Maximizing the benefit of papaya fruits (*Caricapapaye*) in production of some bakery products

Abstract

Celiac disease is an intestinal disorder caused bygluten, resulting in a permanent sensitivity to it. There is no definitive cure for this disease other than a permanent gluten-free diet. Demand for gluten-free baked goods, particularly biscuits, is increasing, particularly among people who have celiac disease, gluten sensitivity, or are worried about their overall health. Biscuits are easy to consume, have a distinct taste and texture, but lack key critical elements such as dietary fiber and micronutrients.This study focused on producing healthy gluten-free biscuits (using corn flour) fortified with various types of papaya flour (whole fruits, pulp, and peels) with high nutritional value that are suitable for special groups of society a with multiple health benefits. Additionally, this product contributes to maximizing the use of papaya and making it available all year. Furthermore, this product helps to reduce the consumption of wheat flour, hence reducing wheat imports. Six alternative biscuit mixes were prepared by replacing corn flour with whole papaya fruit flour at ratios (10% and 25%), pulp flour (20% and 35%), or peel flour (10% and 25%), and compared to a reference sample manufactured from 100% wheat flour or corn flour. Moisture, fat, carbohydrates, calories, and proteins were all reduced (except for the two treatments fortified with papaya flour peels), as were the color values L, a*, b*, hardness, crispness (except for treatment 3), diameter, thickness, spread ratio, and percentage spread. The dietary fiber and mineral content, particularly sodium, calcium, magnesium, iron, and zinc, increased in enriched samples compared to corn flour-based samples (control). Although the a_W of the enriched biscuit samples and control was higher, but it was less than 0.85, which is ideal for long-term storage. The acceptance score of fortified biscuits was lower than that of corn-based biscuits, with the exception of those fortified with papaya pulp flour, which received the best score. Finally, enhancing corn flour with papaya pulp flour can produce gluten-free biscuits with excellent nutritional, health, and sensory attributes.*

Key words: Celiac disease, Gluten-free, Papaya flour, Corn flour, Biscuits, Nutrition.

1. Introduction

Biscuits are a popular snack in different countries and are popular all over the world due to their affordability, long shelf life, and availability in different flavors, often made from wheat flour. The use of bakery products as a means of supplementing various nutrients is advancing day by day. The bakery products made from refined flour are much poorer nutritionally and do not adequately meet the requirements for many macro- or micronutrients (**Nadeem *et al*., 2010**). In addition, there is a growing demand for gluten-free foods, especially for celiac patients who make up 1% of the world's population (**Baljeet*et al*., 2010**). The average number of people with celiac disease worldwide is expected to increase 10-fold over the next few years (**Gallagher *et al*., 2004**), so the challenge here is to strictly adhere to a gluten-free diet.The European Commission Regulation of the European Union (**EC No. 41/2009**) requires that foodstuffs for gluten-intolerant people do not contain a level of gluten exceeding 100 mg/kg (100 ppm) in foods, with this level classified as "very low gluten" and a gluten content not exceeding 20 mg/kg as "gluten-free" (**McCabe, 2010**). Gluten-free bakery products are considered safe for celiac patients, but the nutritional quality of gluten-free bakery products may be deficient due to the use of highly refined flours and starches that are high in starchy carbohydrates but low in protein quantity and quality as well as low in fiber (**Fry*et al*., 2018**). Therefore, relatively more gluten-free cereal flours and starches (e.g rice, corn, and sorghum) that have protein content similar or higher than wheat flour (**Di Cairano*et al*., 2018**) and are rich in fiber, minerals, and antioxidant bioactive compounds, which add additional nutritional value to gluten-free bakery products (**Melini*et al*., 2017**), can be used as supplements.

As a result, other types of flours are gaining attention for their gluten-free properties, such as corn flour for making biscuits.White corn flour is a gluten-free product which makes it suitable for people with gluten sensitivity or celiac disease. It is rich in fiber, which aids digestion, vitamins such as vitamin B, and minerals such as iron and magnesium. It is also a good source of energy and contains a good percentage of protein, which helps build muscle. It contains 360 calories per 100 grams of flour, 75 grams of carbohydrates per 100 grams, 8 grams of protein per 100 grams, and 2.5 grams of fiber per 100 grams. White cornmeal gives a coarser and firmer texture to mixtures as well as mildly sweet taste compared to other flours.

Gluten is essential for the structure and shape of the dough, while its absence can weaken it, leading to a runny dough and poor respiratory properties. Gluten-free dough is less cohesive, inflexible and difficult to handle, with less desirable texture and quality. Gluten-free bakery products are high in carbohydrates and calories, raising concerns for health-conscious consumers. The challenge lies in replacing wheat gluten with other ingredients that provide similar functionality. Binders and improvers such as xanthan gum, guar gum and apple pectin are used to improve the texture and quality of gluten-free biscuits (**Preichardt*et al*., 2011; Matos and Russell, 2015**).There is a growing trend towards incorporating dietary fibers and minerals into baked products as a means to increase their nutritional value as their intake is associated with reduced incidences of cancer, type 2 diabetes, obesity, cardiovascular disease, and chronic respiratory disorders (**Schwingshackel*et al*., 2015**). Dietary fiber plays an important role in maintaining a healthy digestive system, regulating blood sugar levels and promoting satiety, which may help with weight management. Minerals are also essential for many physiological processes, such as bone health, immune function, and nerve and muscle function.

By incorporating fruits into baked products such as biscuits, it is possible to increase their fiber and nutrient content without sacrificing taste or texture to enhance the nutritional composition and functional properties of baked goods.

Papaya (*Carica papaya* L.) whether whole fruit, papaya pulp or peels is an excellent source of fiber, minerals, phytochemicals, and vitamins C and A. Traditional methods of disposing of papaya peels contribute to environmental pollution, even though they are rich in bioactive compounds. Papaya is a tropical fruit with a presence both in the national and international market due to its therapeutic and nutritional properties. 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*et al*., 2020).** Papaya fruits differ in terms of their physical and chemical properties. Fruit weight ranged from 645.40 to 1740.00 g, the average weight of the pulp was from 550 to 1400 g and it represented 80 to 87% of the fruit weight, while the peel represented 12 to 14%, while the seeds represented 0.5-7%. pH ranges from 4.2 to 4.5, TSS from 9 to 13%, acidity from 2 to 2.3%, total sugars from 7 to 10.50%, reducing sugars from 3.4 to 6.90%, and vitamin C from 40 to 44 mg/100 g **(Zaman *et al*. 2006)**. Ripe papaya fruits contained high moisture content (>85.5%), low acidity (<0.18% GA), low crude fat (0.10 g/100 g edible fraction), moderate crude fiber content (1. 45 g/100 g edible fraction), high ascorbic acid content (>84.5 mg/100 g w/w), and moderate content of total sugars (>13.0%) and soluble solids (>12.9%). Among the identified macronutrients (Ca, K, Mg, Na), the potassium content (420 mg/100 g) was the highest **(Othman, 2009).** Papaya contains nutrients and phytochemicals that help improve digestion, reduce inflammation, and support cardiovascular, immune, and digestive health. It may also reduce the risk of colon, lung and prostate cancer as it acts as a detoxifier, metabolism booster, rejuvenator and maintains body balance because it is rich in antioxidants, B vitamins, folic acid, pantothenic acid, potassium, magnesium as well as fiber. Due to its high content of vitamin or carotenoids, it can help prevent cataracts and age-related macular degeneration **(Ali *et al*., 2012)**. Papaya is rich in fiber, which helps avoid constipation and lowers cholesterol. They are also rich in vitamins C and A. One fruit contains about 100% vitamin C and 30% vitamin A. They also include vitamins E, K, β-carotene and folic acid, which help lower homocysteine levels, which is a risk factor for heart attacks and strokes **(Noshad*et al*., 2018)**. Papaya is known for its nutritional and therapeutic properties as it contains papain enzymes, chymopapain (anti-cancer activity), carotenoids, alkaloids, monoterpenoids, flavonoids, minerals, and vitamins. Its multiple medicinal properties include: - Antifertility, uterine tonic, diuretic, antihypertensive, antihyperlipidemic, anthelmintic, anti-wound, antifungal, antibacterial, antitumor, and anti-free radical **(Nakhate*et al*., 2019; Zainul*et al*., 2022)**. Papaya is a rich source of bioactive compounds such as isothiocyanates and lycopene, as well as enzymes such as chymopapain that aid digestion and papain with antioxidant properties, making it a cholesterol-lowering, anti-hypertensive, and anti-diabetic fruit **(Verma *et al*., 2017)**. It is also a powerful anti-cancer agent **(Ramadan *et al*., 2015).** Since papaya peel is rich in phenols, it has been used as an alternative source of phenols, as it has strong antioxidant properties, used as antitumor, anticancer and antiviral agents, as well as lowering blood pressure **(Jamal *et al*., 2017)**. A recent study also showed that papaya contains the amino acid arginine, which is essential for male fertility (**Rovira, 2009**).

There is a wide scope for improving the nutritional quality of biscuits while meeting the demand for consumer health has led to the development of many healthy alternatives by adding healthy ingredients in the biscuit industry to make it more nutritious, tasty and suitable for many patients such as celiac patients (**Abd El-Hamid *et al*., 2019**). Therefore, this study aims to develop new types of gluten-free biscuits with nutritional value enhanced with different types of papaya flour while promoting the utilization of underutilized fruit in the production of value-added products.

2. Materials and methods

2.1. Materials

The Egyptian Company for Maize Products, 10th of Ramadan City, Egypt, provided the whitecorn flour 97%. The local market in Giza, Egypt, provided the papaya (*Carica papaya* L.) fruits and baking supplies, such as corn oil, sugar, and salt. All chemical used in this study was analytical grade.

2.2. Methods

2.2.1. Preparation of papaya powder

The following are the processes to manufacture papaya powder, as stated in **Varastegani*et al*. (2015)**, with some modifications: Papaya fruits were carefully washed with tap water and the seeds were removed. The papaya was separated into three treatments: whole fruit, pulp alone, or peel only, and cut into pieces varying in thickness from 0.5 to 1 mm. Then, for 24 hours, dry in an oven set at 60 degrees Celsius. Individual samples were crushed into fine powder with a desktop mill and sieved through a 60-mesh sieve. The powder was stored in polyethylene bags at 4 ± 1 °C until used.

2.2.2. Preparation of gluten-free biscuits

A biscuit recipe consists of major and minor ingredients. Flour, oil, sugar, water, chemical leavening agents (sodium bicarbonate, ammonium bicarbonate) are the main primary ingredients while salt, egg, emulsifier, and flavoring compounds act as optional secondary ingredients **(Mancebo*et al*., 2015).**Gluten-free biscuits were prepared according to the method of **Schober *et al*. (2003)** with some modifications. The ingredient quantities were quantified in accordance with the recipes presented in Table 1. The eggs were initially homogenized using a hand mixer (Braun Multiquick 5 (600 W), Kronberg, Germany)for a few seconds. Next, the sugar, corn oil, and eggs were mixed for 20 seconds at speed 3. Half of the flour and all other ingredients were then included and mixed for 20 seconds. The remaining flour was then added and mixed for 140 seconds. A total mixing time of 3 minutes. After a 20-minute rest, the dough was shaped into 5 mm thick sheets with a diameter of 50 mm. After shaping the biscuits by hand, they were baked at 180°C for 20 minutes in a laboratory oven. The biscuits cooled at room temperature for 75 minutes.

Table 1. Recipe for the production of biscuit by grams.

			Papaya					
	Control 1	**Control 2**	**Dried fruits at25% (T1)**	**Dried fruits at 30%(T2)**	**Dried pulp at 10% (T3)**	**Dried Pulp at 35% (T4)**	**Dried peel at 15% (T5)**	**Dried peel at 20% (T6)**
Wheat flour	100	-	-	-	-	-	-	-
Corn flour	-	100	75	70	90	65	85	80
Sugar	35	35	35	35	35	35	35	35
Corn oil	28	28	28	28	28	28	28	28
Eggs	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5
Sodium bicarbonate	2	2	2	2	2	2	2	2
Vanillia	1	1	1	1	1	1	1	1
Salt	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Ammonium bicarbonate	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cream of tartar	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Carboxy methylcellulose	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

2.2.3. Analysis

2.2.3.1. Proximate composition

Moisture, fat, ash, crude fiber, and crude protein (N x 5.7), as well as mineral content (Na, Ca, P, K, Fe, Zn, and Mg), were measured according to **AOAC (2012)**, whereas available carbohydrate was estimated by the difference, 100-(protein + fat + fiber + ash) according to **Fraser and Holmes, 1959**. The total calorieswere computed (kcal/100g) using the **FAO (2003),** E= 4 X (carbohydrate% + protein%) + 9 X (fat%).

2.2.3.2. Physical properties

Diameter of biscuits was measured by laying six biscuits edge to edge with the help of a scale rotating them 90o and again measuring the diameter (cm) of six biscuits and then taking average value. The thickness of the biscuits was measured by arranging six biscuits in a stack and determining the mean thickness (in centimeters).The weight (g) of the biscuits was obtained by measuring the average of six separate biscuits using a digital balance. Spread ratio was calculated by dividing the average value of diameter by average value of thickness of biscuits **(Gomeaz*et al*., 1997)**. The percent spread calculation was performed by dividing the value of spread ratio for biscuits manufactured with gluten-free flour by the spread ratio of the control biscuits and the result was then multiplied by 100 to obtain the percent spread value.The hardness was measured using a texture analyzer (Brookfield, CT3, USA). Crispness was estimated as the count of a positive peaks obtained from penetration test**(Hamdani *et al*., 2020).**

2.2.3.3. Water activity

Water activity (a_w) of the samples was measured using aw measurement device (Hygrolab, Cole Parmer) with an accuracy of ± 0.001 at 25 °C. Before the test, the a_w meter was activated and permitted to reach thermal equilibrium for a period of 30 minutes. The measurement of each sample was executed in accordance with the instrument's protocol **(Dawit *et al*., 2019)**.

2.2.3.4. Color

The color measurement achieved bycolor meter (Konica Minolta CR-400). The results of lightness, redness, and yellowness were recorded in L*a*b*, respectively.

2.2.3.5. Sensory evaluation

Ten panelists from the Bread and Pastry Research Department of the Food Technology Research Institute, Agric. Res. Center, Giza, assessed the sensory qualities of biscuits. According to **(Mudgil*et al*., 2017 and Naseer *et al*., 2021)**, the following criteria were used to create the grading system: color (10), flavor (10), mouthfeel (10), crispness (10), appearance (10), and overall score 50 degrees.

2.2.3.6. Statistical analysis

Every measurement was done 3 times. The statistical software SPSS (version 20.0) was used to analyze the data, and at a significance level of 5%, the analysis of variance test (ANOVA) was used to examine significant differences in accordance with Duncan's Multiple Range Tests.

3. Results and discussion:

3.1. Chemical structure of the starting materials (on dry weight basis)

Table 2. Chemical structureof raw materials (g/100 g)

Constituents	Wheat flour	Corn flour	Whole papaya fruit flour	Papaya pulp flour	papaya peel flour	Eggs
Moisture content	12.21^{b}	9.95^{c}	6.49^{d}	6.14^{d}	9.06^{c}	76.20^{a}
Protein	13.00^{a}	8.12^{d}	2.19^{e}	0.84^{f}	12.13^{c}	12.56^{b}
Fat	1.00^{e}	1.00^{e}	3.97^{c}	4.13^{b}	2.79^{d}	9.52^{a}
Fiber	0.50^{e}	2.50^{d}	18.32^{b}	16.48c	31.78^{a}	0.00
Carbohydrate	72.63^{b}	75.89^{a}	65.01^{d}	68.55^{c}	48.15^{e}	1.17^{f}
Ash	0.66^{e}	2.54^{d}	4.01^{b}	3.86^{c}	5.15^{a}	0.55^{f}

Means within rows with differed superscripts are significantly different at ($p < 0.05$).

As illustrated in Table 2, the chemical composition of the raw materials utilized in the production of the various biscuit treatments examined in this study is presented. With regard to moisture content, the moisture content of the wheat flour used (12.21%) was higher than the moisture content of the corn flour used (9.95%). The moisture content of the various types of papaya flour ranged from 6.14% to 9.06%, with the dried papaya peel exhibiting the highest moisture content (9.06%). The moisture content of eggs reached 76.20%. Wheat flour exhibited a higher protein content (13%) compared to corn flour (8.12%), and the protein content of wheat was also higher than that of eggs (12.56%). The dried peel of papaya exhibited the highest protein content (12.13%), surpassing both dried whole fruits (2.19%) and dried pulp (0.84%). With regard to fat content, no significant differences were observed between wheat flour and corn flour, both exhibiting a 1% fat content. However, eggs demonstrated the highest fat content, reaching 9.52%. Additionally, corn flour exhibited a higher fiber content (2.50%) compared to wheat flour (0.5%). The fiber content of papaya peels was higher than that of the fruit and higher than that of the pulp. Eggs had the lowest fiber content (1.17%) of all the materials used in the manufacture of biscuits. The carbohydrate content of corn flour was higher (75.89%) than that of wheat (72.63%), followed by that of dried papaya pulp (68.55%). The mineral content of the raw materials used in the manufacture of biscuits ranged from 0.66% to 5.15%. It is evident that the flour produced from the peels and fruits of papaya and dried pulp will be a significant source of mineral fortification in manufactured biscuits due to the high mineral content of these raw materials.

3.2. Chemical structure for the different types of biscuits (g/100 g)

Table 3.Chemical structurefor the different types of biscuits (g/100 g)

	Moisture	Protein	Fat	Fiber	Carbohydrate	Ash	Calorie's kcal/100g
C1 (Control wheat)	**4.52^{a}**	**9.65^{a}**	**14.54^{e}**	**0.38^{g}**	**69.74^{a}**	**1.18^{g}**	**448.40^{a}**
C2 (Control corn)	**3.65^{d}**	**7.80^{c}**	**14.54^{e}**	**1.89^{f}**	**70.24^{a}**	**1.89^{f}**	**442.99^{b}**
T1(Whole dried fruits at 25%)	**3.85^{c}**	**7.25^{e}**	**14.82^{b}**	**4.87^{d}**	**67.18^{c}**	**2.03^{c}**	**431.11^{d}**
T2(Whole dried fruits at 30%)	**3.96^{c}**	**7.14^{e}**	**14.88^{b}**	**5.47^{b}**	**66.50^{d}**	**2.05^{b}**	**428.45^{f}**
T3(Dried pulp at 10%)	**3.68^{d}**	**7.53^{d}**	**14.66^{c}**	**3.94^{e}**	**68.25^{b}**	**1.94^{e}**	**435.05^{c}**
T4(Dried pulp at 35%)	**3.70^{d}**	**6.84^{f}**	**14.95^{a}**	**5.58^{b}**	**66.86^{c}**	**2.06^{a}**	**429.40^{e}**
T5(Dried peel at 15%)	**4.17^{b}**	**7.99^{b}**	**14.57^{d}**	**5.18^{c}**	**66.07^{e}**	**2.02^{d}**	**427.35^{g}**
T6(Dried peel at 20%)	**4.32^{a}**	**8.05^{b}**	**14.58^{d}**	**6.27^{a}**	**64.71^{f}**	**2.07^{a}**	**422.26^{h}**

Means within columns with differed superscripts are significantly different at ($p < 0.05$).

Moisture content ranged from 3.65 to 4.52 g/100 g and shows variation among all biscuits. Moisture plays a crucial role in determining the quality and shelf life of sugar-based confectionery **(Ergun *et al*., 2010)**. It is observed from Table 3 that the relative moisture content is low in all types of biscuits made from corn flour, whether fortified with papaya or not, compared to biscuits made from wheat flour, and this may be due to the strength of the gluten network formed in the biscuits because it contains gluten protein. The different types of papaya flour added to corn flour increased the moisture retention capacity of the biscuits.This could be due to their high-water absorption capacity because of their fiber content which tend to bind and retain more water (**Maboh*et al*., 2024**). The moisture level of a food is an indicator of its water activity and is used to assess its susceptibility to microbial infection. According to (**Rebellato*et al*., 2015)**, the moisture content of biscuits should not exceed 14% and the optimum moisture content should be no more than 5% which maximizes the shelf life of the biscuits. It is clear from the above results that the moisture content was in a suitable range for the biscuits, ranging from 3.65 to 4.52%.**Ng *et al*. (2020)** found similar results using overripe banana pulp chocolate cookies.

Protein content varied among all types of biscuits, with wheat flour biscuits recording the highest protein content of 9.65 g/100 g, followed by the treatment in which corn flour was replaced with dried papaya peels at a rate of 20 percent and the one in which corn flour was replaced with peels at a rate of 15 percent. The protein content of all biscuit treatments ranged from 6.84 to 9.65 g/100 g with a difference in calorie content from 27.36 to 38.6 kcal.

The presence of fat influences the shelf life of the food **(Addisu*et al*., 2019)**. High fat concentration may hasten degradation by encouraging rancidity, resulting in the production of undesirable smells and aromas. The **fat** content ranged from 14.54 to 14.95g per 100g, where the treatment with dried pulp at 35% recorded the highest fat content, while biscuits made from wheat and corn flour recorded the lowest fat content (14.54%). Despite the observed increase, fat content remained below the requirement of 15% **(Rutkowska*et al*., 2012)**. The difference in calories for fat between the highest and lowest fat content treatments was only 3.69 calories compared to carbohydrates which was23.32 calories.

Thetotal dietary fiber in all samples ranged from 0.19 to 3.13 g/100 g. The percentage of fiber increased as the proportion of peels added to the treatment increased and the increase was higher when the peels were added purely than when added in the form of whole fruits and the increase in fiber has many health benefits. High fiber content improves digestion and thus reduces constipation **(Elleuch*et al*., 2011)**. According to the Institute of Medicine's **(IM, 2006)** the males over 50 should consume 30 grams of dietary fiber per day, while females should consume 21 grams of dietary fiber per day. 100 grams of a biscuits fortified with papaya peel in treatment 6 can provide 21 and 30% of the daily dose of fiber for males and females, respectively, over the age of 50 years. Eating foods rich in dietary fiber reduces the risk of cardiovascular disease, some cancers, and type 2 diabetes, as well as promotes the regulation of physiological functions, according to epidemiological research **(Sharma *et al*., 2016)**.

Ash content also varies among all biscuits. Samples with a high ash content are predicted to have a high concentration of different mineral elements, which are thought to expedite metabolic processes and boost growth and development.

Table 3 shows the approximate composition of biscuits made from wheat, corn, and other treatments. It is clear from the table that carbohydrates were the main component of the macronutrients and ranged from (64.71 to 70.24 g per 100 g) and contributed 257.64 to 280.96 kcal of the total calories.

Food energy is particularly important because it helps determine the fuel value of food. Although energy is not a nutrient, it is essential in the system for metabolic activities, biological performance, muscle activity, heat production, growth, and tissue formation**(Bello *et al*., 2013)**.The energy output of biscuits made from corn flour fortified with various forms of papaya flour is lower than that of biscuits made from corn flour alone, which also has a lower energy output than biscuits made from wheat flour.

3.3. Mineral's compositionof different types of biscuits

Table4. Mineral content of different types of biscuits (mg/100 g)

	mg/100g				
Sample	**Na**	**Ca**	**Mg**	**Fe**	**Zn**
C1 (Control wheat)	**216.8^{e}**	**82.4^{h}**	**33.4^{a}**	**4.7^{b}**	**2.4^{c}**
C2 (Control corn)	**208.7^{g}**	**87.0^{g}**	**19.6^{e}**	**3.1^{g}**	**2.3^{d}**
T1(Whole dried fruits at 25%)	**221.3^{d}**	**213.0^{d}**	**20.8^{d}**	**3.3^{e}**	**2.5^{b}**
T2 (Whole dried fruits at 30%)	**226.7^{c}**	**238.2^{b}**	**21.3^{b}**	**3.4^{d}**	**2.5^{b}**
T3 (Dried pulp at 10%)	**210.5^{f}**	**113.7^{f}**	**19.8^{e}**	**3.1^{g}**	**2.3^{d}**
T4 (Dried pulp at 35%)	**216.8^{e}**	**180.3^{e}**	**20.4^{e}**	**3.2^{f}**	**2.4^{c}**
T5 (Dried peel at 15%)	**230.3^{b}**	**226.0^{c}**	**21.7^{b}**	**4.6^{c}**	**2.6^{a}**
T6 (Dried peel at 20%)	**234.9^{a}**	**270.6^{a}**	**22.1^{b}**	**5.0^{a}**	**2.6^{a}**

Means within columns with differed superscripts are significantly different at ($p < 0.05$).

The mineral composition of the various biscuit treatments is delineated in **Table 4**. The predominant minerals detected in the biscuits are sodium (Na), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn). Notably, sodium levels were significantly reduced in biscuits made from corn flour (208.7 mg/100g) compared to those prepared with wheat flour (216.8 mg/100g). The fortification of corn flour with various additives derived from dried papaya fruits, dried pulp, or dried peels led to a substantial increase in sodium content compared to the control sample made from corn flour. Notably, the addition of dried papaya peels resulted in the most significant increase, particularly when the percentage of peels added was higher compared to the other treatments. The calcium content of the various biscuit treatments ranged from 82.4 to 270.6 mg/100 g. The wheat flour biscuits exhibited the least significant decrease among the treatments and were outperformed by the corn flour biscuits in calcium content, which reached 87.0 mg/100 g. A significant difference in calcium content was observed between the corn flour biscuits ($p < 0.005$). The incorporation of papaya flour, in its various forms, led to a substantial increase in the calcium content of the biscuits, particularly when the peels were incorporated. The increase in calcium was directly proportional to the increase in the content of the added peels. With regard to the magnesium, iron, and zinc content, biscuits made from wheat flour exhibited significantly higher levels of these minerals compared to biscuits made from corn flour. However, the incorporation of papaya flour in various forms, particularly with high levels of added peels, led to a substantial increase in the mineral content of the biscuits. The study's findings indicate that biscuits fortified with diverse papaya flours exhibited higher concentrations of calcium, sodium, magnesium, iron, and zinc compared to their unenriched counterparts. This observation aligns with the results reported by **Ndife*et al*. (2014)**. The outcomes of this investigation corroborate the earlier research conducted by **Emelike*et al*.(2020).**

3.4. Moisture content and water activity of different types of biscuits

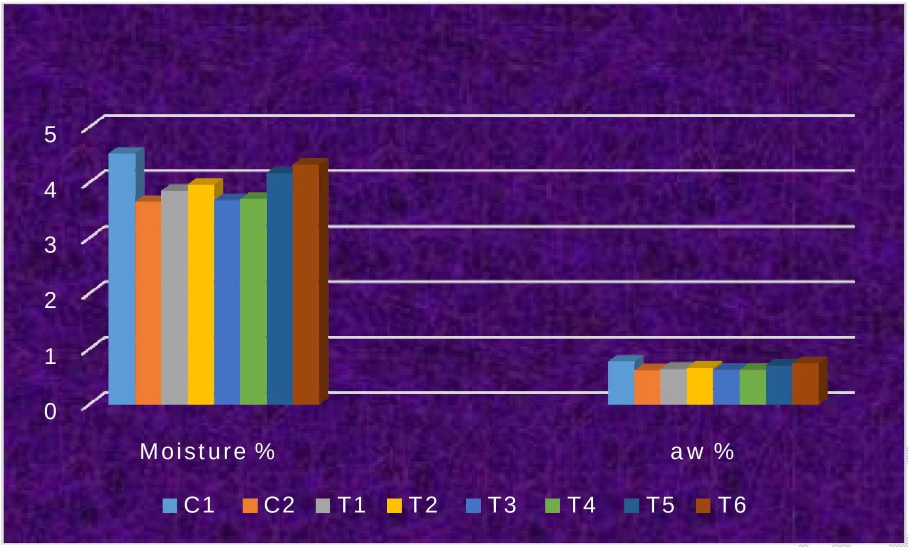

Figure1. Moisture content and water activity of different types of biscuits

The amount of water that is available for biological responses is measured by water activity, or aw. It is a critical factor in determining the viability of microorganisms and their capacity to proliferate. It has been identified as a critical factor in determining the safety or shelf-life of a product **(IFT/FDA 2001 and Kilcast& Subramaniam 2000)**. Figure 1illustrates the a_w values of various biscuit samples. The analysis reveals that the water activity value of biscuits made from corn flour (0.61) is lower than that made from wheat flour (0.77). The incorporation of papaya pulp flour into biscuit formulations led to a negligible increase in water activity, while the fortification with whole fruit flour elicited a more pronounced effect, and a further enhancement was observed with the addition of papaya peel flour. The findings indicate that the estimates of water activity are consistent with the estimates of moisture content for the diverse biscuit samples. **Rockland & Nishi (1980)** established a threshold of ≤0.85 for water activity (a_w), which is considered non-hazardous for foods, based on its ability to impede the growth and toxin production of Staphylococcus aureus. Furthermore, **Cook & Johnson (2010)** have asserted that a_w is a particularly salient factor influencing the spoilage of numerous bakery products, including breads and cakes, which typically have levels above 0.94. The findings on water activity, therefore, offer a basis for predicting the stability, safety, and quality of biscuits prepared with an a_w below or equal to 0.85.

3.5. Color attributes of different types of biscuits

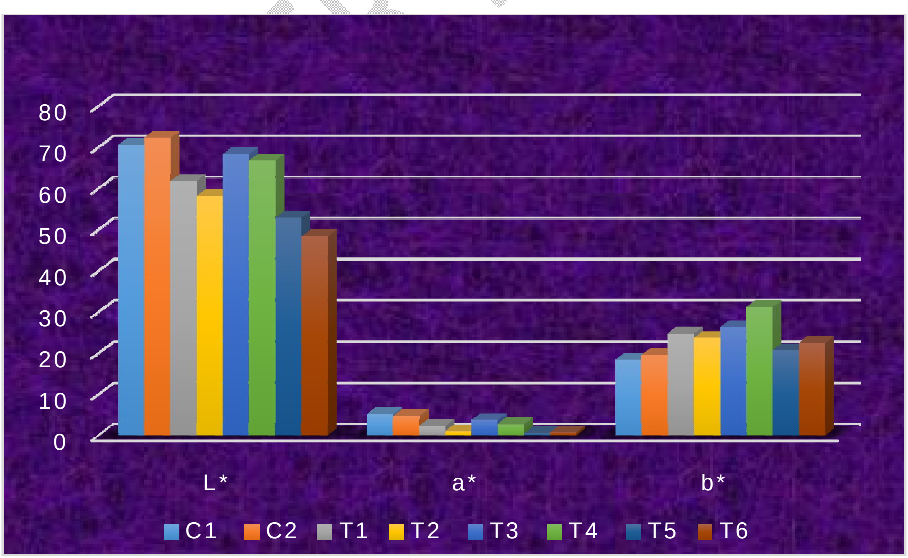

Figure2. Lightness, Redness and Yellowness of different types of biscuits (lightness, redness, and yellowness were recorded in L*a*b*, respectively)

As illustrated in Figure 2, the incorporation of diverse papaya flours, encompassing whole fruits, pulp, and peels, exerts a discernible influence on the color attributes of the resultant biscuits. In general, biscuits made from corn flour exhibited a higher lightness value (72.3) compared to those made from wheat flour (70.5). It is noteworthy that the lightness values exhibited a decline in conjunction with the incorporation of various papaya flours into the corn flour matrix. Notably, the samples containing papaya pulp exhibited the highest lightness, particularly when the percentage of added pulp was reduced. Conversely, an increase in the level of peels added to the flour resulted in a decrease in lightness, particularly when the peels were used in their pure form. Furthermore, the redness level (a*) of biscuits made from corn flour was found to be lower compared to those made from wheat flour. Additionally, the redness rate of biscuits made from corn flour and fortified with different papaya additives decreased compared to the control made from corn, particularly when the peels were incorporated as whole fruit. The magnitude of this decrease was more pronounced when the peels were added in their pure form. Moreover, the yellowing values increased from 20.7 to 31.3 when papaya in its various forms was incorporated into corn flour, as compared to the corn control (19.6) and also compared to the biscuit control made from wheat flour (18.4). The addition of pulp flour to corn flour resulted in the highest degree of yellowing, while the samples containing peels exhibited the lowest level of yellowing. This phenomenon may be attributed to the presence of green hues in the yellow peels, which could have influenced the color perception.

3.6. Crispness and hardnessof different types of biscuits

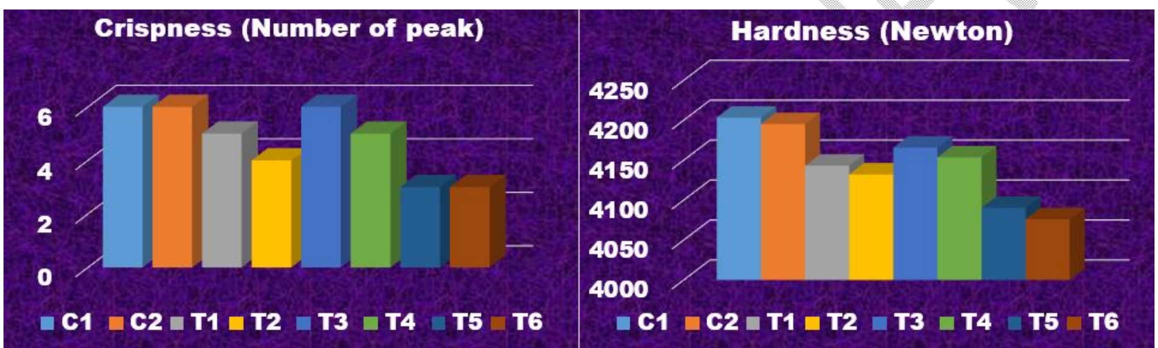

Figure 3. Crispness and hardness of different types of biscuits

As demonstrated in Figure 3, the results indicate that the biscuit samples formulated from corn and wheat flour, in conjunction with those produced through the incorporation of 10% dried papaya pulp, exhibited the optimal level of crispness among the produced biscuit samples. However, when the percentage of pulp added increased to 35%, the degree of crispness decreased, reaching a level comparable to that of the sample containing 25% dried whole papaya fruits. Furthermore, increasing the percentage of dried fruits added led to a subsequent decrease in crispness, with this decrease being more pronounced when corn flour was substituted with dried papaya peels, particularly at higher percentages of peels incorporated. The hardness results indicated that the optimal biscuit samples were produced from wheat flour (4203.33), followed by corn flour (4195.22). The analysis revealed a decline in hardness with the substitution of corn flour with dried papaya fruit flour, dried pulp flour, or dried papaya peel flour. The biscuit sample with 10% pulp added exhibited optimal characteristics, followed by the sample with 35% pulp added. The biscuit samples with added peels exhibited the lowest hardness compared to the other samples.

3.7. The physical properties of different types of biscuits

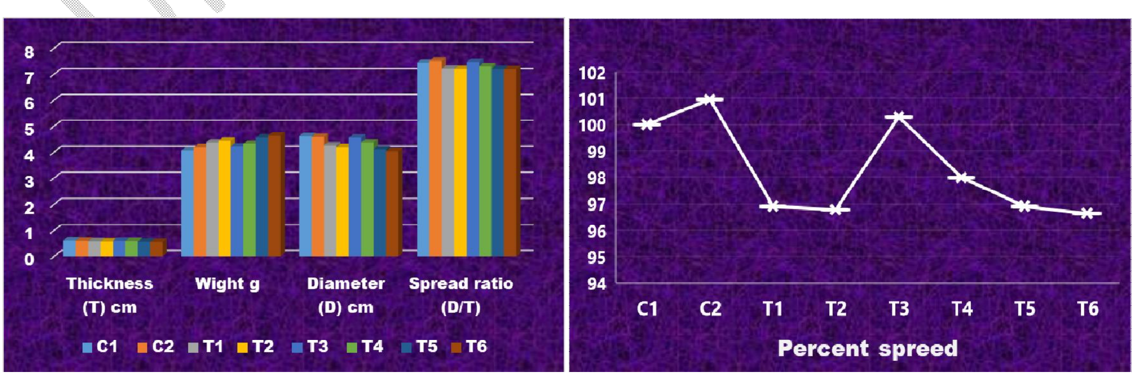

Figure4. The physical properties of different types of biscuits

Eight treatments of biscuits were prepared. The first treatment involved the production of biscuits from wheat flour containing gluten protein, which were then compared with other samples made from corn flour only (control 2) or other samples made from corn flour partially replaced by dried whole papaya flour, pulp flour, or peel flour in different proportions. The physical properties of the biscuits were evaluated, and the results are presented in Figure 4. The weight range of the biscuits was from 4.06 g to 4.64 g, with the maximum value observed in biscuit T6. A comparison of the weights of biscuits made from corn flour (control 2) and those made from wheat flour (control 1) revealed that the former was heavier, as illustrated in the results presented in Figure 4. Furthermore, the fortification or replacement of corn flour with papaya flour from different sources (whole fruits, pulp, or peels) resulted in an increase in the weight of the resulting biscuits compared to the corn control. The highest recorded weight was observed when replacing with papaya peel flour, particularly when increasing the percentage of replacement. In contrast, replacing with papaya pulp led to a less significant increase in biscuit weight compared to replacing with whole fruits. However, both replacement methods resulted in an increase in biscuit weight with increasing replacement percentages. The results of the study demonstrated that the weight of all types of biscuits containing gluten-free compound flour was greater than the weight of the control biscuits (control1) containing 100% wheat flour. It is widely acknowledged that a high biscuit diameter and a greater spread ratio constitute optimal product quality attributes **(Ekissi*et al*., 2020)**. The diameter of the biscuits ranged from 4.03 to 4.62 centimeters, with the highest value recorded for the control sample made from wheat flour containing gluten (4.62 centimeters), followed by the control sample made from corn (4.59 centimeters). Generally, the diameter of the biscuits decreased with the incorporation of papaya flour, or the decrease increased with the increase in the percentage of added peels, whether peels in pure form or in the form of whole fruits, compared to the addition of papaya pulp flour, which resulted in larger diameters. A similar trend was observed in the thickness of the biscuits. The relationship between breaking strength or decreasing gluten and reducing thickness has been reported by **Nwosu and Akubor (2016)**. The spread ratio is a pivotal criterion for biscuit quality, as it impacts the texture, grain fineness, bite, and overall mouthfeel of the biscuit. The alterations in diameter and thickness were reflected in the spread ratio and biscuit spread ratio. The incorporation of varying quantities of dried papaya flour, categorized into three distinct types, has been observed to result in a reduction of the spread ratio when compared to biscuits composed exclusively of corn flour. This reduction in spread ratio was further accentuated when contrasted with biscuits formulated with wheat flour. This phenomenon can be attributed to the competition among ingredients for available water, as previously observed by **Dayakar*et al*. (2016). Nwosu and Akubor (2016)**further suggested that the spread ratio is affected by the water absorption capacity of the ingredients. It was further observed that the addition of flour or other ingredients during dough mixing that absorb water would result in a reduction of biscuit spread. The decline in the spread ratio was observed to increase in proportion to the percentage of added peels. Overall, there was no discernible difference in the percent spread between the two control samples and sample 3, which incorporated 10% dried pulp. The percent spread of the remaining treatments ranged from 96.64 to 69.91%, with the exception of treatment 4, which outperformed them and was fortified with 35% dried pulp. The reduced percent spread of biscuits containing gluten-free compound flour can be attributed to the propensity of compound flour to form clusters, which result in an increased number of available hydrophilic sites. These sites compete for the limited free water in the biscuit dough (**McWatters and Holmes, 1979).**

3.8. Sensory evaluation of different types of biscuits

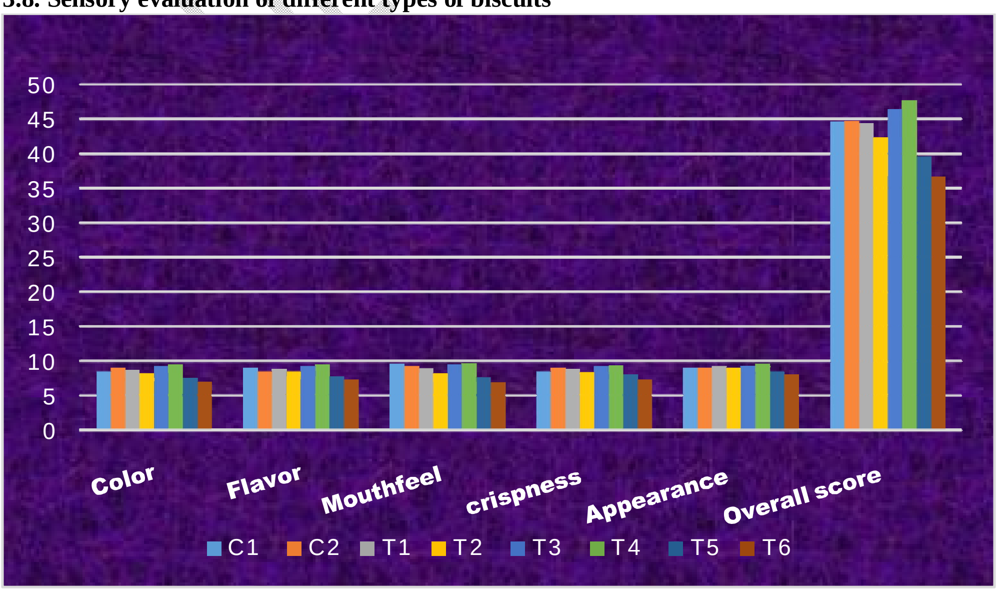

Figure5. The sensory attributes of different types of biscuits

Sensory attributes have been identified as a primary factor influencing consumer acceptance. Consequently, a comprehensive evaluation was conducted to assess the impact of various treatments on key sensory characteristics, including color, flavor, mouthfeel, crispness, and appearance. In regard to sensory attributes, treatment T4 was found to be superior to all other treatments in all sensory attributes, including color, flavor, mouthfeel, crispness, and appearance. Treatment T3, in which corn flour was substituted with proportions of dried papaya pulp, followed T4. The T4 and T3 treatments exhibited the lowest water content and moisture percentage, which are significant factors contributing to texture changes, such as the mechanical changes observed in biscuits **(Nikolaidis and Labuza, 1996)**. The preferable textures and crispness of the T4 and T3 treatments could be attributed to the quality of the proteins added, which may enhance the acceptability of gluten-free biscuits in terms of texture, as reported by **Matos *et al*. (2014). Shaabani*et al*. (2017)** also demonstrated that the addition of proteins from other sources or hydrocolloids improved the acceptability of gluten-free biscuits in terms of texture. The third reason for exceeding the two treatments, particularly on the control treatments, may be due to the use of CMC, a common ingredient in bakery products that functions as a viscosity enhancer or coagulant to improve texture and sensory properties. This results in a more homogeneous cell distribution in the biscuits, akin to the texture of conventional biscuits made from wheat flour. Furthermore, they have been shown to enhance the specific volume and texture, as evidenced by a reduction in hardness and delayed spoilage **(Preichardt*et al*., 2011).** The fourth reason may be attributed to the increased viscosity of the corn flour mixture due to swelling and gelatinization of starch granules during heat treatment, thus improving the biscuits' texture **(Marston *et al*., 2016)**. In the following ranking of sensory properties, the wheat flour and corn flour biscuit samples demonstrated similar results and were thus considered comparable, followed by the samples with the incorporation of whole dried fruits in terms of the degree of quality in sensory properties. Finally, the biscuit samples fortified with dried papaya peels demonstrated the least favorable organoleptic properties. It is evident from Figure 5 that sample T4 was by far the most optimal sample. While the T3 sample exhibited comparable overall acceptability to the wheat and corn control samples, supplemented with 25% whole fruit, it surpassed the others in terms of crispness, mouthfeel due to its reduced fiber content, and flavor, color, and appearance. In contrast, the biscuit samples fortified with papaya peels exhibited the lowest acceptability, primarily due to the increase in fiber content, which led to a reduction in mouthfeel and crispness.

4. Conclusion

The demand for gluten-free baked goods is on the rise, especially for individuals with gluten sensitivity. Bakery products lack some essential ingredients such as dietary fiber and micronutrients. Therefore, there is a need to fortify some popular products such as biscuits, which are often used as snacks due to their unique taste and texture, with ingredients with high nutritional value due to their richness in bioactive substances. Healthy gluten-free biscuits are made using corn flour and fortified with different types of papaya flour (whole fruit, pulp and peel). Six different biscuit blends were prepared by partially replacing corn flour with whole fruit papaya flour (10% and 25%), pulp flour (20% and 35%) or peel flour (10% and 25%), and compared to a reference sample made with 100% wheat flour and another made with 100% corn flour. The results showed that the biscuit samples made from corn flour fortified with papaya pulp flour outperformed the control samples made from corn flour only and the other fortified samples. In conclusion, it can be concluded that gluten-free biscuits with high nutritional and health value and sensory quality characteristics can be produced by fortifying corn flour with papaya pulp flour at (20% and 35%).

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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