Ethnomathematics: Modelling the volume of solid of revolution at Buginese and Makassarese traditional foods

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ARTICLE INFO	ABSTRACT
	Ethnomathematics can empirically improve the cognitive abilities of students in elementary and secondary schools. However, in undergraduate study, there are still limited studies on integrating ethnomathematics in learning resources. This study aims to apply interpolation in modelling polynomial functions and integral volume on the shape of Buginese and Makassarese traditional foods. Furthermore, it can be used by students as relevant learning resources regarding interpolation and the concept of volume of solid of revolution (VOSR). This is a qualitative study using an ethnographic approach. The data were collected through observations to obtain general information, interviews with informants to find out food-making techniques, and documentation to obtain physical models of each type of food. Data Analysis Techniques consist of the domain analysis to obtain an overview of Buginese and Makassarese traditional foods and the taxonomic analysis to categorize mathematical concepts obtained from the modeling and simulation. The result of this research reveals that *lammang* is suitable with the slabs. It can be represented as constant functions that revolved around the *x*-axis or the *y*-axis. While *paso*, *bolu cukke, and cantik manis* as well as *barongko batara*, *Putu,* and *cucuru* can be outlined in linear functions rotating about the *x*-axis, *y*-axis, or others fixed-line. They meet the criteria of the disks method. However, they are described in the function of polynomials of n-degree. The use of washers can be described in the model of *blundered* and *sarang semut* with a hole in the middle caused by the intersection of two curves rotated about the *x*-axis or the *y*-axis. For shells, the model can be applied to determine the cover volume of the cover of *pisang ijo* flour and *onde-onde.* Thus, all types of traditional foods in this study can be appropriate objects for a learning resource in modelling the VOSR.

Introduction

The integration of mathematics with various other disciplines encourages someinnovations in mathematics learning. One of the most relevant branches in the development of mathematics learning is Ethnomathematics. Since it was first introduced by D'Ambrosio (1985), ethnomathematic studies have grown rapidly and provided many innovations in mathematics learning. Ethnomathematic brings great benefits such as

maintaining cultural awareness and improving intellectual, social, and emotional intelligence through the uniqueness of the culture owned by students. The approach of local culture-based mathematics learning can change people's perspective regarding the existence of mathematics in daily life (Herawaty, Widada, Novita, Waroka, & Lubis, 2018).

Ethnomathematic also provides a new approach to the school curriculum. In this case,mathematics learning needs to involve various attributes or cultural activities related to the live of students. Under a cultural approach, ethnomathematic tends to build a strong relationship between students' knowledge and experience related to formal math learning activities (Ezeife, 2002). Moreover, ethnomathematics studies can improve students' understanding in terms ofmathematical concepts through the elaboration of meaning on cultural aspects depthly (Rosa & Orey, 2011). In this part, the cultural context relates to personal, occupational, and cultural activities.

Ethnomathematics is terminologically divided in three phrases: *ethno*, *mathema* and *tics*. D'Ambrosio (1990) stated that *Ethno is* defined as a term referred to the socio-cultural context, including language, signs, myths, jargons or motto, stories, symbols and the way of thinking (Orey & Rosa, 2007). Furthermore, *mathema* has the meaning of explanation, knowledge, thought, understanding and assessment of phenomena. The suffix of *tics* denotes the same meaning as *techne* which means a way. Rosa and Orey (2011) stated that *tics* or *techne* is a technique more specifically related to counting, sorting, measuring, classifying, inferring, and modelling.

The study related to ethnomathematics has been widely analyzed and spanned some aspects of culture. The exploration of ethnomathematics at traditional food markets in the Special Region of Yogyakarta has been conducted by the previous study (Huda, 2018). In the study, various mathematical elements, such as types of plane and space geometry, were explored in the shape of traditional snacks. Another exploration has also been found in traditional Buginese foods demonstrating that some kinds of them can be applied as contextual learning resources for students at elementary and secondary school levels (Pathuddin et al., 2021).

Prior studies have uncovered that mathematical concepts are based on local attributes and can be used as a source of learning in elementary and secondary schools (Herawaty et al., 2018; Nur, Waluya, Rochmad, & Wardono, 2020; Pathuddin, Kamariah, & Nawawi, 2021). The implementation of ethnomathematics-based contextual learning can improve students' cognitive levels (Nur et al., 2020). However, ethnomathematical studies are less found in a source of learning for students at higher education level. The implementation of ethnomathematics in mathematics learning at the higher education level requires a specific exploration suitable with the   topic in courses with local cultural atributes. The study of the introduction of shapes and concepts of 3D shapes in local cultural objects is no longer sufficient as a source of mathematics studies in universities. As courses in calculus and numerical methods, the study of functions, interpolations and integration requires the selection of local cultural objects and relevant substances. Moreover, it could be appropriate learning media for students.

Interpolation is one of specific topics in courses of numerical methods. It refers to a technique used to construct a new function as a mathematic model from a set of pairs (x,y). In some references, interpolation is presented in an abstract concept and simulated on natural phenomena using numerical computations. Learning resources about interpolation based on local cultural approaches are less explored. Therefore, this study seeks to utilize interpolation techniques in a function showing elements of local culture. Technically, interpolation learning is still presented directly in data pairs (x,y), without being complemented by contexts represented in real data. In addition, the existence of functions

as a result of interpolation is still abstract (Cheney & Kincaid, 2012), with the result that it becomes an obstacle in mathematics learning for students.

One of topics in Calculus courses is application of integration (Bittinger, Ellenbogen, & Surgent, 2012). It is enough hard for students when the contexts presented are different with the experience and daily life. As stated by Varberg's book Calculus (2006), the topic of the volume of solid objects is still abstract. The presentation of theory and problem in the context of applications of the integral is only in the form of equations without completing it with a real physical model. Abstract curve is generated directly from a defined function. Although this source presents physical phenomena such as fluid mechanics, moment and center of mass, the phenomena are still far away from the student environment.

Another difficulty encountered in learning the VOSR is the ability to draw graphs, and construct them into rotating objects (Kusumaningrum, Irfan, & Agustito, 2019; Mofolo-mbokane, Engelbrecht, & Harding, 2013). Therefore, this research seeks to explore mathematical concepts at the university level by including elements of traditional foods as a part of local culture. Various types of traditional foods are assumed similar to solid of revolution characters, such as cylinders, cones, wheels, and spheres (Huda, 2018; Pathuddin & Raehana, 2019). The diversity of shapes of traditional food allows them can be represented in various types of polynomials. Moreover, it can be simulated into a solid of revolution.In this study, Buginese and Makassarese traditional foods would be used as the primary object in modeling the VOSR.

In constructing a mathematical model, there are general steps to consider, namely recognizing problems in the surrounding environment or the real world, collecting data, analyzing data, constructing the model, solving the original problem, interpreting the solution, and testing the model. If it has been successful, it will be used to explain, to predict or to decide (Bittinger et al., 2012; Hall & Lingefjard, 2017). A function representing the phenomenon or real object is the type of mathematical model obtained using interpolation techniques. Such as Newton's polynomial interpolation, it is applied to estimate the data set of a bottle into one polynomial function (Sihombing, Marmaini, & Dahlia, 2020). However, through the development of numerical computations, interpolation methods have directly been used by software such as (Cooper, 2017). In this study, Interpolation is used as a technique to formulate the polynomial models that could represent the shape of traditional foods.

Furthermore, related to the aspect of using the concept of interpolation and integral in exploring VOSR, it has also been researched by Ozdemir and Cataloglu (2014). This research differs with prior studies. It is in differences between object and focus of the research. In the prior study, Ozdemir and Cataloglu (2014) utilized glass and bottle objects as media for rotating objects. As a distinction, this research further selects traditional Buginese and Makassarese foods. The main focus in Ozdemir's research is to use interpolation studies and integral calculus as a medium in implementing inquiry-based learning (Ozdemir & Cataloglu, 2014) while this research prioritizes ethnomathematical exploration in the study of integral application to determine the VOSR model.

In addition, the polynomial model through interpolation of each Buginese and Makassarese is visualized into a solid object using the concept of VOSR. From these results, volume models were constructed by the integral application in Calculus. Each model of the volume is categorized in the characteristics of the solid and they are grouped over slabs, disks, washers, and shells (Varberg, Purcell, & Rigdon, 2006). The process of interpolation, simulation and physical visualization of solid objects is explored using *GeoGebra* software.

GeoGebra is a mathematical software made firstly by Markus Hohenwarter in 2001 at the University of Salzburg (Hohenwarter & Hohenwarter, 2002). It has been a multi-

platform, open source project, and free for educational purpose.The design of the application integrates algebra, plane geometry, 3D geometry functions, statistics and symbolic algebra (Hohenwarter & Fuchs, 2004). Moreover, *GeoGebra* can be demonstrating, visualizing and constructing mathematical concepts (Hall & Lingefjard, 2017). Furthermore, *GeoGebra* can be used as a learning medium so as to encourage discovery and experimentation both in learning and in exploration activities. Through the use of *GeoGebra*, students can determine the volume of rotating objects and visualize them independently. Besides, students can also understand how to describe the basic concept of volume of swivel solid disc method (Tasman, Padang, & Ahmad, 2018). *GeoGebra* in this study is used as a tool for modeling polynomial representations and fitting curve based on the physical shape of traditional cakes through interpolation techniques. Moreover, *GeoGebra* is also used to display a simulation of the rotation of the curve about a fixed line.

The main purpose of this research is to apply the concept of interpolation in modelling the VOSR Buginese and Makassarese traditional foods. From a cultural perspective, this study attempts to reveal information about ingredients and techniques in making food and explain the factors affecting the shape of the Buginese and Makassarese foods. This research contributes to the contextual learning resources for mathematics students in higher education. Due to traditional Buginese-Makassarese foods as the object of this research, the contribution also is addressed as the relevant study material for students that knowing Buginese or Makassarese cultural culiners.

Research Methods

This research is a qualitative using an ethnographic approach. This research identified and explored mathematical models contained in the physical shapes of Buginese and Makassarese traditional foods. The data collection consisted of observation, interview, and documentation. Observation is intended as a step to obtain an initial and general description about traditional foods of Buginese and Makassarese. Furthermore, the interview technique was aimed at obtaining information about recipes, and uses in the cultural perspective of each traditional food. While the documentation is focused on taking pictures that will be processed in modelling and simulation.

Procedurally, this research implemented the ethnographic cycle initiated by Spradley (2006) as cited in Abdullah (2017). The stages included selection of research scope, determining informants, making notes through interviews and documentation, conducting domain analysis, taxonomic analysis and writing ethnographic (Abdullah, 2017; Pathuddin & Raehana, 2019).

The first stage is the selection of the research scope. In this phase, the types of traditional food are selected and determined spread over several areas whose population is dominated by Buginese and Makassarese ethnics. In this study, the research locations were selected in several cities, including Parepare City, Makassar City, Gowa Regency, Bulukumba Regency, and Barru Regency. Objects were chosen by considering the existence of traditional food sources deriving of some regions in South Sulawesi. In each region, informants were selected based on their involvement in making food, processing food, selling food, or the use of food in cultural activity. In order to ensure the validity of data, a triangulation was implemented. Specifically, data of each type of traditional food in this study require validations from different informants consists of key informants and supporting informants. However, in this study the exact number of informants was not determined. It is based on suitability and sufficiency of information for each type of cake.

Interview is the second stage carried out by asking questions related to the general description of the traditional food being studied. At this stage, structural questions are also

asked and used to find out information about ingredients, food-making techniques and cultural uses. The third phase is to make ethnographic notes based on the result of interviews and to take photos of traditional food as field notes and documentation. The fourth stage is a domain analysis oriented to an in-depth study of the general description of the traditional food being studied.

The fifth stage is a taxonomic analysis focusing on extracting mathematical concepts by reduction, modelling, and simulation. At this stage, data reduction was carried out by selecting food images from the documentation that meet the criteria for solid of revolutions. Image of each fixed food, selected and imported into *GeoGebra*. Moreover, at this stage polynomial modeling and fitting curve were also carried out using the interpolation technique. In this part, *GeoGebra* is used as the main tool in polynomial modeling with interpolation techniques. Expressions of mathematical formulas in *GeoGebra* can be written in the input box. Especially in interpolation problems, there are several models on the function that can be generated from a data set, namely `FitPoly` for polynomial functions, `FitExp` for exponential functions, `FitLogistic` for logistic models (Hall & Lingefjard, 2017). However, in this study the *GeoGebra* command for interpolation only uses `Fitpoly` to generate polynomial and to fit curve based on the shape of traditional foods. The results of modeling curves with interpolation techniques are grouped based on the degree of polynomial.

In the solid of rotation simulation, it only uses the *surface* as a command to rotate the curve about the axis. It displays a shape that matches the traditional food observed. The volume model for each type of food is formulated with an integral approach determined based on the slab, disk, washer, and shell method (Bittinger et al., 2012; Varberg et al., 2006). The general description of all stages in this research is illustrated in diagram as follows:
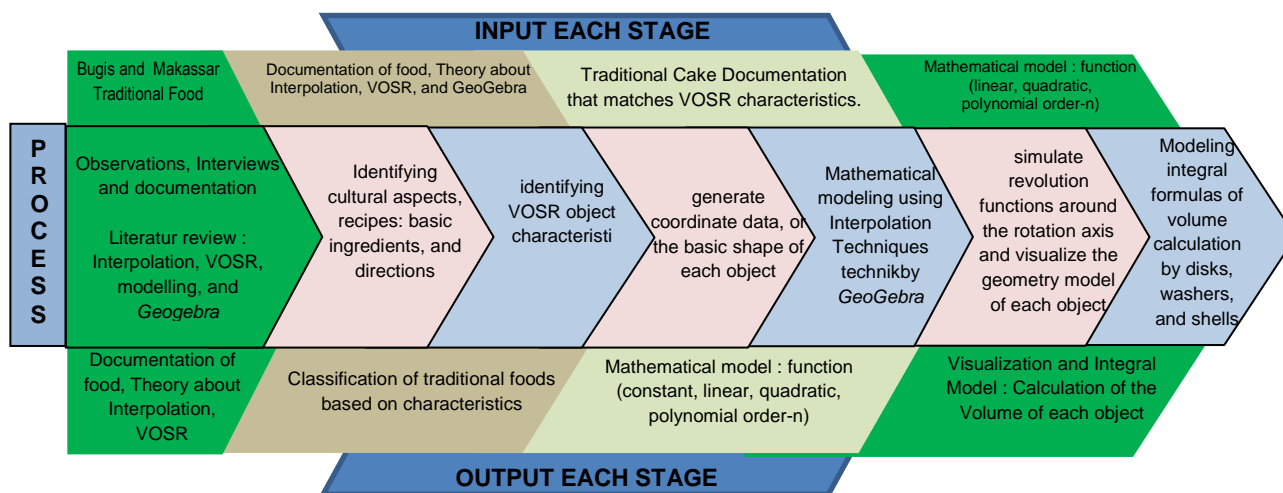

Figure 1. Research stage diagram

The systematic of discussion is presented based on results of classifying the characteristics of the VOSR model and the type of polynomial that is owned by each selected food. The ethnographic notes are added as part of results of interviews regarding ingredients, food-making techniques and cultural aspect of each traditional foods.

Results and Discussion

Buginese and Makassarese traditional foods can be categorized in the type of staple food, snack food, or food served in the cultural rituals. Based on the observations, there are

many types of Buginese and Makassarese traditional food, such as *lammang, legese, tumbu', kapurung, barobbo', burasa, kampalo, gogos, dumpi cucuru, onde-onde, onde-onde jawa, buroncong, rokok-rokok, pisang ijo, putu cangkir, kue cantik manis, tenteng, baje', barongko, lapisi, katiri salla, pawa', panada, jalang kote', apang, bolu cukke, baruasa, bagea, pallu butung, paranggi, paso.* However, not all of the above types of food are compatible with the criteria for solid of revolution. some types of traditional foods suitable with the criteria of solid of revolution are *lammang, legese, tumbu', paso, bolu cukke, cantik manis, putu cangkir, cucuru, bludere, sarang semut, pisang ijo, dan onde-onde.*

Some prior studies analyze ethnomathematics. Pathuddin and Raehana (2019) have identified the content of the concept of plane figure and geometry on Buginese traditional foods; *paso* represents the concept of conical, *onde-onde* denotes the concept of spherical, and *putu coppa* resembles the concept of a cylinder (Pathuddin & Raehana, 2019). Huda's research (2018) has also explored various shapes of traditional market snacks in Yogyakarta. The additional finding is also provided by Pathuddin et al. (2021) focusing on the basic concepts of flat and space figures in the process of making *barongko*. Their result found that the process of making *barongko* cakes generates divisions, congruences, and similarities concept (Pathuddin et al., 2021).

The similarities between this study and the research conducted by Huda (2018) and Pathuddin and Raehana (2019) are the use of traditional food objects. However, this study also has many fundamental differences with previous studies. This research does not emphasize on exploring the suitability of the geometric shapes of traditional foods with the concept of plane and solid figures, but it is more oriented towards a modeling through the interpolation process and the application of integration in modeling the volume of solid of revolution (VOSR). Particularly, the type of solid revolution is reclassified in three methods, namely disks, washers and shells (Varberg et al., 2006). All various foods have been selected based on four characteristics.

Volume of solid: Method of slab
Lammang

Lammang is one of traditional foods similar to snacks. It can be found in Buginese and Makassarese community in South Sulawesi. *Lammang* in many other areas is known as *lemang* and commonly called as Rice Bamboo (Wahyudi, Octavia, Hadipraja, Isnaeniah, & Viriani, 2017). Based on the result of interviews with three informants regarding the basic ingredients and the way of making *lammang,* they explained that:

> *"In the process of making it, lammang needs glutinous rice, coconut milk, and salt as the basic ingredients. In addition, frozen fresh banana leaves and bamboo pieces (bodak) that have a tube-like shape with a length of 40-70 cm and a diameter of 7-15 cm are also required. At the beginning, glutinous rice is washed and rinsed until it is clean. Coconut, milk and salt are used as a seasoning. Glutinous rice and coconut milk mixture with salt are merged into hollow bamboo pieces that is coated young banana leaves. To make it ripe, the bamboo which contains a mixture of rice and spices is burned until desired level of maturity".*

The basic ingredients and manufacturing techniques presented by informants are similar to manufactures of *lemmang* in Sumatera (Wahyudi et al., 2017). Based on the result of the interview, it has also been given that in fact there are other types of traditional foods with same characteristics as *lammang* including *legese', tumbu'* and *lannga'.*

Figure2. Taking *lammang* in bamboo

Figure3. Tumbu'

Figure 4. Legesse'

Figure 5. Lannga'

In the mathematical perspective, *lammang* has the basic circumstance of a solid cylinder because it follows the shape of bamboo as a mold container. Then the young banana leaves as a cover, have become very thin and stick to the edges of glutinous rice matured. *Lammang* volume can be described practically using formula of volume of a cylinder i.e. $V = \pi r^2 t$. But in this study, the mathematical model of *lammang* volume was obtained using applications of integrations. By observing the wide uniformity on the *lammang* side, the volume model with slabs can be written in a formula as follows:

$$\Delta V_{lammang} = A(\bar{x}_i)\Delta x \qquad (1)$$

In this case, the representation of *lammang* volume with the slab approach can be written in a formula as follows:

$$V_{lammang} = \lim_{\Delta x \to 0} \sum_{i=1}^{n} A(\bar{x}_i)\, \Delta x = \int_{a}^{b} A(x)\, dx \qquad (2)$$

While based on the principle of revolution of the object, we need to determine the function representing the outside edge of the *lammang*. Using the straight edge of the *lammang*, a function can be yielded by interpolation at just two data points. Through linear interpolation, a constant function is obtained, $g(x) = k$.

This function is rotated around the *x*-axis. In the integral application, if a constant function is revolved around the *x*-axis, then the volume of the rotating object can be determined using the integral. The straight-line, as geometrical representations of constant functions, can be seen as the radius of the *lammang* equivalent to the value of the constant function (k).

Furthermore, the physical model of *lammang* can be visualized as follows.
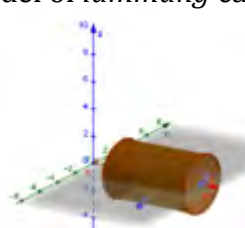

Figure6. Ploting and interpolationof *lammang*
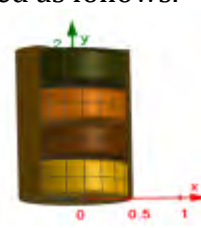

Figure7. Revolution of constant function

Figure 8. Simulation of revolution of $x = g(y)$around y-axis

The mathematical model of lammang volume can be represented by:

$$V_{lammang} = \pi \int_{a}^{b} k^2\, dx \qquad (3)$$

The principles of model construction and simulation of computational geometry from *lammang* also apply equally to the types of food *tumbu'*, *Lannga'* and *Legese*. Based on the sliced serving method, this type of food is very suitable with a contextual resource in VOSR learning.

Volume of solid of revolution by disk method
Paso

Paso is one of traditional cakes from Mandar Tribe. However, it can also be consumed by Buginese people. This cake is made from starch, salt to taste, coconut milk, and palm sugar. The ingredients are mixed and stirred until they become liquid doughs. The mixture is put into a cone-shaped banana leaf. According to Pathuddin and Raehana (2019), the characteristics of cones can be found in *paso*.   In this study, *paso* is explored by constructing the algebraic model using the interpolation method. In addition, the algebraic model is revolutionized around a certain axis of rotation.

Figure 9. Paso

By using the interpolation, the edge of one piece of *paso* can be represented in a linear function. In the coordinate system, the peak point of the Pasois centered on O(0,0), then the equation model is obtained $f_{paso}(x) = mx$. Furthermore, the linear function is rotated around the rotary axis, obtained cones resembling *paso*.   The volume model uses the concept of a rotating solid object disc method. This can be outlined in integral as follows.

$$V_{paso} = \pi \int_a^b (mx)^2 \, dx \qquad (4)$$

The geometric visualization of *paso* can be expanded by considering the direction of rotation not only through the *x*-axis or *y*-axis, but it also simulates the rotation of various linear functions with a varying gradient. The following results showing *r* simulation of the rotation of linear functions against different types of rotary axes are:
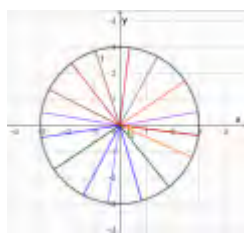

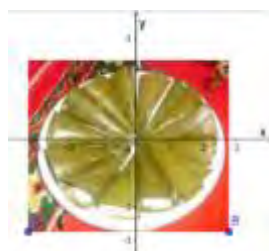**Figure10**. Visualization of a set of straight line segments of a paso cake.
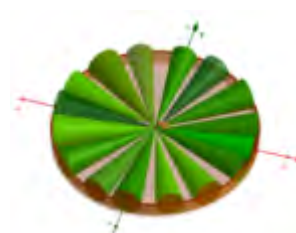
Figure 11. Paso cake serving

Figure 12. Simulation of revolution of linear equation equals paso cake dish

Bolu cukke and cantik manis

Another traditional snack in the Buginese-Makassarese community is *bolu cukke*. This cake can be found in Pinrang, Soppeng, Barru, Sinjai, Bulukumba and other cities or some districts in South Sulawesi. *Bolu cukke* is known for its high-calorie snacks because is composed of chicken eggs, wheat flour and brown sugar (Manjilala, Ekariskawati, & Agustian, 2019). *Bolu Cukke* is made using molds with various shapes. The mixture of ingredients is inserted into the mold, then ripened by a baking. In the perception of local culture, *bolu cukke* is served in *Anggaukeng* as a part of Bugis wedding ceremonies (Ridha,

Kadir, & Sudirman, 2000). One of shapes matches the characteristics of the rotating object following the shape of the mold.

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Figure 13. *Bolu Cukke* served

In mathematical tenet, the basic shape of the edge of *bolu cukke* can be described in a constant function $f(x)$ on the base, a linear function *of* $g(x)$ on the edge side and a quadratic function *of* $h(x)$ on the upper side. By using interpolation, three different functions are obtained as follows:

$$f(x) = 1 \qquad\qquad ; 0 \leq x \leq 2 \qquad\qquad (5)$$
$$g(x) = 3x - 5 \qquad\quad ; 2 \leq x \leq 3 \qquad\qquad (6)$$
$$h(x) = -0.02x^2 + 4.22 \; ; 0 \leq x \leq 3 \qquad\qquad (7)$$

Furthermore, all functions are revolvable around the *y*-axis. Simulation of rotation of the function yieldsthe following form of *bolu cukke*.
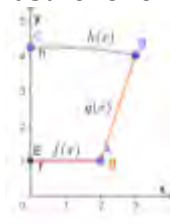

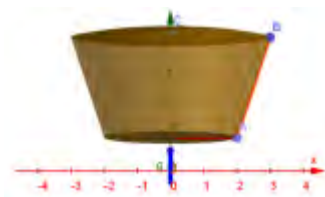**Figure 14**. Linear and quadaratic function by interpolation

Figure 15. The simulation of linear and qauadratic function that are rotated around y-axis

The volume formula can be obtained using the disk method. Because it revolves around the y-axis, the functions and the boundaries are inverse into new functions and boundaries.

$$V_{bolucukke} = \pi \int_{1}^{4} \left(\frac{x+5}{3}\right)^2 dx + \pi \int_{4.04}^{4.22} \left(\frac{x-4.22}{-0.02}\right) dx \qquad\qquad (8)$$

Another traditional cake resembling the geometry characteristics of *bolu cukke* is *cantik manis*. The difference from the physical appearance between *cantik manis* cake and *bolu cukke* is in top surface. *Cantik manis* cake seems more evenly, so that in its depiction, it is quite necessary for one linear function with a certain boundary and rotates against the *y*-axis. The way to obtain function marking the edges of the *cantik manis* is the use of interpolation providing bounded linear function:

$$f(x) = 4.55x - 4.55 \; ; (1 \leq x \leq 1.66) \qquad\qquad (9)$$

Furthermore, the volume model is formulated using the disc method. The linear function is first reversed, and boundaries are adjusted, so that the integral model can be obtained as follows:

$$V_{CantikManis} = \pi \int_{0}^{3} \left(\frac{x+4.55}{4.55}\right)^2 dx \qquad\qquad (10)$$

The process of plotting, interpolation, and revolution of linear functions around the y-axis is visualized in the following figure:

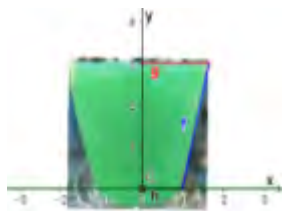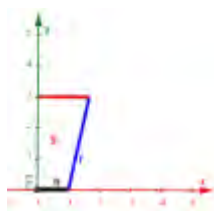**Figure 16**. Plotting point at side edge of *Cantik Manis*

Figure 17. Linear and constant function by interpolation

Figure 18. Revolution of linear and constant functions around y-axis

n^{th}-*Degree polynomial*
Putu cangkir

Putu Cangkir is one of traditional cakes leading enhancement the economy of Buginese-Makassarese community. Based on the results of the interview, it can be explained that the processing technique starts with mixing white glutinous rice flour and sprinkling crushed brown sugar until evenly and it becomes a ready to mold dough. The dough is put in the middle of a bowl-shaped mold, then added grated young coconut and covered with rice flour dough. The next step is the dough with the coconut mixture in a steamed mold until being cooked. The explanation about ingredients and the processing *putu cangkir* is similar with the report on community empowerment in *putu cangkir* business development (Sahban, 2017).
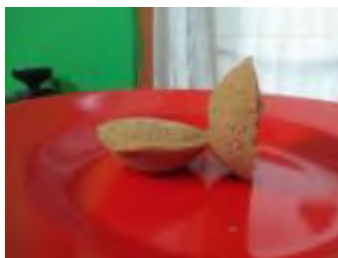

Figure 19. *Putu Cangkir*

The utilization of the bowl as a mold makes this cake resemble the characteristics of the solid object. the result of interpolation in *GeoGebra* obtains the side generating quadratic polynomial equation as shown in the equation as follows:

$$f(x) = -0.33x^2 + 2.84x - 3.14 \; ; (1.81 \leq x \leq 4) \qquad (11)$$

The polynomial square is revolved around the *x*-axis. The rotation of the function results in a rotating solid object with disc characteristics resembling *putu cankir*.
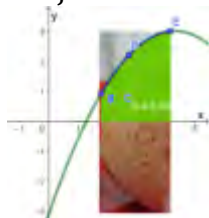

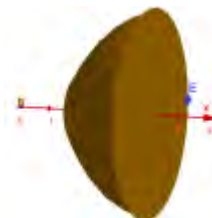**Figure 20**. Quadratic polynomial as a result of interpolation

Figure 21. Simulation of quadratic polynomial thet is rotated around the x-axis

Using the concept of the disk method, the volume model can be written in the following integral formula:

$$V_{PutuCangkir} \quad = \pi \int_{1.4}^{3.7} (-0.33x^2 + 2.84x - 3.14)^2 \, dx \qquad (\,12\,)$$

Barongko batara

A variety of traditional corn-based foods should be preserved because they become a part of Nusantara's wealth. For Buginese and Makassarese people, they process the corn as the traditional food in someways. One of ways is *pudding* served in some types including *barongko batara, bassang, barobbo,* and *marning*. *Barongko batara* is the result of modification of corn *dodol* into pudding. It can further be processed to be corn barongko. In addition to corn, other ingredients used in making *barongko batara* are coconut milk, eggs, sugar, gelatin, vanilla and salt to taste. Corn pudding dough is made from a mixture of sliced corn that has been mashed with other ingredients. In the process, *barongko batara* is explored to find characteristics of revolution.

Figure 22. *Barongko Batara*

Geometrically, this corn pudding has different shapes following the shape of the dough mold. However, *barongko batara* has a shape appropriate with the characteristics of solid of revolution. Some images of corn pudding are presented. By fitting data, a quatric polynomial function is obtained as follows:

$$g(x) = -0.007x^4 + 0.53x^3 - 1.59x^2 + 2.15x + 1.3. \; ; \; 1.4 \le x \le 3.7 \qquad (\,13\,)$$

This quartic polynomial is rotated around the x-axis resulting in a rotating object
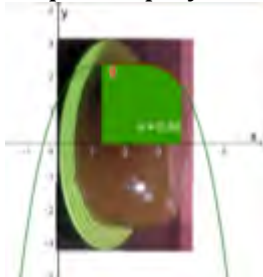

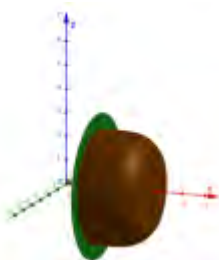**Figure 23.** Plotting and interpolation on the side of *barongko batara*

Figure 24. Revolution of quatric polynomial

Figure 25. Rotating image to the horizontal view

The volume model formulated by disk method can be written as follows:

$$V = \pi \int_{1.4}^{3.7} (-0.007x^4 + 0.53x^3 - 1.59x^2 + 2.15x + 1.3)^2 \, dx \qquad (\,14\,)$$

Barongko batara has various variants depending on the shape of the mold. One of variants is that there is a hole in the middle of the pudding. Moreover, it can also be explored by using a solid of revolution with the method of washers.

Cucuru

Dumpi cucuru, or *Dumpi eja* in Konjo language, is one of highly sacred traditional foods. This cake should be served in various traditional ceremonies. For Kajang people in

Bulukumba Regency particularly, *dumpi eja* must be dished out in Kalomba event. It is one of cultural heritages in the form of rituals conducted Kajang people, as a life cycle ceremony intended to ask for safety for children in order to avoid curses, and diseases (Raodah, 2020). As the result of the interview conducted with Ramlah, as a *jannang* or *dumpi cucuru* maker, she stated that:

> "*Dumpi cucuru is made from crab rice soaked for 10 hours and ground into fine flour, mixed with palm sugar that has been finely sliced and diluted. It is further added with water and stirred until evenly so that it becomes a dough. Next, the dough is put in boiling oil. In Kalomba activities, dumpi eja becomes a prayer for children in orderto look physically sweet, behave politely, and speak politely. Dumpi cucuru is also used as a ceremony in the wedding ceremony addressed to the groom to the bride. With a sweet taste, dumpi eja is also believed as a prayer to combinethe sweet feelings and bind the affection between the bride and groom".*

Figure 26. *The dought of Cucuru*   **Figure 27**. *the process of frying*   **Figure 28**. *Dumpi Eja*

Source : https://www.tagar.id/dumpi-eja-kue-sakral-suku-kajang-bulukumba

In the concept of its geometry, *cucuru dumpi* is similar to the characteristics of irregular rotating objects. Its shape is irregular because the dough being put in the frying pan, form an uneven surface. However, it can still be approximated using interpolation methods. In the stage of data ploting and interpolation, the basic curve can beobtained in the form of *nonic* polynomial as follows:

$$p(x) = 1.12x^9 - 25.02\,x^8 + 242.15x^7 - 1335.23x^6 + 4619.44x^5 \\ - 10396{,}5x^4 + 15223.62x^3 - 13993.66x^2 + 7336.11x \qquad (15) \\ - 1671.96\,; (1 \le x \le 4)$$

The result of simulating the revolution of the $p(x)$ function around the *x*-axis, can be visualized in figures:
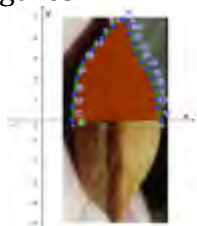

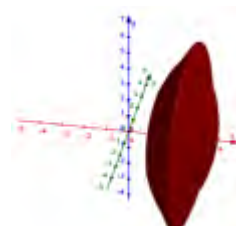**Figure 29**. Plotting point and Interpolation at image of *cucuru*   **Figure 30**. Simulation of revolution of nonic polynomial

Nevertheless, this cake can be found in Buginese or Makassares people, especially in some cultural activities. As in the previous type, the volume model of the spell *dumpi* can be written in integral formula:

$$V = \pi \int_1^4 p(x)^2 \, dx \qquad (16)$$

Solid of revolution : Washers method
Bludere

Bludere is the type of bread categorized as a traditional cake. In *Aggaukeng* event held in wedding parties, *bludere* is in the type Indo Beppa cake. It is relatively large size and has been not sliced. It is stored in the *Bosara* and brought as a groom to the bride (Ridha et al., 2000). Based on the result of the interview with two informants, they said that:

> "*The main ingredients of this bludere cake are eggs, wheat flour, granulated sugar, brown sugar, and water coupled with a number of cake mixture ingredients such as TBM, vanily powder, milk, chocolate powder and additional walnuts. The ingredients are mixed and processed specifically so as to produce a soft texture.*"

Figure 31. The mold of *bludere*

Figure 32. *Bludere* cake

Under geometry concept, the shape of *bludere* resembles the charactericic of a rotating solid object with a cavity in the middle. The *bludere* shape follows a cylindrical mold and has a border resembling a cone cut in the middle. Mathematical model obtained through interpolation techniques from the outer boundaries of *bludere* consists of four functions:

$$f_1(x) = 3x - 5 \qquad ; 2 \le x \le 2.5 \qquad (17)$$
$$f_2(x) = -4.42x + 5.42 \qquad ; (0.66 \le 杜 \le 1) \qquad (18)$$
$$f_3(x) = 1 \qquad ; (1 \le x \le 2) \qquad (19)$$
$$f_4(x) = 2.5 \qquad ; (0.66 \le x \le 2.5) \qquad (20)$$

In the VOSR concept, *bludere* meets the characteristics of the washers method. The simulation of revolution of four functions revolves around the *y*-axis as shown figure 32.
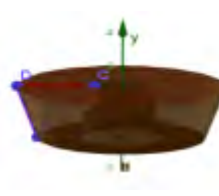

Figure 33. Ploting and interpolation at the edge of *bludere*

Figure 34. revolution of linear and constant function around *y*-Axis

The volume model can be completed by an inverse the above functions along with the transformation of the boundaries.

$$V_{outside} = \pi \int_1^{2.5} \left(\frac{x+5}{3} \right)^2 dx \qquad (21)$$

$$V_{cavity} = \pi \int_1^{2.5} \left(\sqrt{\frac{x - 5.42}{-4.42}} \right)^2 dx \qquad (22)$$

As a result, volume model can be formulated by : $V_{bludere} = V_{luar} - V_{rongga}$

$$V_{bludere} = \pi \int_1^{2.5} \left(\frac{x+5}{3}\right)^2 - \left(\sqrt{\frac{x-5.42}{-4.42}}\right)^2 dx \qquad (23)$$

Sarang semut

Sarang semut is also known as caramel sponge. It is not only famous in Buginese community, but it is also almost in all over Indonesia. This cake is included in the type of wet cake favored in various communities. Although the *sarang semut* is known as modern cake, it is also often found in various events such as in religious events, in family gatherings, or in cultural ceremonies. In the manufacturing process, palm sugar is melted into a dark brown liquid and water is then added. The melted brown sugar that has been recooled is mixed with the whipped butter, some eggs and also additional flour, bicarbonate, and baking powder. The whole of this mixture, becomes a dough. It is then ready to be put into the mold or baking pan. Through the baking process, it becomes an ant nest cake with a shape following the baking pan. Generally, the mold used is the same shape as the mold in making *bluder* cake, which is cylindrical in shape with a cavity in the middle.

Figure 35. *Bolu sarang semut*

Based on the geometrical point of view, the shape of *sarang semut* is found similar to the characteristics of a solid of revolution with the basic shape of a curved plane. Through the implementation of interpolation, two algebraic equations are obtained including the quadratic equation for the outer side and the linear equation for the cavity side.

$$f_{outside}(x) = -1.73x^2 + 5.96x - 2.68 \; ; (1.64 \leq x \leq 2.1) \qquad (24)$$

$$f_{cavity}(x) = 0.1x + 0.73 \; ; (1,64 \leq x \leq 2.1) \qquad (25)$$

The results of the rotation of the quadratic and linear equations about the *x*-axis can be figured as follows:
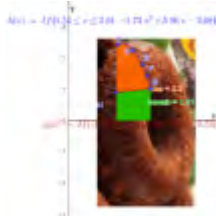

Figure 36. Plotting point and interpolation at image of *sarang semut*

Figure 37. Revolution of two functions with washers method

The integral model for its volume uses the ring method (Varberg et al., 2006). The cake has a cavity or hole in the middle so that the volume model can be written as follows:

$$V_{SarangSemut} = V_{outside} - V_{cavity} = \pi \int_{1.64}^{2.1} (f_{outside})^2 - (f_{cavity})^2 dx \qquad (26)$$

The volume of solid of revolution by shells method
Pisang ijo

Pisang ijo (Green Banana) is very popular as one of culinary snacks in the region of South Sulawesi. *Pisang ijo* has culturally become a popular culinary icon for the Buginese and Makassareses communities. Moreover, *es pisang ijo* is one of Makassar's local culinaries registered as intellectual property rights from Ministry of Tourism of the Republic of Indonesia (Perwira & Haming, 2017). However, there are no accurate sources regarding the origin of *pisang ijo*, but the green color for Makassarese people in the aspect of food is assumedly sacred, and gives a cool and peaceful feeling.

Figure 38. The shape of *pisang ijo*

Figure 39. The slices of *pisang ijo*

Based on the basic shape of *pisang ijo*, the model of VOSR is found. The methods applied to find the model are the disk and the cylindrical shell methods. The shape of the banana as the basic material makes the *pisang ijo* align with the basic character of solid of revolution.

In this study, a set of points has been constructed in such a way as to represent the basic shape of omelette and banana layers. Furthermore, through the interpolation method, the following are two functions obtained:

$$f_{total}(x) = -0,02x^4 + 0.25x^3 - 1.84x^2 + 6.97x - 8.74 \; ; (2.27 \leq x \leq 19.46) \qquad (27)$$

$$f_{banana}(x)$$
$$= 0.01x^5 - 0.02x^4 + 2.56x^3 - 19.38x^2 + 75.88x$$
$$- 118.37 \; ; (4.48 \leq x \leq 17.44) \qquad (28)$$

Two functions rotate about the *x*-axis using a surface with *GeoGebra*. The following are figures:
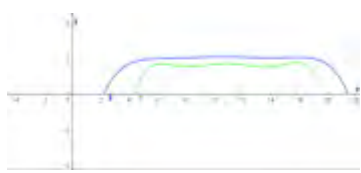

Figure 40. The representation function of *pisang ijo*

Figure 41. The rotation of two layers

The shape of bananas as a basic factor of solid rotation can be explored by disk method. Otherwise, omelette covered in bananas can be explored using the ring method approach, as the difference between the total volume and the volume of bananas is expressed in the following formula:

$$V_{total} = \pi \int_{2.27}^{19.46} (f_{total})^2 \, dx \qquad (29)$$

$$V_{banana} = \pi \int_{4.48}^{17.74} (f_{banana})^2 \, dx; \qquad (30)$$

$$V_{tepung} = V_{tot} - V_{pis} \qquad (31)$$

Exploration and application of the cylindrical shell method can be viewed by taking a cylindrical piece of green banana. The physical model of the flour omelette covering the banana can be illustrated in the following figures:
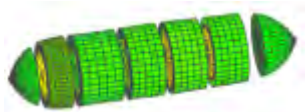

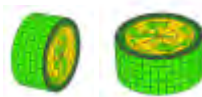**Figure 42**. The pieces of *pisang ijo*

Figure 43. Visuaitation of a pieces of *pisang ijo* by horizontaly and vertically

Figure 44. The layer of green omlete without banana

Figure 45. Overlaid omelette visualization

The integral model for determining the volume of flour omelet in the selected pieces can be represented by tube shell method.

$$\Delta V_{pieces\ of\ omlete} = 2\pi f(x)h\left(f_{tot}(x) - f_{banana}(x)\right); h = x_{i+1} - x_i \qquad (32)$$

$$V_{tepung} = 2\pi \int_{x_i}^{x_{i+1}} \left(f_{tot}(x) - f_{banana}(x)\right) dx \qquad (33)$$

Onde-onde

Onde-onde has a basic shape like a ball, although it doesn't use a mold like in the previous descriptions of making cakes or food. In cultural perceptions, onde-onde for Buginese ethnic groups is a food served at special ceremonies, such as *mappakulawi* (aqiqah), *mappano lopi* (first boat drop off to sea), *mappettuada'* (engagement ceremoni), *mappacci*, *mappenre bola beru* or *ambaung balla'* (building house). It is similar with the results of interview conducted by Hapi' and Nurdeni in Bulukumba. It explains that the making of *onde-onde* don't use a mold, but by hands directly and rolling it. *Onde-onde* is a traditional cake made from glutinous rice flour and processed by boiling. In addition, the process of making *onde-onde* also requires brown sugar, white grated coconut, and clean boiled water. The small sphere is made by processing the shape using rolled and kneaded ways with the palm of the hand. This circle is flattened and given a piece of brown sugar in the form of a dice. Hereafter, the flour dough is rolled back using the palm of the hand so that the dough wraps around the sugar pieces. Further, the spheres are reboiled. After the process of boiling, the brown sugar inside is no longer in the form of diced, because it has been rounded and boiled so that it becomes thick. Because of using the basic ingredients of solid flour, palm sugar and coconut, *onde-onde* is believed to be able to give people a clear purpose and goodness (Nahriana & Pangki, 2019).

Figure 46. The Process of making
Source: https://asianfoodnetwork.com

Figure 47. Boiling Proces

Figure 48. *Onde-onde*

In previous studies, the geometry of *onde-onde* was investigated for obtaining the adjustment to the properties of spherical geometry (Huda, 2018; Pathuddin & Raehana, 2019). In their study, mathematical aspects in *onde-onde* focus on modeling functions showing the outer shape. The resulting function is rotated through the *x*-axis. Furthermore, the volume model is made using two methods, namely the ring method and the spherical shell method made as the development of the shells method.

Furthermore, the shape of sugar after being boiled is assumed in the form of a sphere and follows the shape of cover, so that its volume is smaller than the volume of the flour that surrounds it. A mathematical model of *onde-onde* cake is distinguished from the blanket model with the brown sugar model in the middle.

The mathematical model is formulated without an interpolation technique. However, it is assumed that both cover of *onde-onde* and brown sugar are represented by parabolic equation, showing $f_1(x)$ for flour as a cover of *onde-onde* and also $f_2(x)$ for thick brown sugar. The following equation is:

$$f_1(x) = \sqrt{1 - (\text{祇} - 1)^2}; 0 \leq x \leq 10 \tag{34}$$

$$f_2(x) = \sqrt{0.75 - (x - 1)^2}; 0 \leq x \leq 10 \tag{35}$$

According to the geometry computational using *GeoGebra* for simulating the revolution of two parabolic functions around the *x*-axis, the physical model of *onde-onde* is obtained as shown in the following figure:
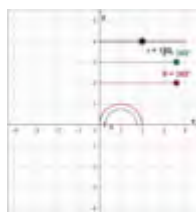

Figure 49. *Onde-onde* served

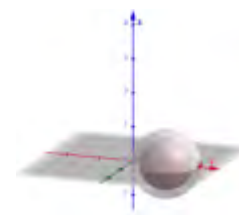**Figure 50**. A couple of parabolic equation

Figure 51. Revolution of two parabolic equations

Basically, the volume model of *onde-onde* can be written using $V_{bola} = \frac{4}{3}\pi r^3$ as the general spherical volume formula. However, the volume model is inthe integral approach of disk method. In the VOSR, the volume model of each layer can be written as follows:

$$V_{palmsugarball} = \pi \int_{a_2}^{b_2} (f_2(x))^2 \, dx \tag{36}$$

$$V_{cover} = \pi \left[\int_{a_1}^{b_1} (f_1(x))^2 \, dx - \int_{a_2}^{b_2} (f_2(x))^2 \, dx \right] \tag{37}$$

Furthermore, the standard equation of the circle used can be shown that if the standard equation of the circle is reintegrated using the disk method, it will obtain the volume of a sphere in general as the following equation:

$$x^2 + y^2 = r^2 \Leftrightarrow y = \sqrt{r^2 - x^2} \tag{38}$$

$$V_{onde-onde} = \pi \int_{-r}^{r} \left(\sqrt{r^2 - x^2} \right)^2 \, dx == \frac{4}{3}\pi r^3 \tag{39}$$

The shells of sphere

In addition, the volume of sphere can also explored by calculating the volume of spherical shells at a certain thickness. In this study, each layer of the spherical skin can be opened and overlaid with a thickness Δr and with an area of $L_{selimut} = 4\pi r^2$. Thus, the volume of each layer and the total can be written as follows :

$$\Delta V = Lselimut_i \cdot \Delta r \qquad (40)$$

$$V = \sum_{i=1}^{n} 4\pi r^2 \cdot \Delta r \qquad (41)$$

If the thickness of each layer is made thinner, the following integral model is obtained:

$$V = \lim_{\Delta r \to 0} \sum_{i=1}^{n} 4\pi r^2 \cdot \Delta r = \int_{0}^{r} 4\pi r^2 \; dr = \frac{4}{3}\pi r^3 \qquad (42)$$

Buginese and Makassarese traditional foods as a contextual learning media

This research is only focused on mathematical modeling of the physical shape of traditional foods using the concept of interpolation for polynomial models and integrals for volume models. The results of this exploration have not been implemented in mathematics learning based on local culture. However, contextual learning can be designed by demonstrating the process of plotting points, generating polynomials, and visualizing a solid of revolution. Through contextual learning, students acquire a learning process involving cultural attributes. It can provide a comprehensive understanding for students (Pathuddin et al., 2021). Based on this research, exercises and problems can be developed as contextual learning for college students by using Buginese local food as a medium and *GeoGebra* as a tool.

Concept of interpolation

Contextual learning can be implemented on the topic of Interpolation. Technically, precise images are taken on contextual objects and then processed in the *GeoGebra* application. *GeoGebra* interpolation is functioned by plotting the boundary points, and generating the equation using the `fitpolynomial` command. For example, the assignment instructions to students can be shown in the following assignment instructions:
1. *Find the some cakes that match the characteristics of solid of revolution*
2. *Create a polynomial model on this cake using the concept of interpolation on GeoGebra!*

Concept of volume of solid of revolution

Based on the result of polynomial functions, it can be simulated in a rotating object through the rotation process of the generated function. This experiment can be explored with the aid of *GeoGebra* so that in the learning process of the Integral application, students can be given assignments to explore VOSR. The assignment given can be designed through the following instructions:
1. *Simulate the polynomial into a solid of revolution object implemented in GeoGebra !*
2. *Determine the integration model that represents the volume of the selected cake!*
3. *Solve the definite integral model by using the basic rules for integrating polynomial!*

Conclusion

The finding of this research mathematically discloses the application of the concept of interpolation and simulation of rotating objects by *GeoGebra* is very powerful in modeling polynomial functions and VOSR on the shape of Buginese and Makassarese traditional

foods. The application of interpolation with *GeoGebra* shows that the basic shape equation can be represented by a constant function, a degree-1 polynomial, a degree-2 polynomial, or a degree-*n* polynomial. Furthermore, in the simulation of rotating solid objects, they are classified into rotation about the *x*-axis, the *y*-axis, and the straight-line axis by linear equations. Certainly, the direction of rotation of each function affects the shapes and the volume model with the integral model. In addition to the direction of rotation, the volume model also depends on the method used, and the selection of method depends on the geometric characteristics. In this case, they are categorized in the slab, disk, washer, and cylinder shell method groups. Finally, the volume model of each type of food is represented in definite integral relying on the boundary, polynomial models, direction of rotation and four types of methods in the volume of solid.

Buginese and Makassarese traditional foods are unique in the perspective both culture, and education. Culturally, these traditional foods can be categorized as a part of food group served in religious events, traditional wedding ceremonies, or culinary snacks. Based on the discussion, this research finds that the geometric shape of each type of cake, is influenced by the shape of molds, the ingredients and directlyby hand.

The findings of this research are expected to be a source of mathematics learning for students. The diversity of shape of traditional food conforming with the characteristics of solid of revolution are also expected to help students understand the distinction of concept of slabs, disks, washers and shells. This research can be also used as a basis in developing further research such as in exploring the effectiveness of using these media in building students' creative and critical thinking skills.

Acknowledgment

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