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EFFECT OF BAKING TIME AND TEMPERATURE ON THE BAKING QUALITY AND SENSORY ATTRIBUTE OF CAKE PRODUCED FROM WHEAT-TIGERNUT POMACE FLOUR BLENDS BY SURFACE METHODOLOGY

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ABSTRACT

This study was carried out to evaluate the effect of baking temperature and baking time on the baking quality and sensory attribute of cake from wheat-tigernut pomace flour blends. Response surface methodology using Box-Behnken design was employed with three independent variables at three levels of variations resulting into 17 experimental runs. The independent variables are baking temperature (160-180 ºC), baking time (30-40mins) and level of tigernut pomace flour (5-15%) added to the wheat flour. Cake was baked from wheat and tigernut pomace flour and was analyzed for physical properties, colour attributes and sensory qualities. There was significant effect ($p < 0.05$) in the physical properties of wheat-tigernut pomace cake such as the cake weight and oven spring ranged from 50.75g to 69.80g and 2.3cm to 3.5cm. The crumb and crust colour of cake from wheat-tigernut pomace varied significantly ($p < 0.05$) and ranged from 55.84 to 66.77, 0.16 to 2.54, 24.65 to 31.77 and 36.71 to 86.36, 9.76 to 13.32 and 19.96 to 34.51.The result of the sensory evaluation revealed that cakes from wheat flour with low amount of tigernut pomace and those baked at lower temperature and time were rated alike in almost all the quality attributes. The addition of tigernut pomace into wheat flour for cake baking had a significant effect on the physical and sensory qualities. The resultant effect of the baking temperature, baking time and tigernut pomace significantly affected the cake oven spring and led to decrease in cake weight. The lightness, redness and yellowness of the cake samples varied significantly among different levels of the substitution. However, cake can be baked from wheat- tigernut pomace flour between 160-170°C for 30-35 minutes with inclusion of 10% tigernut pomace flour to yield cake of enhanced qualities

1. Introduction

Cakes are a form of food that is usually sweet and often baked (Clerk and Herbert 2000). They are usually prepared from flour, sugar, shortening, baking powder, egg, and flavour as principal ingredients (Clerk and Herbert 2000; Atef *et al.,* 2011). Wheat is the major flour used in cake production. Cakes have enjoyed a relatively constant place in our diet for a long time and its continuous popularity has encouraged the development of newer and more attractive products that are available in the market today. Wheat flour has also been known to be expensive in Nigeria compared to other cereals mainly because of wheat not been cultivated locally. However, there are so many other crops grown in Nigeria and attempts have been made by many researchers and government to complement wheat flours with non-wheat flour (Oyeyinka *et al.,* 2014). Wheat are grown in few developing countries with the exceptions of where there is a temperate zone caused by high latitude or high altitude or both (examples are Mexico, Northern India, Eastern Africa) (Dendy, 2001).Tigernut is imported from temperate countries most especially where they are cultivated. Due to urbanization and rapid population growth, wheat imports to Nigeria have grown rapidly. According to United States Department of Agriculture, Nigeria imported 4.1 million metric tonnes of wheat in 2011. These imports are paid for with scarce foreign currency and this is depleting Nigeria's external currency earnings and reserve. In the bid to lower or stop out rightly imports of wheat, the Nigerian government & Food and Agriculture Organization (FAO) have encouraged the use of composite flours and blends of non-wheat flours or meals for the production of aerated products such as cake, bread, biscuit, sausage roll, doughnut, etc. Replacing a portion of wheat flour with tigernut pomace flour for the production of cake will therefore decrease the demand for imported wheat, increase the utilization of tigernut and hence the production of fibre-enriched cake.

Consumer attention in dietary fibre has continued to rise as more information about its potential impact on health keeps emanating. In order to tackle the problem of malnutrition in Africa, there is need to explore the underutilized crops; some of which are reported to be rich in dietary fibre. Among the underutilized crops in Nigeria is tigernut which could find useful application in baking industry because of its high level of dietary fibre and other inherent properties (Ade-Omowaye *et al.,* 2008).

Tigernut (*Cyperus esculentus L*) belongs to the division Magnoliophyta, Class-liliopsida, order-cyperales and family-cyperaceae and was found to be a cosmopolitan perennial crop of the same genus as the papyrus plant. Other names of the plant are earth almond as well as yellow nut grass (Odoemelan, 2003; Belewu and Belewu, 2007). In Nigeria, where three varieties (Black, Yellow and Brown) are cultivated,tigernut is kown as `Aya' in Hausa, `Ofio' in Yoruba and Akiausa in Igbo.Tiger nut has been demostrated to be a rich source of good quality oil (Dubois, 2007;Yeboah *et al.,* 2011) and contain a moderate amount of protein (Oladele and Aina, 2007). It has been reported to be high in dietary fibre content (Joy-Toran and Farre-Rovira, 2003), which could be effective in treatment and prevention of many diseases including colon cancer (Adejuyitan *et al.,* 2009), coronary heart disease (Chukwuma *et al.,* 2010), obesity, diabetes, gastrointestinal disorders (Anderson *et al.,* 2009) and losing weight (Borges *et al.,* 2008).

Tigernut pomace is the solid residues which remain after milling and pressing of tigernut for milk and oil production. Tigernut pomace is one of the most common functional ingredients in food products and has been used as fat replacer, fat reducing agent during frying, volume enhancer, binder, bulking agent and stabilizer. Tigernut pomace which is a by-product from tigernut milk production is a suitable fibre source (Sánchez-Zapata *et al.,* 2009). Tigernut pomace has a unique sweet taste, which is ideal for different uses. It is a good alternative to many other flours like wheat flour, as it is gluten free and good for people who cannot take gluten in their diets. It is considered good flour or additive for the bakery industry, as its natural sugar content is high, avoiding the necessity of adding extra sugar (Anderson *et al.,* 2009). The flour is used to make cakes and biscuits and the oil is used for cooking (Wise, 2009).

Tigernut seeds are cheap and readily available but grossly underutilized and need more attention because of its nutritional qualities such as high fibre. Recent application of tigernut for baked product has been studied extensively. Ade-omowaye *et al.* (2008) reported the use of brown variety of tigernut in bread making using 10-50% dilution of wheat flour with tigernut flour. The report further shows that only bread baked from 10% dilution of wheat with tigernut (brown variety) flour was acceptable. Oke *et al.* (2017a) also reported the use of yellow variety of tigernut in bread making using 2-10% dilution of wheat flour with tigernut flour. The report further shows that incorporation of tigernut flour into wheat flour bread production dramatically improved the parameter investigated as well as bread quality. Oke *et al.* (2016) also reported the proximate, functional, pasting and rheological properties of dilution of wheat flour with tigernut flour. The study showed that addition of tigernut flour has the advantage of improving the mineral and fibre content of flour. However, there is dearth of information on the use of tigernut pomace in cake baking. The nutritional content of wheat is low in fibre due to the various processes the whole wheat might have undergone.

Also, controlling parameters like time and temperature combination during baking has been an engineering problem which is critical to successful implementation of commercial composite flour baking technology. In most developing countries such as Nigeria, baking of cake are mostly done with ovens that lack temperature-time control at cottage level in which fewer small and medium scale bakeries uses automated devices (Shittu *et al.,* 2007). Baking time differs widely and high subjective means developed through long time baking experience are being used by bakers for fueling of ovens and temperature control. Therefore, the inclusion of tigernut pomace flour would serve as a source of fibre supplement for the production of cake and the use of recent and emerging technological ovens for baking of cake will also assist in the design and development of appropriate process for baking cake from the blend. The objective of this study is to investigate effect of baking time and temperature on the baking quality and sensory attribute of cake produced from wheat-tigernut pomace flour blends

2. Materials and methods

2.1. Materials

Wheat flour, tigernut (brown variety) and ingredients such as baking flour, sugar, nutmeg, and margarine were purchased from Osiele market in Abeokuta, Nigeria.

2.2. Methods

2.2.1. Tigernut Pomace Preparation

Tigernut pomace was prepared according to the method described by Oke *et al.* (2017b). Brown tigernut (*Cyperus esculentus*) was sorted to remove unwanted materials like stones, pebbles and other foreign materials before washing with tap water. It was soaked inside the water for eight hours; the soaked nuts was wet milled using laboratory hammer mill. The tigernut co-products were pressed inside the muslin cloth to obtain the extract which is tigernut pomace. The tigernut pomace was dried in the cabinet at 60°C for 24hours. The tigernut pomace was packed and sealed in polyethylene bags until further analysis.

Table 1. Uncoded values for baking variables

Variables	-1	0	1
Baking time (mins)	30	35	40
Baking temperature (°C)	160	170	180
Tigernut pomace (%)	5	10	15

Table 2. Experimental design for the baking runs using response surface methodology

Run	Baking Temperature (°C)	Baking Time (minutes)	Tigernut pomace (%)
1	170.00	35.00	10.00
2	180.00	40.00	10.00
3	160.00	40.00	10.00
4	180.00	35.00	5.00
5	170.00	35.00	10.00
6	180.00	35.00	15.00
7	160.00	35.00	15.00
8	170.00	35.00	10.00
9	170.00	35.00	10.00
10	170.00	40.00	15.00
11	160.00	30.00	10.00
12	180.00	30.00	10.00
13	160.00	35.00	5.00
14	170.00	40.00	5.00
15	170.00	30.00	15.00
16	170.00	35.00	10.00
17	170.00	30.00	5.00

2.2.2. Experimental design

Response surface methodology using Box-Behnken design was employed with three independent variables at three levels of variations resulting into 17 experimental runs. The independent variables are baking temperature, baking time and level of tigernut pomace flour added to the wheat flour. Table 1 shows the range of baking variables while Table 2 shows the baking runs for the production of wheat-tigernut pomace cake.

2.2.3. Preparation of cake produced from wheat-tigernut pomace flour blends

Cake was prepared from the flour blends according to the modified method described by Akubor and Ishiwu (2013) with little modification of recipe. The recipes for the preparation of cake include sugar (50g) baking powder (0.5g), egg (60g), vanilla flavour (1.5g) and margarine (80g). The dry ingredients was weighed and mixed thoroughly in a spiral mixer (for 5minutes). Cream was also made by mixing sugar and margarine thoroughly using an electric hand mixer till a fluffy texture is obtained. The mixed dried ingredient was added and folded in until thoroughly kneaded. The batter was shared out and baked in greased pans in the baking oven.

2.2.4. Determination of physical properties of cake produced from wheat-tigernut pomace flour blends

The cake weight was determined using the method of Shittu *et al.* (2007). The cake weights was determined with the aid of weighing balance after cooling and the weight values was recorded for each sample.

Cake volume was measured using the modified method described by Feili *et al.* (2013). Cake volume was determined using sorghum seed displacement method. The sorghum seeds were poured into a container to measure the volume and were measured in a graduate cylinder and mark as V_1. Thereafter, the sample was placed in the same container and seeds were poured till the test cake is covered. Again, the sorghum seeds were measured in another graduated cylinder and mark as V_2**.** The volume of sample was then calculated based on the following equation.

Cake volume (ml) = $V1 - V2$ (1)

Where: *V_1 represents the volume of the sorghum seeds in the empty container (ml),*

V_2 represent volume of the sorghum seeds in the container containing sample (ml).

The specific volume was also calculated using the method described by Feili *et al.* (2013) as shown in the following equation below:

$$\text{Specific volume (cm}^3\text{/g)} = \frac{Cake\ volume}{Cake\ weight} \quad (2)$$

The cake density was determined using method described by Feili *et al.* (2013). The cake density was calculated by dividing the weight of cake obtained by the volume of cake.

$$\text{Density (g/cm}^3\text{)} = \frac{cakeweight}{cakevolume} \quad (3)$$

Oven spring was determined from the differenced in the height of dough just before and after baking using the method described by Idowu *et al.* (1996).

$$Height\ of\ cake\ before\ baking - Height\ of\ cake\ after\ baking \quad (4)$$

2.2.5. Colour attribute of cake produced from wheat-tigernut pomace flour blends

Crust and crumb colour measurement was measured by the method described by Feili *et al.* (2013). Minolta chroma meter was used based on (CIE) L*a*b* scale. After calibrating the instrument by covering a zero-calibration mask followed by white calibration plate, crust and crumb was analyzed by placing them on the petri dish and the image was captured on the samples. The colour attributed such as lightness (L*) and (0 = black and 100 = white) and chromatically coordinated (a* corresponds to the colour range from red-green coordinates (- is given, while + is red)), (b* corresponds to the colour range from blue-yellow coordinates (- is blue with + indicating yellowness) was recorded.

2.2.6. Sensory evaluation of cake produced from wheat-tigernut pomace flour blends

The method described by Iwe (2002) was used. The sensory panel consisted of 50 members who were familiar with the product and they were asked to score the Cake using a 9-point hedonic scale based on their degree of likeness where 9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely. Cake quality attributes evaluated are: Crust colour, Crust texture, aroma, taste, and overall acceptability.

2.3. Statistical analysis

All experimental data obtained were done in triplicate, which equal to the sum of fifty one (51) samples. Data obtained were subjected to means, analysis of variance using SPSS version 21.0 and the difference between the mean values were evaluated at $p<0.05$ using Duncan multiple range test. The effect of optimization procedure was investigated using Design expert based on Box Behnken design and significant effects of the independent variables were determined at 5% confidence level.

3. Results and discussion

3.1. Physical properties of cake produced from wheat-tigernut pomace flour blends

The physical properties of cake produced from wheat-tigernut pomace blends are presented in Table 3. Weight basically is determined by the amount of dough baked and the amount of moisture and carbon dioxide diffused out of during baking (Shittu *et al.,* 2007; Oke *et al.,* 2017a). The weight of the cake ranged between 50.75 g and 69.08g. From the regression coefficient table (Table 4), the main effect of baking temperature, baking time and tigernut pomace and the quadratic effect of tigernut pomace had a significant effect ($p<0.05$) on the weight while the quadratic effect of baking time had a negative effect on the weight.

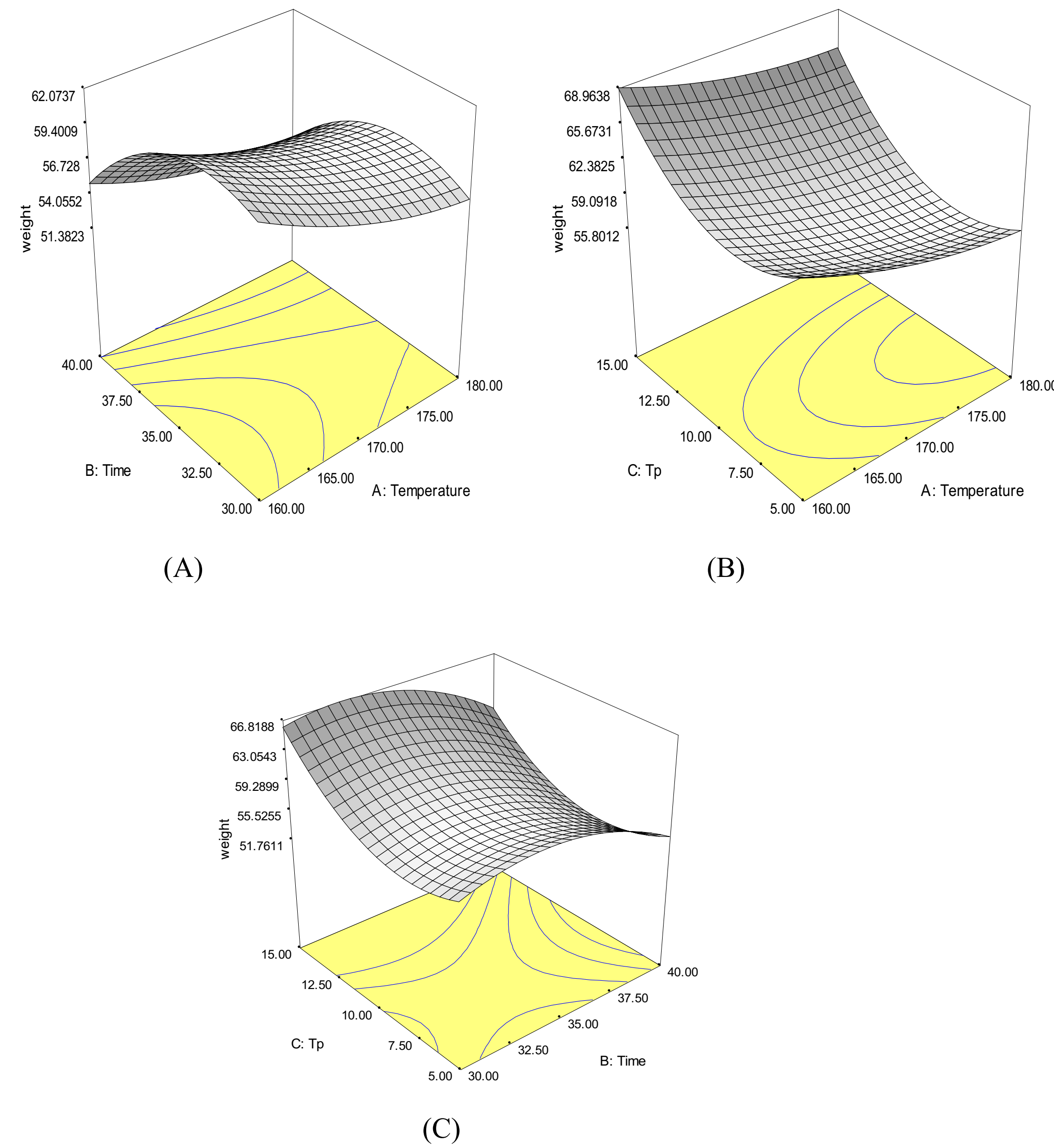


Figure 1. Response surface plot for weight of cake from wheat-tigernut pomace flour blends

The response surface plot for the weight (Figure 1) reveals that increase in baking time and baking temperature when tigernut pomace was held constant led to a decrease in weight. Also, increase in baking temperature and tigernut pomace when baking time was held constant resulted to decrease in weight and while the baking temperature was held constant, increase in baking time and tigernut pomace led to decrease in weight. This can be attributed to lower level of gluten network in the dough and therefore decreasing the ability of the dough to rise (Aluko and Olugbemi, 1989; Oke *et al.,* 2017a).

Table 3. Physical properties of cake produced from wheat- tigernut pomace flour blends

Baking Temperature (°C)	Baking Time (minutes)	TPF (%)	Weight (g)	Oven spring (cm)	Volume (cm^3)	Specific volume (cm^3/g)	Density (g/cm^3)
170	35	10	57.96^{abcd}	2.80^{e}	450^{abc}	7.76^{bc}	0.13^{ab}
180	40	10	50.75^{a}	2.60^{c}	600^{de}	11.82^{g}	0.09^{a}
160	40	10	53.72^{ab}	2.60^{c}	550^{cd}	11.17^{fg}	0.09^{a}
180	35	5	57.33^{abc}	2.85^{e}	450^{abc}	7.85^{bc}	0.13^{ab}
170	35	10	57.96^{abcd}	2.80^{e}	450^{abc}	7.76^{bc}	0.13^{ab}
180	35	15	64.74^{de}	2.70^{d}	350^{a}	5.41^{a}	0.19^{b}
160	35	15	69.08^{e}	2.45^{b}	600^{de}	8.69^{bcd}	0.12^{ab}
170	35	10	57.96^{abcd}	2.80^{e}	450^{abc}	7.76^{bc}	0.13^{ab}
170	35	10	57.96^{abcd}	2.80^{e}	450^{abc}	7.76^{bc}	0.13^{ab}
170	40	15	60.57^{bcde}	2.35^{a}	600^{de}	8.50^{bcd}	0.12^{ab}
160	30	10	61.79^{bcde}	2.30^{a}	450^{ab}	7.28^{b}	0.08^{a}
180	30	10	56.29^{abcd}	2.70^{d}	400^{ab}	7.30^{b}	0.14^{ab}
160	35	5	63.54^{cde}	3.15^{f}	600^{de}	9.44^{cde}	0.11^{a}
170	40	5	54.94^{abc}	2.50^{b}	550^{cd}	10.01^{def}	0.10^{a}
170	30	15	65.16^{abcd}	2.30^{d}	700^{bcd}	10.74^{bcd}	0.09^{a}
170	35	10	57.96^{abcd}	2.80^{e}	450^{abc}	7.76^{bc}	0.13^{ab}
170	30	5	56.69^{de}	2.70^{a}	500^{e}	8.87^{efg}	0.11^{a}

TPF: Tigernut pomace flour; values are means of triplicate determination. Mean values with different superscripts within the same column are significantly different ($p < 0.05$)

Table 4. Regression coefficient of physical attribute of cake produced from wheat-tigernut pomace flour blends

Parameters	Weight	Oven spring	Volume	Specific volume	Density
β_o	57.96	2.80	450.00	7.76	0.13
A	-2.38*	0.044	-50.00	-0.52	0.019*
B	-2.49*	6.250E-003	31.25	0.91	-.2.500E-003
C	3.38*	-0.17*	18.75	-0.35	8.750E-003
A^2	1.00	0.038	-18.75	-0.025	1.250E-003
B^2	-3.33*	-0.29*	68.75	1.66	-0.031*
C^2	4.71*	-0.050	68.75	0.11	6.250E-003
AB	0.63	-0.100	25.00	0.16	-0.015

AC	0.47	0.14*	-25.00	-0.42	0.013
BC	-0.71	0.063	-37.50	-0.85	1.000E-002
R^2	0.978	0.936	0.623	0.602	0.89
F-VALUE	35.02	11.38	1.29	1.18	6.36

* = Significant difference ($p<0.05$); β_o= Intercept, A =main effect of temperature, B = main effect of baking time, C = main effect tigernut pomace flour, A^2 = Quadratic effect of temperature, B^2= Quadratic effect of time, C^2 = Quadratic effect of tigernut pomace flour, AB = Interaction effect of temperature and time, AC =Interaction effect of temperature and tigernut pomace flour, BC = Interaction effect time and tigernut pomace flour, R^2= coefficient of determination

Volume is one of the main quality characteristics of baked product and it is negatively affected when wheat is replaced with composite flour. Volume is affected by the amount and quality of protein in the flour (Ragaee and Abdel-Aal, 2006) as well as proofing time (Zghal*et al.,* 2002). The cake volume ranged from 350cm^3 to 700cm^3.

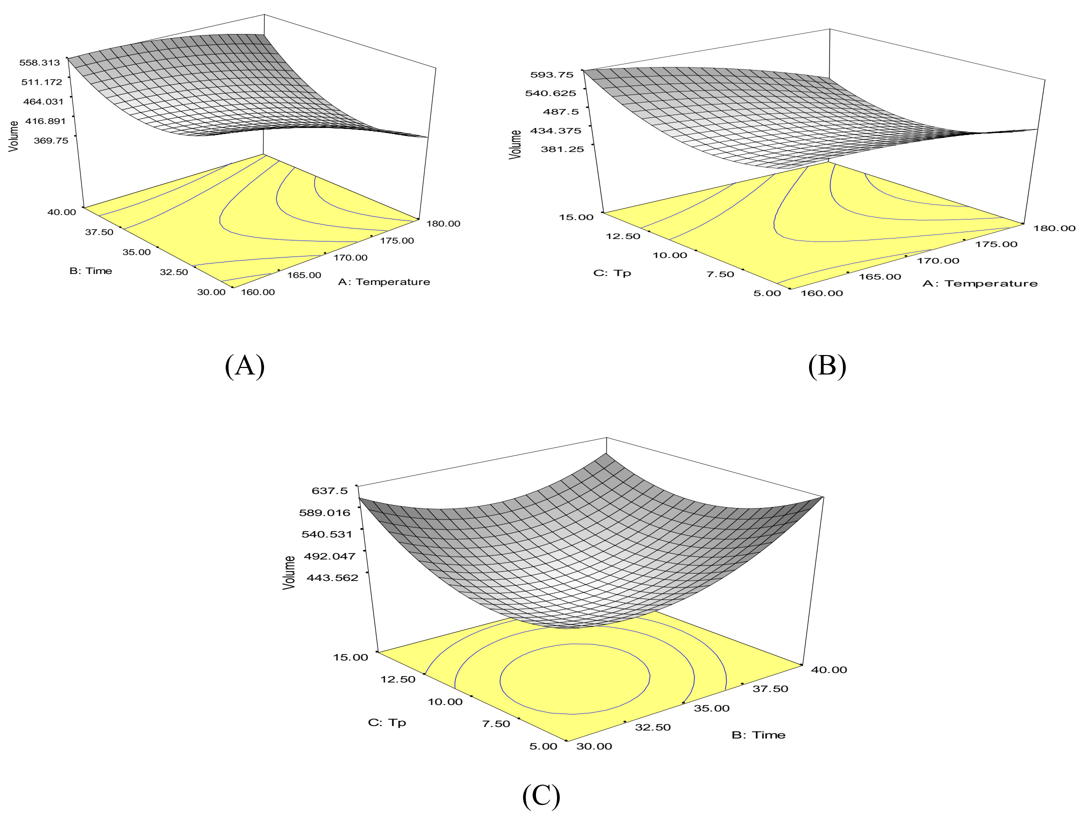


Figure 2. Response surface plot for volume of cake from wheat-tigernut pomace flour blends

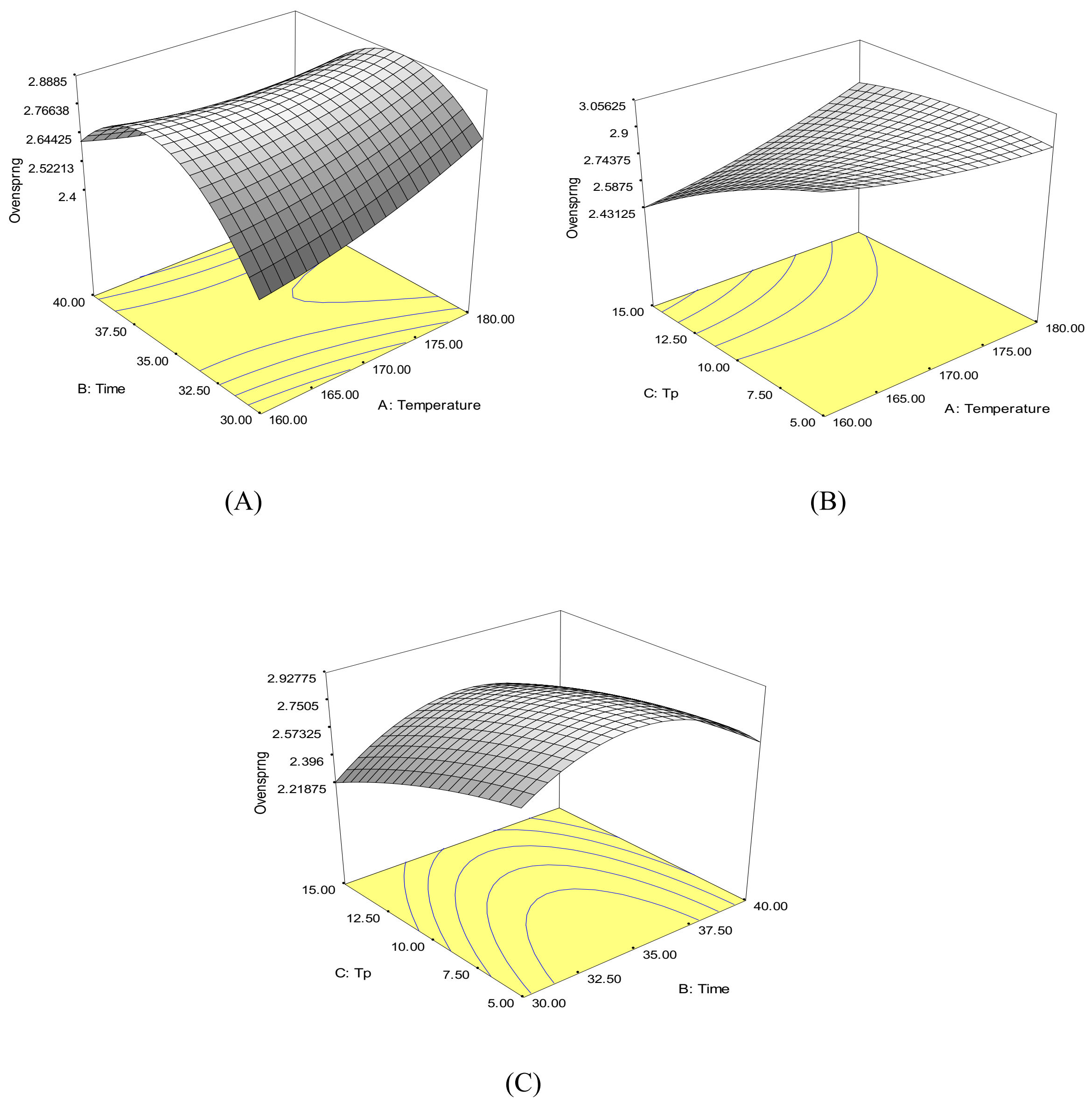


Figure 3. Response surface plot for oven spring of cake from wheat-tigernut pomace flour blends

The volume of the wheat-tigernut pomace cake showed no definite trend but varied significantly ($p<0.05$) from each other. However, the response surface plot for the cake volumes (Figure 2) reveals that increase in the baking time and baking temperature when tigernut pomace was held constant led to a decrease in cake volume. Increasing baking temperature and tigernut pomace led to decrease in cake volume when baking time was held constant while increasing baking time and tigernut pomace when baking temperature was held constant led to an increase in the volume of the cake. From the regression coefficient table, the main, quadratic and interaction effect had no significant effect ($p>0.05$) on the volume of wheat-tigernut pomace cake. The variation in the volume of the cake could be as a result of high fibre in the tigernut pomace flour causing gluten dilution and as a result affecting the gluten matrix and baking. However, other researchers such as Wang *et al.*

(2002) reported that fibre addition in baked product such as bread could cause reduction in loaf volume.

Cake oven spring is a measure of the cake expansion in volume (difference in the height of dough just before and after baking) (Idowu *et al.,* 1996). It measures the dough strength against heat related changes that take place in the oven (Akobundu *et al.,* 1998).The cake oven spring ranged from 2.3 cm to 3.5cm. From the regression coefficient (Table 4), the quadratic model developed for the oven spring had coefficient of determination (R^2) of 0.939 and F-value of 11.38 as shown in Table 4. The interaction effect of baking temperature and tigernut pomace had a significant effect ($p<0.05$) on the cake oven spring while the main effect of tigernut pomace and the quadratic effect of baking time had a negative effect on the oven spring. The response surface plot for cake oven spring (Figure 3) shows that when tigernut pomace was held constant, increase in baking temperature and baking time led to increase in oven spring. Increase in baking temperature and tigernut pomace when baking time was held constant led to a decrease in the oven spring while increasing baking time and tigernut pomace when baking temperature was held constant led to a decrease in oven spring. However, oven spring obtained in this study was higher than the values of 0.36 to 1.09 reported by Oke *et al.* (2017a) for wheat flour substituted with tigernut flour for bread. As the substitution increased, there was decrease in the oven spring, and this can be attributed to the reduction in the amount of gluten and a lower ability of the dough to enclose air (Akobundu *et al.,* 1998).

3.2. Colour attribute of cake produced from wheat-tigernut pomace flour blends

3.2.1. Crumb and crust colour

The values of the tristimulus colour parameters L*, a* and b* of the cake crumb as affected by various temperature–time combination in baking are shown in Table 5.

Table 5. Crumb colour of cake produced from wheat- tigernut pomace flour blends

Baking Temperature (°C)	Baking Time (mins)	TPF (%)	L*	(CRUMB) a*	b*
170	35	10	59.69^{e}	1.47^{f}	27.85^{b}
180	40	10	55.91^{b}	2.31^{i}	27.01^{b}
160	40	10	57.28^{c}	2.04^{h}	27.34^{b}
180	35	5	61.03^{f}	1.30^{e}	30.92^{c}
170	35	10	59.69^{e}	1.47^{f}	27.85^{b}
180	35	15	54.86^{a}	2.54^{j}	25.62^{a}
160	35	15	55.84^{b}	2.00^{h}	24.65^{a}
170	35	10	59.69^{e}	1.47^{f}	27.85^{b}
170	35	10	59.69^{e}	1.47^{f}	27.85^{b}
170	40	15	56.88^{c}	2.26^{i}	25.55^{a}
160	30	10	60.91^{f}	1.23^{d}	27.36^{b}
180	30	10	58.23^{d}	1.82^{g}	27.19^{b}
160	35	5	65.84^{h}	0.08^{a}	31.77^{c}
170	40	5	64.25^{g}	0.70^{c}	31.32^{c}
170	30	15	57.24^{i}	2.04^{b}	25.71^{c}
170	35	10	59.69^{e}	1.47^{f}	27.85^{b}
170	30	5	66.77^{c}	0.16^{h}	30.80^{a}

TPF: Tigernut pomace flour, values are means of triplicate determination. Mean values with different superscripts within the same column are significantly different ($p < 0.05$); L*= lightness, a*= Redness, b*= yellowness

Table 6. Regression coefficient of crumb colour of cake from wheat- tigernut pomace flour blends

CRUMB			
Parameter	L*	a*	b*
β_o	59.69	1.47	27.85
A	-1.23*	0.33*	-0.047
B	-1.10*	0.26*	0.020
C	-4.13*	0.83*	-2.91*
A^2	-1.75*	0.29*	-0.37*
B^2	0.14	0.095	-0.26
C^2	1.45*	-0.27*	0.76*
AB	0.33	-0.080	-0.740
AC	0.96*	-0.17	0.46*
BC	0.54	-0.080	-0.17
R^2	0.991	0.981	0.995
F-VALUE	88.45	4.43	142.67

* = Significant difference ($p<0.05$); β_o= Intercept, A =main effect of temperature, B = main effect of baking time, C = main effect tigernut pomace flour, A^2 = Quadratic effect of temperature, B^2= Quadratic effect of time, C^2 = Quadratic effect of tigernut pomace flour, AB = Interaction effect of temperature and time, AC =Interaction effect of temperature and tigernut pomace flour, BC = Interaction effect time and tigernut pomace flour, R^2= coefficient of determination, L*= lightness, a*= Redness, b*= yellowness

Table 7. Crust colour of cake produced from wheat - tigernut pomace flour blends

Baking Temperature (°C)	Baking Time (minutes)	TPF (%)	(CRUST)		
			L*	a*	b*
170	35	10	53.31^{i}	11.00^{c}	32.32^{i}
180	40	10	36.71^{a}	12.6^{g}	19.96^{a}
160	40	10	49.62^{g}	12.96^{h}	31.04^{g}
180	35	5	37.9^{b}	13.28^{i}	21.33^{c}
170	35	10	53.31^{i}	11.00^{c}	32.32^{i}
180	35	15	36.97^{a}	12.61^{g}	20.68^{b}
160	35	15	45.4^{d}	12.35^{f}	27.72^{d}
170	35	10	53.31^{i}	11.00^{c}	32.32^{i}
170	35	10	53.31^{i}	11.00^{c}	32.32^{i}
170	40	15	47.45^{e}	11.9^{e}	28.94^{e}
160	30	10	48.63^{f}	11.55^{d}	29.01^{e}

180	30	10	39.26[b]	13.00[h]	21.73[c]
160	35	5	50.07[g]	12.39[f]	31.64[h]
170	40	5	47.96[ef]	13.32[i]	30.33[f]
170	30	15	51.51[j]	10.67[a]	30.18[j]
170	35	10	53.31[i]	11.00[c]	32.32[i]
170	30	5	86.36[h]	9.76[b]	34.51[f]

TPF: Tigernut pomace, values are means of triplicate determination.Mean values with different superscripts within the same column are significantly different ($p < 0.05$), L*= lightness, a*= Redness, b*= yellowness.

Table 8. **Regression coefficient of crust colour of cake from wheat- tigernut pomace flour blends**

Parameter	CRUST		
	L*	a*	b*
β_o	53.31	11.00	32.32
A	-5.36	0.28	-4.46*
B	-5.50	0.73*	-0.64
C	-5.12	-0.15	-1.29*
A^2	-12.76*	1.39*	-6.27
B^2	2.99	0.14	-0.62
C^2	2.02	0.27	-0.71
AB	-0.89	-0.45	-0.95*
AC	0.93	-0.16	0.82
BC	8.59*	-0.58	0.74
R^2	0.841	0.900	0.988
F-VALUE	4.13	7.00	64.48

* = Significant difference ($p<0.05$); β_o= Intercept, A =main effect of temperature, B = main effect of baking time, C = main effect tigernut pomace flour, A^2 = Quadratic effect of temperature, B^2= Quadratic effect of time, C^2 = Quadratic effect of tigernut pomace flour, AB = Interaction effect of temperature and time, AC =Interaction effect of temperature and tigernut pomace flour, BC = Interaction effect time and tigernut pomace flour, R^2= coefficient of determination, L*= lightness, a*= Redness, b*= yellowness

Colour is an important quality attribute in the food and bioprocess industries, and it influences consumer's choice and preferences. Food colour is governed by the chemical, biochemical, microbial and physical changes which occur during growth, maturation, postharvest handling and processing (Pathare *et al.,* 2013). It is one of the parameters used for process control during baking and roasting, because brown pigments appear as browning and caramelization reactions progress (Pereira *et al.,* 2013). The values for lightness, redness and yellowness of wheat-tigernut pomace cake crumb ranged from 55.84 to 66.77, 0.16 to 2.54 and 24.65 to 31.77 respectively. The values obtained in this study were within the range obtained in previous works for various baked products such as those reported by Oke *et al.* (2017a) which ranged from 74.63 to 83.50, 1.39 to 3.39 and 27.08 to 30.79 respectively. From the regression coefficient table (Table 6), the main effect of baking temperature, baking time and tigernut pomace and also the quadratic effect of baking temperature negatively affected the crumb lightness. The quadratic effect of tigernut pomace and also the interaction effect of baking temperature and tigernut pomace were significant (p<0.05) on the crumb lightness. The regression coefficient table also reveals that the main effect of baking temperature, baking time and tigernut pomace and the quadratic effect of baking temperature were significant (p<0.05) while the quadratic effect of tigernut pomace had a negative effect on the crumb redness. Figure 4-6 reveals the response surface plots for the crumb colour of cake produced from wheat-tigernut pomace blends.

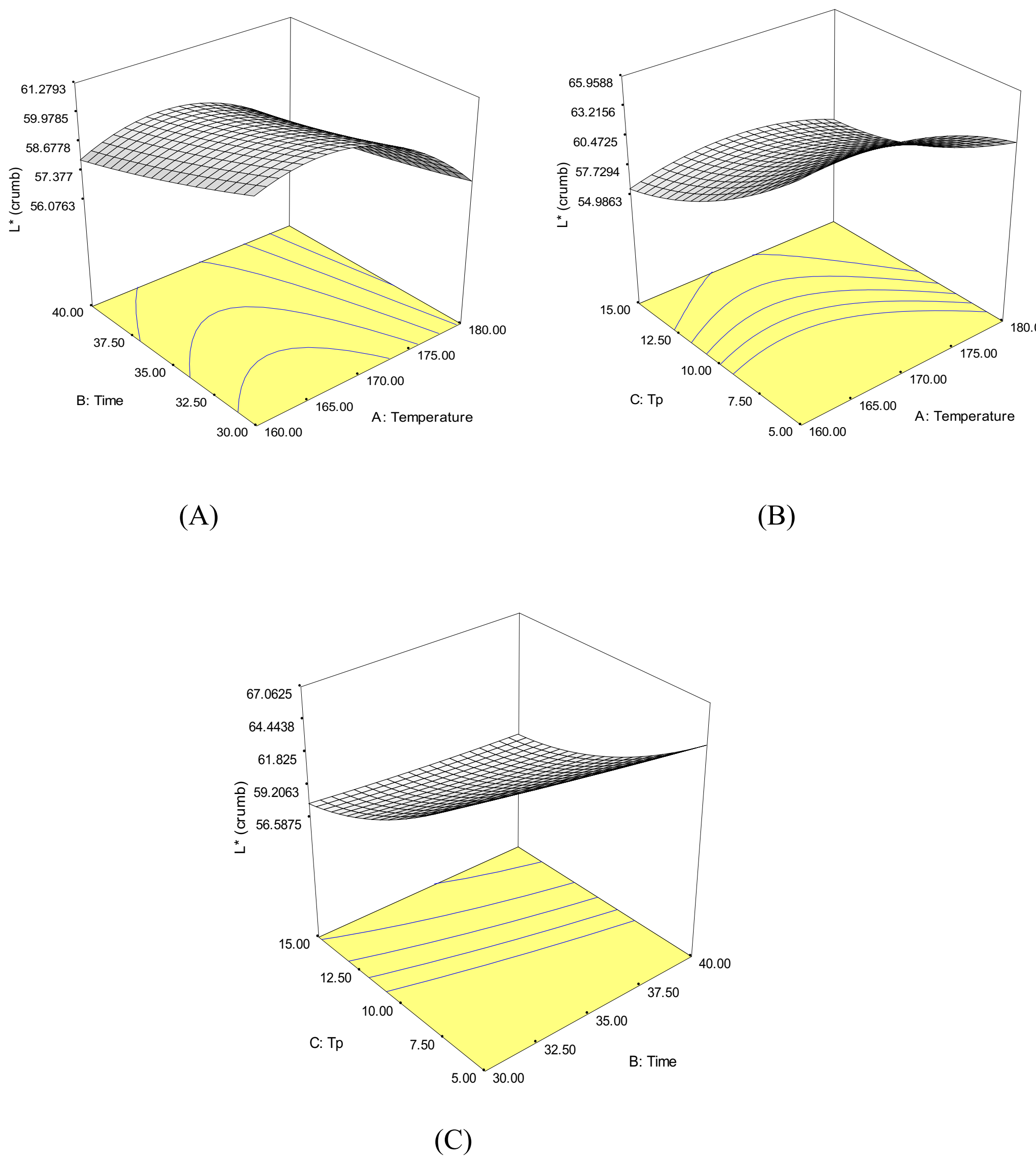
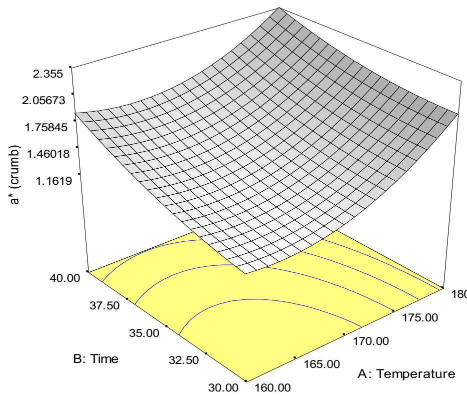
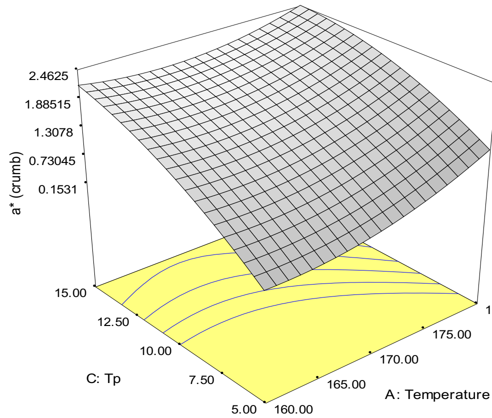


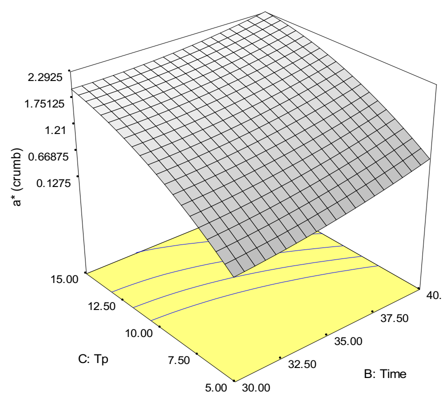
Figure 4. Response surface plot for lightness (L*) of crumb cake from wheat-tigernut pomace flour blends



(A)

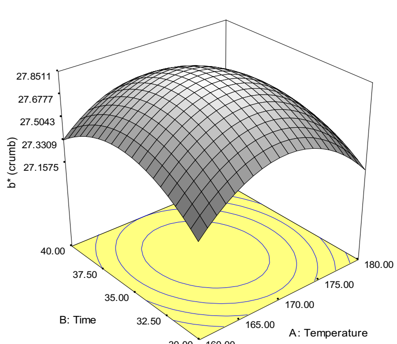


(B)

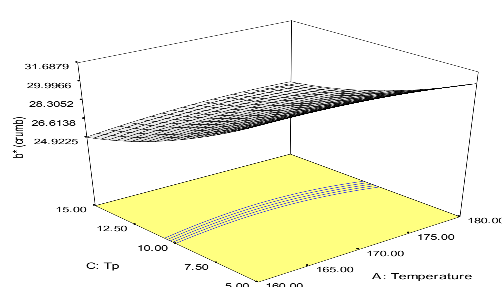


(C)

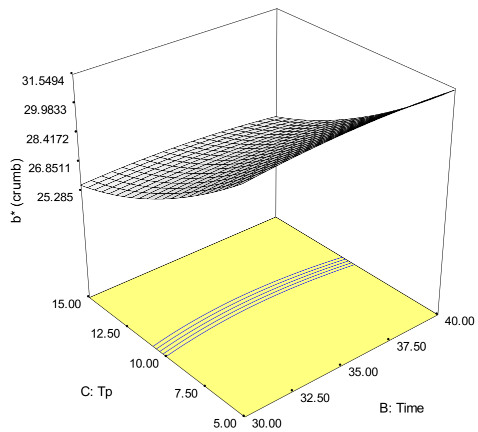
Figure 5. Response surface plot for redness (a*) of crumb cake from wheat-tigernut pomace flour blends



(A)

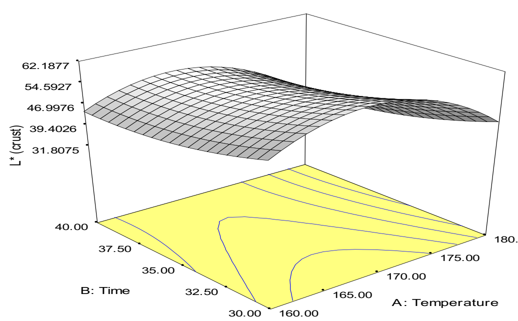


(B)

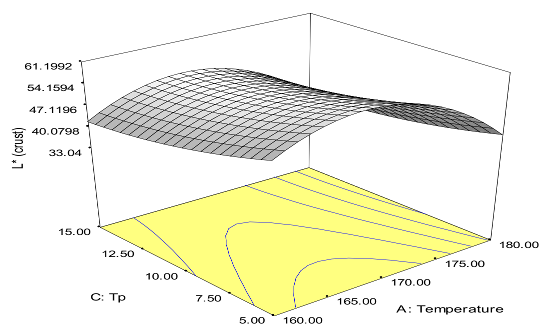


(C)

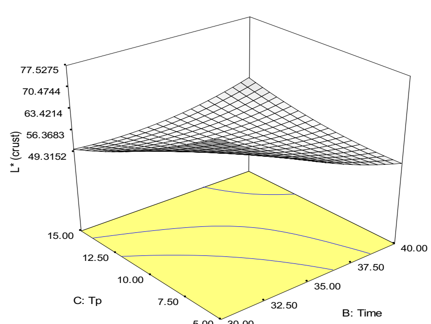
Figure 6. Response surface plot for yellowness (b*) of crumb cake from wheat-tigernut pomace flour blends



(A)

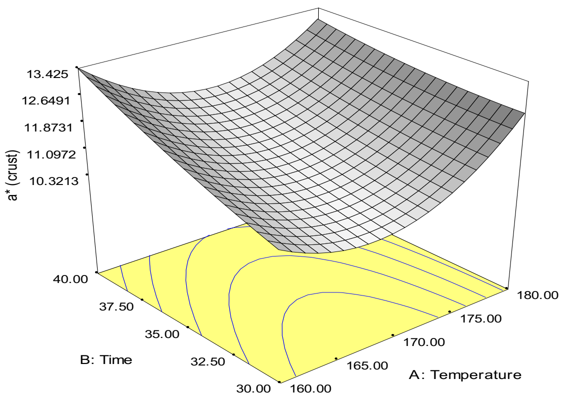


(B)

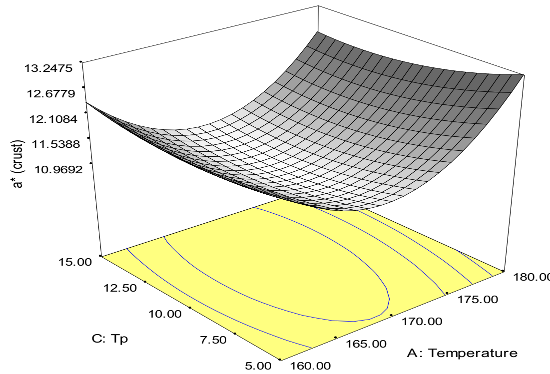


(C)

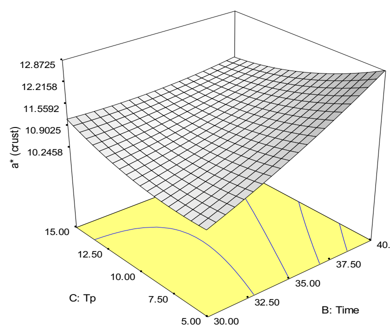
Figure 7. Response surface plot for lightness (L*) of crust cake from wheat-tigernut pomace flour blends



(A)

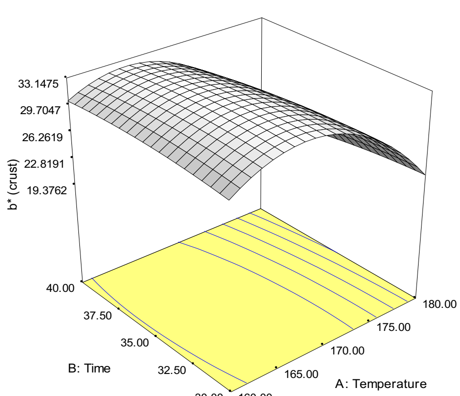


(B)

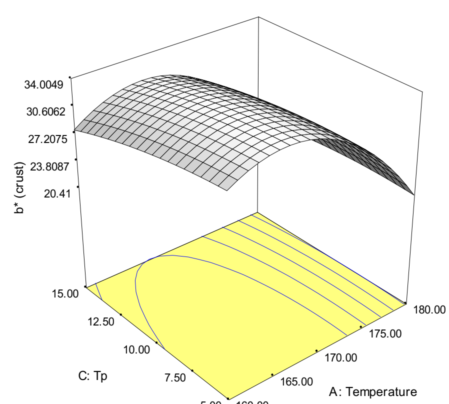


(C)

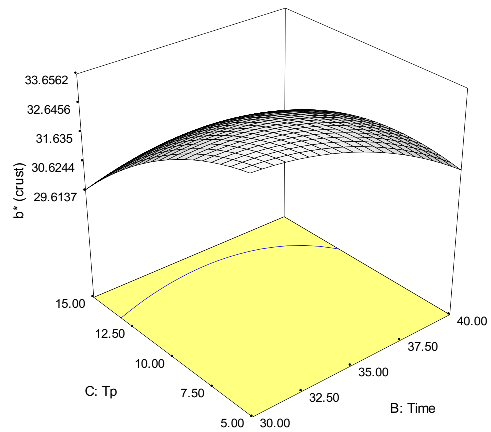
Figure 8. Response surface plot for redness (a*) of crust cake from wheat-tigernut pomace flour blends



(A)



(B)



(C)

Figure 9. Response surface plot for yellowness (b*) of crust cake from wheat-tigernut pomace flour blends

The mean values of crust lightness, redness and yellowness of cake produced from wheat - tigernut pomace colour ranged from 36.71 to 86.36, 9.76 to 13.32 and 19.96 to 34.51 respectively as shown in Table 7. From the regression (Table 8), the interaction effect of time and tigernut pomace had a significant ($p<0.05$) effect on the crust lightness while the quadratic effect of temperature had a negative effect on the crust lightness. The main effect of temperature and tigernut pomace and also the interaction effect of temperature and time had a significant ($p<0.05$) effect on the yellowness of the cake crust negatively. However, as tigernut pomace level increased, the crust colour of the cake became dark brown. The dark brown colour of the cake could be attributed to an increased maillard reaction taking place during baking due to higher lysine content (Abdelrahman, 2014). In the maillard reaction reducing carbohydrates react with free amino acid side chain of protein mainly lysine and lead to amino acid–sugar reaction products (polymerized protein and brown pigments). However, Amir *et al.* (2013) reported that temperature, time and moisture could influence the maillard reaction. Figure 7,8,9 shows the response surface plots for lightness, redness and yellowness of crust colour of cake produced from wheat - tigernut pomace

3.3. Sensory scores of cake produced from wheat-tigernut pomace blends

The mean sensory scores for the cake produced from the wheat-tigernut pomace blends are presented in Table 9. The colour ranged from 5.92 to 7.62. This shows that cake baked from the combination was more appealing to the panelists. The crumb texture of the cake ranged from 5.60 to 7.74 with cake baked at 170°C for 40mins and inclusion of 15% tigernut pomace having the highest score while cake baked at 160°C for 35mins and inclusion of 5% tigernut pomace had the least score. The aroma values for the cakes were significantly different ($p<0.05$). The result showed that cake baked at 160°C for 35mins and inclusion of 5% tigernut pomace had the best aroma and was more preferred by the panelists. The taste ranged from 5.96 to 6.94 with cake baked at 160°C for 40mins and inclusion of 10% tigernut pomace having the highest score for taste and cake baked at 170°C for 40mins and inclusion of 15% tigernut pomace having the lowest score. The overall acceptability of the cake ranged from 5.86-7.86 with cake baked at 160ºC for 35 mins at 5%

tigernut pomace inclusion having the highest while cake baked at 170ºCfor 40 minutes at 15% tigernut pomace inclusion having the lowest in terms of overall acceptability. The result of the sensory evaluation revealed that cakes from wheat flour with low amount of tigernut pomace and those baked at lower temperature and time were rated alike in almost all the sensory attributes evaluated, indicating the feasibility of adding tigernut to baked goods.

Table 9. Sensory score of cake from wheat- tigernut pomace flour blends

Baking Temperature (°C)	Baking Time (minutes)	TPF (%)	Colour	Texture	Aroma	Taste	Overall acceptability
170	35	10	6.28^{abc}	6.06^{abcd}	5.92^{abc}	6.36^{abc}	6.28^{abc}
180	40	10	6.18^{abc}	5.76^{ab}	5.51^{ab}	6.41^{abc}	6.02^{ab}
160	40	10	6.98^{ef}	6.46^{defg}	6.50^{d}	6.94^{d}	6.64^{cd}
180	35	5	6.44^{bcd}	6.24^{bcdef}	5.62^{ab}	6.22^{ab}	6.00^{ab}
170	35	10	6.54^{bcd}	6.32^{cdefg}	5.68^{ab}	6.26^{ab}	6.08^{ab}
180	35	15	6.14^{ab}	5.94^{abc}	5.98^{bc}	6.52^{bcd}	6.22^{abc}
160	35	15	7.16^{fg}	6.66^{fg}	6.34^{cd}	6.88^{cd}	6.92^{d}
170	35	10	6.22^{abc}	5.98^{abcd}	5.98^{bc}	6.52^{bcd}	6.22^{abc}
170	35	10	6.20^{abc}	5.76^{ab}	5.46^{ab}	6.40^{abc}	6.02^{ab}
170	40	15	5.92^{a}	5.60^{a}	5.56^{ab}	5.96^{a}	5.86^{a}
160	30	10	7.52^{gh}	7.32^{h}	7.54^{e}	7.54^{e}	7.58^{e}
180	30	10	5.92^{a}	5.74^{ab}	5.66^{ab}	6.20^{ab}	6.00^{ab}
160	35	5	7.62^{h}	7.74^{h}	7.64^{e}	7.60^{e}	7.86^{e}
170	40	5	6.44^{bcd}	6.16^{bcde}	5.90^{abc}	6.40^{abc}	5.94^{ab}
170	30	15	6.64^{cde}	6.56^{efg}	6.30^{cd}	6.62^{bcd}	6.46^{bc}
170	35	10	6.34^{abcd}	6.06^{abcd}	5.40^{a}	6.12^{ab}	5.90^{a}
170	30	5	6.76^{def}	6.78^{g}	6.40^{cd}	6.52^{bcd}	6.44^{bc}

TPF: Tigernut pomace flour; Mean values with different superscripts within the same column are significantly different

4. Conclusions

The addition of tigernut pomace into wheat flour for cake baking had significant effect on the baking and sensory qualities of cake. The resultant effect of the baking temperature, baking time and tigernut pomace significantly affected the cake oven spring and led to decrease in cake weight. The lightness, redness and yellowness of the cake samples varied significantly among different levels of the substitution. The sensory evaluation revealed that cakes produced from the combination had desirable aroma, taste, crust colour, crumb texture and overall acceptability. However, cake can be baked from wheat-tigernut pomace flour blends between160-170°C for 30-35 minutes with inclusion of 10% tigernut pomace flour to yield cake of enhanced quality attributes especially volume, colour, texture and overall acceptability. Further studies should be carried out on the proximate and storage stability of cake from wheat-tigernut pomace.

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