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Physical, functional properties and storage study of biscuits from partially digested corn and green gram flour

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Abstract

A popular snack around the world, biscuits are valued for their versatility and low cost. In this study, nutritional biscuits manufactured with different flour proportions from partially digested maize and green grams are examined. The study analyzes their nutritional and physical characteristics after modifying biscuit composite flour mixes. In addition to changing the texture, the addition of partially digested composite flours increased the protein's digestibility and mineral content, as well as its bioavailability. All biscuit varieties showed higher levels of moisture and free fatty acid over the course of three months, highlighting the importance of proper packing and storage. Occasionally, sensory assessments revealed a decrease in overall flavor, color, and crunch. But there was no sign of microbiological deterioration. Further developments in biscuit manufacture and storage will be determined by the study, which highlights the use of pre-digested corn and green gram flours to improve biscuit nutrition and discusses how storage conditions affect biscuit shelf life.

Keywords: Biscuit, composite flour, shelf-life, corn, green gram

Introduction

Biscuits are small, thin, crispy baked items that are vital to many diets, from easy snacks to weaning meals. Conventional refined wheat biscuits are low in protein and fiber and heavy in fat, carbohydrate, and energy. Utilizing whole or coarsely ground grains and leguminous flours such as whole wheat, oats, maize, rye, and other millets, such as sorghum, might improve their nutritional profile. These substitutes offer a healthier choice by supplying vital minerals, antioxidants, and dietary fiber, offering a healthier option (Oskaybaş-Emlek *et al.*, 2022) ^[20].

According to Bakare *et al.* (2020) ^[3], biscuits are an inexpensive, popular meal that is enjoyed by many people in Nigeria, particularly youngsters. Because they lack vital minerals, traditional biscuits which are frequently manufactured with refined wheat flour can be linked to health issues like obesity and heart disease (Best *et al.*, 2023) ^[4].

Alternatives including corn, rice, and tuber starches are used in gluten-free baked goods to accommodate people with wheat allergy and gluten sensitivity. Although corn is a major gluten-free food and a good source of minerals, fiber, proteins, B vitamins, folic acid, vitamin C, and provitamin A, it is best consumed with a diverse diet because it is deficient in the amino acids tryptophan and lysine. In rural areas, maize, which is synonymous with corn, is grown all year round for a variety of purposes, including fodder and various types of corn (Ullah *et al.*, 2016) ^[22]. Andhra Pradesh, Karnataka, and other major Indian states produce more than 80% of the country's maize. Corn flour's significance in food manufacture is shown by the fact that it is a staple in many different food products (Shakouri *et al.*, 2020) ^[21]. A popular legume throughout the tropics of Asia, particularly in Thailand, India, and Pakistan, is the green gram, or *Vigna radiata*. It is the third most important legume in India, making up 9% of the country's total production. It is prized for being easier to digest and having less flatulence than other legumes (Islam *et al.*, 2020) ^[14]. Green grams are a healthy choice because they are high in protein, vitamins, and minerals and contain 8-27.5% dietary fiber, green gram is packed with protein, vitamins, and minerals, making it a nutritious option.

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Enhancing biscuits' nutritional quality involves using fortified, germinated, or fermented grains.

The digestibility of starch and protein is improved by germination, which also increases dietary fiber, protein, and mineral availability while decreasing anti-nutritional factors (Jaya *et al.*, 2020) ^[15]. These methods greatly improve the final product's nutrient profile, safety, and appeal, which makes fermented and sprouted grains a wise choice for the production of nutritious foods (Kamau *et al.*, 2020) ^[16].

Lactic acid bacteria fermentation increases protein and mineral absorption and decreases anti-nutritional components such as phytic acid, improving food safety and nutrition (De Pasquale *et al.*, 2021) ^[8]. It also improves the texture and flavor of meals. When cereals and legumes are mixed to create wholesome and useful foods, this procedure is especially beneficial (Mupangwa *et al.*, 2021) ^[19].

Materials and Methods

Materials

Microorganism: ATCC or the Institute of Microbial Technology in Chandigarh, India, provided the pure culture of *Lactobacillus acidophilus* ATCC. Every 30 days, the culture was subcultured and kept on MRS slants.

Grain: The Department of Genetics & Plant Breeding at CCS Haryana Agricultural University in Hisar provided the corn and green gram.

We purchased more ingredients from the nearby market

Treatments: The grains were hygienised. Green gram and corn were grown and fermented separately (Ullah *et al.*, 2016) ^[22]. The lactic acid fermentation of grains was carried out by *Lactobacillus acidophilus* (107 cells/ml). The grains that had germinated and fermented were stored in airtight containers and dried at 55±5 °C (AOAC 2000) ^[1].

Preparation of biscuits

Using pre-digested mix (1:1, corn: green gram) and different amounts of flour (25, 50, 75 and 100%), value added biscuits will be made as WF: MF: CF of 25:25:50 of (C₂) and 12.5:12.5:75 of (C₃), 25:25:50 of (G₅), and 12.5:12.5:75 of (F₉). To ensure even mixing, the composite flours were passed through a 60 mesh sieve. The following steps were included in the biscuit preparation procedure flow chart (AOAC 2005) ^[2]:

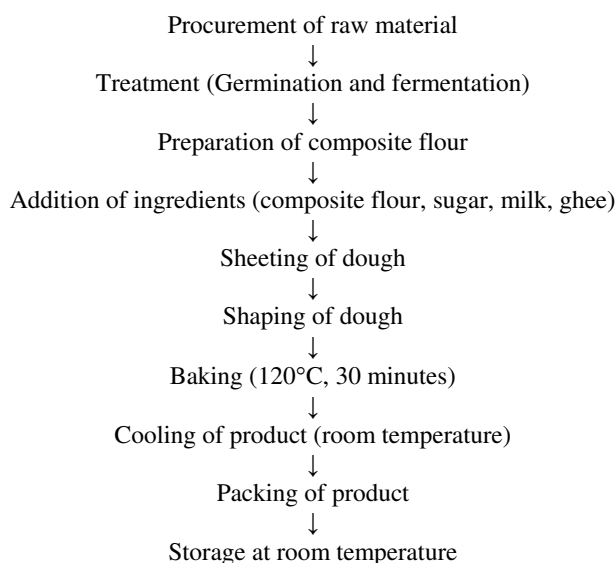


Fig 1: Flow Sheet for Preparation of Biscuits

Physical characteristics of biscuits

Using a digital scale, the average weight of five distinct biscuits was used to calculate the biscuits' weight. Using a Vernier Caliper, the thickness also known as the spread ratio was determined by measuring the diameter of five separate biscuit samples. Using a snap test with a three-point bending apparatus (HPD/3DB), the breaking force required for the biscuits made with and without varying amounts of whole flour, dehulled flour, and guar gum was assessed (AOAC 2005) ^[2].

Physico-chemical characteristics of biscuits

Specific procedures, Kjeldahl, and SOCS plus extraction systems were used to measure the fat, protein, and moisture levels, respectively. Fibre-Plus equipment and AOAC techniques were used to measure crude fiber and ash (2005). Proteins and carbohydrates contributed four calories per gram, while fats contributed nine calories per gram. Energy was determined using the factorial technique, while carbohydrates were determined by subtraction (AOAC 2005) ^[2].

Using standard methods, the following parameters were measured: sugars, total polyphenols, phytic acid, calcium, zinc, accessible iron, and zinc (AOAC 2005) ^[2]. Tannic acid equivalent was used to quantify the polyphenolic substances. Furthermore, *in vitro* protein and starch digestibility were carried out using standard methods (AOAC 2000) ^[1].

Sensory evaluation

Using a 9-point hedonic scale, 10 panelists evaluated the color, appearance, taste, texture, smell, and overall acceptance of biscuits made with both processed and unprocessed mung beans and maize. Biscuits were considered suitable for additional research if their mean score was 6 or higher (AOAC 2005) ^[2].

Shelf life studies

For three months, biscuit samples will be stored at room temperature in polypropylene bags, and their quality will be evaluated every month (AOAC 2000) ^[1].

Statistical analysis

The data collected will be analyzed using appropriate statistical methods. In this study, the data were analyzed using analysis of variance under a completely randomized design format, and the critical difference at the 5% level was used to compare different treatments over a three-month storage period. SAS software was used for statistical analysis (AOAC 2005) ^[2].

Results and Discussion

The study monitored changes in chemical constituents over time during storage and analyzed at both the chemical and physical structure of biscuits produced with pre-digested mix. Additionally, it evaluated the biscuits' sensory qualities and the growth of microbes over the period of storage at room temperature and in the refrigerator.

Physical Parameters

Spread ratio and texture

The spread ratio and texture information for the biscuit samples W₀, C₂, C₃, G₅, and F₉ are shown in Table I. There were differences observed in these biscuits' texture and

spread ratio. As seen in table I, the texture analysis specifically calculated the force in kilograms required to shatter the biscuits. Porosity affects biscuits' hardness (Budhwar *et al.*, 2020) [5].

The spread ratio decreases as the percentage of wheat flour is reduced in favor of composite flour (Feyera, M. 2021) [9]. In an identical way, adding more maize flour reduces the volume of wheat biscuits. The product may become more spreadable as a result of this decreased cohesiveness, which could allow some ingredients that melt at the high baking temperatures to leave the product (AOAC 2005) [12].

Table 1: Spread ratio and texture of best acceptable biscuits

Types of biscuits	Spread ratio	Texture (Newton)
W ₀	6.15±0.12 ^a	0.94±0.23 ^b
C ₂	3.68±0.15 ^c	1.89±0.89 ^{ab}
C ₃	4.14±0.07 ^b	1.51±0.80 ^{ab}
G ₅	4.44±0.08 ^b	0.98±0.90 ^b
F ₉	3.35±0.35 ^c	4.10±3.03 ^a
C.D. at 5%	0.34	2.76

According to the current study results, W₀ biscuits needed a breaking force of 0.94 kg and showed a spread ratio of 6.15%. The G₅ biscuits displayed a breaking force of 0.98 kg and a spread ratio of 4.44%, whereas the C₂ biscuits had a breaking force of 1.89 kg and a spread ratio of 3.68%. In the W₀, C₂, C₃, G₅, and F₉ biscuits, the spread ratio decreased with increasing flour concentrations; larger concentrations of refined wheat flour resulted in higher spread ratios. The C₃ and F₉ biscuits had breaking forces of 1.51 kg and 4.10 kg, respectively, with spread ratios of 4.14% and 3.35%. a reduced spread ratio when high-quality components were substituted for wheat flour.

A lower spread ratio in maize flour formulations when protein and fiber-rich components were substituted for wheat flour (Carcea, M. 2021) [7]. The W₀ and G₅ biscuits were found to be more easily broken in during this study than the C₂, C₃, and F₉ varieties. However, compared to the control (C₃), it took significantly more force to broke the F₉ biscuits. The gluten-free cookies produced using pregelatinized cross-linked corn starch in corn flour had a high level of sensory acceptability, even outperforming cookies manufactured with refined wheat flour. The significance of the spread ratio as a crucial biscuit quality attribute, connecting it to the bite, texture, fineness of grain, and mouth feel in general (Zhang, A. 2021) [24].

The results of the investigation show that, when compared to the control sample, the hardness of the F₉ biscuits increased when fermented flour was used, but it decreased for the G₅ biscuits created with germinated flour (Table I). The spread ratio and hardness of cookies produced with composite flours varies significantly from one another (Bakare *et al.*, 2020) [3].

Nutritional composition of best acceptable biscuits

Proximate composition

The proximate composition of the biscuit varieties W₀, C₂, C₃, G₅, and F₉ is shown in Table 4.8. 2.09% moisture, 22.46% fat, 0.67% crude ash, 7.16% crude protein, and 1.05% crude fiber produced the ingredients in W₀ biscuits. The nutritional value of W₀ biscuits was 503.16 kilocalories of energy per 100 grams, with 69.09 grams of carbohydrates. A staple in many baking recipes, wheat flour normally has 78.10% carbs, 14.7% protein, 2.10% fat, and 2.10% minerals (Ma and Baik 2021) [17].

Table 2: Proximate composition of best acceptable biscuits prepared from composite flour

Type of biscuits	Moisture (%)	Fat (%)	Crude ash (%)	Crude protein (%)	Crude fibre (%)	Carbohydrates (%)	Energy (kcal/100 g)
W ₀	2.09±0.15 ^b	22.46±9.53 ^a	0.67±0.82 ^b	7.16±1.49 ^b	1.05±0.01 ^a	69.09±20.02 ^a	503.16±100.27 ^b
C ₂	2.14±1.39 ^b	11.76±2.89 ^a	0.80±0.66 ^a	11.70±6.62 ^a	1.51±1.65 ^a	74.20±2.54 ^a	449.53±32.58 ^a
C ₃	2.18±0.87 ^b	20.28±11.76 ^a	0.71±0.62 ^b	7.89±0.81 ^a	1.45±1.49 ^a	69.64±14.68 ^a	492.75±94.00 ^a
G ₅	2.85±1.43 ^a	20.15±7.61 ^a	0.43±0.17 ^a	8.44±3.66 ^a	1.22±1.25 ^a	70.08±14.74 ^a	492.49±86.61 ^b
F ₉	3.07±0.40 ^a	13.39±1.56 ^a	0.70±0.48 ^a	6.53±1.90 ^a	1.14±1.55 ^a	76.22±16.17 ^a	469.59±73.52 ^a
C.D. at 5%	0.12	7.04	0.08	3.50	0.43	7.00	7.49

Control (WF 100%); C₂ (50% Wheat, 25% Maize, 25% Cassava Flour); C₃ (75% Wheat, 12.5% Maize, 12.5% Cassava Flour); G₅ (50% Wheat, 25% Green Millet, 25% Green Cassava Flour); F₉ (75% Wheat, 12.5% Fermented Millet, 12.5% Fermented Cassava Flour). Differences indicated by superscripts ($p \leq 0.05$), averages shown with standard error (Mean ± SE)

Crude ash concentrations were 0.80% and 0.43%, crude protein contents were 11.70% and 8.44%, moisture contents were 2.14% and 7.98%, fat contents were 11.76% and 20.15%, and crude fiber values were 1.51% and 1.22% for the C₂ and G₅ biscuits, respectively. Additionally, they had energy contents of 449.53 kcal and 492.49 kcal per 100 g, respectively, and carbohydrate levels of 74.20 g and 70.08 g per 100 g. A higher fiber content tends to give biscuits a darker color and less crispiness (Malleshi *et al.*, 2021) [18]. It was shown that while the total carbohydrates and crude fiber considerably decreased, biscuits treated with legume flour showed an increase in moisture, protein, fat, and ash content. It was discovered that biscuits made with millet flour and legumes have more protein, making them a healthy source of protein (Oskaybaş-Emlek *et al.*, 2022) [20]. According to this current study, the G₅ biscuit has a higher energy content, crude ash content, and crude fat content than the Control (C₂) biscuit. Similar results were found for

mung bean biscuits with energy levels between 445 and 454 kcal, carbohydrate levels between 62.57 and 65.02%, protein levels between 7.57 and 8.04%, fat levels between 17.94 and 19.15%, moisture levels between 5.11 and 6.75%, ash levels between 0.95 and 1.74%, and fiber levels between 1.50 and 2.75%. Previous studies have demonstrated that adding legume flours, such as gram flour, to cookies has effectively increased their nutritious content (Verni *et al.*, 2019) [23]. In comparison to the C₃ biscuits, the F₉ biscuits included more moisture and carbohydrates. In particular, the C₃ and F₉ biscuits had the following contents: 2.37% and 6.39% moisture, 20.28% and 13.39% fat, 0.71% and 0.70% crude ash, 7.89% and 6.53% crude protein, and 1.45% and 1.14% crude fiber, respectively. The energy values of C₃ and F₉ biscuits were 492.75 kcal and 469.59 kcal per 100 g, respectively, and their carbohydrate contents were 69.64 g and 76.22 g per 100 g. Biscuits made with malted and fermented pearl millet flour showed similar results. The

high concentrations of polyphenols and tannins in biscuits made with corn flour may be the cause of the effects shown (Verni *et al.*, 2019) ^[23].

Minerals availability

Different biscuit varieties had different mineral contents: W₀ biscuits included 23.33 mg of calcium, 1.67 mg of iron, and 1.39 mg of zinc per 100g. Zinc levels in C₂ and G₅ were 0.64 mg and 2.34 mg, iron levels were 2.19 mg and 3.42 mg, and calcium levels were 31.66 mg and 36.66 mg, respectively. As a result, G₅ had greater levels of calcium, iron, and zinc than W₀ and C₂. In comparison to G₅, F₉ biscuits had less zinc but higher iron and comparable calcium. The C₃ and F₉ biscuits reported zinc levels of 1.82 mg and 2.40 mg, iron levels of 1.68 mg and 2.80 mg, and

calcium levels of 27.50 mg and 26.66 mg, respectively. The mineral content across biscuit types varied: W₀ biscuits had 1.39 mg zinc, 1.67 mg iron, and 23.33 mg calcium per 100g. C₂ and G₅ had 0.64 mg and 2.34 mg zinc, 2.19 mg and 3.42 mg iron, and 31.66 mg and 36.66 mg calcium respectively. Thus, G₅ showed higher zinc, iron and calcium than W₀ and C₂. C₃ and F₉ biscuits reported zinc at 1.82 mg and 2.40 mg, iron at 1.68 mg and 2.80 mg, calcium at 27.50 mg and 26.66 mg, respectively, with F₉ having less zinc but more iron and similar calcium compared to G₅. The benefits of including value foods such germinated legumes, which are known to promote mineral bioavailability through processes including solubilization of cell walls, are indicated by the enhanced mineral levels in G₅ and F₉ (Gur'ev *et al.*, 2023) ^[11].

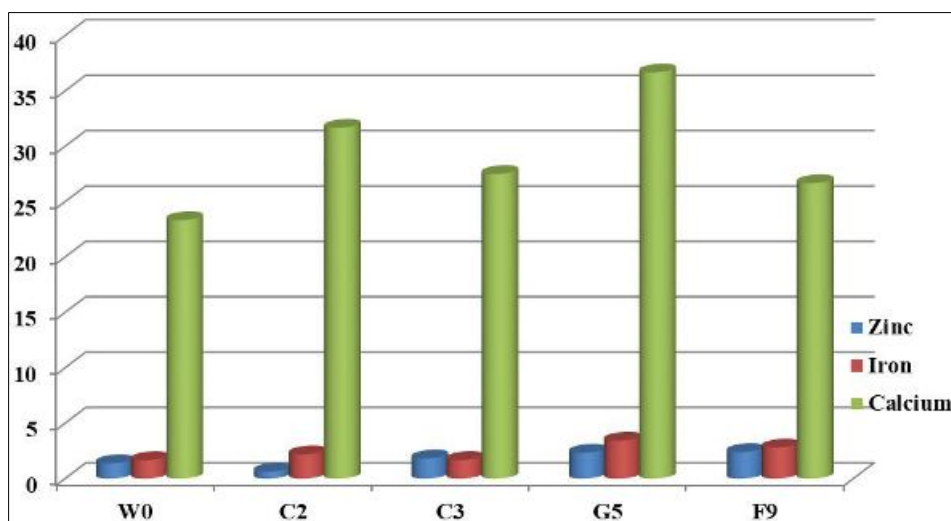


Fig 2: Minerals Availability (mg/100 g) in best acceptable biscuits

In vitro digestibility

In vitro protein digestibility was higher for the G₅ biscuit than for the W₀, C₂, C₃, and F₉ biscuits. Compared to a control biscuit, the proteins in multigrain biscuits were more easily digested. According to Oskaybaş-Emle *et al.* (2022) ^[20], biscuits generally have a high protein digestibility but a low starch digestibility.

In vitro protein digestibility was 10.09% and starch digestibility was 45.67% for the W₀ biscuit. Protein

digestibilities for the C₂ and G₅ biscuits were 16.44% and 30.89%, respectively, while starch digestibilities were 37.26% and 42.80%. The G₅ biscuit showed the highest total *in vitro* digestibility when compared to the C₂ biscuit, although there was no significant difference in the starch digestibility between the two. The treated biscuit sample's *in vitro* protein digestibility increased from 11.03% for the control to 69.03% (Carcea, M. 2021) ^[7].

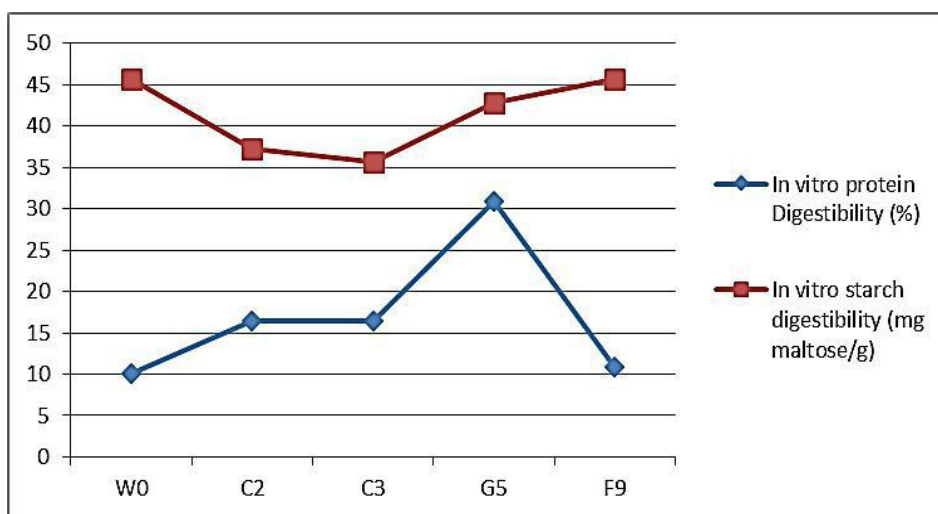


Fig 3: *In vitro* protein digestibility and *in vitro* starch digestibility of best acceptable biscuits

The protein and starch digestibility in C₃ and F₉ biscuits was found to be 16.44% and 10.81% for the former, and 35.66% and 45.66% for the latter. The protein digestibility of C₃ and F₉ biscuits did not differ significantly. The digestibility improvement is affected by starch present, which strengthens the digestion of albumin and globulin proteins. This happens when starch binds to protein structures, creating a more open structure that makes it easier for proteolytic enzymes to function (Zhang, A. 2021) [24].

Storage study of best acceptable biscuits

Moisture content

All biscuit varieties experienced increases in moisture throughout a three-month storage period: W₀ changed from 2.09% to 2.42%, C₂ from 2.14% to 2.47%, C₃ from 2.18% to 2.51%, G₅ from 2.85% to 3.76%, and F₉ from 3.07% to 3.53%. Due to the hygroscopic nature of biscuits and the variables of humidity, temperature, and packaging, G₅ saw the greatest moisture uptake. By lowering microbial growth, lower moisture increases shelf stability and durability, highlighting the significance of appropriate packaging and storage procedures for prolonging the shelf life of confectionery products.

Table 3: Effect of storage period on moisture content (%) of biscuits prepared from composite flours

Type of biscuits	0 days	1 st month	2 nd month	3 rd month
W ₀	2.09±0.15 ^b	2.15±0.35 ^b	2.35±0.11 ^b	2.42±0.35 ^b
C ₂	2.14±1.39 ^b	2.27±1.80 ^b	2.34±1.72 ^b	2.47±1.29 ^b
C ₃	2.18±0.87 ^b	2.38±1.34 ^a	2.45±1.36 ^b	2.51±1.45 ^b
G ₅	2.85±1.43 ^a	2.98±1.47 ^a	3.12±1.52 ^a	3.76±2.78 ^a
F ₉	3.07±0.40 ^a	3.34±1.70 ^a	3.40±1.66 ^a	3.53±1.55 ^a
C.D. at 5%	0.12	1.05	0.64	0.41

Free fatty acid

FFA levels in W₀, C₂, C₃, G₅ and F₉ biscuits varied over a three-month period. W₀ increased somewhat from 2.82 to 3.53 KOH/100 g, C₂ increased more noticeably from 1.31 to 2.00 KOH/100 g, and C₃ increased significantly from 1.09 to 2.60 KOH/100 g. The FFA levels in G₅ peaked at 3.47 to 3.93 KOH/100 g, while those in F₉ also increased from 1.12 to 2.93 mg KOH/100 g. G₅ has a significant increase in acidity, indicating greater deterioration with time, and the growing FFA is linked to moisture-related fat hydrolysis (Canali *et al.*, 2020) [6].

Peroxide value

The peroxide value in W₀ biscuits rose from 2.80 to 3.80 meq peroxide per 1000 g during the duration of the three-month storage period. The peroxide value of C₂ biscuits increased from 1.53 to 2.50 meq peroxide per 1000g within the same time period, while that of G₅ cookies increased from 1.53 to 3.49 meq peroxide per 1000 g. G₅ biscuits had a higher third-month peroxide value than the control (C₂) biscuit. During the same storage period, the peroxide value of C₃ biscuits increased slightly from 1.93 to 2.05 meq peroxide per 1000 g, whereas that of F₉ biscuits increased from 1.94 to 2.87 meq peroxide per 1000 g.

According to table 4.11, the biscuits produced using the W₀ formulation had the highest peroxide value content when compared to the other kinds (C₂, C₃, G₅, and F₉). A comparable increase in biscuits' peroxide value over storage

times. The oxidation of lipids in food products is frequently linked to an increase in peroxide value, which may indicate that the product is degrading while being stored (Canali *et al.*, 2020) [6].

Table 4: Effect of storage period on peroxide value (meq peroxide /1000 g) of biscuit prepared from composite flours

Type of biscuits	0 days	1 st month	2 nd month	3 rd month
W ₀	2.8±0.52 ^a	2.86±0.61 ^a	3.26±0.64 ^a	3.80±1.26 ^a
C ₂	1.53±1.14 ^a	1.66±1.30 ^a	1.86±1.02 ^a	2.50±0.42 ^{ab}
C ₃	1.93±0.61 ^a	2.00±0.87 ^a	2.33±0.72 ^a	2.05±0.33 ^c
G ₅	1.53±0.81 ^a	1.60±0.60 ^a	1.80±1.11 ^a	3.49±0.73 ^a
F ₉	1.94±0.21 ^a	2.06±0.30 ^a	2.86±0.70 ^a	2.87±0.26 ^{bc}
C.D. at 5%	1.31	1.47	1.56	1.16

Values are mean ± SE of three independent determinations abc unlike superscripts in the column differ significantly ($p \leq 0.05$)

Texture

Over a period of three months, the study assessed the force required to break biscuits (W₀, C₂, C₃, G₅, and F₉) using a TAXT texture analyzer. With W₀ increasing from 0.94 N to 2.42 N, C₂ from 1.89 N to 3.06 N, C₃ from 1.51 N to 2.81 N, and G₅ from 0.98 N to 2.41 N, the results indicated a non-significant increase in the force required. F₉ biscuits, in contrast, showed a decrease from 4.10 N to 2.44 N. When compared to C₂ biscuits, G₅ consistently required less power, while F₉ had the highest hardness at first but gradually dropped. According to some theories, biscuit hardness is inversely related to moisture content and correlated with porosity (Canali *et al.*, 2020) [6].

Sensory value

During baking, the Maillard reaction which involves reducing sugars and amino acids contributes to the biscuits' brown color and aroma. It produces chemicals with flavor and aroma, along with additional processes like sugar caramelization. The main sources of biscuit aromas are the reactions between ingredients such as sugar, ghee, and baking powder, as well as the production of volatile chemicals (Garrido-Galand *et al.*, 2021) [10].

Color

With initial color acceptance scores of 8.3, W₀, C₂, and C₃ biscuits were the most acceptable; however, after three months of storage, all of them decreased. Specifically, the color grade for C₂ biscuits dropped to 7.6. In accordance with consumer preferences for lighter-colored biscuits, G₅ retained a comparatively higher color score by the end when compared to the other groups (W₀, C₂, C₃, and F₉). Compound synthesis during storage may be the cause of this coloring change (Kamau *et al.*, 2020) [16].

Taste

With scores of 8.2, 7.9, 8.1, and 6.8 for biscuits W₀, C₂, G₅, and F₉, respectively, the flavor evaluations were noticeably different. With a score of 8.2, the W₀ biscuits had the highest taste rating at the beginning (day zero). The F₉ biscuits' flavor score significantly decreased throughout storage, decreasing from 6.8 to 6.3. It was highlighted that biscuits are available in a wide variety of textures and flavors and are popular all across the world was emphasized (Ilza and Karnila 2021) [13].

Table 5: Effect of storage period on sensory value of biscuit prepared from composite flours

Parameter	Storage period (in days)	Biscuit variants					
		W ₀	C ₂	C ₃	G ₅	F ₉	C.D. at 5%
Color	0	8.30±0.48 ^a	8.30±0.48 ^a	8.30±0.47 ^a	8.10±0.56 ^a	7.30±0.82 ^b	0.52
	30	8.00±0.66 ^a	7.70±0.48 ^a	8.20±0.63 ^a	8.10±0.56 ^a	7.10±0.56 ^b	0.59
	60	8.00±0.47 ^a	8.20±0.63 ^a	8.10±0.56 ^a	8.10±0.56 ^a	7.00±0.66 ^b	0.50
	90	7.80±0.63 ^a	7.60±0.69 ^a	7.90±0.31 ^a	8.00±0.47 ^a	6.90±0.56 ^b	0.49
Taste	0	8.20±0.42 ^a	7.90±0.73 ^a	7.90±0.73 ^a	8.10±0.87 ^a	7.10±0.99 ^b	0.70
	30	8.10±0.56 ^a	8.10±0.57 ^a	8.00±0.81 ^a	8.10±0.87 ^a	6.80±1.03 ^b	0.72
	60	8.00±0.66 ^a	7.70±0.48 ^a	8.00±0.81 ^a	8.00±0.66 ^a	6.60±0.69 ^b	0.60
	90	7.80±0.78 ^a	7.50±0.52 ^a	8.00±0.80 ^a	7.90±0.56 ^a	6.30±0.48 ^b	0.58
Texture	0	8.30±0.48 ^a	8.10±0.63 ^a	8.10±0.56 ^a	7.90±0.56 ^a	6.80±0.63 ^b	0.50
	30	8.10±0.73 ^a	7.80±1.03 ^a	8.20±0.63 ^a	7.90±0.56 ^a	6.60±0.69 ^b	0.59
	60	7.90±0.99 ^a	8.10±0.56 ^a	8.20±0.63 ^a	7.90±0.56 ^a	6.50±0.70 ^b	0.64
	90	7.80±1.03 ^a	7.90±0.31 ^a	8.10±0.57 ^a	7.80±0.63 ^a	6.40±0.51 ^b	0.57
Aroma and flavour	0	8.40±0.51 ^a	7.90±0.73 ^a	7.90±0.73 ^a	8.00±0.66 ^a	6.90±0.73 ^b	0.61
	30	8.20±0.63 ^a	8.10±0.73 ^a	7.80±0.78 ^a	8.00±0.66 ^a	6.80±0.63 ^b	0.62
	60	8.10±0.73 ^a	8.10±0.73 ^a	7.70±0.82 ^a	8.00±0.47 ^a	6.60±0.51 ^b	0.60
	90	8.00±0.66 ^a	7.80±0.42 ^a	7.50±0.52 ^a	7.70±0.48 ^a	6.40±0.69 ^b	0.51
After taste	0	7.90±0.31 ^a	7.90±0.56 ^a	7.90±0.56 ^a	7.90±0.56 ^a	7.10±0.56 ^b	0.47
	30	7.70±0.48 ^{ab}	7.70±0.48 ^{ab}	7.80±0.63 ^a	7.90±0.56 ^a	7.20±0.63 ^b	0.50
	60	7.60±0.47 ^a	7.60±0.51 ^a	7.70±0.48 ^a	7.80±0.63 ^a	7.10±0.56 ^b	0.48
	90	7.50±0.52 ^a	7.50±0.52 ^a	7.50±0.52 ^a	7.60±0.69 ^a	6.80±0.42 ^b	0.49
Overall acceptability	0	8.22±0.30 ^a	8.02±0.44 ^a	8.02±0.44 ^a	8.00±0.42 ^a	7.04±0.60 ^b	0.40
	30	8.02±0.31 ^a	7.90±0.40 ^a	8.00±0.51 ^a	8.00±0.42 ^a	6.90±0.63 ^a	0.47
	60	7.90±0.35 ^a	7.84±0.32 ^a	7.94±0.44 ^a	7.90±0.33 ^a	6.76±0.42 ^b	0.34
	90	7.78±0.41 ^a	7.60±0.26 ^a	7.78±0.40 ^a	7.80±0.32 ^a	6.50±0.42 ^b	0.33

Texture

The sound and power of a biscuit breaking or biting is used to determine how crisp the consumer wants their biscuits (Zhang A., 2021) ^[24]. The highest initial texture rating was 8.3 for W₀ biscuits, but as storage went on, all varieties witnessed a decrease: W₀ to 7.8, C₂ from 8.1 to 7.9, C₃ slightly from 8.1 to 8.0, G₅ to 7.8, and F₉ from 6.6 to 6.4.

Aroma and flavor

All biscuits decreased flavor and aroma throughout storage; the highest initial ratings were 8.40 for W₀ and the lowest were 6.80 for F₉. W₀, C₂, C₃, G₅, and F₉ cookies' scores decrease to 8.00, 7.80, 7.50, 7.70, and 6.40, respectively, after three months. Throughout the period, F₉ had the lowest flavor and aroma, whereas W₀ had the highest quality (Hatta 2020) ^[12].

After taste

Although F₉ biscuits had a decrease from 7.20 to 6.80 after three months of storage, the aftertaste scores for W₀, C₂, C₃, and G₅ biscuits decreased from an initial 7.90 to 7.50 for W₀, C₂, and C₃, and to 7.60 for G₅, according to Table V. The aftertaste of W₀, C₂, C₃, and G₅ remained acceptable than that of the F₉ biscuit during the duration of the storage period (Hatta 2020) ^[12].

Overall acceptability

Initially, the study gave the biscuits W₀, C₂, C₃, and G₅ greater overall acceptance ratings than F₉. Nevertheless, after three months of storage, acceptability scores for all categories declined. W₀, C₂, C₃, G₅, and F₉, for example, went from initial values of 8.22, 8.02, 8.02, 8.00, and 6.94 to 7.78, 7.66, 7.78, 7.80 and 6.56, respectively. In polyethylene bags, the biscuits maintained their organoleptic qualities for up to two months, however the F₉ biscuits' sensory quality significantly decreased the most (Canali *et al.*, 2020) ^[6].

Microbial count

Throughout the storage period, from the initial day to the third month, all varieties of stored biscuits showed no microbial growth, attributed to their low moisture content.

Conclusion

The nutritional profile of biscuits can be enhanced with whole grains and legumes. By examining different flour combinations, the study reveals how such modifications can affect both nutritional content and physical properties like spreadability, texture and hardness. Nutritional analysis indicates that altering biscuit recipes can boost mineral content and protein digestibility which aid in a balanced diet. During storage, all biscuit types showed an uptick in moisture, with G₅ exhibiting the greatest rise, highlighting the role of factors such as hygroscopicity, storage conditions and packaging on shelf life. The study concludes the nutritional value of partially digested composite flour biscuit formulas was good enough to appeal taste and consumer health.

Conflict of Interest

It is declared that none of the authors has any Conflict of Interest.

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