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RESEARCH ARTICLE

Storage study on compositional analysis of quinoa and ragi based snacks

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Abstract

This research focuses on examining compositional changes in quinoa and ragi seed-based snack products (Khakhara, Mathari, Laddu, and Cookies) during storage, aiming to provide comprehensive insights into their nutritional stability. The study addresses parameters such as total ash, total moisture, protein, fat, carbohydrates, energy, crude fiber, iron, and calcium content. The background underscores the significance of understanding alterations in these snacks' composition during storage, and the purpose is to assess their implications for nutritional value and quality. Methodologically, the investigation thoroughly analyzes the specified parameters over the storage period. The principal results reveal dynamic changes in total ash, moisture, protein, fat, carbohydrates, energy, crude fiber, iron, and calcium content, shedding light on the evolving nature of these popular snacks during storage. This study contributes to the field by highlighting the need for strategies to enhance the shelf life and nutritional stability of quinoa and ragi-based snacks. The major conclusions drawn underscore the importance of further research to comprehend the driving factors behind these compositional changes. Acknowledging research limitations, the study recognizes the necessity for ongoing investigations to unravel underlying mechanisms. In terms of practical implications, the findings suggest a potential impact on the nutritional quality of these snacks, urging the development of strategies to mitigate such effects. Socially, the study's insights into popular snack products contribute to broader discussions on food quality, nutrition, and health. In summary, this research advances our understanding of compositional changes in stored snacks and prompts further exploration for practical and societal advancements in the field.

Keywords: Cookies, Khakhara, Laddu, Mathari, Nutritional analysis, Storage study.

Introduction

Due to changes in lifestyle, the production and consumption of ready-to-eat meals have expanded dramatically in recent years. Attempts are being undertaken to increase the nutritional value of snack foods by altering their nutritive content in response to the rising demand for healthy, natural, and convenient meals among consumers (Brennan *et al.*, 2013). The food industry has produced products such as nutrition bars because of busy lifestyles and rising customer demand for short sources of high nutrition and convenience (Popkin & Reardon, 2018). Multiple components, including cereals, legumes, millets, nuts, sugar, vegetable oil, and syrups, comprise cereal bars (Kowalska *et al.*, 2023). Due to the many health advantages of cereals as a rich source of dietary fiber, antioxidants, and vitamins, the consumption of diets rich in whole grains has increased in recent years. However, the protein quality of grains is poor because they lack lysine. However, the presence of legumes in the diet increases the protein quality of cereals since legumes are high in lysine and because cereal protein is rich in methionine, it complements legume protein (Anitha *et al.*, 2020). Various standard techniques may be used to cook traditional meals that are nutritious, nutrient-dense, and have a longer shelf life. Traditional foods serve an essential role in rural development, especially for small and medium-sized businesses, since they prevent unfair commercial competition (Antonelli & Viganò, 2018). For customary preparations in India, several culinary techniques such as boiling, roasting, frying, and steaming, were often used. In boiling, food is cooked consistently, protein is denatured, starch is gelatinized, and collagen is hydrolyzed, but in frying, food is cooked extremely quickly, resulting in a higher caloric content, enhanced flavor, and

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suitability for snack foods. In addition, meals prepared by steaming are cooked slowly, are readily digested, and have an excellent nutritional profile (Fang *et al.*, 2023). According to the mentioned literature, experts in many regions of the globe have studied the creation of quinoa salad, porridges, soup, and health beverages, and quinoa has lately been utilized to create morning cereals granola bars (Reynolds, 2023). Due to its nutritional value, it is utilized to manufacture healthful snacks (Serna-Saldivar, 2022). Traditional Indian snacks hold a significant place in Indian cuisine and are cherished for their unique flavors and textures. Khakhara, cookies, mathari, and laddu are popular examples of such snacks. Recently, there has been a growing interest in incorporating alternative flours, such as quinoa and ragi flour, into food products due to their nutritional benefits and gluten-free nature. Quinoa (*Chenopodium quinoa Willd*) is a gluten-free pseudo-cereal that contains a high amount of fiber, high biological-value proteins, essential fatty acids (ω-3 and ω-6), vitamins, and minerals. Food products' quality and shelf life are crucial considerations for manufacturers and consumers. Storage conditions and duration can significantly impact food items' sensory attributes, nutritional composition, and microbial quality. Therefore, it is essential to study the effect of storage on quinoa and ragi flour-based snacks to determine their stability and acceptability over time. The primary objective of this research paper is to investigate the effect of storage on the quality and shelf life of quinoa and ragi flour-based khakhara, cookies, mathari, and laddu. Specifically, the study aims to analyze variations in the snacks' nutritional composition (moisture, protein, fat, carbohydrate, fiber, and mineral content) over time. This research holds significant importance for understanding the effects of storage on quinoa and ragi flour-based snacks will enable manufacturers to optimize packaging, storage conditions, and shelf life, ensuring that the products meet consumer expectations and remain safe for consumption. Consumer's knowledge about the changes occurring in sensory attributes, nutritional composition, and microbial quality of the snacks during storage will assist consumers in making informed choices regarding the purchase and consumption of these products. Quinoa and ragi flour-based snacks have the potential to provide healthier alternatives to traditional snacks. Health professionals can advise individuals seeking nutritious and gluten-free options by studying their storage characteristics. The findings of this study will contribute to the existing body of knowledge on alternative flours and their applications in snack foods, facilitating further research and development in this field.

Materials and Methods

Raw Materials

Raw materials like quinoa and ragi seeds were acquired at the Prayagraj local market. The grains were cleaned to remove any foreign debris, dust, dirt, straw, and immature and broken grains.

Pre-treatment and Processing of Raw Materials

The quinoa and ragi seeds were rinsed and steeped in a 2% sodium bicarbonate and 1% citric acid solution to minimize anti-nutritional elements. The seeds were emptied, cleaned under running water, and allowed to dry. After the pits were removed from the dates, they were steamed for 20 to 25 minutes until they were soft.

Preparation of Quinoa Flour and Ragi Flour

To eliminate anti-nutritional elements, the quinoa and ragi seeds were soaked for six hours in a solution of 2% sodium bicarbonate and 1% citric acid, containing 2% sodium bicarbonate and 1% citric acid. The grains were emptied, rinsed with running water, and let to dry. After drying, quinoa and ragi were roasted at 140°C for seven minutes and then ground into fine flour. Ragi was milled into fine flour and defatted at 60°C using a soxhlet extractor and petroleum ether. The acquired flour was roasted to enhance the items' flavor and sensory qualities. A paper should have a short, straightforward title directed at general readers in no more than 20 words.

Sample Preparation

The snacks were prepared using standardized recipes, with the substitution of wheat flour with quinoa and ragi flour. Each snack variety was prepared in triplicate to ensure the accuracy and reproducibility of the results. The detailed procedure for preparation of khakhara, mathari, laddu, and cookies mentioned in my previous studies where the optimized sample (T3) of mathari, khakhara, and laddu were prepared by using combination 40% wheat flour, 30% quinoa flour, and 30% ragi flour whereas in cookies the optimized product (T2) was prepared by combination of 60% wheat flour, 20% quinoa flour, and 20% ragi flour. The control (T0) sample of mathari and cookies were prepared by 100% of refined flour, whereas the control sample of khakhara and laddu was prepared by 100% of wheat flour.

Storage Conditions

The snacks were stored in airtight containers to simulate real-life storage conditions. Samples designated for ambient temperature were stored in a controlled environment chamber.

Analytical Methods

Proximate analysis

Proximate analysis was performed to determine the nutritional composition in optimized and control snacks. Parameters such as moisture, protein, fat, carbohydrate, fiber, and mineral content were analyzed using standard methods (AOAC, 2005) (Sobowale *et al.*, 2021). The samples were analyzed at different storage time points to observe any changes in the nutritional composition.

Statistical Analysis

Multiple replications of each experiment were conducted. Analysis of Variance (ANOVA) with Duncan multiple range tests were performed at a significance level of 0.05 using the statistical software (Minitab 21 software) to assess whether or not there were significant differences between the mean values of each parameter.

Result and Discussion

Storage Study on the Compositional Analysis of Khakhara

Total ash represents the inorganic residue left after burning the product. It primarily consists of minerals and trace elements. In this case, both types of products, khakhara To (Control) and khakhara T3, show a decrease in total ash content over the storage period (Figure 1). The total ash content decreases slightly from 3.7% at 0 days to 3.5% at 60 days in the control sample, whereas in product khakhara T3 total ash content also exhibits a decreasing trend from 2.8% at 0 days to 2.4% at 60 days. Total moisture refers to the amount of water present in the product. It affects the texture, microbial stability, and overall quality of the product. The total moisture content increases from 7.8% at 0 days to 8.2% at 60 days, indicating a slight rise in water content over time in control (T0) and in khakhara (T3) slight increase from 8.6% at 0 days to 9.1% at 60 days, indicating a similar trend of increased water content (Table 1). However, moisture content at the end of 60 days was highest as compared to the initial moisture content of khakhara. Similarly, the increased moisture content of khakhara over the period may be due to the changes in water holding capacity of quinoa during the storage reported (Bhatt *et al*., 2023). (Inglett *et al*., 2015) reported increased water holding capacity of quinoa-oat composites. The moisture content of food is inversely related to its shelf life. Protein content is a crucial nutritional parameter that indicates the amount of protein present in the product. Both types of products, khakhara to and khakhara T3, demonstrate relatively stable protein content throughout the storage period, with only minor variations observed (Table 1). A non-significant decrease ($p > 0.05$) was observed in the protein content of control khakhra (To) after a storage period of 30 days while a significant decrease ($p < 0.05$) was observed after storage period of 60 days whereas in khakhra T3, significant changes was observed during storage upto 60 days. The decrease in protein content may be attributed to increase in proteolytic activity due to increase in moisture content (Ahmad & Tahir, 2016). Total fat content signifies the amount of fat in the product, contributing to its flavor, texture, and nutritional value. The total fat content in control sample shows a slight decrease from 9.6% at 0 days to 9.2% at 60 days, suggesting a minor decline in fat content whereas in khakhara T3, it remains consistent at 8.2% throughout the storage period, indicating a stable fat content (Table 1). Decrease in fat content of cereals over a period during storage has also been reported (Trono, 2019). This might be attributed to the lipid oxidation due to their larger surface area of the snack bar which is in contact with air and moisture (Nawaz *et al*., 2021). Decrease in fat content can also be attributed to increased lipase activity, which is highly influenced by the moisture content of food (Mazaheri *et al*., 2019). Lipase is responsible for oxidative rancidity, leading to the hydrolysis of fat present in the food matrix and the formation of free fatty acids, which also imparts flavor to the food product (Chandra *et al*., 2020). Total carbohydrate content represents the combined amount of sugars, starches, and dietary fibers present in the product. Both types of products (khakhara To and T3) display slight decreases in total carbohydrate content over the storage period, although the variations are minor (Table 1). Energy

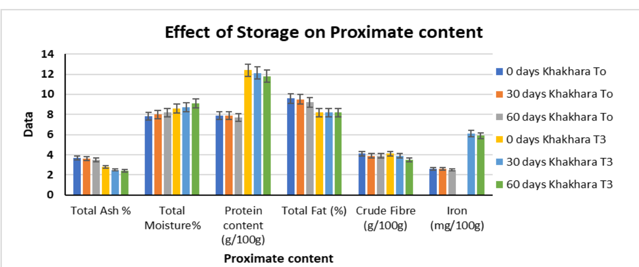

Figure 1: Effect of storage on proximate content of khakhara

Table 1: Compositional analysis of developed khakhra

Storage period	*Types of products*	*Total ash%*	*Total moisture%*	*Protein content (g/100g)*	*Total fat(%)*	*Total carbohydrate (g/100g)*	*Energy (Kcal)*	*Crude fibre (g/100g)*	*Iron (mg/100g)*	*Calcium (mg/100g)*
0 days	Khakhara To	3.7 ± 0.1^{b}	7.8 ± 0.3^{c}	7.9 ± 0.2^{a}	9.6 ± 0.2^{a}	70.6 ± 1.1^{a}	401.9 ± 1.5^{c}	4.1 ± 0.2^{a}	2.6 ± 0.1^{a}	170.5 ± 0.2^{b}
30 days	Khakhara To	3.6 ± 0.2^{b}	8 ± 1.2^{a}	7.9 ± 0.4^{a}	9.5 ± 1.1^{c}	69.4 ± 0.9^{b}	399.4 ± 1.3^{b}	3.9 ± 0.5^{a}	2.6 ± 0.4^{a}	169.8 ± 0.1^{b}
60 days	Khakhara To	3.5 ± 0.8^{a}	8.2 ± 0.7^{a}	7.7 ± 0.6^{b}	9.2 ± 0.1^{b}	68.3 ± 2.1^{c}	395.4 ± 3.1^{a}	3.9 ± 0.1^{a}	2.5 ± 1.1^{a}	165.2 ± 0.3^{a}
0 days	Khakhara T3	2.8 ± 0.3^{c}	8.6 ± 0.4^{b}	12.4 ± 0.2^{a}	8.2 ± 0.2^{f}	68.1 ± 1.1^{a}	396.2 ± 3.2^{c}	4.1 ± 0.1^{a}	6.4 ± 0.2^{a}	210.2 ± 0.7^{a}
30 days	Khakhara T3	2.5 ± 0.4^{b}	8.7 ± 1.1^{a}	12.1 ± 0.1^{c}	8.2 ± 0.2^{f}	67.7 ± 1.7^{b}	397.6 ± 1.3^{b}	3.9 ± 0.3^{c}	6.1 ± 0.5^{b}	211.1 ± 0.1^{a}
60 days	Khakhara T3	2.4 ± 0.5^{a}	9.1 ± 0.9^{c}	11.8 ± 0.4^{b}	8.2 ± 0.2^{f}	67.3 ± 2.1^{b}	395.2 ± 2.3^{c}	3.5 ± 0.3^{b}	5.9 ± 0.1^{c}	208.5 ± 0.3^{b}

All values shown are mean ± SD and superscript with different alphabets in a column were significantly different from each other.

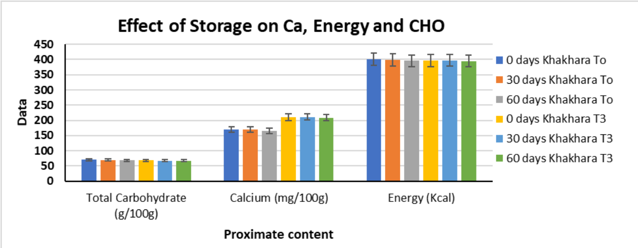

Figure 2: Effect of storage on calcium content, total CHO and energy of khakhra product

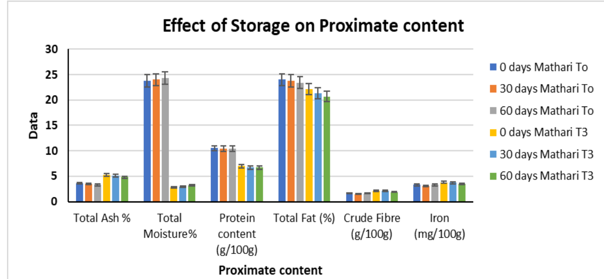

Figure 3: Effect of storage on proximate content of mathari

content refers to the amount of calories provided by the product and is influenced by the levels of carbohydrates, fats, and proteins present. Both types of products (khakhara To and T3) maintain relatively stable energy content throughout the storage period, with only minor fluctuations observed (Table 1). Crude fibre content represents the indigestible portion of plant-based foods, which provides dietary fiber and aids in digestion. Both types of products (khakhara To and T3) exhibit slight variations in crude fiber content over the storage period, although no clear trend is observed. The findings of khakhara T3 showed a significant decrease in crude fibre content during storage, whereas in Khakhara T0 non-significant decreased trend was found (Table 1). Iron content reflects the amount of this essential mineral present in the product, which is important for various biological processes in the body. khakhara to demonstrate relatively stable iron content throughout the storage period, whereas in khakhara T3 significant decrease of iron content was observed during the storage period (Figure 2). Calcium content indicates the presence of this essential mineral, which plays a vital role in bone health and other physiological functions. Both types of products (khakhara To and T3) maintain relatively stable calcium content over the 30 days of storage, whereas after the 60 days of storage, a significant decrease in ash content was observed (Table 1).

Storage Study on Compositional Analysis of Mathari

The total ash percentage in Mathari T0 remains relatively consistent up to 30 days of storage period but a significant decrease from 3.6 to 3.3% was found over 60 days. In Mathari T3 the total ash percentage was significantly decreased 5.3 to 4.8% over 60 days (Figure 3). A decrease in ash content during storage period has also been reported by Nadarajah *et al.*, in coconut cookies (Parmar & Deshmukh, 2023). Decreased ash content may also be due to increased moisture content, favoring microbiological growth. During their growth period, the microbes utilize minerals and other nutrients, decreasing ash content (Mohapatra *et al.*, 2012). The total moisture percentage in Mathari To and T3 shows a slight increase from 23.8 to 24.3% and 2.8 to 3.2%, respectively over 60 days. A significant increase ($p < 0.05$), in moisture content was observed in both sample at an interval of 30 and 60 days (Table 2). However, moisture content at the end of 60 days was highest as compared to the initial moisture content in both samples. The increased moisture content of quinoa bars over the period may be due to the changes in water holding capacity of quinoa during the storage as already reported (Park *et al.*, 2021). (Inglett *et al.*, 2015)reported increased water-holding capacity of quinoa-oat composites. Increase in moisture content might also be due to water vapor transmission through the polythene packaging material used to store the bars (Shishir *et al.*, 2017). As food's moisture content is inversely related to its shelf life (Gichau *et al.*, 2020), the results depict degradation in shelf life of formulated bars with time. The protein content mathari t`o remains consistent throughout the storage period, with values around 10.4 to 10.5/100 g with non-significant ($p > 0.05$) whereas the protein content shows

Table 2: Compositional analysis of developed mathari

Storage period	*Types of products*	*Total ash%*	*Total moisture%*	*Protein content (g/100g)*	*Total fat(%)*	*Total carbohydrate (g/100g)*	*Energy (Kcal)*	*Crude fibre (g/100g)*	*Iron (mg/100g)*	*Calcium (mg/100g)*
0 days	Mathari To	3.6 ± 0.2 ^{b}	23.8 ± 0.1^{b}	10.5 ± 0.1^{a}	24 ± 0.2^{a}	38.4 ± 0.2^{a}	411.4 ± 0.9^{b}	1.6 ± 0.3^{b}	3.3 ± 0.2^{a}	170.6 ± 1.9^{b}
30 days	Mathari To	3.5 ± 0.5^{b}	24 ± 0.4^{c}	10.4 ± 0.4^{a}	23.8 ± 0.1^{b}	38.3 ± 0.3^{a}	411.1 ± 0.6^{b}	1.5 ± 0.8^{b}	3.1 ± 0.3^{b}	169.9 ± 2.1^{b}
60 days	Mathari To	3.3 ± 0.2^{a}	24.3 ± 0.3^{a}	10.4 ± 0.1^{a}	23.4 ± 0.4^{c}	36.7 ± 0.7^{b}	408.7 ± 2.9^{a}	1.6 ± 0.3^{e}	3.3 ± 0.4^{a}	167.5 ± 4.2^{a}
0 days	Mathari T3	5.3 ± 0.1^{a}	2.8 ± 0.4^{b}	7 ± 0.2^{a}	22.1 ± 0.8^{b}	63.4 ± 2.5^{a}	480.5 ± 0.8^{a}	2.1 ± 0.1^{a}	3.8 ± 0.3^{a}	159.9 ± 4.1^{b}
30 days	Mathari T3	5.1 ± 1.1^{c}	2.9 ± 0.6^{a}	6.7 ± 0.6^{b}	21.3 ± 1.2^{c}	61.7 ± 1.2^{c}	479.6 ± 1.6^{a}	2.1 ± 0.2^{a}	3.7 ± 0.6^{b}	159.9 ± 2.6^{b}
60 days	Mathari T3	4.8 ± 0.6^{b}	3.2 ± 0.1^{c}	6.7 ± 0.4^{b}	20.7 ± 0.7^{b}	60.3 ± 0.9^{b}	477.1 ± 1.1^{b}	1.9 ± 0.1^{b}	3.5 ± 0.1^{c}	157.5 ± 1.3^{a}

All values shown are mean ± SD and superscript with different alphabets in a column were significantly different from each other.

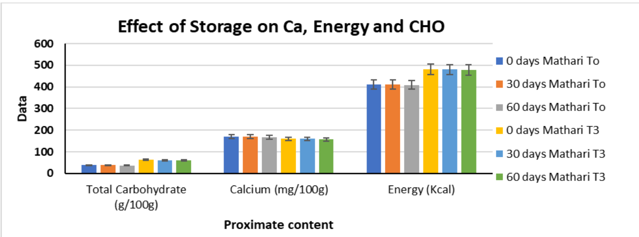

Figure 4: Effect of storage on calcium content, total CHO and energy of mathari product

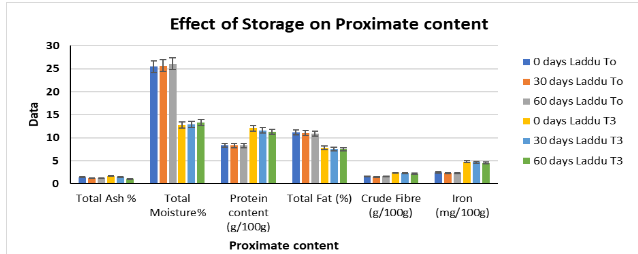

Figure 5: Effect of storage on proximate content of laddu

some variation, with significant decrease from 7.0/100 g to 6.7/100 g over 60 days (Table 2). The decrease in protein content may be attributed to increase in proteolytic activity due to increase in moisture content (Ahmad & Tahir, 2016). The total fat percentage was significantly decreased during the storage condition in both mathari T0 and T3 from 24 to 23.4% and 22.1 to 20.7%, respectively (Table 2). A decrease in fat content of cereals over a period during storage has also been reported (Trono, 2019). This might be attributed the lipid oxidation due to the larger surface area of snack bar, which is in contact with air and moisture (Nawaz *et al.*, 2021). A decrease in fat content can also be attributed to increased lipase activity, which is highly influenced by the moisture content of food (Mazaheri *et al.*, 2019). The total carbohydrate content in mathari to remains relatively consistent, with values around 38.3 to 38.4/100 g, whereas in mathari T3 a significant decrease in carbohydrate content was observed from 63.4 to 60.3% over 60 days of storage. The carbohydrate content of control snack bars was observed to decrease (Table 2). This may be due to the activation of enzyme, α-amylase, upon an increase in moisture content, which results in degradation of starch (Xie *et al.*, 2019). The total energy significantly decreased during the storage condition in mathari T0 and T3 from 411.4 to 408.7 kcal and 480.5 to 477.1 kcal over 60 days (Table 2).

The crude fiber content in T0 showed significant decrease during 60 days of storage ranging from 1.5/100 g to 1.6/100 g, whereas in T3 the significant decrease in crude fiber was found after 30 and 60 days storage. The mean value of crude fiber content was higher in mathari T3 as compared to mathari T0 (Table 2). Iron content remains relatively stable in mathari T0, with values around 3.1 to 3.3 mg/100 g; in mathari T3, a significant decrease in iron content was observed during storage, with values around 3.5 to 3.8 mg/100 g (Table 2). The calcium content significantly decreased during the storage condition in mathari T0 and T3 from 170.6 mg/100 g to 167.5 mg/100 g and 159.9 mg/100 g to 157.5 mg/100 g respectively over 60 days (Figure 4).

Storage Study on Compositional Analysis of Laddu

The total ash percentage in laddu to shows a slight decrease from 1.4 to 1.2% over 60 days, whereas in laddu T3 total ash percentage varies across the storage period, with a decrease from 1.7 to 1.1% over 60 days (Figure 5). Decrease in ash content during storage period has also been reported (Chaudhary *et al.*, 2017). Decreased ash content may also be due to increased moisture content, favoring microbiological growth. During their growth period, the microbes utilize minerals and other nutrients, decreasing ash content (Mohapatra *et al.*, 2012). The total moisture percentage in laddu to shows a slight increase from 25.5 to 26.1% over 60 days whereas in laddu T3: The total moisture percentage remains relatively stable, ranging from 12.8 to 13.3% over 60 days (Table 3). The moisture content at the end of 60 days was highest in both products as compared to the initial moisture content. Increased moisture content of quinoa bars over the period may be due to the changes in water holding capacity of quinoa during the storage as already reported

Table 3: Compositional analysis of developed laddu

Storage period	*Types of products*	*Total ash%*	*Total moisture%*	*Protein content (g/100g)*	*Total fat(%)*	*Total carbohydrate (g/100g)*	*Energy (Kcal)*	*Crude fibre (g/100g)*	*Iron (mg/100g)*	*Calcium (mg/100g)*
0 days	Laddu To	1.4 ± 0.2 ^{a}	25.5 ± 0.2 ^{a}	8.4 ± 0.3 ^{a}	11.2 ± 0.3 ^{a}	53.7 ± 0.3 ^{a}	369.9 ± 0.9 ^{a}	1.6 ± 0.1 ^{c}	2.5 ± 0.1 ^{a}	169.3 ± 2.2 ^{c}
30 days	Laddu To	1.2 ± 0.5 ^{b}	25.7 ± 0.3 ^{b}	8.3 ± 0.5 ^{b}	11 ± 0.7 ^{b}	53.5 ± 0.5 ^{a}	368.7 ± 1.7 ^{b}	1.5 ± 0.2 ^{b}	2.3 ± 0.3 ^{b}	168.1 ± 1.7 ^{a}
60 days	Laddu To	1.2 ± 0.3 ^{b}	26.1 ± 1.2 ^{c}	8.3 ± 0.6 ^{b}	10.9 ± 0.5 ^{b}	52.1 ± 1.1 ^{b}	367.5 ± 1.2 ^{c}	1.6 ± 0.2 ^{c}	2.3 ± 0.2 ^{b}	166.5 ± 3.1 ^{b}
0 days	Laddu T3	1.7 ± 0.4 ^{c}	12.8 ± 0.1 ^{b}	12.1 ± 0.2 ^{b}	7.8 ± 0.1 ^{a}	65.6 ± 0.3 ^{a}	381.4 ± 3.1 ^{a}	2.4 ± 0.1 ^{a}	4.8 ± 0.2 ^{b}	210 ± 0.1 ^{a}
30 days	Laddu T3	1.5 ± 0.7 ^{b}	12.9 ± 0.1 ^{b}	11.6 ± 0.4 ^{a}	7.6 ± 0.3 ^{b}	65.4 ± 0.5 ^{a}	380.4 ± 1.4 ^{b}	2.3 ± 0.2 ^{a}	4.7 ± 0.3 ^{b}	211 ± 1.1 ^{c}
60 days	Laddu T3	1.1 ± 0.3 ^{a}	13.3 ± 0.1 ^{a}	11.3 ± 0.3 ^{c}	7.5 ± 0.5 ^{c}	63.8 ± 1.2 ^{b}	378.4 ± 0.8 ^{c}	2.2 ± 0.3 ^{b}	4.5 ± 0.5 ^{a}	208 ± 0.8 ^{b}

All values shown are means ± SD and superscript with different alphabets in a column were significantly different from each other.

(Park *et al*., 2021). (Inglett *et al*., 2015) reported increased water holding capacity of quinoa-oat composites. Increase in moisture content might also be due to water vapour transmission through the polythene packaging material used upto store the bars (Shishir *et al*., 2017). The protein content in laddu to remains relatively consistent throughout the storage period, with values around 8.3 to 8.4/100 g while a significant decrease ($p < 0.05$) in Laddu T3 was observed after storage period of 60 days, ranging from 11.3/100 g to 12.1/100 g (Table 3). The decrease in protein content may be attributed to increase in proteolytic activity due to increase in moisture content (Ahmad & Tahir, 2016). A non-significant decrease ($p > 0.05$) was observed in fat content of laddu T0 after storage period of 30 days, while in laddu T3 a significant decrease ($p < 0.05$) was observed over 60 days of storage ranging from 7.5 to 7.8% over 60 days (Table 3). A decrease in fat content of cereals over a period during storage has also been reported (Trono, 2019). This might be attributed to lipid oxidation due to the larger surface area of snack bar which is in contact with air and moisture (Nawaz *et al*., 2021). The decrease in fat content can also be attributed to increased lipase activity, which is highly influenced by moisture content of food (Mazaheri *et al*., 2019). Lipase is responsible for oxidative rancidity, leading to the hydrolysis of fat present in the food matrix and the formation of free fatty acids, which also imparts flavor to the food product (Chandra *et al*., 2020). A non-significant decrease ($p > 0.05$) was observed in carbohydrate content of both products after storage period of 30 days while significant decrease ($p < 0.05$) was observed after storage period of 60 days. The total carbohydrate content shows a gradual decrease in laddu T0 and T3 from 53.7/100 g to 52.1/100g and 63.8 to 65.6%, respectively over 60 days (Table 3). This may be due to the activation of enzyme, α-amylase, upon an increase in moisture content, which results in degradation of starch (Xie *et al*., 2019). The energy content was significantly decrease during storage over 60 days in laddu T0 and T3 from 369.9 to 367.5 kcal and 381 to 4-378.4 kcal, respectively (Table 3). A non-significant decrease ($p > 0.05$) was observed in the crude fibre of both products after a storage period of 30 days while a significant decrease ($p < 0.05$) was observed after storage period of 60 days (Table 3). The total crude fibre in laddu T0 and T3 ranged from 53.7/100 g to 52.1/100 g and 63.8 to 65.6% over 60 days. A significant decrease ($p < 0.05$) was observed in iron content of laddu T0 after storage period of 30 days while a non-significant decrease ($p > 0.05$) was observed after storage period of 60 days. Similarly, in laddu T3 a non-significant decrease ($p > 0.05$) was observed in iron content after storage period of 60 days (Table 3). The calcium content was significantly decrease during storage over 60 days in laddu T0 and T3 from 169.3 mg/100 g to 166.5 mg/100 g and 208 to 210 mg/100g, respectively (Figure 6).

Storage Study on Compositional Analysis of Cookies

A non-significant decrease ($p > 0.05$) was observed in ash content of cookies T0 after a storage period of 30 days while a significant decrease ($p < 0.05$) was observed after storage period of 60 days. Similarly, in cookies T2 significant decrease ($p < 0.05$) was observed ash content after storage period of 30 days while non-significant decrease ($p > 0.05$) was observed after storage period of 60 days (Figure 7). Decrease in ash content during storage period has also been reported by Nadarajah *et al*., in coconut cookies (Parmar & Deshmukh, 2023). Decreased ash content may also be due to increased moisture content, favoring microbiological growth. During their growth period, the microbes utilize minerals and other nutrients, decreasing ash content (Mohapatra *et al*., 2012). The total moisture percentage in cookies T0 and T2 ranged from 4.5 to 4.8% and 1.6 to 2.1%, respectively over 60 days. A significant increase ($p < 0.05$), in moisture content was observed in both cookies T0 and T3 at an interval of 30 and 60 days. However, moisture content at the end of 60 days was highest as compared to the initial moisture content in both products (Table 4). Sujitha and Thirumani also reported increase in moisture content from 3.6-5.6% of flaxseed cookies during the storage period of 60 days (Khedkar *et al*., 2021). This increase was primarily due to packaging material (polythene bags). The packaging was not airtight, and lack of temperature control resulted in an increase in moisture contents of cookies. Moreover, cookies absorbed moisture from surrounding atmosphere due to hygroscopic behavior of wheat flour. An increase in moisture contents of cookies samples during storage has also been reported by (Singh *et al*., 2019), either due to atmosphere or packaging materials(Ahmed & Ashraf, 2019; Hemalatha *et al*., 2007; Sachanarula *et al*., 2022; Tanhehco & Ng, 2008; Wanyo *et al*.,

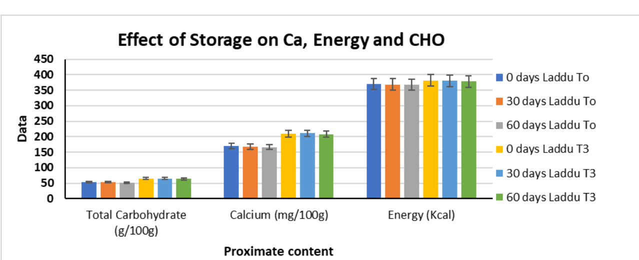

Figure 6: Effect of storage on calcium content, total CHO and energy of laddu product

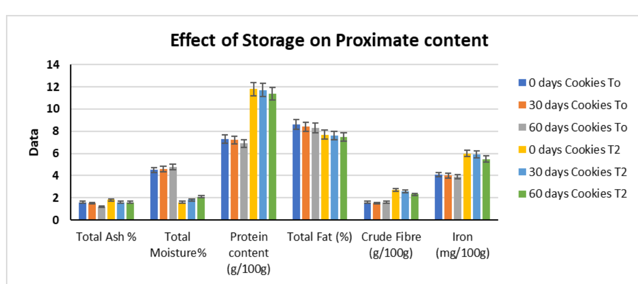

Figure 7: Effect of storage on proximate content of cookies

Table 4: Compositional analysis of developed cookies

Storage period	*Types of products*	*Total ash%*	*Total moisture%*	*Protein content (g/100g)*	*Total fat(%)*	*Total carbohydrate (g/100g)*	*Energy (Kcal)*	*Crude fibre (g/100g)*	*Iron (mg/100g)*	*Calcium (mg/100g)*
0 days	Cookies To	1.6 ± 0.1^{b}	4.5 ± 0.2^{a}	7.3 ± 0.3^{a}	8.6 ± 0.1^{a}	78 ± 0.2^{a}	420.5 ± 1.3^{c}	1.6 ± 0.2^{a}	4.1 ± 0.3^{a}	110.7 ± 0.3^{a}
30 days	Cookies To	1.5 ± 0.5^{b}	4.6 ± 0.8^{b}	7.2 ± 0.1^{a}	8.4 ± 0.4^{b}	76.4 ± 0.2^{b}	420.1 ± 1.7^{b}	1.5 ± 0.3^{b}	4 ± 0.1^{b}	110.1 ± 0.5^{b}
60 days	Cookies To	1.2 ± 0.2^{a}	4.8 ± 0.7^{c}	6.9 ± 0.6^{b}	8.3 ± 0.5^{b}	76.1 ± 0.5^{b}	416.5 ± 1.1^{a}	1.6 ± 0.1^{a}	3.9 ± 0.2^{b}	109.9 ± 0.7^{b}
0 days	Cookies T2	1.8 ± 0.3^{b}	1.6 ± 0.3^{a}	11.8 ± 0.1^{a}	7.7 ± 0.2^{a}	77.1 ± 0.1^{b}	421.9 ± 1.5^{b}	2.7 ± 0.1^{b}	6 ± 0.2^{b}	131.1 ± 0.1^{b}
30 days	Cookies T2	1.6 ± 0.1^{a}	1.8 ± 0.8^{c}	11.7 ± 0.4^{b}	7.6 ± 0.6^{c}	75.8 ± 0.5^{a}	419.6 ± 2.2^{a}	2.6 ± 0.2^{b}	5.9 ± 0.3^{b}	130.9 ± 0.3^{a}
60 days	Cookies T2	1.6 ± 0.4^{a}	2.1 ± 0.3^{b}	11.4 ± 0.6^{c}	7.5 ± 0.9^{b}	75.5 ± 0.7^{a}	418.3 ± 0.5^{c}	2.3 ± 0.1^{a}	5.5 ± 0.2^{a}	126.7 ± 1.3^{a}

All values shown are means ± SD and superscript with different alphabets in a column were significantly different from each other.

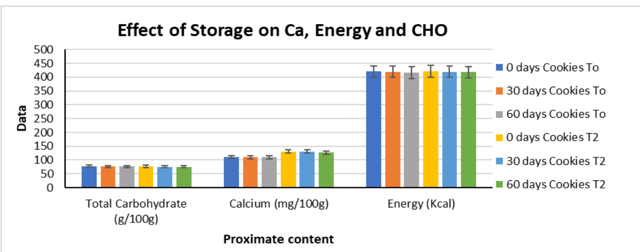

Figure 8: Effect of storage on calcium content, total CHO and energy of cookies product

2014). The protein content in cookies T0 remains relatively consistent throughout the storage period, with values around 6.9 to 7.3/100 g whereas significant decrease ($p < .05$) was observed in protein content of cookies T2 after storage period of 30 and 60 days (Table 4). Decrease in protein content may be attributed to increase in proteolyic activity due to increase in moisture content (Ahmad & Tahir, 2016). A significant decrease ($p < 0.05$) was observed in fat content of cookies T0 after storage period of 30 days while non-significant decrease ($p > 0.05$) was observed after storage period of 60 days. The total fat percentage in cookies T0 ranging from 8.6 to 8.3% over 60 days. Similarly in cookies T2 the total fat percentage significantly decreased from 7.7 to 7.5% over 60 days (Table 4). In cookies production, addition of fat imparts tenderness making it more palatable; assist in texture improvements. External added fat during preparation of cookies have plasticizing effects reported (Fu *et al*., 1997). Decrease in fat content during storage were also given by (Deshwal *et al*., 2020; Dev *et al*., 2021; Narender Raju & Pal, 2009). This might be attributed to the lipid oxidation due to their larger surface area of snack bar which is in contact with air and moisture (Nawaz *et al*., 2021). The non-significant decrease ($p > 0.05$) was observed total carbohydrate of cookies T0 and T2 after storage period of 60 days while significant decrease ($p < 0.05$) was observed after storage period of 30 days. The total carbohydrate content in both cookies T0 and T2 from 78/100 g to 76.1/100 g and 75.5 to 77.1 g/100 g, respectively over 60 days (Table 4). Carbohydrate content was observed to be decreased throughout storage which may be due to breakdown by amylase and reduction in amount of fat over time due to cookies absorbing moisture from the atmosphere and lipid breakdown into other various molecules by lipase enzyme (Kumar *et al*., 2021). The significant decrease in energy content during storage was observed during 30 and 60 days of storage in cookies T0 and T2 from 420.5 to 416.5 kcal and 418.3 to 421.9 kcal, respectively (Table 4). The crude fibre of cookies T0 was content remains relatively stable, ranging from 1.5/100 g to 1.6/100 g over 60 days while cookies T2 exhibited a non-significant decrease ($p > 0.05$) in carbohydrate content after 30 days and a significant decrease after 60 days ranging from 2.3 g/100 g to 2.7/100 g. The mean value of crude fiber content was higher cookies T2 as compared to cookies T0 (Table 4). The non-significant decrease ($p > 0.05$) was observed in iron content of cookies T0 after storage period of 60 days while significant decrease ($p < 0.05$) was observed after storage period of 30 days. Similarly, in cookies T2 non-significant decrease ($p > 0.05$) in iron content after storage period of 30 days while a significant decrease ($p < 0.05$) was observed after storage period of 60 days (Table 4). The iron content in cookies T0 and T2 ranging from 3.9 to 4.1 mg/100 g and 5.5 to 6 mg/100 g, respectively. The calcium content in cookies T0 remains relatively stable, with values around 109.9 to 110.7 mg/100 g whereas in cookies T2 the significant decrease ($p < 0.05$) in calcium content was observed after storage period of 60 days, ranging from 126.7 mg/100g to 131.1 mg/100 g over 60 days (Figure 8).

Conclusion

These findings highlight the changes in the nutritional composition of the snacks during storage. The variations in ash content may be influenced by moisture content and microbiological growth. The decrease in fat content can be attributed to lipid oxidation and increased lipase activity. The decrease in protein content may be due to proteolytic activity caused by increased moisture content. The gradual decrease in carbohydrate content may be a result of starch degradation. The iron and calcium content changes indicate the potential for nutrient loss during storage. Overall, these findings emphasize the importance of understanding the effects of storage on the quality and shelf life of quinoa and ragi flour-based snacks. They provide valuable insights for manufacturers to optimize packaging, storage conditions, and shelf life, ensuring that the products meet consumer expectations and remain safe for consumption. Additionally, consumers can make informed choices regarding purchasing and consuming these products based on their knowledge of the changes occurring during storage. The research contributes to the existing body of knowledge on alternative flours and their applications in snack foods, paving the way for further research and development in this field.

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