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ASSESSING THE ETHNOMATHEMATICAL VALUES OF *GUDEG JOGJA*: A QUALITATIVE INQUIRY INTO THREE-DIMENSIONAL SPATIAL DECOMPOSITION AND SEQUENTIAL PROGRAMMING

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ABSTRACT

This study aims to identify and analyze mathematical concepts embedded in the processing of Gudeg Yogyakarta through an ethnomathematical approach. The research employed a qualitative method with an educational ethnographic design. The research subjects consisted of traditional gudeg producers, besek craftsmen, and home-based gudeg industry practitioners in the Yogyakarta region, selected purposively. Data were collected through participant observation, in-depth interviews, and visual documentation to capture cultural practices and the underlying mathematical meanings. Data analysis was conducted descriptively and analytically through the stages of data reduction, data display, and conclusion drawing by transforming cultural activities into formal mathematical representations. The results indicate that the gudeg processing process contains various mathematical concepts, including three-dimensional and plane geometry in raw materials and packaging, fractions and ratios in ingredient measurements, sequences and series in the canning process, and algorithmic logic in deep cooking techniques. These findings confirm that Gudeg Yogyakarta has significant potential as a meaningful, contextual mathematics learning resource grounded in local wisdom.

Keywords: *Ethnomathematics, Gudeg Yogyakarta, contextual learning, local wisdom, school mathematics*

1. INTRODUCTION

Mathematics is frequently perceived by many students as an abstract, rigid discipline, detached from the realities of daily life [1], [2]. This perception arises because mathematics education in schools tends to focus on formal formulas and procedural methods. There is often little effort to link these concepts to the cultural roots in which students are raised. According to D'Ambrosio [3], mathematics is essentially a cultural product born from human efforts to explain, understand, and manage their environment. The gap between academic mathematics and the practical mathematics existing within society is what necessitates ethnomathematics as a bridge to integrate cultural values into formal mathematics learning, making it more meaningful and contextual [4], [5].

Indonesia, with its abundant cultural diversity, possesses immense ethnomathematical potential, particularly within the realm of traditional culinary arts. One cultural heritage rich in mathematical thinking is the process of making Gudeg Jogja. Yuliani et al. [6] and Vilarin [7] states that mathematical activities in local cultures often emerge implicitly through activities such as measuring, weighing, designing, and estimating without the use of formal symbols. In the context of Gudeg, the process from the selection of young jackfruit raw materials to the presentation techniques is a series of cognitive processes involving geometric logic and arithmetic that has been passed down through generations via oral tradition and direct practice.

The activity of cutting young jackfruit into small pieces to ensure seasonings are evenly absorbed serves as a tangible example of the decomposition of three-dimensional geometric shapes. Traditional communities intuitively understand that by transforming the shape of the jackfruit from a cylinder-like form into triangular prisms or small cubes, the total surface area of the ingredients increases significantly. This aligns with the principles of Rosa & Orey [8], who emphasize that every cultural group develops unique ways to solve problems of space and time. Furthermore, the understanding of the volume capacity of the kendil (clay pot)

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and the packing density of the jackfruit within it demonstrates that local culinary wisdom has long adopted highly systematic mathematical logic before such concepts are taught in formal schooling.

Furthermore, the use of non-standard measurement units, such as sak gegem (a handful) or sajumput (a pinch), in determining spice compositions reflects a unique yet precise practice of social arithmetic. This phenomenon demonstrates an anatomical conversion of the human body into functional mathematical variables to maintain flavor stability. Additionally, the lengthy "deep cooking" process of Gudeg involves sequential algorithms and predictive logic regarding fluid evaporation rates. According to Gerdes [9], cultural activities such as weaving or cooking are not merely manual skills but contain complex algorithmic logic structures. A Gudeg cook must be able to calculate the shrinkage ratio of water volume relative to spice concentration to ensure a balanced final result an ability that involves calculating the rate of change of variables in its most applied form.

Despite the rich mathematical potential in the preparation of Gudeg, scientific exploration of this topic remains very limited. The lack of mathematical documentation regarding traditional culinary practices often causes this local wisdom to be dismissed as mere "habit" rather than recognized as an intellectual process. In fact, integrating the ethnomathematics of Gudeg into education, particularly through the Realistic Mathematics Education (RME) model, could serve as an innovative strategy to dismantle the stigma that mathematics is a difficult and foreign subject. Therefore, research into the ethnomathematical exploration of Gudeg Jogja is crucial to reconstruct mathematical values within local culture and to preserve traditional heritage through a modern scientific lens.

2. LITERATUR REVIEW

2.1. Ethnomathematics

Ethnomathematics serves as a vital interdisciplinary bridge between cultural anthropology and formal mathematics, providing a framework to examine how specific cultural groups utilize mathematical ideas to navigate and organize their daily lives. According to Rahmadani [10] , this concept transcends simple numerical calculation, encompassing a broad spectrum of "ticing" (techniques), "mathema" (explaining and understanding), and "ethno" (identifiable cultural groups). This includes the complex activities of measuring, classifying, and modeling natural phenomena that have been meticulously passed down through generations. By acknowledging that every culture possesses a unique logical framework, ethnomathematics effectively challenges the Eurocentric view of mathematics as a rigid, singular discipline. Instead, it redefines mathematics as a dynamic social product that evolves through human interaction with the environment, allowing for the recognition of intellectual rigor in traditional practices that were previously overlooked by formal academic structures [11], [12].

In the contemporary educational landscape, ethnomathematics has evolved into a strategic instrument for reality-based mathematics education, bridging the gap between abstract school curricula and students' lived experiences. Rosa and Orey [8], assert that the integration of ethnomathematical perspectives into the curriculum enables students to recognize mathematical concepts within their own social and historical contexts, which significantly enhances learning motivation and cognitive engagement. Identifying mathematical principles in local artifacts, culinary traditions, or architectural heritage is not merely an act of cultural preservation; it is a critical pedagogical effort to dismantle the perceived abstractions of school mathematics. By rooting mathematical problems in concrete experiences such as the geometric logic found in traditional crafts or the algorithmic structures of indigenous cooking educators can foster a more inclusive and relevant learning environment that empowers students to view themselves as mathematically capable within their own cultural identity [13].

2.2. Gudeg Jogja

Gudeg Jogja serves as a profound traditional culinary icon that encapsulates the philosophical and historical identity of the Yogyakarta community. Technically, this dish is prepared using young jackfruit (tewel) which undergoes an intensive processing cycle involving coconut milk, palm sugar, and a specific blend of aromatic spices, all simmered within a traditional clay vessel known as a kendil. This process transcends the boundaries of routine domestic labor; it is a meticulously preserved heritage procedure that demands extreme precision in temporal management and ingredient composition to achieve its characteristic authentic flavor profile. Academic literature focusing on Javanese gastronomy frequently identifies the "slow cooking" or deep-cooking methodology as the essential determinant of both its unique organoleptic qualities and its remarkable

shelf stability, reflecting an indigenous form of food preservation that relies on biochemical reactions over several hours [14].
From the perspective of cultural science and ethnomathematics, Gudeg represents a complex reservoir of indigenous knowledge and applied logic. The strategic arrangement of ingredients within the kendil often involving specific layering techniques and the deliberate selection of firewood types to control thermal intensity demonstrate a sophisticated, albeit informal, understanding of heat distribution and spatial efficiency. Risdiyanti [15] posits that such traditional culinary practices function as "unrecognized applied mathematics laboratories," where practitioners utilize mathematical logic to solve practical problems without formal notation. Consequently, Gudeg is increasingly recognized as a fertile object for scientific inquiry; every production stage, from the initial geometric decomposition of the jackfruit to the final volumetric presentation, harbors quantifiable mathematical variables that offer deep insights into the cognitive sophistication of local wisdom [16].

2.3. Geometry

Geometry within the ethnomathematical framework of Gudeg production is understood as the human capacity to organize space and form for functional, rather than merely aesthetic, purposes. This begins with the spatial decomposition of the young jackfruit, where its natural cylindrical volume is manually transformed into smaller, consistent polyhedral shapes, such as triangular prisms or cuboids. Mathematically, this transformation is a strategic application of increasing the surface-area-to-volume ratio; by reducing the volume of individual pieces while maintaining the total mass, the cumulative surface area exposed to the seasoning is maximized, thereby facilitating efficient flavor diffusion through cellular osmosis [17], [18], [19]. Beyond the ingredients, three-dimensional geometry is prominently displayed in the construction of the besek (woven bamboo container). The besek represents a sophisticated hexahedron structure that requires precise dimensional tolerance between the base and the lid to ensure a perfect interlocking fit, demonstrating an intuitive grasp of congruence and similarity in Euclidean geometry.

Furthermore, the utilization of the kendil (clay pot) introduces the concept of packing density and the management of geometric voids. Gudeg artisans must intuitively calculate the optimal arrangement of jackfruit prisms within the convex frustum of the vessel to ensure that the interstitial spaces allow for the uniform circulation of coconut milk and heat. This spatial reasoning extends to the use of banana leaves, which are manipulated from irregular biological planes into standard geometric figures such as circles for liners or complex folded triangles for pincuk packaging. These folding techniques often involve the precise bisection of angles and the identification of symmetry lines to maintain structural integrity under the weight of the contents. As Gerdes [9] notes, such geometric forms in traditional artifacts are the result of empirical experimentation aimed at structural strength and material efficiency, proving that geometry in this context is a vital technical solution rather than a theoretical abstraction.

2.4. Algorithms

In the realm of ethnomathematics, algorithms within traditional practices are defined as logical, consistent, and rigorous step-by-step procedures designed to achieve a specific, high-fidelity result [20]. In the production of Gudeg, these sequential algorithms are manifested through a strict "order of operations" regarding the introduction of spices and primary ingredients, which cannot be interchanged without compromising the final product. This procedural logic mirrors fundamental programming structures where inputs (raw materials), processes (thermodynamic heating), and temporal variables (duration) are managed within a coherent instruction set. If the sequence of these variables is altered for instance, by adding coconut milk before the jackfruit has reached a certain level of tenderness the resulting chemical reactions and the structural texture of the fruit fibers will fail to reach the established standards of authenticity. Consequently, the Gudeg maker functions as an intuitive programmer, executing a complex culinary script that ensures the stabilization of flavor and preservation through a precise, iterative workflow [21].

Furthermore, the sophisticated algorithm governing the cooking of Gudeg involves advanced predictive logic centered on time management and fluid dynamics, specifically regarding the rate of evaporation. During the "deep cooking" phase, which typically spans over twelve hours, the cook must act as a dynamic variable controller, calculating the constant rate of water volume reduction to prevent carbonization (burning) while simultaneously achieving the target level of dryness or "nyemek" consistency. This requires a profound understanding of inverse proportions: as the liquid volume decreases over time, the concentration of solutes such as palm sugar and salt increases, necessitating a projection of the final flavor profile hours before the process concludes. Literature on indigenous knowledge systems suggests that these informal algorithms are not merely trial and error, but are based on empirical observations refined over centuries into stable, reliable patterns [22], [23]. This indicates an advanced form of algorithmic thinking where human intuition serves as a substitute for formal sensors, managing a dynamic production system to ensure quality and consistency in every batch.

2.5. Local Wisdom

Local wisdom, scientifically referred to as indigenous knowledge, constitutes the original, localized intelligence of a specific community derived from noble values and empirical experiences passed down through collective generations. In Javanese culture, this wisdom is prominently manifested through the epistemological concept of tithen the refined ability to acutely mark, recognize, and predict patterns in natural and social phenomena through disciplined observation. In the production of Gudeg, tithen is operationalized to determine precise spice measurements without the aid of modern digital scales; instead, it utilizes standardized anatomical units such as gegem (a handful) or jumput (a pinch). This practice demonstrates that local wisdom is an intelligent and highly functional form of human adaptation, where the human body itself is converted into a reliable mathematical instrument for environmental management [24]. Such ethnomathematical techniques prove that traditional societies possess a systematic "common sense" that aligns with the principles of estimation theory and anatomical ratios [25].

Furthermore, local wisdom plays a pivotal role in preserving socio-economic and ecological values through the strategic use of sustainable materials, such as banana leaves for packaging and the clay kendil for thermal processing. This knowledge is not merely technical but deeply ethical, embodying a cultural appreciation for the "slow process" and the patience required to produce a culinary work of art a stark contrast to the rapid, homogenized production of modern industries. The integration of this indigenous wisdom into a scientific perspective through ethnomathematics provides essential intellectual recognition to traditional societies, challenging the marginalization of non-Western knowledge systems. By exploring these practices objectively, it becomes evident that culture is an inexhaustible source of sophisticated logic. Such findings reinforce the theory that traditional heritage, when viewed through a modern scientific lens, can contribute significantly to the broader understanding of applied mathematics and the philosophy of science [26].

3. METHODS

This study employs a qualitative approach with an educational ethnographic design integrated with ethnomathematical studies, aimed at identifying and analyzing mathematical concepts internalized within the processing of Yogyakarta's Gudeg. According to Nailalmarom et al. [27], ethnographic methods are essential for uncovering the shared knowledge of a cultural group and how they perceive their reality. The research subjects include traditional Gudeg makers, besek artisans, and home-based Gudeg industry actors in the Yogyakarta region, selected through purposive sampling based on their extensive experience and direct involvement in the production process [28]. The object of research is focused on cultural activities in Gudeg production that contain mathematical elements, including the processing of young jackfruit, spice measurements, the use of containers and packaging, the canning process, and deep-cooking techniques.

Data collection techniques are conducted through participant observation, in-depth interviews, and visual documentation including photographs, field notes, and process sketches. Observation is utilized to record actual practices and workflow sequences, while interviews are conducted to explore the meanings, underlying reasons, and mathematical intuitions of the practitioners. Documentation serves as supporting data to strengthen the validity of the findings [29], [30]. Following the framework of D'Ambrosio [31], these techniques allow the researcher to bridge the gap between "ethno" (the cultural context) and "mathema" (the way of explaining and understanding).

Data analysis is performed using a descriptive-analytical method, referring to the stages of data reduction, data display, and conclusion drawing/verification [32]. The empirical data obtained from cultural activities are subsequently transformed into formal mathematical representations, such as solid and plane geometry, fractions and ratios, sequences and series, and algorithmic logic. This process involves contextual interpretation by comparing cultural practices with relevant school mathematics concepts. To ensure data trustworthiness, this study implements technical and source triangulation, comparing results from observations, interviews, and documentation across different informants [33]. The results of the analysis are presented in the form of an ethnomathematical narrative, complete with contextual mathematical problems and discussions. Thus, the research findings not only reflect local cultural practices but also serve as an applicable, meaningful, and relevant mathematics learning resource for formal education.

4. RESULTS AND DISCUSSION

4.1. Results

4.1.1. Geometry of the Base Ingredient (Young Jackfruit)

The application of ethnomathematics in the processing of young jackfruit for Gudeg production begins with the observation of the whole fruit's physical form, which naturally resembles a prolate cylinder. Although its natural shape is imperfect, Gudeg makers intuitively grasp the concept of cylindrical volume when selecting fruit for use. This initial phase involves the estimation of mass and dimensions, where a larger jackfruit possessing a greater diameter and cylindrical height will yield a higher quantity of pieces for larger servings. This spatial understanding serves as a foundational prerequisite before the jackfruit is transformed through a meticulous manual cutting process.

Subsequently, the jackfruit is sliced into smaller, simpler segments, resembling triangular prisms or small cuboids. This process is not merely a random act of cutting; rather, it is a practical application of spatial decomposition designed to increase the surface-area-to-volume ratio. In mathematics, as a solid is divided into smaller units while maintaining the same total mass, the cumulative surface area increases significantly. This principle underlies the rationale for cutting the jackfruit into small pieces: to ensure that the coconut milk and palm sugar can diffuse evenly across the expanded surface area, allowing the flavors to penetrate deeply into the fibers of the jackfruit.

Thirdly, the use of traditional cooking vessels, such as the kendil (clay pot), demonstrates an interaction between two distinct geometric volumes. A kendil typically features a shape approximating a sphere or a convex frustum (truncated cone). Here, Gudeg makers apply the concept of packing density. They must estimate how many jackfruit prisms can be accommodated within the volume of the kendil. This intuition involves calculating the voids (empty spaces) between the pieces; if the pieces are too large, the voids become excessive, leading to inefficient volume utilization and poor spice distribution.

Lastly, this ethnomathematical aspect illustrates that traditional communities have practiced three-dimensional geometry for generations without relying on formal formulas. Measurements are conducted through sensory intuition and habit (tithen in Javanese), which are, in fact, the results of complex mathematical cognitive processes. The ability to predict the shrinkage of the jackfruit volume after hours of cooking also involves the logic of variable volume change due to thermal effects, combined with geometric understanding to ensure the final product fits the presentation capacity of the serving containers.

Implementation Example: Mathematical Problem

A Gudeg vendor has a young jackfruit in the shape of a cylinder with a diameter of 28 cm and a height of 40 cm. To accelerate the absorption of spices, the jackfruit is cut into small pieces in the shape of right-angled triangular prisms. Each prism has a base length of 3 cm, a base height of 4 cm, and a prism height (thickness) of 2 cm. If 10% of the total volume is discarded during the cutting process (such as the core or skin), how many small jackfruit pieces are produced?

Mathematical Solution:

1. Calculate Total Volume of the Jackfruit (V_j): Using the formula for the volume of a cylinder: $V = \pi r^2 h$
   - Radius (r) = 14 cm
   - $V_j = \frac{22}{7} . 14^2 . 40 = 24{,}640 \text{ cm}^3$
2. Calculate Net Volume after 10% Waste:
   - $\text{Net Volume} = 90\% . 24{,}640 = 22{,}176 \text{ cm}^3$
3. Calculate Volume of One Small Piece (Prism) (V_p): Using the formula for the volume of a triangular prism: $V_p = \left(\frac{1}{2} . \text{base} . \text{height}\right) . \text{prism height}$
   - $V_p = \left(\frac{1}{2} . 3 . 4\right) . 2 = 12 \text{cm}^3$
4. Calculate Total Number of Pieces (N):
   - $N = \frac{22{,}176}{12} = 1{,}848 \text{ pieces}$

4.1.2. Fractions and Ratios in Spice Measurements

The application of ethnomathematics in Gudeg seasoning reflects a profound use of ratios and proportions, despite the absence of modern measuring instruments. Traditional cooks rely on the correlation between the volume of coconut milk and the weight of the primary ingredients to achieve the perfect texture. For instance, there is an unwritten rule regarding the ratio of thick coconut milk (kanil) to thin coconut milk to ensure the young jackfruit is perfectly submerged while maintaining a final consistency that is either nyemek (semi-moist with a thick sauce) or dry. This ratio is strictly maintained through sensory experience to preserve the signature flavor profile of each specific Gudeg establishment.

Beyond fluid ratios, the concept of fractions is manifested in the use of non-standard units of measurement, such as sak gegem (a handful), seiris (a slice), or sajumput (a pinch). These units function as simplified fractions relative to the total volume of the dish. For example, the amount of palm sugar added is often determined by a color ratio; if a kendil full of jackfruit requires a deep dark brown hue, the ratio of palm sugar might reach one-fifth of the total weight of the ingredients. The use of hand-based measurements demonstrates a form of social arithmetic, where the community converts anatomical dimensions into functional mathematical variables to produce precise flavor standards.

During the cooking process, the balance between sweet, savory, and salty flavors is managed through the logic of inverse proportion. As the cooking time increases (resulting in the reduction of water volume), the concentration of the seasoning intensifies. Consequently, the cook must estimate the initial seasoning proportions by projecting the final volume after the liquid has evaporated. If a dominant sweet flavor is desired, the cook must calculate the ratio of palm sugar against the estimated volume of the jackfruit after a 12-hour deep cooking process, during which the ingredient volume typically shrinks to nearly half of its initial state. Finally, this concept of proportion is applied to other spices such as shallots, garlic, and candlenuts, which often follow a fixed ratio. The ability to scale seasoning without altering the original flavor profile provides clear evidence of linear transformation in the traditional culinary world, mastered self-taught through years of observation and practice.

Implementation Example: Mathematical Problem
A Gudeg maker follows a standard recipe: to process 2 kg of young jackfruit, 150 grams of palm sugar and 500 ml of thick coconut milk are required to achieve the correct flavor and color. If, for a special event, they must cook 12 kg of young jackfruit, calculate the following:

1. What is the total amount of palm sugar required based on direct proportion?
2. If the cook currently possesses only 1.5 liters of coconut milk, how many additional liters must be purchased?

Solution:
1. Calculating Palm Sugar:
   - Initial Ratio: 2 kg jackfruit : 150 g sugar
   - Scaling Factor: $\frac{12\text{ kg}}{2\text{ kg}} = 6$ kg
   - Sugar Required: 6 . 150 g = 900 g
   - Result: The total palm sugar required is 900 grams.
2. Calculating the Coconut Milk Deficit:
   - Initial Ratio: 2 kg jackfruit : 500 ml coconut milk
   - Total Milk Required: 6 . 500 ml = 3,000 ml (or 3 liters)
   - Current Inventory: 1.5 liters
   - Deficit: 3 liters − 1.5 liters = 1.5 liters
   - Result: The cook must purchase an additional 1.5 liters of coconut milk.

4.1.3. Plane Geometry in Packaging (Besek and Banana Leaves)

The use of besek (woven bamboo boxes) and banana leaves as containers for Gudeg is a tangible manifestation of plane and spatial geometry within Javanese culture. Structurally, a besek adopts the form of a hexahedron (cube or rectangular prism) consisting of two complementary parts: the base and the lid. Mathematically, the construction of a besek requires precise calculations during the bamboo weaving process to ensure the lid possesses a slightly larger dimension than the base (dimensional tolerance) so they can interlock perfectly. The square-based pattern of the besek serves as a geometric foundation for vendors to arrange Gudeg components in a compartmentalized manner [34].

Banana leaves, used either as liners for the besek or as independent traditional packaging (pincuk), involve the manipulation of irregular planes into standard geometric shapes. Before use, the leaves are often cut into circles to line the kendil or rectangles for the besek base. This transformation aims to maximize the surfacecovering efficiency of the container. The selection of a leaf diameter larger than the container's base is a practical application of surface area and circumference calculations, allowing the leaf edges to extend upward and cover the inner walls.

The most compelling ethnomathematical aspect is the concept of symmetry and angularity found in the folding techniques, particularly in creating a pincuk. To create a vessel capable of holding coconut milk gravy (areh) without leaking, the leaf is folded by precisely bisecting angles to create tight joints. These folds typically form lines of symmetry that divide the leaf into two congruent parts. The use of a small wooden pin (biting) as a fastener at a specific coordinate indicates an intuitive understanding of fulcrums and load distribution, ensuring the weight of the Gudeg does not compromise the structural integrity of the fold.

Lastly, there is the application of fractal geometry within the besek weave itself. The diagonal or sasak weaving patterns utilize principles of geometric repetition and interlocking patterns. Artisans must calculate the number of bamboo strips (iratan) so that the resulting tessellation remains consistent across the entire surface. An error in the count of strips in a single row would cause the symmetry of the besek to become skewed or non-precise. This demonstrates that the aesthetic of Gudeg packaging is built upon a highly logical and measurable mathematical foundation.

Implementation Example: Mathematical Problem
A Gudeg vendor wishes to line the interior of a besek with a banana leaf. The besek has a square base with a side length of 20 cm and a wall height of 10 cm. The vendor intends to cut a single rectangular sheet of banana leaf large enough to cover the base and all four inner walls as a single continuous piece.

1. What is the minimum surface area of the banana leaf required?
2. If the leaf is then folded into two equal parts (reflective symmetry) before being placed, what is the area of each resulting section?

Solution:

1. Calculating the Internal Surface Area of the Besek:
   An open-top besek consists of one base and four lateral walls.
   - Area of the Base: $s \cdot s = 20 \cdot 20 = 400$ cm^2
   - Area of the 4 Walls: $4 (s \cdot h) = 4 (20 \cdot 10) = 4 \cdot 200 = 800$ cm^2
   - Total Surface Area: Base Area + Wall Area = 400 + 800 = 1,200 cm^2
   - Result: The minimum area required is 1,200 cm^2.
2. Calculating the Area of the Symmetrical Fold:
   If the total area of 1,200 cm^2 is folded into two equal parts along a line of symmetry:
   - Area per section $= \frac{1{,}200\text{cm}^2}{2} = 600\ \text{cm}^2$
   - Result: The area of each folded section is 600 cm^2.

4.1.4. Concepts of Sequences and Series in the Canning Process

The canning process of Gudeg Jogja, as an effort to preserve traditional cuisine, involves not only cultural aspects and food technology but also mathematical concepts that can be analyzed through sequences and series. Within the production phase specifically during filling, cooking, and sterilization there are observable patterns of regularity that are both repetitive and measurable. For instance, the number of Gudeg cans produced in each cooking cycle often increases incrementally based on machine capacity, raw material availability, and market demand. This growth pattern can be modeled as an arithmetic sequence if the increase in the number of cans per cycle remains constant, or as a geometric sequence if production increases by a specific ratio. Thus, the production activities of canned Gudeg indirectly reflect the application of sequence concepts within the practical life of the Yogyakarta community.

Beyond daily production figures, the concept of series is evident in the calculation of total cumulative output over a specific duration. Canned Gudeg producers typically structure their daily, weekly, or monthly production targets. If the daily output follows an arithmetic or geometric sequence, the total amount of canned Gudeg generated over a period can be determined using series formulas. These calculations are vital for production management, cost control, and distribution planning. In a mathematical education context, this scenario serves as a contextual learning resource, helping students understand that series concepts are not merely abstract theories but functional tools for solving real-world problems related to economic activities and local culture.

Furthermore, integrating the concepts of sequences and series into the Gudeg canning process holds significant educational value within an ethnomathematical framework. Students can be encouraged to analyze production data, identify growth patterns, and calculate total yields using relevant mathematical formulas. This approach not only enhances the understanding of sequences and series but also fosters an appreciation for local wisdom and regional traditional industries. By linking mathematics to the canning process, learning becomes more meaningful and contextual, encouraging students to think critically and apply their knowledge to solve everyday challenges.

Implementation Example: Mathematical Problem
A home-based canned Gudeg industry in Yogyakarta produces 200 cans on the first day. Due to rising market demand, the daily production increases by 25 cans every subsequent day.
1. Determine the number of canned Gudeg produced on the 10th day.
2. Calculate the total number of canned Gudeg produced over the course of 10 days.

Solution:
Given:
- First-day production (a or u_1) = 200 cans
- Common difference (d) = 25 cans
- Number of days (n) = 10

1. Number of cans produced on the 10th day u_{10}:
   Since the production follows an arithmetic sequence:
   $U_n = a + (n - 1)b$
   $U_{10} = 200 + (10 - 1)(25) = 200 + 225 = 425$
   Result: The production on the 10th day is 425 cans.
2. Total production over 10 days (S_{10}):
   The total production is calculated using the arithmetic series formula:
   $S_n = \frac{n}{2}(a + U_n)$
   $S_{10} = \frac{10}{2}(200 + 425) = 5 \times 625 = 3125$
   Result: The total number of canned Gudeg produced over 10 days is 3,125 cans.

4.1.5. Algorithmic Logic in the Cooking Process (Deep Cooking)

The production of Gudeg Jogja is a clear manifestation of a strict sequential algorithm within the domain of traditional culinary arts. This algorithm begins with the "foundation preparation" phase, where the base of the kendil is lined with teak leaves to facilitate natural reddish-brown pigmentation through chemical reactions upon heating. The order of adding ingredients starting from the young jackfruit, followed by the ground spices, and ending with the coconut milk must be performed incrementally rather than randomly. In mathematical logic, this procedure follows the rule of ordered instructions, where each step is a prerequisite for the next; should this sequential structure be violated, quality variables such as the texture of the jackfruit and the shelf life of the final product will suffer a systematic failure or fail to meet the specifications of authentic Gudeg Jogja.

During the processing phase, there is an application of profound time and temperature optimization logic through the deep cooking technique. The cook must manage a time variable ranging from 12 to 24 hours while keeping temperature parameters constant at a "low heat" level. Mathematically, this involves an understanding of heat transfer rates and the process of fluid volume reduction. Cooks perform mental calculations regarding the relationship between cooking duration and the viscosity of the coconut milk; the longer the duration, the higher the percentage of evaporation, which directly shifts the culinary phase from "wet" Gudeg (Gudeg Basah) to a more concentrated and durable "dry" Gudeg (Gudeg Kering).

Furthermore, time management in Gudeg production involves shrinkage estimation. Young jackfruit, which initially possesses a large solid volume, undergoes mass contraction as natural moisture is expelled and the sugar-coconut milk solution permeates the cellular fibers. The cook employs predictive logic to determine the exact "stopping point" of the process. The distinction between the wet and dry versions is not merely a matter of preference but the result of calculating this specific point within the cooking algorithm. Missing this stopping point by even a few hours can destroy the equilibrium of a texture that is tender yet firm (not mushy), necessitating continuous monitoring of the time variable.

Lastly, this logical aspect encompasses efficient energy resource management. In using a luweng (traditional stove), the arrangement of wood or charcoal fuel is designed to create a uniform radial heat distribution across the circular base of the kendil. This arrangement aims to minimize temperature fluctuations that could damage the protein structures and jackfruit fibers. The ability of cooks to predict when to add or reduce fuel to maintain thermal stability for over a dozen hours is a form of variable control, where a consistent output in flavor is only achievable if the thermal energy input is managed with precise and measurable logic.

Implementation Example: Mathematical Problem
A Gudeg entrepreneur intends to produce "Dry Gudeg" using young jackfruit mixed with thin coconut milk. The total initial volume of the mixture in the kendil is 40 liters. Based on experience, the liquid volume evaporates at a constant rate of 1.2 liters per hour under stable heat. To achieve the perfect texture for "Dry Gudeg," the final volume must remain at 40% of the initial volume.

1. What is the final volume required for the dish to be categorized as "Dry Gudeg"?
2. How much time (in hours) is required for this cooking process?
3. If the cooking process begins at 05:00 AM, at what time should the heat be turned off?

Solution:
Given:

- Initial volume (V_i) = 40 liters
- Evaporation rate (r) = 1.2 liters/hour
- Target final volume (V_f) = 40% of V_i
- Start time = 05:00

1. Determining the Final Volume of "Dry Gudeg":
   The desired final volume is 40% of the initial volume.
   $V_f = \frac{40}{100} . 400 \text{ liters} = 16 \text{ liters}$
   Result: The final volume must be 16 liters.
2. Determining the Cooking Duration:
   First, calculate the total volume of liquid that must evaporate (V_e):
   $V_e = V_i - V_f$ = 40 liters – 16 liters = 24 liters
   Given the evaporation rate is 1.2 liters/hour, the time (t) required is:
   $t = \frac{V_e}{r} = \frac{24 \text{ liters}}{1.2 \text{ liters/hour}} = 20 \text{ hours}$
   Result: The time required to cook the Gudeg until dry is 20 hours.
3. Determining the Shutdown Time:
   - Start Time: 05:00
   - Duration: 20 hours
   - Calculation: 05:00 + 20:00 = 25:00 (which is 01:00 the following day).

   Result: The heat should be turned off at 01:00 AM the next morning.

4.2. Discussion

The production process of Yogyakarta Gudeg is profoundly embedded with ethnomathematical practices that are naturally internalized within traditional culinary activities. Regarding the base ingredient of young jackfruit, the concept of spatial geometry is evident from the material selection stage, where the prolate cylindrical form of the fruit serves as the basis for the producer's intuition in estimating volume and final yield. This finding aligns with D'Ambrosio [31], who asserts that ethnomathematics emerges from cultural activities involving measurement, estimation, and spatial reasoning without the need for formal mathematical symbols. These processes also reinforce the research by Rosa and Orey [13], which states that traditional communities possess contextual mathematical abilities developed through daily social and cultural practices.

Furthermore, the practice of slicing jackfruit into simple prismatic forms demonstrates an application of spatial decomposition and the relationship between volume and surface area. Mathematically, the increase in surface area resulting from these cuts plays a vital role in the effectiveness of spice absorption a principle empirically understood by Gudeg cooks. This is consistent with Siswanto [35], who found that traditional cooking activities often involve implicit understandings of geometric optimization and process efficiency, even when not expressed in formal mathematical language. Consequently, Gudeg culinary practices function not only as cultural activities but also as vehicles for contextual geometry education.

The use of the kendil as a cooking vessel reveals a complex interaction between two distinct spatial volumes: the jackfruit pieces and the volume of the kendil itself. Filling the kendil involves concepts of packing density and the estimation of voids, which directly impact the quality of the dish. This finding supports Prahmana's [15] research, which indicates that the traditional activities of the Indonesian archipelago are rich in three-dimensional geometric concepts, particularly regarding spatial and volume management, offering significant potential as a context for school mathematics. The intuition of Gudeg makers in organizing the contents of the kendil reflects spatial abilities formed through repetitive experience and the intergenerational transmission of knowledge.

The aspects of fractions and ratios in spice measurements further confirm the strong presence of ethnomathematics in the Gudeg tradition. The use of ratios for coconut milk, palm sugar, and other ingredients relative to the amount of jackfruit demonstrates a consistent application of direct and inverse proportions. Previous research by Setyawati [36] found that traditional Javanese culinary practices rely on non-standard measurement systems that are essentially mathematical representations of fractions and ratios based on sensory experience. The ability of Gudeg cooks to scale recipes while maintaining the flavor profile reflects an applied and contextual understanding of linear transformation.

In terms of packaging, the use of besek and banana leaves represents the application of plane geometry, symmetry, and repetitive patterns (fractals) within Javanese material culture. The processes of cutting, folding, and securing banana leaves demonstrate an understanding of surface area, angles, and structural balance. These findings are in line with Hasibuan [37] and Zuliana et al. [38], who states that cultural products such as weaving and traditional packaging contain complex mathematical structures, including symmetry and recurring geometric patterns, which can be utilized as local culture-based learning resources. Thus, the aesthetics of Gudeg containers are inseparable from their underlying mathematical logic.

Finally, the canning and deep cooking processes of Gudeg showcase the application of sequences, series, and sequential algorithms in production management and quality control. Patterns of increased production, total yield calculations, and the estimation of liquid evaporation rates reflect the use of arithmetic sequences and algorithmic logic in a real-world context. This supports findings by Hendriyana [39] and Wikasari et al. [40], which suggest that ethnomathematics-based contextual learning can improve the understanding of abstract concepts, as students can link them directly to everyday phenomena. In conclusion, this research confirms that the entire production process of Yogyakarta Gudeg constitutes a holistic ethnomathematical system that is highly relevant as a meaningful, contextual, and culturally rooted source for mathematics education.

5. CONCLUSION

The comprehensive processing of Yogyakarta Gudeg represents a rich and integrated manifestation of ethnomathematical practices. This includes spatial and plane geometry found in raw materials and packaging, fractions and ratios in spice measurements, sequences and series within the canning process, and algorithmic logic applied during deep-cooking techniques. These stages demonstrate that traditional communities have intuitively applied systematic, contextual, and functional mathematical reasoning through cultural experience and ancestral practices, albeit without formal mathematical formulations. These findings confirm that traditional culinary arts specifically Yogyakarta Gudeg possess immense potential as a meaningful contextual mathematics learning resource that is relevant to real-life situations. Consequently, it is suggested that future research develop empirical ethnomathematics-based learning models using the Gudeg context in classrooms to test its impact on students' conceptual understanding and attitudes toward mathematics.

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