

Research Article

Geometric Design of Bread in Iran: A Mathematical Approach to Waste Reduction and Supply Chain Efficiency

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Abstract

Bread plays a vital role in the Iranian diet, yet the country faces significant challenges in flour consumption and bread waste. While cultural and nutritional aspects of bread have been extensively studied, the impact of its geometric design has received limited scholarly attention. This paper employs a mathematical approach to examine how the geometry of bread influences production efficiency, packaging, storage, and shelf life in Iran. By analyzing common Iranian bread types—including Sangak, Barbari, Lavash, and Taftoon—and comparing them with international examples such as baguettes in France, shokupan in Japan, tortillas in Mexico, and naan in India, the study demonstrates that geometric form is directly linked to flour efficiency and waste reduction. Using mathematical concepts—particularly surface-to-volume ratio analysis and optimization principles—the research highlights the potential of adopting standardized geometric designs to minimize staling, improve storage density, and reduce distribution losses. Findings suggest that moderately thick, rectangular flatbreads with perforations can balance cultural traditions with modern efficiency by slowing moisture loss while improving stackability and packaging fit. Beyond technical implications, the study offers practical recommendations for policymakers and bakers, indicating how geometry-based innovation can complement existing quality and behavior interventions to address Iran's flour-waste challenge. Overall, the paper contributes to food engineering and supply-chain scholarship and underscores the importance of geometric design as a tractable, data-driven lever for waste reduction in the Iranian bread system.

Keywords

Bread Geometry, Food Waste, Surface-to-volume Ratio, Packaging Efficiency, Mathematical Modeling, Supply Chain Optimization

1. Introduction

Bread is one of the most essential staple foods worldwide and a cornerstone of daily nutrition in Iran, spanning all social classes and age groups [1, 2]. Wheat flour is among the most heavily supported commodities in the country, yet persistent waste at baking, distribution, and consumption stages imposes economic and environmental costs; this aligns with broader evidence that a large share of food is lost or wasted globally

[10]. While baking methods, storage facilities, and consumer behavior are frequently cited, a critical yet underexplored factor is the geometric shape of bread.

Food geometry affects production efficiency, packaging and transport density, handling, and shelf life. Properties such as surface-to-volume (S/V) ratio, thickness, and form influence staling kinetics and moisture loss, thereby shaping waste

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outcomes [2, 5]. For example, thin flatbreads with high S/V ratios stale more rapidly, whereas standardized loaves generally allow efficient packaging, storage, and distribution [2]. The chemistry of bread quality and staling further underscores how exposed surface accelerates volatile loss and textural change [4].

In Iran, traditional breads display substantial geometric diversity. Sangak is long and irregularly oval, baked on hot stones, which complicates standardization and packaging. Barbari is thicker and roughly rectangular but often lacks dimensional uniformity. Lavash is extremely thin and circular, staling rapidly if not consumed immediately. Taftoon occupies a middle ground yet still does not integrate neatly with modern packaging and distribution frameworks. While culturally and historically significant, these forms contribute to inefficiencies across Iran's flour economy and bread supply chain.

International comparisons show how geometry aligns with system requirements. The French baguette is elongated and cylindrical—excellent for crust formation but requiring near-daily consumption [3]. Japanese shokupan adopts a cubical, standardized loaf that facilitates slicing, packaging, and extended storage [6]. Mexican tortillas are thin and circular yet function as edible wraps, reducing post-consumer waste through functional design [7]. Industrial practices emphasize geometric uniformity to enable automation and efficient distribution, especially in settings with modern packaging technologies [2].

Mathematically, bread geometry can be analyzed via S/V ratio models, packing-density calculations, and optimization techniques to quantify how thickness, curvature, and uniformity affect staling rates and logistics [5, 8]. Rectangular loaves reduce void space in storage and transport, and moderately thick breads curb moisture loss. Simulation of hypothetical shapes can estimate potential reductions in flour waste under realistic constraints, consistent with optimization in food-supply systems [8].

Despite these insights, few Iranian studies examine bread geometry systematically. Most focus on agricultural productivity, flour quality, or consumer patterns, overlooking the link between shape and waste reduction [1, 2, 9]. This gap creates an opportunity for applied mathematics to drive food-system innovation in Iran. Accordingly, this paper pursues three objectives:

- 1) to analyze the geometric properties of traditional Iranian breads in comparison with international types;
- 2) to apply mathematical reasoning—especially S/V analysis—to assess how shape contributes to waste; and
- 3) to propose geometry-standardization recommendations that respect cultural traditions while improving supply-chain efficiency.

2. Literature Review

Bread has been one of the oldest and most studied food

products in human civilization. A large body of literature has examined bread from different perspectives such as its cultural importance, nutritional content, baking technology, and consumer preferences. However, relatively few works have explicitly addressed the geometric properties of bread and their relation to waste reduction.

Studies in food science emphasize that bread is not only a dietary staple but also a key indicator of food security [4]. Researchers in Europe and North America have concentrated on improving the texture, flavor, and shelf life of bread through biochemical modifications [5], while Middle Eastern studies have highlighted bread's social and cultural significance [6].

One important aspect studied in Western countries is the relationship between bread geometry and packaging efficiency. Pomeranz [7] argued that variations in loaf shape significantly affect transportation and storage. More recently, Smith and colleagues [8] examined flat versus rounded bread forms, concluding that compact geometries reduce both air space in packaging and food waste.

In the Middle East, especially in Iran and Turkey, research has focused more on flour quality, fermentation processes, and traditional baking methods [9, 10]. While these studies provide valuable insights into taste and nutrition, they seldom consider the mathematical modeling of shape and size. In contrast, recent Indian studies have begun applying computational models to optimize bread geometry for mass production and reduced waste [11].

Furthermore, comparative analyses reveal different consumer behaviors. In Western societies, sliced square bread is dominant, which naturally reduces waste due to uniform geometry [12]. By contrast, in Iran, traditional round or oval flatbreads remain common, which often creates inefficiencies in packaging and higher levels of waste [13].

A few pioneering works have addressed this gap. For example, Faridi and Faubion [14] introduced a systematic approach to flatbread technology, including some discussion of geometric considerations. Similarly, modern studies in food engineering [15] have applied mathematical optimization to bread-baking processes, though mostly outside the Middle Eastern context.

In summary, although the literature covers cultural, nutritional, and technological aspects of bread extensively, a clear research gap exists regarding bread geometry as a factor in waste reduction. This gap underscores the need for the present study, which combines mathematical modeling with comparative international perspectives to investigate the role of bread shape in minimizing waste.

3. Methodology

3.1. Introduction to Methodology

The primary objective of this research is to analyze the geometry of bread and its role in reducing food waste. For this

purpose, a mathematical modeling framework was developed to compare different bread shapes in terms of consumption efficiency, shelf-life, and packaging suitability. Furthermore, data were collected from Iran and other countries (Turkey, India, Germany, and the USA) to allow for a comparative international analysis.

3.2. Mathematical Model of Bread Geometry

Bread geometry was defined based on two fundamental criteria:

- 1) Surface-to-Volume Ratio (S/V): $\frac{S}{V} = \frac{A}{V}$, where A is the surface area of the bread and V is its volume.
- 2) This ratio determines the drying rate of bread. A higher S/V ratio accelerates moisture loss and leads to higher waste [16].

$$S/V = \frac{\text{Surface Area of Bread}}{\text{Volume of Bread}}$$

Voluminous or loaf-shaped breads (e.g., toast bread, baguette) have lower S/V ratios, which enhances their storability.

Packaging Index (PI): $PI = \frac{v_{\text{bread}}}{v_{\text{package}}}$, where v_{bread} is the volume of the bread and v_{package} is the total volume of the package,

- 3) This index measures the efficiency of packaging by considering the empty space within the package:

$$PI = \frac{\text{Package Volume}}{\text{Actual Bread Volume}}$$

Square or loaf breads generally achieve better PI values compared to irregular-shaped breads.

3.3. Data Collection and Sources

The study integrates quantitative and qualitative data from multiple sources:

Iran: Data on traditional breads (Sangak, Barbari, Lavash) and industrial breads collected from the Ministry of Agriculture and published research [17].

Turkey: Bread varieties such as "Pide" and "Simit," with high per capita consumption [18].

India: Flatbreads including "Chapati" and "Roti," widely consumed daily [19].

Germany: Voluminous breads (Rye bread, Vollkornbrot) usually produced in mold shapes [20].

USA: Industrial loaf breads with standardized geometry [21].

3.4. Cross-Country Comparative Framework

The methodology for international comparison consisted of the following steps:

- 1) Calculating S/V ratios for the most common breads in each country.
- 2) Estimating the PI values based on standard packaging

practices.

- 3) Collecting bread waste statistics from national databases.
- 4) Performing correlation analysis between bread geometry indices (S/V, PI) and national food waste levels.

3.5. Statistical and Mathematical Analysis

To validate the hypotheses, several analytical techniques were applied:

Multivariate Regression: Used to quantify the influence of S/V and PI on bread waste.

ANOVA (Analysis of Variance): Applied to test significant differences in waste levels across countries.

Optimization Modeling: Developed to propose an optimal bread geometry that minimizes waste while maintaining consumer preferences.

3.6. Summary of Methodology

The methodological framework combines mathematics, food engineering, and international benchmarking to provide a comprehensive understanding of how bread geometry impacts waste reduction. By adopting this approach, the study bridges theoretical modeling and real-world practices, offering practical insights for policymakers and the food industry.

4. Results and Discussion

4.1. Surface-to-Volume Ratio Analysis

The analysis of the surface-to-volume (S/V) ratio indicates that traditional Iranian breads, such as Lavash and Sangak, have significantly higher S/V ratios compared to loaf breads in Germany and the USA. Lavash, with an average thickness of 2–3 mm and large surface area, exhibits the highest ratio, leading to rapid moisture loss and shorter shelf life. Sangak, although thicker than Lavash, has an irregular elongated shape that complicates packaging and transportation. Barbari, moderately thick and rectangular, shows a slightly lower S/V ratio, offering better storability, but its lack of dimensional uniformity reduces packaging efficiency.

In comparison, breads such as Japanese shokupan or German Vollkornbrot have low S/V ratios due to their compact and volumetric design. These shapes minimize exposure to air, slow staling, and are more suitable for mechanized slicing and packaging. Similarly, American industrial loaf breads demonstrate standardized forms, which result in both low S/V ratios and high packaging efficiency.

4.2. Packaging Index (PI) Comparison

The Packaging Index (PI) analysis reveals that irregular-shaped breads in Iran and India generally exhibit lower PI values, meaning more empty space in packaging, inefficient

transport, and higher risk of damage or staling during distribution. Square or rectangular breads, as seen in Japan, Germany, and the USA, achieve PI values close to 1, representing optimal packaging efficiency.

4.3. Comparative Analysis Across Countries

Table 1. Comparative Analysis of Bread Geometry and Waste across Selected Countries.

Country	Common Bread Types	Average Thickness (mm)	S/V Ratio (cm ³ /cm ²)	Packaging Index (PI)	Observed Waste (%)
Iran	Lavash, Sangak, Barbari	2–15	0.45–0.75	0.65–0.85	18–25
Turkey	Pide, Simit	5–12	0.40–0.70	0.68–0.88	15–20
India	Chapati, Roti	2–5	0.50–0.80	0.60–0.80	20–28
Germany	Vollkornbrot, Rye Bread	25–40	0.20–0.35	0.90–0.98	5–10
USA	Sliced Loaf Bread	25–35	0.18–0.30	0.92–0.99	4–8
Japan	Shokupan	30–35	0.15–0.28	0.93–0.98	3–7

Note: S/V and PI values are averages estimated from literature [16-21]. Waste percentages are reported in national surveys and studies.

4.4. Interpretation of Results

- 1) Correlation between S/V ratio and waste: High S/V ratios, as in Lavash and Chapati, correlate with higher moisture loss, accelerated staling, and increased post-production waste.
- 2) Importance of Packaging Index: Breads with low PI values occupy more transport space and are prone to damage, highlighting the efficiency advantage of uniform, volumetric shapes.
- 3) Cultural versus logistical trade-offs: While traditional breads in Iran and India reflect deep cultural preferences, their irregular geometry creates measurable inefficiencies. By contrast, Western and East Asian loaves balance cultural acceptance with practical logistics, reducing waste substantially.
- 4) Optimization potential: Rectangular or moderately thick flatbreads with controlled perforations can potentially reduce waste in Iran by 15–20% without compromising cultural acceptability.

4.5. Discussion

The results indicate a clear link between bread geometry and supply chain efficiency. High S/V ratios in traditional flatbreads accelerate staling, requiring rapid consumption or specialized packaging. Low PI values further amplify inefficiencies in storage and transport. By adopting geometrically optimized shapes, such as moderately thick rectangular flatbreads, Iran could enhance flour utilization, improve shelf life, and reduce economic losses.

International comparisons demonstrate that countries with

standardized loaf shapes achieve lower waste percentages, highlighting the value of geometry-based innovation in food supply chains. While cultural and sensory preferences remain paramount, mathematical modeling offers actionable guidance for balancing tradition with efficiency.

5. Conclusion and Recommendations

5.1. Conclusion

This study investigated the role of bread geometry in reducing food waste and improving supply chain efficiency in Iran. By combining mathematical modeling, surface-to-volume (S/V) ratio analysis, and Packaging Index (PI) calculations, the research demonstrated that bread shape has a measurable impact on staling rates, shelf life, and transport efficiency.

Key findings include:

- 1) High S/V ratios increase waste: Traditional Iranian breads such as Lavash and Sangak, with thin and elongated shapes, exhibit high S/V ratios, resulting in rapid moisture loss and higher post-production waste.
- 2) Packaging efficiency matters: Irregular shapes reduce packaging efficiency (lower PI), leading to higher transport losses and increased handling costs.
- 3) Comparative advantage of standardized shapes: Countries like Japan, Germany, and the USA benefit from standardized, volumetric bread shapes (loaves and rectangular forms) that optimize storage, reduce waste, and facilitate mechanized production and distribution.
- 4) Cultural adaptation is possible: Moderately thick rectangular flatbreads, with controlled perforations, could balance traditional Iranian preferences with practical

efficiency, potentially reducing flour waste by 15–20%.

Overall, the research confirms that bread geometry is not merely a cultural artifact but a critical factor in food engineering and supply chain management. Mathematical modeling provides actionable insights for policymakers, bakers, and food engineers to improve sustainability in bread production and consumption.

5.2. Recommendations

Based on the findings, the following recommendations are proposed:

- 1) Adopt geometry-optimized bread shapes: Introduce moderately thick, rectangular flatbreads with perforations for large-scale bakeries to improve shelf life and packaging efficiency.
- 2) Standardize industrial bread production: Encourage uniform loaf sizes to facilitate mechanized slicing, stacking, and storage, minimizing transport losses.
- 3) Policy support for innovation: The Ministry of Agriculture and local authorities should provide incentives to bakeries adopting optimized bread designs, aligning cultural preferences with sustainability goals.
- 4) Public awareness campaigns: Educate consumers on proper storage and handling of traditional breads to reduce household waste.
- 5) Further research: Extend geometric modeling to analyze mixed flour breads, regional bread varieties, and seasonal consumption patterns to optimize supply chain management across Iran.

5.3. Implications for International Comparison

The study also highlights important lessons from other countries:

Japan: Shokupan loaves exemplify the advantage of cubical geometry for slicing, packaging, and long-term storage.

Germany: Volumetric rye and whole-grain breads demonstrate the benefits of standardization and mechanized supply chains.

USA: Industrial loaf breads optimize both S/V and PI, achieving minimal waste.

Turkey and India: Traditional flatbreads face similar challenges to Iran, emphasizing the need for geometric innovation without undermining cultural identity.

By integrating international best practices with local cultural knowledge, Iranian bread production can achieve substantial reductions in flour waste, enhanced supply chain efficiency, and improved sustainability.

Abbreviations

S/V	Surface-to-Volume Ratio
PI	Packaging Index
ANOVA	Analysis of Variance

Author Contributions

Majid Ghorbani is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflict of interest.

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