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Changes of Powder Composition during Foam Mat Drying of Tomato Juice: Influences of Glycerol Monostearate Concentration and Storage Condition

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Abstract

Tomato is a seasonal horticultural product that has beneficial effects on human health. It contains a high concentration of lycopene and vitamin C. Due to its high moisture content; harvested tomato relatively has a short shelf-life. One way to prolong tomato's shelf-life is by converting it into powder. In this research, the tomato was shifted into tomato powder using a foam mat drying method. The weight ratio of GMS totomato juice was varied:(1) 4%-w/w, (2) 5%-w/w, and (3) 6%-w/w. Tomato powder was then stored in two types of materials (sealed brown glass bottle and laminated aluminium foil (LAF) resealable zipper) and three different conditions (refrigerator (± 4 ℃), room temperature (± 25.2 ℃) and direct sunlight exposure (± 30 ℃)). According to the results, foam mat drying could maintain the nutrients of the tomato powder. Increasing GMS larger than 5%-w/w had no big impact on reserving lycopene and vitamin C. At 5%-w/w GMS, tomato powder consisted of 1.09%/w/w moisture, 42.58 mg/100 g lycopene, and 123.28 mg/100 g vitamin C. It was found that moisture and vitamin C on tomato powder content was influenced by storage conditions, while lycopene content was influenced by storage material. Moisture content and vitamin C were best maintained at direct sunlight exposure condition and room temperature, respectively. While lycopene was best stored in the laminated aluminium foil (LAF) resealable zipper.

Keywords: *tomato powder; foam mat drying; food processing; lycopene; food storage*

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INTRODUCTION

Tomato (*Lycopersicum esculentum*) is a horticultural plant planted in the lowlands or the highlands. The average consumption of tomatoes in Indonesia is around 631.29 thousands tonnes/year, while the average production is around 1020.33 thousands tonnes/year (BPS, 2019). For several years, the gap between consumption and production leads to the waste of fresh tomatoes. Furthermore, tomatoes have short shelf-life due to their water content. Thus, farmers tend to throw away the unsold fresh tomatoes. To overcome wasted fresh tomatoes, converting tomatoes to tomato powder through drying can be an alternative. Tomato drying can be carried out naturally through sun drying or mechanically driven processes, such as tray dryers, rotary dryers, and freeze dryers. Mechanical drying has the advantage of shorter drying times and more uniform product quality.

Tomato drying is used to reduce the water content in tomato to the extent that the development of microorganisms and enzyme activity that can cause rot is inhibited, thus the material has a long shelf-life (Taib & Said, 1988). This drying principle is to expose hot air around the material so that the material's water vapour pressure is greater than the water vapour pressure in the air. The pressure difference causes a flow of water vapor from the material to the air. In the drying process, water in the moisture layer of a solid will evaporate first followed by the liquid in the pores of the solid. However, drying using hot airflow has disadvantages such as the degradation of nutrients. Therefore, to minimize nutrients' degradation, alternative drying such as foam mat drying is introduced.

Foam-mat drying consists of transforming liquid or semi-liquid food ingredients into a stable foam through stirring with the addition of foaming agents and stabilizers (Kadam et al., 2010). Foam mat drying is carried out at a low temperature to form a thin and porous mat. The advantage of foam is that its structure has a large surface area so that water evaporation can take place more quickly (Brygidyr *et al*., 1977). Capillary diffusion is also one of the activators of moisture in the product during drying (Sankat & Castaigne, 2004). The products obtained from this drying have better quality and are porous. The advantages of this foam-mat drying method are faster drying time at low temperature, suitability for drying various types of juices, retain nutrients in the juice, easy to perform and low operating costs (Kudra & Ratti, 2006). Therefore, this drying method is cheaper than other drying methods such as vacuum, drum, puff, freeze, and spray drying (Morgan, *et al*., 1961).

Kadam *et al*. (2012) conducted foam mat drying with different foam agents on various temperatures obtained 8.5566 mg/100 ml vitamin C using milk as a foaming agent at 65 °C and 26.4748 mg/100 g lycopene using 1.0%-w/w CMC as a foaming agent at 75 °C. Hariyadi *et al*. (2018) found that 2 mm and 50 °C are the best conditions drying tomato juice using a foam mat drying method. Kandasamy *et al*. (2014) found that 3%-w/w GMS at 60 °C and 4mm foam thickness are the best condition to foam mat drying papaya pulp.

This research was conducted to produce tomato powder with glycerol monostearate (GMS) variation. GMS was selected due to its common usage as emulsifier and surfactant in the food industry. Based on the previous research, temperature 50 °C, 2 mm foam thickness, and 5%-w/w CMC were the best condition to maintain lycopene (Armani, 2019). According to these results, GMS will be varied from 4 – 6%w/w at the drying temperature of 50 °C and 2 mm foam thickness.

MATERIALS AND METHODS

Materials

The tomato used for this research is called "Tomat Gondol" and obtained from Gandok Local Market, Ciumbuleuit, Bandung. The ripe tomatoes have bright red colour, oval shape, and relatively thick meat. Food grade glycerol monostearate (GMS) 99% used as a foaming agent for foam mat drying was obtained from Brataco Chemika.

Karl Fischer reagent was used to determine the water content of tomato juice and obtained from Merck. Amylum (starch indicator) and 5% iodine solution were used to determine vitamin C or ascorbic acid in tomato juice and tomato powder. Both were obtained from a local chemical store in Bandung.

Hexane, acetone, and ethanol were used to analyze lycopene concentration and obtained from Merck, Indonesia. Lycopene analytical standard (90%) was obtained from Sigma Aldrich.

Methods

Juice Preparation

Clean and fresh tomatoes were steam blanched for 5 minutes then cut into a smaller size and separated from the seeds. Afterwards, tomatoes were converted into juice using a blender food processor for 5 minutes, then filtered using ten mesh sieve to remove solid particles. Moisture content of tomato was measured using a moisture analyzer (Mettler Toledo). Vitamin C and lycopene content of filtered juice wereanalyzed byiodometric titration and a UV-Vis spectrophotometer (Thermo Scientific Genesys 20), respectively.

Foam Mat Drying

Varied GMS (4,5,6%-w/w)and tomato juice were mixed using a mixer (Princess Pro Mixer) around one minute until foams were formed. Tomato juice foams were poured onto the tray with 2 mm foam thickness. Drying was then conducted in the tray dryer at 50 °C and 12.3 m/s airflow rate untilthe tomato powders were attained and its weight was constant.

Tomato powders were cooled and analyzed to measure water content, lycopene, and vitamin C. Moisture content was measured using a moisture analyzer (Mettler Toledo). Vitamin C was measured by iodometric titration following method by Ciancaglini. *et al*. (2001). Lycopene was extracted following method by Sharma & LeMaguer (1996). Lycopene concentration was measured using UV-Vis spectrophotometer (Thermo Scientific Genesys 20).

Tomato Powder Storage

Tomato powder with the lowest moisture content will be stored in various storage materials and conditions. Two different materials(sealed brown glass bottle and laminated aluminium foil (LAF) resealable zipper) were selected to store tomato powder. Each material was stored in three different conditions (refrigerator (± 4 ℃), room temperature (± 25.2 ℃) and direct sunlight (± 30 ℃)). The water content, lycopene, and vitamin C of stored tomato powders were measured weekly for three weeks.

Vitamin C Measurement

Vitamin C concentration in a tomato juice and tomato powder was measured by iodometric titration (Ciancaglini. *et al*., 2001). Around 25 ml sample was placed and mixed with distilled water until reach 50 ml volume. An aliquot 10 ml was placed in a 50 ml Erlenmeyer flask then few drops of the starch indicator were added. The sample was then titrated with iodine solution until colour change was observed. Each sample was duplicated.

Lycopene Measurement

Lycopene was extracted and measured using UV-Vis spectrophotometer (Sharma & LeMaguer, 1996). Five grams of sample were placed inside 100 ml Erlenmeyer flask and dissolved with 50 ml of solvent mixture (2:1:1 v/v/v of hexane, acetone, and ethanol). The solution was mixed for 30 minutes using magnetic stirrer then filtered using Buchner funnel. Ten millilitres of distilled water was added to the filtrate, and then the solution was mixed until it formed two layers of solutions (polar and non-polar). The polar layer (top layer) was separated and placed in a 100 ml Erlenmeyer flask, then the solvent mixture was added. Absorbances of each sample were measured using UV-Vis spectrophotometer at 470 nm. Lycopene concentration was calculated using Eq. 1 and Eq.2.

$$Y\ (\text{Abs}) = 0.3415\ X\ (\text{mg/L juice}) \qquad (1)$$

$$Y\ (\text{Abs}) = 0.0085\ X\ (\text{mg/g powder}) \qquad (2)$$

Data Analysis

ANOVA One Way testing and least significant difference (LSD) analysis were conducted to determine the influence of each parameter statistically using Microsoft Excel^{TM} as a tool.

Following the study conducted by Wibowo *et al.* (2015), the degradation rate of lycopene and vitamin C in the tomato powder was evaluated using zero-order (Eq.3) and first-order kinetic models (Eq.4). The most suitable model was selected by comparing the correlation coefficient (R^2).

$$C = C_o - k_o.t \qquad (3)$$

$$C = C_o\ .\ \exp(-k_1.t) \qquad (4)$$

C is ascorbic acid or lycopene concentration (mg/100 g) at time t, Co is the ascorbic acid or lycopene concentration at t = 0, k_o and k_1 are the degradation rate constant for zero-order (mg/100 g powder.h) and first-order (h^{-1}) model.

RESULTS AND DISCUSSION

Tomato Juice

Tomato juice was analyzed for water, lycopene, and vitamin C content. The result can be seen in Table 1.

Table 1. The composition of tomato juice

Component	Value	Std.dev	Unit
Water	94.46	1.083	%-w/w
Lycopene	4.69	0.153	mg/100 g juice
Vitamin C	28.00	0.903	mg/100 g juice

According to Sánchez-Moreno *et al.* (2006), the composition of lycopene in the fresh tomato juice is between 1.024 mg/100 g to 3.435 mg/100 g. Another study reported that lycopene is in the range between 5.02 g/100 g to 9.49 g/100 g (Pinela *et al*., 2012). The composition of lycopene in the tomato depends on the tomato's variety, growth environment, and ripeness. Ripe tomatoes have red colour and tend to have a high concentration of lycopene (Valšíková-Frey *et al*., 2017). Since the lycopene composition obtained from this variety of tomato (Tomat Gondol) is still on the range with the references, the result showed in Table 1 was still acceptable.

Similar to lycopene, the vitamin C composition also depends on the tomato's variety, growth environment, and ripeness (Valšíková-Frey *et al*., 2017). It can be seen that the composition of vitamin C in Table 1 was 28.00 mg/100 g. This result is in accordance with literature (Sánchez-Moreno *et al*., 2006), where it stated that vitamin C composition is in the range of 9.19 – 67.6 mg/100 g juice.

The Influence of GMS Concentration to The Drying Curve

The drying curve of foam mat drying was plotted to Fig. 1. It can be seen that adding a higher concentration of GMS could decrease moisture content faster. This is due to the increase of drying surface area (Brygidyr *et al*., 1977). Mixing GMS to tomato juice would form a foam-like structure. These foams were porous, thus enable to facilitate water vaporization.

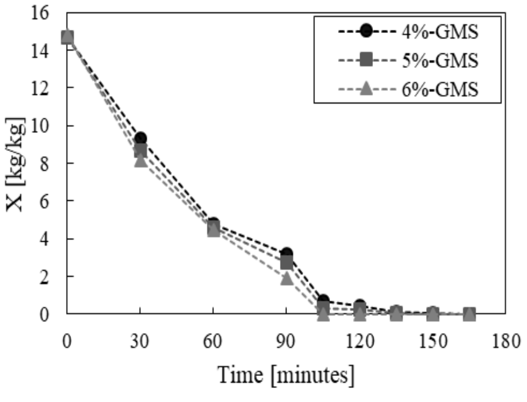

Figure 1. Drying Curve of Tomato Powder Using Foam Mat Drying for Different GMS Concentration

As shown in Fig. 2, traditional drying (without GMS) took a longer than 8 hours, while foam mat drying could be completed in less than 3 hours. It showed that foam mat drying was able to reduce drying time by 67%.

The standard moisture content for powder food should be around 2-5%-w/w (Mujumdar & Chen, 2009). Table 2 shows that the water content using foam mat drying was lower than traditional drying and the standard reference. The low moisture content was due to the larger surface area and capillary diffusion during foam mat drying (Sankat & Castaigne, 2004). Increasing GMS to 5%-w/w could decrease moisture content to 1.09%, the lowest of all experiments. Increasing GMS concentration to 6%-w/w did not necessarily decrease water content. This phenomenon might occur due to water content in GMS or excess GMS creating barriers for bound water to vaporize. The low moisture content will consequently prolong the shelf-life of tomato powder.

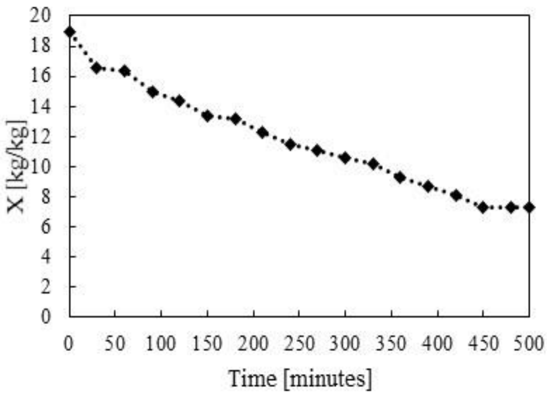

Figure 2. Drying Curve of Tomato Powder using Tray Drying without GMS

Table 2. The moisture content in tomato powder for different GMS composition

GMS (%-w/w)	Moisture (%-w/w)	Std. Dev
0	7.06	0.339
4	1.61	0.064
5	1.09	0.042
6	1.71	0.021

ANOVA One Way Testing and LSD analysis were also conducted to determine whether GMS concentration has a strong influence in reducing moisture content and which GMS concentration that differs significantly.

Table 3. One-Way ANOVA statistical analyses performed for moisture content (α = 0.05)

Source	Sum of Square	DoF	Mean Square	F
Factor	47.36	3	15.79	519.77
Error	0.12	4	0.03	
Total	47.49	7		

Table 4. LSD analyses for moisture content

i	j	$\lvert y_i - y_j \rvert$	LSD	Result
0%	4%	5.46	0.24	Very Signific.
0%	5%	5.97		Very Signific.
0%	6%	5.36		Very Signific.
4%	5%	0.52		Signific.
4%	6%	0.10		Not Signific.
5%	6%	0.62		Signific.

From Table 3, the factor and error' degree of freedom (DoF) of One-Way ANOVA were three and four. Based on these values, the F's critical value was equal to 6.59. The value was much lower than the F value calculated (519.77). This meanta rejection of the null hypothesis that stated moisture content is not influenced by GMS concentration. In other words, adding GMS or using a foam mat drying method indeed influenced the moisture content in tomato powder. LSD analysis (Table 4) also supported this statement, where there was a very significant difference between GMS 0%-w/w with other GMS concentrations (4% - 6%-w/w).

It also noted in Table 4, there was significant difference of moisture content between GMS 4% & 5%-w/w and GMS 5% & 6%-w/w, however there was no different between GMS 4% & 6%-w/w. This meant GMS 5% has the most influence in reducing moisture content, as shown in Table 2 as well.

The Influence of GMS Concentration to Lycopene and Vitamin C Content

The influence of GMS concentration on lycopene and vitamin C in tomato powder was also analyzed as can be seen in Table 5 and Table 8, respectively.

Lycopene degradation could be influenced by photodegradation, oxygen, and heat (Kanasawud & Crouzet, 1990). From Table 5, it can be seen that by adding GMS for foam mat drying could retain lycopene 1.6 – 2.6 times larger than traditional drying (GMS 0%). This might occur due to the shorter time length of heat and air exposure. Traditional drying of tomato juice required 500 minutes or around 8 hours to evaporate water content, while foam mat drying only needed 165 minutes (2.75 hours). Under prolong thermal treatment and exposure to oxygen, lycopene experience degradation via isomerization (trans-isomers to cis-isomers) and oxidation into fragment products such as acetone, methyl-heptenone, laevulinic aldehyde, and glyoxal (Cole & Kapur, 1957; John Shi *et al*., 2003).

Table 5. The concentration of lycopene in tomato powder with GMS variation

GMS (%w/w)	Lycopene	
	(mg/100 g)	Std. Dev
0	17.28	0.911
4	27.99	0.497
5	42.58	0.911
6	44.16	1.159

]

Table 6. One-Way ANOVA statistical analyses performed for lycopene (α = 0.05)

Source	Sum of Square	DoF	Mean Square	F
Factor	977	3	325.67	400.63
Error	3.25	4	0.81	
Total	980.25	7		

Based on Table 6, the calculated F value for lycopene was much higher than the F's critical value of 6.59. It showed that foam mat drying indeed exceptionally significant in maintaining lycopene content in tomato powder. This result was also proven through LSD analysis (Table 7), where it showeda very significant difference between traditional drying (GMS 0%-w/w) and foam mat drying (GMS 4% - 6%-w/w).

According to Table 7, there was great significance between lycopene content using GMS 4%-w/w & 5%-w/w and GMS 4%-w/w & 6 %-w/w. However, the least significant for GMS 5% and 6%-w/w. It indicated that increasing GMS larger than 5%-w/w had a small impact on increasing lycopene content on tomato powder.

Table 7. LSD analyses for lycopene

i	j	$\lvert y_i-y_j \rvert$	LSD	Result
0%	4%	10.72	1.25	Very Signific.
0%	5%	25.30		Very Signific.
0%	6%	26.88		Very Signific.
4%	5%	14.58		Very Signific
4%	6%	16.16		Very Signific
5%	6%	1.58		Signific.

Vitamin C or ascorbic acid in tomato powder without using foam mat drying was around 50.72 mg/100 g powder. This value was smaller compared to tomato powder obtained from foam mat drying (Table 8). Vitamin C is a thermal labile nutrient and easily oxidized. Under aerobic condition, vitamin C is oxidized to DHAA and further hydrolyzed to 3-deoxy-L-pentosone (3DP) and 2,3-diketo-L-gulonic acid (DKG) (Fennema, 2008; Kurata & Sakurai, 1967). It starts to denature at a temperature of 30 ºC (Igwemmar, *et al*., 2013). Prolong exposure to heat and air would denature vitamin C faster; thus, vitamin C content with foam mat drying method was greater due to less exposure to air and heat during the drying process.

ANOVA testing and LSD analysis were also conducted to analyse the influence of GMS concentration on vitamin C in tomato powder. From Table 9, the calculated F value was larger than the critical F value (6.59), so it exhibited the significance of using foam mat drying to maintain vitamin C content.

The LSD analysis of vitamin C could be seen in Table 10. The vitamin C content on tomato powder hada similar pattern as lycopene content, where there was great significancebetween vitamin C content between foam mat drying and traditional method.

Table 8. The concentration of vitamin C in tomato powder with GMS variation

GMS (%w/w)	Vitamin C (mg/100 g)	Std. Dev
0	50.72	3.985
4	102.15	4.981
5	123.28	4.981
6	126.10	0.996

Table 9. One-Way ANOVA statistical analyses performed for vitamin C (α = 0.05)

Source	Sum of Square	DoF	Mean Square	F
Factor	7310.13	3	2436.71	146.56
Error	66.50	4	16.63	
Total	7376.64	7		

Table 10. LSD analyses for vitamin C

i	j	$\lvert y_i-y_j \rvert$	LSD	Result
0%	4%	51.43	5.66	Very Signific.
0%	5%	72.56		Very Signific.
0%	6%	75.38		Very Signific.
4%	5%	21.13		Very Signific
4%	6%	23.95		Very Signific
5%	6%	2.82		Signific.

Highly significant vitamin C content differences were also noted between GMS 4%-w/w & 5%-w/w and GMS 4%-w/w & 6 %-w/w. Nevertheless, there was a small difference between GMS 5% and 6%-w/w, which meant increasing GMS larger than 5%-w/w hada small impact on retaining vitamin C content.

The Influence of Material and Storage Conditions to Water, Lycopene, and Vitamin C Content

The statistical analysis using ANOVA testing and LSD analysis displayed that GMS 5%-w/w was the formulation that has a significant impact on moisture, lycopene, and vitamin C content. Therefore, the formulation of 5%-w/w GMS was selected to analyze the influence of storage condition and material on the moisture, lycopene, and vitamin C content of tomato powder. Three conditions (refrigerator/4 ºC, room temperature/25.2 ºC, and direct sunlight/30 ºC) and two materials (laminated aluminium foil (LAF) resealable zipper and brown glass bottle) were applied.

Initially, the powder contained 1.09%-w/w moisture, but after three weeks of storage, the moisture content increased in all storage conditions and materials. It can be seen in Fig. 3 that LAF resealable zipper was not a suitable material to maintain moisture content as the value of water was five times higher (in the range 5.24 – 5.83 mg/100 g) than the initial value. The moisture content of tomato powder stored in the glass bottle has a lower value than the one stored in the LAF resealable zipper.

Study by Bailey & Elban (2008) suggested that brown glass bottle warmed slightly faster than alumunium bottle. This theory explained the tomato powder's low moisture content in the glass brown bottle.

Storing tomato powder in the refrigerator was not suitable to retain water content for both LAF resealable zipper and glass bottle. There is condensation tendency occurred in the refrigerator that will affect the water content and stability of a product. Hence, it will shorten the life-shelf of tomato powder. Direct sunlight exposure condition managed to maintain tomato powder's water content to 1.965 %-w/w after three weeks of storage in a brown glass bottle. Due to brown glass bottle could warm faster, it might suppress the water content of tomato powder.

Based on Fig.3, varying storage conditions only affected in suppressing moisture content in the glass bottle instead of LAF resealable zipper. Therefore, to ensure the influence between two parameters, ANOVA Two Way testing was conducted as depicted in Table 11. It showed that storage material had no significant impact on moisture content, while the storage condition influenced moisture content.

The lycopene content on tomato powder after three weeks of storage can be seen in Fig. 4. Initially, the lycopene content was 42.58 mg/100 g powder. After three weeks of storage, the lycopene content in LAF resealable zipper was in the range of 21.903 – 23.836 mg/100 g powder, while brown glass bottle managed to retain lycopene in the range of 12.240 – 16.984 mg/100 g powder. Based on this result, the LAF resealable zipper had better performance in maintaining lycopene content.

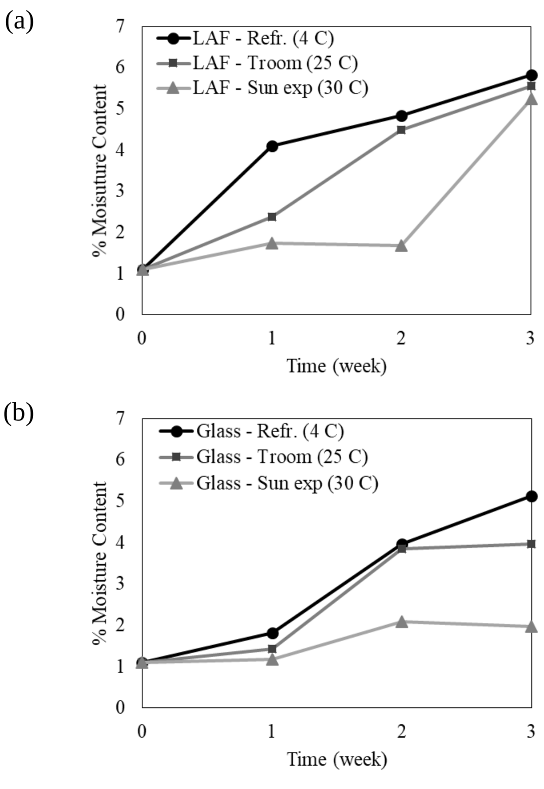

Figure 3. Moisture Content in Tomato Powder after 3 weeks of Storage in (a) LAF and (b) Brown Glass Bottle

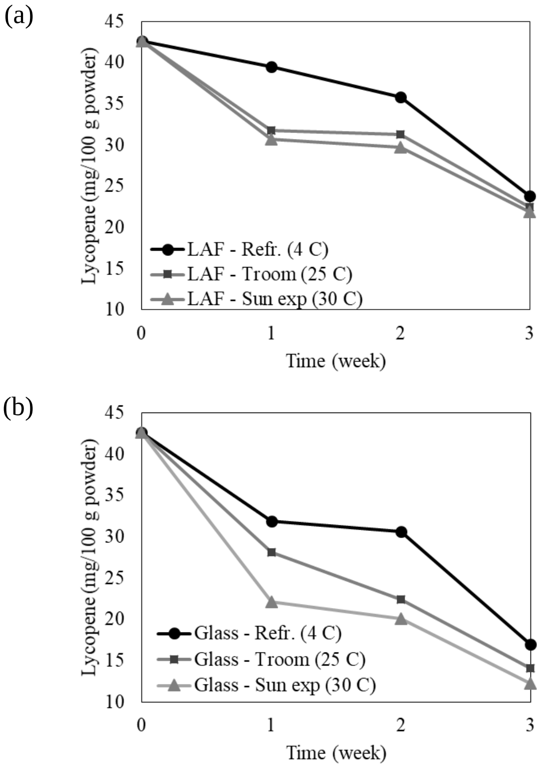

Figure 4. Lycopene content in Tomato Powder after 3 weeks of Storage in (a) LAF and (b) Brown Glass Bottle

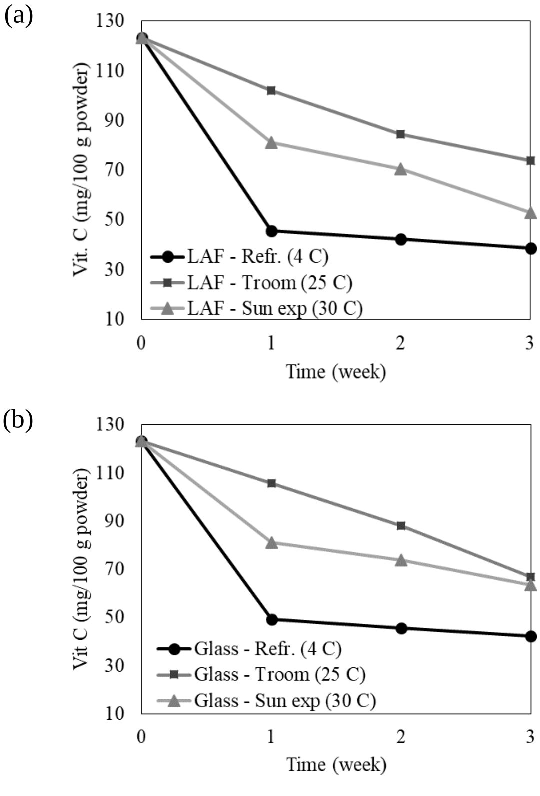

Figure 5. Vitamin C content in Tomato Powder after 3 weeks of Storage in (a) LAF and (b) Brown Glass Bottle

Lycopene degradation is mainly caused by thermal and photodegradation. Due to brown glass bottle retain heat faster than LAF resealable zipper, thermal degradation of lycopene was rapid in the glass bottle. LAF resealable zipper has high reflectivity of 70%, 86% and 97% in the UV, visible range, and infra red spectrum, respectively (Coblentz & Stair, 1930; Pozzobon *et al.*, 2020). This makes LAF resealable zipper performed better to avoid lycopene's photodegradation.

The refrigerated temperature was the best condition to retain lycopene for both LAF resealable zipper and brown glass bottle. According to Demiray *et al.*, (2013), lycopene's degradation rate is slower in lower temperature. Storing tomato powder in a higher temperature will encourage the isomerization and autooxidation of lycopene. Therefore, lowering the lycopene content in the tomato powder.

After three weeks, the storage condition seemed to have no impact on maintaining lycopene content since the value fell within the same range. This result was proven through ANOVA testing in Table 11. The calculated F value for the material was larger than the critical F value, which displays its significance. Storage conditions and interaction between material and storage conditions had no impact on lycopene content.

Fig. 5 indicates the influence of storage material and condition on vitamin C after three weeks of storage. Based on Fig. 5, the room temperature was the best condition to maintain vitamin C in tomato powder for both LAF resealable zipper and brown glass bottle. Vitamin C is sensitive to heat and light, thus storing in direct sunlight exposure condition will destroy vitamin C overtimes. However, according to this research, storing tomato powder in refrigerator degraded vitamin C even faster than the direct sunlight condition. According to Jutkus *et al.* (2015), vitamin C's destruction rate is much faster when the higher water content presents. When enough water was available, it significantly increases the vitamin C sample's water activity, which coincided with the decrease in chemical stability.

From Fig 3, moisture tended to increase when storing in the refrigerator. This increase in water content will cause vitamin C instability and consequently, deterioration of vitamin C.

Table 11. Two-Way ANOVA statistical analyses performed for storage (α = 0.05)

Source	Sum of Square	DoF	Mean Square	F	F_{crit}
Moisture Cont.					
Material (A)	9.15	1	9.15	3.39	4.072
Condition (B)	17.83	2	8.91	3.31	3.222
Interaction (AB)	0.06	2	0.03	0.01	3.222
Error	113.28	42	2.70		
Total	140.32	47			
Lycopene					
Material (A)	392.6	1	392.60	4.33	4.072
Condition (B)	231.23	2	115.61	1.28	3.222
Interaction (AB)	9.81	2	4.91	0.05	3.222
Error	3803.86	42	90.57		
Total	4437.51	47			
Vitamin C					
Material (A)	50.66	1	50.66	0.06	4.072
Condition (B)	8414.22	2	4207.1	5.02	3.222
Interaction (AB)	26.88	2	13.44	0.02	3.222
Error	35230.5	42	838.82		
Total	43722.3	47			

Table 12. Kinetic degradation rate of Lycopene according to zero and first order (k_o = mg/100 g powder.h & k_1= h^{-1})

Material Condition	Zero Order		First Order		$t_{1/2}$ (h)
	k_o	R^2	k_1	R^2	
LAF					
Refrigerator	0.0357	0.8863	0.0011	0.8810	633.6
Room T	0.0362	0.9107	0.0012	0.9135	602.7
Direct sunlight	0.0375	0.9091	0.0012	0.9272	574.5
Glass Bottle					
Refrigerator	0.0465	0.9218	0.0017	0.8781	416.2
Room T	0.0554	0.9634	0.0021	0.9815	327.7
Direct sunlight	0.0554	0.8615	0.0023	0.9337	303.5

Storage material and condition were analyzed statistically to determine its influence in vitamin C content, as shown in Table 11. Vitamin C was heavily affected by the storage condition. Storage material and interaction between two parameters have no significant influence in the vitamin C concentration.

The Degradation Rate of Lycopene and Vitamin C in Tomato Powder

According to the study conducted by Li *et al*. (2018) and Wibowo *et al*. (2015), the degradation rate of lycopene and vitamin C was well fitted with the zero-order and first-order kinetic models. The results can be observed in Table 12 and Table 13. It can be seen that the concentration for both lycopene and vitamin C gradually decreased over time during storage.

From Table 12, based on the value R^2 the degradation rate of lycopene in LAF resealable zipper and glass bottle followed the first-order kinetic model. The lycopene degradation rate constant (k_1) increased by rising temperature or changing storage conditions from colder to warmer condition. This present study's result was in good agreement with Demiray *et al*., (2013) and Li *et al*. (2018), who reported that the lycopene degradation rate followed the first-order kinetic model and increasing temperature would accelerate the degradation rate of lycopene. Additional heat due to increase of temperature cause lycopene conversion from *trans*-isomers to unstable *cis*-isomers (Shi & Le Maguer, 2001). Sunlight is the main source of UV radiation. According to Siems *et al*. (1999), lycopene also decomposes rapidly due to photooxidation in the presence of UV light.

Lycopene degradation rate constant was slower in LAF resealable zipper compared to a brown glass bottle. As explained previously, a brown glass bottle maintains heat faster compared to LAF material. Thus, prolonged heat exposure will deteriorate lycopene content in tomato powder. Additionally, LAF resealable zipper has high UV reflectance that prevent photooxidation of lycopene. The longest half lifetime ($t_{1/2}$) of lycopene was achieved at 633.6 hours or 3.77 weeks when stored in LAF resealable zipper at the refrigerated temperature (4 ^{o}C).

Table 13. Kinetic degradation rate of Vitamin C according to zero and first order (k_o = mg/100 g powder.h& k_1= h^{-1})

Material Condition	Zero Order		First Order		$t_{1/2}$ (h)
	k_o	R^2	k_1	R^2	
LAF					
Refrigerator	0.153	0.6682	0.0020	0.7194	347.4
Room T	0.099	0.9796	0.0011	0.9939	657.2
Direct sunlight	0.132	0.9156	0.0016	0.9637	434.2
Glass Bottle					
Refrigerator	0.147	0.6712	0.0020	0.7194	354.5
Room T	0.111	0.9979	0.0012	0.9815	577.9
Direct sunlight	0.111	0.8423	0.0012	0.8957	558.2

Table 13 indicates the degradation rate of vitamin C after three weeks. By comparing the R^2 constant, first-order kinetic model is more suitable to depict vitamin C degradation. This result is in accordance to research by Nakilcioğlu-Taş & Ötles, (2020), who reported that vitamin C followed the first-order kinetic model and storage temperature had no significant effect on the vitamin C content. The degradation constant (k_1) of vitamin C was higher at refrigerator than in the room and direct sunlight temperature. This present study found that refrigerator created moisture build up in the product. Vitamin C will be unstable due to oxidation in the presence of moisture (Jutkus *et al*., 2015; Lee & Labuza, 1975). Thus, despite storing in colder temperature, the presence of water in tomato powder will deteriorate vitamin C faster. The longest half lifetime ($t_{1/2}$) of vitamin C was 657.2 h or 3.91 weeks when it stored in LAF resealable zipper at room temperature.

CONCLUSION

Foam mat drying is a proven method to reduce water content faster compared to the traditional drying method. It could reduce the drying time to 67%. Foam mat drying could also maintain lycopene and vitamin C 2.5 times higher than the traditional drying method.

Storage conditions influenced moisture and vitamin C content. Direct sunlight temperature (30 ^{o}C) wasa suitable condition to maintain moisture content, while room temperature (25 ^{o}C) was suitable for maintaining vitamin C content on tomato powder.

The lycopene content was influenced by storage material, where laminated aluminium foil (LAF) resealable zipper-maintained lycopene 1.3 times higher than the brown glass bottle.

The degradation rate of lycopene and vitamin C followed the first-order kinetic model. The degradation rate contants of lycopene decreased when stored in refrigerated temperature, while the degradation rate of vitamin C decreased when stored at room temperature.

For future storage of tomato powder, it is best to be stored in a material with low heat transfer and high resistant to sunlight exposure, such as LAF resealable zipper.

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