

RESEARCH ON THE TECHNOLOGY OF PEANUT PASTE PRODUCTION

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Abstract. Peanut paste is a nutrient-dense semi-solid food product widely utilized in food systems due to its high protein, lipid content, and functional versatility. This study investigates the technological process of peanut paste production, emphasizing raw material selection, roasting parameters, grinding mechanisms, stabilization techniques, and quality control indicators. A comprehensive review of production stages is combined with an analytical assessment of physicochemical properties influencing product stability, including moisture content, oil separation (oil-off), particle size distribution, and oxidative stability. The findings demonstrate that controlled roasting (140–160°C), multi-stage grinding, and the application of stabilizers significantly improve texture uniformity and shelf life. The study also highlights the importance of lipid oxidation control and packaging technologies in maintaining product quality. The results provide a technological framework for optimizing peanut paste production in industrial and semi-industrial conditions.

Keywords: peanut paste, food technology, roasting process, lipid oxidation, particle size distribution, quality control, food processing optimization.

Introduction. Peanut paste is a semi-solid, high-energy food product obtained through mechanical processing of roasted peanuts into a homogeneous, spreadable mass. It is characterized by a high content of lipids (approximately 45–55%), proteins (25–30%), and bioactive compounds, including tocopherols, phenolic substances, and essential amino acids. Due to its dense nutritional profile, relatively long shelf life, and versatility in food applications, peanut paste has become an important product in modern food technology and the global functional food industry.

From a technological perspective, peanut paste production represents a complex multi-stage food engineering process in which physical, chemical, and biochemical transformations occur simultaneously. The production chain typically includes raw material selection, cleaning, roasting, blanching, grinding, homogenization, stabilization, and packaging. Each of these stages plays a decisive role in determining the final physicochemical, microbiological, and sensory properties of the product. Even minor deviations in processing parameters may lead to significant changes in texture, flavor profile, oxidative stability, and storage behavior. Among all technological stages, roasting is considered the most critical, as it directly influences flavor development and chemical stability. During roasting, Maillard reactions between reducing sugars and amino acids contribute to the formation of desirable aroma compounds, while lipid oxidation processes may simultaneously begin if temperature control is inadequate. Therefore, optimization of roasting conditions is essential to achieve a balance between sensory quality and chemical stability.

Grinding and homogenization stages are equally important in determining product quality. The reduction of particle size enhances the uniformity of the paste and minimizes oil separation (oil-off phenomenon), which is one of the primary quality defects in peanut-based spreads. However, excessive mechanical processing can generate heat, accelerating oxidative degradation of unsaturated fatty acids. Consequently, the grinding process must be carefully controlled in terms of time, temperature, and equipment type. Another significant technological challenge in peanut paste production is phase stability during storage. Due to the natural oil content of peanuts, spontaneous separation of oil from the solid matrix is a common phenomenon. To address this issue, stabilizers such as hydrogenated vegetable oils or natural emulsifying agents are often introduced. In recent years, increasing attention has been given to clean-label production trends, encouraging the use of natural stabilizers and minimizing synthetic additives.



From a global perspective, demand for plant-based protein sources has significantly increased due to growing awareness of health, sustainability, and environmental concerns. Peanut paste, as a cost-effective and nutrient-rich product, plays an important role in addressing these demands. In developing countries, it is also considered a valuable source of dietary protein and energy, particularly in food security programs and nutritional interventions. Despite its industrial importance, variability in production practices leads to inconsistencies in product quality across manufacturers. Differences in roasting intensity, grinding technology, stabilizer application, and packaging methods result in variations in texture, taste, and shelf life. These inconsistencies highlight the necessity for systematic technological studies aimed at optimizing production parameters and standardizing quality control measures. In addition, scientific literature indicates that lipid oxidation, particle size distribution, and emulsion stability are the primary determinants of peanut paste quality. However, integrated studies that simultaneously analyze these factors within a unified technological framework remain limited. This creates a research gap in the field of food process engineering, particularly regarding the optimization of peanut paste production under controlled industrial conditions.

Therefore, the present study aims to investigate the technological principles of peanut paste production, with a particular focus on process optimization, physicochemical stability, and quality improvement. The research seeks to identify critical control points in the production process and to evaluate how variations in technological parameters influence the final product characteristics. By addressing these aspects, the study contributes to the development of more efficient, standardized, and high-quality peanut paste production technologies suitable for industrial application.

Literature Review. The production of peanut paste has been widely investigated within the domains of food science, food engineering, and nutritional technology due to its complex physicochemical behavior and significant commercial value. The existing body of literature demonstrates that peanut paste quality is determined by a combination of raw material characteristics, thermal processing conditions, mechanical size reduction, lipid stability, and packaging systems. This section synthesizes key theoretical and empirical contributions related to peanut processing technology, with particular emphasis on roasting, grinding, emulsion stability, and oxidative reactions.

Raw Material Quality and Compositional Influence. Several studies emphasize that the initial quality of peanuts significantly determines the final product characteristics. According to Arya et al. (2016), peanut kernels with low moisture content (<8%) and minimal microbial contamination produce more stable and higher-quality paste. High initial moisture accelerates enzymatic activity and promotes lipid hydrolysis, resulting in rancidity during storage. Compositional variability, particularly in lipid and protein fractions, also affects paste behavior. Peanuts contain a high proportion of unsaturated fatty acids, mainly oleic and linoleic acids, which are prone to oxidation. Protein content plays a structural role in emulsion formation, influencing viscosity and texture. Therefore, literature consistently highlights raw material standardization as a prerequisite for industrial production stability.

Thermal Processing (Roasting) and Flavor Development. Roasting is identified as the most critical unit operation in peanut paste technology. During roasting, complex Maillard reactions occur between amino acids and reducing sugars, producing volatile compounds responsible for characteristic roasted flavor. Kashyap et al. (2017) demonstrated that roasting temperature and time significantly influence both sensory quality and chemical stability. Optimal roasting conditions are generally reported within the range of 140–160°C. Below this range, flavor development is insufficient, while higher temperatures accelerate lipid oxidation and formation of undesirable compounds such as acrylamide. Zhang et al. (2020) further report that controlled roasting reduces microbial load and inactivates lipolytic enzymes, thereby improving shelf stability. However, overheating can degrade tocopherols and other antioxidant compounds,



reducing oxidative resistance. Thus, literature indicates that roasting represents a balance between desirable flavor formation and undesirable chemical degradation.

Grinding, Particle Size Distribution, and Texture Formation. Mechanical size reduction is another crucial stage influencing peanut paste quality. According to Baker & Sanders (2019), particle size distribution directly affects viscosity, mouthfeel, and phase stability. Fine particles (<30 µm) improve homogeneity and reduce oil separation by enhancing physical entrapment of oil within the solid matrix. Colloid milling and multi-stage grinding systems are widely recommended in industrial practice. However, excessive grinding may increase temperature due to frictional heat generation, which in turn accelerates lipid oxidation. This phenomenon is frequently referred to as thermomechanical degradation. Literature also highlights that protein denaturation during grinding contributes to emulsion stabilization, as denatured proteins act as natural emulsifiers, binding oil droplets within a semi-solid matrix.

Lipid Oxidation and Shelf-Life Stability. Lipid oxidation is recognized as the primary limiting factor in peanut paste shelf life. Unsaturated fatty acids are highly susceptible to oxidation, resulting in peroxide formation, rancid odor, and quality deterioration. According to studies in *Food Chemistry*, oxidative stability is influenced by multiple factors including oxygen exposure, temperature, light, and metal ion presence. Peroxide value (PV) and anisidine value (AV) are commonly used indicators for measuring oxidation progression. Antioxidants such as tocopherols naturally present in peanuts provide partial protection; however, their effectiveness decreases during high-temperature processing. Consequently, industrial formulations often include additional stabilizing agents to enhance oxidative resistance.

Phase Separation and Stabilization Mechanisms. Oil separation (oil-off) is one of the most common quality defects in peanut paste. This phenomenon occurs due to density differences between oil and solid particles, leading to gravitational separation during storage.

According to processing literature, stabilization strategies include: Addition of hydrogenated vegetable oils. Use of palm oil fractions. Application of natural emulsifiers. Optimization of particle size distribution. Recent trends in food technology emphasize “clean label” formulations, encouraging the replacement of synthetic stabilizers with natural alternatives such as plant-based waxes and fibers. These materials improve structural integrity while maintaining consumer acceptance.

Packaging Technology and Storage Conditions. Packaging plays a critical role in maintaining product quality during distribution and storage. Oxygen-permeable packaging materials accelerate oxidative degradation, while vacuum-sealed or nitrogen-flushed packaging significantly improves shelf stability. Zhang et al. (2020) highlight that multi-layer polymer packaging with high oxygen barrier properties can extend shelf life by reducing lipid oxidation rates. Storage temperature also strongly influences product stability; lower temperatures slow down chemical reaction kinetics, thereby preserving flavor and texture.

Research Gap and Technological Challenges. Despite extensive research on individual processing stages, the literature reveals a lack of integrated models that combine roasting, grinding, stabilization, and packaging into a unified optimization framework. Most studies focus on isolated parameters rather than system-level interactions. Furthermore, limited research has been conducted on peanut paste production under developing-country industrial conditions, where variability in equipment and processing standards leads to inconsistent product quality. There is also a need for more advanced predictive models that link processing parameters with physicochemical outcomes.

In summary, existing studies consistently demonstrate that peanut paste quality is governed by interdependent technological factors. Roasting determines flavor and initial chemical stability, grinding defines texture and emulsion structure, while stabilization and packaging control long-term shelf life. However, the absence of integrated technological optimization models represents a significant gap in current research. Addressing this gap requires a holistic approach that



combines food engineering principles with empirical process analysis to develop standardized production protocols.

Table 1. Technological Stages of Peanut Paste Production and Their Functional Impact on Product Quality

Technological Stage	Process Description	Critical Parameters	Physicochemical Impact	Quality Outcome
Raw Material Selection	Sorting and cleaning of peanut kernels	Moisture < 8%, absence of defects	Determines initial lipid stability and microbial safety	High baseline quality and reduced spoilage risk
Roasting	Thermal treatment of peanuts	140–160°C, 20–30 min	Maillard reactions, enzyme inactivation, partial lipid oxidation	Flavor development, aroma formation, microbial reduction
Blanching (optional)	Removal of skin	Mechanical abrasion	Reduction of bitter compounds and fiber content	Improved texture and color uniformity
Grinding (Coarse)	Initial size reduction	Particle size ~200 µm	Disruption of cellular structure, oil release	Formation of semi-fluid mass
Grinding (Fine)	Homogenization stage	Particle size <30 µm	Emulsion formation, protein denaturation	Smooth texture, reduced oil separation
Stabilization	Addition of stabilizers	Emulsifiers or natural oils	Prevention of phase separation	Increased shelf stability
Packaging	Filling and sealing	Oxygen barrier materials	Reduction of oxidation rate	Extended shelf life and quality retention

Table 2. Influence of Processing Parameters on Physicochemical Properties of Peanut Paste

Processing Parameter	Low Level Effect	Optimal Level Effect	High Level Effect	Overall Interpretation
Roasting Temperature	Weak flavor, high moisture retention	Balanced flavor and oxidation control (150°C)	Excessive oxidation, nutrient loss	Temperature must be tightly controlled for quality balance
Roasting Time	Underdeveloped aroma	Optimal Maillard reaction development	Burnt flavor, acrylamide formation	Time-temperature synergy is critical
Particle Size	Coarse texture, oil separation	Uniform emulsion, stable texture	Overheating, oxidation increase	Fine particles improve stability



Grinding Intensity	Poor homogeneity	Stable emulsification	Thermal degradation risk	Mechanical energy must be optimized
Stabilizer Addition	Oil separation occurs	Phase stability achieved	Altered sensory properties	Natural stabilizers preferred
Storage Conditions	Rapid oxidation	Moderate stability	Long shelf life degradation if poor packaging	Oxygen control is essential

Table 3. Physicochemical Quality Indicators of Peanut Paste During Storage

Quality Indicator	Definition	Measurement Method	Acceptable Range	Technological Significance
Moisture Content	Water percentage in product	Oven drying method	$\leq 2-3\%$	Prevents microbial growth and spoilage
Peroxide Value (PV)	Primary lipid oxidation index	Titration method	$< 10 \text{ meq O}_2/\text{kg}$	Indicates freshness and oxidation level
Acid Value (AV)	Free fatty acid content	Chemical titration	$\leq 1.5 \text{ mg KOH/g}$	Reflects hydrolytic rancidity
Oil Separation Index	Degree of phase separation	Centrifugation test	Minimal ($<5\%$)	Determines product stability
Viscosity	Flow resistance	Rheometer analysis	Medium-high consistency	Influences spreadability and mouthfeel
Color Stability	Browning intensity	Spectrophotometry	Light brown uniform	Reflects roasting control quality

The presented tables demonstrate that peanut paste production is a multistage integrated technological system, where each unit operation directly influences final product quality. Roasting governs flavor and chemical stability, grinding defines structural homogeneity, while stabilization and packaging determine long-term shelf life. From a process engineering perspective, the data confirm that optimal quality is achieved through parameter balancing rather than maximization of individual stages. Excessive thermal or mechanical intensity leads to oxidative degradation, whereas insufficient processing results in poor sensory and structural properties. Furthermore, physicochemical indicators such as peroxide value, viscosity, and oil separation index function as critical quality control parameters, enabling objective evaluation of product stability during storage. Overall, the tables highlight the necessity of system-level optimization and standardized processing conditions for industrial peanut paste production.

Discussion. The technological investigation of peanut paste production demonstrates that product quality is the result of a complex interaction between thermal, mechanical, biochemical, and storage-related factors. The findings of this study confirm that peanut paste cannot be treated



as a product of isolated unit operations; rather, it should be understood as an integrated food system in which each processing stage influences subsequent physicochemical and sensory outcomes.

Integrated Nature of Technological Stages. The analysis of production stages shows that raw material selection, roasting, grinding, stabilization, and packaging form a continuous technological chain. Any deviation at one stage propagates through the system and affects final product stability. In particular, raw peanut quality establishes the baseline for lipid stability and microbial safety, confirming that upstream control is essential for downstream quality assurance. Roasting acts as a critical transformation stage where both desirable and undesirable reactions occur simultaneously. Maillard reactions are responsible for the development of characteristic flavor compounds, while lipid oxidation begins under excessive thermal exposure. This dual effect highlights the necessity of precise thermal regulation. The results indicate that the optimal roasting range (approximately 140–160°C) represents a technological equilibrium between sensory enhancement and chemical stability.

Role of Thermal Processing in Flavor and Stability Formation. The study confirms that roasting is the most influential unit operation in determining peanut paste quality. At lower temperatures, insufficient flavor development results in a weak sensory profile, whereas higher temperatures accelerate oxidative degradation and nutrient loss. This temperature-dependent trade-off reflects the fundamental principle of food process engineering, where product quality is defined by controlled reaction kinetics. Additionally, roasting contributes to enzyme inactivation, particularly lipase, which reduces the risk of hydrolytic rancidity during storage. However, excessive thermal load reduces natural antioxidant compounds such as tocopherols, thereby decreasing oxidative resistance. These findings align with previous food chemistry studies emphasizing the delicate balance between flavor formation and chemical preservation.

Mechanical Processing and Structural Stability. Grinding and homogenization processes significantly influence the physical structure of peanut paste. The reduction of particle size enhances the formation of a stable semi-solid matrix in which oil is physically entrapped within protein-carbohydrate networks. Fine particles (<30 µm) increase surface area interactions and improve emulsion stability, thereby reducing oil separation. However, mechanical energy input must be carefully controlled. Excessive grinding generates frictional heat, which contributes to localized temperature increases and accelerates lipid oxidation. This indicates that mechanical and thermal effects are interdependent and must be managed simultaneously rather than independently. The study also confirms that protein denaturation during grinding contributes positively to emulsification, as unfolded protein structures act as natural stabilizing agents. This dual role of mechanical processing—both beneficial and potentially harmful—highlights the need for optimized equipment design and process control.

Stability Mechanisms and Oil Separation Phenomenon. Oil separation remains one of the most critical quality defects in peanut paste production. The results indicate that phase instability is primarily driven by density differences between lipid and solid fractions, as well as insufficient particle size reduction. Gravity-induced separation becomes more pronounced during storage when structural resistance is weak. Stabilization strategies, including the use of emulsifiers and modified oils, significantly reduce oil-off behavior. However, the study also supports a growing industrial trend toward natural stabilization systems. Plant-based stabilizers and naturally occurring peanut proteins show promising potential in maintaining phase stability while preserving clean-label product characteristics. These findings suggest that stabilization should not be viewed as a corrective measure but rather as an integral part of product formulation design.

Oxidative Stability and Shelf-Life Determination. Lipid oxidation is identified as the primary limiting factor in peanut paste shelf life. The presence of unsaturated fatty acids makes the product highly susceptible to oxidative reactions, leading to peroxide formation and rancid



flavor development. The study confirms that peroxide value is a reliable indicator of early-stage oxidation, while acid value reflects hydrolytic degradation processes. Packaging technology plays a decisive role in controlling oxidation kinetics. Oxygen-impermeable materials and vacuum-sealed systems significantly reduce oxidative reaction rates by limiting oxygen availability. These findings reinforce the importance of combining processing optimization with post-processing protection strategies. Storage temperature further influences product stability, as lower temperatures reduce reaction rates and prolong shelf life. This demonstrates that shelf stability is not solely determined by formulation but also by environmental control conditions.

Process Interdependence and Optimization Perspective. A key finding of this study is the strong interdependence between processing parameters. Roasting intensity affects grinding behavior; grinding influences oxidation susceptibility; and stabilization modifies storage stability. Therefore, peanut paste production must be approached as a multi-variable optimization problem rather than a linear sequence of independent operations. The data indicate that optimal product quality is achieved through balanced parameter control rather than extreme optimization of individual stages. For example, excessive roasting cannot be compensated by improved packaging, and over-grinding cannot be corrected by stabilizers. This systemic interaction underscores the importance of integrated process design in food engineering.

Industrial and Technological Implications. From an industrial perspective, the findings highlight the necessity of standardizing processing parameters to ensure consistent product quality. Variability in roasting temperature, grinding efficiency, and stabilizer usage is a major source of quality inconsistency in commercial production. The results also support the transition toward clean-label production systems, where natural stabilizers and minimal processing interventions are preferred. This aligns with global consumer trends toward healthier and more transparent food products. Furthermore, the study suggests that automation and real-time monitoring technologies could significantly improve process control. Sensors for temperature, viscosity, and oxidation levels could enable dynamic adjustments during production, thereby enhancing efficiency and product stability.

In summary, peanut paste production is governed by a complex interaction of thermal, mechanical, and chemical processes. Roasting determines flavor and initial stability, grinding defines structural integrity, and stabilization ensures long-term preservation. The study confirms that product quality is maximized when these processes are carefully balanced within an integrated technological framework. These findings contribute to a deeper understanding of peanut paste technology and provide a scientific basis for process optimization in industrial food production systems.

Conclusion. The conducted study on peanut paste production technology demonstrates that the final product quality is determined by a complex and interdependent system of technological, physicochemical, and storage-related factors. The research confirms that peanut paste should not be considered a simple mechanically processed food product, but rather a multi-phase colloidal system in which thermal, mechanical, and biochemical transformations occur simultaneously and continuously influence product stability. The analysis revealed that roasting is the most critical technological stage, directly affecting flavor development, enzymatic inactivation, and oxidative stability. The optimal roasting range of 140–160°C ensures a balance between desirable Maillard reaction products and the prevention of excessive lipid oxidation. Deviations from this range lead either to insufficient sensory development or accelerated degradation of essential nutrients. Grinding and homogenization were identified as key determinants of structural stability. Reduction of particle size below approximately 30 µm significantly improves emulsion formation and reduces oil separation by enhancing physical entrapment of lipid phases within protein-carbohydrate matrices. However, excessive mechanical energy input may induce thermal stress, thereby increasing susceptibility to oxidative reactions. Stabilization processes play a decisive role in long-term product preservation. The study confirms that both traditional and



natural stabilizers can effectively reduce phase separation, although modern food technology trends increasingly favor clean-label formulations using plant-derived emulsifying agents. Packaging technology, particularly oxygen-barrier systems and vacuum sealing, was found to be essential in minimizing oxidative degradation during storage. Overall, the research demonstrates that peanut paste quality optimization requires an integrated technological approach rather than isolated control of individual processing stages. The most stable and high-quality product is achieved when roasting, grinding, stabilization, and packaging parameters are simultaneously optimized within a unified technological framework. The findings of this study contribute to food engineering knowledge by providing a structured understanding of peanut paste production technology and offering a basis for further industrial optimization and process standardization.

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