Proximal: Jurnal Penelitian Matematika dan Pendidikan Matematika
ISSN 26158132 (cetak)
ISSN 26157667 (online)

UNVEILING THE HIDDEN MATHEMATICS IN TRADITIONAL INDONESIAN CULINARY ART: AN EXPLORATION OF KNOT THEORY AND ALEXANDER POLYNOMIAL IN KETUPAT TELUR

Ja'faruddin
Jurusan matematika
Universitas Negeri Makassar
Email: jafaruddin@unm.ac.id

Corresponding Author: Ja'faruddin email: jafaruddin@unm.ac.id

Abstract. This research delves into the intriguing relationship between mathematical concepts and traditional Indonesian cultural heritage, particularly in the context of ketupat telur. By applying the theory of knots (knot theory) as a field of topology, the study aims to identify geometric patterns that underlie the making of ketupat telur, as well as to understand the role of symmetry in the formation of knots. The main focus of this research is the ketupat telur knot diagram with 13 points of intersection and Alexander polynomial calculations, as an alternative method for obtaining knot polynomials. The results of the geometric structure analysis of ketupat telur with Alexander polynomial calculations yield:

$$A_k = -t^3 + 7t^2 - 18t + 23 - 18t^{-1} + 7t^{-2} - t^{-3}$$

This finding produces a polynomial that reflects its geometric and structural properties. This illustrates how fundamental mathematical concepts such as knots and polynomials can be applied to culture to achieve a deeper understanding of both.
Keywords: Knot theory, topology, Alexander polynomial, ketupat telur, Ethnomathematics

A. Introduction

The intersection of mathematics and culture, particularly in the field of ethnomathematics, is a subject of considerable academic interest. Ethnomathematics examines the ways in which mathematical concepts and practices are embedded in cultural traditions and activities. The systematic literature review by Fuat et al. (2024) highlights the lack of practical connection between mathematical concepts and cultural aspects in temple ethnomathematics research, suggesting a need for broader application of the Mathematical Landscape in ethnomathematics studies.

Leton et al. (2020) explores the mathematical elements in the culture of the Boti Tribe, demonstrating how ethnomathematics can be used to create innovative mathematics learning models. Septianawati et al. (2017) focused on the mathematical practices within the cultural activities of Kampung Naga, revealing the use of traditional units of measurement and their conversion to standard units. Supriyadi et al. (2022) discusses the connection between ethnomathematics and music, suggesting that integrating cultural and aesthetic traditions can enhance mathematics instruction.

Johnson et al. (2022) presents an IOS Math App incorporating ethnomathematics modules based on Emirati culture, showing the positive impact of cultural relevance on students' mathematics learning. Hasibuan and Dewi (2024) examined the correlation between mathematical philosophy and culture-based learning models, emphasizing their close connections with ethnomathematics. Supriyadi et al. (2022) reviews the impact of Sundanese ethnomathematics on students' academic development, while Sholihah and Marsigit (2022) explores mathematics learning resources based on ethnomathematics in Osing culture. Dawson (2015) discusses the role of elders in validating indigenous knowledge and practices in addresses the management of math anxiety through ethnomathematics learning that respects the human side of students and their cultural environment.

The cited papers collectively underscore the significance of integrating cultural context into mathematics education through ethnomathematics. They revealed that cultural practices can provide

https://doi.org/10.30605/proximal.v5i2.3755

a rich foundation for mathematical concepts and learning, and that ethnomathematics can contribute to a more holistic and enjoyable learning experience, potentially reducing math anxiety and improving academic outcomes.

Topology and knot theories are closely related to various mathematical disciplines. Knot theory, a branch of topology, is concerned with the study of mathematical knots, which are closed loops in a three-dimensional space that cannot be untangled without cutting the loop (Gabriel & Uma, 2023). Topology itself is a broader field that deals with the properties of space that are preserved under continuous transformations, including knot theory as a subfield (Buck et al., 2014; Gabriel & Uma, 2023). Interestingly, while the knot theory is a part of topology, it also has applications and connections in various other fields. For instance, it has been applied in the study of DNA (Murasugi, 1997), theoretical physics (Kauffman, 2005), and cultural traditions (Ja'faruddin & Haw, 2024). These interdisciplinary connections highlight the versatility and broad relevance of the knot theory beyond pure mathematical interest.

As society continues to evolve over time, so does the theory of simpul, which follows this evolution. Just as ketupat symbolizes unity and diversity in various cultures around the world, the theory of simpul serves as a mathematical foundation that reflects the complexities and relationships within it. With the Alexander polynomial as its primary tool for analysis, the theory of simpul provides deep insight into the structure and fundamental nature of the simpul world. The term "ketupat" or "kupat" in Javanese language is an abbreviation for "Ngaku Lepat," meaning "I acknowledge my mistake." This indicates that as humans, we are bound to make mistakes towards one another, and with the culture of kupatan held annually, it serves as a reminder to acknowledge our own mistakes and to forgive one another. With mutual forgiveness, we can ensure peace, tranquility, and serenity (Arif et al., 2019). Ketupat is a traditional Indonesian food that is well-known throughout the country. Although it is known by different names in various regions of Indonesia, such as Tipat in Bali, Katupa in Makassar, Katopak in Madura, and Katupek in Minangkabau, it remains a beloved staple of Indonesian cuisine (Hotima & Hariastuti, 2021).

The intersection of ketupat, a traditional dish, with mathematics has been explored in several studies. Ja'faruddin and Haw (2024) delved into the mathematical properties of ketupat's knot diagrams using knot theory and the Alexander polynomial, revealing a unique polynomial associated with ketupat Nabi's knot diagram (Ja'faruddin & Haw, 2024). Additionally, Utami et al. (2022) discussed the use of the Ketupat Eid tradition in learning mathematics, where the shape of Ketupat is connected to geometric concepts such as rhombuses, prisms, and beams (Utami et al., 2022). Furthermore, Risnanosanti et al. (2024) highlighted the mathematical concepts in traditional games such as kite flying, which, while not directly related to ketupat, emphasize the broader theme of ethnomathematics and its application in STEM education (Risnanosanti et al., 2024).

While Ja'faruddin (2024) and Utami et al. (2022) directly address the relationship between ketupat and mathematics, Risnanosanti (2024) provides context on the application of cultural traditions in mathematics education, albeit not specifically focused on ketupat. It is interesting to note that these studies underscore the potential of integrating cultural elements into mathematical learning, thereby enriching the educational experience and understanding of mathematical concepts through cultural practice.

Limited reference has been made regarding ketupat, a traditional Indonesian food despite its widespread recognition throughout the country. Generally, twelve varieties of ketupat are known, including ketupat jago, ketupat tumpeng, ketupat sidalungguh, ketupat sari, ketupat bata, ketupat debleng, ketupat sidapurna, ketupat bebek, ketupat geleng, ketupat bage, ketupat pandawa, and ketupat gatep (Dwi & Farabi, 2017).

One of the current hot topics in mathematics education is integrating mathematical learning with the surrounding cultural life. Ethnomathematics is the term that combines culture and mathematics (Hutauruk, 2020). In this context, the relationship between ketupat and knot theory provides an interesting analogy, as ketupat is tightly tied by the weave of leaves, just as culture is tied by interrelated knots of values, norms, and practices. Therefore, understanding knot theory can provide deep insights into the complexity and interrelatedness of traditional culture as well as describe the strength of the relationships that bind society.

B. Methodolgy

This study uses a quantitative method by taking a purposive case study to ensure its accuracy, thereby providing a deeper and more varied understanding of specific cases. The main focus of this research is the exploration of certain Knot polynomial, especially the Alexander polynomial, on the ketupat Telur.

The subject of this research is ketupat Telur, which has symbolic value in traditional cultures in Southeast Asia. The ketupat Telur is a variation of the shape of Ketupat , a traditional Indonesian dish made from rice, coconut milk and wrapped in coconut or pandan leaves..

The research procedure began with the selection of the ketupat Telur by combining nodes or links as a fundamental component of the turtle shell geometry structure. This was an important factor.

The next step is to establish the primary focus of the research and gather relevant data by photographing the Ketupat and collecting information about its philosophy, history, and role in traditional culture. This step is crucial for gaining a contextual understanding of Ketupat. The third step was to identify the knots or connections present in the ketupat. This was done by visually inspecting the ketupat and conducting a comparative analysis with the scientific literature on knot theory.

After identifying the crossings, a diagram of the knot is created from the punnet square. This diagram functions as a visual representation of the identified crossings, and assists in a more detailed inspection of the configuration. Subsequently, mathematical calculations are performed for each crossing or link described in the knot diagram, particularly the Alexander polynomial calculation. This step is crucial for a mathematical understanding of the characteristics of the crossings, which involves in-depth mathematical analysis to explore the topological structure of the crossings and understand the special properties that can be used for the classification and identification of crossings in a broader context. Handedness or chirality, commonly known as the left-hand or right-hand rule, is also a special property in this context. This property refers to the ability to distinguish between two different crossings or links using the convention of the left-hand and right-hand rules. In knot topology analysis, the handedness property helps identify topologically different crossings. The sixth step involved an in-depth analysis of the polynomial that was calculated to distinguish the unique characteristics of the crossings present in the 'punnet square.' This inspection helps to reveal the intricacies of the crossings and understand their functional role in the structure. A comprehensive literature review was conducted to ensure the validity of the findings. This process is an integral part of strengthening the analysis results, thereby reinforcing the credibility and reliability of the research.

C. Result and discussion.

Ketupat is a traditional Indonesian food that is widely known throughout the country. In general, there are twelve types of ketupat, which include: ketupat jago, ketupat tumpeng, ketupat sidalungguh, ketupat sari, ketupat bata, ketupat debleng, ketupat sidapurna, ketupat bebek, ketupat geleng, ketupat bage, ketupat pandawa, and ketupat gatep (Dwi & Farabi, 2017).

Ketupat in the form of a round rice cake is a variation of the traditional Indonesian dish made from cooked rice woven into coconut leaves. This type of ketupat resembles a round egg, with bulging top and bottom and elongated sides. the ketupat Telur has symbolic value in the traditional cultures of Southeast Asia. In addition to being a staple food in various religious celebrations, such as Idul Fitri, Christmas, and other religious celebrations, ketupat also symbolizes simplicity, unity, and prosperity in the culture of its people. In Indonesia, ketupat plays an important role in various traditional celebrations such as Lebaran, Nyepi Day (in Bali), and other religious celebrations of Hindu, Buddhist, and Christian faiths.

Figure 1. Ketupat Telur

According to Sartini and Ni Wayan (2017), the round-shaped ketupat (a type of rice cake) in the traditional Hindu Balinese offering (sesajen) has a unique meaning, although the interpretation may vary depending on the context and beliefs of each family or Hindu religious leader in Bali. Some meanings that may be associated with the round-shaped ketupat in Hindu Balinese offerings include the following:

- Symbol of Harmony and Balance: The round shape of the ketupat can be interpreted as a symbol of harmony and balance. The ball represents unity, completeness, and harmony in both spiritual and material life. In the context of the offering, the round ketupat with an egg inside can depict harmony between humans, nature, and the gods.
- Acceptance and Perfection: The round shape can also be interpreted as a symbol of acceptance and perfection. A whole round ketupat egg signifies an openness and sincerity in accepting blessings and goodness from the gods.
- Cycle of Life Symbol: In Hindu philosophy, the ball can also symbolize an unending cycle of life. The round ketupat egg in the offering can be interpreted as a reminder of the continuous cycle of birth, life, and death.
- Symbol of Fertility and Prosperity: The round egg shape can also be associated with symbols of abundance, fertility, and prosperity. In the offering, the round ketupat egg can be a prayer and hope for an abundance of wealth, success, and happiness for the family or community.

It is crucial to note that the meanings of these symbols are symbolic and can vary depending on cultural context, beliefs, and individual interpretation. Therefore, the round patty made of egg in the tradition of Hindu Bali for offerings can symbolize deep spiritual values and the way of life that is deeply embraced by the Hindu community in Bali.

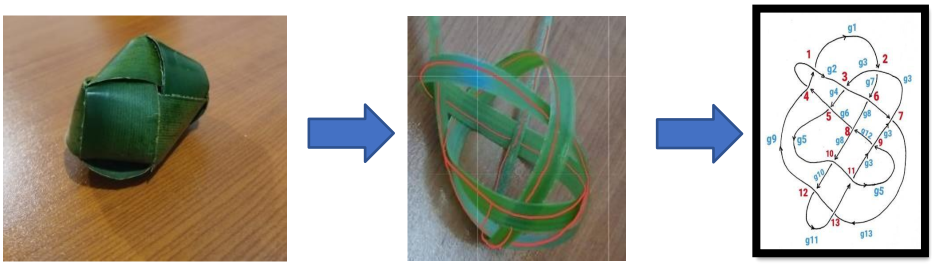

Figure 2. The process of obtaining knots diagram of the Ketupat telur

https://doi.org/10.30605/proximal.v5i2.3755

The knot diagram image sketch for Ketupat Telur has been labeled with designations for its cutting points (1, 2, 3, 4, ...13) and labels for each line ($g1$, $g2$, $g3$, … $g13$). As evidenced in the knot diagram image of Ketupat Telur, there are 13 cutting point labels and 13 line labels..

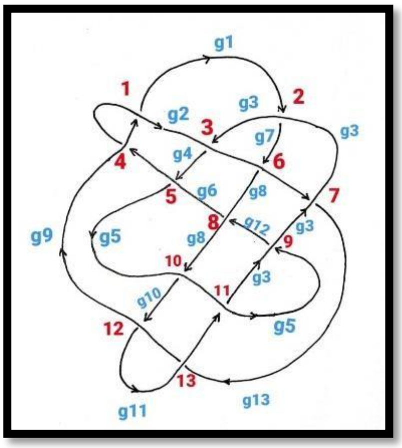

Figure 3. Knot Diagram of Ketupat Telur

In determining the calculation of the polynomial knot of eggs, the rules of the right-hand and left-hand rules are first applied to determine the lines that are directly connected to the points of intersection. The results obtained are depicted in the table below:

	1	2	3	4	5	6	7	8	9	10	11	12	13
g1	t	-1	0	0	0	0	0	0	0	0	0	0	0
g2	1-t	0	1-t	t	0	1-t	t	0	0	0	0	0	0
g3	0	1-t	t	0	0	0	1-t	0	1-t	0	t	0	0
g4	0	0	-1	0	-1	0	0	0	0	0	0	0	0
g5	0	0	0	0	t	0	0	0	-1	1-t	1-t	0	0
g6	0	0	0	-1	1-t	0	0	-1	0	0	0	0	0
g7	0	t	0	0	0	t	0	0	0	0	0	0	0
g8	0	0	0	0	0	-1	0	1-t	0	t	0	0	0
g9	-1	0	0	1-t	0	0	0	0	0	0	0	1-t	0
g10	0	0	0	0	0	0	0	0	0	0	-1	-1	t
g11	0	0	0	0	0	0	0	0	0	-1	0	t	1-t
g12	0	0	0	0	0	0	0	t	t	0	0	0	0
g13	0	0	0	0	0	0	-1	0	0	0	0	0	-1

Gambar 4. Diagram Koefisien Ketupat Telur

Using the software Matlab, we can calculate the determinant value from a table.and the

Output Mathlab

```
M =

[  t, 1 - t,     0,  0,     0,     0, 0,     0,    -1,  0,  0, 0]
[ -1,     0, 1 - t,  0,     0,     0, t,     0,     0,  0,  0, 0]
[  0, 1 - t,     t, -1,     0,     0, 0,     0,     0,  0,  0, 0]
[  0,     t,     0,  0,     0,    -1, 0,     0, 1 - t,  0,  0, 0]
[  0,     0,     0, -1,     t, 1 - t, 0,     0,     0,  0,  0, 0]
[  0, 1 - t,     0,  0,     0,     0, t,    -1,     0,  0,  0, 0]
[  0,     t, 1 - t,  0,     0,     0, 0,     0,     0,  0,  0, 0]
[  0,     0,     0,  0,     0,    -1, 0, 1 - t,     0,  0,  0, t]
[  0,     0, 1 - t,  0,    -1,     0, 0,     0,     0,  0,  0, t]
[  0,     0,     0,  0, 1 - t,     0, 0,     t,     0, -1,  0, 0]
[  0,     0,     t,  0, 1 - t,     0, 0,     0,     0,  0, -1, 0]
[  0,     0,     0,  0,     0,     0, 0,     0, 1 - t, -1,  t, 0]

>> det(M)

ans =

- t^9 + 7*t^8 - 18*t^7 + 23*t^6 - 18*t^5 + 7*t^4 - t^3
```

Figure 4. Koefisien Matriks of Ketupat Telur's diagram

So that the ketupat telur's polynomial knots are obtained as follows:
det(M) =

$$-t^9 + 7 * t^8 - 18 * t^7 + 23 * t^6 - 18 * t^5 + 7 * t^4 - t^3$$

$$A_k = t^6(-t^3 + 7 * t^2 - 18 * t^1 + 23 - 18 * t^{-1} + 7 * t^{-2} - t^{-3})$$

$$\approx -t^3 + 7 * t^2 - 18 * t^1 + 23 - 18 * t^{-1} + 7 * t^{-2} - t^{-3}$$

$$A_k = -t^3 + 7 * t^2 - 18 * t^1 + 23 - 18 * t^{-1} + 7 * t^{-2} - t^{-3}$$

Kesimpulan adalah pernyataan singkat dan tepat yang merupakan jawaban dari rumusan masalah. Saran berisi pertimbangan yang ditujukan kepada pihak lain yang terkait dengan hasil penelitian.

D. Conclution and suggestion

In this study, the theory of knots (knot theory) was successfully applied to the geometric structure of an eggplant cluster. In the calculation of the Alexander polynomial of the ketupat Telur , deep insights were gained into the complexity and mathematical relationship within traditional culture, as well as the strength of the social ties that bind society. The polynomial knot of the ketupat Telur obtained is as follows:

$$A_k = -t^3 + 7 * t^2 - 18 * t^1 + 23 - 18 * t^{-1} + 7 * t^{-2} - t^{-3}$$

The results obtained illustrate the mathematical properties of knots and links. In this context, the shape and pattern of ketupat telur as a cultural symbol can be interpreted as a knot in mathematics. When we apply Alexander's polynomial theory to model , we can produce polynomials that reflect its geometric and structural properties. This illustrates how fundamental mathematical concepts such as knots and polynomials can be applied to culture to produce a deeper understanding of both. Thus, the use of mathematics in this context not only results in a deeper understanding of the ketupat as a cultural symbol but also enriches our perspective on the relationship between mathematics and culture as a whole.

To further explore the applications of Alexander's polynomial simplices theory in the diverse cultural symbols, it is crucial for future research to delve deeper. By adopting a multidisciplinary approach, this study can investigate the relationships between the geometric forms of cultural symbols and concepts in the theory of simplices, as well as apply relevant mathematical methods for a more in-depth analysis.

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