

Analysis of Physcho-Chemical Changes and Mechanical Damage of Tomato (*Lycopersicum Esculentum L.*) During the Transportation

Susi Susanti^{1*}, and Diyah Yumeina^{1,2}

¹Department of Agricultural Technology, Faculty of Agricultural, Hasanuddin University, 90245, Makassar, Indonesia

²Center of Excellence in Science and Technology on Food Product Diversification, Hasanuddin University, 90245, Makassar, Indonesia

Abstract. Quality analysis on tomatoes must always be done to maintain the shelf life and physical, chemical and mechanical damage of a product. However, generally the initial damage to tomatoes occurs in the post-harvest handling process during the transportation of tomatoes for distribution to marketing areas. Damage often occurs due to the distribution process with improper selection of packaging containers. This study aims to analyze the physical, chemical and mechanical changes due to the transportation process of various types of packaging during the distribution of tomato fruit so that it can be known which type of packaging container is able to maintain the quality of tomato fruit during the distribution process. This research method uses three treatments, namely tomatoes packed in plastic bags, wooden boxes and styrofoam during the transportation process. Data analysis was carried out by measuring parameters, namely weight loss, color, percentage of defects and total soluble solids. Based on the research that has been done, it can be concluded that the type of wooden box packaging has the most changes in weight shrinkage, mechanical damage, and Total Soluble Solid (TSS) and styrofoam packaging can minimize the occurrence of weight shrinkage, mechanical damage and Total Soluble Solid (TSS).

1 Introduction

Quality analysis can be interpreted as one of the activities carried out to see the various properties and characteristics of a product or material that are expressed directly or indirectly. Quality improvement must always be carried out to maintain the shelf life and physical, chemical and mechanical damage of a product, because in essence, consumers want fruits or vegetables to have a good appearance, including good fruit skin, no spots and no deviation from the normal condition of the fruit or vegetable itself [1].

Post-harvest handling of tomatoes is a special activity that needs to be considered so that the quality of tomatoes can last until it reaches consumers. Primary post-harvest handling of tomatoes is generally carried out by farmers, namely tomatoes packed into sacks without

* Corresponding author: susisusanti1108@mail.com

sorting and grading processes, while collectors usually pack tomatoes into wooden boxes because it is easier to transport to transportation [2]. Based on initial observations and observations, the primary post-harvest handling of tomatoes carried out by farmers in Malino and surrounding areas is that farmers have carried out post-harvest activities, namely sorting but not grading. After sorting, the tomatoes are packed using red plastic bags and stacked into transportation equipment to be distributed to the destination market.

The packaged tomato harvest will be distributed to big cities due to the high level of consumer consumption in large populated areas. The level of consumption of tomatoes in big cities is quite high because tomatoes are used as raw materials for tomato sauce in the industry and are consumed as food complementary ingredients in eating places, both processed home food and restaurants. The tomatoes are transported and distributed to big cities using pickup trucks. The use of pickup trucks is preferred by farmers because it has more capacity for transportation and is more easily found in the community. However, generally the initial damage to tomatoes occurs in the post-harvest handling process, namely in the process of transporting tomatoes for distribution to marketing areas, such as experiencing vibrations, product piles, pressure and shocks during transportation. Mechanical damage that often occurs due to the distribution process with improper selection of packaging containers is a decrease in the weight loss of tomato fruit and defects, bruises due to hard shocks either influenced by transportation with excessive piles of products, the shape of the road traveled and the material of the container used [3].

Based on this description, this research will be conducted to analyze the physical, chemical and mechanical changes that occur to tomato fruit distributed using several types of packaging such as plastic bags, wooden boxes and Styrofoam, so that from the research conducted, mechanical damage and physical and chemical changes from the use of several types of packaging containers are known and the packaging is good and suitable for transportation during the distribution process.

2 Materials and Methods

2.1. Time and place

This research was conducted from December 2022 - February 2023 at the Processing Laboratory, Agricultural Engineering Study Program, Department of Agricultural Technology, Faculty of Agriculture, Hasanuddin University and sampling was carried out in Tombolo Pao, Kab. Gowa, South Sulawesi to Makassar City.

2.2. Tools and materials

The tools used in this research are red plastic bags (40 x 60 cm), wooden boxes (52 x 38 x 33 cm), styrofoam boxes (52 x 38 x 33 cm), digital scales, colorimeter, refractometer, camera and Hilux S Cab pickup truck. The research material used was tomato fruit with an average weight of 5.8 g and an average diameter of 4.52 cm taken from the Tombolo Pao area, Kab. Gowa, South Sulawesi.

2.3. Research procedure

The research procedure will be carried out as follows;

2.3.1 Preparation Stage

Preparation of materials in this study was, prepare packaging containers, namely red plastic bags (40 x 60 cm), wooden boxes (52 x 38 x 33 cm) and styrofoam boxes (52 x 38 x 33 cm) and sorting tomatoes and ranking 5 tomatoes that will be sampled at the top, bottom, middle left and right based on the same level of maturity, namely tomatoes that are red and free from defects and bruises.

2.3.2 Research Stage

Research stage was started from began the sample was put into the container for the transportation process, weight measurement is carried out by weighing the weight of tomatoes. Crushing tomatoes with a mortar, then the results of the tomato water solution are put into the refractometer and took color measurement. Marking using labels so that the tomatoes that have been measured were not confused with other tomatoes after arriving at the distribution location. Putting the same number of tomatoes, namely 440 pieces (20 kg) with a total 8 rows x 11 columns of stacks in each plastic bag, wooden box and Styrofoam box packaging container and stored at room temperature before transportation. Transporting tomatoes from Tombolo Pao to the Faculty of Agriculture Unhas with a distance of ± 2 hours 13 minutes (± 76 km) using a pickup truck. Counting the mechanically damaged tomatoes and damage-free tomatoes to determine the percentage of mechanical damage after the samples arrived in Makassar. Re-conduct measurements of weight loss, color and Total Soluble Solid (TSS). Repeating the data collection once to see a more accurate comparison of the results and processing data using Microsoft Excel 2019 and analysis of variance (ANOVA) using IBM SPSS Statistic.

2.3.3 Observation Parameters

The parameters observed in this study were to determine changes in weight loss, water content, color changes, percentage of mechanical damage and Total Soluble Solid (TSS) as follows.

a. Weight Loss

Weight loss measurements were carried out gravimetrically, based on the percentage of weight loss (wet weight) of the material. Weight loss measurements were taken before and after distribution. To determine the weight loss measurement, the following equation can be used [3]:

$$SB = (W_o - W_b) / W_o \times 100\% \quad (1)$$

Description SB Weight loss %, W_o Initial weight before distribution (g), W_b Final weight after distribution (g).

b. Discoloration

Color measurement was carried out to see the color change of tomato fruit both before the distribution process and after the distribution process. The percentage of color change was observed in each sample, then measured using a colorimeter.

$$chroma = \sqrt{a^2 + b^2} \quad (2)$$

c. Percentage of Mechanical Damage

The percentage of damage to tomatoes after being distributed immediately was tested visually for mechanical damage, namely if the product was scratched, rotten, bruised on the skin and flesh of the tomato. Scratches are characterized by deep (3-5 mm) and elongated (1-2 cm) wounds. The percentage of damage can be calculated with the following equation [4]:

$$\% \text{damaged} = (\text{number of damaged (pieces)}) / (\text{total sample}) \times 100\% \quad (3)$$

d. Total Soluble Solid (TSS)

Total Soluble Solid can be calculated by smoothing the sample after distribution using a pestle or mortar to produce a liquid that will be measured with a refractometer and expressed in units of °Brix (%).

2.3.4 Statistical Analysis

To determine the effect of treatment on the parameters tested using ANOVA (Analysis of Variance) analysis of variance. If the results show significant differences with a significance level of 5%, it is continued with the Duncan Multiple Range Test (DMRT).

3 Results and Discussion

3.1 Weight Loss

Weight loss is a decrease in fruit mass due to respiration, transpiration and bacterial activity. Weight loss in tomatoes occurs because tomatoes are climatic fruits where tomatoes will continue to carry out metabolic processes. Measurement of weight loss parameters was carried out before and after distribution. Tomatoes are sampled after sorting and grading at several points, namely top, center, bottom, left and right. After the sample has arrived in Makassar, the weight loss is re-weighed to determine the weight change that occurs. The following data is the change in weight loss of the sample before distribution and after arriving in Makassar.

Table 1. Weight Loss Changes Before and After Distribution with Various Packagings

No.	Packaging Type	Average Weight Loss (%)
1.	Plastic Bag	1.71
2.	Wooden Box	1.98
3.	Styrofoam	0.16

Based on the research conducted, it can be seen in Table 1 that the highest weight shrinkage occurred in the wooden box packaging type at 1.98% and the lowest occurred in styrofoam at 0.16%. Significant weight loss changes in the wooden box packaging type occurred due to the large number of tomatoes that experienced friction and impact to the side of the hard wooden box during distribution, causing scratches on the surface of the tomato skin. Scratches on the surface of tomatoes accelerate the respiration process which results in water loss and evaporation which has an impact on the shrinkage of tomato weight. This is in accordance with the statement [3] that the increase in weight loss is influenced by wounds on tomatoes because it accelerates the process of water loss.

Another thing that caused the high weight loss in the wooden box packaging was that the samples were exposed directly to the sun compared to the closed styrofoam. Samples exposed to direct sunlight will experience an increase in temperature so that the fruit undergoes a transpiration process which results in water evaporation. This is in accordance

with the statement [4] that tomatoes experience the process of transpiration and respiration during the transportation process resulting in a reduction in water content and evaporation associated with weight loss.

Table 2. The results of the DMRT (Duncan's Multiple Range Test) mean test of Percentage Weight Shrinkage Against the Treatment of Packaging Type.

Treatment	Weight Loss (%)
Plastic Bag	1.7000 ^b
Wooden Box	2.0000 ^b
Styrofoam	0.1500 ^a
<i>P-Value (Sig)</i>	0.027

Notes: Numbers followed by the same lowercase letter in the same column are not significantly different according to the Duncan test at the 0.05 (5%) level.

Based on Table 2, the average percentage of weight loss with data analysis that has been done gets a p-value of 0.027 where the p-value <0.05 (5%), so proceed with further tests (Duncan test). Based on Duncan's test, the treatment of tomato packaging with various types of packaging has a significant effect on the percentage of tomato weight loss during transportation. In the transportation process using plastic bags, wooden boxes and Styrofoam packaging types showed a real interaction on the percentage of weight loss of tomatoes. The difference in notation behind the numbers in Table 2 shows a significant difference in treatment with the type of tomato packaging during transportation.

3.2 Color Change

Table 3. Results of Brightness Level Analysis (L* Value) of Tomatoes.

No.	Packaging Type	Average L* value	
		Before distribution	After distribution
1.	Plastic Bag	48.54	49.34
2.	Wooden Box	51.80	54.49
3.	Styrofoam	50.77	50.39

The L* value indicates the level of brightness displayed in positive, measured values ranging from 0 (black) to 100 (white). Based on the result data in Table 3, the average L* value before distribution on each packaging type ranged from 48.54 to 51.80 and after distribution ranged from 49.34 to 54.49. The L* value in each package shows that tomatoes have a positive brightness value which means they tend to be bright. This is in accordance with the statement [5] that the L* value states the brightness of the fruit, the higher the L* value, the higher the brightness of the fruit.

Based on the data analysis that has been done, the p-value is 0.694 where the p-value > 0.05 (5%) which indicates that the treatment of tomato packaging with various types of packaging does not significantly affect the L* value during transportation.

Table 4. Analysis Results of *a Value of Tomatoes.

No.	Packaging Type	Average *a value	
		Before distribution	After distribution
1.	Plastic Bag	54.95	54.76
2.	Wooden Box	51.17	52.36
3.	Styrofoam	47.69	52.87

The a* value has positive (+a) and negative (-a) values, positive values range from 0-100 (red), while negative values range from 0-80 (green). Based on the results data in Table

4, the a^* value before distribution in each package ranged from 47.69 to 54.95 and after distribution amounted to 52.36 - 54.76. This positive value indicates that the color of these tomatoes tends to be red. The red color change in tomatoes is due to the degradation and formation of lycopene in tomatoes as they ripen. This is in accordance with the statement [5], that as much as 85-90% of the red color in ripe tomatoes is due to the presence of lycopene pigment.

Based on the data analysis that has been done, the p -value is 0.907 where the p -value > 0.05 (5%) which indicates that, the treatment of packaging tomatoes with various types of packaging does not significantly affect the value of a^* during transportation.

Table 5. Tomato b^* Value Analysis Results.

No.	Packaging Type	Average b^* value	
		Before distribution	After distribution
1.	Plastic Bag	45.41	45.85
2.	Wooden Box	47.97	49.41
3.	Styrofoam	44.03	44.98

The b^* value indicates the chromatic color of the mixture between blue and yellow, positive values range from 0-70 (yellow) and negative values range from 0-80 (blue). Based on the results of the b^* values in Table 5, the b^* values before distribution in each package ranged from 45.41 to 47.97 and after distribution from 44.98 to 49.41. The b^* value of tomatoes in each type of packaging is positive, so it can be said that tomatoes tend to be yellow in color. The yellow color change in tomatoes is due to the degradation and formation of lycopene in tomatoes as they ripen. This is in accordance with the statement [6] that lycopene is one of the carotenoid pigments that functions to give yellow to red color to tomatoes.

Based on the data analysis that has been done, the p -value is 0.067 where the p -value > 0.05 (5%) which indicates that the treatment of tomato packaging with various types of packaging does not significantly affect the b^* value during transportation.

Table 6. Average Value of Tomato Parameters Before and After Distribution.




Packaging Type	Color Parameter Before Distribution				Color Parameter After Distribution			
	L	a	b	Chroma	L	a	b	Chroma
Plastic Bag	48.54	54.95	45.41	71.38	49.34	54.76	45.85	71.57
Wooden Box	51.80	51.17	47.97	70.48	54.49	52.36	49.41	72.38
Styrofoam	50.77	47.69	44.03	65.41	50.39	52.87	44.98	69.78

Based on the results in Table 6, the Chroma value of the wooden box packaging type has a higher Chroma value after distribution, which is 72.38. The high Chroma value of the wooden box is in accordance with the a^* and b^* values which are higher than the Chroma value of other packaging types, indicating that tomatoes packed in plastic bags have a more intense red color. The red color is the result of chlorophyll degradation as well as synthetic lycopene and other carotenoids. The color of tomato fruit is largely related to the lycopene content in the fruit. This is in accordance with the statement [7] that the higher the Chroma value, the tomato fruit has a high lycopene content.

3.3 Percentage of Mechanical Damage

Mechanical damage due to transportation is usually the trigger for commodity keep due to wounds on the fruit that cause high weight loss. Tomatoes exposed to shock will experience mechanical damage due to collisions between tomatoes or containers.

Table 7. Mechanical Damage Classification and Number of Damage Samples.

No.	Total Samples (Pieces)	Type Damage	Total Damaged (Pieces)			Image
			Plastic	Wooden Box	Styrofoam	
1.	440	Bruises	13	20	8	
2.	440	Broken	4	2	1	
3.	440	Scratched	4	36	-	

Based on Table 7, it can be seen that tomato fruit suffered mechanical damage in various types of packaging. The number of mechanical damages that occurred in plastic bags was 21 pieces, of which bruises amounted to 13 pieces, scratches 4 pieces and ruptures 4 pieces. The number of bruises on the plastic bags was due to the impact of the material with the surface of the car because of the thin plastic packaging. Then the amount of mechanical damage to the wooden box was 58 pieces, including 20 bruises, 2 broken pieces and 36 scratched pieces. The amount of mechanical damage to wooden boxes is the highest total damage, especially in scratched samples. This occurred due to the collision of the material with the surface of the wooden box so that the samples on the right, left and bottom sides experienced scratches due to the formation and squeezing of the wooden box.

Table 8. Mechanical Damage Percentase.

No	Packaging Type	Mechanical Damage (%)
1.	Plastic Bag	4.3
2.	Wooden Box	14.0
3.	Styrofoam	2.4

Based on the research that has been done, it can be seen from Table 8 that the highest level of mechanical damage to tomatoes occurred in the type of wooden box packaging at 14.0% and the lowest occurred in the type of styrofoam box packaging at 2.4%. The level of damage to wooden boxes is higher than plastic and styrofoam packaging types because during the distribution process, tomatoes experience shocks and vibrations due to the shape and uneven road area so that the tomatoes collide into each side of the hard wooden box and

cause the tomatoes to experience bruises and scratches. This is in accordance with the statement [4], that wooden boxes have a hard surface so that if they are not coated with packaging fillers there will be a lot of empty space which can cause friction between the tomato skin and the larger surface of the wooden box.

Table 9. Results of DMRT (Duncan's Multiple Range Test) Mean Mechanical Damage on Packaging Type Treatments.

Treatment	Mechanical Damage
Plastic Bag	4.3500 ^a
Wooden Box	14.0000 ^b
Styrofoam	2.3500 ^a
P-Value (Sig)	0.008

Notes: Numbers followed by the same lowercase letter in the same column are not significantly different according to the Duncan test at the 0.05 (5%) level.

Based on Table 9, the value of mechanical damage with data analysis that has been done gets a p-value of 0.008 where the p-value <0.05 (5%), so it is continued with further tests (Duncan test). Based on Duncan's test, the treatment of tomato packaging with various types of packaging has a significant effect on the percentage of mechanical damage during transportation. In the transportation process using plastic bags, wooden boxes and Styrofoam packaging types showed a real interaction on the percentage of tomato weight loss. The difference in notation behind the numbers in Table 8 shows a significant difference in treatment with the type of tomato packaging during transportation.

3.4 Total Soluble Solid (TSS)

Total Soluble Solid (TSS) is the amount of sugar and carbohydrate content contained in a material or product. In the case of climatic fruits, carbohydrates and glucose are used for the ripening process so that they can undergo changes.

Table 10. Table Changes in Total Dissolved Solids (TSS) Value.

No.	Packaging Type	Total Soluble Solid (TSS)		
		Before distribution	After distribution	Increase Brix (%)
1.	Plastic Bag	4.48	4.76	0.28
2.	Wooden Box	4.93	5.45	0.52
3.	Styrofoam	4.36	4.57	0.21

Based on the research that has been conducted, it can be seen in Table 10 that the Total Soluble Solid (TSS) on distribution using various types of packaging is different. Tomatoes packed in plastic packaging experienced an increase in Total Soluble Solid (TSS) value of 0.28 Brix (%). In wooden box packaging, the increase in Total Soluble Solids (TSS) value was 0.52 Brix (%) and the increase in Total Soluble Solids (TSS) value in styrofoam was 0.21 Brix (%). The increase in Total Soluble Solids (TSS) of tomatoes packed in wooden boxes is higher than other types of packaging because the fruit is exposed to direct sunlight so that the glucose in tomatoes becomes rapidly soluble, resulting in the breakdown of carbohydrates into sugar content during distribution. Fruit that has a high Total Soluble Solids (TSS) value indicates sweeter fruit due to higher glucose content which indicates more mature fruit. The level of fruit maturity is characterized by the highest Total Soluble Solids (TSS) value, due to the hydrolysis of starch into sugar and will touch the peak of ripening. This is in accordance with the statement [8], that during the storage of fruit or products, carbohydrate breakdown occurs into glucose content. In fruits that have not touched the

climatic peak, they still contain carbohydrates in the form of starch and during the process towards ripening the content will become glucose.

Based on the data analysis that has been done, the p-value is 0.055 where value of the p-value > 0.05 (5%) which indicates that, the treatment of tomato packaging with various types of packaging does not significantly affect the value of Total Soluble Solid (TSS) during transportation.

4 Conclusions

Based on the research of Physico-Chemical Changes Analysis and Mechanical Damage of Tomato Fruit (*Lycopersicum esculentum L.*) During the Transportation Process that has been done, the following conclusions can be drawn:

1. Of the 3 types of distribution packaging commonly used by farmers to distribute tomato crops, the type of wooden box packaging experienced the most changes in weight loss, mechanical damage, and Total Soluble Solid (TSS).
2. The effect of packaging type on tomato distribution had a significant effect on weight loss and percentage of mechanical damage, but no significant effect on L* value, *a value *b value and Total Soluble Solid (TSS).
3. Styrofoam packaging shows that it can maintain the quality of tomatoes from weight loss, Total Soluble Solid (TSS) and minimize the occurrence of mechanical damage.

References

1. N.S. Tarigan. Mempertahankan Mutu Buah Tomat Segar Dengan Pelapisan Minyak Nabati. *Jurnal BETA* **4**, 1 (2016).
2. D. Nofriati. *Penanganan Pascapanen Tomat* (L. Izhar & S. Primilestari (eds.); 1st ed.). Balai Pengkajian Teknologi Pertanian Jambi, (2018)
3. Z.A. Varanita, and A. Haryanto. Pengaruh Getaran Terhadap Kerusakan Mekanis Tomat (*Lycopersicum Esculentum Mill*). *J. Teknik Pertanian Lampung* **5**, 2 (2016)
4. J. Warti, A.P. Munir, and R. Sigalingging. Pengaruh Bahan Pengisi Kemasan Keranjang Bambu pada Transportasi Darat Terhadap Mutu Tomat (*Lycopersicum Esculentum Mill*). *J. Rekayasa Pangan Dan Pertanian* **6**, 1 (2018).
5. C.A. Salingkat, A. Noviyanty, and Syamsiar. Pengaruh Jenis Bahan Pengemas, Suhu dan Lama Penyimpanan Terhadap Karakteristik Mutu Buah Tomat. *Agroland : J. Ilmu-ilmu Pertanian* **27**, 3 (2020)
6. I.A. Widhiantari, S.M Sutan, and G. Djoyowasito. Rancangan Wadah Buah Tomat Untuk Menahan Getaran Selama Transportasi Berbahan Eceng Gondok dan Pelepah Pisang. *Indonesian Green Technology Journal* **5**, 1 (2016)
7. A. Widyasanti, N.C. Muchtarina, and S. Nurjana. Karakteristik Fisikokimia Bubuk Ampas Tomat-Apel Hasil Pengeringan Pembusaan Berbantu Gelombang Mikro. *Agrointek* **14**, 2 (2020)
8. Kusumiyati, Farida, W. Sutari, J.S. Hamdani, and S. Mubarak. Pengaruh Waktu Simpan Terhadap Nilai Total Padatan Terlarut , Kekerasan dan Susut Bobot Buah Mangga Arumanis. *J. Kultivasi* **17**, 3, 766–771, (2018)