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Ethnoscience Study: Chemistry Aspects of the Local Practice of Mango (*Mangifera Indica L.*) Fruit Ripening with Carbide for Contextualized Chemistry Learning

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ABSTRACT

This study aims to explore the chemistry aspects of local practices on Mango (Mangifera indica L.) fruit ripening process with calcium carbide to be integrated in contextual chemistry learning. Literature studies from scientific journals related to natural and artificial fruit ripening were comparatively analyzed in relation to local knowledge and scientific concepts to identify potential integration into science learning (especially chemistry). The results showed that the integration of natural science with local practices, such as fruit ripening, is an innovative way to teach chemical kinetics in a contextualized way. The study of the fruit ripening process can help students understand chemical concepts, especially chemical kinetics, in a more relevant and practical context. Thus, chemistry learning is not only limited to theory and laboratory experiments, but also includes real applications that are relevant to the lives of students and society.

Keywords: Calcium carbide, ethnoscience, fruit ripening, chemistry learning, *Mangifera indica L.*

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1. INTRODUCTION

Chemistry is a field of science that studies the composition, structure, properties, and changes of matter that requires various forms of representation (macroscopic, sub-microscopic, and symbolic) to understand it, thus various challenges in understanding chemistry are often experienced by students for several reasons, including (i) many concepts in chemistry are very abstract (such as atomic structure, electron orbitals, and interactions between molecules, which cannot be seen or directly felt); (ii) transitions between representations (e.g., from submicroscopic to symbolic representations, or from symbolic to macroscopic); and (iii) students' lack of math skills (Sanchez, 2021; Derman & Ebenezer, 2020; Mekwong & Chamrat, 2021). In terms of overcoming material difficulties in learning chemistry (such as abstraction of concepts, application of theory to practice, connection with real life, learning deficiencies and resources), educators must have strategies to overcome these difficulties, such as learning strategies with visualization and concrete models, stepwise approaches, integrating with real experiences, differentiated teaching, representation transition exercises, and strengthening mathematical concepts (Dewi et al.., 2021; Avargil & Piorko, 2022). By adopting a more inclusive and supportive approach, educators can help students overcome difficulties in understanding chemistry as a multi-representational science, increase student confidence, and ultimately improve student learning achievement in chemistry.

Based on the previous explanation, one of the strategies to help students' difficulties in learning chemistry is that educators need to present examples from everyday life that are relevant to students to make chemical concepts more real and relevant (Rahmawati et al.., 2022; Avargil & Piorko, 2022). For example, integrating local wisdom or local practices that exist in the community into chemistry learning can make the material more interesting and relevant to students, by connecting chemistry concepts to the context of everyday life that is familiar to them. The potential of promoting local wisdom or local practices has also been proven by several studies that show success in achieving learning objectives. Arifiani et al. (2019) and Osawa (2023) show that local wisdom and practices in communities have proven over centuries to ensure sustainability. Risdianto et al. (2019) and Sumarni & Kadarwati (2020) examined that learning with cultural context and local practices succeeded in improving students' critical thinking skills. Furthermore, Astuti et al. (2021) showed that the integration of local wisdom and local practices improved students' problem solving skills.

Therefore, connecting chemistry concepts with applications in daily life through local wisdom and local practices not only helps students understand the material better but also nurtures appreciation for their cultural heritage and also develops a conservative attitude that encourages changes to local practices that have a negative impact. This creates more meaningful and enriching learning, motivating students to be more engaged and enthusiastic in learning chemistry. This research aims to explore local Sundanese practices related to the process of ripening mango fruit with carbide is often carried out in Majalengka Regency as a means of contextual chemistry learning. Local practices in the process of ripening fruit with carbide offer a rich context for teaching chemistry concepts in a more applicable and interesting way for students. The research topic on artificial fruit ripening was raised in this study because it has a connection with one of the chemistry materials such as chemical kinetics. Chemical kinetics is one of the important chemistry materials to learn because this material has many connections to everyday life and has a role in improving students' critical thinking skills. Although chemical kinetics is closely related to our daily lives, there are still many students who have difficulty in learning it and have low learning outcomes. This is because reaction rate is a complex material because of the combination of abstract knowledge in the form of reaction rate equation, reaction order, factors affecting reaction rate, and collision theory.

The preliminary study found that there are not many studies that specifically examine the local practices of Sundanese culture in the context of chemistry learning, especially the process of ripening mango fruit with carbide. This research seeks to integrate local practices, which are often overlooked in modern educational curricula, particularly in chemistry learning and provide a basis for the development of learning materials and curricula that are more contextualized and enjoyable for students. As such, this research can contribute to innovation in chemistry teaching methods, making it more interesting and relevant to the younger generation as learning materials are linked to real life.

2 RESEARCH METHOD

This research is a descriptive qualitative research. The research was conducted in the community of Majalengka Regency, West Java, Indonesia. This location was chosen due to the widespread local practice of using synthetic materials in mango fruit ripening in the area. This research uses a qualitative descriptive approach, which aims to describe and analyze the phenomenon of using synthetic materials such as calcium carbide (carbide) in ripening mango fruit in Majalengka Regency, as well as its implications for scientific aspects. The data collected is secondary data which includes literature studies from scientific journals related to natural and artificial fruit ripening. The number of articles reviewed was 25. The data were then analyzed by comparing local knowledge and scientific concepts to identify the potential for integration into science learning (especially chemistry) through identification of the main themes that emerged, especially related to aspects of science in the context of mango fruit ripening with carbide.

3. RESULTS AND DISCUSSIONS

3.1. Science Aspect of the Fruit Ripening Process

Fruit ripening is a genetically coordinated process characterized by a series of physiological (such as color and texture), biochemical (such as increased respiration, chlorophyll degradation, biosynthesis of carotenoids, anthocyanins, essential oils), organoleptic (such as flavor and aroma), and organoleptic (such as taste and aroma) changes, leading to the development of soft, edible ripe fruit with desirable quality attributes due to increased production or synthesis of ethylene in fruit tissues (Prasanna et al.., 2007).

Naturally, ethylene (C_2H_4) is contained in fruits (called endogenous ethylene). Ethylene is a phytohormone that triggers many cellular metabolic events albeit in small amounts including ripening and senescence processes. This endogenous ethylene is synthesized autocatalytically at levels as low as 0.01 μl L^{-1} and 0.05 μl L^{-1}. The biosynthetic pathway of endogenous ethylene as a hormone that initiates fruit ripening naturally is illustrated in **Figure 1**. First, S-adenosylmethionine (SAM) is converted to 1-aminocyclopropane carboxylic acid (ACC) by the enzyme ACC synthase. At the beginning of fruit ripening, the expression of several ACC synthase genes is activated, resulting in increased ACC production. In most cases, it is the activity of ACC synthase that determines the rate of ethylene biosynthesis. ACC is then oxidized to ethylene by ACC oxidase (Prasanna et al., 2007; Tharanathan et al., 2006; Palafox-Carlos et al., 2012).

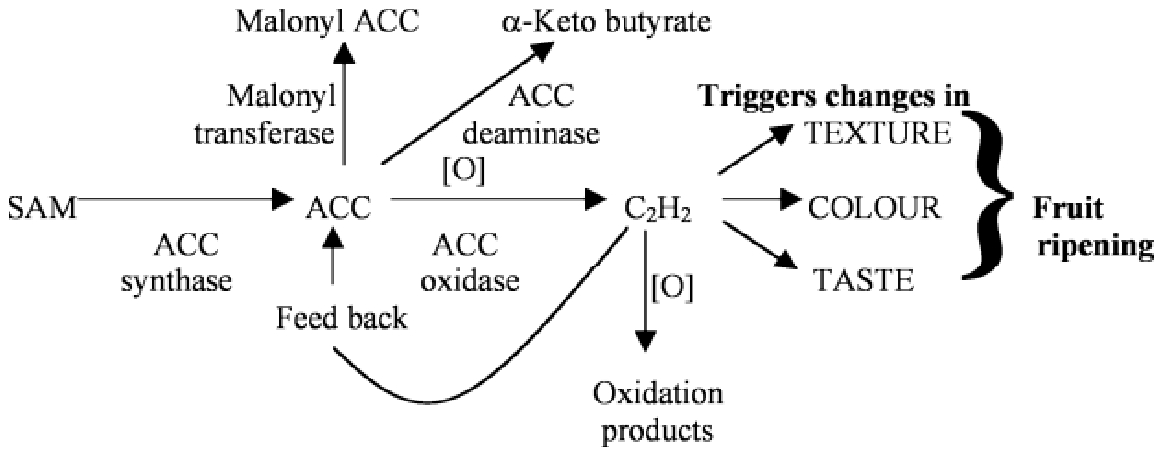

Figure 1. Ethylene biosynthesis pathway (adopted from Prasanna et al., 2007).

Artificial ripening of fruits is also often a popular practice among farmers and fruit sellers due to the huge demand for fruits and vegetables. As a result, there is great pressure on the industry to supply fresh fruits and vegetables to consumers. This pressure on the industry may encourage the use of fruit ripening agents and preservatives (Liu et al., 2022). For example, due to today's lifestyle of instant and fast, rapid ripening of fruits through synthetic materials has become a popular trend. One of the synthetic materials used for fruit ripening is calcium carbide (CaC_2) as practiced by the people of Majalengka Regency, West Java, Indonesia.

The fruit ripening process can change the physiological, biochemical, and organoleptic characteristics of the fruit. The physiological and organoleptic conditions of the fruit are the most identifiable characteristics when the fruit ripens, illustrated in **Figure 2**. These changes in mango mainly include increased respiration and ethylene release, changes in cell wall microstructure and textural softening, gluconeogenesis, acid decomposition, pigment synthesis and accumulation, color changes, and synthesis and accumulation of characteristic aromatic compounds (Hussain et al., 2024).

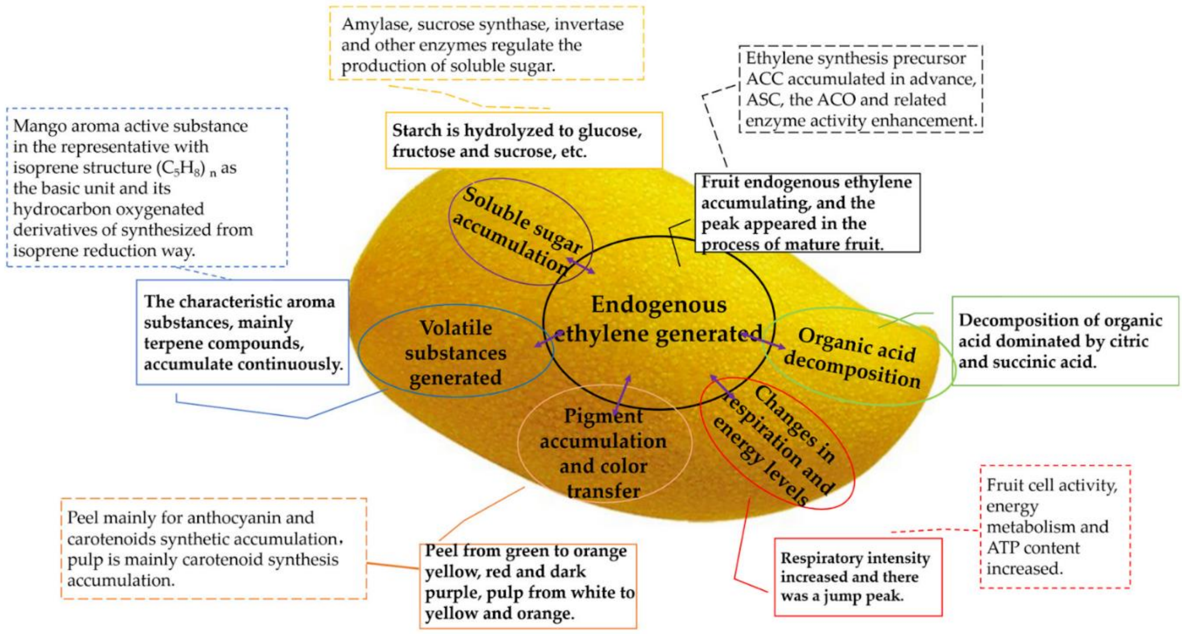

Figure 2. Main changes in mango fruit physiology during ripening (adopted from Liu et al., 2022).

The physiological changes illustrated in Figure 2 occur when certain enzymes are activated, initiating reactions that lead to fruit ripening or even senescence. Some of the enzymes that are activated and the reactions that occur during fruit ripening to senescence are summarized in Table 1 (Paul and Pandey, 2009).

Table 1. Important enzymes and reactions associated with fruit ripening (Paul & Pandey, 2009).

Enzym	Reaction	Implication
Polygalacturonase	Hydrolysis of glycosidic bonds between adjacent polygalacturonic acid residues in pectin	Tissue softening
Pektin Esterase	Hydrolysis of galacturonan ester bonds in pectin	Tissue strengthening
Klorofilase	Phytol ring cleavage of chlorophyll	Loss of green color
Selulase dan Hemiselulase	Cell wall hydrolysis	Loss of texture
Amilase	Hydrolysis of amylase and amylopectin	Loss of texture and increased sweetness due to sugar production
Polifenol oksidase, katalase, peroksidase	Fenolic oxidation	Formation of dye precursors and polymers leads to unwanted browning
Lipase	Lipid hydrolysis	Hydrolytic rancidity
Lipoksigenase	Lipid oxidation	Production of bad taste and odor
Protease	Protein Hydrolysis	Loss of nutritional value and increased or decreased digestibility
Ascorbic acid oxidase	Ascorbic acid oxidation	Loss of nutritional quality

3.2. Science Learning Materials Accommodated by the Local Practice of Ripening Fruit with Calcium Carbide (Artificially)

Nowadays, a large number of fruits found in the market are ripened by artificial methods due to the need for consumption of large quantities of fresh fruits and vegetables, but due to the perishable nature of fruits and vegetables, post-harvest losses cannot be controlled. As a result, there is great pressure on the industry to supply fresh fruits and vegetables to consumers (Hussain et al., 2024). The pressure on the industry encourages the use of non-food grade ripening and preservatives such as the use of carbide in mango ripening, which is a local practice in Majalengka District, Indonesia. In addition, the abundant production of mangoes of different varieties (see **Table 2**) encourages farmers to use carbide especially during the harvest season for ripening because the huge volume of fruit must be sold immediately to avoid damage or loss (Ashgi & Pancoro, 2021).

Table 2. Varieties and Differences in Physical Characteristics of Mangoes Produced in Majalengka Regency (Ashgi dan Pancoro, 2021)

Variety	Shape	Size	Peel Color	Flesh	Color	Texture
Gedong Gincu	• Oval	Not too big	Green in color if not ripe, will turn yellow when ripe	• Thick • Soft • Orange in color	Sweet and distinctive aroma	Dense
Manalagi	Round	Not too big	Green in color if not ripe, will turn yellow when ripe	• Thick • Soft • Orange in color	Sweet like a sweet fragrant mango, but has the texture of a golek mango, which is dense and fibrous.	Dense with a sweet flavor and distinctive aroma
Arumanis	Elongated with a smaller size	Small	Dark green in color with white spots coated in some sort of waxy coating	Thick, soft, and yellow in color with a fibrous texture, lots of water and a sweet taste.	Sweet and creamy and does not have a sour taste that will create a fresh impression when eating the fruit.	Fibrous, contains a lot of water
Cengkir	Elongated with a smaller size	Small	Green color when young and turns	Thick, soft, and bright orange in color	Sweetness with a distinctive	Dense with a sweet taste and

Variety	Shape	Size	Peel Color	Flesh	Color	Texture
			yellow when the fruit is ripe		aroma is characteristic	distinctive aroma
Golek	Slightly elongated and has greenish-white spots	Medium	Green in color when young and turns brown when ripe	Thick, soft, and bright orange in color	Sweet fresh and fragrant	Dense with a sweet taste and distinctive aroma

The use of carbide in fruit ripening is a long-standing practice in artificial fruit ripening. The rapid ripening process of mangoes, with the use of carbide, was found to be associated with the production of exogenous acetylene gas (as shown in equation 1), as a result of the moisture obtained by the carbide from the fruit surface, and triggers the ripening process. The use of carbide for fruit ripening in villages in Majalengka, as in many other parts of Indonesia, is most likely the result of knowledge transferred through social and economic interactions and local experimentation over time as the use of carbide as a way to artificially ripen fruits is not knowledge derived from traditional practices, but rather the result of the invention and spread of modern technology. Studying how village communities in Majalengka and other regions adopted and adapted to the use of carbide for fruit ripening requires an approach that considers economic, social and technological factors and how these factors interact with each other in the local context. For example, the use of carbide for fruit ripening is known by villagers when there is interaction and knowledge exchange between people who are outside the village or migrate. The existence of farmers who dare to experiment with new methods and share the results with neighbors and family is also a catalyst for the spread of new knowledge. Furthermore, the presence of farmers who are members of the community who have attended formal training or education in agriculture may have gained knowledge about various modern farming techniques, including the use of carbide. However, it should be underlined that carbide is a hazardous chemical as exposure to carbide dust or powder can cause skin, eye and respiratory tract irritation. Therefore, the practice of artificially ripening fruits (with the addition of chemicals such as carbide) is actually unhealthy, toxic, and prohibited because it has the potential to harm health (Rahman et al., 2021).

$$CaC_{2(s)} + 2H_2O_{(l)} \rightarrow C_2H_{2(g)} + Ca(OH)_{2(s)} \quad (1)$$

Figure 3 is the steps of the mango fruit ripening process with carbide carried out in Majalengka Regency.

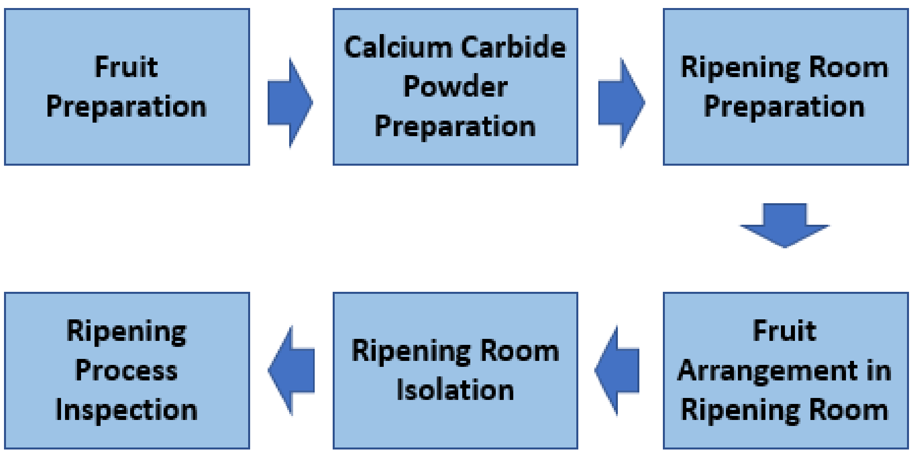

Figure 3. Fruit ripening stages with calcium carbide addition (Hussain et al., 2024).

The stages of fruit ripening in **Figure 3** are explained in detail as follows:

(i) Fruit preparation
The fruits selected are those that have reached their maximum size but are not yet ripe (green and firm) and in good condition (without wounds or damage).

(ii) Carbide preparation
The carbide used is usually well-packaged carbide to minimize ineffective use because the carbide has been exposed to moisture. In addition, the carbide used must usually be pulverized first.

(iii) Ripening room preparation
Ripening container can be boxes, drums, or specialized rooms that are ventilated, controlled, clean, and dry.

(iv) Placement of carbide at the bottom of the container or ripening chamber

(v) Fruit arrangement
The fruits are arranged in the container or ripening room in a manner that is not overly stacked.

(vi) Close the ripening container tightly
After some time, usually 24-48 hours depending on the type of fruit and conditions, the ripening room is opened for ventilation. Then, the fruit is checked to assess whether it has reached the desired level of ripeness.

The use of carbide to ripen mangoes and other fruits can be an interesting topic in science teaching, especially related to chemistry material on chemical kinetics. The use of carbide as a synthetic material to accelerate ripening is a practice that can be explored in education, especially through inquiry learning methods in a contextual teaching context that aims to develop students' understanding of socio-critical issues and problem-oriented approaches in science. In this lesson, students invited to learn how carbide is used in the mango fruit ripening process. Mango ripening with carbide is a practice that can be explained through chemistry concepts (such as chemical kinetics) and other natural science concepts. Integrating the local practice of ripening fruit with carbide into chemistry learning materials offers a unique opportunity to explore reaction rate concepts. **Table 3** is a concept analysis on each stage of ripening with carbide.

Table 3. Explanation of indigenous science, scientific science, and analysis of science concepts in the process of ripening mango fruit with carbide.

Ripening Stages	Indigeneous Science	Scientific Science	Science Concepts Involved	References
Preparation of mango fruit by selecting good fruit with no wounds	The selection of mangoes in good condition (without wounds and damage) is done to prevent the rotting process. In addition, wounds or damage can cause some parts of the fruit to ripen faster than others, resulting in inconsistent quality.	Fruit with wounds have the potential to lose water content and nutrients. As water drains out of the wound on the fruit, the area around the wound may become more moist. A moist environment favors the growth of microorganisms as many of them require moisture to survive and reproduce.	**The concept of osmosis:** the movement of water from areas with lower solute concentrations (e.g. sugars and minerals inside cells) to areas with higher solute concentrations (e.g. the outer area of cells damaged by wounds).	(Abu et al., 2021)
		Wounds on the fruit cause nutrients to	**Concept of Diffusion:** movement of substances	(Abu et al., 2021)

Ripening Stages	Indigeneous Science	Scientific Science	Science Concepts Involved	References
		diffuse more easily to the surface making it more accessible to microorganisms	from areas of high concentration to areas of low concentration	
		With nutrients more readily available and moist conditions ideal for microorganisms, microorganisms can grow and multiply faster and eventually the rapidly multiplying microorganisms produce enzymes that break down fruit components, resulting in decay and changes in the texture, color, and aroma of the fruit.	**Concept of macro environmental changes and microorganism growth**	(Abu et al.., 2021)
Preparation of carbide in powder form and packed to avoid contamination to the fruit.	The carbide used is carbide in powder form. This is intended for more economical and efficient use.	Grinding the carbide increases the surface area of the particles. This allows water to access more parts of the carbide thus accelerating the acetylene formation reaction. The larger surface area facilitates more efficient contact between the reactants leading to faster and more even production of acetylene.	• **Concept of Surface Area:** when particles of substance have a larger surface area, the area available for chemical reaction also increases. In the context of fine carbide, the fine particles increase the total surface area that can interact with water (H_2O). • **Concept of Reaction Rate:** The rate of a chemical reaction is affected by several factors, including the concentration of the reactants, temperature, and the surface area of the reactants. By increasing the surface area of the reactants (in this case, carbide), the reaction between CaC_2 and H_2O becomes more efficient. More water molecules can meet and react with the carbide particles in the	(Orisa et al., 2020)

Ripening Stages	Indigeneous Science	Scientific Science	Science Concepts Involved	References
			same amount of time, compared to larger particles with a smaller surface area.	
	The packing of carbide before use in the fruit ripening process is to protect the fruit from direct carbide chemical contamination.	Ethylene precursors such as calcium carbide (CaC_2) are encapsulated for longer availability. In addition, carbide reacts quickly with water (moisture). Therefore, carbide needs to be wrapped or possibly encapsulated so as to provide a continuous supply of acetylene gas, which increases the respiration rate during the ripening process due to the continuous availability of acetylene.	• **Controlled Release Concept:** Encapsulation is the process of packing a substance in a "capsule" which can be a polymer coating, gel, or other material that allows controlled diffusion of the substance out of the capsule. • **Concept of Reaction Kinetics:** Encapsulation affects the kinetics of the reaction between CaC_2 and H_2o. By controlling the rate of CaC_2 to water, a more even and sustained release of acethylene can be achieved. • **Concept of Diffusion**	(Orisa et al., 2020)
Preparation of ripening room	• The container acts as a barrier that protects the fruit from external environmental factors such as pests, dust, and other contaminants during the ripening process. This helps maintain the quality of the fruit during the process. • By covering the fruit and carbide in a container, the process of absorbing acetylene gas by the fruit is facilitated, which in turn	The function of fruit ripening room is to provide a controlled space. By covering the fruit and carbide in a container, the temperature inside the container can be warmer than the temperature of the outside environment. The heat produced from the reaction of the carbide with moisture (water) is also trapped in the container, which helps increase that temperature. Warmer temperatures accelerate the biochemical processes involved in ripening, such as organic acid degradation, sugar synthesis, and changes in color and texture. In addition, by using a container, the	• **Exothermic Reaction**: The reaction between CaC_2 and H_2O is exothermic, meaning it produces heat. This heat contributes to increasing the temperature inside the container, which accelerates the ripening process further • **Thermodynamic Concept**: Enclosing the fruit and carbide in a container creates a more isolated system, in which the heat generated from chemical reactions and heat from the external environment are trapped, causing an increase in temperature. Higher temperatures can increase the rate of chemical reactions, including biochemical	(Dieye et al., 2022)

Ripening Stages	Indigeneous Science	Scientific Science	Science Concepts Involved	References
	triggers the ripening process	acetylene gas produced is trapped and its concentration around the fruit increases, which effectively accelerates ripening. The container ensures that the fruit is evenly exposed to acetylene, supporting uniform ripening	reactions involved in the fruit ripening process. ● **Heat Transfer:** Heat generated from chemical reactions and trapped in the container is transferred to the fruit through conduction, convection, and radiation, causing the fruit to become warmer and speeding up the ripening process.	
Placement of carbide at the bottom of the ripening chamber	Placing carbide at the bottom of a pile of fruit, in a closed container, is effective in accelerating even fruit ripening	Placing carbide at the bottom of the fruit maximizes process efficiency by ensuring that the resulting acetylene gas is evenly dispersed (diffuses from areas of high concentration to areas of low concentration) allowing for uniform ripening	**Diffusion concept**	(Lobo & Montero-Calderon, 2020)
Fruit arrangement	Fruit that is arranged too closely together tends to ripen unevenly, can cause rot in some parts, and reduce overall quality	The fruit ripening process often involves the production of ethylene gas. If the fruit is too close together, these gases cannot be dispersed efficiently, which can result in uneven ripening. Fruit that is piled too high or too densely can restrict air circulation, creating moist conditions that are ideal for the growth of spoilage microorganisms	**Restricted Air Circulation:** Tight stacking of fruit can hinder air circulation. Efficient air circulation is important to distribute ethylene evenly among the fruits, as well as to remove moisture and heat produced by fruit respiration. Without adequate air circulation, ethylene builds up and triggers rapid ripening or spoilage	(Lobo & Montero-Calderon, 2020)
Close the ripening room tightly	The container acts as a barrier that protects the fruit from external environmental factors such as pests, dust, and other contaminants	● Tightly covering the ripening container ensures that acetylene (and/or ethylene) concentrations remain high around the fruit, speeding up the ripening process. It also prevents this	**Concept of Isolation and Environmental Control:** The tight closure helps to create an environment that is isolated from external conditions. This allows better control of environmental factors that affect ripening, such as temperature, humidity, and gas concentration,	(Lobo & Montero-Calderon, 2020)

Ripening Stages	Indigeneous Science	Scientific Science	Science Concepts Involved	References
		gas from leaking to the outside, increasing the efficiency of carbide use. • Controlled and isolated environment helps minimize external variables that might affect the maturation process	minimizing external variables.	

Based on **Table 3**, several concepts of science and chemistry materials are accommodated in the local practice of artificial fruit ripening, including:

(i) Osmosis concept
(ii) Diffusion concept
(iii) Macro-environmental changes and microorganism growth concept
(iv) Chemical kinetics concept (including surface area, reaction rate, and effect of concentration)
(v) Heat transfer concept

The results of this study show that through local practices provide valuable local knowledge to students through integrating with science or chemistry learning resources that are not only theoretical and only refer to book materials, but directly learn from nature and the surrounding environment. In short, local knowledge in chemistry learning relates chemistry concepts to real situations, such as how local people utilize chemicals in their daily lives so that it helps students to understand the relevance of chemistry material to the context of everyday life. In addition, this research also provides an example of active science or chemistry learning because students contextually learn directly from nature and the surrounding environment (real world) which is expected to strengthen students' understanding of chemical concepts. According to Susanti (2017), learning that is integrated with local potential or practice can also provide meaningful experiences to students because students are given the opportunity to be able to improve generic skills through direct or indirect observation in the learning process. Through these observations, learners will be able to use prior knowledge to refer to logic and understand the law of cause and effect in the learning activities that are being carried out.

The implications of this study for teachers include teachers need to consider developing contextual teaching materials that utilize local knowledge or ethnoscience and the need for adequate teacher training related to local knowledge obtained from local potential or local practices or ethnoscience to ensure effective integration in learning. Then, the implication of this study for students is that students have the opportunity to understand the relevance of chemistry concepts in local potential or local practices thus strengthening students' understanding of the concepts learned and students are trained to develop analytical skills because students are invited to critically analyze local practices thus students get a deep understanding.

4. CONCLUSION

This study provides valuable insights for students regarding the application of chemistry in everyday life related to contextual chemistry learning that integrates chemical aspects of local practices in the process of ripening mango fruit with carbide. This study also has the potential to be applied to chemistry learning topics at the high school and university levels related to chemical kinetics which includes chemical reactions, the natural state of reactants to react, reaction rates, and factors that play a role in accelerating reaction rates.

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