SEED DETERIORATION PATTERN OF FOUR BAMBARA GROUNDNUT LANDRACES 
(Vigna subterranea subterranean (L) Verde) IN OPEN STORAGE SYSTEM

Pola Deteriorasi Benih Empat Lanras Kacang Bambara (Vigna subterranea (L) Verde) pada Sistem Penyimpanan Terbuka

Happy Suryati¹, Abdul Qadir², Satriyas Ilyas² and Bambang Budhianto³

¹Field Study of Seed Science and Technology, Postgraduate Program of Bogor Agricultural University, Jl. Meranti, Kampus IPB Dramaga, Bogor 16680, Indonesia
²Department of Agronomy and Horticulture, IPB University, Jl. Meranti, Kampus IPB Dramaga, Bogor 16680, Indonesia
³Agricultural Extension and Human Resources Development Agency, Ministry of Agriculture, Jl. Harsono RM, Ragunan, South Jakarta, Indonesia

Telp. (0251) 8622642, Faks. (0251) 8622642
E-mail: happy.hamami@gmail.com
(Makalah diterima, 06 Agustus 2018 – Disetujui, 03 Desember 2018)

ABSTRACT

Bambara groundnut (Vigna subterranea (L.) Verde) is a potential commodity to be developed in Indonesia, however, the production is done only once a year, therefore, it needs proper seed storage. The aim of this research was to study seed deterioration patterns of four bambara groundnut landraces stored in packages with different permeability in an open storage system for up to 6 months. This experiment was conducted from November 2015 to July 2016 at Seed Technology Laboratory, Department of Agronomy and Horticulture, IPB. Stages of experiment as follow: calculation of packaging permeability, seed storage, preparation and fitting data to regression equation. The packaging used in the study is aluminum foil, pp plastic and plastic sacks which have measured its permeability. The result showed that the seed deterioration of four bambara groundnut landraces in three packaging permeability has common sigmoid pattern with equation model: \( y = \frac{a}{1 + \exp \left( \frac{x + b}{c} \right)} \). The seed deterioration pattern based on SG and EC variables with the faster rate of decline occurred in Sumedang landrace packed in plastic sack (permeability = 1.4681 g/day m² mm/Hg), thus having a shorter storability. The slower rate of decline occurred in Gresik landrace packed in aluminum foil (permeability = 0.098 g/day m² mm/Hg), this means that it has a longer storability.

Key words: vignasubterranea (L.) Verde, landraces, permeability, sigmoid, storability
INTRODUCTION

Bambara groundnut (Vigna subterranea (L) Verdc) cultivation in Indonesia was begun at the beginning of 18th century (Redjeki et al., 2013), but up to now, the government has not yet released any superior variety of bambara groundnut. Bambara groundnut contains high nutrients, which include 17-25% protein, 46-65% carbohydrate (Mabhaudhi et al. 2013), 5.88% fat, 10.43% water, and 3.03% ashes (Redjeki 2007), as well as calcium, phosphor, iron, and vitamin B1 (Suwanpraset et al. 2006).

Seeds used by the farmers for the cultivation are still derived from their own farming. In general, bambara groundnut seeds are only available from March to June. It is due to life span of bambara groundnut ranges between 17 WAP (weeks after planting) and 18 WAP, depends on the weather condition (Ilias and Sopian 2013; Redjeki 2007), moreover, life span of some landraces is about 6 months (Toure et al. 2012), so that cultivation of bambara groundnut could not be done year-round. The yielded seeds were stored in order to be planted in the next planting season, and duration between planting seasons require proper storage to maintain high viability of the seeds.

Farmers used to store the bambara groundnut in cans with scouring sands, which is intended to maintain low water content, to avoid the infestation of fungi and insects. According to Justice and Bass (2002), water content and temperature of storage are important factors that affect life span of the seeds, as well as chemical contents in the seeds, initial viability, water content of the seeds, temperature of the storage space, and diverse packaging materials (Hashbianto 2012). Carbohydrate as dominant chemical composition of bambara groundnut has enabled the seeds to be stored longer than other legumes.

Estimation of bambara groundnut vigor for storability plays important role in estimating its storability, since vigor of storability has closely related to complex deterioration process of the seeds (Copeland and McDonald, 2001). Such deterioration of seeds occurs during the storage periods, both open storage and controlled storage. Seeds deterioration is affected by many factors, both internal and external factors (Copeland and McDonald 2001). According to Justice and Bass (2002), internal factors that affect on seed deterioration include initial viability of seeds, water content of seeds, and genetic factors (for example, varieties, seed size, testa permeability, chemical composition of seeds), while the external factors include physical environment (temperature, relative atmospheric humidity, atmosphere) and biotic (virus, fungi, bacteria, and pest). Information about storability of bambara groundnut and the packaging ability to maintain viability of the seeds within longer period of storage, is still limited.

Objective of this experiment was to obtain seed deterioration pattern of four bambara groundnut landraces on three different permeability packaging for six months of open storage.

MATERIALS AND METHODS

Experiment of seed storage was conducted from November 2015 to July 2016 at Seed Technology Laboratory, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University. Stages of experiment are as follow: 1) calculation of packaging permeability, 2) seed storage, 3) arranging the equation of deterioration patterns, and 4) fitting equation model of deterioration patterns.

Bambara groundnut seeds, which were used, comprise of four landraces: Sumedang (harvested in April 2015), Sukabumi (harvested in May 2015), Gresik (harvested in April 2015), and Tasikmalaya (harvested in June 2015). Seed germination, electrical conductivity, and moisture content of the seeds were tested before they are stored in the room storage at ± 20°C and ±RH 60%.

Calculation of Packaging Permeability

The packaging permeability is measured by ASTM D895-79 method (whole bag desiccant method, (Arpah 2007)). Desiccant (silica gel) was dried in oven at 105°C for three hours, and then incubated in desiccators for 30 minutes and after that ± 20 g desiccant was put into the packaging, in which its surface area has been measured first. Packaging, which was filled with desiccant, was kept in incubator at ± 44°C and RH ±99% for 14 days. Weight of desiccant is weighed everyday and a correlation curve is drawn between desiccant weights against time (day), so that the daily absorbed water values are obtained. The permeability values are counted using Moys’s equation in Arpah (2007) as follow:

\[
\text{Packaging permeability} = \frac{n/t}{A \times (RH_{out} - RH_{in})P_o}
\]

Whereas n/t (amount of the absorbed water per day, g/day), A (surface area of packaging, m²), RH_{out} (RH outside the packaging, %), RH_{in} (RH inside the packaging, %) and Po (saturated vapor pressure, mmHg).

Seeds Storage

The experiment was arranged using randomized complete design by nested packaging permeability factor in storage period. The packaging permeability values
Seeds of each accession in the seedling beds, which were filled with sands as the medium and had three replications, were put in a chamber at 25°C. SG is calculated using the equation below (ISTA 2014):

\[
SG(\%) = \frac{\sum NS_{I+II}}{\sum seeds} \times 100\%
\]

Whereas \( NS_I \) = observation on germinate at 5th day, \( NS_{II} \) = observation on germinate at 10th day.

**Electrical Conductivity Testing after the Seeds Being Stored**

Electrical conductivity (EC) on each accession was made by three replications, 25 seeds each. Seeds were weighed and then put them in a jar, which was filled with aquadest, and then incubated for 24 hours at 20°C. EC calculation uses the equation below (ISTA 2014):

\[
EC = \frac{\mu S \cdot cm^{-1}}{g}
\]

**RESULT AND DISCUSSION**

**Packaging Permeability**

Packaging permeability is ability of the packaging to release vapor that could permeate the packaging (PB Depdiknas 2008). Low permeability indicates fewer vapors that could permeate the packaging and hit the seed’s surface within the packaging. Results of calculation against the packaging permeability, which were used in the experiment, were based on Moyls’ equation as presented in Table 1.

Table 1 showed permeability of aluminum foil (0.0981 g/day m² mm/Hg), plastic PP (0.1572 g/day m² mm/Hg), and plastic sack (1.4681 g/day m² mm/Hg). Aluminum foil has the lowest permeability, and followed by plastic PP, and plastic sack. Plastic sack has porous, which enable the vapor absorption, which means that plastic sack is easily permeable than aluminum foil and plastic PP (Arizka and Daryatmo 2015). Hasbianto (2012)

| Variable                        | Type of packaging |
|---------------------------------|-------------------|
|                                | Aluminum foil     | Plastic PP        | Plastic sack     |
| n/t (g/day)                     | 0.0217            | 0.0364            | 0.3021           |
| A (m²)                          | 0.0043            | 0.0045            | 0.0040           |
| Permeability (g/day m²/mm Hg)   | 0.0981            | 0.1572            | 1.4681           |

Notes: RH incubator: 71.27%, Temperature: 44°C, \( P_o \): 72.18 mm Hg (saturated vapor pressure at 44°C based on Bennefield et al. 1982)
suggested that packaging permeability values may 
affect the stored-water content of the seeds. The lower 
permeability, the slower increase of moisture content 
(MC) of the seeds, so that it will prolong the storability.

**Seeds Storage**

Seeds, which were used in this research were harvested 
between April – June 2015, and post-harvest time, the 
seeds were processed by the farmers. The seeds were 
tested before they are kept in storage space at 20°C and 
RH 60% (Table 2).

Seeds, which were used in this research, had been kept 
in open storage for 5 months (April to August) by the 
farmers before they were applied in November 2015. 
During seeds storage, SG and EC were tested, and then 
seed deterioration patterns were made on each landrace 
and packaging permeability.

**SG Variable after the Seeds being Stored**

Behavioral pattern of SG during storage on all 
landraces and packaging permeability based on nonlinear 
regression analysis has sigmoid equation. It confirmed 
to research by Walter *et al.* (2010), seeds deterioration 
is described by sigmoid correlation between viability 
and time, even though no significant change was found 
on seed vigor, but faster rate of death was occurred. The 
equation that match with the pattern formed is as follows 
(Birch 1999):

\[
y = \frac{a}{1 + \exp \left(\frac{x + b}{c}\right)}
\]

For a, b, and c are constant, x is storage period (month) 
and y is seed deterioration variables (SG and EC). Results 
of regression analysis are presented in Table 3.

Equation of SG behavior was followed by descriptive 
fitting that used standard of deviation. Descriptive fitting 
was shown from lines that enter to ranges of deviation 
standard on point of the observation. Results of fitting are 
presented in Figure 1.

Figure 1 showed that dominantly, lines that resulted 
from the equation pattern were included in range of 
the deviation standard on each point of observation.

| Variable     | Smedang | Sukabumi | Gresik | Tasikmalaya |
|--------------|---------|----------|--------|-------------|
| SG (%)       | 89      | 96       | 96     | 93          |
| EC (μS·cm⁻¹·g⁻¹) | 0,9    | 0,9      | 2,5    | 1,4         |
| MC (%)       | 9,6     | 10,1     | 10,1   | 10,2        |

Notes: *SG = seed germination, EC = electrical conductivity, MC = moisture content*

| Landrace     | Type of Packaging | Equation                                               | SG(%) at 6th month |
|--------------|-------------------|--------------------------------------------------------|--------------------|
| Sumedang     | Alfoil            | y = 91.8664/(1 + exp⁹(x - 5.43623)/1.61247)           | 56                 |
|              | PP                | y = 92.6205/(1 + exp⁹(x - 6.32346)/2.01133)           | 45                 |
|              | Plastic sack      | y = 89.0609/(1 + exp⁹(x - 4.0322)/1.19404)            | 37                 |
| Sukabumi     | Alfoil            | y = 749.343/(1 + exp⁹(x + 16.5948)/4.93457)           | 77                 |
|              | PP                | y = 679.448/(1 + exp⁹(x + 30.0652)/16.219)            | 60                 |
|              | Plastic sack      | y = 2921.14/(1 + exp⁹(x - 4.04914)/4.31028)           | 59                 |
| Gresik       | Alfoil            | y = 96.4466/(1 + exp⁹(x - 2.99022)/0.778764)          | 79                 |
|              | PP                | y = 96.8416/(1 + exp⁹(x - 2.43074)/0.829895)          | 77                 |
|              | Plastic sack      | y = 1597.45/(1 + exp⁹(x + 15.7881)/3.84057)           | 75                 |
| Tasikmalaya  | Alfoil            | y = 1262.28/(1 + exp⁹(x + 41.0952)/88.662)           | 62                 |
|              | PP                | y = 3433.46/(1 + exp⁹(x + 78.3115)/189.719)          | 48                 |
|              | Plastic sack      | y = 135.281/(1 + exp⁹(x - 4.04914)/4.31028)           | 41                 |

Table 2. Initial data of seeds before seeds storage

Table 3. Results of exponential equation for DB variable
It prevails on all landraces and all packaging that being used and it shows no difference between patterns resulted from equation and testing. Seed deterioration patterns with SG variable are presented in Figure 2.

In general, seeds deterioration behaviors that are kept in plastic sacks have lower SG than other packaging during storage period. Low permeability of packaging (aluminum foil) showed the highest SG. According to Putro (2012), aluminum foil has longer storability than polypropylene. It is due to aluminum foil has lower water vapor transmission and water vapor transmission than polypropylene and plastic sack.

The fastest deterioration by SG variable occurred on Sumedang landrace, as shown by faster rate of decline than with other landraces. Seeds deterioration with sigmoid line pattern comprise of two declining rates, faster and slower. Both declining rate patterns are restricted by anomaly points as critical points of seeds viability period. Different forms of line patterns are determined by the amount constants, which construct the equation.

Seed deterioration behaviors of four landraces on those three packaging types have sigmoid declining pattern with different declining rates. These differences are determined by the constant values of \( a \), \( b \), and \( c \) as presented in Table 3. The higher constant value of \( a \), the higher declining rate will be before anomaly point. The higher value of \( b \) will reduce the deterioration rate after anomaly point with higher vigor by the end of storage period. Constant value of \( c \) contributes in increasing deterioration rate after the anomaly point.

Anomaly points on SG behavioral patterns of Sumedang and Tasikmalaya landraces were between storage periods 2 and 3 months. It showed that during the storage, the seeds will decrease sharply that indicated shorter storability. Gresik and Sukabumi landraces showed different result, the declining rate was not so fast, which indicated longer storability.

SG of Gresik landrace to the end of storage period was still above 75%. Gresik landrace used in this research was the product of purifying (F7), while other three landraces were derived from culturing products by local farmers. It is presumed that it caused Gresik landrace has higher SG. Research by Pillay (2003) showed that bambara groundnut, which has passed through purification, had better viability than the seeds derived from culturing product by the farmers. Gresik landrace has smaller seeds than other three landraces. Rasyid (2012) suggested that smaller seeds of soybean have slower declining rate of quality, so that they have longer storability. Furthermore, storability is affected by water content, temperature of the storage space, and characteristics of seeds are affected by genetic and environmental interactions during maturity to the harvest time (Walters et al. 2010).
**EC Variable after the Seeds being Stored**

EC behavioral patterns on all landraces and packaging types are presented in Table 4. Such behavioral patterns establish sigmoid function with different constant values for each equation. Different constant affects on the resulted shape of the equation line pattern.

The resulted patterns of the equation and testing will be fitting based on standard of deviation. Results of fitting between testing and equation are presented in Figure 3.

Almost all lines of the equation results include within range of deviation standard on each point of observation during storage period. It indicates that behavioral pattern of EC resulted from the equation may describe behavioral pattern of EC during the test. Seed deterioration patterns with EC variable are presented in Figure 4.

EC behavior shows that the longer storability, the higher EC values will increase. The increase patterns of EC were different on those four landraces. Different landrace showed different response on EC increase,

| Landrace | Type of Packaging | Equation | EC(μS.cm⁻¹.g⁻¹) at 6th mo |
|----------|-------------------|----------|--------------------------|
|          |                   |          | Testing                  | Equation                  |
| Sumedang | Alfoil            | $y = -56.5224 / (1 + \exp^{(x + 14.3287)/6.02724})$ | 7.0                       | 6.5                       |
|          | PP                | $y = 0.463066 / (1 + \exp^{(x - 1.86725)/0.801414})$ | 6.6                       | 6.4                       |
|          | Plastic sack      | $y = 1.37051 / (1 + \exp^{(x - 2.7974)/0.802216})$ | 11.7                      | 12.0                      |
| Sukabumi | Alfoil            | $y = 1.69665 / (1 + \exp^{(x - 1.86725)/0.801414})$ | 7.6                       | 7.3                       |
|          | PP                | $y = - 149.075 / (1 + \exp^{(x + 14.5471)/6.00079})$ | 9.5                       | 9.3                       |
|          | Plastic sack      | $y = - 4.84463 / (1 + \exp^{(x - 0.460923)/1.24385})$ | 9.3                       | 9.0                       |
| Gresik   | Alfoil            | $y = - 104.229 / (1 + \exp^{(x + 8.57083)/2.70785})$ | 5.3                       | 4.7                       |
|          | PP                | $y = - 103.985 / (1 + \exp^{(x + 15.0014)/5.53290})$ | 7.8                       | 7.3                       |
|          | Plastic sack      | $y = - 112.539 / (1 + \exp^{(x + 14.4792)/6.05907})$ | 9.6                       | 9.0                       |
| Tasikmalaya | Alfoil       | $y = - 66.4152 / (1 + \exp^{(x + 18.1409)/9.21187})$ | 6.9                       | 6.4                       |
|          | PP                | $y = - 100.285 / (1 + \exp^{(x + 21.7885)/10.2971})$ | 7.3                       | 6.9                       |
|          | Plastic sack      | $y = 0.622291 / (1 + \exp^{(x - 4.09364)/1.80522})$ | 10.0                      | 10.2                      |

Table 4. Results of exponential equation for EC variable

![Figure 3. Fitting of the equation pattern of seed deterioration and outcomes of testing on EC variable](image)
![Figure 4. Seed deterioration patterns by EC variable](image)
and it was presumed that it related to different chemical composition among landraces (Wahyun, 2014). The higher increase of EC was on plastic sack, which has the highest permeability value for each landrace. The effects of plastic PP and aluminum foil permeability were not significantly different against the change of EC values, except on Sumedang landrace.

EC behavioral pattern of Sumedang landrace with plastic sack showed the fastest increase and followed by plastic PP and aluminum foil. EC behavioral patterns were inversely proportionate to deterioration rate, so that Sumedang landrace with plastic sack showed the fastest deterioration rate. The increase value of EC was seen after the second month, whereas during the previous storage period, it tended to increase sloping. Different shapes of line from EC behavioral pattern on Sumedang landrace were seen within 2 months-storage period. It also occurred on variable pattern of the SG during the same period of storage. EC is the preliminary indication of seed deterioration physiologically, which is marked by damages on cell membrane that finally affects on normal growth performance of the germinate.

EC behavioral patterns on Gresik and Tasikmalaya landraces have the similar patterns. Seeds, which were stored in plastic PP and aluminum foil, showed almost similar increase of EC, as described with line patterns that were very close together. EC behavioral pattern of Gresik landrace with plastic sack was above behavioral patterns of other packaging. EC behavioral pattern of Tasikmalaya landrace, which was kept in plastic sack, showed the same pattern with other packaging up to the period of 2.5 months, and then increase sharply. The anomaly point on behavioral pattern of Sukabumi landrace was on 3-month-storage period. It was shown by different lines, which tended to be sloping after the period. Seeds, which were stored in plastic sack and plastic PP, showed almost similar values of EC at the beginning and by the end of storage period that was shown by lines that were very close together at the point. Size and testa color are factors that affect the increase of electrical conductivity. According to Wain-Tassi et al. (2012) small seeds of soybean may cause leakage of ions K⁺, Ca²⁺, and Mg²⁺, which is lower than the big ones. Correlation between moisture content, organization on cell membrane of the seeds and amount of leakage in soaking agent solution of the seeds is basic theory of electrical conductivity test (Wain-Tassi et al. 2012). Low electrolyte leakage, which was released into the soaking agent solution of the seeds, indicates that seeds have high vigor (Carvalho et al. 2009).

**CONCLUSIONS**

General pattern of seed deterioration on bambara groundnut of Sukabumi, Sumedang, Gresik, and Tasikmalaya landraces is sigmoid by equation model of: $y = a / (1 + \exp ((x + b)/c))$ in which a, b, and c are different constants on each landrace and type of packaging.

Seed deterioration pattern based on SG and EC variables on Sumedang landrace, which was kept in plastic sack, showed faster of deterioration rate pattern that indicated that Sumedang landrace has shorter storability.

Seed deterioration pattern based on SG and EC variables on Gresik landrace, which was kept in aluminum foil, showed slower of deterioration rate pattern that indicated that Gresik landrace has longer storability.

Research on such deterioration pattern can be utilized to determine seed storability an establish vigor estimation model of seed storability of four bambara groundnut landraces.

**REFERENCES**

Arizka, A.A. dan J. Daryatmo. 2015. Perubahan kelembaban dan kadar air selama penyimpanan pada suhu dan kemasan yang berbeda. Jurnal Aplikasi Teknologi Pangan 4 (4) :124-129

Kadaluwarsa Pangan. Bogor (ID): Bogor Institute of Agriculture.

Birch, C. P. D. 1999. A new generalized logistic sigmoid growth equation compared with the Richards growth equation. Annals of Botany 83: 713-723.

Carvalho, L. F., C.S Sediyama, M. S Reis, D. C. F. S Dias, M. A Moreira. 2009. Influence of soaking temperature of soybean seeds in the electrical conductivity test to evaluate physiological quality. Revista Brasileira de Sementes 31: 9-17.

Copeland, L. O., Mc Donald M. B. 2001. Principles of Seed Science and Technology. 4th edition. London (GB): Kluwer Academic Publishers.

Hashianto, A. 2012. Pemodelan penyimpanan benih kedelai pada system penyimpanan terbuka. Msc thesis, Bogor (ID): Bogor Institute of Agriculture

Ilyas, S. and O. Sopian. 2013. Effect of seed maturity and invigoration on seed viability and vigor, plant growth, and yield of bambara groundnut (Vigna subterranea (L.) Verdc.). ActaHort 979, 695-701.

ISTA International Seed Testing Association. 2014. International Rules for Seed Testing. Switzerland (CH): International Seed Testing Association.

Justice, O and L. N Bass. 2002. Prinsip dan praktek penyimpanan benih. Roesli R, translator. Jakarta (ID): PT Raja grafindo persada. Translation from: Principles and Practices of Seed Storage.

Mabhaudhi, T., A. T Modi, and Y. G Beletse. 2013. Growth, phenological, and yield responses of a bambara groundnut accession to imposed water stress: II. Rain shelter conditions. Water SA 39: 191-198.
Pillay, D. 2003. Physiological and Biochemical Characterization of Four African Varieties of Bambara Groundnut (*Vigna subterranea* (L.)Verdc.). Swedia (SWE): Uppsala Universitet.

Putro, J. S. 2012. Optimasi proses penggorengan hampa dan penyimpanan keripik ikan pepeteke (Leiognathus sp.). J. Ketehnikan Pertanian 26 (1) : 25-32.

Rasyid, H. 2012. Model pendugaan daya simpan benih kedelai (Glycine max (L) Merrill) biji besar dengan pengusangan cepat sebagai teknologi penentu mutu benih. Jurnal Gamma. 7(2): 34-52.

Redjeki, E. S. 2007. Pertumbuhan dan hasil tanaman kacang bogor galur Gresik dan Bogor pada berbagai warna benih. Proceeding National Seminar on Results of Research Funded by Competitive Grant. Bogor, 1-2 August 2007. pp. 114-118.

Redjeki, E. S., S. Mayes, and S. N. A Ali. 2013. Evaluating the stability and adaptability of bambara groundnut (*Vigna subterranea* (L.) Verdc.) landraces in different agro-ecologies. ActaHorticulturae 979 : 389-400.

Suwanprasert, J., T. Toojinda, P. Srinives, and S. Chanprame. 2006. Hybridization technique for bambara groundnut. Breed.Sci. 56 (2) : 125-129.

Toure, Y., M. Kone, H.K. Tanoh, and D. Kone. 2012. Agromorphological and phenological variability of 10 bambara groundnut accessions cultivated in the Ivory Coast. Tropiculutra 30 : 216-221.

Wahyuni, A. 2014. Model dinamik daya simpan pada penyimpanan terbuka benih kedelai. Thesis. Bogor (ID): Bogor Institute of Agriculture.

Wain-Tassi, A. L., J. F Santos, R. J Panizzi, and R. D Vierira. 2012. Seed-borne pathogens and electrical conductivity of soybean seeds. Sci.Agric. 69 (1) : 19-25.

Walters, C., B. Daniel, and V. A Vertucci. 2010. Structural mechanics of seed deterioration: Standing the test of time. Plant Science 179, 565-573.