DOI: 10.29050/harranziraat.1874075
Harran Tarım ve Gıda Bilimleri Dergisi 2026, 30(1): 856-866

Research Article/Araştırma Makalesi

Effect of different flour types on histamine content, physicochemical, microbiological, and sensory quality of tarhana

Farklı un türleri kullanılarak üretilen tarhanaların histamin miktarının, fizikokimyasal, mikrobiyolojik özelliklerinin incelenmesi ve duyusal analizi

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To cite this article:
Akbaş, E., Karakaş, R., Çayır, Z. Y., & Omurtag Korkmaz, B. İ. (2026). Effect of different flour types on histamine content, physicochemical, microbiological, and sensory quality of tarhana. Harran Tarım ve Gıda Bilimleri Dergisi, 30(1): 856-866

DOI: 10.29050/harranziraat.1874075

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Received Date:
28.01.2026
Accepted Date:
28. 02.2026

ABSTRACT
The aim of this study was to compare the histamine levels of tarhana produced with different types of flour (wheat, corn, chickpea, and sorghum) and to assess their physicochemical, microbiological, and sensory properties. Tarhana samples were produced using the traditional methods and analyzed after the drying and milling stages. Moisture, dry matter, and pH values, as well as histamine levels, were determined; microbiological analyses included total mesophilic aerobic bacteria, *Lactobacillus* spp., and yeast-mold counts, and the sensory properties of the products were evaluated. The highest *Lactobacillus* spp. count was observed in sorghum flour tarhana. Total mesophilic aerobic bacteria counts ranged from 3.3×10^3 to 1.25×10^4 CFU/g, with the highest value recorded in sorghum flour tarhana. Mold-yeast was detected only in chickpea flour tarhana. The moisture content of wheat flour tarhana was significantly higher, while its dry matter content was significantly lower than that of the other samples. The pH values of sorghum and chickpea flour tarhana were significantly higher than those of corn and wheat flour tarhana. Histamine was detected only in chickpea flour tarhana. Sensory analysis results indicated that wheat-flour tarhana received the highest scores for consistency, color, taste, and overall acceptability. In contrast, sorghum flour tarhana exhibited the lowest sensory profile for most parameters. In conclusion, the type of flour used in tarhana production plays a decisive role in histamine formation, microbiological characteristics, and sensory acceptability, highlighting flour selection as a particularly important factor for individuals with histamine intolerance.

Key Words: *Tarhana, Histamine, Fermentation, Flour, Sensory analysis*

ÖZ

Bu çalışmanın amacı, farklı un türleri (buğday, mısır, nohut ve sorgum) kullanılarak üretilen tarhanaların histamin düzeylerini karşılaştırmak ve bu ürünlerin fizikokimyasal, mikrobiyolojik ve duyusal özelliklerini değerlendirmektir. Tarhana örnekleri geleneksel yöntemiyle hazırlanmış; kurutma ve öğütme aşamalarının ardından analiz edilmiştir. Nem, kuru madde ve pH değerleri ile histamin düzeyleri belirlenmiş; mikrobiyolojik analizlerde toplam mezofilik aerob bakteri, *Lactobacillus* spp. ve küf–maya sayımları yapılmış, ürünlerin duyusal özellikleri değerlendirilmiştir. En yüksek *Lactobacillus* spp. sayısı sorgum unu ile üretilen tarhanada saptanmıştır. Toplam mezofilik aerob bakteri sayıları 3.3×10^3 ile 1.25×10^4 KOB/g arasında değişmiş olup, en yüksek değer sorgum unu tarhanasında belirlenmiştir. Küf ve maya yalnızca nohut unu tarhanasında tespit edilmiştir. Buğday unu tarhanasının nem içeriğinin anlamlı düzeyde daha yüksek, kuru madde içeriğinin ise diğer örneklere kıyasla anlamlı düzeyde daha düşük olduğu belirlenmiştir.

Sorgum ve nohut unu tarhanalarının pH değerleri, mısır ve buğday unu tarhanalarına göre anlamlı düzeyde daha yüksek bulunmuştur. Histamin yalnızca nohut unu tarhanasında saptanmıştır. Duyusal analiz sonuçlarına göre, buğday unu tarhanası kıvam, renk, tat ve genel beğeni açısından en yüksek puanları almıştır. Buna karşılık, sorgum unu tarhanası çoğu duyusal parametre bakımından en düşük değerlere sahip olmuştur. Sonuç olarak, tarhana üretiminde kullanılan un türü; histamin oluşumu, mikrobiyolojik özellikler ve duyusal kabul edilebilirlik üzerinde belirleyici bir rol oynamakta olup, un seçiminin histamin intoleransı olan bireyler için özellikle önemli olduğu görülmektedir.

Anahtar Kelimeler: *Tarhana, Histamin, Mikrobiyolojik Kalite, Un Türü, Duyusal Analiz*

Introduction

Tarhana is a traditional fermented food known by different names in various regions of the world. It is referred to as "kishk" in Egypt, Syria, and Lebanon; "trahana" in Greece; "kushuk" in Iraq; and "tahonyaltalkuna" in Finland and Hungary (Sormaz et al., 2019). Produced through lactic acid and yeast fermentation of cereal flours, yogurt, vegetables, yeast, and spices, tarhana is a nutritious product with a long shelf life due to its low pH (3.8–4.4) and low moisture content (60–90 g/kg) (Bilgiçli et al., 2006). In Türkiye, tarhana varieties with geographical indication status include Muğla Göce Tarhanası, Uşak Tarhanası, Maraş Tarhanası, Kütahya Kızılcık Tarhanası, and Bolu Kızılcık Tarhanası (Uslu & Yılmaz, 2022). Uşak tarhana, classified as a flour-based tarhana according to Turkish standards, differs from other regional tarhana varieties in Türkiye in terms of its distinct composition and production characteristics. One of its most notable features is the use of a relatively high proportion of raw vegetables, particularly paprika, which contributes to its unique flavor profile. In addition, Uşak tarhana is produced using an extended fermentation period that can reach up to 21 days, a process considered to play an important role in shaping its fermentation dynamics and sensory characteristics (Mitaf et al., 2024).

Histamine is a biogenic amine that may be naturally present in foods or formed during processing and fermentation. It is also synthesized endogenously in the human body, primarily by mast cells and enterochromaffin cells (Öztekin, 2024). While biogenic amines play roles in nervous system function and vascular regulation, they can accumulate to high levels in fermented foods due to microbial decarboxylation of free amino acids (Bayesen & Yüksel, 2023; EFSA, 2011).

The European Food Safety Authority (EFSA) ranks histamine as the second-most-toxic biogenic amine (EFSA, 2011). In cases of impaired histamine metabolism, histamine intolerance may develop, characterized by gastrointestinal, dermatological, respiratory, and neurological symptoms (Comas-Basté et al., 2020). Abdominal distension, postprandial diarrhea, and abdominal pain are reported among the most common symptoms in the literature (Schnedl et al., 2019). Beyond its toxicological relevance, histamine formation in fermented foods is closely associated with key quality parameters, including physicochemical properties, microbial composition, and sensory characteristics. Fermentation conditions, such as pH, moisture content, and water activity, influence both microbial growth and enzymatic activity, thereby affecting biogenic amine accumulation, product texture, aroma, and overall acceptability (Gardini et al., 2016; Spano et al., 2010). It has been observed that histamine levels naturally present in foods increase during processes such as canning, ripening, smoking, and fermentation (Gagic et al., 2018). In particular, certain bacterial strains belonging to the genera *Lactobacillus* and the family Enterobacteriaceae have been reported to produce histamine by increasing L-histidine decarboxylase enzyme activity under favorable conditions during fermentation (Doeun et al., 2017). Therefore, histamine formation in tarhana should be considered not only a food safety concern but also an integral component of overall product quality that may indirectly influence sensory perception and consumer acceptance.

Several studies in the literature have investigated the biogenic amine content of tarhana. One study reported the absence of methylamine, β-phenylethylamine, and tryptamine in tarhana samples, while varying amounts of putrescine, cadaverine, spermidine, spermine, tyramine, histamine, and agmatine were detected (Keşkekoğlu & Üren, 2009). Current evidence indicates that the biogenic amine profile and concentration of tarhana vary depending on formulation and storage duration (Akan & Ocak, 2019; Özdestan & Üren, 2013). Although different cereal and legume flours have been shown to influence the nutritional composition, technological properties, and sensory characteristics of tarhana (Atasoy, 2018; Dadalı & Elmacı, 2021; Göncü, 2020; Koca & Tarakçı, 1997), the relationship between these variations and histamine formation has not been sufficiently elucidated. Different flour types differ in their protein content and free amino acid composition, which are known to influence microbial decarboxylation activity during fermentation (Barbieri et al., 2019). Fermentation parameters such as pH and substrate availability have also been reported to modulate microbial selection and biogenic amine accumulation (Gardini et al., 2016). However, comparative studies directly evaluating histamine formation across different flour matrices in cereal-based fermented foods remain limited.

This study aimed to compare the histamine levels of tarhana produced from wheat flour, corn flour, chickpea flour, and sorghum flour, along with their physicochemical, microbiological, and sensory properties. In addition, the study aims to provide preliminary data on tarhana alternatives with potentially lower histamine content for individuals with histamine intolerance.

Materials and Methods

This study is an experimental research design. Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of the Faculty of Health Sciences (29.01.2025/02).

Sample Preparation

The sample preparation stages of the study were conducted at the Food Preparation and Cooking Laboratory of the Department of Nutrition and Dietetics. Wheat flour tarhana was used as the control sample, while corn flour, chickpea flour, and sorghum flour were selected as alternative flour types to evaluate their effects on fermentation characteristics and histamine formation.

Traditional tarhana production involves mixing, fermentation, drying, and milling. In the first step, onions, peppers, tomatoes and parsley were cooked in water until softened, then cooled. The cooled mixture was strained to separate the pulp, and yogurt, flour, sourdough starter, and salt were added to the liquid phase to obtain a homogeneous dough.

Wheat flour tarhana was used as the control sample, representing the traditional flour-based formulation. Corn flour, chickpea flour, and sorghum flour were used as alternative flour types in order to evaluate their substitution effects on fermentation characteristics and histamine formation.

The strained fiber residue, yogurt, and dry yeast were first mixed thoroughly to obtain a homogeneous base matrix. All ingredients except flour were combined at this stage. The resulting mixture was then divided into four equal portions to ensure comparable fermentation dynamics across samples. Each portion subsequently received a single flour type, which was added as a full replacement of wheat flour. The flour amounts used for each sample were as follows: wheat flour (91 g), chickpea flour (83 g), sorghum flour (170 g), and corn flour (206 g).

Fermentation was carried out for 4 days at room temperature in a dry and dark environment. During fermentation, the dough was kneaded twice daily to ensure uniform microbial activity and gas release. No external starter culture was added apart from traditional sourdough.

Fermentation duration (4 days), kneading frequency (twice daily), and environmental conditions were kept constant for all flour types to allow direct comparison of flour-related effects on microbial development and histamine formation.

At the end of the fermentation process, the doughs were divided into small pieces and dried at 70 °C for 8 hours using a Tribest–Sedona Express Fruit and Vegetable Dehydrator. The dried samples were milled and stored at +4 °C in glass jars wrapped with aluminum foil. The researchers carried out all production stages in the same laboratory environment.

Chemical Analyses

The dry matter content of tarhana samples was determined by oven-drying at 100°C, and dry matter content was determined according to AOAC; moisture content was calculated by difference (100 − dry matter), and results were expressed on a percentage dry-matter basis (AOAC, 1984). The pH values of the samples were measured using a Milwaukee pH meter, which was calibrated before measurement with pH 4.0, 7.0, and 10.0 buffer solutions. For pH determination, 5 g of the sample was homogenized with 100 mL of distilled water (Ibanoglu et al., 1995).

Histamine analysis was performed by an accredited private food control laboratory using liquid chromatography–tandem mass spectrometry (LC–MS/MS) in accordance with the NMKL 196 method (Nordic Committee on Food Analysis, 2013). The method allows simultaneous determination of biogenic amines and provides high sensitivity and specificity for histamine detection. The limit of detection (LOD) was 1 mg/kg.

All physicochemical analyses were performed in triplicate, and the mean values were used for evaluation.

Microbiological Analyses

For microbiological analyses, 25 g of sample was homogenized in 225 mL of sterile peptone water, and serial dilutions ranging from 10^{-1} to 10^{-6} were prepared from the resulting suspension. Total mesophilic aerobic bacteria, mold-yeast, and *Lactobacillus* spp. counts were determined using appropriate culture media (Gülbandılar et al., 2014).

Total Mesophilic Aerobic Bacteria Count

Total mesophilic aerobic bacteria were enumerated using the pour plate method. From appropriate dilutions, 1 mL of sample was transferred into duplicate Petri dishes, followed by the addition of Plate Count Agar (PCA) cooled to 45 °C using the pour plating method. The plates were incubated at 30 °C for 24–48 hours, aerobically. Plates containing 30–300 colonies were counted, and results were expressed as CFU/g (Gülbandılar et al., 2014).

Mold and Yeast Count

From the prepared dilutions, 0.1 mL of the sample was transferred by the streak plate method onto the sterile Petri dishes with Dichloran Rose Bengal Chloramphenicol Agar (DRBC). The plates were incubated at 25 °C for 5 days (Gülbandılar et al., 2014).

Lactobacillus sp. Count

From appropriate dilutions, 0.1 mL aliquots were spread-plated onto MRS Agar. The plates were incubated under anaerobic conditions at 37 °C for 48 hours. Results were recorded as CFU/g (Gurgun & Halkman, 1990).

Sensory Analysis

The sensory analysis was conducted at the Department of Nutrition and Dietetics, Faculty of Health Sciences, between May 2025 and June 2025, with the participation of volunteer academic staff and postgraduate students aged 25–65 years. Individuals with acute conditions affecting taste or smell and those with known food allergies were excluded from the study.

A hedonic sensory evaluation was conducted using a five-point scoring scale (1 = very poor, 5 = very good). Samples were randomly coded, and panelists were not informed about product contents; evaluations were performed under single-blind conditions. Assessments were conducted by semi-trained panelists. Panelists evaluated the samples for consistency, color, aroma, taste, sourness, homogeneity, and overall acceptability.

The arithmetic mean of the scores obtained for each parameter was calculated. Water was provided between tastings to neutralize the palate. Written informed consent was obtained from all participants before the study.

Statistical Analysis

Statistical analyses were performed using SPSS–Statistical Package for the Social Sciences software, version 22.0. For sensory evaluation, each sample was evaluated once by nine independent panelists, and individual panelist scores were used as statistical observations ($n = 9$). Differences among sensory evaluation parameters were assessed using one-way analysis of variance (ANOVA), and Tukey's post-hoc test was applied for pairwise comparisons. Results were presented as mean ± standard deviation. A p-value <0.05 was considered statistically significant.

Results and Discussion

The highest *Lactobacillus* spp. count was detected in sorghum flour tarhana (1.4×10^3 CFU/g). Total mesophilic aerobic bacteria counts ranged from 3.3×10^3 to 1.25×10^4 CFU/g, with the highest value observed in sorghum flour tarhana. Mold and yeast were detected only in chickpea flour tarhana (1.0×10^2 CFU/g), while no growth was observed in the other samples (Table 1).

In traditional tarhana, lactic acid bacteria generally constitute the dominant microbial group; however, total microbial load and the presence of other microorganisms vary depending on raw material composition and processing conditions (Sengun et al., 2009; Ömeroğlu et al., 2023). The relatively low LAB counts observed in all samples may be attributed to the low pH and reduced water activity of the final product following fermentation and drying. These conditions are known to suppress microbial survival, particularly among microorganisms with low acid tolerance (Dimitreli et al., 2025). Furthermore, legume and whole-grain flours provide more heterogeneous nitrogenous substrates, potentially leading to a more complex microbial ecosystem during fermentation (Atasoy, 2018; Bilgiçli, 2009; Köse & Çağındı, 2002). The observed variability among samples is therefore consistent with previous reports on tarhana produced with alternative cereal and legume flours (Durmuş, 2015; Ertaş et al., 2009).

Table 1. *Total bacteria, Lactobacillus spp., and mold–yeast counts in tarhana samples (CFU/g)*

Sample	Chickpea	Corn	Sorghum	Wheat
MRS (*Lactobacillus* spp.)	2.0×10^2	2.0×10^2	1.4×10^3	5.0×10^2
PCA (Total bacteria)	4.1×10^3	3.3×10^3	1.25×10^4	3.7×10^3
DRBC (Mold + Yeast)	1.0×10^2	-	-	-

The moisture content of wheat flour tarhana was significantly higher, whereas its dry matter content was significantly lower compared to chickpea and corn flour tarhana ($p <0.05$). This inverse relationship is expected, as dry matter is calculated on a moisture-free basis. The higher moisture retention observed in wheat flour tarhana may be attributed to the gluten–starch matrix of wheat flour, which enhances water-binding capacity and limits moisture mobility during processing and drying, resulting in reduced moisture loss compared to legume- and corn-based formulations (Bilgiçli, 2009; Wang et al., 2024).

The pH values of sorghum and chickpea flour tarhana were significantly higher than those of corn and wheat flour tarhana (p <0.001) (Table 2). These findings suggest that flour type significantly influences acidification dynamics during fermentation. Buffering capacity, largely determined by protein, mineral, and ash content, plays a critical role in resistance to pH reduction (Mennah-Govela et al., 2020). The higher protein and mineral content of legume and whole-grain flours may limit the pH-lowering effect of organic acids produced by LAB (Bilgiçli, 2009; Demir, 2018; Kömürcü & Bilgiçli, 2022). Such differences are of particular importance because pH is a major determinant of microbial selection and fermentation ecology.

Histamine was detected only in chickpea flour tarhana, with a concentration of 8.29 ± 1.50 mg/kg (Table 2). This is one of the most notable findings of the study. Biogenic amines are produced by microbial amino acid decarboxylation and are strongly influenced by both microbial composition and substrate availability (Barbieri et al., 2019; Visciano & Schirone, 2022). Less acidic environments may support greater microbial diversity and increase the likelihood of biogenic amine formation (Pawul-Gruba et al., 2025; Turna et al., 2024). The presence of histamine exclusively in chickpea flour tarhana supports the "matrix effect" concept, whereby legume flours, owing to their high protein and free amino acid content, provide more abundant precursors for biogenic amine synthesis (Atasoy, 2018; Tuluk & Ertaş, 2019). Previous studies similarly report substantial variation in biogenic amine profiles of tarhana depending on raw material composition (Keşkekoğlu & Üren, 2013; Özdestan & Üren, 2013).

From a food safety perspective, the detected histamine concentration remained well below levels commonly associated with adverse health effects. Suggested threshold values for histamine in foods are around 100 mg/kg, while symptoms in healthy individuals are generally associated with intake levels exceeding 50 mg per meal and may occur at much lower doses (5–10 mg per meal) in sensitive individuals (Turna et al., 2024). In this context, the histamine level measured in chickpea-flour tarhana can be considered low relative to reported toxicological thresholds. Nevertheless, even relatively low histamine concentrations may trigger symptoms in individuals with histamine intolerance, particularly when cumulative dietary exposure is considered (Comas-Basté et al., 2020). Therefore, while the findings do not indicate an acute food safety risk for the general population, formulation strategies involving legume flours should be carefully evaluated when targeting sensitive consumer groups.

The detection of mold and yeast only in chickpea flour tarhana further supports this interpretation. In fermented foods, biogenic amine formation is not limited to LAB; yeasts and molds may also exhibit decarboxylase activity (Gardini et al., 2016; Spano et al., 2010). This suggests that the chickpea-based matrix may have promoted a fermentation ecology more favorable to histamine-producing microorganisms (Doeun et al., 2017). Accordingly, when developing tarhana formulations with legume flours, assessment of biogenic amine risk and careful process control are essential. Previous studies indicate that optimization of fermentation conditions and the use of selected starter cultures or phenolic-rich components can reduce biogenic amine accumulation (Akan & Ocak, 2019; Hernández-Macias et al., 2022; Świder et al., 2024).

Regarding color evaluation, wheat flour tarhana (4.67 ± 0.71) received significantly higher scores compared to sorghum flour tarhana (3.67 ± 1.12) (p <0.05). For the flavor parameter, corn (4.00 ± 0.71) and wheat flour tarhana (4.11 ± 0.78) received the highest scores, whereas sorghum flour tarhana (2.78 ± 0.83) was rated significantly lower (p <0.05). In terms of homogeneity, wheat flour tarhana scored significantly higher than sorghum flour tarhana (2.33 ± 1.00) (p <0.05).

Table 2. *Chemical analysis results of tarhana samples*

Sample	Chickpea	Corn	Sorghum	Wheat	p
Moisture (%)	4.23±1.27^{a}	4.50±0.38^{a}	5.43±0.12^{ab}	8.11±2.22^{b}	0.022
Dry matter (%)	95.77±1.27^{b}	95.50±0.38^{b}	94.57±0.12^{ab}	91.89±2.22^{a}	0.022
pH	4.50±0.03^{b}	4.38±0.02^{a}	4.54±0.01^{b}	4.41±0.03^{a}	<0.001
Histamine(mg/kg)	8.288±1.496	-	-	-	NA

Values are presented as mean ± standard deviation. One-way analysis of variance (ANOVA) followed by Tukey's post-hoc test was used to assess differences among groups. Different superscript letters indicate statistically significant differences between groups (p <0.05). Superscript letters do not imply a ranking order.

The highest overall acceptability score was observed in wheat flour tarhana (4.00 ± 0.50), followed by corn flour tarhana (3.56 ± 0.53). Sorghum flour tarhana (2.78 ± 0.67) received significantly lower scores compared to corn and wheat flour tarhana (p <0.05). No statistically significant differences were found among samples for texture, odor, and sourness parameters (p> 0.05) (Table 3).

Table 3. *Sensory analysis results of tarhana samples*

Parameters	N1 (Corn flour)	N2 (Wheat flour)	N3 (Sorghum flour)	N4 (Chickpea flour)	p
Texture	3.22 ± 0.97	4.33 ± 0.50	3.67 ± 1.12	3.67 ± 0.87	0.089
Color	4.56 ± 0.53^{ab}	4.67 ± 0.71^{b}	3.67 ± 1.12^{a}	4.11 ± 0.60^{ab}	0.038
Odor	4.22 ± 0.44	3.89 ± 0.93	3.22 ± 1.30	3.11 ± 1.17	0.078
Flavor	4.00 ± 0.71^{b}	4.11 ± 0.78^{b}	2.78 ± 0.83^{a}	3.22 ± 0.67^{ab}	0.001
Sourness	3.44 ± 1.01	4.22 ± 0.97	3.11 ± 1.05	3.11 ± 1.05	0.090
Homogenity	2.89 ± 1.05^{ab}	3.67 ± 1.12^{b}	2.33 ± 1.00^{a}	3.56 ± 0.88^{ab}	0.031
Overall acceptability	3.56 ± 0.53^{bc}	4.00 ± 0.50^{c}	2.78 ± 0.67^{a}	3.22 ± 0.67^{ab}	0.001

Values are presented as mean ± standard deviation. One-way analysis of variance (ANOVA) followed by Tukey's post-hoc test was used to assess differences among groups, and does not imply a ranking order. Different superscript letters indicate statistically significant differences between groups (p <0.05).

Wheat flour tarhana (N2) achieved higher scores in terms of texture, color, flavor, sourness, and overall acceptability. Corn flour tarhana (N1) showed moderate scores across most parameters and relatively higher values, particularly for odor and flavor. Sorghum flour tarhana (N3) exhibited the weakest sensory profile, receiving lower scores across most sensory attributes. Chickpea flour tarhana (N4) generally demonstrated a moderate sensory profile, showing a more balanced distribution, particularly for color and homogeneity, compared to corn and sorghum flour tarhana. The radar chart illustrates that wheat flour tarhana stands out in terms of overall sensory acceptability, whereas sorghum flour tarhana shows more limited sensory acceptance (Figure 1).

Sensory evaluation results showed that wheat flour tarhana stood out in terms of overall acceptability, whereas sorghum flour tarhana exhibited a weaker sensory profile. In fermented cereal-based products such as tarhana, sensory acceptance is closely related to the flour's pigment and phenolic composition, starch–protein matrix, particle structure, and aroma compounds formed during cooking (Kömürcü & Bilgiçli, 2022; Köse & Çağındı, 2002; Tuluk & Ertaş, 2019; Yalcin et al., 2008). Although substituting wheat flour with alternative cereal and legume flours has been reported to enhance the nutritional and functional value of tarhana, high substitution levels are often associated with declines in color, taste, and overall acceptability (Bilgiçli, 2009; Demir, 2018; Köse & Çağındı, 2002). In the present study, the amount of alternative flours added to the dough differed among formulations, which may have contributed to the observed sensory variations. In particular, the relatively higher substitution levels applied for sorghum and corn flours may have intensified their inherent phenolic content and characteristic flavor profile, potentially influencing panelists' perception of color and taste. Previous studies indicate that increasing substitution ratios of nonwheat flours may lead to darker coloration, altered texture, and reduced overall acceptability beyond certain thresholds (Bilgiçli, 2009; Demir, 2018). Therefore, the lower sensory scores observed for sorghum flour tarhana in this study may be partly associated not only with flour type but also with the level of substitution applied.

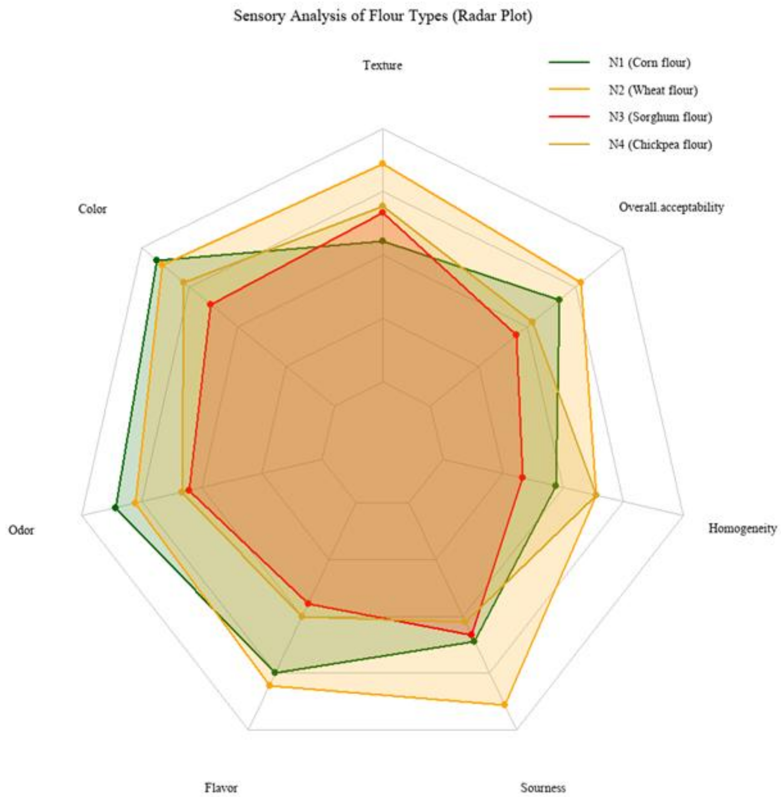

Figure 1. *Radar chart of sensory attributes of tarhana samples produced using different types of flour (N1: Corn flour, N2: Wheat flour, N3: Sorghum flour, N4: Chickpea flour).*

The acceptance of wheat flour as a "reference raw material" in tarhana production is largely attributed to its ability to provide familiar color, aroma, and mouthfeel characteristics for panelists. While the use of whole wheat flour, buckwheat, quinoa, and sorghum can enhance nutritional content, sensory acceptance may be limited due to darker coloration and distinct flavor profiles (Bilgiçli, 2009; Demir, 2014; Demir, 2018). One study reported that a 50% substitution level of whole wheat flour achieved an optimal balance between nutritional improvement and sensory acceptability. These findings support the interpretation that the lower sensory scores observed for sorghum flour tarhana in the present study may be associated with its high phenolic content and tendency toward darker coloration (Demir, 2018).

The moderate yet balanced sensory profile of corn-flour tarhana aligns with the relatively neutral flavor and light color of corn flour. Previous studies have reported that tarhana produced with alternative flours, such as corn and rice, may exhibit sensory acceptability comparable to that of control samples when appropriately formulated (Avcı et al., 2019; Yalcin et al., 2008). This suggests that corn flour may be considered a sensorially acceptable alternative raw material in tarhana production.

A major strength of this study lies in its comprehensive, comparative evaluation of histamine levels alongside physicochemical, microbiological, and sensory characteristics of tarhana produced with different cereal and legume flours. The preparation of all samples under identical production protocols and controlled conditions enabled the observed differences to be largely attributed to flour type.

Nevertheless, several limitations should be acknowledged. Histamine analysis was performed only on the final product, and time-dependent changes in histamine formation during fermentation were not monitored. Additionally, microbiological analyses were conducted at the level of total microbial groups, and no species- or gene-level analyses were performed to identify histamine-producing microorganisms. The use of a limited number of semi-trained panelists for sensory evaluation also represents a limitation. Future studies incorporating detailed monitoring of fermentation dynamics and molecular microbiological analyses would be valuable for further elucidating these findings.

Conclusion

In conclusion, this study demonstrates that the type of flour used in tarhana production plays a decisive role in microbial structure, pH dynamics, biogenic amine formation, and sensory acceptance. Histamine was detected only in tarhana produced with chickpea flour, indicating that flour type may influence histamine formation in fermented cereal-based products. Although the detected histamine level was relatively low, this finding suggests that tarhana formulations based on legume flours may require more careful consideration, particularly for individuals with histamine intolerance.

From a sensory perspective, wheat flour tarhana received the highest scores for consistency, color, taste, and overall acceptability, indicating that it remains the most favorable formulation in terms of consumer acceptance. In contrast, tarhana produced with sorghum flour exhibited lower sensory scores across most parameters, suggesting reduced acceptability when compared with the control sample.

While alternative cereal and legume flours have the potential to enhance the nutritional and functional properties of tarhana, careful optimization of substitution levels and processing conditions, as well as attention to raw material selection, is required to ensure product safety and sensory acceptability.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgement

This study was supported by TÜBİTAK 2209-A University Students Research Projects Support Program (Project No: 1919B012472978).

Author Contributions

Study design: EA, RK, YZÇ; Data collection: EA, RK, YZÇ; Data analysis: EA, RK, BİOK; Manuscript drafting: EA; Critical revision: EA, BİOK; Final approval: EA, RK, YZÇ, BİOK.

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