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Product Development, Nutritional Characteristics and Consumers Acceptability Studies of Doughnut Partially Substituted with Carrot (*Daucus Carota*) and Mango (*Mangifera Indica L*) Flour Fortified with Date (*Phoenix Dactylifera L*) Fruits Syrup as Sweetener

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Abstract

A monotonous diet, bad eating habits, and micronutrient deficiencies that typically accompany food-related illnesses are all linked to a heavy reliance on a few primary crops. Food and nutrition security may be achieved by eating a diversified healthy diet that emphasizes cheap, nutrient-dense plant-based foods such fruits, vegetables, whole grains, and legumes. The goal of this study was to use mango and carrot powder to partially replaced wheat flour and in combination with date syrup in a sugar-free doughnut recipe to increase the health-promoting characteristics of doughnut. For consumer-acceptable doughnuts, product design was utilized to identify the proper quantity of mango and carrot powders, as well as date syrup. The doughnut was tested for its physical characteristics, proximate composition, micronutrient contents, and consumer acceptability. The findings of the physical study revealed that the values of Carrot flour (CF), Mango pulp flour (MPF) and Date-Syrup (DS) replacement had a significant ($P<0.05$) impact on the weight, volume, and specific volume. The chemical analysis revealed an increased proportion of fibre (1.62-5.20%), fat (25.50-34.67%), calorie content (372.48-451.55%), β-carotene (33.50-69.30µg/100g), as well as a decreased in protein (13.13-7.40%) and moisture (33.89-21.63%) in doughnuts substituted with MPF, CF, and DS. Calcium

(21.63-43.24 mg/100 g), Iron (4.87-8.90 mg/100 g), Potassium (176.10-236.14 mg/100 g), and Phosphorus (200.30-280 mg/100 g) all exhibited a substantial increase in minerals. The quantity of CF, MPF and DS added to the doughnut caused the crust and crumb to shift from a light to a darker hue, which was connected with the amount of CF, MPF and DS added. Overall acceptance was significantly ($P<0.05$) highest for doughnuts made with 25% CF, 25% MPF, and 25% DS (7.63) and significantly ($P<0.05$) from the control. The study found that improving the selection of one or more components can be a useful method for improving the health benefits of snack foods without sacrificing sensory qualities.

Keywords: Product design, sustainable diet, doughnut, Nutritional characteristics, Carrot, Mango

1. Introduction

Providing universal access to sufficient, wholesome, and cheap food that is produced sustainably is one of the world's greatest challenges (Gina *et al.,* 2017). Current food trends do not indicate a well-nourished population, and the sustainability of how we produce, distribute, and consume food is also a source of worry. Malnutrition as well as overweight and obesity are on the rise. Two billion individuals are deficient in vital vitamins and minerals required for good nutrition (Gina *et al.,* 2017). Obesity afflicted 5.7 percent (38.9 million) of children under the age of five in 2020, while wasting affected 45.4 million (6.7 percent). Adult obesity is on the rise, with a global prevalence of 13.1 percent in 2016 up from 11.7 percent in 2012. Between 2012 and 2016, all subregions saw an increase in adult obesity prevalence, falling short of the World Health Assembly's 2025 aim of reversing the trend by 2025. (FAO *et al.,* 2021). Simultaneously, non-communicable diet-related disorders (such as diabetes and high blood pressure) are on the rise. Poor nutrition is one of the primary causes of these various burden of malnutrition and Diet-related factors are currently the leading cause of disease and death in the world (Forouzanfar *et al.,* 2015).

A monotonous diet, bad eating habits and micronutrient deficiencies that typically accompany food-related illnesses are all linked to a heavy reliance on a few primary crops. Although global food energy supply has grown in recent decades as a result of increasing worldwide yield and production (FAO, 2019), this does not guarantee the nutritious quality of the food we eat, nor does it assure food availability, accessibility, and affordability for vulnerable groups (Tan *et al.,* 2020). The importance of diet in the prevention and treatment of degenerative illnesses has been widely acknowledged by scientific bodies and public health agencies. Obesity, cardiovascular disease, dental cavities, glucose intolerance, diabetes mellitus, hypertension and behavioural issues such as hyperactivity in children may all be increased by increasing added sugar intake (Johnson and Yon, 2010). Limiting lipid intake and decreasing saturated fat levels in processed foods are among the latest WHO guidelines for healthy eating (WHO, 2013). As a result, people are becoming more health-conscious about their food choices and curious about the nutritional content of foods (Domingo Ruiz-Cano *et al.,* 2016). The calorie content of food, as well as the quantities of fat and saturated fat in food, are their key concerns owing to their possible negative health impacts (Brugiapaglia *et al.,* 2014; Realini *et al.,* 2015).

With the UN Sustainable Development Goal (SDG) of Zero Hunger by 2030 still in sight, adopting a varied healthy diet with an emphasis on affordable nutrient-dense plant-based foods such as fruits, vegetables, whole grains, and legumes cannot only contribute to the achievement of SDG 2, but also have an impact on food and nutrition security (FAO *et al.,* 2020; EAT, 2019). Dietary fibre, micronutrients, and prebiotic substances found in fruits and vegetables benefit human health by modifying the microbiota, lowering postprandial glycemic response, normalizing cholesterol levels, avoiding constipation, and transporting phenolic compounds, among other methods (Pop *et al.,* 2021; Delcour *et al.,* 2016; Holscher, 2017). The most promising approaches with positive effects on the environment, the food industry, and finally on consumer health may be reusing fruit and vegetable waste and by-products (Ng *et al.,* 2020) or making the most of them by extracting valuable compounds that can be used in functional foods or nutraceuticals (Dueñas and Garcia-Estevez, 2020; Galanakis, 2020). Unlocking the planetary richness of various fruits, vegetables, legumes, and grains, especially nutrient-dense variety among these food categories, has the potential to provide the desired win-win outcome for people and the environment (Gina *et al*., 2017). For best health, dietary standards all over the globe advocate a diversified diet rich in fruits, vegetables, whole grains, nuts, seeds, and legumes (Fischer and Garnett, 2016).

Mango (*Mangifera indica L.*) is a popular tropical fruit that is noted for its high nutritional content and is widely farmed in tropical and subtropical countries (Wongkaew *et al.,* 2021a). Several preserved mango products, such as canned, dried mango, frozen slices, puree, liquids, and nectar, are commercially necessary (Wongkaew *et al.,* 2021b). Dried mango is the most popular and widely used method of processing (Kante-Traore Hyacinthe *et al.,* 2018). Provitamin A and vitamin C are abundant in mangoes. The kernels are used as a replacement for cocoa butter in soap production (Baliga and Shitole, 1981). The provitamin A content of dietary supplements and milk fortifiers (Britnell, 1991) was enhanced by combining dried mesocarp with legumes and grain flour (Badifu *et al.,* 2000; Sengev *et al.,* 2021). Rompies *et al.,* (2021) made cookies with fermented mango and pineapple fruits that had a large increase in vitamin C and antioxidant activity, as well as being an excellent source of prebiotics for the gut microbiota, which is important for the immune system. Carrots (*Daucus carota*) are a popular vegetable because of its high level of carotenoids, fibre, vitamins, minerals and bioactive substances (Leahu and Hretcanu, 2017). In the event of neurological or digestive diseases, carrots are indicated for enhancing eyesight, decreasing cholesterol levels, and skin care (Salwa *et al*., 2004). Because carrot juice and flour are high in beta-carotene, ascorbic acid, and tocopherol, they produce a nutritionally balanced food (Leahu *et al*., 2013).

The Arecaceae family's Date palm (*Phoenix dactytifera L*), known as Debino in Hausa (Nigeria), has 20% moisture, 3,000 kcal/kg calories, carbs (88% total sugar), 0.5% fat, 5.6% protein, vitamins (vitamin A, B, C, K), and 11.5% fibre (Agu *et al.,* 2020). Dates are known to aid in the production of blood. Dates are also high in fibre, magnesium, calcium, and phosphorus, as well as being low in salt and cholesterol. n order to avoid heart disease and colon cancer, fibre and calcium are essential. Dates are a diabetic food because they include invert sugar, which is better utilised as an energy source by diabetics than glucose, and sucrose, which supplies roughly 180 Kcal/100g (Tufail *et al.,* 2002). The fructose content of the date fruit is about half that of its sugar content (Al-shahib and Marshal, 2003). Many sugar replacements are used in baking, especially in cases where low-calorie alternatives might help with illnesses like diabetes where sugar consumption is prohibited (Agu *et al.*, 2021). Raw honey, maple syrup, molasses, fructose, barley malt syrup, and brown rice syrup are some natural alternatives to white sugar used in baking (Morgan, 2015). Date syrup is a popular date product that comprises a majority of fructose, glucose and a tiny amount of sucrose as well as other solubles. Dates are a great sweetener in baked products and other confections because of their sugar composition and mineral and antioxidant characteristics, which contribute sweetness and much-needed nutrients while also increasing shelf life (Tufail *et al.,* 2002).

To maximize product qualities and features such as form, color, appearance, taste and texture, new product development is required (Samakradhamrongthai *et al.,* 2021). Snacking and good eating habits have been linked to a variety of health advantages in adults (Cowan *et al.,* 2020) and persons with diabetes, including hunger management, body weight regulation, and improved blood sugar control (Morris *et al.,* 2020). However, it is widely agreed that the contemporary obesity situation encourages overeating as a result of bigger portion sizes, palatability, and food calorie density, as well as the numerous social and psychological signals that encourage people to snack excessively (Miller *et al.,* 2013). Hence, fried snacks continue to be a big part of our daily diet, despite changing consumer diet trends toward healthier eating (Onipe *et al.,* 2019) as a result of a busy lifestyle that allocates only short periods to eat (Noha *et al.,* 2021; Jayawardena *et al.,* 2017; Sönmez and Nazik, 2019; Suhadi *et al.,* 2020). Fried dishes are popular because of their pleasing crunchy texture and unique flavor. Many of the items served in this manner are affordable and popular in low-cost eateries. A donut, often known as a doughnut, is a fried pastry or treat. The doughnut, which is popular in many countries, is a sweet snack that may be produced at home or purchased from bakeries, supermarkets, food stalls and specialist franchise stores (Satish *et al.,* 2018). Doughnuts are normally made from a flour batter, are ring-shaped or without a hole, and are frequently filled. Other types of dough can be utilized, and different toppings and tastes, such as sugar, chocolate, or maple frosting, are used for different sorts. Doughnuts may also contain ingredients such as water, sourdough, eggs, milk, sugar, oil/shortening, natural flavors and artificial flavors in addition to flour (Hatae *et al.,* 2003; Rehman *et al.*, 2007). Deep-frying dough comprised of flour, water, egg, oil, sugar and milk is used to make doughnuts (Hatae *et al*., 2003). Doughnuts manufactured with unfortified wheat flour are deficient in other vital nutrients. Rather of depending on ready-made vitamins and minerals, alternative ingredients are increasingly being used to strengthen basic meals. Consumers and producers alike benefit from this technique because it takes a more holistic approach to fortifying or enriching food, utilizing previously underused plant species and diversifying the diet with more than just the single mineral or vitamin. Because of their affordability, adaptability, nutritional quality, and sensory acceptance, carrot, mango, and date palm fruits have the potential to be used as food fortification components.

This research focuses on transforming carrot, mango pulp flour, and dates syrup into doughnuts that may be used in place of wheat flour on replacement basis. It contributes to our understanding of the design and diversification of food products containing carrots and mangoes, potentially reducing post-harvest losses of these climacteric fruits. Using fruit instead of refined sugar when making sweet foods is also a good way to cut down on refined sugar consumption. Because dates have a high sugar content, 3,000 kcal/kg energy, carbohydrate-88% total sugar with almost half of the amount of sugar in the form of fructose (Al-shahib and Marshal, 2003), they can be used to substitute sugar in new product development as it is done with Bread (Sidhu *et al.*, 2003); Biscuits (Agu *et al.*, 2020), Cake (Tufail *et al.*, 2002); Muffin (Aboubacar *et al.*, 2010); ice cream (Gouhari *et al.*, 2005).

2. Materials and Methods

2.1 Sample Procurement

Fresh mango (*Mangifera indica L.)* of local varieties (Ogbomosho/Enugu type, the most widely acceptable, sweet and aromatic), carrot (*Daucus carota*) local varieties (Nantes- orange colours and widely grown in Nigeria), and date fruits (*Phoenix dactytifera L*) with similar degree of maturity and ripeness were procured from a local fruit market in Lafia-Nigeria during the March-April 2022 fruiting season. Commercial wheat flour (Honey Well PLC, Nigeria) with 8-9% protein contain, dry yeast, skimmed dry milk powder (Peak milk, made by frieslandcompina WAMCO Nigeria PLC, Lagos-Nigeria), Sucrose (Golden penny brand), margarine (Simas, Indonesia), salt (Dangote, Lagos), baking powder (Princess K, Kano) and Eggs, were purchased from modern market in Lafia-Nigeria. All of the chemicals and equipment used for simple preparation and for analyses were of analytical grade (M&B brand) and are obtained and purchased from local stores in Nigeria.

2.2 Samples Preparation

Production of Mango (*Mangifera indica L)* Pulp powder*:* The maturity stages were classified as fully mature (M3), according to morphological development of fruit shoulder. Ripening was observed at ambient temperature (28 ± 2°C) for 2-3 days according to the maturity stage until fruits reached full yellowing of peel. Mangoes were sorted (only fruits that did not show any visual signs of bruises, cuts, infestation were selected for the study), weighed and washed under running water. After that, they were wiped, peeled by hand and the seeds were removed. The acquired pulp was sliced for size reduction and to speed up the drying and milling processes, and the sliced pulp was steam blanched for 10 min at 60°C to deactivate enzymes that may induce browning reactions. The slices were distributed uniformly on a perforated stainless-steel pan after blanching and dried in a 65°C oven for 24 h. The discs were crushed into flour using a tabletop hammer mill (Brook Crompton, Series 2000, England) after drying and passing through a 0.2 mm particle size filter. The flours were then packed in dark-colored Ziploc low-density polyethylene bags, kept at room temperature (30 ± 2°C) in a 500mL plastic container with airtight lids for 24 h, and utilized for product design and analysis.

Production of Carrot *(Daucus carota)* flour*:* Before slicing, the carrots at fully mature (M3) and ripeness were cleaned and peeled by hand using a stainless-steel knife. The discs were uniformly dispersed on a perforated stainless-steel tray, dried to a consistent weight in a drying oven, then ground in a disc attritor (Asiko A11, Addis Nigeria) to a particle size of 0.2 mm. The flours were then packed in dark-colored Ziploc low-density polyethylene bags, kept at room temperature (30 ± 2°C) in a 500 mL plastic container with airtight lids for 24 h and utilized for product design and analysis.

Production of Date *(Phoenix dactylifera L)* Fruit Syrup*:* To make grinding easier, the fruit was cleaned, de-pitted, and sun dried to a moisture level of 10%. The dried date samples were crushed in a mortar to decrease size before milling and processed to a particle size of 0.2 mm in a disc attritor (Asiko A11, Addis Nigeria). To generate a slurry that had not been filtered, the ground dates were boiled with 1:4 dates/water ratio at 100°C for 30 min at a 25% w/v. The date slurry was placed in an airtight container and kept in a household refrigerator before being employed in product development within three days.

2.3 Product design and blends formulation

The blends of wheat flour, mango flour, carrot flour and date syrup were formulated and were optimized on the basis of one factor at a time method at five different levels ranging from 5, 10, 15, 20 and 25% on w/w basis of whole wheat flour as reported by Arya and Sachin (2016). Once the level of flour was optimized, D-optimal mixture design was constructed using the software Design Expert Version 6.0.10 (Stat-Ease Corporation, Minneapolis, Minn., USA) and was used to analyze the results. Maximum and minimum predictor variable levels were chosen by carrying out preliminary trials as explained above. The sum of the factors were kept constant that is at 125. Hence, the product design formulation of this study was focused on the substitution of wheat flour with carrot and mango mesocarp flour on the basis of 100% flour weight. The carrot and mango mesocarp flour were measured as mixed fruits flour on equal percentage basis as demonstrated by Samakradhamrongthai *et al.*, (2021). The date-syrup which was in a paste-in-liquid emulsion containing both liquid and date fibres are used as fortifier account to 125% flour weight basis. The rest of the ingredient, water: 36%, margarine: 22%, egg: 10%, sugar: 25%, milk powder: 15%, baking powder: 1.5%, dry yeast: 5%, salt: 1% were added in the given proportion to the blend formulation. Formulation of the dough involved measuring the required proportions of raw materials and ingredients, then mixing them to produce the dough for the doughnuts.

Table 1 Experimental Design of Four Main Ingredients of Composite Doughnuts.

Sample Codes	Product design Components (%)				
	Wheat Flour	Carrot Flour	Mango Pulp Flour	Sucrose	Date Paste-Syrup
661	100.0	0.0	0.0	25	00
662	90	5.0	5.0	-	25
663	80	10	10	-	25
664	70	15	15	-	25
665	60	20	20	-	25
666	50	25	25	-	25

2.4 Doughnuts production process

Doughnuts were prepared by the straight-dough method according to modified formulation by Chong and Noor Aziah (2008). Ingredients consisted of wheat flour: 100%, water: 36%, margarine: 22%, egg: 10%, sugar: 25%, milk powder: 15%, baking powder: 1.5%, dry yeast: 5%, salt: 1%. A portion of wheat flour and sugar was replaced with an appropriate portion of CF, MPF and DS and water was adjusted to produce a desired dough consistency. All ingredients were manually mixed and kneaded for 10 mins. The resulting dough was transferred to a cutting board and lightly dusted with flour. It was sheeted to 12 mm thickness and cut with a doughnut cutter having a diameter of 6 cm. The cut pieces were then placed on a greased tray, covered with a damp cloth and proof for 30 min. The doughnuts were then deep-fried in refined palm oil at 165 ± 5°C on each side for 3 min. Until it became golden brown on the outside and well-cooked on the inside.

2.5 Analysis

Physical Characteristics

The Volume of doughnuts was determined using the volume replacement method (AACC, 2000) and they were weighed after cooling for 30 min at ambient temperature. Three samples were randomly selected from each doughnut for physical measurements.

The specific volume of the bread was determined as shown in Equation below:

$$\textbf{Specific volume (cm}^3\textbf{/g)} = \frac{\textbf{Loaf volume}}{\textbf{Loaf weight}}$$

Colour Analysis

Dough, Crumb and crust colour of doughnuts were measured by using Minolta colorimeter (model CM - 3500d) for L* (Lightness), a*Hue value (Redness) and b* (Yellowness)

Proximate Analysis

Moisture, crude protein, ash, crude fat and crude fibre contents of doughnuts were determined according to the AACC (2000) method. Protein content (%N × 5.7) was determined by the Kjedahl method. Moisture was determined by oven drying for 4 h at 105°C. Ash was measured by dry combustion [AACC, 2000 (Method 08-01)]. Free lipids were measured by petroleum ether extraction, followed by evaporation to constant weight [AACC, 2000 (Method 30-25)]. Crude fibre was determined according to the procedure of AACC, 2000 (Method 32-07). Available carbohydrate was calculated as 100% - (% moisture + % ash + % fat + % protein + % crude fibre). All samples were done in triplicate.

Caloric Values (L*, a*, b*) Analysis

Caloric values for all samples were determined by calculation. Percentages for protein, crude fat and carbohydrate were multiplied with their respective factors. Caloric value (kcal/100g) = (% protein x 4) + (% crude fat x 9) + (% carbohydrate x 4). All samples were done in triplicate.

Determination of Beta-Carotene

The method of Chaturved and Nagar (2001) was adapted with slight modification. Five grams (5.0 g) of the prepared sample was transferred into a separating funnel and the solution containing 60 mL hexane: 40 ml ethanol and swung vigorously after addition of 2 mL of 2% sodium chloride (NaCl) solution. The mixture was allowed to settle and the lower layer was run off. The absorbance 400 nm of the top layer of the mixture was determined at spectrophotometer (model: Bausch and Lamb-Cat. No: 33-31.72, Belgium). Calculation from Beer- Lambert expression

$$\beta\text{- Carotene}\left(\frac{mg}{100g}\right) = \frac{\text{Absorbance}}{\text{Specific extinction Coefficient} \times \text{Path length of cell}}$$

Where: Molar extinction Coefficient (ε) of β – Carotene 460nm = 15^{-4}
Specific extinction coefficient (a^{1cm}) = ε x molar mass of β – carotene.
Molar mass of β – carotene = 536.88g/mol. β – carotene

Determination of Mineral Matter

Mineral composition (Iron, Calcium, Potassium and Phosphorus) was determined by acid digestion. Ash obtained (3.8) after incineration at 600°C was digested into solution by wet digestion using a mixture of conc. nitric, perchloric and sulphuric acids in the ratio 9:2:1 respectively. Fe and Ca were determined by Atomic Absorption Spectrophotometer (AAS) (UNICAM 960 series). While K was determined using atomic emission spectrometer (200-A model, Buck Scientific Ltd UK) and colorimetric method was used to determined Phosphorus (AOAC, 2000).

Consumer Acceptability Test

Consumers were recruited from the students and staff of Federal University of Agriculture, Makurdi, Nigeria. The sensory evaluation of doughnut was prepared for product preference consumer acceptance using thirty-five (35) untrained consumers. The sensory evaluation of doughnuts was carried out within 6 h of frying using a 9-point hedonic scale on appearance, aroma, texture, crust colour, crumb colour, taste, overall acceptability. To unify the conditions of the evaluation, all samples were prepared in disposable plastic plates coded with a three-digit number, evaluated by each panelist in a monadic order, following a balanced-incomplete box design (Stone *et al.*, 2020). The samples were served in three sessions consisting of 3-4 samples for each round, and served in random order to each panelist. During the test, the panelists were asked to pause between the samples and cleanse their palate with prepared tap water at room temperature Samakradhamrongthai *et al.*, 2021). The evaluation was performed in individual booths under white light at the Sensory Evaluation and Consumer Testing Unit (Department of Food Science and Technology, College of Food Technology and Human Ecology, University of Agriculture, Makurdi, Nigeria).

Statistical Analysis of Data

Data were analyzed with SPSS version 11.0 (Illinois, U.S.A) using one-way Analyses of variance (ANOVA). Significant differences were tested using the Duncan Multiple Range test. Three replications were used for chemical and physical measurements and once for sensory evaluation.

3. Results and Discussion

3.1 Physical Characteristics of Fortified Doughnuts

The physical parameters of the doughnut samples are shown in Fig 1. The weight of the doughnuts significantly ($P<0.05$) decreased when the other flour types (carrot flour and mango pulp flour) are replaced in an equal amount, with doughnut sample 661, composed wholly of wheat flour, significantly ($P<0.05$) having the maximum weight of 122.50 g and composite doughnut sample 666 having the lowest weight of 92.55 g. This could be attributed to the increase in mango and carrot flour lacking gluten that trap air during doughnut raising and frying. The volume of the doughnut samples followed a similar pattern, with the control sample significantly ($P<0.05$) having the largest volume of 110.65 m^3/g and a specific volume of 0.90 cm, and the composite sample 666 significantly ($P<0.05$) having the lowest volume and a specific volume of 45.25 m^3/g and 0.49 cm, respectively. Chong and Noor Aziah (2008) found a similar tendency in banana doughnut, Oke *et al.* (2018) in breadfruit doughnuts, and Satish *et al*. (2018) in millet doughnuts. This has been related to the increased use of gluten-free flour, which has resulted in a decreased gluten concentration. Gluten is a protein component that contributes to a harder dough matrix and the ability to trap air cells, resulting in higher volume doughnuts (Chong and Noor Aziah, 2008).

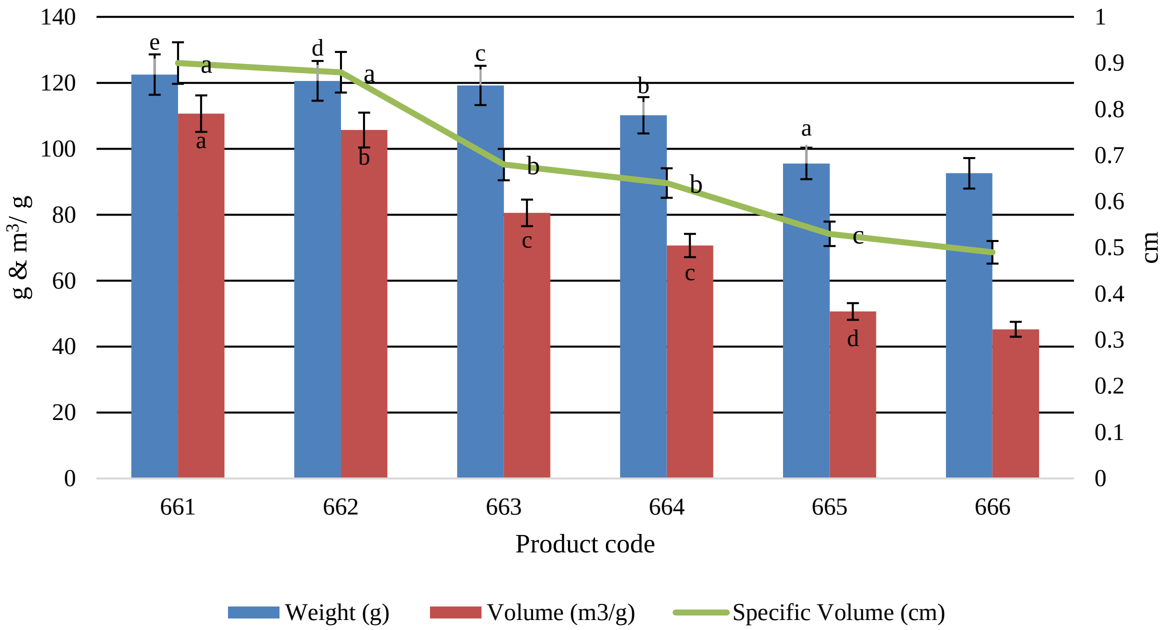

Fig 1 Physical Properties of Fortified Doughnut. Same letter on the bars and points of Six different formulation of doughnut showed no significant differences (P<0.05).

3.2 Proximate Composition of Fortified Doughnut

The proximate composition of all doughnut samples is shown in Fig 2. As the amount of carrot and mango pulp flour substituted increases, the moisture level of the doughnuts significantly (P<0.05) decreases. This is possible because of the low starch concentration in the fruit, which has a lesser water holding ability than wheat starch (Chong and Noor Aziah, 2008). The reduction in moisture content in the doughnut samples when compared to the control doughnut is not surprising, as it has been documented by Shaker (2014) in Potato Strips, Kante-Traor *et al.* (2018) in maize-rice-mango doughnut, Chong and Noor Aziah in a banana doughnut, and Oke *et al.*, (2018) in breadfruit doughnuts. During the frying process, the water in the doughnut may have evaporated. As a result of the high amount of fruit flour in the doughnut, more water is lost during the frying process because when the doughnuts are cooked, the water evaporates and the oil is exposed to endosmosis (Oroszvari *et al.*, 2005). Frying, in reality, is the outcome of dehydration at high heat in a hydrophobic environment, resulting in a decrease in water content (Courtois *et al.*, 2012).

The enriched doughnut samples 663 and 664 had significantly (P<0.05) a lower ash content than the control sample 661, whereas the enriched samples 665 and 666 had significantly (P<0.05) a greater ash level. The ash level of the doughnut is determined by the quality of flour available (Kim et al., 1996), and thus corresponds to increased mineral content in the fruit, such as phosphorus and potassium, which led to the much higher ash content in 665 and 666. This was in line with Chong and Noor Aziah (2008) findings in banana doughnuts and Oke *et al*. (2018) findings in breadfruit doughnuts.

The blended doughnut samples showed significantly (P<0.05) lower protein content compared to the control sample, with protein content decreasing as alternative flour substitution increased; The mixed doughnut sample 666 significantly (P<0.05) had the lowest protein content of 7.40%. This could be attributed to the dilution effect of the fruit's low protein content compared to wheat flour. Chong and Noor Aziah (2008), Kante-Traor *et al*. (2018) and Oke *et al*. (2018) reported a similar result.

The fortified doughnuts had more fibre content compared to that made solely from wheat flour, with the fibre content increasing steadily as substitution with composite flour increases. The relatively high percentage of crude fibre content was contributed from the hemicelluloses in the flour produced from mango, carrot and date palm. This agreed with the findings of Chong and Noor Aziah (2008) and Oke *et al.,* (2018). The increased in fibre content of composite breads have several health benefits, as it will aid in the digestion of the bread in the colon and reduce constipation often associated with bread produced from refined wheat flour (Elleuch *et al.,* 2011).

The fortified doughnuts had significantly (P<0.05) a higher fibre content compared to those made solely from wheat flour with fibre content steadily increasing with increasing substitution with mixed flour. The relatively high crude fibre content was contributed by the hemicelluloses in the flour from mango, carrot and date palm. This agreed with the results of Chong and Noor Aziah (2008) and Oke *et al.,* (2018). The increased fibre content of mixed bread has several health benefits, as it aids in the digestion of the bread in the colon and reduces constipation, which is often associated with bread made from refined wheat flour (Elleuch *et al.,* 2011). Dietary fibre, according to well-documented research, has an important role in avoiding a variety of disorders, including cardiovascular disease, diverticulosis, constipation, irritable bowel syndrome, cancer, and diabetes (Slavin, 2005; Elleuch *et al.,* 2011).

In comparison to the composite doughnut samples, the control sample significantly (P<0.05) had less fat and carbohydrate. Due to the absorbed oil, this may have helped to replenish the pores by boosting the fat content of the combination flour and date syrup. Mellema (2003), Chong and Noor Aziah (2008), Kante-Traor *et al*. (2018), and Oke *et al*. (2018) observed comparable findings for fried foods.

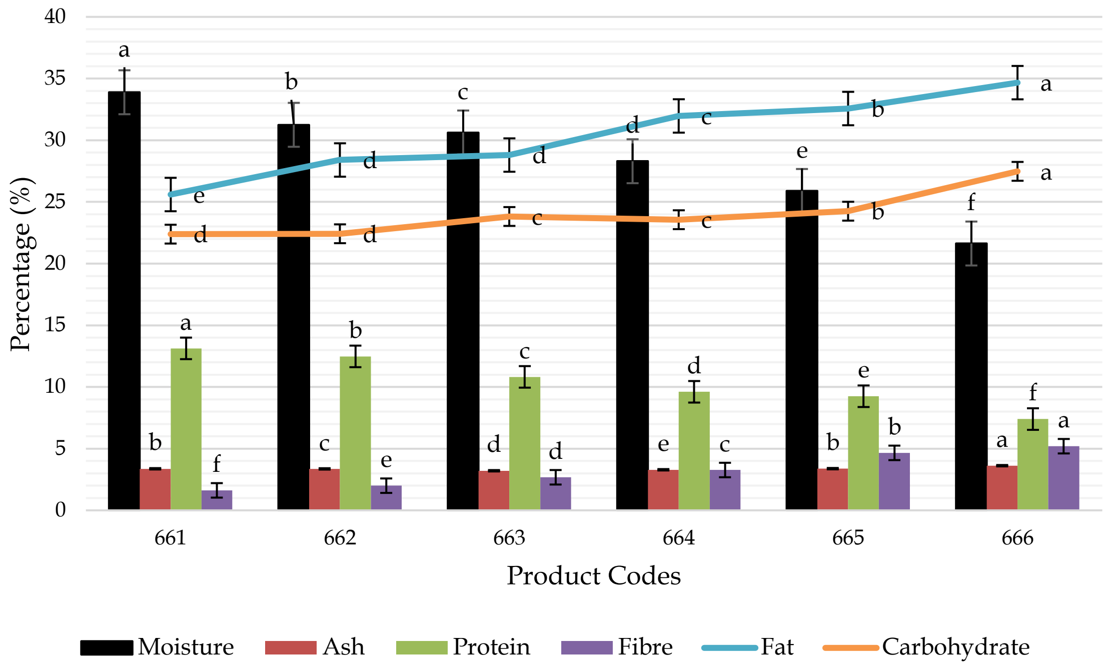

Fig 2 Proximate Composition of Fortified Doughnut (%) Same letter on the bars of six different formulation of doughnut were not significantly different (P<0.05)

3.3 Caloric and Beta-Carotene Content of Fortified Doughnut

Doughnuts' calorie and β-carotene content are shown in Table 4. The calorie value ranges from 372.48 to 451.55 kcal and the β-carotene content increases significantly (P<0.05) from 33.50 µg/100g to 69.30 µg/100g. In the fortified doughnuts, the replacement of alternative flours for wheat flour results in a significant (P<0.05) increase in β-carotene and caloric value. The high concentration of β-carotene in carrots and mango might explain the significantly (P<0.05) increase in β-carotene. Beta carotene is a valuable nutrient because it is an antioxidant, and human bodies can convert it into vitamin A, which has important roles in ensuring healthy eyes and other tissues. Due to fat absorption during frying, calorie content was strongly connected to fat content of doughnuts. As a result increasing fat content in doughnuts enhanced the caloric value of the doughnut indirectly (Chong and Noor Aziah, 2008).

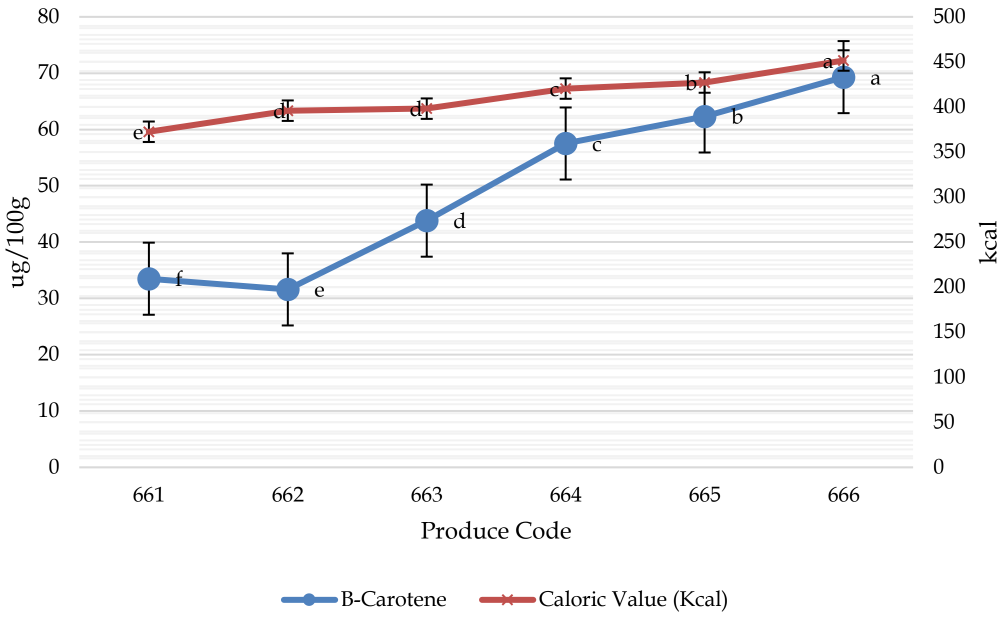

Fig 3 Caloric and Beta-Carotene Content of Fortified Doughnut Values are mean ± standard deviations of duplicate determinations. The different letter on the bars of six different formulation of doughnut were statistical different at (P<0.05).

3.4 Mineral Content of fortified Doughnut

Fig 4 depicts the mineral composition of the doughnut samples. When compared to non-fortified doughnuts, the fortified doughnuts have significant (P<0.05) higher mineral content, which can be attributable to the high quantities of important minerals contained in carrot and mongo plants. Carrot and mango fruits are high in minerals, which are essential for human development and growth. The calcium, iron, and potassium content of the fortified doughnut reported in this study is lower than potato bread fortified with soybean flour (Dorina Isabel Gomes Natal *et al.*, 2013), Moringa seed flour enriched bread (Bolarinwa *et al.*, 2017), and wheat bread supplemented with stabilized non-defatted rice bran (Ameh *et al.*, 2013). The phosphorous concentration of the fortified doughnut, on the other hand, was greater than that reported by Bolarinwa *et al.* (2017). This study accords with Igbabul *et al.* (2014) for composite bread produced from wheat, corn, and orange flesh sweet potato flour. Potassium and phosphorus are essential components of cells and bodily fluids for heart rate and blood pressure regulation.

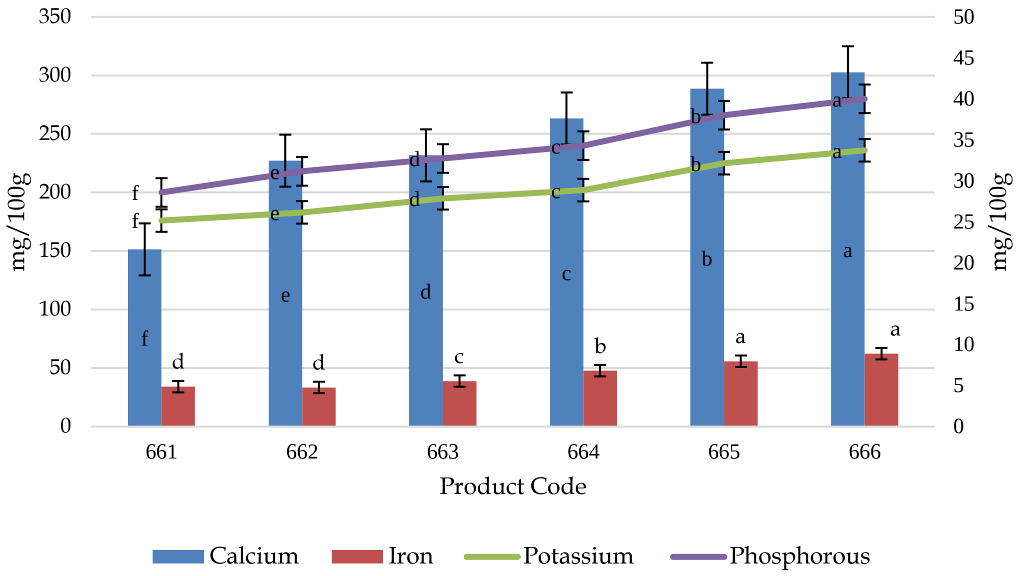

Fig 4 Mineral Profile of Fortified Doughnuts Values are mean + standard deviations of duplicate determinations. The different letter on the bars of six different formulation of doughnut were statistical different at (P<0.05).

3.5 Dough, Crust and Crumb Colour of Fortified Doughnuts

Table 2 displays the colour determination result of the dough, crust, and crumb colour of the various doughnut samples. All the colour values were observed and showed significant differences among treatments. Finally, the use of alternate flours changed the colour of the dough, crust, and crumb of the doughnuts significantly. As the amount of alternative flour in the doughnuts increased, the brightness values of the dough, crust and crumb decreased significantly (P<0.05). This could be attributed to the natural pigments in carrot and mango. Dried carrots and mangos are a concentrated source of beta carotene and carotenoids are lipid soluble pigments, responsible for yellow, orange and red coloration. The L* value was changed significantly by increasing the fruit amount, due to the pigment in coloured mango, carrots and date palm fruits causing the lightness to be altered (Comet *et al.*, 2019). Similar behaviour was observed for the a* value representing the red (positive values) and green (negative values) colours and b* value which defines the yellow (positive values) and blue (negative values) colours. Samakradhamrongthai *et al.* (2021); Chong and Noor Aziah (2008) and Oke *et al.* (2018) all observed comparable findings. The reduction might be due to the increased amount of oxidized phenolic and carotenoids from carrots and mangoes compounds generated during the frying process in the enriched doughnuts. The heating process disrupts the cells and carotene crystals, mixes the carotene molecules with other fatty materials in the carrot and mango tissues and the rest of food matrix making them more readily available for absorption. The deeper crumb colour in enriched doughnuts compared to control doughnuts was owing to the doughnuts more compact structure, which resulted in lesser light reflection (Chong and Noor Aziah, 2008). The oil absorption effect and the Maillard reaction between protein and invert sugar in the presence of heat were aided by the crust's colour. As a result, the crust L* values for various varieties of doughnuts were significant (P<0.05) lower than those reported by for dough and crumbs

(Chong and Noor Aziah, 2008). The a* and b* value from fortified doughnuts exhibited significant differences as a result of all treatments. Increasing the amount of fruit ingredients decreased the a* and increased b* value, because of the variables related to the quantities of components in the product (Lins *et al.*, 2014; Samakradhamrongthai *et al.*, 2021).

Table 2 Color Determination Results of Fortified Doughnuts

Product Codes	Dough			Crust			Crumb		
	L*	a*	b*	L*	a*	b*	L*	a*	b*
661	80.72±0.08^{a}	90.67±0.23^{a}	17.95±0.30^{f}	58.83±0.00^{a}	48.04±2.00^{a}	27.65±0.50^{f}	76.46±2.40^{a}	45.09±0.50^{a}	25.95±0.30^{f}
662	75.87±0.05^{b}	87.09±0.05^{b}	19.18±0.60^{e}	54.21±0.07^{b}	45.67±0.30^{b}	31.35±0.80^{e}	73.26±1.10^{b}	43.24±0.34^{b}	27.18±0.60^{e}
663	67.16±0.09^{c}	82.81±0.10^{c}	23.08±1.50^{d}	50.43±0.03^{c}	44.46±0.45^{bc}	33.95±2.50^{d}	70.81±0.00^{c}	40.93±0.40^{c}	31.08±1.50^{d}
664	63.29±0.09^{d}	80.16±0.06^{d}	25.38±0.20^{c}	47.05±0.40^{d}	43.04±0.70^{c}	37.15±0.20^{c}	67.23±3.50^{d}	40.00±2.50^{c}	33.38±0.20^{c}
665	58.48±0.09^{e}	77.00±0.40^{e}	26.28±0.40^{b}	43.27±0.20^{e}	40.10±0.30^{d}	38.65±0.70^{b}	64.06±0.90^{e}	39.36±1.50^{cd}	34.28±0.40^{b}
666	51.91±0.09^{f}	70.50±0.80^{f}	28.98±0.70^{a}	39.89±1.00^{f}	36.56±0.10^{e}	41.85±0.40^{a}	60.00±1.50^{f}	38.67±1.50^{de}	36.98±0.70^{a}

values are mean ± standard deviation of triplicate determination. The different letter in the same column stated the statistical different at 95% confidence level (P<0.05).
L* (Lightness) a*Hue value (Redness) b* (Yellowness)

3.6 Consumer acceptability of fortified doughnuts

The hedonic rating for crust colour (7.39-7.65), crumb colour (7.55-7.93), taste (7.45-7.82), aroma (7.75-8.00), texture (6.87-7.83), appearance (7.30-8.10) and overall acceptability (7.17-7.73) are shown in Table 3. Significant differences (P<0.05) existed in some of the sensory attributes as the doughnuts changed when different flours were used. Sample 665 had the highest crust colour mean of 7.65 while sample 664 had the least mean of 7.39 and Sample 664 had the highest crumb colour mean of 7.93 while sample 662 had the least mean of 7.55. The incorporation of mango, carrots and date palm made the colour of the doughnut acceptable. Mango, carrots and date palm fruits are as good source of dietary fibre, antioxidants, mainly carotenoids and phenolics (Nurkolis *et al.*, 2020; Mantik *et al.*, 2021; Al-Farsi and Lee, 2008). Hence, that acceptable colour may be from the carotenoids and the phenolics (Agu *et al.*, 2020). Colour is an essential parameter in judging baked and fried food products that not only reflect the quality of raw materials but also provide information about the formulation and quality of the product (Ikpeme-Emmanuel *et al.*, 2010).

The mean score for taste ranged from 7.82-7.45 with sample 661having the highest value while sample 665 had the least. The decreased rating for taste may be due to the expected increased sweetness intensity of refined sugar over sugar content from the date palm syrup, mango and carrot flour. Flavour is the main criterion that makes the product liked or disliked (Agu *et al.*, 2020). The aroma of the doughnuts varied significantly (P<0.05) among different proportions. The doughnuts prepared with mango, carrot and date palm fruit syrup had higher aroma score than the control. This may be attributed to the high categories of phenolic acids in these fruits, hydroxybenzoic (gallic, vanillic, syringic, protocatechuic, and p-hydroxybenzoic acids) and hydroxycinnamic acid derivatives (p-coumaric, chlorogenic, ferulic, and caffeic acids). (Maldonado-Celis *et al.*, 2019). Hence, it is not surprising that incorporation of mango, carrot and date palm received acceptable mean score for consumer acceptability of the fortified doughnut for taste and aroma. The acceptable taste and aroma could be from the sugars, high fibre and phenolic acid from the flours of mango and carrot and date palm syrup which may give a feeling of satiety (Agu *et al.,* 2020). Knowing the preferences of consumers and aiming to fulfil those expectations regarding the flavour of fruits, besides increasing the probability of producers to easily sell their commodities (Gonçalves *et al.,* 2018), they will also be linked to an expected improvement in nutritional uptake, as better-tasting fruits doughnut will likely replace less healthy snack foods (Klee, 2010).

The overall acceptability (Fig 5) showed that doughnut 661 had the highest value of 7.3, followed by 666 (7.63) and 665 (7.46) while sample 663 had the least (7.17) followed by 664 (7.20). Increasing the proportion of carrot, mango and date palm flour significantly affected the overall acceptability of the doughnuts. The doughnuts, 661, 666 and 665 were the most generally accepted. None of the doughnut samples was disliked by the panelists on all sensory attribute assessed including the overall acceptability. According to Knuckles *et al.* (1997), items with an overall acceptance score of more than 5 are deemed excellent quality products in sensory evaluation. This study generally recorded more mean score of 7 and above in all sensory parameters. As a result, the quality of all fortified doughnuts was confirmed to be satisfactory. Chong and Noor Aziah (2008), Oke *et al.* (2018) and Igbabul *et al.* (2014) all found comparable findings (2014).

Table 3 Consumers Acceptability Scores of Fortified Doughnuts

Product Codes	WF	CF	MPF	Sucrose	DPS	Appearance	Aroma	Texture	Crust Colour	Crumb Colour	Taste
661	100.0	0.0	0.0	25	00	7.30±1.50^{d}	7.75±4.40^{b}	7.83±2.40^{a}	7.43±1.30^{b}	7.63±0.90^{b}	7.82±2.00^{a}
662	90	5.0	5.0	-	25	7.60±2.40^{c}	7.75±1.90^{b}	7.42±1.00^{b}	7.46±1.30^{a}	7.55±0.90^{c}	7.74±2.00^{b}
663	80	10	10	-	25	7.58±1.60^{cd}	8.00±1.70^{a}	7.11±1.30^{d}	7.43±1.30^{b}	7.57±0.90^{c}	7.64±2.00^{c}
664	70	15	15	-	25	7.82±1.40^{b}	8.00±0.80^{a}	7.38±2.60^{c}	7.39±1.30^{c}	7.93±0.90^{a}	7.74±2.00^{b}
665	60	20	20	-	25	8.10±2.70^{a}	7.95±1.45^{a}	6.87±1.00^{e}	7.65±1.30^{a}	7.80±0.90^{ab}	7.45±2.00^{d}
666	50	25	25	-	25	7.96±3.05^{ab}	7.99±2.00^{a}	6.79±3.00^{e}	7.45±1.30^{ab}	7.62±0.90^{b}	7.46±2.00^{d}

Mean values ± standard deviation of scores (n = 35 assessors). Different superscripts letters (a-f) within a column indicate statistically significant differences (P<0.05), WF = Wheat Flour; CF = Carrot flour; MPF = Mango pulp flour; DPS = Date paste syrup.

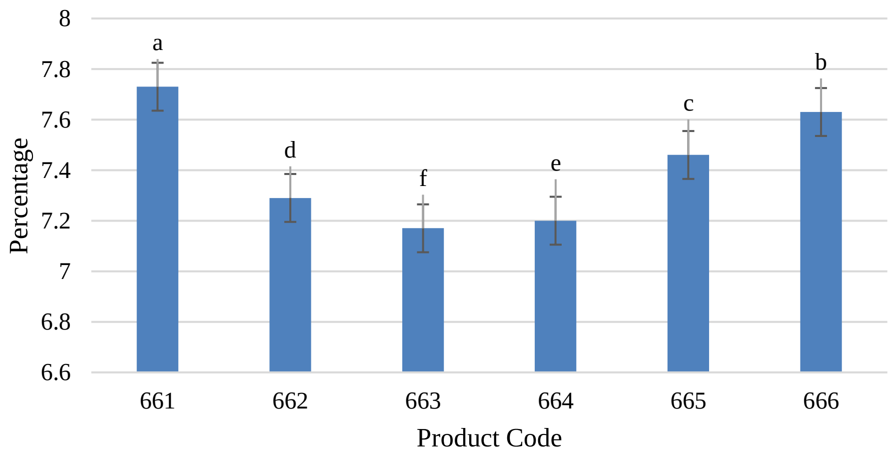

Fig 5 Overall Acceptability of Doughnut Samples Values are mean ± standard deviations of duplicate determinations. The different letter on the bars of six different formulation of doughnut were statistical different at (P<0.05).

4. Conclusion

Doughnuts may be created using wheat-carrot-mango mixed flour, according to this study. The enriched doughnut's physical qualities, such as weight, volume and specific volume, reduced, but its approximate composition in terms of ash, fat, fibre, and carbohydrates improved. When wheat flour was replaced with CF, MPF and DS in doughnuts, the fibre, minerals and beta-carotene content increased, making it a good source of these nutrients. Between varying degrees of replacement, there were substantial changes in brightness, redness, and yellowness. The degree of substitution was directly connected to the colour of the crust and crumb. Doughnut produced from all the blend formulations was significantly ($P<0.05$) preferred by the panelist. Therefore, acceptable doughnut can be prepared by substituting wheat flour with CF and MPF up to 50% and with 25% DS as sweetener. Future studies could focus on the effect of substitution with carrot, mango and date-syrup on the storage stability of doughnut.

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