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Physicochemical and Sensory Properties of Cookies: Effect and Optimization of Baking Conditions and Partial Substitution of Fat with Papaya Puree of Varying Ripening Levels

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ABSTRACT

This study aims to evaluate and optimize the effect of baking temperature, oven rack speed and partial substitution of fat with papaya puree of varying ripening levels on the physicochemical and sensory properties of cookies. Cookies produced with very ripe papaya puree reduced the baking time, increased the protein, fat, ash, calcium, total phenolic contents and sensory properties desirability. Cookies produced with hard ripe papaya puree increased the vitamin C, fiber, carbohydrate and spread ratio while cookies produced with the unripe papaya puree had the lowest moisture content and highest cookies thickness. The optimum conditions for cookies with desirable moisture, crude protein, vitamin C, calcium and total phenolic contents was established at 154°C oven temperature, 8 rpm oven rack speed and the use of very ripe papaya puree. The use of papaya puree with varying ripening levels could increase the diversity of healthy cookies that can be produced from papaya.

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ripening; optimization

Introduction

Papaya (*Carica papaya* L.) is a tropical fruit with a presence both in the national and international market due to its therapeutic and nutritional properties (Bolarinwa, Aruna, Adejuyitan, Alabi, & Alabi, 2020). It is also appreciated for its characteristics flavor and sweetness (Fabi & Do Prado, 2019). According to the Food and Agriculture Organization of the United Nations (FAOSTAT) (2017), Asia countries account for 56% of the worldwide production of papaya, 16% in South America, 10% in Africa and 9% in Central America. Papaya compared to other fruits like oranges and carrots is a good source of protein, vitamin C, β -carotene, calcium, potassium, iron, sodium and magnesium (Bolarinwa, Aruna, Adejuyitan, Alabi, & Alabi, 2020; Chukwuka, Iwuagwu, & Uka, 2013). The ripening stages of papaya can be classified as unripe, hard ripe and very ripe with the stages having different nutritional compositions

(Chukwuka, Iwuagwu, & Uka, 2013; Oloyede, 2005). Researchers over the years have only emphasized on the use of hard ripe papaya for the production of different products such as bread, cake and cookies with little or no emphasis on the use of unripe and very ripe papaya. Most times, the unripe papaya and very ripe papaya are usually disposed of as waste or categorized as an uneconomical fruit. However, due to the urgent need to accelerate the agricultural productivity of food by 100% based on the 2030 agenda of the United Nations, there is a need to explore the use of unripe and very ripe papaya in the design and development of nutraceutical ingredients or functional products. According to Ovando-Martinez et al. (2018) and Akubor and Popoola (2017), the biological properties of the edible part of papaya could serve as a fat replacer, thickening agents, antimicrobial, antioxidant and flavoring agents. These have made them an interesting ingredient for use in the food industry.

Cookies have become popular among modern consumers due to their general acceptability, shelf life and convenience. Cookies are popular and widely consumed all over the world (Kolawole, Akinwande, & Ade-Omowaye, 2020). According to Lobstein and Jackson-Leach (2007), eating three meals in a day may not be adequate to provide the essential nutrients needed for human development, so snacking in between regular meals is important to compensate for any deficiencies. Cookies are relatively high in fat and fat provides about 50% of the calories found in its nutrient (Wekwete & Navder, 2008). Fat is one of the most common ingredients used in cookies production to improve the product's sensory characteristics such as taste, flavor, mouthfeel and texture. However, because of the health risks associated with the use of fat, as well as consumer demand for low-fat or fat-free food items, there is a need to find an alternative ingredient that can be used to substitute fat during cookies production. Excessive intake of foods high in fat can be detrimental to humans, resulting in diseases such as diabetes, cardiovascular disease, cancer, dental caries, and osteoporosis, as well as overweight and obesity (Akubor & Popoola, 2017). As a result, consumers are concerned about the amount of fat in their diets and are interested in low-fat and heart-healthy foods. Alternative additives must be produced and used as fat replacers to satisfy market demand for low fat or fat-free cookies. Lipid, starch, and protein-based derivatives are the three types of fat-replacers (Akubor & Popoola, 2017). Natural fat replacers such as avocado puree (Wekwete & Navder, 2008), Pumpkin puree (Arifin, Izyan, & Huda-Faujan, 2019), Okra gum (Romanchik-Cerpovicz, Tilmon, & Baldree, 2002), Mug bean paste (Adair, Knight, & Gates, 2001) and papaya puree (Akubor & Popoola, 2017; Duffrin, Holben, & Bremner, 2001) have been used with some degree of success in baked products such as cookies, muffins, biscuits and cakes. Hard ripe papaya puree had been used by Duffrin, Holben, and Bremner (2001) and Akubor and Popoola (2017) as a fat substitute in the production of muffins and cake.

However, literature is sparse on the use of papaya puree made from unripe or very ripe papaya as a fat replacer or substitute for the production of cookies. The flexibility, durability and efficiency of rotary oven in the baking of different baked products such as bread, cookies, pastries, and puddings has made it the equipment of choice among bakers (Sanusi, Sunmonu, Adepoju, Abodunrin, & Ajibade, 2020). However, there is also a paucity of information on the effect of baking temperature, oven rack speed and ripening levels of papaya puree on the physicochemical (baking time, cookies thickness, spread ratio, proximate composition, calcium content, vitamin C content and total phenolic content) and sensory properties of cookies. Information on the partial substitution of fat with varying degrees of papaya puree from unripe, hard ripe and very ripe papaya puree could aid in establishing the most suitable fat replacer and help in increasing the usage of under-utilized unripe or very ripe papaya. It could also be a strategic way of producing cookies with diverse nutritional and sensory properties. Therefore, this study aimed to evaluate and optimize the effects of baking temperature (130°C, 150°C and 170°C), oven rack speed (stationary, 10 and 20 rpm) and partial substitution of fat with papaya puree of varying ripening levels (unripe, hard ripe and very ripe) on physicochemical and sensory properties of cookies using Response Surface Methodology (RSM).

Materials and methods

Materials

Wheat flour, margarine (fat), sodium bicarbonate, sugar, skimmed powdered milk and exotic chicken eggs used were purchased from a local manufacturer in Ilorin, Nigeria. Mature unripe, hard ripe and very ripe papayas were harvested at the University of Ilorin research farm for easy identification based on ripening levels as shown in [Figure 1](#).

Methods

Preparation of papaya puree

Hard ripe and very ripe papaya were washed, peeled and de-seeded while the unripe papaya was peeled and de-seeded, and the mesocarp was cut into small slices and boiled in hot water at 100°C for 5 min to soften the mesocarp. The mesocarp of the unripe, hard ripe and very ripe papaya were blended in an electric blender (Model 550w: India) separately until smooth purees were obtained ([Figure 1](#)). The smooth papaya purees were poured inside a container and kept in a refrigerator until when required for use.

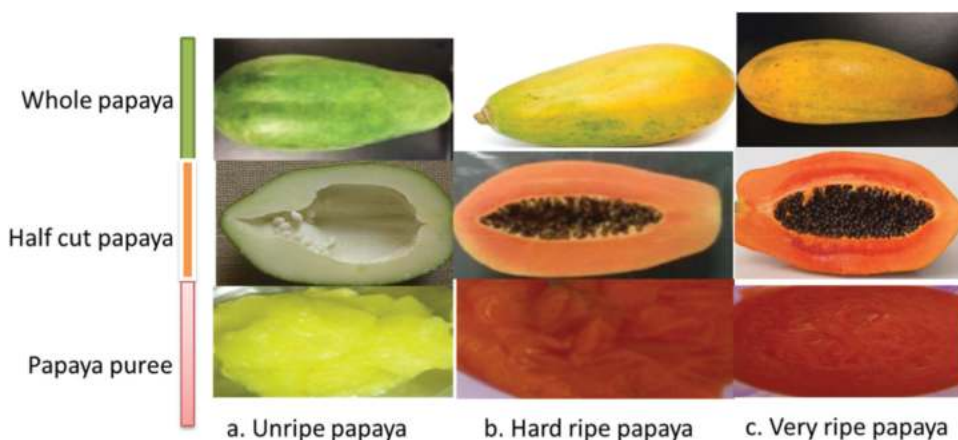


Figure 1. Ripening levels of papaya based on unripe, hard ripe and very ripe.

Table 1. RSM-CCD design of effect of papaya puree, baking temperature and oven rack speed on the physicochemical properties of cookies.

Process Factors	Code	Unit	Low (−1)	Medium 0	High (+1)
Papaya puree type	A		1	2	3
Baking temperature	B	°C	130	150	170
Oven rack speed	C	rpm	0	10	20

where 0 is stationary oven rack speed, 1 is unripe papaya puree, 2 is hard ripe puree and 3 is very ripe puree.

Experimental design

The Response Surface Methodology-Faced Central Composite Design (RSM-FCCD) of design expert-13 was used to study the effects of ripening levels of papaya puree, baking temperature and oven rack speed on the physicochemical and sensory properties of cookies. Table 1 shows the experimental design variables. The FCCD has three factors and three levels as shown in Table 1. The levels of each process factor were established based on preliminary trials and previous works of Wiese and Duffrin (2003) and Sanusi, Sunmonu, Adepoju, Abodunrin, and Ajibade (2020).

Cookies preparation

The margarine (fat) was partially substituted with 50% of papaya purees. Papaya purees of 7.7% unripe, hard ripe and very ripe were mixed separately with 51% wheat flour to produce wheat flour-papaya puree blends. The wheat flour-papaya blends were mixed with 17.2% of sugar, 8.6% exotic chicken egg, 7.7% margarine (fat), 7.7% skimmed milk powder and 0.3% sodium bicarbonate to form dough. The dough was rolled and flattened on a clean surface into a uniform thickness of 2 mm before cutting out to shapes using a hand-cutter. The cutout doughs were baked in a developed rotary oven as shown in Figure 2 at a baking temperature

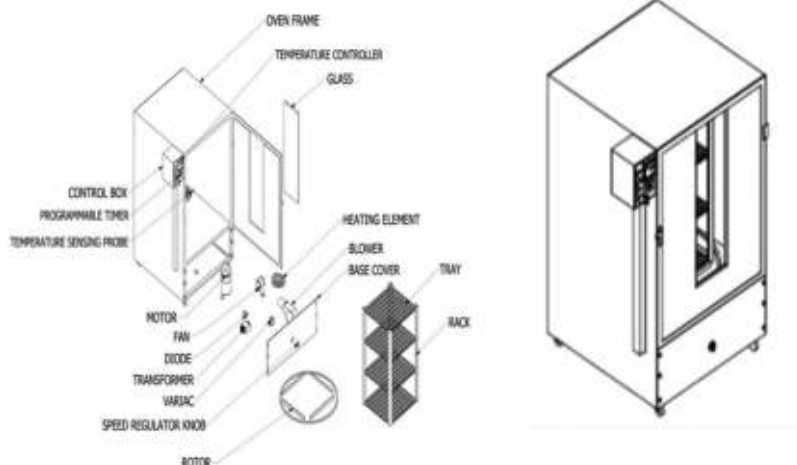


Figure 2. Developed rotary oven.

that ranged from 130°C to 170°C and oven rack speed of 0–20 rpm. To determine the doneness of the cookies, the rotary oven was opened at intervals and the sides of the cookies were pushed very lightly with a spatula, if the edge was observed to stay firm and does not fall inwards, then the cookies were assumed to be done and the baking time was recorded. However, if there is a noticeable indentation, then the cookies would be allowed to stay for more minutes in the oven. After baking, the cookies were cooled to room temperature by natural air and then packed in transparent zip-lock nylon before being taken for analysis.

Physicochemical properties of cookies

Physical properties

The thickness and spread ratio of the cookies were determined using the approach described by Kolawole, Akinwande, and Ade-Omowaye (2020).

Proximate composition

The crude protein, ash, crude fat, crude fiber and moisture content of the cookies were determined using the AOAC official method (2012). The carbohydrate contents of the cookies were determined by difference.

Vitamin C content

The determination of vitamin C contents of the cookies samples was done by reversed-phase HPLC using the pronto SIL C18 AQ column and smart line HPLC. Staroverov et al. (2004) reported a similar approach.

Calcium content

Calcium contents were determined using flame photometry (AOAC, 2010). The concentration was determined after wet digestion with a mixture of perchloric and nitric acid using Atomic Absorption Spectrophotometry (AAS, Model Spq, pyeunicam, UK).

Total Phenolic Content (TPC)

Total phenols (TP) were determined colourimetrically using Folin–Ciocalteu reagent, as previously described by Paśko et al. (2009). Total phenols assay was conducted by mixing 2.7 mL of de-ionized water, 0.3 mL extracts, 0.3 mL 7 g/100 g, Na_2CO_5 and 0.5 mL Folin–Ciocalteu reagent. The absorbance of the mixture was measured at 725 nm using spectrophotometer Jasco UV-530 (Medson, Paczkowo, Poland). A standard curve was prepared with gallic acid. The final results were given as gallic acid equivalents (mg GAE/g).

Sensory evaluation

The cookies were coded and served to thirty-five (35) randomly selected semi-trained panelists (22–45 year old male and female). The semi-trained panelists were selected based on their familiarity with cookies. The panelists were asked to score the cookies samples for taste, texture, mouthfeel, color and overall acceptability, using a nine (9) point hedonic scale. The scale ranges from 1 to 9. One (1) indicates dislike extremely while nine (9) means like extremely.

Numerical optimization

The numerical optimization of the baking temperature, oven rack speed and papaya puree type was done using a response optimizer in the design expert 13 software. The objective of the optimization was to optimize the moisture content, crude protein, vitamin C, calcium and total phenolic contents of the cookies. The global desirability function of the optimum conditions was determined using the approach reported by Sanusi and Akinoso (2020).

Validation of the optimal conditions

The predicted optimal conditions obtained from producing the cookies were experimented with within the laboratory to validate the optimal conditions using relative error using Equation 2 as described by Sanusi and Akinoso (2021).

$$re = \frac{EV - PV}{EV} \times 100 \quad (2)$$

where *re* is a relative error, *EV* is the experimental value and *PV* is the predicted value.

Results and discussion

Physical properties of the cookies

The baking time for the cookies ranged between 21.50 and 56.70 min, cookies thickness (5.93 and 8.29 mm) and spread ratio (3.26 and 4.71). The longest baking time was observed at 130°C baking temperature, stationary oven rack speed and when unripe papaya puree was used while the shortest baking time was observed at 170°C baking temperature, stationary oven rack speed and when very ripe papaya puree was used. [Figure 3a](#) showed that an increase in baking temperature leads to a decrease in baking time. This trend could be associated with an increase in the temperature profile due to heat transfer, which accelerates the baking time. The result corroborates with the findings of Ureta, Olivera, and Salvadori (2017) and Sanusi, Sunmonu, Adepoju, Abodunrin, and Ajibade (2020) that no matter the conventional mode of heat transfer, baking time decreases with an increase in baking temperature. Also, cookies produced with unripe papaya increased the baking time than the ones produced with hard ripe papaya puree and very ripe papaya puree. This could be attributed to the difference in the composition of each puree. The cookies' thickness with the highest value was observed at 170°C baking temperature, stationary oven rack speed and when the cookies were produced from unripe papaya puree. The cookies thickness with the lowest value was obtained at 130°C oven temperature, 10 rpm oven rack and when the cookies were produced from hard ripe papaya puree. [Figure 3b](#) showed that cookies produced with unripe papaya puree favored an increase in cookies thickness. This could be a result of the low moisture content that was present in unripe papaya, thus, making the dough to be more viscous with reduced water content. Spread ratio is one of the key quality parameters in cookies production. Barak, Mudgil, and Khatkar (2013) stated that the higher the spread ratio, the better the cookies desirability. The highest spread ratio (4.71) was observed at 130°C baking temperature, 10 rpm oven rack speed and when very ripe papaya was used. [Figure 3c](#) showed that a higher spread ratio can be obtained with either ripe papaya puree or overripe papaya puree. The spread ratio obtained in this study was within the range of the spread ratio reported by Kolawole, Akinwande, and Ade-Omowaye (2020) during the production of cookies from orange-fleshed sweet potato cookies enriched with sclerotium of edible mushroom.

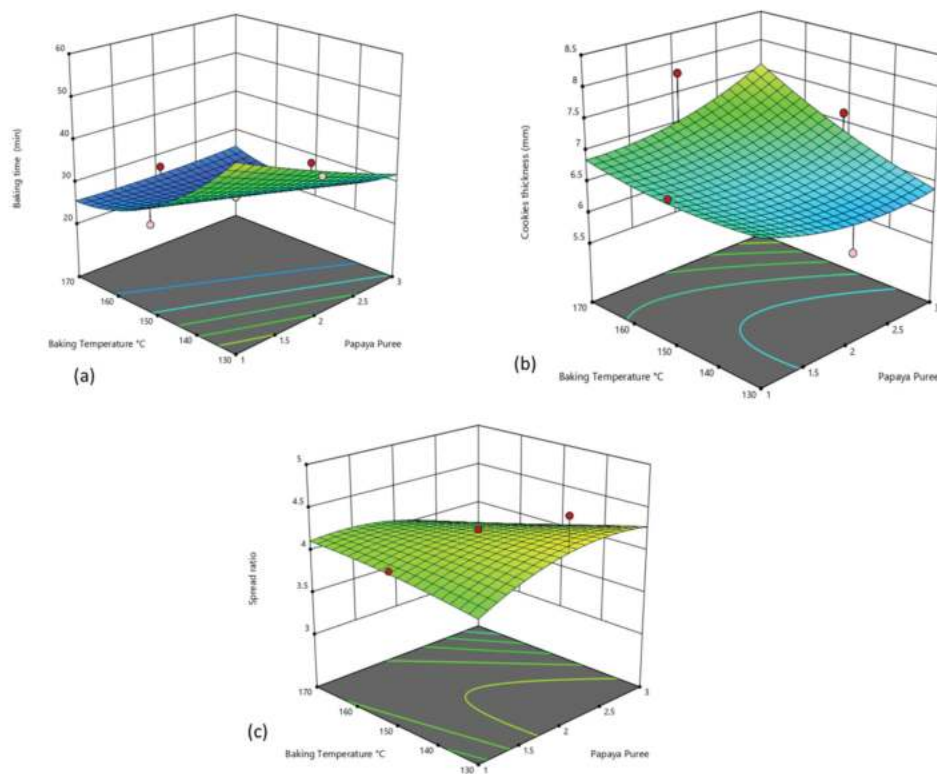


Figure 3. Effect of baking temperature and papaya puree on the physical properties: (a) baking time (b) cookies thickness and (c) spread ratio of cookies.

Proximate composition of the cookies

Table 2 showed the effect of varying ripening levels of papaya puree, baking temperature and oven rack speed on the proximate composition of cookies. The moisture content of the cookies ranged between 6.92 and 8.09, ash content (2.01 and 4.09%), crude fat content (1.49 and 1.87%), crude protein content (7.69 and 12.67%), fiber content (1.41 and 1.66%) and carbohydrate (72.77 and 79.28%), respectively. The highest moisture content was achieved at 170°C baking temperature, stationary oven rack speed, and when very ripe papaya puree was used while the lowest moisture content was achieved at 130°C baking temperature, 10 rpm oven rack speed, and when unripe papaya puree was used. Ripening levels of papaya puree was observed to influence the moisture content. The substitution of fat with very ripe papaya puree gave cookies higher moisture content than hard ripe and unripe papaya puree irrespective of the baking temperature and oven rack speed. Ash content is the inorganic constituent of the products that are important in mineral quantifications and microelement determinations. The highest ash content was achieved at 130°C baking temperature, stationary oven rack speed, and

Table 2. Effect of papaya puree, baking temperature and oven rack speed on proximate composition of cookies.

Samples	Papaya puree type	Baking temperature (°C)	Oven rack speed	Moisture content (%)	Ash content (%)	Crude fat content %	Crude protein content (%)	Crude fiber content	Carbohydrate content
A	1	130	0	6.92 ± 0.01 ^e	3.88 ± 0.06 ^c	1.78 ± 0.01 ^c	8.07 ± 0.01 ^j	1.47 ± 0.02 ^h	77.89 ± 0.08 ^d
B	3	130	0	8.07 ± 0.01 ^a	4.09 ± 0.02 ^a	1.87 ± 0.01 ^a	10.15 ± 0.01 ^h	1.53 ± 0.01 ^e	74.30 ± 0.03 ^h
C	1	170	0	7.09 ± 0.01 ^{de}	3.14 ± 0.02 ^e	1.51 ± 0.01 ^{ij}	8.04 ± 0.01 ⁱ	1.44 ± 0.01 ⁱ	78.80 ± 0.03 ^c
D	3	170	0	8.09 ± 0.02 ^a	2.09 ± 0.01 ^k	1.81 ± 0.01 ^b	12.19 ± 0.01 ^b	1.51 ± 0.01 ^{ef}	74.29 ± 0.08 ^h
E	1	130	20	7.09 ± 0.01 ^{de}	2.97 ± 0.02 ^h	1.49 ± 0.01 ^j	8.01 ± 0.01 ^{lm}	1.41 ± 0.01 ^j	79.05 ± 0.01 ^b
F	3	130	20	8.02 ± 0.01 ^a	4.02 ± 0.01 ^b	1.87 ± 0.01 ^a	11.49 ± 0.01 ^f	1.55 ± 0.01 ^d	73.06 ± 0.00 ⁱ
G	1	170	20	6.97 ± 0.02 ^e	3.04 ± 0.02 ^g	1.52 ± 0.01 ⁱ	8.05 ± 0.01 ^{kl}	1.46 ± 0.01 ^{hi}	78.98 ± 0.01 ^b
H	3	170	20	7.24 ± 0.36 ^d	2.70 ± 0.01 ⁱ	1.71 ± 0.01 ^e	9.65 ± 0.01 ⁱ	1.53 ± 0.01 ^e	76.96 ± 0.02 ^e
I	1	150	10	7.01 ± 0.01 ^e	3.09 ± 0.01 ^f	1.57 ± 0.02 ^h	7.99 ± 0.01 ^m	1.49 ± 0.01 ^{gh}	78.86 ± 0.02 ^c
J	3	150	10	7.56 ± 0.01 ^{bc}	3.66 ± 0.01 ^d	1.74 ± 0.01 ^d	12.67 ± 0.01 ^a	1.56 ± 0.01 ^d	72.83 ± 0.01 ^j
AA	2	130	10	7.75 ± 0.01 ^b	2.11 ± 0.01 ^k	1.56 ± 0.01 ^h	7.69 ± 0.01 ⁿ	1.62 ± 0.01 ^b	79.28 ± 0.01 ^a
BB	2	170	10	7.96 ± 0.02 ^a	3.99 ± 0.01 ^b	1.65 ± 0.01 ^f	12.05 ± 0.01 ^c	1.59 ± 0.01 ^c	72.77 ± 0.04 ^j
CC	2	150	0	7.59 ± 0.01 ^{bc}	3.02 ± 0.01 ^g	1.59 ± 0.01 ^g	11.86 ± 0.03 ^e	1.66 ± 0.01 ^a	74.28 ± 0.04 ^h
DD	2	150	20	7.46 ± 0.03 ^c	2.01 ± 0.01 ^l	1.64 ± 0.01 ^f	10.67 ± 0.01 ^g	1.47 ± 0.01 ^{gh}	76.76 ± 0.05 ^f
EE	2	150	10	7.61 ± 0.02 ^{bc}	2.17 ± 0.02 ^j	1.69 ± 0.01 ^e	12.01 ± 0.01 ^d	1.51 ± 0.01 ^{ef}	75.02 ± 0.01 ^g

Mean and standard deviation with different superscript along the same column are significantly different at $p < 0.05$. Note: 0 is stationary oven rack speed, 1 is unripe papaya puree, 2 is hard ripe papaya puree and 3 is very ripe papaya puree.

when very ripe papaya puree was used while the lowest ash content was achieved at 150°C baking temperature, 20 rpm oven rack speed, and when hard ripe papaya puree was used. The ripening levels of papaya puree were observed to influence the ash content. The substitution of fat with very ripe papaya puree gave the cookies the highest ash content than hard ripe and unripe papaya puree. Ash content of 2.86% was reported by Bolarinwa, Aruna, Adejuyitan, Alabi, and Alabi (2020) in the production of papaya fortified pan bread while Akubor and Popoola (2017) reported 2.3% in cake fortified with hard ripe papaya puree. However, the ash content obtained in this study was higher and this could be traced to the use of very ripe papaya puree. Cookies with higher ash content are expected to promote food nutrition as well as increase longevity. The highest fat content was observed at 130°C baking temperature, stationary and 20 rpm oven rack speed and when very ripe papaya puree was used, while the lowest fat content was achieved at 130°C baking temperature and 20 rpm oven rack speed, and when unripe papaya puree was used to produce the cookies. It was observed that the use of unripe papaya puree gave cookies with lower fat content than the hard ripe and very ripe papaya puree regardless of the baking temperature and oven rack speed. Khatun, Jahan, Hosain, Mardy, and Rahman (2016) reported fat content of 1.75% for crackers fortified with hard ripe papaya. Protein serves as a bodybuilder and enzyme for numerous purposes and it is of great importance in the growth and development of humans. The highest protein content (12.67%) was achieved at 150°C baking temperature and 10 rpm oven rack speed, and when very ripe papaya puree was used. It was observed that very ripe papaya puree provided cookies with the highest protein content than the hard ripe and unripe papaya puree. Akubor and Popoola (2017) reported a crude protein of 12.0% for cake fortified with hard ripe papaya puree while Bolarinwa, Aruna, Adejuyitan, Alabi, and Alabi (2020) reported 11.41% as the highest crude protein obtained in hard ripe papaya puree fortified pan bread. These values were lower than the 12.67% achieved in the cookies produced with very ripe papaya puree. The highest crude fiber (1.66%) was observed at 150°C baking temperature, stationary oven rack speed, and when the hard ripe papaya puree was used. The substitution of fat with the hard ripe papaya puree gave cookies with higher fiber content than unripe and very ripe papaya. Bolarinwa, Aruna, Adejuyitan, Alabi, and Alabi (2020) reported the crude fiber content of papaya fortified pan bread to range between 0.80 and 1.38% and this was lower than the range obtained in this study. The difference could be traced to the composition of the papaya used and the processing conditions. Cookies with higher crude fiber content aid in lowering blood cholesterol level and slow down the process of absorption of glucose, thereby helping in keeping blood glucose level in control (Emede, Ajayo, & Agho, 2017). The highest carbohydrate content was observed at 130°C baking temperature, 10 rpm oven rack speed, and when hard ripe papaya puree was used while

the lowest carbohydrate content was achieved at 170°C oven rack speed, 10 rpm oven rack speed, and also when the hard ripe papaya puree was used. It can be deduced that the baking temperature at a lower temperature favors higher carbohydrate content than at a higher temperature. In addition, it was also observed that cookies produced with unripe papaya puree have higher carbohydrate content than the ones produced with very ripe papaya puree.

Calcium, Vitamin C and Total phenolic content of the Cookies

The calcium content of cookies produced with varying ripening levels of papaya puree and baking temperature are shown in [Figure 4a](#). The calcium content ranged between 21.95 mg/100 g and 58.3 mg/100 g. The highest calcium content was observed at 150°C baking temperature and when very ripe papaya puree was used while the lowest was observed at 130°C baking temperature and when hard ripe papaya puree was used. Therefore, the substitution of fat with very ripe papaya puree gave cookies with higher calcium content than the unripe and ripe papaya puree. The highest calcium content obtained for the cookies was higher than 24.88 mg/100 g reported by Pathak, Thakur, and Gupta (2018) in the production of biscuits fortified with ripe papaya. The vitamin C content cookies produced with varying ripening levels of papaya puree and baking temperature is shown in [Figure 4b](#). The vitamin C content ranged between 1.55 mg/100 g and 4.05 mg/100 g. The highest value of vitamin C content was observed at 170°C baking temperature and when the hard ripe papaya puree was used to produce cookies, while the lowest was achieved at 170°C baking temperature and when unripe papaya puree was used. From [Figure 4b](#), the use of hard ripe papaya puree and very ripe papaya puree increases the vitamin C content than unripe papaya puree regardless of the baking temperature and oven rack speed. The highest vitamin C content (4.05 mg/100 g) obtained in this study was higher than vitamin 3.60 mg/100 g reported by Kolawole, Akinwande, and Ade-Omowaye (2020) in the production of novel cookies produced from orange-fleshed sweet potato cookies enriched with sclerotium of edible mushroom (*Pleurotus tuber-regium*). Cookies high in Vitamin C tend to act as an antioxidant in the blood and other fluids (World Health Organization, 2003). The total phenolic content ranged between 1.44 mg GAE/g and 2.21 mg GAE/g based on the effect of the varying ripening levels of papaya puree and baking temperature. [Figure 4c](#) showed that substitution of fat with very ripe papaya puree gave cookies with higher total phenolic content than the unripe and hard ripe papaya puree. The use of very ripe papaya puree in cookies gave higher total phenolic content (2.21 mg GAE/g)

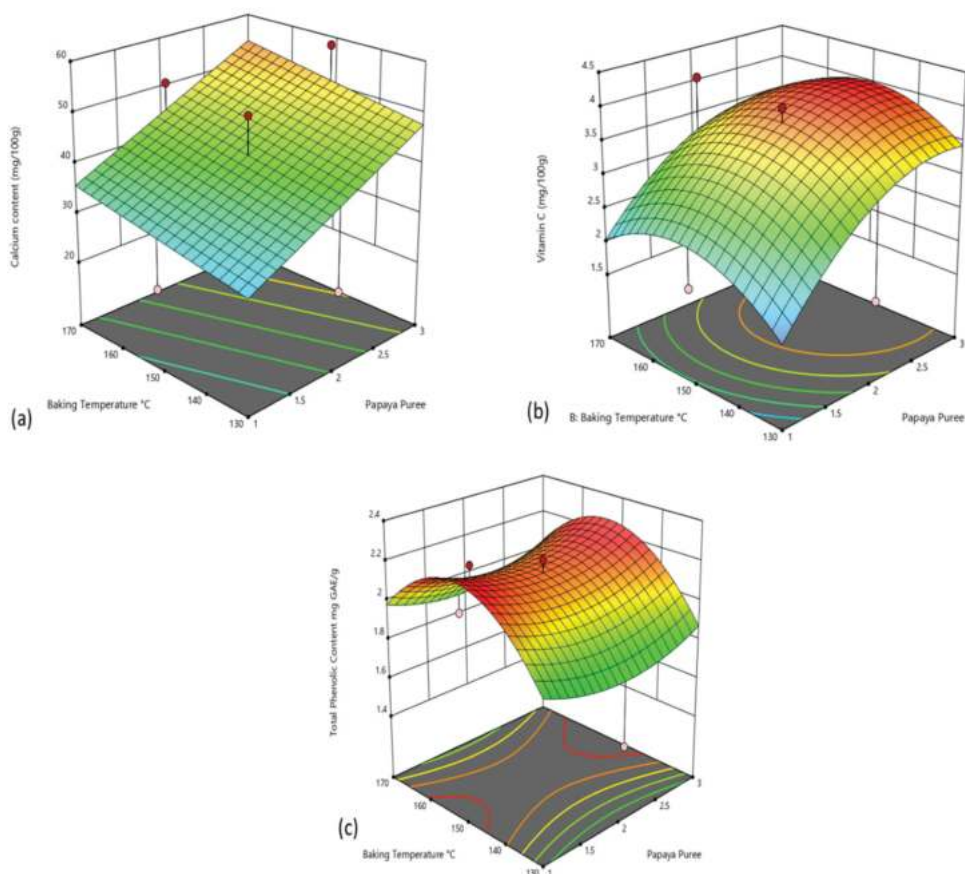


Figure 4. Effect of baking temperature and papaya puree on the: (a) calcium content (b) vitamin C and (c) total phenolic content of cookies.

than 1.02 mg GAE/g reported by Pathak, Thakur, and Gupta (2018) in the production of biscuit fortified with papaya.

Cookies sensory attributes

The sensory attributes of the cookies vary significantly at $p < 0.05$. Table 3 showed the sensory attributes of the cookies. The taste of the cookies ranged between 6.80 and 8.20 while the texture ranged between 7.00 and 8.60. Sample EE was rated to have the best taste and texture. The choice for sample EE could be a result of the higher fat content that is present in the very ripe papaya puree used to produce the cookies, as fat improves taste and texture. In addition, the baking temperature (150°C) and oven rack speed (10 rpm) could influence the texture due to the form of starches in the cookies composition and causes its outer surfaces to brown, giving it an attractive appearance and taste. The color of samples ranged between 7.00 and 9.00. Sample E and DD were rated to have

Table 3. Sensory attributes of the cookies.

Samples	Papaya puree type	Oven Temperature	Oven Rack Speed	Taste	Texture	Color	Mouthfeel	Overall Acceptability
A	1	130	0	8.00 ± 0.00 ^{ab}	8.00 ± 0.65 ^{bc}	8.60 ± 0.51 ^b	8.00 ± 0.65 ^a	8.20 ± 0.41 ^{bc}
B	3	130	0	6.80 ± 0.41 ^f	7.00 ± 0.65 ^f	8.20 ± 0.41 ^{cd}	7.60 ± 0.51 ^{ab}	7.60 ± 0.51 ^d
C	1	170	0	7.60 ± 0.83 ^{bcd}	7.80 ± 0.77 ^{bcd}	8.40 ± 0.51 ^{bc}	7.40 ± 0.51 ^b	8.20 ± 0.77 ^{bc}
D	3	170	0	7.80 ± 0.77 ^{abc}	8.00 ± 0.65 ^{bc}	7.40 ± 0.51 ^e	7.60 ± 0.51 ^{ab}	8.00 ± 0.65 ^{cd}
E	1	130	20	7.00 ± 0.65 ^{ef}	7.20 ± 0.41 ^{ef}	9.00 ± 0.00 ^a	6.80 ± 0.41 ^c	7.80 ± 0.41 ^{cd}
AA	3	130	20	7.60 ± 0.51 ^{bcd}	8.20 ± 0.41 ^{ab}	8.00 ± 0.00 ^d	8.00 ± 0.00 ^a	8.20 ± 0.41 ^{bc}
BB	1	170	20	7.40 ± 0.51 ^{cde}	7.40 ± 0.51 ^{def}	7.40 ± 0.51 ^e	7.80 ± 0.41 ^{ab}	8.20 ± 0.41 ^{bc}
CC	3	170	20	7.40 ± 0.51 ^{cde}	8.20 ± 0.77 ^{ab}	7.00 ± 0.00 ^f	7.40 ± 0.51 ^b	7.80 ± 0.77 ^{cd}
DD	1	150	10	7.80 ± 0.77 ^{abc}	8.20 ± 0.41 ^{ab}	9.00 ± 0.00 ^a	7.60 ± 0.51 ^{ab}	8.60 ± 0.51 ^{ab}
EE	3	150	10	8.20 ± 0.77 ^a	8.60 ± 0.41 ^a	8.00 ± 0.00 ^d	7.80 ± 0.41 ^{ab}	8.80 ± 0.41 ^a
AAA	2	130	10	7.80 ± 0.77 ^{abc}	7.40 ± 0.83 ^{def}	8.20 ± 0.41 ^{cd}	7.60 ± 0.50 ^{ab}	8.20 ± 0.41 ^{bc}
BBB	2	170	10	7.60 ± 0.51 ^{bcd}	7.60 ± 0.51 ^{cde}	8.00 ± 0.65 ^d	8.00 ± 0.65 ^a	7.80 ± 0.41 ^{cd}
CCC	2	150	0	7.20 ± 0.42 ^{def}	7.40 ± 0.51 ^{def}	7.40 ± 0.51 ^e	7.40 ± 0.51 ^b	7.60 ± 0.51 ^d
DDD	2	150	20	7.80 ± 0.77 ^{abc}	7.60 ± 0.83 ^{cde}	7.20 ± 0.77 ^{ef}	7.60 ± 0.51 ^{ab}	8.20 ± 0.77 ^{bc}
EEE	2	150	10	7.40 ± 0.51 ^{cde}	7.60 ± 0.51 ^{cde}	7.00 ± 0.65 ^f	7.40 ± 0.51 ^b	7.80 ± 0.64 ^{cd}

Mean and standard deviation with different superscript along the same column are significantly different at $p < 0.05$. Note: 0 is stationary oven rack speed, 1 is unripe papaya puree, 2 is hard ripe papaya puree and 3 is very ripe papaya puree.

the best color and this could be traced to the use of unripe papaya puree used in producing the cookies which gave a lighter color than the ones observed in hard ripe and very ripe papaya puree. The mouthfeel of the samples ranged between 6.80 and 8.00. Cookies with unripe, hard ripe and very ripe papaya puree have good mouthfeel characteristics but differ in their baking temperature and oven rack speed. However, for the overall acceptability of the cookies, it ranged between 7.60 and 8.80 with cookies produced with very ripe papaya puree having the highest preference in sample EE.

Numerical optimization of the cookies processing conditions

The moisture content, crude protein content, calcium content, vitamin C content and total phenolic content were optimized to have optimal conditions for the cookies production. In the multi-objective numerical optimization, the moisture content was kept within its range, and the crude protein, calcium, vitamin C and total phenolic content were maximized. **Figure 5** shows that the predicted optimal conditions for producing the cookies could be achieved at 154°C baking temperature, 8 rpm oven rack speed and with the use of very ripe papaya puree with a global desirability value of 0.94. At the predicted optimal conditions, 7.69% moisture content, 12.50% crude protein, 51.97 mg/100 g calcium content, 4.02 mg/100 g vitamin C content and 2.21 mg GAE/g total phenolic content were obtained. The optimal predicted conditions were experimented with to validate the result. The validation showed that the predicted and experimented values for moisture content, crude protein, calcium, vitamin C and total phenolic content closely matches with a relative error that was 0.20%. Therefore, the optimal conditions

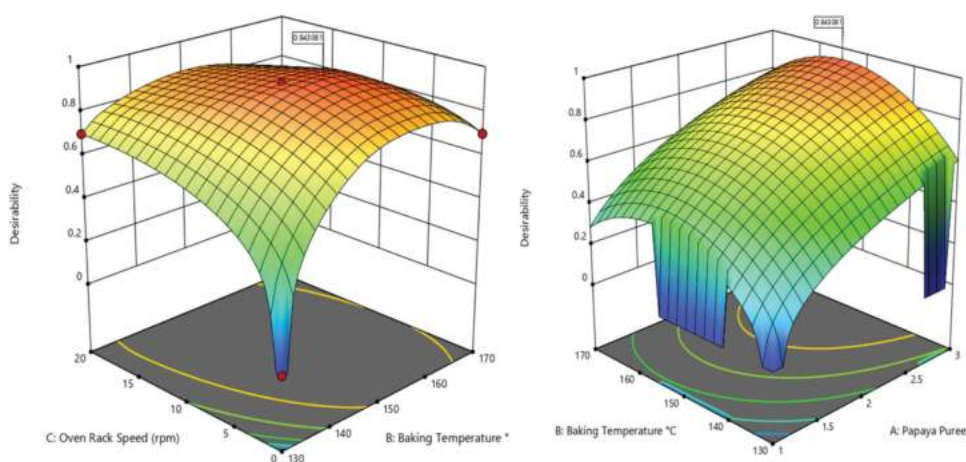


Figure 5. Numerical optimization of papaya puree, baking temperature and oven rack speed on the moisture content, crude protein, calcium, vitamin C and total phenolic contents of cookies.

could be used to produce nutrient-rich cookies with acceptable moisture content that can extend product shelf-life with maximum crude protein, calcium, vitamin C and total phenolic contents.

Conclusions

The cookies produced with very ripe papaya puree gave cookies with the highest moisture content, ash content, crude fat content, crude protein content, calcium content and total phenolic content. The use of unripe papaya puree produced cookies with the longest baking time and highest cookies thickness while the use of hard ripe papaya puree flavored cookies with the highest spread ratio, vitamin C content, carbohydrate content and crude fiber content. In addition, cookies produced with very ripe papaya puree favored desirable taste, texture, mouthfeel and overall sensory acceptability while the unripe papaya puree gave a better color. Cookies with desirable moisture content, crude protein content, vitamin C content, calcium content and total phenolic content were established at 154°C oven temperature, 8 rpm oven rack speed and with the use of very ripe papaya puree with a global desirability value of 0.94. This study has demonstrated that cookies with acceptable nutritional and sensory properties could be produced with partial substitution of fat with very ripe papaya puree. The information on the use of papaya puree as a fat substitute from unripe, hard ripe and very ripe papaya could increase the use of underutilized unripe or very ripe papaya and also serve as a strategic way of producing diverse cookies that is nutrient-dense.

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Data availability statement

Available upon request.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Declaration

The authors declare no conflict of interest.

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