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Using Amaranth and Psyllium for Bread Production

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ABSTRACT

This study aimed to assess the nutritional properties of bread formulated using amaranth flour, lentil flour, corn starch, and psyllium seed husk. This study investigated the chemical composition, mineral content, and antioxidant activity of the raw ingredients. Lentil flour recorded the highest rate of protein (28.05%), followed by amaranth (15.40%). Amaranth too recorded the most noteworthy rate of fat (5.95%), psyllium seed husks (64.04%) recorded the most elevated rate of fiber, and cornstarch recorded the most noteworthy rate of carbohydrates (97.42%). The most elevated rates of potassium, calcium, magnesium, and manganese (209.36, 2123.48, 687.03, and 705.76%) were in amaranth flour, whereas psyllium husks recorded the most elevated rates of sodium, potassium, calcium, and manganese (65.34, 115.26, 40.13, and 54.07%) individually. As for lentil flour, it also recorded the highest levels of sodium, potassium, and calcium (81.25, 876.52, and 122.09%) separately. Lentil flour, moreover, recorded the most noteworthy rate in crude materials, where antioxidant action, added up to phenolics, and added up to flavonoids were (210.37%), (183.73 gallic acid mg/100 g), and (103.20 quercetin mg/100 g). Individually, four formulas were made to get ready for bread: F1 = 80% cornstarch-10% amaranth red seed flour (10% lentils flour), F2 = 70% cornstarch-15% amaranth red seed flour (15% lentils flour), F3 = 60% cornstarch-20% amaranth red seed flour (20% lentils flour), and F4 = 50% cornstarch-25% amaranth red seed flour (25% lentils flour). Psyllium husks were consistently added at a rate of 2 grams per 100 grams of flour to all four bread formulations. Sensory evaluation was then conducted on breads made from these formulations. 2.0 kGy has the potential to kill or, at the very least, minimize the biology of spoilage-causing microorganisms in the bread. The study concluded that gamma irradiation effectively extends the shelf life of gluten-free, high-fiber breads.

1. Introduction

Amaranth (Amaranthus cruentus) belongs to the Amaranthaceae family, which includes annual or short-lived perennial plants collectively known as amaranths (Chauhan et al., 2016). Several amaranth species are cultivated for their leaves (as vegetables), seeds (pseudocereals), and ornamental value (Lemos et al., 2012). In summer, these plants produce densely packed flower clusters that resemble catkins (Tomoskozi et al., 2011). There are around 75 species of this sort, 10 of which are dioecious and near North America, with the remaining 65 monoecious species endemic to each landmass (but Antarctica), from tropical swamps to the Himalayas (Guzmán and Sebastián, 2019). Amaranth grain is collected from the lesson *(Amaranthus cruentu)*. Amaranth grain is collected from the lesson *(Amaranthus cruentu)*. A few species are also eaten. Grain amaranth It is utilized as food is particularly rich in lysine, the most essential principal amino acid that must be shown in the tally of calories for incredible prosperity. It is also high in fiber and other productive supplements, tallying calcium, with twice the whole

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amount available in deplete. Others consolidate press that is five times the level open in wheat and contains higher amounts of potassium, phosphorous, vitamins A, E, and folic acid than are available in most cereal grains (Venkatachalam and Nagarajan, 2017). The grain is known to contain 6–10% oil, comprising overwhelmingly unsaturated oily acids, especially the fundamental linoleic acid. In addition to the wholesome quality, the alter has a wave of profitable agronomic highlights, tallying shorter improvement periods, tall yields in insignificant soils, and resistance to stresses such as moo clamminess and soil abundance. Psyllium *(Plantago ovata),* known by various common names, tallying reasonable plantains (Qaisrani et al., 2014), takes off Indian wheat and is paghol (Vega et al., 2001). It is an herbaceous plant that takes after the family (Plantaginaceae) and is naturalized in central, eastern, and south Asia and North America. (Zandonadi et al., 2010). It is a common source of psyllium, a sort of dietary fiber (Dhankar, 2013). Psyllium seed husks are unpalatable and are a source of undisclosed fiber. The plant is a rosette-forming, interminable herb with leafless, smooth, shaggy bloom stems (10–40 cm or 3.9–15.7 in). The basal clears out are lanceolate, spreading or erect, scarcely toothed, with 3-5 strong parallel veins constrained to a brief petiole. Psyllium husk is utilized in the food, pharmaceutical, and helpful industries. In nourishment, it is utilized in ice cream, minute juices, breakfast cereals, and baked goods like rolls, cakes, breads, and rolls, with changing utilitarian and prosperity perspectives (Capriles et al., 2015). It is utilized in the treatment of stoppage, the runs, and ulcerative colitis point by point (Anjali and Renu, 2015). It is utilized in the treatment of stoppage, the runs, and ulcerative colitis point by point (Anjali and Renu, 2015). Considering such pharmacological viewpoints, the use of this herb has been extended as an anti-obesity, hypoglycemic, and hypocholesterolemia medicine (Javar and Homayouni, 2016). Standard utilization of fiber is a basic calculation to expect various sorts of diseases and is related to a standard balanced tally calorie (Rosell et al., 2009). The positive parcel of dietary fiber as a prebiotic component is related to their influence on the diminishment of unremitting ailments, including cardiovascular sickness, specific sorts of cancer, and stoppage (Beikzadeh et al., 2016). In this way, it is essential to progress diverse nourishments with a collection of dietary strands. Lentil *(Lens culinaris)* central point culinaris is overwhelmingly created in Southeast Asia. It is put to the family *(legumes)* and prepared as thick soup made from whole grain, arranged for utilization; flour is utilized to make soups, stews, purees, and cereals to make bread and cakes; and as a food for infant children (Zia-ul-Haq et al., 2010). It is utilized in culinary dishes in the Indo-Pakistan sub-continent and in the Middle East and solidified into soups in Europe and North America. In Western countries, lentils may be utilized in casseroles and as meat substitutes in veggie-loving diets. Lentil, in showing disdain toward the truth that is called a 'poor man's meat', is additionally delighted in by all monetary bunches in Southeast Asia. Lentils are an awesome source of protein and are also rich in basic vitamins, minerals, and dissolvable and insoluble dietary fiber. The unsaponifiable lipid division of lentils is a potential source of bioactive components such as phytosterols, squalene, and tocopherols (Williams and Singh 1988).

Corn is utilized as human food, cattle feed, and as a source of a few mechanical things and subproducts, such as starch, which is a polysaccharide that collects as granules of different sizes, shapes, and compositions and accounts for 86 to 89% of the grain endosperm (Agama-Acevedo et al., 2005; Eliasson, 2004). It is composed of two homopolysaccharides of glucose, amylose and amylopectin, with coordinate and branched structures exclusively (Liu et al., 2002). Gamma-brightening (60ºC) techniques are a fruitful procedure to completely butcher foodborne minuscule living beings without changing their physico-chemical or material properties (Umesha and Manukumar 2018). As well is a compelling procedure to hurt DNA of living creatures as result living creatures cannot create and increment in the food things. The Joint FAO/IAEA/WHO Ace Committee points out point by point that light up to

10kGy does not cause toxicological perils or dietary issues in foodstuffs (Ravindran and Jaiswal 2019). This technique will decrease the post-harvest incident, extend shelf life, and move forward food security without changing quality. The commercial application of gamma light has been extended for a long time, and without a doubt, the USA has additionally successfully energized to utilize this advancement. Commercial food light development has been, as of late, started in Brazil, China, India, the Republic of Korea, Mexico, and Thailand. In Europe, a few countries were early supporters of mechanical food lighting, particularly the Netherlands and France (Galati et al., 2019; Hamza et al., 2016). The essential reason for conducting this question was to examine the assorted conditions of the amaranth rosy seed, psyllium peels, and lentils for making free gluten, wealthy fiber bread, as well as the ampleness of gamma light as an alternative to other bread preservation methods, especially the questionable ones, in growing the shelf life of bread. Finding the portion of gamma light that extends the shelf life of bread by reducing the closeness of organisms and microorganisms that cause its decay.

2. MATERIALS AND METHODS

Materials

Raw materials

All raw materials were purchased from sources near the Food Technology Research Institute in Giza, Egypt. Amaranth red seeds (Amaranthus cruentus) and psyllium seed husks (Plantago ovata) were obtained from a nursery, ensuring they were clean, free of disease, fungal infection, and defects. Lentils (Lens culinaris) were carefully selected, and good quality, weevil-free ground cornstarch was used.

Methods

Preparation of Flours

First, the amaranth red seeds, psyllium husks, and lentils were cleaned thoroughly to remove any impurities or foreign objects, such as seeds or peels infected with diseases. The cleaned amaranth seeds, psyllium husks, and lentils were then ground into flour using an electric grinder (Model: Moulinex MFP626, 220V, 50-60Hz, 1000W, 250 ml capacity, manufactured in France). The ground flour was then passed through a 250 micrometer sieve to ensure a uniform particle size. The sieved flour was finally packaged in polyethylene bags and stored for further analysis.

Bread preparation

An electric mixer (RBSFOODMIXERPRO, Cuizimate, Thailand) was used for dough preparation. The process involved two mixing stages: Slow Speed Mixing (80 rpm, 1 minute), during this initial mixing stage, all ingredients were incorporated based on a formula where quantities are expressed in grams per 100 grams (g/100g) relative to the cornstarch base. Psyllium seed husks (2g/100g of total flour) were added to each formulation to improve the bread structure. High Speed Mixing (100 rpm, 10 minutes), the dough was then mixed at a higher speed (100 rpm) for 10 minutes to improve its structure. After mixing, the dough was allowed to rest for 10 minutes. Then, it was shaped into bars outside of a mold for proofing. The shaped dough pieces were transferred to baking molds and proofed for 120 minutes at 30°C and 75% relative humidity. The proofed dough was baked in a convection oven (Rotoram, Ramalhos, Agueda, Portugal) at 220°C for 25 minutes (A.A.C.C., 2010). After cooling at room temperature, the bread was stored in sealed polyethylene packages at room temperature (around 25 ± 3°C)."

Formula of bread

F1= 80% cornstarch -10% amaranth red seed flour-10% lentils flour

F2= 70% cornstarch -15% amaranth red seed flour-15% lentils flour

F3=60% cornstarch -20% amaranth red seed flour-20% lentils flour

F4=50% cornstarch -25% amaranth red seed flour-25% lentils flour

Irradiation process of bread samples

The bread samples were irradiated using a research-grade Cobalt-60 (^{60}Co) gamma chamber with a dose rate of 323.5 Gy/h. This chamber is located at the Cyclotron Center of the Egyptian Nuclear and Radiological Regulatory Authority (ENRRA), Egypt. Once all samples were labeled appropriately, they were transported to the Gamma-cell Irradiation Lab for exposure to a dose of 2 kGy. A control group (0 kGy) was not irradiated for comparison purposes. The bread samples were placed inside the gamma irradiator chamber. After loading and securing the chamber, the desired irradiation time was set on the control panel. The irradiation process began by pressing the start button, which triggered a motorized drawer to lower the chamber containing the samples to the radiation source. Upon completion of the preset irradiation time, the chamber automatically returned to its original position, allowing retrieval of the samples. All samples were stored at room temperature until further analysis (Agu´ndez-Arvizu et al., 2006).

Methods of analysis

The chemical composition of cornstarch, amaranth flour, and lentil flour was determined according to the methods of the Association of Analytical Chemists (A.O.A.C., 2005). Analyses included moisture content, ash, crude protein, fat, and crude fiber. Available carbohydrates were calculated by subtracting the sum of all other measured components from 100%.

Determination of mineral

Mineral content of iron (Fe), zinc (Zn), calcium (Ca), potassium (K), sodium (Na), and phosphorus (P) was determined using an Agilent Technologies model 4210 MPAES atomic absorption spectrophotometer, following the method outlined in A.O.A.C. (2011).

Total Antioxidant Activity

The total antioxidant content (TA) was determined using the 2,2-diphenyl-1-picrylhydrazil (DPPH) assay to assess free radical scavenging capacity (Brand-Williams et al., 1995).

Total phenolic content

The concentration of phenolics in plant extracts was determined using a spectrophotometric method (Singleton et al., 1999). Methanolic course of action of the remove in the concentration of 1 mg/ml was utilized in the examination. The reaction mixture was organized by blending 0.5 ml of methanolic course of action of remove, 2.5 ml of 10% Folin-Ciocalteu's reagent broken down in water and 2.5 ml 7.5% NaHCO3. A blank solution was prepared containing 0.5 ml methanol, 2.5 ml 10% Folin-Ciocalteu's reagent diluted in water and 2.5 ml of 7.5% of NaHCO3. Both the extract and blank solutions were then incubated in an incubator at 45°C for 45 minutes. The absorbance of both solutions was measured using a spectrophotometer at a wavelength of maximum absorption (λmax) of 765 nm.

Total flavonoid content

The concentration of flavonoids in the plant extracts was determined using a spectrophotometric method (Quettier et al., 2000). The analysis involved a test solution containing:

- 1 ml of 1 mg/ml methanolic extract solution

1 ml of 2% AlCl3 solution dissolved in methanol

The test solutions were incubated at room temperature for one hour. Afterwards, the absorbance of each solution was measured using a spectrophotometer at a wavelength of maximum absorption (λmax) of 415 nm.

Texture profile analysis

The surface profile of the bread was analyzed using a CT3 Texture Analyzer (Brookfield Instruments, USA) with a 2,100 gram load cell attachment according to AACC method 74-09 (2000).

Microbiological analysis

The microbiological quality of bread samples was evaluated. A 10 g sample was homogenized in 90 ml of sterile saline solution to create a 1:10 dilution. Serial dilutions were prepared up to 10^-7 following the same procedure. Aliquots of 0.1 ml from each dilution were spread plated onto nutrient agar medium and incubated at 37°C for 24 hours. The resulting colonies were counted and expressed as colony-forming units per gram of sample (log CFU/g). For yeast and mold analysis, aliquots of 0.1 ml from each dilution were spread plated onto potato dextrose agar (PDA) medium. The plates were incubated at 20-25°C for 3-5 days. After incubation, yeast and mold colonies were counted separately and expressed as log CFU/g (Al-Ansi et al., 2022).

Sensory evaluation

The sensory properties of the bread samples were evaluated based on color, taste, odor, surface texture, and overall acceptability. A panel of 10 trained food science professionals (not "Nourishment Tech judges") assessed the samples using a 10-point hedonic scale. Bread samples receiving an overall score of 7 or higher were considered acceptable according to the method of (Ayodele and Aladesanmi 2013).

Statistical analysis

The data obtained from chemical analysis, physical analysis, and sensory evaluation were subjected to analysis of variance (ANOVA) followed by a Least Significant Difference (LSD) test for multiple comparisons. Standard errors (SE) were also calculated. All statistical analyses were performed using SPSS software (IBM Corp., Armonk, NY, USA) with a significance level of alpha set at 0.05 (Sarmento and Costa, 2019).

3. RESULTS AND DISCUSSIONS

Proximate composition of amaranth, psyllium, lentil and cornstarch composite on dry weight basis

As shown in Table 1., the chemical analysis of the dry raw material powders revealed variations in their nutrient content. Cornstarch had the highest carbohydrate content (97.42%) and the lowest fiber content (2.03%). Conversely, psyllium husks had the highest dietary fiber content (64.04%) and the lowest carbohydrate content (30.21%). Lentils emerged as the richest source of protein (28.05%), followed by amaranth (15.40%). In terms of moisture content, amaranth had the highest value (10.11%), while cornstarch had the lowest (6.40%). Ash content was highest in lentils (4.33%) and lowest in cornstarch (0.20%). Finally, fat content was highest in amaranth (9.59%) and lowest in cornstarch (0.30%). This analysis highlights the complementary nature of these raw materials. Each ingredient possesses a unique nutrient profile, with high levels of certain components and lower levels of others. By combining these ingredients, it's possible to create a product with a more balanced and overall higher nutritional value. The richness of these raw materials in various nutrients makes them beneficial for human health and suitable for use in the food industry to develop products with high nutritional value (Smirnova et al., 2022 and Fratelli et al., 2021).

Table 1. Chemical composition of the raw materials powder (g/100g on dry weight basis)

Parameter (%)	Concentration			
	Amaranth	Psyllium	Lentil	Cornstarch
Moisture	10.11±1.02[c]	9.42±0.30[c]	8.22±0.03[c]	6.40±0.10[b]
Protein	15.40±1.82[b]	1.74±0.39[f]	28.05±2.53[b]	1.2±0.2[c]
Crude fiber	4.92±1.71[e]	64.04±3.81[a]	5.60±0.12[d]	0.88±0.02[d]
Ash	3.68±0.56[f]	2.65±0.02[d]	4.33±0.32[e]	0.20±0.10[f]
Fat	5.95±1.51[d]	2.00±0.60[e]	1.57±0.54[f]	0.30±0.10[e]
carbohydrates	71.04±2.98[a]	30.21±3.03[b]	60.46±2.57[a]	97.42±0.26[a]

(a) Mean ± SD; with different superscripts in a row differ significantly ($p < 0.05$),
(b) values ±SE; in the same column with different letters are significantly different at $P < 0.05$,
(c) carbohydrates was calculated by difference {100- (Protein+ Fats +Ash and Crude fiber)}

Mineral contents of the raw materials

The raw materials exhibited a rich mineral profile. Amaranth and lentils were particularly high in potassium, with levels of 2163.48% and 876.52% respectively, followed by psyllium husks (115.26%) and cornstarch (3.23%). Similarly, amaranth had the highest calcium content (687.03%), followed by lentils (122.09%), psyllium husks (40.13%), and cornstarch (2.10%). Likewise, magnesium was most abundant in amaranth (705.76%), followed by psyllium husks (54.07%) and cornstarch (3.17%), followed by lentils (1.76%). The highest percentage of iron (26.48%) and manganese (22.36%) was in amaranth compared to the raw materials. While sodium was the highest concentration in lentils (81.25%), followed by psyllium husks (65.34%), then amaranth (40.32%) Cornstarch, as expected, had the lowest mineral content. This analysis highlights the complementary nature of the mineral profiles in these raw materials. Combining ingredients rich in different minerals allows for the development of food products with a more balanced and overall higher mineral content. The presence of essential minerals makes these raw materials valuable in the food industry for creating products that benefit human health. Minerals play a crucial role in various physiological functions within the human body (Matseychik et al., 2021and Paucean et al., 2018).

Table 2. Mineral contents of the raw materials powder on dry weight basis

Mineral (mg/100g)	Concentration			
	Amaranth	Psyllium	Lentil	Corn starch
Na	40.32±0.02[f]	65.34±1.53[b]	81.25±1.58[c]	9.13±0.15[a]
K	2163.48±0.01[a]	115.26±0.23[a]	876.52±2.00[a]	3.23±0.20[b]
Ca	687.03±0.02[c]	40.13±0.02[d]	122.09±1.54[b]	2.10±0.10[d]
Fe	26.48±1.01[g]	2.43±0.15[f]	5.13±1.45[d]	0.47±0.01[f]
Zn	22.36±1.54[h]	1.01±0.01[g]	4.60±0.43[e]	0.57±0.2[e]
Mg	705.76±0.01[b]	54.07±1.05[c]	1.76±0.153[f]	3.17±0.21[c]
Mn	209.36±1.51[d]	4.54±0.01[e]	0.95±0.39[g]	0.06±0.10[g]

Mean ± SD; with different superscripts in a row differ significantly ($p < 0.05$).
Values ±SE; in the same column with different letters are significantly different at $P < 0.05$.

Antioxidant activity of raw materials

Antioxidants are natural substances that enhance the body's immunity and prevent damage to many cells in the human body. They are also important for treatment and preventing many diseases that affect humans, many plants are considered essential foods for growth and good health. (Anitha and Ramya, 2020 and Villegas et al., 2021). Table 3. revealed significant variations in the antioxidant content of the raw materials. Lentils emerged as the richest source of antioxidants (210.37%), phenolics (183.73 mg Gallic Acid Equivalents (GAE)/100g), and flavonoids (103.20mg Quercetin Equivalents (QE)/100g), followed by amaranth with lower but still substantial levels (85.26% antioxidants, 73.40 mg GAE/100g, and 234.44 mg QE/100g). In contrast, both cornstarch and psyllium husks exhibited considerably lower levels of antioxidants, phenolics, and flavonoids. Cornstarch contained 3.61% antioxidants, 1.83 mg GAE/100 g, and 0.61 mg QE/100g, while psyllium husks registered 1.75% antioxidants, 0.75 mg GAE/100 g, and 0.26 mg QE/100g, respectively.

Table 3. Determination of total antioxidant activity (TA), total phenolic, (TP) total flavonoids (TF) of the raw materials dry

Properties	Average			
	Amaranth	Psyllium	Lentil	Corn Starch
TA (%)	85.26±1.04[a]	1.75±0.02[a]	210.37±0.95[a]	3.61±0.21[a]
TP (Gallic acid) mg/100 g	73.40±0.86[b]	0.75±0.03[b]	183.73±1.56[b]	1.83±0.31[b]
TF (Quercetin) mg/100 g	234.44±1.55[c]	0.26±0.15[c]	103.20±1.84[c]	0.61±0.10[c]

a) Mean ± SD; with different superscripts in a row differ significantly ($p < 0.05$).
b) Values ±SE; in the same column with different letters are significantly different at $P < 0.05$.

Sensory evaluation of bread

The overall quality of food products is determined by several factors, including physical properties, chemical composition, contaminant levels (microbiological and toxins), and sensory characteristics. Consumers worldwide demand consistent access to high-quality food items that justify their purchase price. The quality of raw materials and ingredients used in food production ultimately reflects the quality of the final product available to consumers (Kefale and Yetenayet, 2020). Table 4. presents the results of the tactile assessment, which is one aspect of sensory evaluation. Among the bread samples, formula F1 received the highest score for tactile properties, followed by formula F2. Formulas F3 and F4 received the lowest scores.

Table 4. Sensory evaluation of bread

Characteristic	Maximum	F1	F2	F3	F4
Color	10	9.17±0.25	8.47±0.3	7.66±0.3	6.14±0.10
Odor	10	9.12±0.20	9.00±0.10	8.13±0.02	7.11±0.11
Taste	10	8.55±0.50	8.32±0.02	8.00±0.01	6.17±0.15
Texture	10	9.32±0.02	9.20±0.15	8.23±0.25	7.50±0.10
Overall Acceptability	10	9.16±0.11	9.03±0.30	7.08±0.72	6.68±0.27

Mean ± SD; with different superscripts in a row differ significantly ($p < 0.05$).

The texture profile analysis parameters

The changes in surface profile investigation parameters (i.e. hardness, adhesiveness, flexibility, cohesiveness, springiness, gumminess and chewiness) in bread appeared in Table 5. Hardness speaks to the drive required to compress a nourishment (bread) be-tween the molars which can moreover be characterized as drive vital to accomplish a given distortion. Comes about appeared that hardness recorded (36.82 N) in F1(Fig1), whereas recorded (49.27 N) in F2(Fig2), The same drift was watched with adhesiveness, which is the work vital to overcome the at-tractive strengths between the surface of the nourishment and the surface of other materials with which the nourishment comes into contact (e.g. tongue, teeth, sense of taste) So, I recorded (0.60 mJ) in F1and recorded (0.10 mJ) in F2(Fig2), too, Versatility recorded (0.17) in F1(Fig1), and (0.16) in F2(Fig2), individually. Cohesiveness and springiness of F1 (Fig1), (0.29) and (4.23mm) respectively and for F2 (Fig2), it was (0.31) and (5.45mm) separately. Gumminess of bread is based on hardness and cohesiveness. Gumminess of F1 (Fig1), (11.73 N) and F2 (Fig2), (16.94 N) kg separately. Chewiness, that is the vitality required to chew a strong nourishment to the point required for gulping it, (49.60 mJ) in F1(Fig1), and (92.30 mJ) in F2(Fig2), were recorded. The gotten consider concluded that with diminishing esteem of hardness there was to diminish in the values of cohesiveness, gumminess, springiness and adhesiveness. Ponder uncovered that bread arranged from the treatment F1(Fig1), having the great surface profile. The gotten comes about for gumminess and cohesiveness were found to be closely assention with the comes about detailed by (Gangakhedkar et al., 2021)

Table 5. presents the results of texture profile analysis for bread samples F1 and F2. This analysis measures various aspects of a food's texture, including:

Hardness: The force required to compress the bread between teeth. Higher values indicate a harder texture. (F1: 36.82 N, F2: 49.27 N)

Adhesiveness: The work needed to overcome the attractive forces between the bread surface and other surfaces it comes in contact with (e.g., tongue, teeth). Higher values indicate stickier texture. (F1: 0.60 mJ, F2: 0.10 mJ)

Cohesiveness: The extent to which the bread sample can withstand internal deformation during chewing. Higher values indicate a more cohesive texture. (F1: 0.29, F2: 0.31)

Springiness: The ability of the bread to recover its original shape after chewing. Higher values indicate a more springy texture. (F1: 4.23 mm, F2: 5.45 mm)

Gumminess: A combination of hardness and cohesiveness, representing the effort required to chew the bread before swallowing. Higher values indicate a gummier texture. (F1: 11.73 N, F2: 16.94 N)

Chewiness: The energy required to chew the bread to a point suitable for swallowing. Higher values indicate a chewier texture. (F1: 49.60 mJ, F2: 92.30 mJ)

The results suggest that as hardness decreases, values for cohesiveness, gumminess, springiness, and adhesiveness also tend to decrease. Bread formulated with F1 (Figure 1) had a superior texture adhesiveness. The findings regarding gumminess and cohesiveness align with the observations reported by (Gangakhedkar et al., 2021).

Table 5. Textural analysis of prepared bread

Texture parameter	Zero time	
	F1	F2
Hardness (N)	36.82	49.27
Adhesiveness (mJ)	0.60	0.10
Resilience	0.17	0.16
Cohesiveness	0.29	0.31
Springiness (mm)	4.23	5.45
Gumminess (N)	11.73	16.94
Chewiness(mJ)	49.60	92.30

N: Newton, **mJ:** Milli joule, **mm:** millimeter.

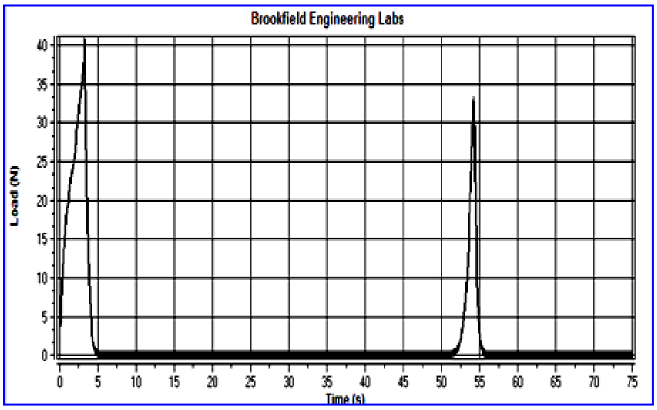

Figure 1. Formula 1

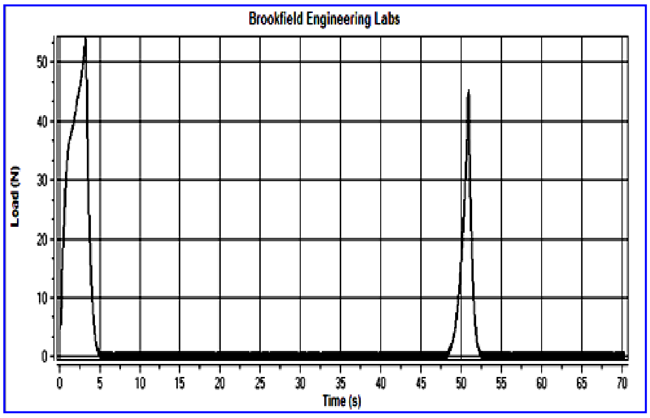

Figure 2. Formula 2

Chemical composition of prepared bread

Table 6. shows the chemical composition of bread prepared with corn starch, amaranth flour, lentil flour, and psyllium husk flour. The addition of amaranth and lentil flours to formula F1 (as shown in Table 1) significantly increased protein (5.34%), dietary fiber (7.43%), and carbohydrate (85.48%) content compared to the control bread (made with just corn starch). In formula F2, due to a higher inclusion rate of these flours, protein (6.76%) and fiber (11.33%) content further increased, while the carbohydrate content (78.84%) decreased. This demonstrates that incorporating amaranth, lentil, and psyllium husk flours effectively enhances the nutritional value of bread by increasing dietary fiber content. These findings align with previous research on breads containing various amaranth flours (Sanz-Penella et al., 2013; Coţovanu and Mironeasa, 2022).

Table 6. Chemical composition of prepared bread (g/100g on dry weight basis)

Parameter %	Concentration		Irradiated 2 kGy	
	F1	F2	F1	F2
Moisture	3.70±0.20[d]	5.16±0.02[d]	3.48±0.15[d]	5.07±0.01[d]
Protein	5.34±1.13[c]	6.76±0.15[c]	5.27±0.25[c]	6.63±0.30[c]
Crude fiber	7.43±0.15[b]	11.33±0.20[b]	7.32±0.26[b]	11.19±0.15[b]
Ash	1.33±0.20[f]	1.80±0.10[f]	1.22±0.02[f]	1.77±0.14[f]
Fat	1.42±0.02[e]	1.60±0.11[e]	1.31±0.16[e]	1.33±0.12[e]
carbohydrates	85.47±0.42[a]	78.84±1.48[a]	85.30±0.01[a]	78.77±0.10[a]

(a) Mean ± SD; with different superscripts in a row differ significantly ($p < 0.05$).
(b) Carbohydrates was calculated by difference {100- (Protein+ Fats +Ash and Crude fiber)}

Antioxidant activity, total phenolic and total flavonoids contents

Table 7. summarizes the content of bioactive compounds in the prepared bread samples. Both bread formulas, F1 and F2, exhibited increases in total antioxidant activity (TA), total phenolics (TP), and total flavonoids (TF) compared to control bread likely made with just corn starch. Formula F2, with a higher inclusion rate of amaranth, lentil, and psyllium husk flours, displayed a slightly greater increase in these bioactive compounds compared to F1. Formula F1 recorded a TA of 73.74%, TP of 198.04 mg Gallic Acid Equivalents (GAE)/100 g, and TF of 987.23 mg Quercetin Equivalents (QE)/100 g, while Formula F2 showed a TA of 83.62%, TP of 205.05 mg GAE/100 g, and TF of 191.83 mg QE/100 g. This suggests that incorporating these flours enhances the overall antioxidant profile of the bread, likely due to the inherent antioxidant properties of these ingredients. Interestingly, bread samples exposed to radiation displayed a further significant increase in TA, TP, and TF content compared to their non-irradiated counterparts. Formula F2 again exhibited the highest overall increase, with values reaching (106.78% TA, 303.63 mg Gallic Acid Equivalents (GAE)/100 g TP, and 204.14 mg Quercetin Equivalents (QE)/100g TF). These findings align with research by (Abdelaleem and Elbassiony 2020) who observed increased levels of antioxidant compounds in irradiated quinoa compared to non-irradiated samples.

The bread components (amaranth, psyllium, lentils, and cornstarch) contribute to the high nutritional value of the final product, rich in dietary fiber, protein, and minerals. These ingredients demonstrably improve the nutritional content of foods they are added to (El-Karamany, 2015). Further research is needed to explore the long-term effects of irradiation on the nutritional profile and overall quality of bread products.

Table 7. Determination of total antioxidant activity (TA), total phenolic, (TP) total flavonoids (TF) of prepared bread

Properties	Average		Irradiated 2 kGy	
	F1	F2	F1	F2
TA (%)	73.74±1.52^{c}	83.62±2.06^{c}	97.70±2.07^{c}	106.78±1.52^{c}
TP (Gallic acid) mg/100 g	198.04±0.99^{a}	205.05±0.03^{a}	202.50± 2.09^{a}	303.63±2.49^{a}
TF (Quercetin) mg/100 g	87.23±1.00^{b}	191.83±1.51^{b}	101.45±2.01^{b}	204.14±3.61^{b}

a) Mean ± SD; with different superscripts in a row differ significantly ($p < 0.05$).
b) Values ±SE; in the same column with different letters are significantly different at $P < 0.05$.

Effect of gamma irradiation on microbial load of bread

Figures 3 and 4 present the total bacterial count and total yeast and mold count in bread samples stored for 10 days at 25°C. These figures visually represent the trends and changes in these microbial counts over time. The figures show data for different storage periods (in days) and treatments (T1 and T2) with 2 kGy dose. The un-irradiated bread (T1) exhibited the highest contamination levels. This finding aligns with research by (Zula et al., 2020) who reported a decrease in microbial counts with increasing amaranth content. During storage at room temperature (approximately 25 ± 3°C), all samples were continuously monitored. The total bacterial, yeast, and mold counts of the un-irradiated bread (Figures 3 and 4) remained within acceptable limits for the first 4 days. However, after 6 days of storage, there was a significant increase in total bacterial count as well as yeast and mold. Visible mold growth also appeared on the surface of the un-irradiated samples, indicating spoilage and making them unsuitable for consumption beyond this point. Irradiated bread samples (T2) displayed a significantly lower microbial load compared to un-irradiated samples. This reduction is likely due to the effects of free radicals or hydrogen peroxide generated during irradiation, which can damage cellular components like proteins and DNA in microorganisms. This finding aligns with research by

(Asad et al., 2004). Irradiated bread exhibited an extended shelf life, with acceptable microbial counts observed up to day 10 for both treatments. These results are consistent with González et al. (2015) who reported a decrease in microbial counts in gamma-irradiated bread. Gamma radiation can damage a cell's vital genetic material (DNA), ultimately leading to cell death. The interaction between gamma radiation and microorganisms disrupts their cellular integrity, hindering their growth and survival.

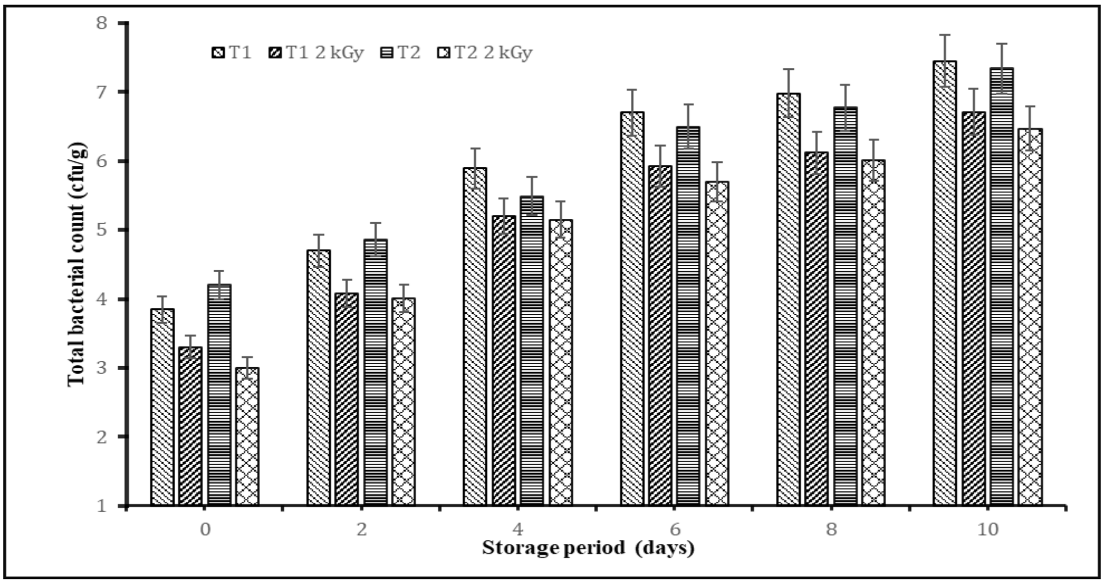

Figure 3. Total bacterial count for bread samples

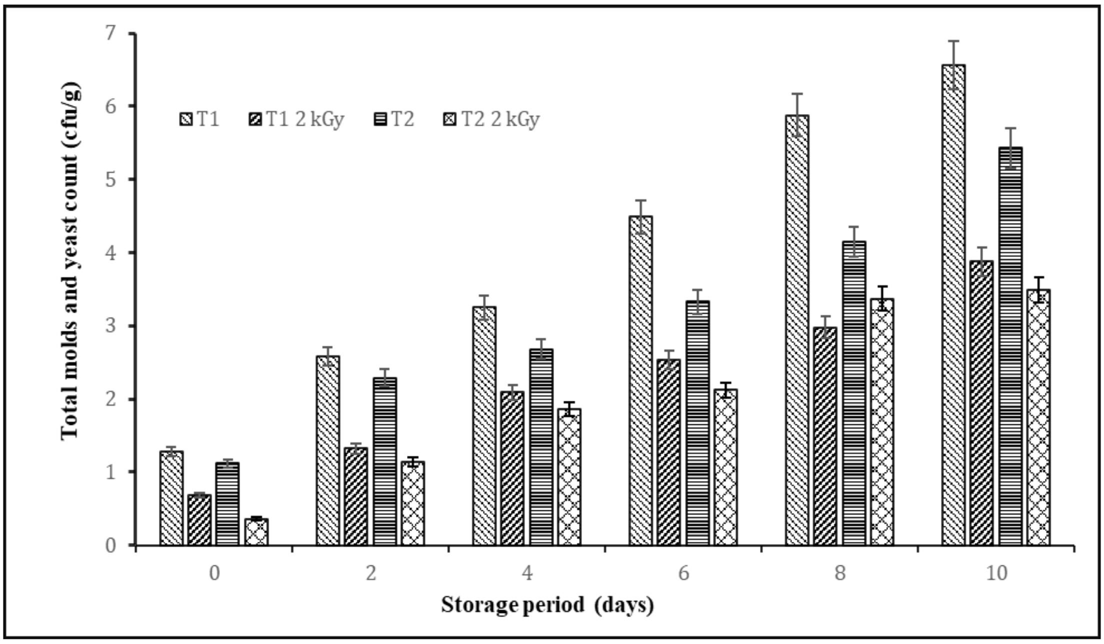

Figure 4. Total molds and yeast count for bread samples

4. Conclusion

This study demonstrates that bread formulated with cornstarch, amaranth flour, lentil flour, and psyllium husk flour possesses high nutritional value. It is rich in dietary fiber and protein, gluten-free (due to the gluten-free nature of the ingredients), and contains a good amount of mineral elements. These characteristics make this bread suitable for individuals with specific dietary needs, such as those managing obesity, gluten intolerance, or mineral deficiencies. While the addition of amaranth flour appeared to have a minor influence on microbial load, all samples remained within the acceptable range (below 10^6 CFU/g) during the initial storage period. However, the study also highlights the effectiveness of gamma irradiation in extending the shelf life of the bread. Gamma irradiation significantly reduced the microbial load (total bacteria, mold, and yeast) in all irradiated samples. This suggests that gamma irradiation could be a valuable method for enhancing bread preservation.

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