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Quality Evaluation of Aloe Vera Gel Powder and its Incorporation in Biscuits to Investigare Textural, Bioactive, and Storage Stability

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Abstract

Aloe Vera gel powder has a great potential as an economic supplement with an adequate nutritional profile. Biscuits offer low cost, varied taste, a wide consumption base, long shelf-life, availability, convenience, and good eating quality. Their long shelf-life allows for large-scale production and distribution, while their good eating quality makes them attractive for nutritional improvements. The growing interest in these bakery products is due to their better nutritional properties and potential use in feeding programs and catastrophic situations. Thus, the aim of the study is to evaluate the functional properties and health benefits of aloe vera gel powder by incorporating it into biscuits, assessing the bioactive properties, functional properties, textural, sensory, and shelf-life study. The potential use of different concentrations of Aloe vera gel powder (0.5, 1.0, 1.5, 2 grams) was mixed with oats and rice flour. Results indicated that Aloe vera gel powder had improved functional properties showing its possible use in formulations bakery products. Addition of 1g and 1.5g of aloe vera gel powder in biscuits investigated positive result in terms of nutritional, bioactive, peroxide value, texture, shelf life and sensory parameters. Thus, it is a source of satisfying the palate with a unique combination of nutrition and medicinal properties.

Keywords: Aloe vera gel powder; Biscuits; Textural properties; Bioactive compounds; Sensory attributes; Shelf-life study

Introduction

Now a days, half of the world's population is on the verge of death from chronic diseases due to lifestyle changes and insufficient dietary planning. Poor eating habits are leading causes of illness and mortality [1]. Traditional healthcare approaches such as herbal medicines have gained popularity due to their fewer side effects despite of the adverse effects of chemical drugs. Presently, nutraceuticals and functional foods are currently playing a crucial and essential part in the enhancement of human health. Over the last decade, global consumption of nutraceutical foods has increased. This could be due to consumers' preference for useful and healthy products [2].

Aloe barbadensis Mill., a species of Aloe vera is a flowering succulent plant native to tropical and sub-tropical regions of North America, Africa, Europe, and Asia. It belongs to the Liliaceae [3]. It is popular due to the combination of nutritional content and pharmaceutical characteristics. Currently, bakery industry is focusing on fortified biscuits and other composite flour products due to their significant role in human nutrition and popularity among people of all ages [4]. Low cost, assorted taste, a wide consumption base, long shelf-life, availability, convenience, and good eating quality is offered by biscuits [5]. Longer shelf-life allows large-scale production and distribution with good eating qualities that make them attractive for nutritional improvements [4]. The growing interest in these bakery products is due to their better nutritional properties and potential use in feeding programs and catastrophic situations. In recent years, there has been a surge interest in the usage of Aloe vera gel particularly in the food industry where it is employed as a component of functional food in various food commodities [6]. Hence, Aloe vera could be used for functional foods in various applications of beverages that is fiber-rich diet drinks, yoghurt, teas, electrolyte-containing soft drinks, healthy fruit juices, diet drinks, instant tea granules and jelly desserts with aloe chunks [7]. Cereals are the best natural sources to serve as the foundation of nutraceuticals (nutraceuticals is the combination of pharmaceuticals and nutrition) because they are easily digested and gives dietary fiber such as oats, barley, sorghum, millet, and wheat are all familiar with the importance of nutraceuticals [8]. Cereals could reduce blood pressure, cholesterol, the risk of heart disease etc. Thus, it is contributing healthy lifestyle [9].

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Aloe vera is a potent nutraceutical with having bioactive compounds that offers potential health benefits like anti-inflammatory and immune-modulating properties [10] also enhances therapeutic, nutritional, and functional properties in food and has been used as a dietary supplement. Moreover, it could enhance food quality and extend the shelf life of products as it has natural preservative properties [11]. The Aloe vera leaf has been extensively studied for its chemical and biological properties with the gel being used in various formulations for food, health, medicinal, and cosmetic purposes, either fresh or powdered concentrate [12].

Aloe vera is widely produced to supply the growing and economically important industry as well as potential use in the food industry such as edible coating, biodegradable film, and encapsulating agent [13]. The purity, quality, and processing methods of aloe vera are crucial for safety and efficacy. Aloe vera's role in the food industry is significant for product quality and consumer health perceptions.

Thus, the aim of this study was to explore the use of Aloe vera gel powder as a food enrichment in biscuits analyzing its parameters such as proximate composition, color profile, bioactive compounds, functional properties, morphological study, and storage stability. The research is focused to promote the use of aloe vera gel powder to enhance the quality of life.

Material and Methods

Collection and Preparation of Aloe Vera Gel

Aloe vera was collected from Multan, Pakistan. The transparent slippery exudate consisting mainly of gel was collected from the mucilage layer of the outer leaf pulp adjacent to the rind.

Powder Formation

Extraction of Aloe vera gel powder: The aloe vera was rinsed in room temperature distilled water before the epidermis was cautiously separated from its inner pulp with a Teflon knife. The pulp filets were cut into small pieces and manually squeezed or blended to extract the aloe vera gel. The gel obtained was filtered through a nylon-cloth. The mucilage gel was placed in Petri dishes and dried at 60 °C in an incubator for 24 h. The dried material was manually ground into a fine powder in a porcelain mortar. In high-density polyethylene bags, the aloe vera powder were kept until use in a desiccator at room temperature with a relative humidity of 30% [13].

Determination of Functional Properties of Aloe vera gel powder

Water absorption capacity (WAC), water solubility index (WSI) and oil absorption capacity (OAC): The Water absorption capacity (WAC) and water solubility index (WSI) was determined by the method of Bala [14] by using following equations:

$$WAC = \frac{Weight\ of\ wet\ sediment\ (g)}{Dry\ weight\ of\ flour\ (g)}$$

The supernatant obtained in the estimation of WAC was dried at 105 C for overnight and weighed. The water solubility index (WSI) was calculated as Eq:

$$WSI = \frac{Weight\ of\ dried\ supernatant\ (g)}{Dry\ weight\ of\ flour\ (g)} * 100$$

Oil absorption capacity (OAC)

For estimation of oil absorption capacity (OAC) method of Olu [15] was used

$$OAC = \frac{Weight\ of\ oil\ absorbed}{Weight\ of\ sample}$$

Foaming Capacity

Foaming capacity (FC) was determined by the method of Kaur and Singh [16].

Swelling index and swelling capacity*:* Swelling Index (SI) of the flour samples was determined by the method of Ukpabi [17] and it was calculated as below:

$$SI = \frac{Volume\ of\ sample\ after\ soaking - Volume\ of\ sample\ before\ soaking}{Weight\ of\ sample}$$

The wet sediment obtained from swelling index determination was used in calculating swelling capacity (SC) using following formula:

$$SC = \frac{Weight\ of\ wet\ sediment}{Weight\ of\ sample} * 100$$

Determination of flowing properties of Aloe vera gel Powder

Bulk density and tapped density: Bulk density and tapped density Bulk density (ρb) of the samples were measured by the following equations: [14].

$$Bulk\ Density = \frac{Mass\ of sample}{Volume\ of\ sample}$$

$$Tapped\ Density = \frac{M}{Vf}$$

Carr's Index and Hausner ratio: Carr compressibility index (CI) or Hausner ratio (HR) were calculated using the Carr (1965) and Hausner (1967) methods, respectively, using the following formulae.

$$CI = \frac{Tapped\ Density - BulkDensity}{Tapped\ Density} * 100$$

$$HR = \frac{Tapped\ Density}{Bulk\ Density}$$

Scanning Electron Microscopy of Aloe Vera Gel Powder

The structure and surface morphology of aloe vera gel powder was analyzed using a scanning electron microscope (JEOL, Musashino, Tokyo Metropolitan, Japan).

Determination of Functional Groups by FTIR (Fourier Transform Infrared)

Aloe vera gel powder was pressed by the ATR accessories straight onto the diamond ATR crystal. All seed samples attenuated total reflectance spectra were scanned with a resolution of 4cm^{-1}, and 4 scans were accumulated per spectrum. All spectra were recorded in triplicate, and the average of three measurements was calculated for each. Prior to each ATR experiment, an air background spectrum was acquired. Spectral data was collected by compressing the sample with the ATR accessory. The ATR cell was cleaned with ethyl alcohol and warm water.

Preparation and Evaluation of Biscuit

The biscuits were prepared by mixing 274g whole rice flour and 176g whole oats flour,60 g brown sugar, 200 g unsalted butter, 0.030 g baking powder blend containing different concentrations as 0, 0.5, 1, 1.5, 2% of aloe vera gel powder. The whole rice flour and whole oats flour was used as a primary ingredient. The aloe vera pulp was incorporated in flour 0%, 0.5%, 1%, 1.5%, 2% in T0, T1, T2, T3, T4 and T5 respectively.

Ingredients and formulation of dough in (%) concentration					
Ingredients	**Samples(g)**				
	To	**T1**	**T2**	**T3**	**T4**
Rice flour (g)	54.8	54.8	54.8	54.8	54.8
Oats flour (g)	35.2	35.2	35.2	35.2	35.2
Aloevera gel powder (g)	0	0.5	1	1.5	2
Unsalted Butter (g)	40	40	40	40	40
Egg (g)	0.006	0.006	0.006	0.006	0.006
Brown sugar (g)	12	12	12	12	12
Baking powder (g)	0.3	0.3	0.3	0.3	0.3

To• represents biscuits without Aloe vera gel powder

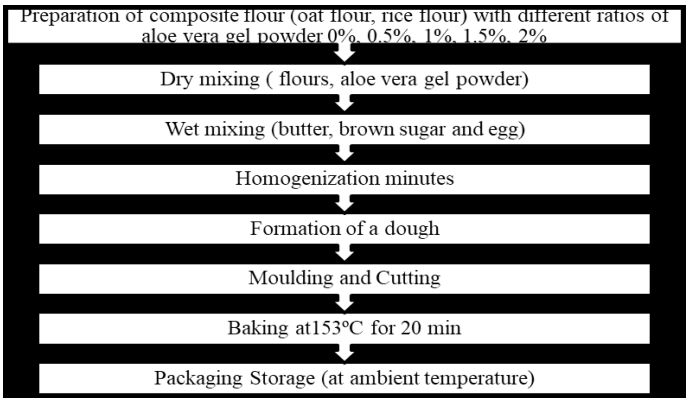
T1• represents biscuits with 0.5 g Aloe vera gel powder

T2• represents biscuits with 1 g Aloe vera gel powder

T3• represents biscuits with 1.5 g Aloe vera gel powder

T4• represents biscuits with 2g Aloe vera gel powder

Biscuit preparation:



Determination of Proximate of Aloe Vera Gel Powder (AGP) and Biscuits Incorporated AGP

Moisture, crude protein, fat and ash of raw materials were determined using methods of Analysis in Association of Official Analytical Chemists [18]. Carbohydrate was obtained by taking out the difference. The Kjeldahl factor of 6.25 was used for crude protein, which is used for all cereals and cereal based foods [19].

Preparation of Extracts for Determination of Bioactive Compounds

Accurately measured 10g of treated kidney bean flour was added in 100ml 100% (v/v) ethanol and homogenized by using orbital shaker for 8 hours. To separate the extract, the mixture was filtered by using filter paper (Whatman No.1). Rotary evaporator (Rotary Vacuum Evaporator, EYELA N.N. Series) was used to remove the residual solvent of ethanolic extract at 40 0C under reduced pressure. The obtained extract was then used to determine the radical scavenging activity and Total Phenolic Content (TPC).

Determination of phenolic content of Aloe vera gel powder (AGP) and biscuits incorporated AGP: Total phenolic content was estimated by following the methods described by Mugwagwa a [20].

Determination of flavonoids of Aloe vera gel powder (AGP) and biscuits incorporated AGP: The total flavonoid content was calculated by following the working method that was followed by Aryal [21].

Determination of free radicals scavenging activity by DPPH of Aloe vera gel powder (AGP) and biscuits incorporated AGP: The antioxidant activity of sample was determined by following the protocol of Lee *[22]*.

Determination of color profile of Aloe vera gel powder (AGP) and biscuits incorporated AGP

Utilizing the methodology developed by Andrabi [23], the surface color of flours was measured.

Determination of peroxide value in AGP biscuits

AOAC (2005) was used to calculate the Peroxide Value (PV) of the lipid fraction extracted of the biscuits. In brief, lipids were extracted with chloroform and dissolved in 15 mL of glacial acetic acid and 1 mL of saturated KI aqueous solution. The sample was stirred and left in the dark for 5 minutes prior to adding 75 mL of water and 1 mL of a starch solution. Titration of formed iodine with 0.01 N sodium thiosulfate was performed. The PV was calculated as the number of milli equivalents of active oxygen per kilogram of lipids (meq O2/kg of lipids). Every sample was examined in triplicate [18,24].

Determination of Moisture Content and Storage Stability in AGP Biscuits

Biscuits were stored at room temperature in a sealed polyethylene bag for 120 days to determine storage stability based on moisture content [25].

Determination of Textural Properties in AGP Biscuits

Textural Analyzer (FRTS-100N-I) was used to determine the texture of biscuits. The maximum force Fmax needed for breaking the biscuits was determined.

Sensory Evaluation

The tests were conducted in a sensory laboratory. A laboratory with necessary facilities, viz., separate booths, provisions for adequate diffused light and air-conditioned odor-free environment, was employed for product evaluation. Sensory evaluation of biscuits was performed by twenty trained panelists using nine-point hedonic scale (1=extremely dislike and 9= extremely like). Sensory assessment was made in terms of color, appearance, texture, flavor, and overall acceptability.

Statistical Analysis

Each analysis was carried out in triplicate. Data collected was statistically analyzed using Analysis of Variance (ANOVA) techniques using SPSS 16.0 software. The significant level among the mean at $p<0.05$ was measured by analyzing the Least significant difference.

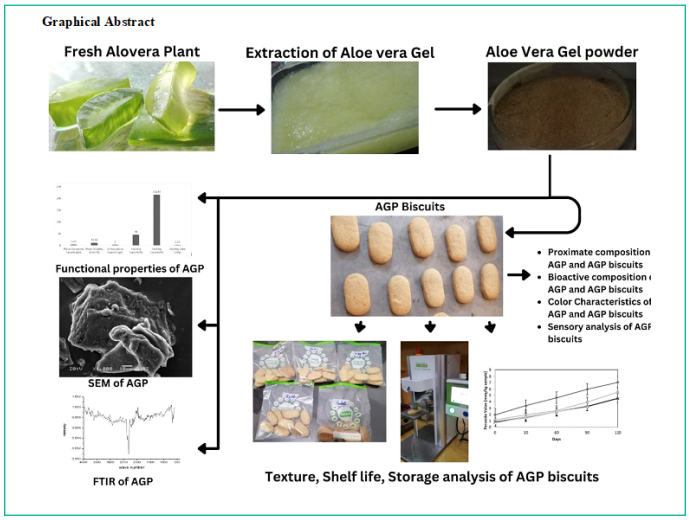


Table 1: Effect of different concentrations of aloe vera gel powder on proximate composition of biscuits[a].

Samples	Moisture Content (%)	Ash (%)	Fat (%)	Protein (%)	Crude Fiber (%)	Carbohydrate (%)
T	5.81±0.56[b]	0.57±0.52	0.79±0.80[a]	1.67±0.13[a]	1.43±0.07[b]	89.72±0.49
T0	8.85±0.56[e]	1.21±0.15[b]	18.93±0.25[f]	8.93±0.04[b]	0.95±0.20	61.10±0.40[b]
T1	7.33±0.30	1.53±0.47	17.76±0.20[e]	9.81±0.15	1.97±0.43	61.58±0.36
T2	6.50±0.40	1.86±0.41	17.09±0.80d	10.65±0.30d	2.55±0.30	61.32±0.12[b]
T3	5.69±0.30[b]	2.10±0.20[e]	16.62±0.25	11.74±0.25[e]	3.64±0.36[e]	60.20±0.04[a]
T4	4.87±0.25	2.60±0.15[f]	15.83±0.41[b]	12.04±0.36[f]	4.77±0.30[f]	59.87±0.36[a]

[a]All values are means of triplicate determinations. Means within a column with different superscripts are significantly different at P<0.05. Abbreviations T: Aloe vera gel powder, To: Biscuits without aloe vera gel powder, T1: Biscuits with 0.5g aloe vera gel powder, T2: Biscuits with 1g aloe vera gel powder, T3: Biscuits with 1.5g aloe vera gel powder, T4: Biscuits with 2g aloe vera gel powder.

Result and Discussion

Extraction of Aloe Vera Gel Powder

Aloe vera gel powder is a compelling substitute for aloe vera gel. More stability along with an extended shelf life was provided by the powdered form, which makes handling and storage easier. The concentration of active compounds in aloe vera gel powder is readily controlled by researchers which aids in the stability of bioactive compounds over time and ensures consistent and trustworthy results. These intrinsic properties make aloe vera gel powder a sensible option for scientific research, providing enhanced stability, convenience, and adaptability for studies examining the possible uses and advantages of aloe vera in various domains.

Functional Properties of Aloe Vera Gel Powder

According to our findings as shown in Figure 1a, Aloe vera gel powder has a Water Absorption Capacity (WAC) of 3.73% and a Water Solubility Index (WSI) of 11.33% indicating important water-holding and solubility capacities. The WAC indicates the powder's capacity to absorb water showing its potential in gel formation or moisture retention in a variety of applications. Meanwhile, the high WSI indicated that significant amounts of the powder were capable of dissolving in water that is required for its possible use in formulations for liquids or beverages. Powder functional properties reflected endogenous physical and chemical properties that affected the characteristics of food during handling, storage, processing, and evaluation. Water absorption increased as the fiber content of the sample increased. WAC has a significant impact on the texture of foods. High WAC results increased swelling properties, leading to uniformity, thickening, viscosity adherence properties, rising weight and decreasing size, specific quantity, and volume of the biscuits [26]. As a result, higher WAC powder may cause an increase in the weight, height, and volume of the biscuits. The study also suggested that OAC (g/g) and was 3.25% as compared to [5]. A significant oil-holding capacity implied that Aloe vera gel powder had a high affinity for lipids. The higher the OAC value, the more likely it would use in food formulations where improved oil retention is desired as well as cosmetic and medicinal products where controlled interactions with oils is critical. The study showed that aloe vera gel powder has a swelling index of 2.21% while swelling capacity was 215.93%. The swelling index is measured the proportion of increase in volume after water absorption whereas the swelling capacity measures the degree of water absorption in relation to original weight of the powder. These results indicated that Aloe vera gel powder had significant capacities to absorb and hold water, showing its possible use in formulations where the ability to hold water is advantageous [5]. According to our findings, the foaming capacity of Aloe vera gel powder is 46% indicated its ability to generate and maintain a stable foam. This property is essential in a variety of uses, especially in the fields of food and cosmetics. The observed percentage represented the volume expansion during the foaming process indicating that Aloe vera gel powder has significant foaming properties.

Flowing Properties of Aloe Vera Gel Powder

The bulk density reflected the total weight of the powder per unit volume prior to tapping whereas the tapped density indicated the maximum packing of the powder during consolidation. The resulting values (0.31g/cm3) showed a relatively low bulk density indicating a favorable particle arrangement with increased interparticle voids. At a given constant mass, density raises as volume decreases. In the current study, the bulk density of powder increased gradually as the carrier agent ratio increased (Figure 1b) [27]. The Hausner ratio and Carr's index of aloe vera gel powder was 1.23% and 18.8% respectively. The Carr's Index and Hausner ratio in powder indicated low compressibility and good flow characteristics with values less than 1.23% showing efficient powder flow or low compressibility.

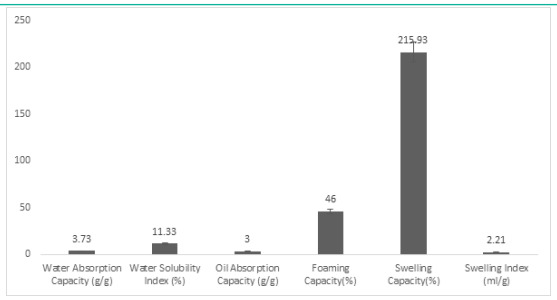


Figure 1a: Effect of Aloe vera gel powder on functional properties
[a]All values are means of triplicate determinations. Means within a column with different superscripts are significantly different at P < 0.05. Abbreviations T: Aloe vera gel powder, To: Biscuits without aloe vera gel powder, T1: Biscuits with 0.5g aloe vera gel powder, T2: Biscuits with 1g aloe vera gel powder, T3: Biscuits with 1.5g aloe vera gel powder, T4: Biscuits with 2g aloe vera gel powder.

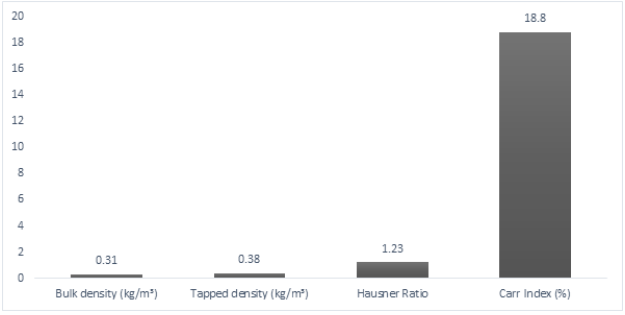


Figure 1b: Effect of Aloe vera gel powder on fun properties
[a]All values are means of triplicate determinations. Means within a column with different superscripts are significantly different at P < 0.05. Abbreviations T: Aloe vera gel powder, To: Biscuits without aloe vera gel powder, T1: Biscuits with 0.5g aloe vera gel powder, T2: Biscuits with 1g aloe vera gel powder, T3: Biscuits with 1.5g aloe vera gel powder, T4: Biscuits with 2g aloe vera gel powder.

Table 2: Effect of different concentrations of aloe vera gel powder on bioactive compounds of biscuits[a].

Samples	DPPH (%)	Total Phenolic Content (mg Gallic acid/g)	Flavonoid Content (mg Catechin/100g)
T	69.93±1.79[a]	28.45±1.09[a]	62.77±5.58[a]
T0	82.81±0.83[b]	38.77±1.32[b]	72.95±1.44[b]
T1	84.72±0.41	41.46±0.64[c]	76.87±0.42[bc]
T2	86.38±0.93[c]	43.05±0.38[cd]	77.81±0.73[c]
T3	89.98±0.57[d]	44.62±1.13[de]	79.82±1.11[de]
T4	90.29±0.22[e]	46.53±0.48[e]	80.36±1.45[e]

[a]All values are means of triplicate determinations. Means within a column with different superscripts are significantly different at P<0.05. Abbreviations T: Aloe vera gel powder, To: Biscuits without aloe vera gel powder, T1: Biscuits with 0.5g aloe vera gel powder, T2: Biscuits with 1g aloe vera gel powder, T3: Biscuits with 1.5g aloe vera gel powder, T4: Biscuits with 2g aloe vera gel powder.

Proximate Composition of Aloe Vera Gel Powder (AGP) and Biscuits Incorporated AGP

Moisture content: Moisture content determination was observed to be one of the primarily fundamental and significant analytical procedures. Aloe vera gel powder (T) had 5.81% moisture content. The moisture contents of the aloe vera gel powder and five formulations ranged from T0 to T4 (To: Biscuits without aloe vera gel powder, T1: Biscuits with 0.5g aloe vera gel powder, T2: Biscuits with 1g aloe vera gel powder, T3: Biscuits with 1.5g aloe vera gel powder, T4: Biscuits with 2g aloe vera gel powder) is 8.85, 7.33, 6.50, 5.69 and 4.87% as shown in Table 1. The moisture content of the control sample was higher as compared to the treated sample of biscuits. However, there was a significant difference in moisture between the control sample and the other five biscuit formulation from T1 to T4 (7.33<4.87) with (P>0.05). In comparison to collected data, it was found that the moisture contents were more effective as lower moisture contents could extend the shelf-life of the product [28].

Fat content: Table 1 showed that the fat content of aloe vera gel powder was 0.79%. The highest percentage of fat was observed in the To (biscuits without aloe vera gel powder) i.e. 18.93%. Biscuits with an increase in percentage of aloe vera gel powder showed a decreased value of fat percentage. It is because of lipolysis that breaks down fats into fatty acids making product more digestible form [29].

Protein content: The total Protein Content (PC) of aloe vera gel powder was 1.67%. While the biscuits incorporating aloe vera gel powder showed an increment in protein content because of presence of different ingredients that also enhanced the protein value [30].

Ash content: The mineral content of food products was expressed as ash content. Since the total ash contents in this study of aloe vera gel powder ranged from 1.21 to 2.6%. As the percentage of aloe vera gel powder increased in biscuit formulation, the ash content percentage would also increase as shown in Table 1. The amount of inorganic minerals in the powdered aloe vera is represented by the ash content. It can reveal information about the product's purity and possible mineral contributions to diet. A food product's ash content indicates how much inorganic mineral content it contains, which includes phosphorus, magnesium, and calcium. Higher ash content can indicate the presence of additional minerals or contamination, making it an effective indicator of food purity [31].

Crude fiber: The crude fiber of aloe vera gel powder was found 1.43%. Hence, it showed the property of treating diabetes, obesity, and gastrointestinal tract illnesses. The crude fiber as shown in Table 2, the least crude fiber was observed in To (0.95%) sample while the highest was observed in T4 (4.77%). It is because of other ingredients i.e. oat flour has approximately 11.13% [32] of fiber and brown rice contains 0.7% [31] that increased in biscuits.

Carbohydrate: The percentage of carbohydrate of aloe vera gel powder was 89.72% as shown in Table 1. Whereas the highest carbohydrate among samples of biscuits was found in To and the least was observed in T4 i.e. 59.8%. This result is parallel to the study of [31].

Scanning Electron Microscopy of Aloe Vera Gel Powder

Aloe vera gel powder was analyzed morphologically by scanning electron microscopy as shown in Figure 2. Aloe vera gel powder showed an uneven and rough structure. According to Liu [33] it involved the presence of separation of phases when biopolymers are used as wall materials. Because of variations in dehydration of the initial layers of polymer attached to the particle surface, polymer networks formed through hydrophobic interactions, hydrogen bonds, or van der Waals forces induce diffusion of bio polymer molecules or water to the particle surface.

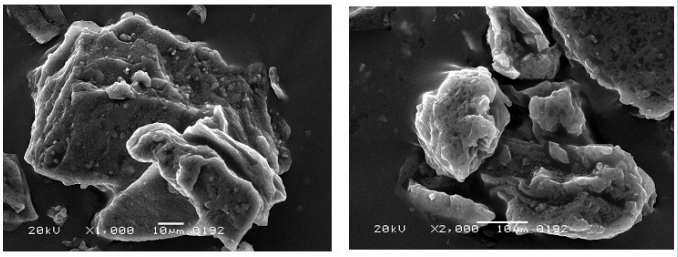


Figure 2: Morphological study of Aloe vera gel powder through scanning electron microscopy
(a) 1000 dimension (b) 2000 dimension

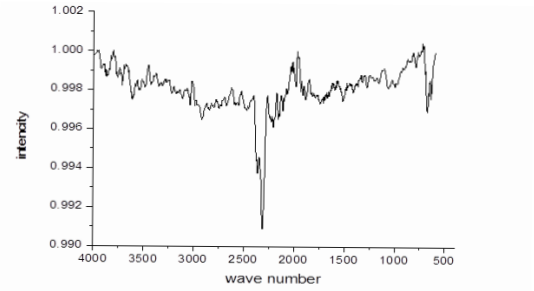


Figure 3: Fourier transform infrared of aloe vera gel powder

FTIR (Fourier Transform Infrared) of Aloe Vera Gel Powder

Figure 3 depicted the FTIR spectrum of Aloe vera gel powder. The analysis of the IR spectra revealed the presence of various functional groups in Aloe vera gel powder. An increasing spectrum from 3800 to 3400 cm^{-1}, caused by the stretching of -OH groups, which is a property of carbohydrate monomers such as mannose and uronic acid. From 3000 to to 2980 cm^{-1}, the symmetrical and asymmetrical C-H stretching of aliphatic -CH and -CH2 groups are allocated. The absorption band at 1800-1740 cm^{-1} was typical of CQO stretching, showing the existence of carbonyl groups in Aloe vera gel powder samples. The asymmetrical and symmetrical -COO stretching of carboxylate compounds in Aloe vera are associated with the absorption peaks at 1600 cm^{-1}. The peak at 1480-1477 cm^{-1} range or 1158 cm^{-1} indicated CH3 groups or C-O stretching (ester). The C-O-C stretching of -COCH3groups corresponds to its absorption peak at 1226 cm^{-1}. The peak of absorption at 1100 to 1075 cm^{-1} could be attributed to C-O stretching related to rhamnogalacturonan, a pectin side-chain constituent. The band is possibly related to

Table 3: Effect of different concentrations of aloe vera gel powder on storage stability on hedonic scale of biscuits[a].

Days	Samples	COLOR	TEXTURE	APPEARANCE	TASTE	OVERALL ACCEPTIBILITY
Zero day	T0	8.40±0.7^{c}	8.25±0.63^{c}	8.70±0.57^{c}	8.45±0.68^{c}	8.60±0.59^{c}
	T1	8.40±0.75^{d}	8.30±0.65^{c}	8.50±0.68^{c}	8.70±0.47^{c}	8.60±0.59^{c}
	T2	8.15±0.81^{d}	8.35±0.58^{c}	8.50±0.68^{c}	8.70±0.47^{c}	8.65±0.48^{c}
	T3	8.50±0.76^{c}	8.45±0.60^{c}	8.55±0.68^{c}	8.70±0.47^{c}	8.65±0.48^{c}
30th day	T4	8.35±0.67^{c}	8.40±0.59^{c}	8.35±0.74^{c}	8.70±0.47^{c}	8.65±0.48^{c}
	T0	7.65±0.74^{b}	7.95±0.75^{cd}	8.45±0.68^{c}	8.25±0.71^{c}	8.45±0.60^{c}
	T1	7.80±0.83^{c}	7.70±0.65^{b}	8.50±0.68^{c}	8.55±0.51^{c}	8.40±0.59^{d}
	T2	7.70±0.80^{d}	8.00±0.72^{c}	8.25±0.78^{c}	8.40±0.75^{c}	8.55±0.60^{c}
	T3	7.65±0.74^{b}	8.35±0.58^{c}	8.40±0.68^{c}	8.40±0.75^{c}	8.25±0.55^{c}
60th day	T4	7.70±0.80^{b}	8.30±0.57^{cd}	8.35±0.74^{c}	8.40±0.75^{c}	8.25±0.55^{c}
	T0	7.20±0.76^{b}	7.35±0.58^{b}	7.55±0.51^{b}	7.40±0.94^{c}	8.25±0.63^{c}
	T1	7.30±0.65^{b}	7.50±0.60^{b}	7.47±0.51^{b}	7.60±0.75^{c}	8.15±0.67^{cd}
	T2	7.40±0.68^{b}	7.55±0.60^{b}	7.47±0.51^{b}	8.00±0.85^{c}	7.95±0.51^{b}
	T3	7.25±0.78^{b}	7.55±0.60^{b}	7.45±0.51^{b}	8.00±0.85^{c}	7.80±0.52^{b}
90th day	T4	7.25±0.78^{b}	7.95±0.60^{c}	7.50±0.51^{b}	7.30±0.47^{c}	7.80±0.52^{b}
	T0	7.20±0.69^{b}	7.60±0.50^{b}	7.35±0.48^{b}	6.60±0.75^{b}	7.40±0.50^{b}
	T1	7.35±0.67^{b}	7.50±0.51^{b}	7.35±0.48^{b}	6.85±0.58^{b}	7.80±0.41^{b}
	T2	6.95±0.75^{ab}	7.55±0.51^{b}	7.45±0.51^{b}	7.10±0.55^{b}	7.70±0.47^{b}
	T3	7.20±0.61^{b}	7.55±0.51^{b}	7.50±0.51^{b}	7.10±0.55^{b}	7.65±0.48^{b}
90th day	T4	6.55±0.88^{a}	7.35±0.67^{b}	7.40±0.50^{b}	6.45±0.68^{b}	7.65±0.48^{b}
	T0	6.70±0.47^{a}	6.20±0.69^{a}	6.15±0.87^{a}	5.75±0.85^{b}	5.95±0.75^{b}
	T1	6.70±0.47 ^{a}	6.4±0.82^{b}	6.85±0.68^{a}	6.25±0.63^{a}	6.90±0.64^{a}
	T2	6.65±0.48^{a}	6.25±0.63^{a}	6.25±0.71^{b}	6.55±0.51^{a}	6.35±0.67^{a}
	T3	6.70±0.47^{a}	6.40±0.59^{a}	6.25±0.71^{a}	6.50±0.51^{a}	7.05±0.60^{a}
	T4	6.15±0.81^{a}	6.35±0.58^{a}	6.25±0.71^{a}	5.45±0.82^{a}	6.05±0.68^{b}

[a]All values are means of triplicate determinations. Means within a column with different superscripts are significantly different at P<0.05. Abbreviations T: Aloe vera gel powder, To: Biscuits without aloe vera gel powder, T1: Biscuits with 0.5g aloe vera gel powder, T2: Biscuits with 1g aloe vera gel powder, T3: Biscuits with 1.5g aloe vera gel powder, T4: Biscuits with 2g aloe vera gel powder.

the C-O a vibration of esters, ether, carboxylic acid, and alcohol. An increase at 900 to 800 cm was caused by carbohydrate monomer C-Hout-of-plane deformation. The high level of mannose and uronic acids, as well as their carbohydrate polymers (acemannans and pectins), is indicated by these absorption peaks. Alkenes has the highest peak. The peaks at 650 cm^{-1} correspond to alkene C-H bonds. The lower peak at 3321 cm^{-1} corresponds to R-OH, which is a hydrogen banded hydroxyl alcohol [34].

Bioactive Compounds of Aloe Vera Gel Powder (AGP) and Biscuits Incorporated AGP

Total Phenolic Content (TPC) and Flavonoid Content (FC) of biscuits incorporated with aloe vera gel powder is shown in Table 2. TPC and FC of Sample T0 (Control biscuits, without aloe vera gel powder) showed 38.77 mg GAE/g and 72.95 mg GAE/g respectively. With the addition of 0.5g, 1g, 1.5g, and 2g aloe vera gel powder in biscuits resulted increased TPC and FC. The highest percentage of TPC and TFC of biscuits was found in T4 incorporated with 2g aloe vera gel powder, i.e. 46.53mg GAE/g and 80.36mg GAE/g followed by biscuits incorporated with 1.5gram of aloe vera gel powder that observed insignificant difference with each other.

Antioxidant activity as shown in Table 2 observed highest in T4 and T3 (90.29% and 89.98% respectively). Bioactive compounds are crucial for human health, fighting oxidative stress and maintaining a balance between oxidants and antioxidants.

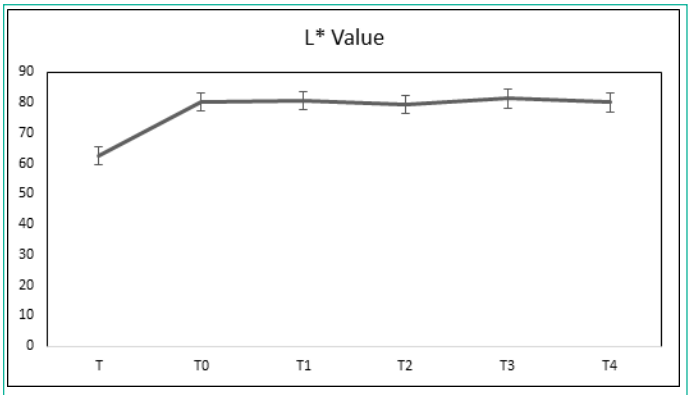


Figure 4a : Effect of aloe vera gel powder on L* Value Profile of biscuits.

[a]All values are means of triplicate determinations. Means within a column with different superscripts are significantly different at P < 0.05. Abbreviations T: Aloe vera gel powder, To: Biscuits without aloe vera gel powder, T1: Biscuits with 0.5g aloe vera gel powder, T2: Biscuits with 1g aloe vera gel powder, T3: Biscuits with 1.5g aloe vera gel powder, T4: Biscuits with 2g aloe vera gel powder.

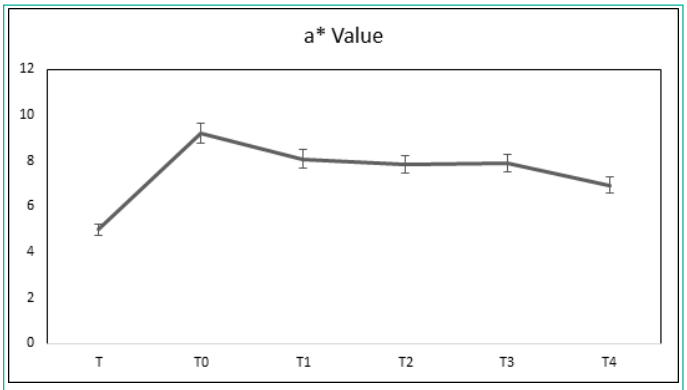


Figure 4b: Effect of aloe vera gel powder on a* Value Profile of biscuits.

[a]All values are means of triplicate determinations. Means within a column with different superscripts are significantly different at P < 0.05. Abbreviations T: Aloe vera gel powder, To: Biscuits without aloe vera gel powder, T1: Biscuits with 0.5g aloe vera gel powder, T2: Biscuits with 1g aloe vera gel powder, T3: Biscuits with 1.5g aloe vera gel powder, T4: Biscuits with 2g aloe vera gel powder.

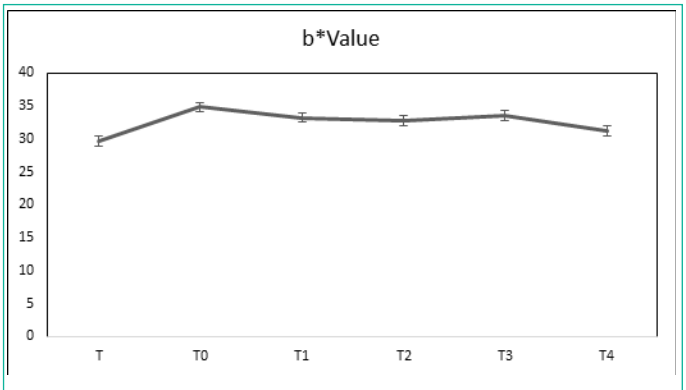


Figure 4c: Effect of aloe vera gel powder on b* Value Profile of biscuits.

[a]All values are means of triplicate determinations. Means within a column with different superscripts are significantly different at P < 0.05. Abbreviations T: Aloe vera gel powder, To: Biscuits without aloe vera gel powder, T1: Biscuits with 0.5g aloe vera gel powder, T2: Biscuits with 1g aloe vera gel powder, T3: Biscuits with 1.5g aloe vera gel powder, T4: Biscuits with 2g aloe vera gel powder.

They support the body by reducing oxidative damage to lipids and low-density lipoproteins, inhibiting platelet aggregation, and protecting against coronary heart disease and cancer risk. Adequate phenolic intake in the diet is essential for overall health [31].

Color Profile of Aloe Vera Gel Powder (AGP) and Biscuits Incorporated AGP

Color constitutes one of the most significant sensory attributes that influences consumer preferences. Bakery products should be given special attention to attract consumer attention. As shown in Figure 4a, the lightness of aloe vera gel powder was 65.52% and it increased with the incorporation of aloe vera gel powder in biscuits. The increase in a* (Figure 4b) and b* (Figure 4c) corresponded to the increase in redness and yellowness, respectively, that occurred at the start of nonenzymic browning. Secondary reactions produce products with more intense green and blue color notes [32].

Storage Stability Based on Texture (N) of AGP Biscuits

Figure 5a depicted the results of the texture properties analyzed by textural machine from 0 to 120 days. During the storage of biscuits, it is observed that the textural properties is reducing with the passage of time. However, T3 and T4 samples investigated the better texture even after 120 days.

In the first 30 days of storage a decrease of hardness appeared simultaneously to an increase of moisture content as shown in Figure 5b. During storage, textural parameters could be influenced because of migration of moisture content and redistribution within the biscuits. On the other hand, hardness of dry foods is strongly affected by different factors such as formulation, fat content in and its structural characteristics [35].

Storage Stability Based on Moisture Content (%) of AGP Biscuits

The biscuits absorb humidity during storage resulting in an increase in moisture content as shown in Figure 5b. The state of equilibrium had been achieved after 120 days. Throughout the experiment, substantial variations were found between biscuits prepared with different formulations of aloe vera gel powder (P>0.05). Previous research has suggested that the rise in moisture content can be attributed to the hygroscopic properties of biscuits, storage conditions, and packaging material [31]. According to our findings, T0 showed the highest increment of moisture content after 120 days while the least was observed in T and T4. This could be due to the degradation of smaller molecules increasing the osmotic pressure, biscuits retained relatively more water resulting the incorporation of aloe vera gel powder into biscuits would give the firmer and crispier texture [36].

Storage Stability Based on Peroxide Value of Biscuits

Peroxide Value (PV) measures the degree of fat oxidation or rancidity in food products. As shown in Figure 5c, at the beginning of the storage stability, peroxide value (expressed as meq /kg of lipids) of T0, T1, T2, T3, and T4 of biscuits observed 1.92, 1.11, 0.81, 0.78 and 0.63 respectively.

PV increased over time as the duration of storage and moisture content of the biscuit increased. Higher levels of PV indicated higher oxidation level. After 120 days of storage, the PV was increased significantly from the zero day. However, the results indicated that samples T2, T3, and T4 observed insignificant difference with each other. Moreover, it is relatively very low as compared to T0 that showed 7.06. It could be due to bio preservative properties found in aloe vera gel powder that cold scavenge free radicals [11].

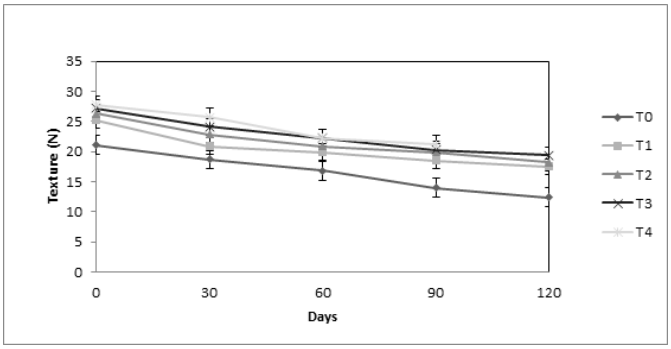


Figure 5a: Effect of aloe vera gel powder on storage stability based on texture (N) of biscuits.

[a]All values are means of triplicate determinations. Means within a column with different superscripts are significantly different at P < 0.05. Abbreviations T: Aloe vera gel powder, To: Biscuits without aloe vera gel powder, T1: Biscuits with 0.5g aloe vera gel powder, T2: Biscuits with 1g aloe vera gel powder, T3: Biscuits with 1.5g aloe vera gel powder, T4: Biscuits with 2g aloe vera gel powder.

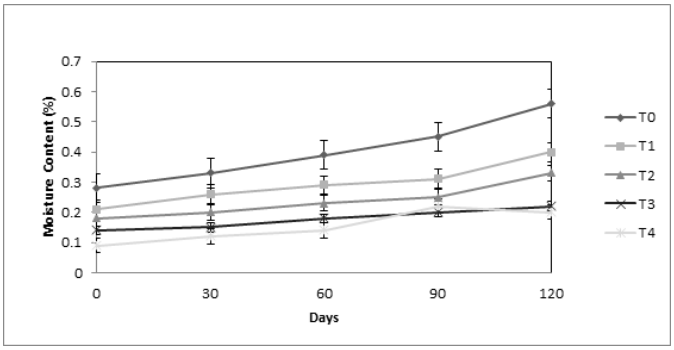


Figure 5b: Effect of aloe vera gel powder on storage stability based on moisture content (%) of biscuits.

[a]All values are means of triplicate determinations. Means within a column with different superscripts are significantly different at P < 0.05. Abbreviations T: Aloe vera gel powder, To: Biscuits without aloe vera gel powder, T1: Biscuits with 0.5g aloe vera gel powder, T2: Biscuits with 1g aloe vera gel powder, T3: Biscuits with 1.5g aloe vera gel powder, T4: Biscuits with 2g aloe vera gel powder.

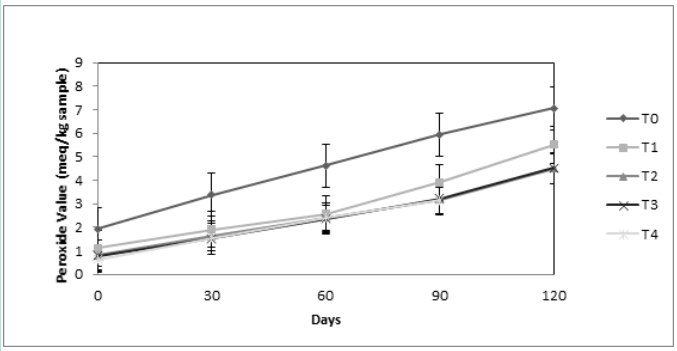


Figure 5c: Effect of aloe vera gel powder on storage stability based on peroxide value of biscuits.

[a]All values are means of triplicate determinations. Means within a column with different superscripts are significantly different at P < 0.05. Abbreviations T: Aloe vera gel powder, To: Biscuits without aloe vera gel powder, T1: Biscuits with 0.5g aloe vera gel powder, T2: Biscuits with 1g aloe vera gel powder, T3: Biscuits with 1.5g aloe vera gel powder, T4: Biscuits with 2g aloe vera gel powder.

Storage Stability Based on Sensory Analysis of Biscuits

It is to consider the physiological effectiveness of the product that will be accepted by consumers. The results as shown in Ta-

ble 3, revealed a significant ($p<0.05$) difference in color acceptability between biscuits of different concentrations. Sample T3 was the most acceptable by the panelist than other biscuits. Sample To and T1 produce the same color results, whereas T2 and T4 produced different results. The color of all samples was good on Day 0, but it began to fade as time passed on Day 120. Color score decreased from (8.40% to 6.70%) from Day 0 to Day 120, and T1, T2, T3, T4 decreased from (8.40% to 6.70%), (8.15% to 6.65%), (8.50% to 6.70%), and (8.35% to 6.15%), respectively, with addition of different formulation. In terms of taste acceptability, a one-way ANOVA revealed a significant (p 0.05) variations from Day 0 to Day 120. T2 and T3 were the most preferred at the 5% level of significance, while to was the one that was least liked. Our evaluation focused heavily on the taste profile. The aloe vera gel powder added a subtle taste that blended well with the sweetness of the biscuit. The taste was generally well-liked, demonstrating the potential for developing an innovative product that offers a balanced taste that is appealing to consumer preferences. In comparison, the taste of biscuits improved with the addition of aloe vera gel powder and received the highest rating. T1 received the highest score in the appearance results. However, control breadsticks had the lowest organoleptic properties scores. The T3 sample with 1% aloe vera gel powder received the highest overall acceptability rating. Thus, when compared to non-aloe vera e powder (control sample) biscuits, the addition of aloe vera in biscuits would be more beneficial due to its higher antioxidant capacity and improved sensory properties. When the amount of aloe vera gel powder was increased to 1%, the aroma was rated "very good," but the taste was rated "satisfactory," and the color and mouthfeel were rated "fair." As a result, 0% and 2% aloe vera gel powder biscuits were less popular.

Incorporating aloe vera in a concentration of 1% to 1.5% results in an appealing nutraceutical food. Biscuits with 1% aloe vera gel received the top grade for texture, color, and overall acceptance.

The texture distinction among control biscuits and aloe vera gel powder biscuits was found to be significant (p 0.05) using ANOVA. After a 4-month period, T3 was more acceptable and significantly different from the other biscuit samples. According to the current study, increasing the incorporation of Aloe vera gel powder improves the texture of biscuits. The biscuits retained an appropriate degree of crispiness, as well as the mouthfeel was fulfilling, all of which contributed to a positive eating experience. In terms of overall acceptability, ANOVA analysis revealed that Sample T3 (1.5% AGP) was the most preferable relative to others over a 4-month period (Table 6). Because aloe vera is a bio preservative, T1 (0.5% AGP), T2 (1% AGP), and T4 (2% AGP) are also considered good in appearance after 120 days.

In terms of overall appearance, ANOVA analysis revealed that Sample T2 (1% AGP) and T3 (1.5% AGP) were the most preferable relative to others over a 4-month period (Table 6). While T1 (0.5% AGP) is also considered desirable after 120 days.

The addition of Aloe vera gel powder gave the biscuits a distinct visual appeal. Consumer perception of the appearance of the biscuits was generally positive, indicating that the inclusion of Aloe vera gel powder did not detract from visual appeal. Color, texture, taste, appearance, and overall acceptability were all best in the 1.5% AGP sample. Sample containing 1.5 gram of aloe vera gel powder in biscuits found to be significantly better in sensory evaluation as compared with other cookies.

Conclusion

The demand for wholesome, nourishing, and health-improving food products has increased in recent years, coinciding with an increase in demand for natural, plant-based ingredients. This has led to the development of aloe vera as a new ingredient in biscuit formulation, potentially improving both the sensory and nutritional properties of biscuits. Aloe vera, known for its digestive support, antioxidants, and health benefits, is a promising addition to food products. According to our findings, addition of 1g and 1.5g of aloe vera gel powder incorporation in biscuits showed a positive result in terms of nutritional, bioactive as well as lipid oxidation, texture, shelf life and sensory parameters. It promises to satisfy the palate and to infuse biscuits with a unique combination of nutrition and medicinal properties while reserving the essence of the biscuit's engagement with consumers.

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