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Study on Extending the Lifetime of MASARO Fertilizer and Feed Concentrate Products

Akhmad Zainal Abidin, Agatha Cecilia Hutahaean* & Novita Sari Siregar

Chemical Engineering Department, Faculty of Industrial Technology, Bandung Institute of Technology, Jalan Ganesa 10, Bandung 40132, Indonesia
*Email: agathacecil28@gmail.com

Abstract. Waste is one of the environmental issues that need to be given more attention. In addition, based on the Central Statistics Agency, about 86.5% of Indonesian farmers use inorganic fertilizers. This will lead to environmental and economic problems. The viable option to solve these problems is by applying Masaro (Manajemen Sampah Zero) to enhance the abundant organic waste as organic liquid fertilizer and improve the agricultural industry's productivity. The fertilizer and feed concentrate are made by enzymatically fermenting decomposing waste using the MASARO catalyst through two fermentation stages where the macro nutrient is converted into organic acid on the first stage and continued with the amino acid decomposition on the second stage. An important indicator of the complete fermentation process of both products is pH which is required in the range 3.9 – 4.2 within four weeks. The lifetime of these products is around one year with the condition stored in a shaded location and is not exposed directly to sunlight. Therefore, the implementation of a system that can extend the lifespan of both products is necessary, so that the lifespan is not solely dependent on the storage methods of the products, which can be advantageous for both consumers and producers.

Keywords: *feed concentrate; fermentation; fertilizer; lifetime; masaro; pH.*

1 Introduction

In most developing countries, 40% losses of food occur during harvest and processing step. Ministry of National Development Planning (Bappenas) reports that Indonesia is the second-largest food waster in the world, with 184 kilograms of waste per capita per year. Food loss and waste (FLW) problem has not been handled in an integrated manner. FLW keeps piling up in the landfill and causing many disadvantages in various aspects.

This also has resulted in some significant impacts, such as food insecurity. It pushes people to the brink of starvation. Indonesia is no exception. In fact, 19.4 million people has to suffer from hunger in 2021. This is still far from the government's goal of pursuing the food estate program. To support the realization of food estate, Indonesia has to utilize its natural resources. In addition, about

86.5% of Indonesian farmers depend on inorganic fertilizer. Excessive inorganic fertilizer will lead to environmental and economic problems. It causes soil, air, and water pollutions.

MASARO may be a reliable way to solve the FLW problems by enhancing the abundant FLW as organic liquid fertilizer and improve the agricultural industry's productivity. MASARO is a waste management scheme that can manage waste until there is no residue (zero) by utilizing the waste into valuable products. The main product of MASARO is liquid organic fertilizer (POCI) and feed concentrate (KOCI). This fertilizer (POCI) and feed concentrate (KOCI) are made by enzymatically fermenting decomposing FLW using the MASARO catalyst. MASARO has great potential to be a solution that can solve environmental problems by replacing conventional landfilling techniques and significantly decreasing food loss and waste.

The important indicator of the complete fermentation process of the fertilizer is pH which is required in the range 3,9 – 4,2 within four weeks. In fact, According to the previous experiment done by Fadli & Aslam (2021), the fermented mixture only needed 12 days to reach the desired pH range after production operation was done. When the pH exceeds 5.2, the fertilizer undergoes a color change from pale yellow to blackish. This process signifies the occurrence of a reaction that converts organic acids and amino acids into ammonia. Additionally, the faster the daily rate of pH increases, the quicker the decomposition of organic waste into fertilizer.

Fertilizer and feed concentrate provide a guarantee of usage or lifetime for a period of one year. This usage period is applicable under the condition that the products are stored in a shaded place and are not directly exposed to sunlight. I the storage conditions are not in accordance with the recommendations, the fertilizer and feed concentrate products may experience damage at a faster rate than the provided guarantee. Therefore, in addition to an optimal production system, a system is also required to extend the lifetime of fertilizer and feed concentrate, so that the lifetime is not solely dependent on the storage methods of the products, which can be advantageous for both consumers and producers.

In the production of MASARO fertilizer and feed concentrate, the decaying waste undergoes catalytic fermentation in five phases (Zieminski and Frac, 2012), such as: hydrolysis phase, acidogenesis phase, acetogenesis phase, methanogenesis phase, and aminogenesis phase.

1.1 Hydrolysis phase

In this phase, insoluble polymeric organic compounds, such as carbohydrates, fats, and proteins, undergo hydrolysis. These compounds are hydrolyzed into their respective monomeric compounds, which are more soluble, such as monosaccharides, fatty acids, and peptides.

1.2 Acidogenesis phase

In this phase, acidifying bacteria will decompose the products derived from the hydrolysis of carbohydrates and fats into short-chain organic acids. Peptide compounds, which are the result of protein hydrolysis, will decompose into amino acids. Carbohydrates will decompose into organic acids through several decomposition reaction as presented in Table 1.

Table 1 Type of carbohydrate fermentation and its products

Type of fermentation	Products
Homolactic acid	Lactic acid
Heterolactic acid	Lactic acid, acetic acid, ethanol, CO_2
Propionic acid	Propionic acid, acetic acid, CO_2
Butyric acid	Butyric acid, acetic acid, CO_2, H_2
Mixed acid	Lactic acid, acetic acid, CO_2, H_2, ethanol
2,3-butanediol	2,3-butanediol, formic acid

1.3 Acetogenesis phase

In this phase, short-chain organic acids are consumed by acetate bacteria, resulting in the production of acetate and hydrogen. These organic acids are the products of the acidogenesis phase. The first three phases of this production mechanism occur in stage I of the fertilizer production process. Stage I takes place at a temperature slightly above ambient (with a difference of approximately 1.5^{o}C) within a pH range of 3 to 6. The formation of organic acids is observed from the generated pH profile, while the formation of CO2 and H2 gas is observed from the appearance of foam during the reaction.

1.4 Methanogenesis phase

In this phase, methane gas is produced by methanogenic bacteria using the products from the previous phase, such as acetic acid, H2, CO2, formic acid, and ethanol.

1.5 Aminogenesis phase

In this phase, amino acids are decomposed into ammonia by ammonifying bacteria. Generally, this phase occurs towards the end of stage II in the production process.

2 Material and Methods

2.1 Preparation of Organic Waste

The waste collected from various sources is first sorted based on its type until homogeneous waste is obtained. Subsequently, the waste is finely chopped or shredded using a grinding machine.

2.2 First Stage of POCI and KOCI production

The chopped waste is put into the bioreactor as much as 2 liters. Then, MASARO I catalyst was mixed into the same bioreactor. Water with a total volume of 5 liters is also mixed as a solvent and diluent. All mixtures are then stirred once a day. Characteristics that appear after the reaction begins to run are in the form of gas foam and a thin white layer on the surface of the liquid. The reaction is said to be complete when all the solids have precipitated.

2.3 Second Stage of POCI and KOCI production

The mixing results from the first stage are filtered, accommodated, and the volume is measured. The filtered solid is then squeezed out and the liquid is put into the bioreactor. Water is added until the total volume is 5 times the initial volume of the filtered liquid. Then the mixture is stirred once a day. The reaction is declared complete when the mixture is pale yellow in color and has a yeast odor. After that, the mixture is put into several containers.

3 Result and Discussion

3.1 The Effect of Waste Type on Product Lifetime

The waste that is used in the production of fertilizer and feed concentrate are orange, pineapple, tomato, mango, and cabbage.

3.1.1 Analysis of pH

The pH profile of each waste type for fertilizer production is shown in Figure 1.

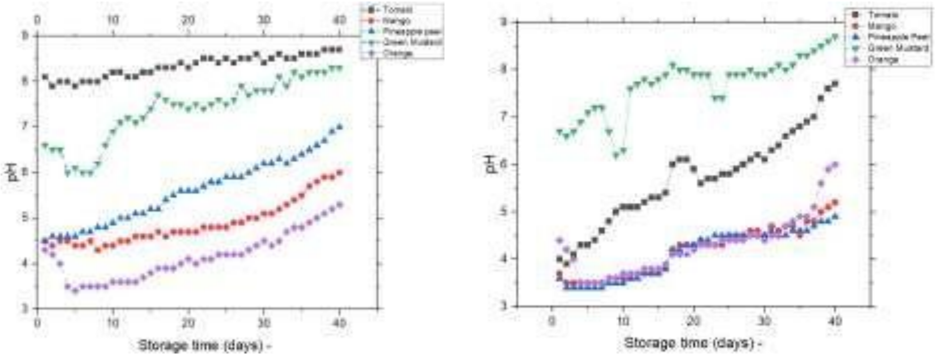


Figure 1 pH Profile of (a)POCI and (b)KOCI

From Figure 1, it is shown that the pH decreased in the first seven days since the production. Afterward, pH began to increase on the next day. The highest to lowest pH of POCI is sequentially generated from tomato, lettuce, pineapple, mango, and orang waste feedstocks. Meanwhile, the highest pH of KOCI is generated from lettuce waste feedstock, followed by tomato, orange, mango, and pineapple. The high pH values indicate that the fermentation process of waste into POCI and KOCI products occurs more rapidly.

Based on data taken from Food Data Central, the macronutrient content of each variant of the waste used is shown in Table 2.

Table 2 Macro nutrient content in each type of waste

Content (%-weight)	Tomato	Cabbage	Orange	Pineapple	Mango
Carbohydrate	6,52	9	21,15	22,95	28,7
Protein	0,88	1,28	0,94	0,54	0,82
Lipid	0,2	0,1	0,12	0,12	0,38

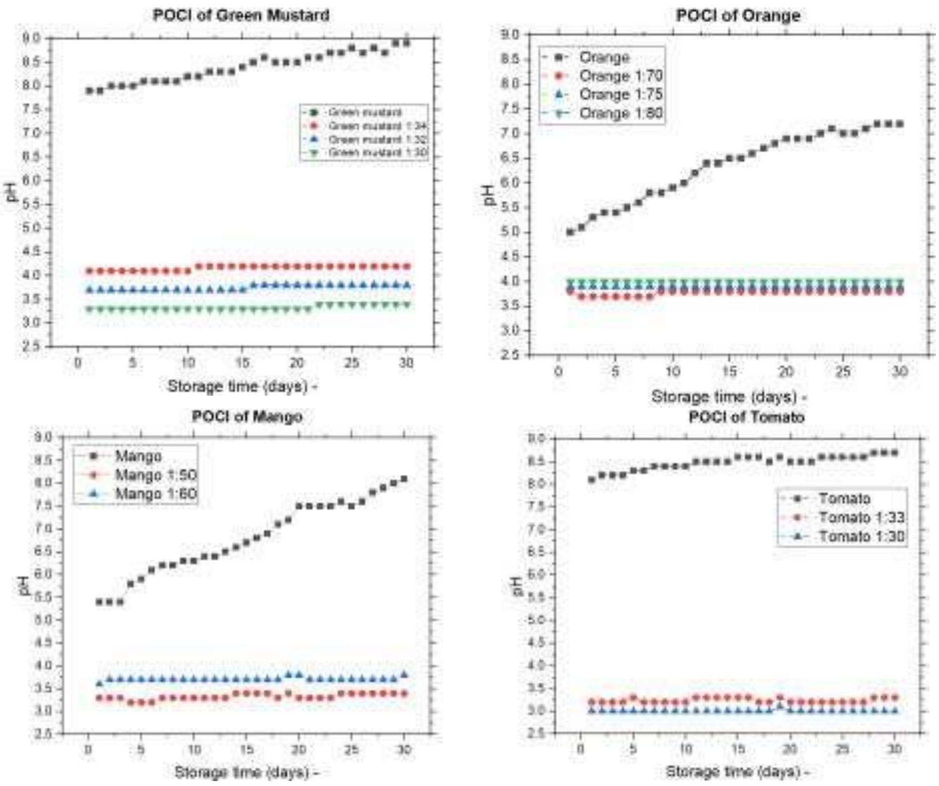
Based on Table 2, it is shown that tomatoes and lettuce have the lowest carbohydrate content. This difference is highly significant compared to the carbohydrate content found in mango, orange, and pineapple. This indicates that the carbohydrate content in the waste feedstock used influences the pH profile of both the fertilizer and feed concentrate. The lower the carbohydrate content, the higher the resulting pH. This aligns with the fermentation mechanism of the fertilizer and concentrate, which states that macro nutrient content, such as carbohydrates, will be decomposed into organic acids. Therefore, the lower the carbohydrate content, the faster the fermentation process occurs, leading to an increase in pH.

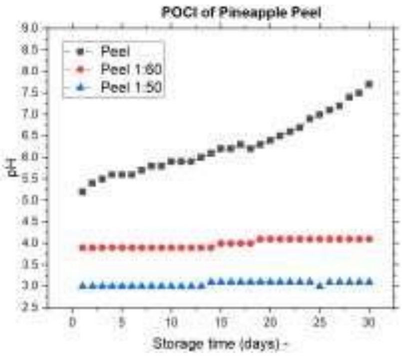
3.2 The Effect of Adding Phosphoric Acid on Product Lifetime

In this experiment, phosphoric acid was added to the fertilizer and feed concentrate solutions that had undergone fermentation. In these solutions, phosphoric acid acted as a buffer solution or pH buffer to maintain the pH of the fertilizer and feed concentrate within the desired range, ensuring that the quality of the products remained in good condition. The effect of phosphoric acid addition was assessed in terms of changes in physical characteristics and pH profiles of the products

3.2.1 Analysis of pH

The variations of waste feed used in this study were orange waste, mango waste, and mustard greens waste. In this experiment, the addition of phosphoric acid was performed at different volume ratios between phosphoric acid and the fertilizer or feed concentrate, based on an initial volume of 1000 mL for the fertilizer or feed concentrate. The pH profiles of each waste feed are presented in Figure 2.

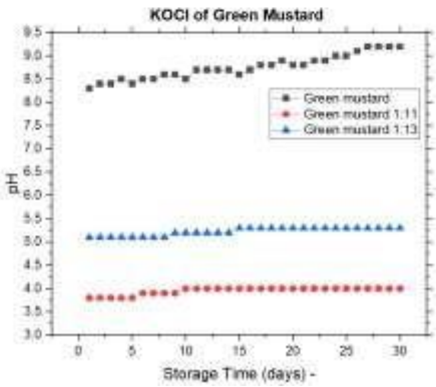


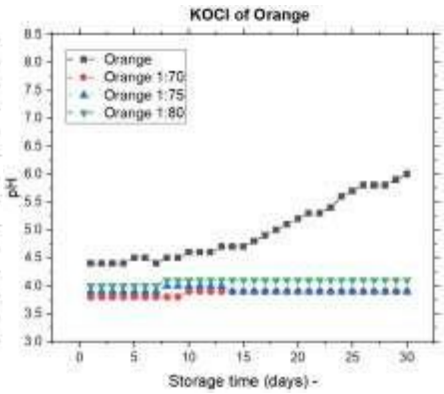


(c) (d)

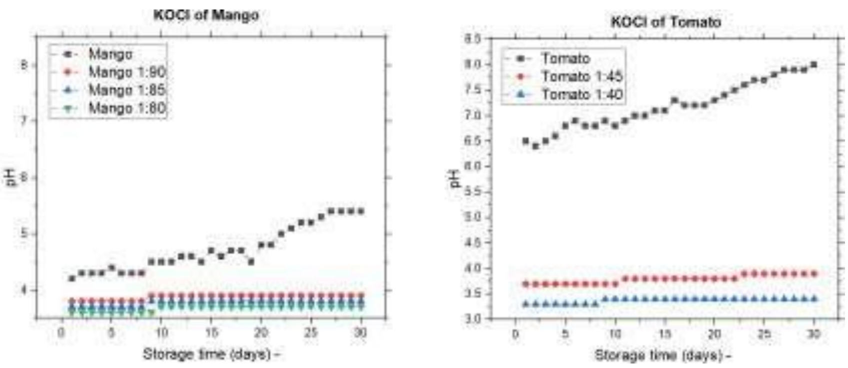
Figure 2 Analysis of POCI pH with and without phosphoric acid

Based on Figure 2, it is shown that the pH of POCI using orange waste as a feed experienced a decrease to pH 3.8 after the addition of phosphoric acid, while the pH of POCI using mustard greens waste experienced a decrease to pH 4.1. The pH profiles of both types of waste feed exhibit relatively constant movement without significant increases or decreases in pH. On the other hand, the pH of POCI using mango waste as a feed experienced a decrease to pH 3.3 and tended to increase after the addition of phosphoric acid. However, on day 27, the pH began to stabilize within the optimal pH range. This increase in pH can be attributed to the fact that mango waste has the lowest protein content compared to the other two types of waste feed. Consequently, the decomposition of proteins into amino acids, which then convert into ammonia, occurs at a faster rate. This aligns with the catalytic mechanism of fermentation in which amino acids turn into ammonia (aminogenesis phase), leading to an increase in pH and color change.

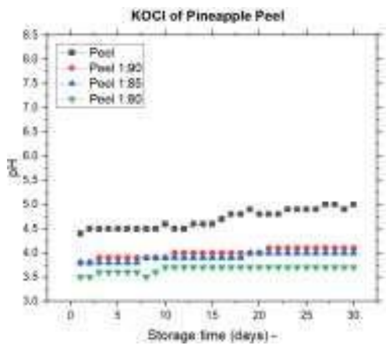




(a) (b)



(b) (d)



(e)

Figure 3 Analysis of KOCI pH with and without phosphoric acid

Based on Figure 3, the pH of KOCI from orange and mango waste feed decreased to pH 3.8. Both waste feed types did not show significant increases and were able to maintain their pH within the optimal range of 3.9 - 4.2.On the other hand, the pH of KOCI from pineapple waste feed decreased to pH 3.7, and from tomato waste feed decreased to pH 3.6. The KOCI from these two waste feed types experienced greater changes in pH compared to the other waste feed types.

Tomato waste and pineapple peel experienced a pH increase of 0.3. This can be attributed to the lower protein content in orange and mango waste compared to the other waste feed types. Based on Figure 3.3, it is shown that KOCI experienced a significant decrease in pH for each waste feed type when phosphoric acid was added. The pH profiles also demonstrate that phosphoric acid successfully acted as a buffer solution as the resulting pH remained relatively constant without significant increases and the pH values were maintained within the optimal pH range.

3.2.2 Analysis of POCI and KOCI Color

The storage duration of POCI and KOCI is 40 days. The analysis of color of POCI and KOCI is presented in Table 3.

Table 3 Color analysis of POCI and KOCI

Name	Gray Value (Without Phosphoric Acid)		Gray Value (With Phosphoric Acid)	
KOCI	103	127	170	171
POCI	125	135	172	176

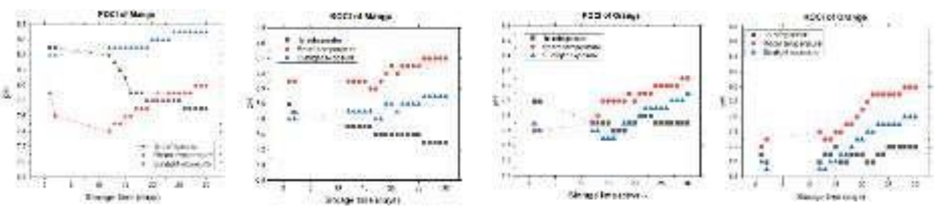
Based on Table 3, the gray value of POCI and KOCI after phosphoric acid addition is not significantly increased as without phosphoric addition. This concludes that the blackening rate of product is slower after phosphoric acid addition. This rate of discoloration serves as an indicator of the formation of NH3 in both fertilizer and feed concentrate during the aminogenesis stage.

3.3 The Effect of Storage Conditions on Product Lifetime

The POCI and KOCI products is stored in three different conditions, which are direct exposure to the sunlight, stored in the refrigerator with average temperature approximately 10oC, and stored in normal conditions (room temperature with no exposure to direct sunlight).

3.3.1 Analysis of pH

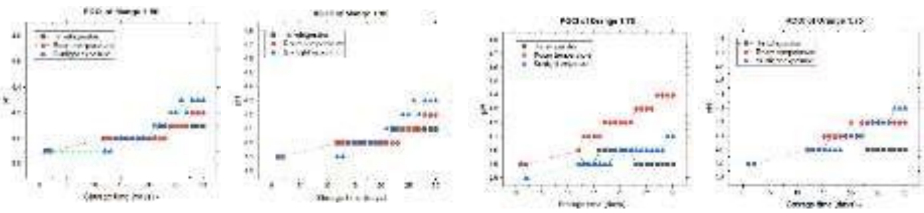
The storage duration of POCI and KOCI is 30 days. The analysis of color POCI and KOCI without phosphoric acid is presented in Figure 4.



(a) (b) (c) (d)

Figure 4 pH Profile of POCI mango (a); POCI orange (b); KOCI mango (c); and KOCI orange (d), without phosphoric acid

The analysis of color POCI and KOCI without phosphoric acid is presented in Figure 5.



(a) (b) (c) (d)

Figure 5 pH Profile of POCI mango (a); POCI orange (b); KOCI mango (c); and KOCI orange (d), with phosphoric acid

Based on Figure 4 to 5, it is indicated that the products stored in the refrigerator exhibit the lowest rate of pH increase compared to other storage conditions. The same thing happened to POCI and KOCI with phosphoric acid addition. This can be attributed to the fact that the products stored in the refrigerator are associated with the lowest temperature. Temperature fluctuations during storage can impact the overall stability of fertilizers. Rapid temperature changes can lead to condensation causing clumping or even degradation of the fertilizer particle that might cause the fertilizer to become less effective. Temperature also has a crucial role in microorganism activity. High temperature can accelerate microbial and enhance the decomposition of organic matters that eventually lead to release nutrient for plant uptake. High temperature can also be able to kill beneficial microorganism.

In the other side, direct exposure to sunlight is proven affect the overall quality of the POCI and KOCI products. Sunlight emits ultraviolet (UV) rays. This UV radiation might cause the degradation the nutrients content in fertilizers. UV radiation can break down or chemically alter organic compounds and sensitive nutrients, such enzymes that can lead to a reduction in the nutrient content and the effectiveness of the products. Sunlight exposure can also accumulate moisture within the POCI and KOCI products. Moreover, sunlight exposure also trigger chemical reactions that can contribute to the change of POCI and KOCI quality, such as the composition, stability, and nutrient.

3.3.2 Analysis of Color

The storage duration of POCI and KOCI is 30 days. The analysis of color of POCI and KOCI is presented in Table 4. Based on Table 3.8, the higher storage temperature and sunlight exposure will fasten the product's blackening. The recommendation to store POCI and KOCI at 8-10°C.

Table 4 Gray value of POCI and KOCI under different storage conditions

Name	Gray value (without hosphoric acid)		Gray value (without phosphoric acid)	
KOCI orange with sunlight exposure	108	162	86	98
KOCI orange in refrigerator	108	94	128	106
Orange KOCI (room temperature, without sunlight exposure)	110	128	118	127
POCI orange with sunlight exposure	66	98	88	100
POCI orange in refrigerator	78	64	132	110
POCI orange (room temperature, without sunlight exposure)	116	118	116	118

Based on Table 4, the gray value of KOCI at a 1:75 dilution exhibited an increase in exposure to sunlight after 30 days, ranging from 86 to 98. Conversely, the gray value of KOCI at a 1:75 dilution decreased from 128 to 106 after 30 days of storage in a refrigerator, as indicated in Figure 4.15. Furthermore, storage at room temperature resulted in an increase from 118 to 127, as depicted in Figure 4.16. Similar trends in gray value movement were observed in POCI at a 1:75 dilution across all three variations shown in Figures 4.17 to 4.19.

The gray value ranges from 0 to 255, with 0 representing white and 255 representing black. Based on the conducted color analysis, it is evident that sunlight exposure and storage temperature influence the rate of color fading in the product. On the other hand, storage at low temperatures can slow down the rate of color fading. This fading rate serves as an indicator of the formation of

NH3 (ammonia) in both fertilizers and feed concentrates, which occurs during the aminogenesis phase. Ideally, aminogenesis should take place when the fertilizer is applied to the plants, not within the packaging. Therefore, storage at low temperatures without direct exposure to sunlight is not recommended to ensure the quality of the fertilizer and concentrate is maintained.

4 Conclusion

Several conclusions can be drawn from this experiment as follows:

1. The type of waste feed used in the production of MASARO POCI and KOCI significantly affects the pH value of the products. The higher the carbohydrate content in the waste feed used, the higher the resulting pH.

2. The addition of phosphoric acid to MASARO fertilizer and feed concentrate can maintain the pH of the fertilizer and feed. The phosphoric acid ratios for POCI with orange, mango, and mustard waste feed, respectively, are 1:75, 1:50, and 1:45. Meanwhile, the phosphoric acid ratios for KOCI with orange, mango, and tomato wastefeed, respectively, are 1:75, 1:90, and 1:60.

3. The direct sunlight exposure causes the increasing of pH and products blackening. The higher products storage temperature can lead to an increase in the rate of pH product.

4. The recommended storage conditions for MASARO POCI and KOCI are storage at temperatures of 8-10°C and without direct exposure to sunlight.

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