Kinetics of shallot powder (Allium ascalonicum) quality change during storage and its shelf life

E Sukasih1*, A C Permata2, M Bintang2 and Setyadjit1
1Indonesian Center for Agricultural Postharvest Research and Development. Jalan Tentara Pelajar No. 12, Bogor 16112
2Departement of Math and Science Bogor Agricultural Institute, Bogor, Indonesia

*Email: ermi_sukasih@yahoo.co.uk

Abstract. Shallot powder is one type of processed products that have a potential to be developed for the time being. The purpose of this research was to study the kinetics of shallot powder quality change during storage and its shelf life. Shallot powder were packed with three packings such as aluminium foil only, aluminium foil covered with PP plastic film, aluminium foil covered with PP plastic film and vacuum condition. Next, samples were stored in three temperatures i.e 20°C, 30°C, and 40°C for 32 days and then observed at four days interval. Parameters observed in this study were color, moisture content, total phenol content, and antioxidant activity. The increase and decrease of each parameter is shown based on the slope value. The results showed that during storage there was increased color, and moisture content at all storage temperatures, while for ash content, total phenol, and antioxidant activity decreased. Shallot powder packed with aluminium foil covered with PP plastic film and vacuum condition has the longest shelf life prediction at all the temperature storages. The shallot powder has 447.37 days at 20°C, for 328.24 days at 30°C, and for 245.64 days at 40°C for predicted of shelf life.

1. Introduction
Shallot bulbs are perishables and often fluctuate in price so it is necessary to stabilise their supply. The shallot bulbs will be damaged by decay and sprout during storage. Processing into several products would be able to overcome of these problems. Shallot powder is one type of processed products that have a potential to be developed for the time being. In the powder formed, has several advantages including the more stable nutritional content and easy the distribution and storage. During storage can be seen changes in quality of shallot powder as an attempt to obtain a longer shelf life.

Packaging has an important role to prevent damage to shallot powder. Packaging may affect the shallot powder characteristics of physical and chemical changes due to the migration of chemicals from packing materials to food, aroma changes, discoloration, and texture changes caused by vapor and oxygen displacement. The relation between type of packing material to shelf life of shallot powder is based on the permeability. The more extensive the surface of the packaging is able to used by water vapor to enters the packages, the critical water content of the product will soon be achieved and the shelflife of the product will be decrease [1].

Aluminum foil and polypropylene plastic (PP) are a flexible packaging and commonly used as packaging material. The properties of aluminium foil is hermetic, flexible, opaque so they can be used to pack of light-sensitive materials [2]. Polypropylene plastic is a type of plastic as a barrier to moisture
in the product because it has a low permeability to moisture [3]. Polypropylene permeability to water vapor is 0.185 g/m² hr.mmHg [4]. Vacuum packaging is technique, with pressure less than 1 atmosphere (atm). The vacuum packaging technique is required to remove oxygen from the packaging and increase the shelf life of the product. Based on these properties then used aluminum foil and polypropylene as well as vacuum packaging techniques to pack the shallot powder [5].

Shallot powder is a new product developed in Indonesia, that will be produced by SME (small and medium enterprises) level, so it is necessary to determine product’s expiry date. One of new products of research and development that has been tested before it was being applied in the field is tomato paste [6]. The purpose of this research was to study the kinetics of shallot powder quality change during storage and its shelf life. This research is expected to provide information on suitable packaging types and able to protect the quality of shallot powder and can extend of the shelf life.

2. Materials and methods

2.1 Raw materials
Raw materials used in the study were fresh shallot Cv. Bima. The packaging material used were aluminium foil and Polypropylene plastic (PP). The chemicals used were citric acid powder, 2,2-Diphenyl-1-Picrilyhydrazyl reagent (DPPH), Folin-Ciocalteau reagent, gallic acid powder, ascorbic acid powder, sodium carbonate powder, and methanol. Equipments used were, chromameter, oven, UV-Vis spectrophotometer, analytical balance, sealer, slicer, incubators (20°C, 30°C, and 40°C), shaker, cuvette, vacuum packaging, refrigerator, and glassware. The study was conducted in the laboratory of Indonesian Centre for Agriculture Postharvest Research and Development in January to April 2014.

2.2 Processing of shallot powder
Shallot bulbs were sorted, then peeled to separate the skin. As much as 17 kg bulbs were weighed, then sliced with a slicer tool. Sliced shallots were then soaked into 1% citric acid for 30 minutes. After soaking, sliced shallot were rinsed with clean water twice. Sliced shallots was drained in a small perforated plate for ±30 minutes to minimise of water left. Drained shallots then were put in the cabinet dryer at temperature of 50°C for 10 hours. The dried shallots then were milled until smooth and filtered. Shallots powder were ready to packed and observed of quality changes during storage.

2.3 Analysis and observation
Shallot powder were packed with three packings such as aluminum foil only, aluminum foil covered with PP plastic film, aluminium foil covered with PP plastic film and vacuum condition. Samples were stored in three temperature storages i.e 20°C, 30°C, and 40°C for 32 days and then observed every four days interval on day 0, 4th, 8th, 12th, 16th, 20th, 24th, 28th, 32nd. Parameters observed in this study were color by chromameter [7], moisture content [8], total phenol [9], and antioxidant activity [10].

2.4 Prediction of storage life of shallot powder
The prediction of shelf life of shallot powder was determined by Arrhenius approach. The calculation of shelf life was to determine the value of ln k obtained from the value of k which is the constant value of the quality degradation [11].

3. Results and discussion

3.1 Kinetics of shallot powder quality change during storage

3.1.1 Color
In some types of food, changes in color could indicate changes in nutritional value, so that color change can be used as an indicator the level of nutritional value [4]. Therefore, the color change can be used to
estimate the length of storage and characteristics of the physical properties of a foodstuff [12]. The \(^{\circ}\)Hue value of shallot powder is between 75-95, which interpreted they had a reddish yellow color. Figure 1 shows the higher the temperature, the \(^{\circ}\)Hue value will be higher also, visually the brightness of the color will decrease and tends to darken. The dark color is thought to be caused by a non-enzymatic browning reaction that occurs due to high temperatures.

The higher storage temperature causes a larger color change in shallot powder. The level of color change indicated by an increase in the value of slope (k) in shallot powder produced in 3 packaging treatments. Nevertheless visually on aluminium foil only, the increase of slope value were not significant at 20°C and 30°C temperatures storages, but otherwise at a temperature of 40°C. The results showed on all types of packaging, on storage temperature 40°C shallot powder has the largest slope value. This is caused by the oxidation of chlorogenic acid by polyphenoloxidase enzyme into melanoidin then brown color formed. With higher temperatures, chlorogenic acid oxidation is faster and brown changes are also faster [13]. Shallot powder that packed with aluminium foil covered with PP plastic film and vacuum condition and stored at 20°C has the smallest slope value of 0.0942, and the color is more stable than the other packaging. This is because packaging with vacuum condition will reduce the air contained in the packaging so that the oxidation reaction is inhibited.

![Figure 1](image_url)  
**Figure 1.** Change the color of shallot powder during storage at various temperatures and packing methods (A) aluminium foil only, (B) aluminium foil covered with PP plastic film, (C) aluminium foil covered with PP plastic film and vacuum condition.

### 3.1.2. Water content

The results showed that water content increased with length of storage time (Figure 2). The figure shows that all treatment factors result in a small increase in slope value. Differences in storage temperatures and packaging types do not significantly affect changes in water content of shallot powder. Shallot powder is packed with aluminium foil covered with PP plastic film and vacuum condition and stored at 30°C has the smallest slope value of 0.026. This suggests that the vacuum technique is better at
maintaining the moisture content of the product. In general, the increase of water content on the shallot powder with the three types of packaging is not too large. This is because the packaging is able to maintain water vapor within and outside the product so there is no water vapor transfer [14].

Low water content will minimize microbial growth on the shallot powder [15]. One of the criteria of good shallot powder is having a maximum water content of 14% [16]. Changes in water content on shallot powder is also caused by the relative humidity of the storage space. The material will change its moisture content during storage. When the relative humidity of the air is higher than the material, then the material will absorb water.

![Figure 2](image)

**Figure 2.** Change the water content of shallot powder during storage at various temperatures and packing methods (A) aluminum foil only, (B) aluminum foil covered with PP plastic film, (C) aluminium foil covered with PP plastic film and vacuum condition.

### 3.1.3. Antioxidant activity

Antioxidant analysis was done by 2,2-diphenyl-1-picrilhidrazil (DPPH) method. DPPH is a free radical that is stable at room temperature. This radical will receive electrons or hydrogen radicals and form a stable diamagnetic molecule. The antioxidant interaction with DPPH will neutralize the highly reactive free radical character [17]. In this antioxidant measurement study used vitamin C as a comparison. Vitamin C has high antioxidant activity [18]. The largest nutritional content of shallot that has a function as an antioxidant is ascorbic acid (vitamin C) of 7 g / 100 mg [19]. Antioxidant activity of shallot powder ranges from 50 to 190 ppm.

The results showed that antioxidant activity on shallot powder decreased during storage. It generally shows a similar pattern of decreased both of antioxidant activity and total phenol in each treatment. In accordance with the research of [20], the total phenols and flavonoids content is positively correlated with antioxidant activity. Shallot powder is packed with aluminium foil covered with PP plastic film and vacuum condition and stored at 30°C has the smallest slope value of -0.9557. The low decrease of slope value on shallot powder with vacuum condition is related to non-enzymatic browning reaction. The antioxidant activity is related to the amino acids of non-enzymatic browning reaction.
products that occur during storage. If amino acid concentration decreases, the antioxidant activity to inhibit the peroxyl radical on shallot powder will increase [21].

![Figure 3. Change the antioxidant activity of shallot powder during storage at various temperatures and packing methods (A) aluminum foil only, (B) aluminum foil covered with PP plastic film, (C) aluminum foil covered with PP plastic film and vacuum condition.](image)

### 3.1.4. Phenol content

Total phenol analysis was determined based on the ability of phenol compounds in extracts that react with phosphomolybdate-phosphotungstate acid in Folin-Ciocalteau reagent [22]. The amount of phenol content of shallot tuber extract using the standard gallic acid curve equation. This is because these compounds are very effective for forming complex compounds with Folin-Ciocalteau reagents, so the reaction will be more intensive [23].

Phenol content of shallot flour ranges from 550 to 950 ppm. Shallot powder is packed with aluminum foil covered with PP plastic film and vacuum condition has the smallest slope value compared to the other two types of packaging of -4.2188 at a temperature of 20°C, -4.4650 at a temperature of 30°C, and -7.2585 at a temperature of 40°C. Decreasing of total phenol concentration was also influenced by storage time, temperature, and citric acid used to soak the shallot. Benkeblia [24] states that after 12 weeks of storage, there will be a sharp increase in total phenol concentration, while this study is only stored for 5 weeks.

The soaking process with citric acid will affect the polyphenol oxidase (PPO) enzyme activity. This enzyme causes in browning reactions on shallot flour. This browning process can usually be known through decreased quality sensitivity and loss of nutritional quality [25]. Previous results by Kim [26] showed that citric acid has inhibitory enzymatic browning reactions of 96.7%. Prevention of browning reaction is with several treatments, including modification of atmospheric packaging and storage in cold temperatures. This treatment will inhibit the activity of PPO enzymes so that the total phenol can be maintained [27]. This is consistent with the results of this study, which is indicated by the low decrease
in the value of shallot flour slope packaged in a vacuum and an increase in the value of the slope along with the increase in storage temperature.

![Figure 4. Change the phenol content of shallot powder during storage at various temperatures and packing methods (A) aluminum foil only, (B) aluminum foil covered with PP plastic film, (C) aluminum foil covered with PP plastic film and vacuum condition.](image)

### 3.1.5. Shelf life prediction of shallots powder

Parameters that are most rapidly damaged during storage are used as critical parameters in estimating shelf life. This is indicated by the absolute $k$ coefficient or the largest correlation coefficient ($R^2$) value [28]. Determination of critical parameters is by selecting parameters that have good linearity. From the results of the research shows that parameters that have a high $R^2$ value are color.

Predicted shelf life of shallot powder was determined using a color change approach. The results showed, the color change reaction follows zero order. Shallot powder has a different rate of quality change for each parameter. A reaction if the quality changes occur constantly or linearly, it will follow a zero order reaction. But if the reaction is not constant but logarithmic or exponential then follow the first order. Some kinds of reactions that follow zero order kinetics such as enzymatic damage, enzymatic browning, and oxidation and color. Predicted shelf life of shallot powder was calculated based on the $ln$ $k$ value with the Arrhenius equation. This determination uses kinetics theory which generally has a zero order or first order [29]. The shelf life prediction for shallot powder on various types of packaging were showed at Table 1. The best treatment was packed with aluminium foil covered with PP plastic film and vacuum condition. At 20°C temperature storage, shallot powder has the longest predicted shelf life of 447.37 days, for 328.24 days at 30°C and for 245.64 days at 40°C storage temperature.
Tabel 1. The shelf life prediction for shallot powder on various types of packaging

| Packaging type                                      | Critical limit | Real temperature (°C) | T (K) | 1/T (a) | ln K | K | Quality unit total | Shelf life (days) | Shelf life (years) |
|-----------------------------------------------------|----------------|-----------------------|-------|---------|------|---|-------------------|------------------|-------------------|
| Aluminum foil only                                 | (126-71.540)   | 20                    | 293   | 0.003   | -1.715 | 0.180 | 54.460            | 302.63           | 0.83              |
|                                                     |                | 30                    | 303   | 0.003   | -1.263 | 0.283 | 54.460            | 192.49           | 0.53              |
|                                                     |                | 40                    | 313   | 0.003   | -0.839 | 0.432 | 54.460            | 126.03           | 0.35              |
| Aluminum foil covered with PP plastic film         | (126-79.867)   | 20                    | 293   | 0.003   | -2.101 | 0.122 | 46.133            | 376.95           | 1.03              |
|                                                     |                | 30                    | 303   | 0.003   | -1.619 | 0.198 | 46.133            | 232.93           | 0.64              |
|                                                     |                | 40                    | 313   | 0.003   | -1.169 | 0.311 | 46.133            | 148.43           | 0.41              |
| Aluminum foil covered with PP plastic film and vacuum condition | (126-79.860)   | 20                    | 293   | 0.003   | -2.272 | 0.103 | 46.140            | 447.37           | 1.23              |
|                                                     |                | 30                    | 303   | 0.003   | -1.962 | 0.141 | 46.140            | 328.24           | 0.90              |
|                                                     |                | 40                    | 313   | 0.003   | -1.672 | 0.188 | 46.140            | 245.64           | 0.67              |

4. Conclusion
Shallot powder would be decreased in quality such as color, antioxidant activity, phenol content and water content during storage. The suitable type of packaging for shallot powder will preserve the quality and extend its shelf life. Shallot powder packed with aluminium foil covered with PP plastic film and vacuum condition has the longest shelf life prediction at all the temperature storages. The shallot powder has 447.37 days at 20°C, for 328.24 days at 30°C, and for 245.64 days at 40°C for predicted of shelf life.

5. References
[1] Robertson GL. 2010. Food Packaging and Shelf Life: A Practical Guide. (Florida: CRC Press).
[2] Julianti E, Nurminah M. 2007. Packaging Technology Textbook (In Indonesia) (Medan: USU Press).
[3] Manley D. 2000. Technology of Biscuits, Crackers, and Cookies 3rd Edition. (Cambridge: Woodhead Publishing Limited).
[4] Arpah.2001. Determination of Expiration of Food Products(In Indonesia) (Bogor: Bogor Agricultural University).
[5] Sacharow S, RC Griffin Jr. 1998. Food Packaging. (London : The AVIPubl.Co).
[6] Sukasih E, Sunarmanji, Budiyanto A. 2008. Journal of Agricultural Postharvest Research 4(2): 76-72. (In Indonesia).
[7] Li H, Deng Z, HonghuiZH, Hu C, Liu R, Young JC, Rong TR. 2012. Journal Food Research International 46(1): 250-259.
[8] AOAC] Association of Official Analytical Chemist. 2005. Official Method of Analysis of The Association of Official Analytical Chemist. The Association of Official Analysis Chemist, Inc. Arlington.
[9] Marinova D, Ribarova F, danAtanassova M. 2005. Journal of University of Chemical Technology and Metallurgy 40(3): 255-260.
[10] Takaya .2003. Journal of Agriculture Food Chemistry 51:8061-8066.
[11] Nurkhoeriyati T.2007.Changes in physicochemical properties and estimation of shelf life of skim milk functional drinks supplemented with isoflavone-rich soy flour and fortified with vitamins C and E (Thesis: Bogor Agricultural University).
[12] Faisal HB. 2014. Estimation of brown UHT milk shelf life by arrhenius equation model acceleration method atDanone Indonesia Company (Thesis: Bogor Agricultural University).
[13] Rachmawati R, Defiana MR, Suriani NL. 2009. Jurnal Biologi 8(2): 36-40.
[14] Haryati, Estiasih T, Heppy F, Ahmadi K. 2014 Jurnal Pangan dan Agroindustri 3: 156-165.
[15] Sumardji. 2003. Analysis of Food and Agricultural Materials. (In Indonesia) (Yogyakarta : UGM Press).
[16] Mulia SA. 2008. Buletin Teknik Pertanian 13(2): 79-82.
[17] Bintang M. 2010. Biochemical Research Techniques (In Indonesia) (Jakarta: Erlangga).
[18] Linder MC. 2010. Nutritional Biochemistry and Metabolism. (In Indonesian) (Jakarta: UI Press).
[19] Science and Technology Agency of Japan. 2002. Standard table of food composition in Japan. (Tokyo: Ministry of Finance Printing Bureau).
[20] Chen S, Shen X, Cheng S, Li P, Du J, Chang Y, Meng H. 2013. Plos One, 8(11): e79730. DOI: http://dx.doi.org/10.1371/journal.pone.0079730.
[21] Moreno.2006.Journal of Food Research International 39(8): 891-897.
[22] Suryanto E, Wehantouw F. 2009. Chem Prog. 2(1):1-7.
[23] Dungir SG, Katja DG, Kamu VS. 2012. Jurnal Mipa Unsrat 1(1):11-15.
[24] Benkeblia N. 2000. Journal of Food Science and Technology 33(2):112-116.
[25] Arnnok P, Ruangviriyachai C, Mahachai R, Techawongstien S and Chanthai S. 2010. Food Research Journal 17: 385-392.
[26] Kim M, Kim CY, Park I. 2005 Journal of Food Chemistry 89(2):181-184.
[27] Gnangui SN, Niamke, SL, Kouame LP. 2010. Journal Science 37(3):464 475.
[28] Kusnandar F. 2011. Predicted shelf life of foodstuff using accelerated shelf-life testing (ASLT). [Internet]. Download 18 October 2012 (http://www.foodreview.biz/preview.php?view2&id=55843.
[29] Syarief R and Halid H. 1993. Food Storage Technology. (In Indonesia) (Jakarta: Arcan).