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Stability of antioxidant activity of aloe vera powder during storage

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Abstract. Aloe vera powder is known to offer health benefits and possesses inherent antioxidant properties. However, the powder shows hygroscopic characteristics and causes a decrease in antioxidant activity. Implementing appropriate packaging measures to safeguard the integrity of the antioxidant activity is essential. In order to assess the antioxidant properties of aloe vera powder's shelf life and stability throughout storage until it reaches critical conditions, this research was conducted. A non-factorial, completely randomized design was used with open and closed storage using 0.80 mm polypropylene plastic packaging. Aloe vera powder was stored at 25°C and relative humidity (RH) of 75-80% until the critical conditions were reached at a moisture content of 12.00%. The analysis was carried out periodically for water, phenol, and antioxidant activity to scavenge free radicals DPPH (2,2-diphenyl-1-picrylhydrazyl). The results showed a significant increase in the moisture content during storage and decreased phenol and antioxidant activity. The unpacked powder reached its critical condition after 120 hours, whereas the powder enclosed in 0.80 mm polypropylene plastic packaging required a significantly longer duration of 44 weeks. Therefore, storage without packaging experienced a decrease in phenol and antioxidant activity levels by 88.69% and 91.45% in critical conditions. In the polypropylene packaging, there was a decline in phenol and antioxidant activity levels by 30.49% and 27.94%, respectively.

1. Introduction

Aloe vera is rich in amino acids, minerals, vitamins, and beneficial phenolic compounds for health [1]. Phenolic compounds in this plant belong to the group of flavonoids such as naringenin and kaempferol at 375.21 ppm and 2.05 ppm, with antioxidant properties [2]. However, aloe vera gel has quite a high moisture content, around 98.74±0.88% [3], making the product susceptible to damage and causing a decrease in its antioxidant effect. According to [4], the resistance of flavonoids is greatly influenced by the presence of oxygen, storage temperature, light exposure, and the duration of storage. Therefore, preservation efforts are needed for aloe vera gel to retain its antioxidant activity, which positively impacts health. However, in fresh form, aloe vera leaves are easily damaged and less practical. Therefore, aloe vera gel is processed as a powder ready to be brewed.



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Aloe vera powder is the result of processing the gel created by mixing with an encapsulating agent such as maltodextrin. According to [5], aloe vera gel powder, when stored at a RH (Relative Humidity) of 90%, temperature of $38\pm 1\text{C}^\circ$ and packaged in polypropylene (PP) plastic, can have a shelf life of up to 42.58 days. The critical properties are marked by changes in the L (lightness) and b (yellowness) color values decreasing. The powder is subjected to physical changes during storage due to increased moisture content, reduced powder porosity, less brightness in color, and clumping. Additionally, the powder can experience chemical degradation due to exposure to air, decreasing antioxidant activity [6]. In this context, packaging materials must have low water permeability to prevent deterioration and extend the shelf life.

Plastics commonly used in powder packaging include polypropylene (PP) plastic. According to [7], PP plastic has a low oxygen and water transmission rate, inhibiting the degradation of anthocyanins in *Alternanthera amoena* Voss or red leaf amaranth powder until a critical condition is reached after 97 days. Furthermore, PP plastic with a thickness of 0.8 mm has a permeability value of 0.185 g/m²hr.mmHg [8]. According to [5], the shelf life is influenced by environmental conditions and the packaging materials used. Plastic reduces direct contact with air; hence, oxidation of flavonoids can be prevented.

Critical condition refers to when a food product is no longer sensory acceptable to consumers [9]. The determination is based on factors that lead to changes in the food product. The critical storage condition for instant aloe vera gel powder can be observed physically by clumping, an essential characteristic calculated by an increase in moisture content. This condition is determined by the rise in moisture content up to 12.00% [10], and the shelf life is conducted by drying using an oven dryer at 60°C. Packaging with plastic is expected to extend the shelf life and inhibit the degradation of antioxidant compounds. Therefore, this study determines the shelf life of aloe vera gel powder packaged in PP plastic and its antioxidant property stability during storage.

2. Materials and Methods

2.1. Materials

The materials used were *Aloe vera* var. *chinensis* leaves with the harvest age of 2 years, has a length of approximately 60 cm with a weight of 700-1000 g and obtained from the Ghra Sambiroto garden in Nanggulan, Kulon Progo, Yogyakarta, Indonesia. The encapsulating agent maltodextrin was purchased from Qinhuangdao Lihua Starch Co. Ltd., China, and gum Arabic was sourced from TIC Gums, Westchester, Illinois, USA. Chemicals for phenol analysis and antioxidant activity were obtained from Merck, except for gallic acid standards and 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical from Sigma-Aldrich.

2.2. Equipment

The equipment used included a material scale (SF-400), a blender (Philip HR2115) to grind the aloe vera gel, a drying oven (Memmert DIN 40050 IP 20), analytical scales (Ohaus), UV-Vis spectrophotometry (Shimadu UV mini 1240) for phenol analysis and antioxidant activity, vortex (Ohaus, type 37600 mixer), plastic sealer (Q2), 0.80 mm polypropylene plastic for packaging aloe vera powder.

2.3. Processing of aloe vera powder

Aloe vera powder was prepared, referred to [6]. Before being processed into powder, aloe vera gel was analyzed for moisture and phenol content using static gravimetry [11] and Folin-Ciocalteu methods [12]. Furthermore, the antioxidant activity was carried out based on the ability to capture DPPH radicals [13][12]. The process of making powder was in stages; the aloe vera leaves were peeled and cut into 2 cm in size and then ground with a blender for 5 minutes at medium speed. The blended gel was mixed with an encapsulating agent as a mixture of 5% maltodextrin and gum arabic (ratio 1/1) (based on the orientation), then stirred until homogeneous. The mixture was poured into the pan until evenly distributed before placing it in a drying oven at 60°C. The dried aloe vera was taken from the

baking sheet with a plastic spatula, crushed with a blender, and filtered with a 35-mesh sieve. The powder was put into plastic and tightly closed for study material.

2.4. *Aloe vera powder storage*

The treatment was to store the powder in open conditions, and the powder was packaged in 0.80 mm polypropylene (PP) plastic. A total of 5 g of the unpackaged powder was placed in a porcelain cup with a diameter of 5 cm, while packed samples were placed in PP plastic measuring 7 x 9 cm. Each sample in each treatment was placed in a desiccator with a 75-78% (RH) regulated with saturated salt NaCl [14] and stored at 25°C. Periodically, the powder from the two treatments was analyzed for moisture content [11], phenol content [12], and antioxidant activity [12] [13] and measured using UV-Vis spectrophotometry (Shimadu UV mini 1240). Testing was carried out for unpackaged samples every hour, while samples with PP plastic packaging were analyzed once a week.

2.5. *Experimental design*

A non-factorial Completely Randomized Design with two factors, namely unpackaged powder storage conditions and packaged in polypropylene plastic was used in this study. The experiment was carried out three times in each treatment and the data obtained was calculated using the ANOVA statistical method. Furthermore, the real difference test was achieved with the DMRT (*Duncan's Multiple Range Test*) with level of confidence of $\alpha = 5\%$.

3. Results and Discussion

3.1. *Chemical characteristics of aloe vera gel*

The results of the analysis of aloe vera gel for components related to antioxidants can be seen in Table 1.

Table 1. The chemical characteristics of aloe vera gel

Parameters	Amount
Moisture content	99.19±0.03 (%)
Total phenol	70.60±1.30 (mg GAE/g dry matter)
Radical Scavenging Activity (RSA)	6.37±0.01 (%)

Table 1 shows that aloe vera gel contains $99.19 \pm 0.03\%$ water. In previous studies, it was 97.86-99.62%, and the phenol content was 24.75 - 25.87 mg GAE/100 g dry matter of aloe gel [3]. Antioxidant activity was expressed as Radical Scavenging Activity (RSA). Table 1 shows that the RSA value is $6.37 \pm 0.01\%$, lower than [6] at 12.09%. Furthermore, [15] found that the gel phenol content was 5.48 mg Gallic Acid Extract/100 g, equivalent to 54.8 mg Gallic Acid Extract/g. [16] stated that the chemical composition of each plant depended on the type or variety, the local geographical condition, and the soil. According to [13], the phenolic content of the sample, which contributed to antioxidant activity, was greatly influenced by the harvest age. The optimum period for producing high phenol levels was four years, depending on the variety. *Aloe vera var. cinensis* was harvested at 12 months of age. Therefore, there are differences in phenol content and antioxidant activity.

3.2. *Aloe vera powder's moisture content during storage*

The moisture content of aloe vera powder under unpackaged storage conditions on day 0 continued to increase significantly until 12 hours (Table 2). This increase was caused by contact between the powder and the outside air. The initial moisture content of freshly prepared aloe vera powder (at hour 0) was recorded at $7.65 \pm 0.17\%$. After 120 hours of storage, it progressively increased, reaching critical conditions with a moisture content of $12.68 \pm 0.11\%$. [10] the critical condition of the powder was determined by increasing the moisture content to 12.00%. The increase in critical conditions over

120 hours indicated the rapid absorption of water from the air due to the absence of packaging that could withstand the interaction. After 120 hours of open storage, the condition of the aloe vera powder was subjected to discernible physical alterations. These changes resulted in a solidified state due to its attainment of critical conditions, rendering it no longer sensory acceptable to consumers

Table 2. Aloe vera powder moisture content during storage

Without packaging		Packaged in PP plastic	
Storage Time (hours)	Moisture content (%wb)*	Storage Time (weeks)	Moisture content (%wb)*
0	7.28±0.33 ^a	0	7.65±0.18 ^a
12	8.08±0.37 ^b	2	8.16±0.11 ^b
24	8.39±0.03 ^b	4	8.25±0.03 ^b
36	9.13±0.17 ^c	6	8.36±0.09 ^{bc}
48	9.67±0.02 ^d	8	8.57±0.13 ^c
60	10.17±0.06 ^e	10	8.87±0.10 ^d
72	10.60±0.06 ^f	12	9.05±0.13 ^d
84	11.10±0.09 ^g	14	9.35±0.12 ^e
96	11.34±0.21 ^{gh}		
108	11.73±0.01 ^h		
120	12.68±0.11 ⁱ		

*Different superscripts in the same column indicated significantly different ($p < 0.05$).

The moisture content of aloe vera powder under unpackaged storage conditions on day 0 continued to increase significantly until 12 hours (Table 2). This increase was caused by contact between the powder and the outside air. The initial moisture content of freshly prepared aloe vera powder (at hour 0) was recorded at $7.65 \pm 0.17\%$. After 120 hours of storage, it progressively increased, reaching critical conditions with a moisture content of $12.68 \pm 0.11\%$. [10] the critical condition of the powder was determined by increasing the moisture content to 12.00%. The increase in critical conditions over 120 hours indicated the rapid absorption of water from the air due to the absence of packaging that could withstand the interaction. After 120 hours of open storage, the condition of the aloe vera powder was subjected to discernible physical alterations. These changes resulted in a solidified state due to its attainment of critical conditions, rendering it no longer sensory acceptable to consumers.

The storage of aloe vera in PP packaging exhibited a gradual increase in moisture content. Specifically, the value increased from the initial level found in fresh powder at week 0 to reach $7.65 \pm 0.17\%$ after 14 weeks of storage, rising to $9.35 \pm 0.12\%$. The 0.80 mm PP plastic possesses a water permeability rate of $0.185 \text{ g/m}^2/\text{hr}\cdot\text{mmHg}$ [8]. Close packaging effectively fulfilled the primary objective of restricting the interaction between aloe vera powder and the external atmosphere, in line with its primary purpose of protecting against microbial contamination [17]. The slow increase in moisture content in closed storage was due to polypropylene packaging, which had low water permeability..

The powder packaged in 0.80 mm PP plastic did not reach critical conditions after 14 weeks of storage. Therefore, a linear equation calculation method was used to determine critical conditions for the correlation between moisture content and storage time (Table 2). Figure 1 shows a simple linear graph of packed storage conditions.

Figure 1 shows an increase in moisture content during storage. The straight line equation for closed storage conditions was obtained based on linear regression analysis, namely the curve equation $y = 0.109x \pm 7.771$ with $R^2 = 0.950$. The straight line equation is substituted to get the critical moisture content value, namely $12.00 \pm 0.02\%$; hence, the shelf life is around 44 weeks. According to [7],

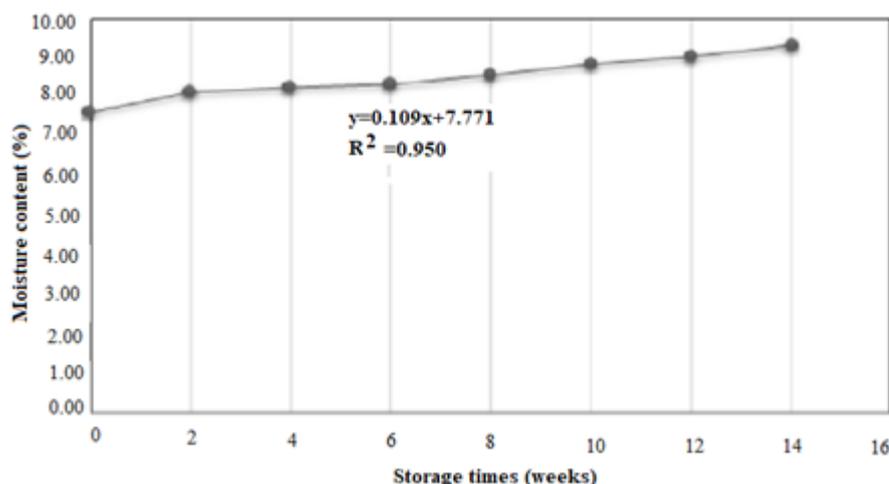


Figure 1. Changes in moisture content of aloe vera powder during storage.

Redleaf amaranth powder has a shelf life of 97 days when stored at a temperature of 28°C. This difference is due to the ingredients and the decreased initial moisture content at 4.66%.

3.3. Phenol content of aloe vera powder during storage

The phenolic compounds have antioxidant activity in aloe vera gel. There is a decline in phenol content during storage (Table 3). The levels of phenolic compounds decreased from the initial condition of 1.15 ± 0.07 mg GAE/g bk powder to 0.13 ± 0.10 mg GAE/g dry matter powder or a decrease of 88.69%, for 120 hours (at critical conditions).

Table 3. Phenol content of aloe vera powder during storage

Without packaging		Packaged in PP plastic	
Storage time (hours)	Phenolic content (mg GAE/g dry matter)	Storage time (weeks)	Phenolic content (mg GAE/g dry matter)
0	1.15 ± 0.07^g	0	1.15 ± 0.07^c
12	0.99 ± 0.02^f	2	1.11 ± 0.01^c
24	0.85 ± 0.05^e	4	1.06 ± 0.03^c
36	0.78 ± 0.03^{de}	6	1.12 ± 0.03^c
48	0.67 ± 0.13^{cd}	8	1.14 ± 0.02^c
60	0.60 ± 0.02^c	10	1.00 ± 0.02^b
72	0.57 ± 0.03^c	12	0.96 ± 0.04^b
84	0.43 ± 0.01^b	14	0.80 ± 0.05^a
96	0.24 ± 0.03^a		
108	0.17 ± 0.04^a		
120	0.13 ± 0.10^a		

* Different superscripts in the same column indicated significantly different ($p < 0.05$).

In closed or packaged storage, the phenol content decreased to 0.80 ± 0.05 mg GAE/g dry matter powder for 14 weeks due to a decrease of up to 30.43% caused by the intensity of contact with oxygen and the presence of light. Flavonoids, part of phenolic compounds, are very unstable to temperature [18]. According to [19], the phenol content of brown rice decreases when stored at 37 °C for 180 days in packaged conditions. [20] states that cherry powder stored in polyethylene plastic packaging experiences a decrease in phenol levels and antioxidant activity during storage.

Storing foodstuffs in low oxygen conditions significantly impacts the stability of phenolic compounds, especially in the long term [21]. In this study, the levels of phenolic compounds in unpackaged or open storage decreased very quickly. In packaged storage, the decrease in phenolic compounds occurred more slowly. The damage to bioactive components becomes more significant and is directly proportional to the increase in moisture content and relative humidity (RH) of the storage room. The decrease in total phenolics is possible because the compounds are subjected to structural changes or degradation and cannot be measured [22].

3.4. *Aloe vera powder's antioxidant activity during storage*

Table 4 shows the antioxidant activity of aloe vera powder during storage. The antioxidant activity decreased from $31.49 \pm 0.70\%$ to $2.67 \pm 0.11\%$ at the 120th hour in closed storage, or PP plastic decreased to $22.65 \pm 0.41\%$ in the 14th week. During storage, there was a decrease in antioxidant activity, which fell by 91.45% in open storage and 27.94% in PP plastic packaging.

Table 4. Antioxidant activity of aloe vera powder during storage

Without packaging		Packaged in PP plastic	
Storage time (hours)	RSA (%)	Storage time (weeks)	RSA (%)
0	31.49 ± 0.70^j	0	31.49 ± 0.70^c
12	22.60 ± 0.04^i	2	31.65 ± 0.56^c
24	19.20 ± 0.01^h	4	32.90 ± 0.33^c
36	17.05 ± 0.59^g	6	30.90 ± 1.20^c
48	14.26 ± 1.03^f	8	25.31 ± 1.89^b
60	13.43 ± 0.05^f	10	23.85 ± 0.91^{ab}
72	12.39 ± 0.12^e	12	23.67 ± 0.02^{ab}
84	9.22 ± 0.02^d	14	22.65 ± 0.41^a
96	5.51 ± 0.33^c		
108	3.79 ± 0.21^b		
120	2.67 ± 0.11^a		

* Different superscripts in the same column indicated significantly different ($p < 0.05$).

Based on Table 4, there was a decrease in antioxidant levels in both storage methods. This condition was in line with the decline in phenolic compounds in aloe vera powder, as stated by [23]. The total phenolic compounds were aligned with the antioxidant activity of the sample. Therefore, the longer the storage, the more significant the decrease in total phenol, leading to a lower antioxidant activity. Storing aloe vera powder in PP packaging can inhibit decreased antioxidant activity. Thus, using aloe vera powder as a source of antioxidants can consider its effects based on changes in its movement until it reaches a critical condition.

4. Conclusion

In conclusion, aloe vera powder stored at a relative humidity of 75-78% and 25°C in 0.80 mm polypropylene plastic packaging was reported to sustain critical conditions longer than unpackaged powder. The shelf life in 0.80 mm polypropylene plastic packaging and unpacked powder was 44 weeks and 120 hours. In this context, antioxidant activity and decreasing powder phenol content were reduced. Furthermore, there was a reduction of 30.49% in phenol levels with a decline of 27.94% in antioxidant activity when aloe vera powder was stored in polypropylene packaging.

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