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Physical Analysis In Making Rowe Pakoda: A Case Study Of Sumba Local Food Wisdom

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ABSTRACT

This study aims to analyze the underlying physical principles of Rowe pakoda, a traditional snack from Sumba, using a case study approach grounded in local wisdom. A qualitative method was employed in this research, with data collected through participatory observation and in-depth interviews. The results indicate that the final quality of the product is significantly determined by the application of applied physics. The boiling process involves thermodynamic mechanisms, in which convective heat transfer and thermal hydration are the key drivers of starch gelatinization, resulting in a smooth texture and cohesion among the raw material components. Furthermore, fluid mechanics plays a role in analyzing the rheology of non-Newtonian dough, which regulates water absorption kinetics and product consistency stability. The findings validate that traditional Sumba cooking techniques are an intuitive and effective application of physical laws, providing a scientific contribution to the optimization of Indonesian archipelago cuisine. The novelty of this research lies in its systematic deconstruction of intuitive indigenous techniques into measurable scientific parameters, specifically by establishing a link between ancestral cooking methods and modern rheological models. This study moves beyond cultural documentation, providing a transformative framework that positions traditional Sumba cuisine as a precursor to contemporary food engineering and sustainable culinary optimization.

INTRODUCTION

Sumba Island in East Nusa Tenggara is known for its semi-arid environment (Kiha & Sirappa, 2025), which demands the development of a sustainable and adaptive food system. This geographic condition has given rise to a rich local wisdom in food processing (Kedan & Dei, 2025; Wiliyani et al., 2025), where empirical knowledge is passed down from generation to generation to maximize the nutrition and shelf life of local food ingredients (Violin et al., 2025), one of which is rowe pakoda. This snack, made from wax gourd leaves and fruit, dried, finely ground corn, cassava leaves, turmeric leaf shoots, and corn rice, has high nutritional and social significance, but what is most relevant to this study is the complexity of the physical transformations involved in its preparation. Rowe pakoda, which is processed through boiling, is a practical arena for the application of the principles of thermodynamics (convection heat transfer), fluid mechanics (control of non-Newtonian dough viscosity), and phase changes (evaporation of internal water to create a complete dough mix).

Rowe pakoda is a local food in Sumba that has been passed down from generation to generation from ancestors. Rowe pakoda is a high-nutrition snack made from various natural ingredients, such as smooth corn pau, corn rice, wax gourd leaves, and fruit. People in Sumba usually serve rowe pakoda as a staple food or as a snack. As an accompaniment to eating rowe pakoda, it is usually served with a chili sauce made from chilies, kaffir lime, basil leaves, and shallots, which are blended into a paste. The people of Sumba recognize rowe pakoda as one of the local foods they are very familiar with. However, not many have studied scientific concepts, such as physics, in the process of making rowe pakoda. This is reinforced by the still-limited empirical studies that specifically discuss the physics concepts in making this traditional Sumbanese food. Rowe pakoda has emerged as an essential traditional food, especially for the people of Sumba.

The process of making rowe pakoda remains traditional, as the Sumbanese people maintain their ancestral heritage, particularly in this practice. Although the effectiveness of this traditional method has stood the test of time, the intuitive knowledge underlying it remains poorly documented. Therefore, scientific analysis using a food physics approach is crucial, as the organoleptic quality, particularly the thickness and consistency of rowe pakoda, is determined by a series of complex physical principles during processing. The boiling process is a complex manifestation of the Laws of Thermodynamics that govern the interaction between the heating medium and the food matrix (Firmanto, 2024; Violin et al., 2025) where water functions as a thermal fluid that transfers heat energy through a convection mechanism to ensure uniform temperature distribution across the surface of the dough (Jamaluddin, 2018; Robbiet al.., 2024). Based on the First Law of Thermodynamics, the energy absorbed by the dough increases the enthalpy of the system, thus triggering a phase change of internal water through evaporation; although the temperature of the medium remains constant at its boiling point, the vapor pressure within the pores of the dough creates a pressure gradient that drives volume expansion as an essential phenomenon in the formation of a perfectly cooked microscopic structure (Ayustangningwarno et al., 2021; Jamaluddin, 2018).

Conductive heat penetration from the surface to the center of the dough further facilitates physicochemical transformations that are crucial for the homogeneity of the raw material, through simultaneous starch gelatinization and protein denaturation, during which intermolecular bonds are broken and rearranged into a cohesive polymer matrix (Fitriani et al., 2023). Thus, boiling acts as a thermodynamic workspace where heat and mass transfer collaborate to structurally unite raw materials at the molecular level (Jamaluddin, 2018), which ultimately creates phase stability and the final texture of the food product. In addition, fluid mechanics (Rheology) explains that the viscosity of dough, a non-Newtonian fluid, must be precisely controlled to minimize water absorption and ensure the product's structural integrity (Fathuroya et al., 2017; Sulaiman & El, 2012). Thus, this study aims to bridge the knowledge gap by translating Sumbanese local wisdom into scientific parameters, providing scientific validation, and laying the foundation for the standardization and optimization of this traditional food.

Rowe pakoda, one of Sumba's traditional foods, is a very interesting research object that deserves further in-depth study. This is because no applied physics analysis has examined the detailed processing of this traditional Sumbanese food. This research is crucial for providing scientifically recorded data on the physics concepts contained in Sumba's local food wisdom, namely the traditional Sumbanese food rowe pakoda. Without in-depth physics analysis, local wisdom that relies on empirical control of temperature and dough consistency cannot be translated into measurable and replicable scientific parameters. This research is highly urgent, viewed from the aspects of cultural conservation, food security, and local economic development. Culturally, the rowe pakoda processing method is an intangible heritage of knowledge threatened with extinction by modernization and migration. Without accurate scientific documentation, critical parameters that ensure product quality can be lost, leading to quality degradation and the loss of Sumba's local food identity. Technically, a deep understanding of Thermodynamics and Rheology in this process is key to standardizing Rowe Pakoda products. This standardization is vital for expanding market access (both national and international) and enabling product optimization to enhance nutritional value. This research is not merely academic, but also a strategic and urgent step to ensure the sustainability, competitiveness, and preservation of Sumba's local food wisdom amid changing times.

Therefore, the research problem formulation in this study is: how are the principles of thermodynamics, fluid mechanics, and material properties applied in the traditional Rowe Pakoda processing technique? Based on the problem formulation, the objective of this research activity is to identify, analyze, and validate the physics concepts involved in the preparation of Rowe pakoda, a local food of the Sumba community. This research offers crucial benefits by focusing on the validation and optimization of local wisdom food. Academically, this research fills the literature gap in the field of Food Physics by analyzing in depth how the principles of Thermodynamics and Rheology affect the viscosity and consistency of rowe pakoda. Practically and culturally, these findings provide a scientific basis for standardizing product quality, which is important for the conservation of Sumba's culinary heritage. This standardization supports efforts to improve process efficiency and increase the competitiveness of local microenterprises in the wider market, while strengthening Sumba's cultural identity through a scientific lens.

METHOD

This research employed a qualitative-exploratory case study design to examine the correlation between traditional culinary practices and the principles of applied physics. The study was conducted from September to November 2025 within an indigenous community on Sumba Island that preserves the authentic production of Rowe Pakoda. By engaging five expert artisans as key informants, data were gathered through participant observation and in-depth interviews to identify critical technical variables, such as material ratios, thermal control, and dough viscosity characteristics. Data validity was ensured through source and method triangulation, synthesizing field observations with physics literature to mitigate subjective bias. Finally, the data were analyzed thematically to transform intuitive local wisdom into a measurable scientific framework, specifically focusing on thermodynamics, fluid mechanics, and phase transitions.

RESULT AND DISCUSSION

1. Description of the Rowe Pakoda Processing Process

Rowe pakoda, a traditional Sumbanese food, is a familiar snack for the people of Sumba. This research was conducted through observations and in-depth interviews with residents in one of the traditional villages in Karuni Village regarding the process of making rowe pakoda. The results of the observations and interviews with the research subjects revealed that the process of making rowe pakoda is very simple and uses various natural ingredients from the surrounding yard or local agricultural produce. Images of the natural ingredients used in making rowe pakoda are shown in Figure 1.

Figure 1. Natural Ingredients Used in Making Rowe Pakoda

The observations indicate that the process of making rowe pakoda is still done traditionally, with 3 (three) main stages: preparation of ingredients, mixing the dough, and boiling the ingredients. This rowe pakoda snack is made from turmeric and corn rice. In addition, it requires water for boiling and salt to add flavor to this rowe pakoda dish. The steps for making rowe pakoda, namely: (1) slice the leaves and fruit of the wax gourd in a slightly large size, slice the cassava leaves, and turmeric leaf shoots; (2) cook the corn rice first; (3) after the corn rice is half boiled, add the vegetables; (4) if the boiling water has reduced, add the corn pau and salt then stir until evenly distributed; (5) serve with raw chili sauce (grinding all the ingredients in the form of chilies, basil leaves, shallots then adding kaffir lime juice). A picture of the rowe pakoda is shown in Figure 2 below.

Figure 2. Rowe Pakoda Sumba

1.1. Dough Properties and Consistency (Local Wisdom in Rheology)

Local wisdom plays a key role in this stage, where traditional practitioners determine the consistency of the dough based solely on visual and tactile experience (Bangun et al., 2023). Mixing various ingredients during boiling produces a rowe pakoda dough that is not too runny. The results of the rheological aspect study obtained that the dough from rowe pakoda is categorized as a high-viscosity non-Newtonian fluid, where the control of shear stress (shear stress) is a critical parameter in maintaining the structural stability of the product during the thermal process (Rao, 2014; Steffe, 1996).

1.2. Boiling Techniques and Temperature Control

Boiling is done using traditional clay pots and wood stoves, with the artisans empirically controlling the heat. The temperature indicators used are the point and speed of bubbles that appear when the material is immersed in water. This intuitively set temperature ensures a smooth boiling process. Heat control determines the boiling phase, which in turn affects the kinetic energy of the water molecules. Related concepts: roiling boil (100°C) is used to boil starchy materials, ensuring that the kinetic energy is sufficient to stimulate starch gelatinization across the entire surface of the material (Rahman, 2018).

2. Physical Analysis of the Mixing Stage (Fluid Mechanics)

The mixing stage of the dough is a direct application of the principles of Fluid Mechanics and Rheology.

Viscosity of Non-Newtonian Dough

The viscosity of rowe pakoda dough is a physical parameter that determines the product's quality. This is because the dough is a suspension of solid particles (wax gourd leaves and fruit, dried fine corn, cassava leaves, turmeric leaf shoots, and corn rice) in a liquid medium (water), and it exhibits non-Newtonian behavior (shear-thinning or pseudoplastic). Optimal dough viscosity, determined empirically by the artisan, is crucial for structural integrity. High viscosity is necessary for the dough to retain its shape when placed in hot water (Gu et al., 2023; Sarkhel et al., 2025).

The water absorption process in making rowe pakoda is, of course, closely related to the viscosity indicator. Too low a viscosity will increase the effective surface area, potentially leading to excessive water absorption after boiling (Adio et al., 2025; Ates et al., 2025). Thus, the craftsman's ability to determine the precise ratio of ingredients is a form of intuitive rheological control that minimizes lipid absorption while ensuring a firm texture. The thermal process in this study integrates ethnoscience principles by using non-digital materials with specific functional characteristics. The use of clay vessels (clay-based vessels) and biomass fuel (wood) acts as a passive temperature control system (Akpomie et al., 2025; Buzzer-Saffron et al., 2025). Clay acts as an efficient heat insulator with low thermal effusivity (Akpomie et al., 2025), thereby maintaining consistent internal temperature stability compared to metal materials. Heat control is carried out empirically by craftsmen through visual observation of nucleation. The temperature indicator is determined based on bubble kinetics (bubble dynamics) that form when a dough sample is placed in a heating medium. Physically, the rate of formation and frequency of bubble release represent the rate of convective heat transfer that occurs on the surface of the material (Bruwono & Pranoto, 2024).

Precise high temperatures cause the surface moisture to evaporate instantly, creating a gelatinized layer. The gelatinized layer is a viscoelastic matrix formed by the thermal hydration of starch granules (Marseno et al., 2023), in which the penetration of water molecules triggers the breaking of hydrogen bonds and the release of amylose (leaching) (Kusweni et al., 2024). This phenomenon creates a physical barrier (physical barrier) which regulates the diffusion of water into the interior of the material and maintains structural integrity by minimizing the dissolution of solids into the boiling medium. This shows that the empirical standardization applied by artisans has a linear relationship with the principles of mass and energy transfer in modern food processing techniques, enabling the production of the final product with maximum organoleptic characteristics and maturity.

3. Physical Analysis of Boiling Stage (Thermodynamics and Phase Changes)

The boiling stage in the process of making rowe pakoda is an open thermodynamic system that involves heat transfer by convection and conduction, as well as mass transfer through evaporation. The use of clay pots provides advantages in thermal stability; ceramic materials have lower thermal conductivity than metals but a higher specific heat capacity, so they are able to distribute heat isothermally throughout the dough. Empirical heat control, carried out by craftsmen through observation of bubble kinetics, is a means of identifying local boiling points and heat flux intensity. Physically, the speed of bubble emergence when the dough is dipped indicates that the system has reached the nucleate boiling phase, where the kinetic energy of water molecules is high enough to overcome atmospheric pressure, and there is a phase change to vapor at the nucleation points on the surface of the dough (Waziiroh et al., 2023). The process of boiling the rowe pakoda is shown in Figure 3.

Figure 3. Rowe Pakoda Boiling Process

The phenomenon in the boiling process of rowe pakoda is closely related to achieving a high convective heat transfer rate to trigger instant starch gelatinization. This intuitively determined boiling temperature forms a gelatinized matrix on the dough surface, which mechanically acts as a physical barrier (Hendrasty & Santoso, 2024) to minimize the dissolution of solids (solid leaching) and maintain the structural integrity of the dough matrix during the thermal process. The instantaneous phase transformation of water to steam at the surface creates a uniform pore structure, ensuring maximum maturity by enabling conductive heat diffusion to the core without damaging the material's molecular structure. Thus, synchronizing the furnace temperature with the bubbles' visual response is a form of thermodynamic parameter optimization to achieve consistent thermal efficiency and organoleptic quality of the product. The local wisdom in making rowe pakoda is a form of ethnoscience, in which the craftsman's intuition indirectly applies the laws of thermodynamics. The use of clay pots and wood stoves reflects a deep understanding of specific heat capacity and emissivity. Clay has microscopic pores that help regulate vapor pressure, while its low thermal conductivity ensures heat is retained longer and released slowly (in steady state), creating temperature stability that is difficult to achieve with conductive metal vessels.

Simultaneous initiation of starch gelatinization at the material's surface creates a cohesive, viscoelastic matrix, ensuring a conductive distribution of thermal energy to the core without triggering molecular structural disintegration. Thus, synchronizing the furnace heat intensity and the visual response to fluid turbulence (boiling bubbles) is a form of thermodynamic parameter optimization to achieve thermal efficiency and consistent organoleptic quality of the product. This relates to the First Law of Thermodynamics, where heat energy from the furnace is converted into internal energy to break the bonds in water molecules (latent heat of vaporization). Mechanically, the boiling temperature, determined by the artisan's sensory estimation, is set to create an internal vapor-pressure gradient. When the dough interacts with the hot aqueous medium, instant thermal hydration occurs, followed by the expansion of water vapor from within the matrix. This outward vapor pressure kinetically inhibits the penetration of excess water into the dough structure and prevents the dissolution of starch solids (solute leaching), a phenomenon which in food science is classified asbarrier masstransfer through the formation of a gelatinized matrix Thus, Sumbanese local wisdom in making rowe pakoda is a form of traditional technology optimization that accurately utilizes the principles of convective heat transfer and gas kinetics to produce superior food quality.

Overall, the results of this study demonstrate that the process of making rowe pakoda is a clear manifestation of the integration of local wisdom and scientific principles, particularly physics. The results of the analysis of thermodynamic and fluid-mechanical mechanisms indicate that the traditional techniques of the Sumbanese people are intuitively able to optimize starch gelatinization and the rheological stability of rowe pakoda dough through appropriate thermal control and hydration kinematics. These findings confirm that Indonesian culinary practices have a strong scientific basis, thereby providing opportunities to standardize and modernize traditional foods without diminishing their cultural value. The limitation of this study is that, for future research, further quantitative research is needed to precisely map temperature and viscosity parameters. In addition, the study concept can be used as an example in physics teaching by creating integrated teaching materials that include examples related to local wisdom, such as the process of making rowe pakoda.

CONCLUSION

This study shows that the process of making rowe pakoda is a manifestation of Sumbanese local wisdom that aligns with the principles of modern physics, particularly thermodynamics and mass transfer. The use of traditional media, such as a clay pot and a wood stove, is scientifically proven to maintain heat flux stability through their low thermal inertia and thermal effusivity, thereby creating a cooking environment that approaches isothermal conditions. Empirical temperature control by artisans through observation of bubble dynamics is an accurate nucleate boiling phase identification technique, in which the rate of convective heat transfer is optimized to achieve instant surface gelatinization, a crucial step for the structural integrity of the dough.

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