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The Role Of Potassium And Calsium In Improving The Quality And Shelf Life Of Tomato (*Lycopersicum* esculentum var. *servo)*

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Abstract

Tomato has the characteristics natural to damage. Damage fruits are caused by destitute of fruit quality and sensory attributes. The loss of tomato production on harvest in developing countries reached 50% due to the long duration of tomato distribution. Servo varieties of tomatoes are in demand by farmers because of their genetic advantages, high productivity, and abundant fruit weights. The shortage of servo varieties of tomatoes is the short shelf life of fruit, which is seven days after harvest. Short shelf life is influenced by fruit thickness and fruit hardness. In improving the quality and shelf life of tomatoes, potassium (K) nutrition plays a role in photosynthetic translocation, strengthens the cell wall, and involved in the lignification process of sclerenchyma tissue. Tomatoes, as climacteric fruits have a high respiration rate influenced by ethylene. Ethylene production can be inhibited by calcium chloride ($CaCl_2$) application by strengthening the cell wall mechanism, cross-link with pectin, and increase the cell wall regeneration can change the texture of the fruit become harder, and it reduces sensitivity to physiological damage. Based on the treatment of this research, the quality and shelf life of servo varieties of tomato is increased.

1. INTRODUCTION

Tomatoes are horticultural products that have the characteristics of being susceptible to damage. In the tropics the rate of damage to post-harvest tomatoes reaches 22% to 78% which is largely due to physiological factors (FAO, 1981). The loss of tomato production from the time of harvest in developing countries reaches 50% due to the duration of transportation in the distribution of tomatoes resulting in delays to be received by consumers and the presence of mechanical injuries to the product (Muchtadi and Sugiyono, 1989).

Tomatoes are commodity that is classified as climatic, so tomatoes still carry out metabolic processes and still maintain a physiological system even though the fruit has been harvested. During those processes, there will be deterioration which result in the fruit becoming rapidly damaged (Normasari and Bambang, 2002).

One of the superior tomato varieties in Indonesia is servo variety. These varieties are in great demand by farmers and the communities because of their genetic advantages, which have the potential yield of an average productivity of 50 tons / hectare, resistance to several plant pests and diseases, quite large fruit weights ranging from 80g and short life 65 days after planting (EWSI, 2013). However, there is one disadvantage of this variety. It has low shelf life which can only survive for 7 days at room temperature storage ranging from 25-27°C (PVTPP, 2013). The low shelf life of servo tomatoes is influenced by the thickness of the meat and the level of hardness of the fruit. It is caused by the component of the cell wall that changes with fruit ripening (Winarno, 1981).

In relation to improve the quality and shelf life of tomatoes, the potassium (K) nutrients have an important role. Potassium is an important macro nutrient for plants because it is directly involved in several physiological processes and plays a vital role in various plant metabolisms. Potassium affects photosynthetic translocation so that it affects the increase in yield and quality of post-harvest fruits and vegetables (Mengel and Kirkby, 1987). Good photosynthetic translocation is also expected to have a positive effect in increasing tomato meat thickness, so that the quality and post-harvest shelf life can be maintained in a relatively longer time. In addition, according to Tucker et al. (1994), stated that the lack of potassium elements resulted in thinner skin and fruit flesh and increased the risk of accelerating decomposition of fruit after harvest, resulting in a short shelf life of fruit. The role of potassium in improving the quality and shelf life of post-harvest tomatoes can also be done by mechanisms to strengthen cell walls and be involved in the lignification process of sclerenchyma tissue (Amrutha et al, 2007).

The character of tomatoes as climates, there is a stimulation process in the fruit which makes the fruit ripens, accompanied by increased respiration and begins with the formation of ethylene gas. High ethylene production in tomatoes can be inhibited by administration of calcium chloride ($CaCl_2$). Calcium chloride ($CaCl_2$) is an ionic compound with high calcium ion content. Sam (1999) reported that calcium is a nutrient in plants by strengthening the cell to make cross bonds with pectin so that a harder texture occurs. Increased cell wall rigidity is expected to improve fruit quality and reduce sensitivity to physiological damage.

Looking at the potential of potassium (K) and calcium ($CaCl_2$) in previous studies that were able to influence the increase in the quality and shelf life of the fruit, research was needed on the application of K and $CaCl_2$ in an effort to improve the quality and shelf life of tomatoes.

2. MATERIALS AND METHODS

Time and Location

This research was carried out on the experimental field of the Faculty of Agriculture - University of Jember - Jember Regency - East Java Province with an altitude of ± 89 m above sea level starting July – November 2018. Variable analysis of fruit quality was carried out in the Jember State Polytechnic BIOSAINS laboratory and Jember University CDAST laboratory.

Research Methods

The experimental design used in this study was Factorial Randomized Compelte Block Design (RCBD) consisting of 2 factors. The first factor consists of 4 levels of treatment and the second factor consists of 5 levels of treatment.

First Factor is fertilization dosage of KCl (K) which consists of 4 treatment levels. K_1 = 50 kg/ha, K_2 = 100 kg/ha, K_3 = 150 kg/ha, K_4 = 200 kg/ha. Reference to treatment: Amisnaipa *et al* (2009).

The second factor is concentration of solution $CaCl_2$ (C) which consists of 5 levels of treatment levels. C_0 = 0 % (Aquadest), C_1 = 1,5 % (15g $CaCl_2$ / l aquadest), C_2 = 3 % (30g $CaCl_2$ / l aquadest), C_3 = 4,5 % (45g $CaCl_2$ / l aquadest), C_4 = 6 % (60g $CaCl_2$ / l aquadest). Reference to treatment: Daundasekera et al (2015).

There were 20 combinations of treatments; each combination of treatments was repeated 3 times, so that 60 experimental units were obtained. Factorial RCBD randomization uses a random number table (Microsoft Excel) with the aim that the resulting data is more accurate and anticipates the occurrence of errors when placing the experimental unit.

The application of KCl (K) fertilizer is carried out divided 50% of the treatment dose given at 7 days before the tomato seedling transplanting process (as basic fertilizer) when processing the land and the remaining 50% applied when the plant is 30 days after planting (DAP).

Application of $CaCl_2$ (C) concentration was carried out 1 time at 7 days after full bloom (DAFB). Spraying $CaCl_2$ is done by spraying evenly on the test plants according to the level of concentration of treatment. Spraying is done by making sure the entire surface of the tomato plant is moistened with $CaCl_2$ solution.

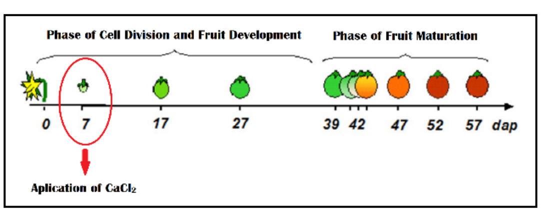

Figure 1. Development of tomatoes and time of application of CaCl2 treatmen

Analysis of Fruit Quality

The tomatos will be harvested when the fruit reaches the turning stage (10-30% of the fruit's surface is yellow), which is a 30 days after full bloom (DAFB). Testing the quality of tomatoes is carried out starting from 0-15 day after harvest (DAH) on the observation variables as follows.

a) Thickness of Flesh Fruit (cm)

Observation of tomato thickness of flesh was carried out on 0 DAH. Observation was carried out by measuring the thickness of flesh manually by using a sliding length with Image J method (5 point).

b) Fruit Softness (mm/g/second)

Measurements of tomato fruit softness were carried out on day 0 (before storage), 5, 10 and 15 DAH. Performed using the Pnetrometer in 3 parts, namely: bottom, center and top of the fruit. Measurement of fruit softness is based on the depth of tensile strength needle that enters the fruit flesh. The softness value is measured as the penetrating distance of the penetrometer needle with a load of 150 g within 5 seconds. The greater the penetration distance, the greater the softness of tomatoes.

c) Vitamin C

The content of vitamin C was measured using a spectrophotometric method and the absorbance value was measured using a VIS spectrophotometer with a wavelength of 271 nm and expressed as mg / 100 g of tomatoes.

Data Analysis

Data obtained from observations and analyzes were then tested using the F test (ANOVA). If the results of variance show significant or significantly different results, then a further test is carried out with Duncan Multiple Range Test (DMRT) at the level of 5% to determine the difference in treatment.

3. RESULTS

Based on the results of this study is was no significant interaction from the treatment of giving potassium (KCl) and calcium chloride ($CaCl_2$) to all observed variables (Table 1).

Table 1. Effect of Potassium (K) and Calcium (C) on the Quality and Shelf Life of Servo Tomatoes

Variable	Potassium (K)	Calsium (C)	K x C
	Note		
Thickness of Flesh	**	ns	ns
Fruit Softness	**	**	ns
Vitamin C	**	**	ns

In the observation variable of thickness of flesh it can be seen that only the treatment of potassium (K) gives significant results, while the treatment of calcium (C) and the interaction between potassium and calcium (KxC) does not show significant results. The effect of the best dosage of potassium treatment is K_3 = 150 kg / ha KCl which produces the best thickness of flesh of 0.74 cm.

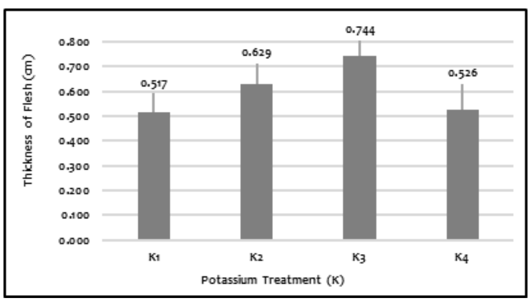

Figure 2. Graph of the effect of treatment doses of potassium (K) on thickness of flesh

There was no treatment interaction (KxC) in the observation variable of fruit softness, but the treatment of potassium (K) and calcium (C) each had a significant effect on 15 DAH of shelf life. The best dose of potassium treatment is K_3 = 150 kg / ha KCl, with the lowest fruit softness value of 0.0088 mm / 150g / 5 seconds.

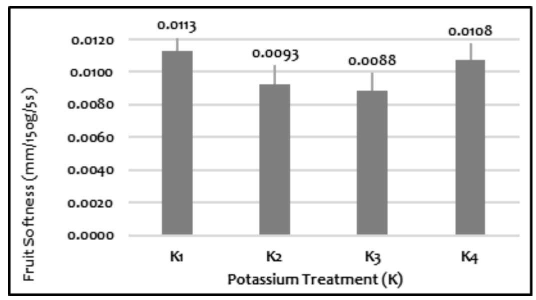

Figure 3. Graph of the effect of treatment doses of potassium (K) on the fruit softness of tomatoes at 15 DAH storage.

While the best calcium concentration that can provide the lowest softness value is treatment C_2 = 3% $CaCl_2$ (30g $CaCl_2$ / l aquadest) which is equal to 0.0087 mm / 150g / 5 seconds.

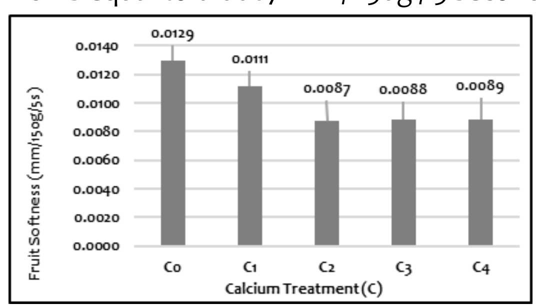

Figure 4. Graph of the effect of treatment of the concentration of calcium (C) on the softness of tomatoes at a 15 DAH storage

In the observation variable of vitamin C content shows that there was no treatment interaction (KxC), but the treatment of potassium (K) and calcium (C) each had a significant effect on 15 DAH shelf life. The best dose of potassium treatment is K_3 = 150 kg / ha

KCl with the highest vitamin C content of 50.21 mg / 100g.

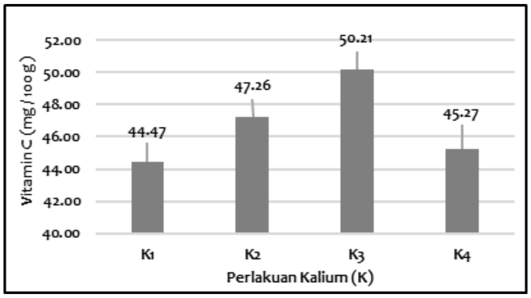

Figure 5. Graph of the effect of treatment of potassium (K) doses on the content of vitamin C tomatoes at 15 DAH storage

While the best concentration of calcium chloride which can provide the highest vitamin C content is treatment C_2 = 3% CaCl2 (30g CaCl2 / l aquadest) which is equal to 48.14 mg / 100g.

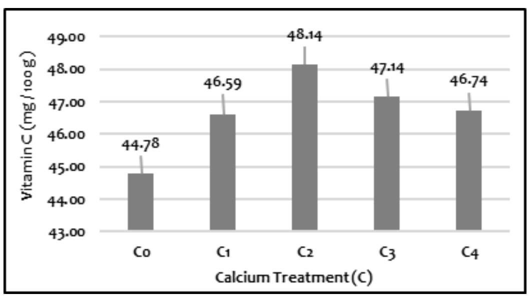

Figure 6. Graph of the effect of treatment of the concentration of calcium (C) on the content of vitamin C tomatoes at a 15 DAH storage

4. DISCUSSION

Thickness of Flesh Fruit

Based on the data from the results of this study, it can be seen that only potassium dose treatment is able to provide significant results on the variable thickness of fruit flesh, with the best treatment dose being 150 kg / ha KCl (K_3). This dosage is the best because it is possible in substance the nutritional needs of potassium tomato plants have been in the right proportion so that they can increase the thickness of tomato flesh better than the other dosages of potassium treatment

The positive influence of the application of potassium is very possible because basically potassium is one of the nutrients needed by plants in large quantities. Potassium nutrition is able to give a good influence in increasing the thickness of flesh because potassium plays an important role in the process of photosynthetic translocation from leaves to fruit tissue (Marschner, 1995). In a process of growth and metabolism, plants need a mechanism for translocation of carbohydrates produced from photosynthesis in the leaves of plants to various other organs. The main form of carbohydrate contained in this translocation process is sucrose which is then transported through phloem vessels, and this process is strongly influenced by the availability of potassium elements. (Trankner et al, 2018). If the elemental substance potassium is in a condition of deficiency, it will affect the efficiency of carbon transport over long distances in the plant.

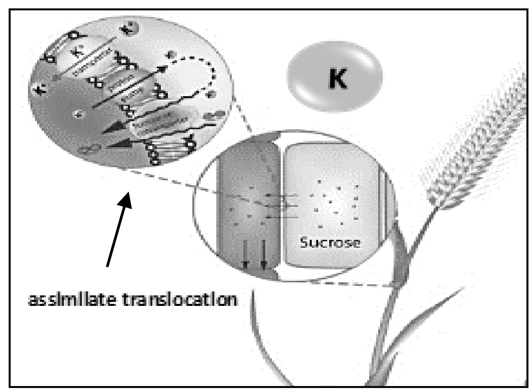

Figure 7. K+ is needed as a source of material for photoassimilation translocation, because it has an important function in apoplastic sucrose loading in phloem

The movement of solutes in phloem tissue follows a graph of hydrostatic pressure derived from differences in solute concentration. The most abundant cations in phloem tissue are K^+ which, together with sucrose and amino-N compounds, is the most important osmotic compounds in phloem sap, so it makes very important in the process of transporting the phloem. Therefore, the presence of concentrations of K^+ in phloem sap is closely related to the level of externally supply of potassium (Mengel and Haeder, 1997).

In the process of apoplastic loading in phloem, sucrose must be transported actively to pass through the cell plasma membrane and some filter elements by sucrose transporters according to their concentration gradients. The energy needed in this process is obtained from H+ -ATPase where K+ functions as an exchange cation which can then create a proton pump gradient to cross the plasma membrane (Michelet and Boutry 1995). The K+ gradient formed will provide energy which will then be used by other transporters to load sucrose in phloem tissue, so this mechanism is also called a "potassium battery" which functions as a cellular energy source to overcome local ATP deficiencies and maintain the efficiency of the distance transportation far (Dreyer et al. 2017).

Based on the results of the study which states clearly that the presence of potassium nutrients plays an important role in the photosynthetic translocation process. With the right amount of potassium fulfillment, of course it will have a positive impact related to some of the plant's metabolic processes, among which can produce better fruit flesh. If the fruit flesh produced is better, of course in an effort to increase the shelf life of the fruit can also be maintained in a relatively longer time.

Fruit Softness

In the observation variable of tomato softness, the treatment of potassium (K) and calcium (C) doses gave significant results, but there was no treatment interaction between the two treatments. The results showed that the potassium dosage treatment which can provide the lowest percentage rate of increase in fruit softness when stored for 15 DAH was 150 kg / ha KCl (K_3).

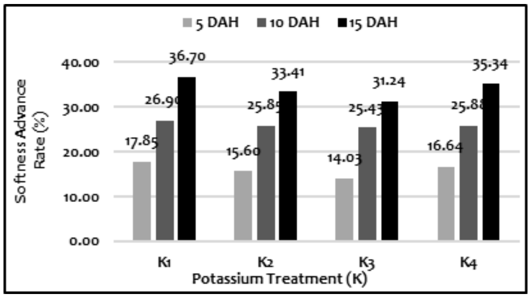

Figure 8. Graph of the effect of potassium (K) on the percentage advance rate of softness in tomatoes during 15 DAH storage.

Based on the graph (figure 8), it can be seen that K3 treatment tends to give the lowest percentage rate of increase in tomato softness on all observation days. The low value of tomato softness is thought to result from the application of the right potassium dose so that it can meet the needs of tomato plants. The role of potassium nutrition is very vital in suppressing the rate of fruit softness. It is because potassium can strengthen the cell wall through a mechanism to maintain cell turgor. Tomatoes are climatic fruits that are strongly influenced by turgor from living cells during the ripening process. Turgor is a pressure from the cell contents to the cell wall. The cell wall has plastic properties, where the contents of the cell can enlarge because it absorbs water from its surroundings. Therefore, turgor can affect the hardness (firmness) of parenchyma cells so that it can also affect the texture of the fruit. If the water condition in the cell decreases, the cell will become soft and weak. Vice versa, if the water continues to increase in the cell contents to exceed normal conditions, then the cells will be at risk of rupture so that cell constancy will disappear (IPNI, 2011).

With the role of potassium which can maintain cell turgor, it can maintain passive transport or cell turgidity will remain in optimal conditions. The advantage if the cell's tidiness is maintained is that it can cause cells to have a fixed shape. In cell turgidity there will be passive transport, which is in the form of molecular displacement, ions and certain compounds that are needed by plants in the process of diffusion and osmosis. Potassium's nutritional potential in maintaining cell turgor is very positive, besides being able to keep the texture of the fruit firm, it can also minimize fruit damage caused by the attack of harmful microorganisms. This is because when cell turgor is in optimal condition it will result in microorganisms having difficulty in carrying out the attack on the fruit and tend to push the organism away when the attack is carried out through the cell membrane.

The existence of K can also increase the work of metabolic enzymes in plants. In sufficient potassium conditions in plants can increase the synthesis of high molecular weight molecular compounds (protein, starch, cellulose) so that it can reduce the synthesis of low molecular weight molecules (organic acids, amino acids and amides) in plant tissue, so that with the presence of sufficient potassium can increase the formation of thicker lignin compounds (Rosyidah, 2016), so that the value of increasing fruit softness when stored can be suppressed.

The results also showed that calcium (C) treatment also had a significant effect on the fruit softness variable. The best concentration level of treatment that can suppress the percentage of fruit softness rate is 3% CaCl2 (C_2).

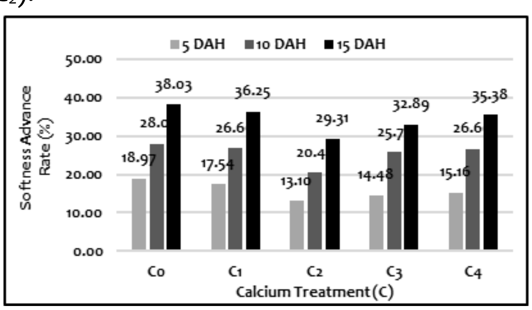

Figure 9. Graph of the effect of calcium (C) on the percentage advance rate of softness in tomato during 15 DAH storage.

The C_2 treatment showed a lower percentage of fruit softness on all observation days compared to other concentrations (Figure 9). This is because calcium has the ability to maintain membrane stability and integrity so that it is not easily degraded. With a low fruit softness value, it will cause the fruit's shelf life to be longer so that it is suitable when used in distant distribution transportation and can maintain good quality because the fruit will tend to be more resistant to physical damage.

The fruit softening process is one of the processes that occurs when the fruit has been harvested from the parent plant. In this condition the fruit will experience deterioration during the ripening process. This condition occurs because of the dissolution of insoluble protopectin to dissolve pectin. The amount of pectate during fruit ripening will increase. Increasing the content of pectate and pectinate which dissolves will reduce fruit toughness. Substances that exist on the cell wall will be degraded, so the cell wall will be soft. The fruit will become soft and the levels of pectin ingredients increase during maturation (Zulkarnain, 2010). This is because the dissolution of pectin affects the physical properties of cell walls which have an impact on the integration of fruit structures. This process will be faster if the fruit is at high temperature.

The treatment of $CaCl_2$ in fruit can increase the calcium content in the fruit. Calcium plays a role in cross-linking pectin in the cell wall and middle lamella and results in the formation of calcium pectate from calcium binding into a carboxyl group free of galakturonase polymers which play a role in stabilizing and strengthening cell walls (Serrano et al., 2004). changes in composition of cell walls, specifically the impact of de-esterification of pectin and calcium crosslink formation (Redgwell et al., 1997).

Vitamin C

Based on the data from this study, it can be seen that only potassium dose treatment is able to provide significant results on the variable content of vitamin C in tomatoes, with the best treatment dose being 150 kg / ha KCl (K_3).

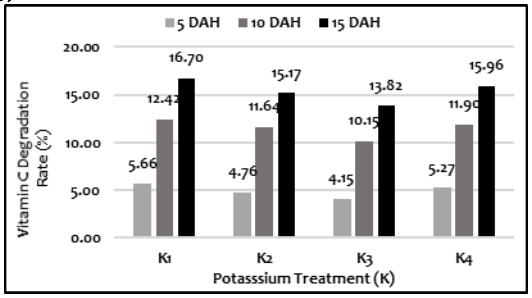

Figure 10. Graph of the effect of Potassium (K) on the percentage degradation rate of vitamin C in tomatoes during 15 DAH storage

The character of vitamin C will decrease during the maturation and storage process, the role of K is very helpful in reducing the rate of decline with the mechanism of strengthening the cell wall and involved in the lignification process of sclerenchymal tissue (Amrutha et al. 2007). With thick and strong cell walls will certainly reduce the risk of damage and loss of vitamin C content in tomatoes.

Besides being able to reduce the rate of decrease in vitamin C, potassium can also function to increase vitamin C contained in the fruit. The function of potassium is strongly related to the quality of nutritional value in an agricultural product which refers to the content of certain elements such as protein, fat, and components of vitamins

and minerals. The role of potassium in quality can also occur indirectly from positive interactions with nitrogen in several physiological processes (Usherwood, 1985). Potassium functions as a reverse ion along with nitrate (NO_3) in transportation activities through xylem. The presence of K can take N in greater amounts and can convert N faster to protein.

Nitrates in plants will be reduced first to amines and then will be put into amino acids to eventually form proteins. With a low K supply, it tends to limit nitrate transport and will inhibit protein formation (IPI, 2013). The higher the protein content in the fruit, the higher the content of vitamin C, this is because vitamin C is the result of protein synthesis (Rosyidah, 2017).

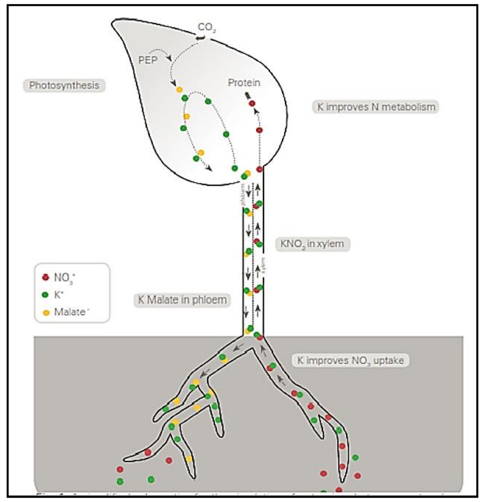

Figure 11. Simple scheme of potassium circulation between roots and leaves in relation to transport of nitrate and malate (PEP, phosphoenol pyruvate) (Marschner et al., 1996)

The results also showed that the treatment of calcium (C) also had a significant effect on the variable content of vitamin C tomatoes. The best concentration level of treatment that can suppress the percentage degradation rate of vitamin C is 3% $CaCl_2$ (C_2).

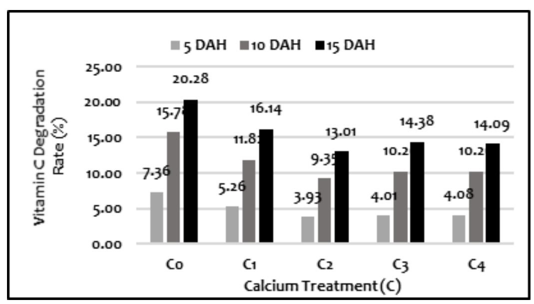

Figure 12. Graph of the effect of calcium chloride (C) on the percentage degradation rate of vitamin C in tomatoes during 15 DAH storage

Tomatoes are a source of vitamin C with a range of 15 to 23 mg / 100g from tomato parts (Dumas et al., 2003). Decreased levels of vitamin C occurs during storage. Physiological processes in the fruit, namely respiration and transpiration are the main causes of nutrient degradation and deterioration. In addition, harvested fruit still continues the life process while there is no longer transfer of food from the parent plant to the fruit and must rely on stored food reserves to stay fresh. Along with the length of storage, food reserves will run out including vitamin C, which eventually results in aging and decay (Ullah, 2009).

Exogenous addition of CaCl2 can add Ca^{2+} content which will bind to pectin which is cellulose microfibrils from the cell wall to Ca pectat through esterization reaction. The bond between pectin and Ca^{2+} results in a rigid cell wall. The administration of Ca^{2+} can form crosslinking between Ca^{2+} with pectic acid and other polysaccharides so as to limit the activity of softening enzymes and respiration such as polygalcturonase by stabilizing membrane integrity (Kramer et al., 1989). The more stable the fruit membrane integrity is treated with CaCl2, the respiration rate decreases so that it can further reduce the rate of degradation of vitamin C.

5. CONCLUSION

There is no treatment interaction (KxC) on all observation variables. On the thickness of fruit flesh, the best potassium treatment is (K_3) of 0.744 cm. For the variable fruit softness, the best potassium treatment is (K_3) with a softness value of 0.0088 mm / 150gr / 5s at a 15 DAH shelf life and the best calcium treatment is (C_2) with a softness value of 0.0087 mm / 150gr / 5s at 15 DAH shelf life. Whereas in the variable content of vitamin C tomatoes, the best potassium treatment is (K_3) with a value of vitamin C of 50.21 mg / 100g at 15 DAH shelf life and the best calcium treatment is (C_2) with a value of vitamin C of 48.14 mg / 100g at 15 DAH shelf life.

6. ACKNOWLEDGEMENTS

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