Temperature	is in range	130	200	1	1	3
Appearance	Maximize	5.8	8.86	1	1	3
Taste	Maximize	6	8.9	1	1	3
Aroma	is in range	6.33	8.96	1	1	3
Crispiness	Maximize	6.3	8.9	1	1	3
Overall acceptability	Maximize	6	8.93	1	1	3

Solutions

1. Solution found and selected

Table 7: Optimum values of process variables on the effect of dough thickness and baking temperature on the sensory properties of cookies produced from wheat-white yam flour

Dough thickness (mm)	Baking temp °C
4.0	165

Number	Dough thickness	Baking Temperature	Appearance	Taste	Aroma	Crispiness	Overall acceptability	Desirability	
1	4.000	165.000	8.86	8.90	8.96	8.90	8.93	1.000	Selected

Optimization of Sensory properties process variables of the cookies

The optimization plot for the process variables for sensory properties of the cookies is shown on Fig 6 below. Optimization refers to improving the performance of a system, a process, or a product to obtain maximum benefit from it (Nwuneli *et al.*, 2022). The process variables were set as follows Appearance (maximum), Taste (maximum), aroma (in range), crispiness (maximum) and overall acceptability (maximum). The set up generated one solution for numerical optimization at a maximum desirability of 1.0. Desirability score one, is the highest score in the desirability scale. From the optimization plot, cookies produced from wheat flour and white yam flour at dough thickness and baking temperature of 4 mm and 165°C could be recommended.

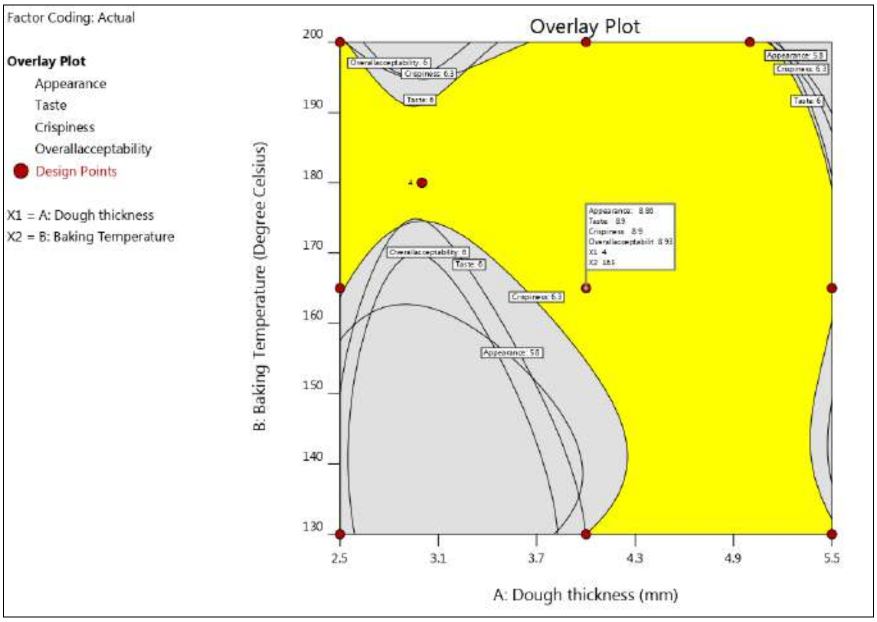


Fig 6: Optimization plot of sensory composition of the cookies

Conclusion

Optimization of the sensory properties result of the cookies revealed that 4.0 mm dough thickness and 165ºC baking temperature yielded an optimized quality cookie with appearance score 8.86, taste score 8.90, aroma score 8.96, crispiness score 8.9 and overall acceptability score 8.93 with the highest desirability function of 1.0.

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