Quality assessment of tortilla chips enriched with microwave stabilized wheat bran

ABSTRACT

This study investigates the effects of incorporating microwave-stabilized wheat bran into tortilla chips, focusing on nutritional, sensory, and storage-related characteristics. Tortilla chips were developed with varying wheat bran levels (0–30%) and evaluated for sensory attributes, moisture content, water activity, lipid stability, and microbial load over a 90-day storage period. Results showed that tortilla chips with 20% wheat bran achieved the highest sensory scores for taste, texture, and appearance, with overall acceptability reaching 7.8 on a nine-point hedonic scale. However, higher bran levels (25–30%) led to declines in sensory qualities, likely due to increased moisture and oxidation effects.Moisture content and water activity ranged from 2.78% to 4.10% and 0.44 to 1.73, respectively, and both values increased with bran levels and storage time. The addition of bran also affected lipid stability; free fatty acid content rose from 0.44% in the control (T1) to 1.73% in the 30% bran treatment (T7), while peroxide values increased from 3.14 to 7.99 meq O_2/kg over 90 days. Microbial counts followed similar trends, with the highest mean load of 2.18 × 10□ cfu/g in the 30% bran formulation, yet all counts remained within acceptable limits.This study highlights the potential for wheat bran-enriched tortilla chips as a fiber-rich snack alternative, contributing valuable data for the formulation of healthier, shelf-stable snacks.

Keywords: Snacks, nutritional, shelf-life, modernization, storage

1. INTRODUCTION

In recent years, snacking has become an integral part of dietary habits globally, shaping food choices and consumption patterns across diverse populations. With changes in lifestyle, such as increased urbanization, busier schedules, and the rise in single-person households, the demand for convenient, ready-to-eat foods has surged, making snacks a vital component of modern diets [1]. Snacks can vary widely in their nutritional composition, from healthy options like fruits, nuts, and yogurt to highly processed, energy-dense products often high in sugar, fat, and salt [2]. The growing market for snacks has encouraged food researchers to explore new product development, focusing on creating healthier snack options that meet consumer preferences for taste, convenience, and nutrition [3].

Health-conscious consumers have driven an increase in snack products that emphasize functionality, such as high-protein, high-fiber, and plant-based ingredients, catering to a broader range of dietary needs and trends [4]. Additionally, food technology advancements have enabled the development of innovative processing methods, improved preservation techniques, and novel ingredients, all contributing to the enhancement of snack quality and nutritional value [5]. Understanding the balance between consumer demands for taste and convenience and the need for nutritious and sustainable snack options has become crucial for food scientists and product developers.

Among popular snack options, tortilla chips hold a prominent place due to their versatility, taste, and appeal across various demographics. Traditionally made from corn, tortilla chips have seen numerous innovations in recent years as food scientists work to enhance their nutritional profile while preserving desirable sensory qualities. One promising approach involves the incorporation of stabilized wheat bran and nixtamalized corn flour, which introduces fiber and beneficial nutrients into a product typically characterized by refined carbohydrates and lower fiber content. Stabilized wheat bran, known for its high fiber and mineral content, not only enhances the nutritional value of product but also improves texture and adds a mild, nutty flavor [6]. Furthermore, the use of nixtamalized corn flour contributes to superior flavor and digestibility, as well as a rich source of calcium and B vitamins, resulting from the alkaline cooking process [7].

The integration of stabilized wheat bran and nixtamalized corn flour in tortilla chips aligns with consumer demand for functional foods that provide health benefits without compromising convenience [8]. These modified tortilla chips cater to a range of dietary needs, including increased fiber intake and the need for complex carbohydrates. In addition, they provide an alternative to traditional snacks, often criticized for their high fat, salt, and sugar content [9]. Research on optimizing ingredient ratios, processing techniques, and sensory evaluation is essential in the development of these enhanced tortilla chips, ensuring that they retain the taste and texture consumers expect. This approach underscores the role of food technology in creating innovative snacks that bridge the gap between nutrition and indulgence, making tortilla chips a viable option for health-conscious snackers.

2. MATERIALS AND METHODS

Procurement of raw materials: The study was conducted in Division of Food Science and Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. Wheat bran used for the study was purchased from Amar flour mills, Gangyal, Jammu. The sample was exposed to microwave stabilization, followed by packaging in low-density polyethylene (LDPE) pouches (150 gauge) and stored at ambient conditions for a period of 90 days. White corn (Ganga safed 2 cultivar) was purchased from the local market of Jammu and was cleaned to remove impurities and dirt and stored at room temperature till further use.

Refined oil and salt used for the preparation of tortilla chips were purchased from the local market.

To microwave the wheat bran, a microwave-resistant glass plate was preheated at 100% power for 3 minutes. Next, 100 g of wheat bran was spread evenly on the plate to a thickness of 0.5 cm. The plate was then placed in a microwave oven (Samsung Electronics Corp, CE137NEL) and heated at 900 Watts for three minutes at a frequency of 2450 MHz.[10]. The temperature of the sample after heating was 105 ±2℃. The treated wheat bran was allowed to cool to room temperature and packed in airtight LDPE bags (150 gauge)

Quality assessment of tortilla chips

water activity: Water activity was measured using an Aqualab water activity meter (Model series 3TE) and readings were corrected at 20^0C [11].

Moisture content: Moisture content in the samples was determined by following the oven drying method as the loss in weight due to evaporation from sample at a temperature of 105 ± 1^0C. The weight loss in each case represented the amount of moisture present in the sample [11].

Free fatty acid: 1 gram of ground sample was mixed with 50 ml of benzene in a 100 ml volumetric flask and allowed to stand for 30 minutes for extraction of free fatty acids [3]. In a separate flask, benzene (5ml) and alcohol (10ml) was added to 1 ml of extract followed by addition of phenolphthalein as an indicator and solution was titrated using 0.02N KOH until disappearance of pink colour indicating that all the free fatty acids have been neutralized [12]

Peroxide value: To determine the peroxide value (PV), 30 ml of acetic acid: chloroform (2:1) was added to the weighed grounded sample. It was kept under a cool and dark place for 30 minutes and 30 ml of distilled water was added. The mixture was then shaken. This was slowly titrated with 0.1 N sodium thiosulphate with vigorous shaking until the yellowcolour disappeared. Then 0.5 ml of 1.0 per cent starch solution was added and titrated continuously with vigorous shaking to release all iodine from chloroform layer until pink colour just disappeared [11].

Total Microbial count: Spread plate technique, described by Palczar and Chan [13] was followed. 1 g of ground sample was aseptically transferred into test tube containing 9 ml of sterile water and was mixed vigorously. After mixing, 1 ml of this mixture was transferred to a test tube containing 9 ml sterile water for further dilution. The process was continued until 4^{th} diluents (10^4). Nutrient agar was inoculated with 0.1 ml of diluted sample (10^4), by spread plating technique and incubated at 37℃ for 48 hours. Colonies were counted and multiplied by dilution factor.

Sensory evaluation: In evaluating the tortilla chips made with stabilized wheat bran and nixtamalized corn flour, a nine-point hedonic scale can be applied to assess the impact of these ingredients on consumer acceptance. Sensory attributes, such as crunchiness, color, and taste are particularly important in snack foods like tortilla chips, where texture and flavor play a significant role in consumer preference [14].

Statistical analysis: The data, collected in triplicate, were subjected to statistical evaluation using the OPSTAT package program for analysis of variance

Table 1: Treatment details for preparation of wheat bran enriched tortilla chips

Treatment	Corn flour (%) (Masa)	Stabilized wheat bran (%)
T_1	100	0
T_2	95	5
T_3	90	10
T_4	85	15
T_5	80	20
T_6	75	25
T_7	70	30

3. RESULTS AND DISCUSSION

Water activity: Water activity, which refers to the amount of unbound or free water available in a food product, is a critical factor in determining food stability and shelf life. Water activity values range from zero (indicating no available water) to 1.0 (pure water) [15]. In this study, the water activity of tortilla chips was found to vary significantly with increasing levels of wheat bran from 0 to 30% (Table 2). As wheat bran levels increased, water activity values also increased, consistent with findings from previous studies on bran-enriched cereal products [16]. This increase in water activity may be attributed to the higher moisture content absorbed due to the hygroscopic nature of the product [17]. Similar trends were observed in bran-enriched baked meat biscuits, where increasing bran content corresponded to an increase in water activity levels [18].

During a storage period of 90 days, the mean water activity values of the tortilla chips continued to increase, likely due to additional moisture absorption during storage, which may be attributed to the hygroscopic properties of bran [19]. Our findings align with other studies showing similar increases in water activity over time in bran-enriched pasta products [20]. A gradual increase in water activity over extended storage periods has also been observed in tortilla chips and other grain-based snack products [21].

Moisture content: The moisture content of tortilla chips decreased significantly from 37.25% in corn masa to 2.78% after processing, a reduction attributed to the high temperatures used during tortilla chip production. Water molecules, being polar, are heated and expelled from the surface through oil during the frying process [22]**).** This reduction in moisture due to frying is consistent with findings in other fried products, such as surimi sausage incorporated with oat powder, where significant moisture loss occurs during high-temperature cooking. In this study, the moisture content of tortilla chips ranged from 2.78% to 4.10% (Table 2), with a noticeable trend of increasing moisture content as wheat bran levels increased from 0% to 30%. This rise in moisture content can likely be attributed to the water-holding capacity of wheat bran fibers, which contain polysaccharides capable of retaining moisture [24]. Similarly, studies on bran-enriched foods, such as pasta and baked goods, have reported an increase in moisture retention with higher wheat bran incorporation, aligning with the results observed in tortilla chips [25]**.** This increase in moisture content has also been documented in products like flatbreads, biscuits, and pasta with added wheat bran or similar fibers [26]. Throughout the 90-day storage period, the mean moisture content of the tortilla chips rose from an initial value of 3.11% to 3.61%. This gradual increase in moisture could be due to the hygroscopic nature of bran, which absorbs moisture over time [27]. Similar findings were reported in buckwheat-based snacks, where moisture content increased progressively during storage [28]. Additionally, a significant increase in moisture content was observed in cereal bran-enriched snacks after six months of storage, likely due to bran's moisture-retentive properties [29].

Table 2: Effect of treatment and storage period on water activity (aw) and moisture content (%) of tortilla chips

Treatments	Water activity Storage days						Moisture content Storage days				
	0	30	60	90	**Mean**		0	30	60	90	**Mean**
T1(100:00::CM:SWB)	0.190	0.230	0.256	0.274	**0.237±0.034**		2.46	2.71	2.89	3.08	**2.78±0.23**
T2 (95:05::CM:SWB)	0.210	0.245	0.257	0.279	**0.248±0.026**		2.63	2.86	3.03	3.18	**2.92±0.23**
T3 (90:10::CM:SWB)	0.215	0.252	0.269	0.286	**0.255±0.025**		2.87	3.09	3.24	3.35	**3.13±0.18**
T4 (85:15::CM:SWB)	0.238	0.271	0.297	0.310	**0.279±0.030**		3.10	3.28	3.40	3.56	**3.33±0.19**
T5 (80:20::CM:SWB)	0.257	0.282	0.307	0.329	**0.294±0.034**		3.37	3.61	3.73	3.82	**3.63±0.20**
T6 (75:25::CM:SWB)	0.276	0.298	0.321	0.343	**0.309±0.026**		3.53	3.70	3.89	3.94	**3.76±0.18**
T7 (70:30::CM:SWB)	0.287	0.311	0.334	0.359	**0.322±0.025**		3.80	4.02	4.22	4.35	**4.10±0.21**
CD(*P*=0.05) Treatment (T)	0.005						0.03				
Storage (S)	0.004						0.03				
T x S	NS						0.07				

Table 3: Effect of treatment and storage period on free fatty acids (%oleic acid) and peroxide valuemeqO_2/ Kg)of tortilla chips

Treatments	Free fatty acids Storage days						Peroxide value Storage days				
	0	30	60	90	mean		0	30	60	90	Mean
T1(100:00::CM:SWB)	0.33	0.42	0.49	0.54	**0.44±0.08**		2.82	4.17	5.48	7.27	**4.93±0.74**
T2 (95:05::CM:SWB)	0.56	0.67	0.75	0.80	**0.69±0.10**		2.90	4.40	5.87	7.45	**5.15±0.72**
T3 (90:10::CM:SWB)	0.75	0.84	0.91	0.96	**0.86±0.08**		3.03	4.70	6.23	7.67	**5.41±0.67**
T4 (85:15::CM:SWB)	0.97	1.10	1.19	1.26	**1.13±0.11**		3.12	4.97	6.52	7.95	**5.64±0.69**
T5 (80:20::CM:SWB)	1.12	1.21	1.28	1.32	**1.23±0.16**		3.24	5.20	6.79	8.19	**5.85±0.75**
T6 (75:25::CM:SWB)	1.30	1.41	1.50	1.58	**1.45±0.11**		3.36	5.74	7.27	8.47	**6.21±0.64**
T7 (70:30::CM:SWB)	1.59	1.70	1.79	1.86	**1.73±0.11**		3.48	6.07	7.54	8.97	**6.51±0.69**
CD(*P*=0.05) Treatment (T)	0.03						0.03				
Storage (S)	0.02						0.03				
T x S	0.06						0.07				

Free fatty acids: Free fatty acids (FFAs) are generated through the enzymatic or microbial breakdown of lipids, serving as indicators of fat stability during storage. In this study, the FFA content in treatment T1 (100:00::CM:SWB) was found to be lower than in corn and corn masa. This reduction may be due to the denaturation of lipase enzymes caused by high processing temperatures used in tortilla chip production (baking at 280°C and frying at 190°C). The incorporation of stabilized wheat bran (SWB) led to an increase in the mean FFA value, from 0.44% in T1 (100:00::CM:SWB) to 1.73% in T7 (70:30::CM:SWB) (Table 3). This increase could be attributed to the higher initial FFA content in bran, which, when added, can alter the lipid composition of the product [30]**.** Similar increases in FFA have been observed in other bran-enriched products, such as pasta, where the addition of cereal bran contributed to elevated FFA content [20]. Research on wheat bran-enriched baked goods has also reported increases in FFA, supporting these findings [31].

Over the 90-day storage period, the mean FFA content of tortilla chips increased significantly from 0.95% to 1.18% as oleic acid. This increase in FFA during storage is likely due to residual lipolytic activity of lipase, which may be enhanced by the rise in moisture content during storage [32]. Similar observations have been made in other studies where hydrolytic rancidity was noted in response to elevated storage temperatures [33]. Progressive increases in FFA content with extended storage have also been documented in bran- and tuber-enriched snack foods, such as breakfast snacks and root-based chips [34].

Peroxide value: Hydroperoxides are the primary products of lipid oxidation and serve as indicators of the early stages of oxidation. The peroxide value (PV) is a widely used to measure the extent of lipid oxidation in foods, including tortilla chips, throughout storage. To maintain product quality, the PV of fried tortilla chips should not exceed 10 meq O_2 per kg [35]. Secondary oxidation products, generated from the breakdown of hydroperoxides, contribute to rancidity by breaking the double bonds in unsaturated fatty acids [36].

In this study, the PV of T1 (100:00::CM:SWB) tortilla chips was significantly lower than that of raw corn and corn masa, as well as other treatments. This decrease in PV may be due to the effects of boiling and frying, which align with findings from studies on fried products, where pre-treatment cooking reduced peroxide levels [37]. In our samples, the mean PV of tortilla chips ranged from 4.93 to 6.51 meq O_2 per kg (Table 3). Replacing corn flour with microwave-stabilized wheat bran resulted in higher peroxide value in the tortilla chips, potentially due to the increased moisture content. Higher moisture levels may activate the lipoxygenase enzyme, facilitating the formation of hydroperoxides and raising peroxide value [19]. Similar observations were reported in bran-enriched biscuits, where increased peroxide value was linked to bran's influence on moisture and enzyme activity [38].

Over a 90-day storage period, the mean peroxide value of tortilla chips increased significantly from 3.14 to 7.99 meq O_2 per kg. This progressive increase is likely due to residual lipase activity, which may be stimulated by the gradual gain in moisture content during storage [39]. Comparable trends have been reported in bran-enriched snack products, including tortilla chips and fried potato crisps, where storage-induced moisture uptake led to elevated peroxide value [40].

Total microbial count: The microbial count of a food product reflects the sanitary quality of the raw materials, processing conditions, and storage practices [41]. In this study, the microbial load of tortilla chips was significantly influenced by both treatment and storage duration (Table 4). The highest mean microbial count was observed in treatment T7 (70:30::CMSWB) with 2.18×10□ cfu/g, while the lowest count of 1.12×10□ cfu/g was recorded in T1 (100:00::CM:SWB). This increase in microbial load with higher levels of wheat bran supplementation may be due to increased moisture content, which supports microbial growth [42]. The addition of microwave-stabilized wheat bran appears to have contributed to the increased microbial count, aligning with findings in wheat bran-enriched flatbreads [43] and pasta [16]**.**

Over the storage period, the total microbial plate count in tortilla chips increased significantly. This increase in microbial count is likely attributable to gradual moisture gain during storage, which provides a favorable environment for microbial growth [44]. However, all microbial counts remained within acceptable safety limits (≤10□ cfu/g), below the maximum level considered safe for consumption for stored foods [45]. Previous studies have also reported increases in microbial load over extended storage periods, particularly in bran-enriched snacks and high-fiber meat products [46&47].

Table 4: Effect of treatment and storage period on total microbial count ($\times 10^4$cfu/g) of tortilla chips

Treatments	Water activity Storage days				
	0	30	60	90	Mean
T1(100:00::CM:SWB)	ND	ND	1.02	1.23	**1.12±0.11**
T2 (95:05::CM:SWB)	ND	ND	1.15	1.32	**1.23±0.09**
T3 (90:10::CM:SWB)	ND	ND	1.30	1.43	**1.36±0.07**
T4 (85:15::CM:SWB)	ND	ND	1.43	1.58	**1.50±0.08**
T5 (80:20::CM:SWB)	ND	ND	1.60	1.78	**1.69±0.09**
T6 (75:25::CM:SWB)	ND	ND	1.87	2.03	**1.95±0.06**
T7 (70:30::CM:SWB)	ND	ND	2.10	2.27	**2.18±0.09**
CD(*P*=0.05) Treatment (T) Storage (S) T x S	 0.05 0.06 0.09				

Sensory evaluation: A hedonic scale is commonly used in sensory evaluation to measure consumer preferences for food products. This scale, typically ranging from "dislike extremely" to "like extremely," provides a quantitative measure of sensory attributes such as taste, texture, aroma, appearance, and overall acceptability [48]. In this study, tortilla chips were evaluated for appearance, texture, taste, and overall acceptability using a nine-point hedonic scale. The overall acceptability scores were calculated based on the sensory quality scores for appearance, texture, and taste [49]. As the level of microwave-stabilized wheat bran increased from 5% to 20%, the scores for appearance, texture, taste, and overall acceptability followed an upward trend. However, at 25% and 30% wheat bran, these scores began to decline (Table5; Figure 1).

The overall acceptability of the wheat bran-enriched tortilla chips exceeded that of the control, which aligns with previous findings by [50] who reported that consumers preferred bran-enriched cookies over refined flour versions. Notably, the 20% wheat bran formulation achieved the highest taste scores, likely due to the distinctive, pleasant bran flavor [51]. The reduced appearance score at higher wheat bran levels may stem from increased oxidation, resulting in a darker hue [52]**,** similar to findings in bran-enriched baked goods. Comparable effects of bran on sensory scores have been documented in biscuits [53], while [54] also observed diminishing sensory appeal in biscuits with 20% bran. [55] highlighted similar trends, noting sensory drawbacks at high bran concentrations. Among the tested formulations, T5 (80:20::CM:SWB) achieved the highest appearance, texture, taste, and overall acceptability ratings. This finding concurs with [56], who reported that bran-enriched biscuits were well-received. The reduction in sensory scores with higher bran levels is consistent with trends reported in pasta [25].

A significant decline in sensory characteristics was observed over a 90-day storage period. The mean scores for appearance, texture, taste, and overall acceptability decreased, likely due to non-enzymatic browning (Maillard reaction) and fat oxidation [57]. These changes align with results from [58], who documented similar declines in wheat bran-enriched meat products. A reduction in sensory scores with storage was also observed in bran-enriched chevon rolls [59].

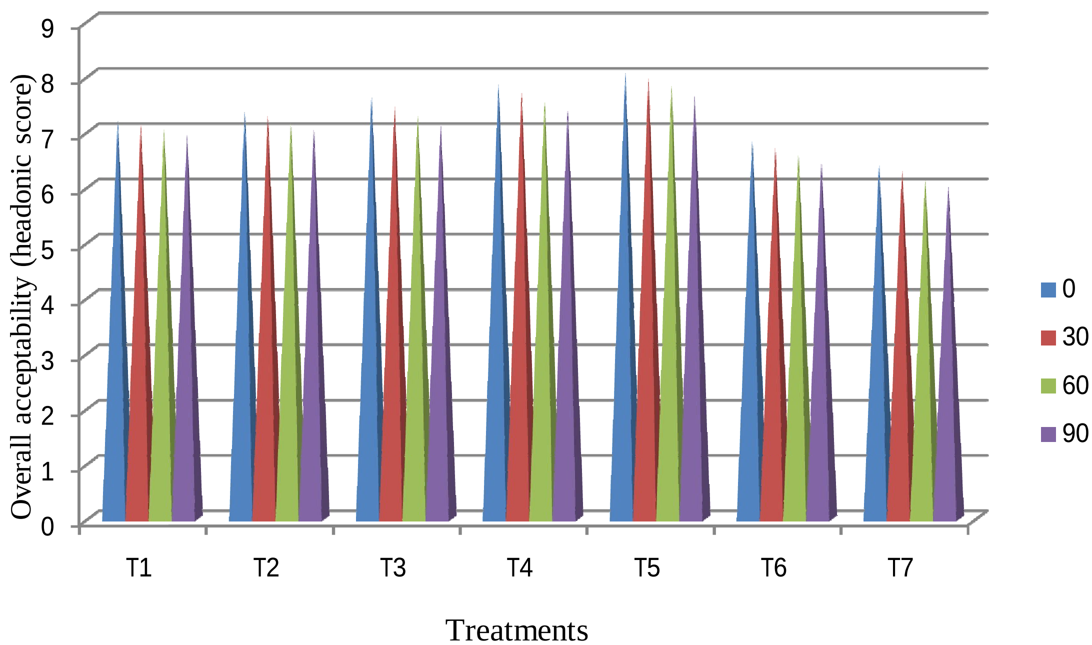

Figure 1: Effect of treatment and storage period on overall acceptability

Table 5: Effect of treatment and storage period on sensory evaluation (hedonic score) of tortilla chips

Treatments	Taste Storage days				Texture Storage days				Appearance Storage days			
	0	30	60	90	0	30	60	90	0	30	60	90
T1(100:00::CM:SWB)	7.00	6.82	6.70	6.58	7.12	7.01	6.95	6.87	7.50	7.48	7.44	7.39
T2 (95:05::CM:SWB)	7.28	7.11	6.96	6.84	7.25	7.19	6.97	6.81	7.56	7.53	7.49	7.43
T3 (90:10::CM:SWB)	7.50	7.35	7.08	6.87	7.50	7.25	7.05	6.85	7.81	7.76	7.72	7.67

T4 (85:15::CM:SWB)	7.68	7.55	7.39	7.19	7.87	7.53	7.29	7.10	8.00	7.95	7.89	7.84
T5 (80:20::CM:SWB)	8.12	8.07	7.89	7.76	7.98	7.77	7.63	7.32	8.10	8.03	7.97	7.91
T6 (75:25::CM:SWB)	6.96	6.73	6.51	6.33	7.00	6.90	6.82	6.60	6.50	6.44	6.39	6.35
T7 (70:30::CM:SWB)	6.56	6.43	6.20	6.08	6.62	6.47	6.26	6.10	6.00	5.95	5.91	5.86
CD(*P*=0.05)												
Treatment (T)		0.02				0.02				0.02		
Storage (S)		0.03				0.02				0.01		
T x S		0.06				0.04				0.04		

4. CONCLUSION

Based on the results of this study, it is evident that incorporating microwave-stabilized wheat bran into tortilla chips can enhance certain nutritional and sensory properties, while also impacting shelf stability and microbial safety. The addition of wheat bran at levels up to 20% significantly improved the taste and overall acceptability of tortilla chips, as consumers appreciated the unique, slightly branny flavor. However, beyond 20% bran inclusion, sensory qualities like appearance and texture began to decline, possibly due to oxidative effects and increased moisture retention associated with higher fiber content.Water activity, and moisture content, increased with the inclusion of wheat bran, which is naturally hygroscopic and can potentially reduce shelf life, highlighting the need for optimized packaging to manage moisture uptake and maintain crispness or texture. During storage, the increase in moisture content also appeared to contribute to an elevation in microbial load, though levels remained within acceptable limits. Consequently, additional control measures may be needed for extended storage, especially in high-humidity conditions.Free fatty acids and peroxide values, both critical indicators of lipid stability, increased with the addition of wheat bran and over the storage period. These increases reflect bran's naturally higher free fatty acid content and the greater susceptibility to oxidation due to bran incorporation. Interestingly, the initial processing of tortilla chips through high-temperature baking and frying effectively limited initial peroxide values, suggesting a protective effect from thermal processing. However, during storage, the slight rise in peroxide and free fatty acid values underscores the need for antioxidant strategies in bran-enriched snacks.

The sensory evaluation results support the development of a tortilla chip formulation with 20% stabilized wheat bran, which was preferred for its taste, texture, and appearance. This formulation achieved high consumer acceptance on the hedonic scale, confirming that bran enrichment can positively influence sensory characteristics at moderate levels. The decrease in sensory scores during storage, attributed to Maillard browning and fat oxidation, aligns with common challenges in bran-enriched products. Despite these declines, the product retained acceptable sensory attributes up to 90 days, especially with proper storage measures to limit moisture uptake and oxidation.

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