

Bewaring van zaaizaad

1 December 2015,
Steven P.C. Groot



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Seed longevity

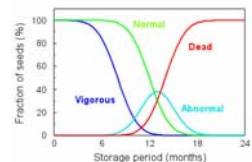
- Most seeds are desiccation tolerant and can survive storage in a dry state, called orthodox seeds
- Some seeds are not desiccation tolerant, these are called recalcitrant seeds (e.g. *Quercus robur*)
- Longevity of desiccation tolerant seeds may vary, but there is evidence of survival for about 2000 years



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Seed longevity

- Seeds eventually deteriorate during storage
 - Germination rate drops
 - Less vigorous seedlings
 - Total germination drops



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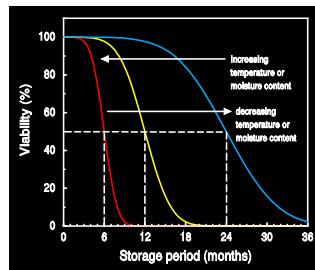
The period for which seeds can remain viable is greatly affected by:

- Quality at the time of collection
- Treatment between collection and storage
- Conditions of storage
 - Moisture content
 - Temperature
 - Oxygen
- Genetics (crop, variety)



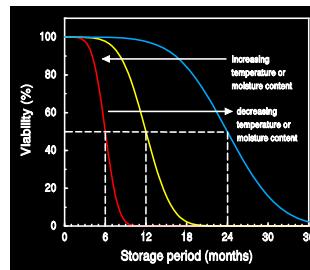
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Rules for Seed Storage



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Rules for Seed Storage



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Car rule
“The distance your car can drive depends on the amount of fuel and the economy in its use”



Seed Moisture Content

Oven method: weigh seeds, dry in oven, weigh again. The difference is the weight of water in the original sample.

$$\text{Fresh weight basis (\%)} = \frac{\text{weight of water} \times 100}{\text{initial total weight}}$$

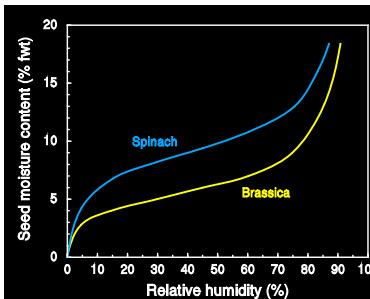
$$\text{Dry weight basis (\%)} = \frac{\text{weight of water} \times 100}{\text{final dry weight}}$$

Low constant temperature method: 103 °C for 17 h

High constant temperature method: 130 °C for 1 h (small seeds),
2 h for cereals, 4 h for maize



Seed Moisture Isotherms



The relationship between seed MC and ambient RH at a given temperature is called a moisture isotherm.

Seed composition, particularly oil content, results in different seed MCs at the same RH.

Volume in the seed occupied by lipids excludes water, so seed MC decreases as lipid content increases.



Seed Moisture Content vs. Relative Humidity at 20 °C

Crop	Relative Humidity (%)				
	15	30	45	60	75
Seed moisture content, fresh weight basis (%)					
Pea	6.0	8.6	10.8	13.1	15.6
Rice	5.9	8.5	10.7	12.9	15.4
Onion	4.9	7.0	8.9	10.8	13.0
Lettuce	4.1	5.9	7.5	9.1	11.0



Water Activity (a_w) is related to MC in non-oil part



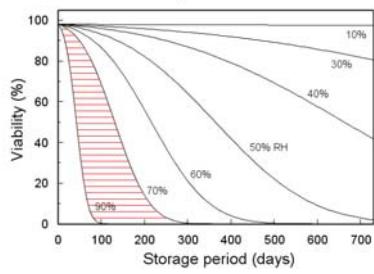
www.rotronic.com/

- Water activity (a_w) ($= \text{RH}/100$)
- Seeds with different composition store more similarly when at the same equilibrium a_w than when at the same MC.



Relative Humidity and Seed Longevity

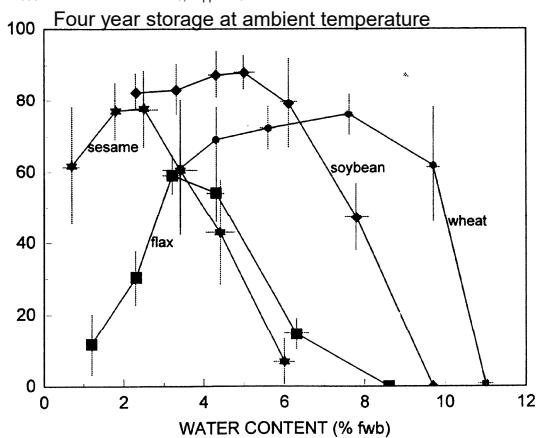
Soybean 30°C



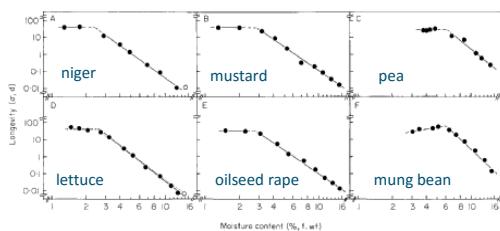
<http://data.kew.org/sid/viability/>



Chai et al. 1998. Seed Science Research 8, supp 1: 23



Seed Moisture Content and Seed Longevity



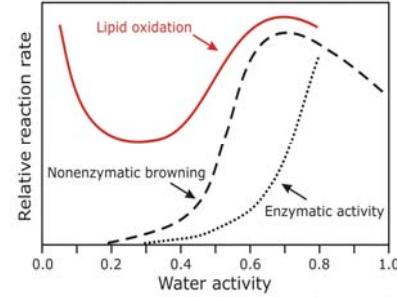
The relationship between lower MC and increased longevity holds for many seeds down to between 2 and 6% MC, depending upon species.

From Ellis, Hong & Roberts (1989) *Annals of Botany* 63: 601-611.



Oxidative damage in food science

Food stability as a function of water activity



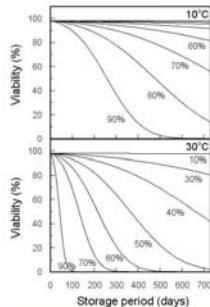
At low water activities lipid oxidation is enhanced

After:
Labuza, T.P. (1971)
Kinetics of lipid oxidation in foods.
CRC Critical Reviews in Food Science and Technology, 2: 355-405

Adapted from Labuza (1971)



Temperature, RH and Seed Longevity



Reducing the temperature can prolong seed storage life, but is less effective at high RH.

The combination of warm temperatures and high RH (high seed MC) is particularly damaging to seeds and can result in very short storage lives.

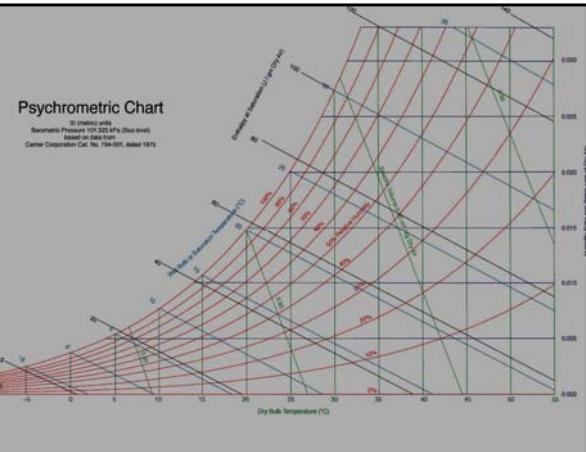


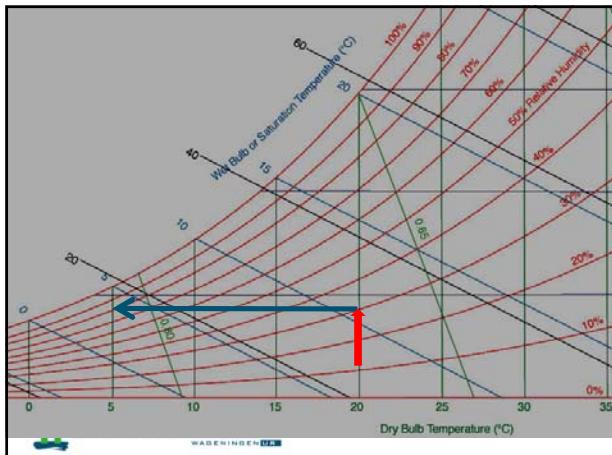
Packaging and Long-Term Storage

- In open storage, seed MC varies with RH
- Controlled climate ware house can maintain low MC
- Hermetic storage keeps a_w constant and oxygen limited

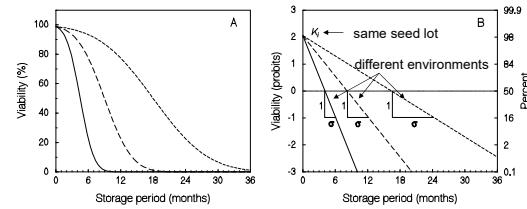


Is cold storage in refrigerator or cold store room advisable?





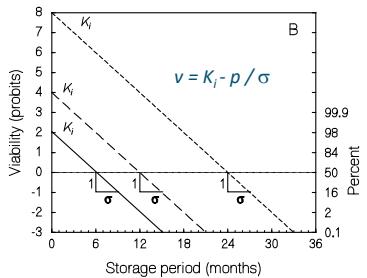
Storage Environment Affects the Rate of Seed Deterioration



The same seed lot stored in different environments will lose viability with different slopes on a probit scale. The intercept (K_i) is an index of initial seed quality, and is obviously a single value for a single seed lot.

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Seed Viability Equation



The seed viability equation describes the relationship between seed longevity, the initial seed quality and the storage environment.
Ellis RH, Roberts EH (1980) Ann. Bot. 45: 13-30.

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Temperature and Moisture Content Effects on Seed Longevity

$$\log \sigma = K_E - C_W \log m - C_H T - C_Q T^2 \quad v = K_i - p / \sigma$$

σ = slope of the probit viability loss line

K_i = species constant

C_W = constant relating to moisture content

m = seed moisture content (fresh weight basis)

C_H = linear temperature constant

C_Q = quadratic temperature constant

T = storage temperature

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Seed Viability Utility

The Kew Gardens web site has compiled the viability constants for many species and can do the calculations to predict storage life under any combination of temperature and seed moisture content.

<http://data.kew.org/sid/viability>

The Seed Information Database at Kew in general is a good site for information about seeds.

Calculating theoretical storability

■ Web site Kew Gardens UK :

<http://data.kew.org/sid/viability>

■ Web tools for calculating seed moisture content in relation to temperature and relative humidity

■ Web tool for calculating expected loss in viability

Visit Kew Gardens | Visit Waterlily | Plants & Fungi | Science & Conservation | Collections | Learn | Support Kew | News | Shop

Where am I? Home Kew Databases Seed Information Database Seed Viability

Seed Viability Equation: Viability Utility

Seed Information Database

Seed Viability Equation: Viability Utility

$$v = K_e - \frac{P}{10} C_H \cdot C_Q \cdot \log(m - C_H \cdot C_Q)$$

(Ellis & Roberts, 1980)

The viability equations were developed from the 1960s onwards and underpin all seed conservation practices. They predict the proportion of seeds in a population that are viable after any period of storage in a wide range of environments and are of use to both seed bank managers and researchers investigating seed longevity.

You can learn more about the seed viability equations [here](#) or start using them right away...

- Predict storage time
- Predict final viability
- Estimate moisture content to give viability at known temperature
- Estimate temperature to give viability at known moisture content

Useful Tools and Conversions

- Calculate seed equilibrium moisture content from known environmental conditions and oil content
- Calculate equilibrium relative humidity from known temperature, seed fresh weight and known oil content
- Convert between probits, NEDS and percentages
- Convert dry weight to fresh weight
- Predict days to lose 1 probit
- Predict required storage temperature

Calculating theoretical longevity

- Web site Kew Gardens UK: <http://data.kew.org/sid/viability/>
- Web tool for calculating expected loss in viability: http://data.kew.org/sid/viability/final_percent.jsp
- Web tool for calculating seed moisture content in relation to temperature and relative humidity <http://data.kew.org/sid/viability/mc1.jsp?constid=0>



Hier een voorbeeld invoeren van variatie in temperatuur en van variatie in eRH

Days to loose one probit

Simulating lettuce seed storage conditions

Seed Viability Equation: Viability Utility

$$v = K_e - \frac{P}{10} C_H \cdot C_Q \cdot \log(m - C_H \cdot C_Q)$$

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- Convert between probits, NEDS and percentages
- Convert dry weight to fresh weight
- Predict days to lose 1 probit
- Predict required storage temperature
- Estimate the species viability constant K_e from the "universal" temperature constants C_H and C_Q in the case of single temperature Cw estimates
- Estimate log σ at different temperatures using the "universal" temperature constants C_H and C_Q and a known test temperature

Screen shot Kew web sites

Royal Botanic Gardens, Kew

Databases

Seed Viability Equations

Predict Storage Time

Orzya sativa (Ellis et al., 1988)

Ke	8.668
Cw	5.03
Ch	0.0329
Cq	0.000478
Known Seed Eq (mc)	0.000478
Storage Temp °C	20
Initial Viability (%)	100
Final Viability (%)	90

calculate

Storage Temp °C

Initial Viability (%)

Final Viability (%)

Calculate Reset

Seed Viability Equations

Estimating Seed Equilibrium

Cromarty A.S., Ellis R.H. & Roberts E.H. 1982. The Design of Seed Storage Facilities for Genetic Conservation, IBPGR, Rome

Oil Content: 2.20 (Eckey, 1954)

Drying Temp °C: 20

Equilibrium %RH: 50

Calculate Reset Return to main menu



Screen shot Kew web sites

Seed Viability Equations

Estimating Seed Equilibrium

Cromarty A.S., Ellis R.H. & Roberts E.H. 1982: The Design of Seed Storage Facilities for Genetic Conservation, ITPGR, Rome

Oryza sativa

Oil Content	2.20 (Eckey, 1954)
Drying Temp °C	30
Equilibrium %RH	60
Calculate	Reset
Return to main menu	

Oryza sativa

Oil Content	2.20 (Eckey, 1954)
Drying Temp °C	30
Equilibrium %RH	60
Calculate	Reset
Seed Eq (mc): 12.0	
NOTE: This value is not automatically fed back into the previous calculation page. Please take a note of this value and place it into the equation accordingly.	

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Screen shot Kew web sites

Seed Viability Equations

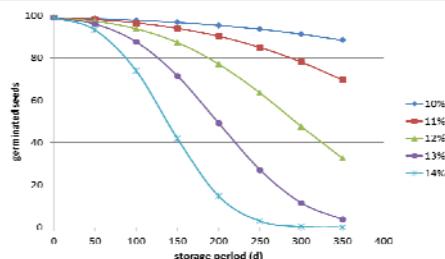
Estimating Final Viability

Oryza sativa (Ellis et al. 1988)

Ke	0.668
Cw	5.03
Ch	0.0329
Cq	0.000478
Known Seed Eq (mc)	12
Storage Temp °C	30
Initial Viability (%)	99
Storage Period	35
Years * Days	
Calculate	Reset
Days to lose 1 Probit: 66	
Years to lose 1 Probit: 0	
Final Viability (%): 96.96	

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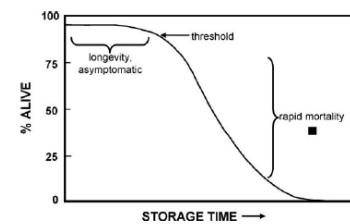
Rice seed viability loss at 30 °C (theoretical)



Seed moisture level has large effect on shelf life

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Loss of Viability Shows a Threshold Pattern



Seeds tend to survive well during storage for a period of time, then die over a relatively shorter period.

The initial lag period is not well modeled by the Ellis-Roberts equation. It applies once viability begins to decline.

Threshold kinetics, deteriorative reactions proceed rapidly once a critical concentration of protection is lost or toxic substances accumulate. This may vary between tissues and cells within a seed.

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Relative ageing rate lettuce seeds at 20 °C

Relative humidity during storage	Seed moisture content (FWB)	Days to loose 1 probit	Relative ageing rate
15%	4,1%	2966	0,22
30%	5,9%	643	1,0
45%	7,5%	235	2,7
60%	9,1%	104	6,2
75%	11,0%	47	13,7
90%	13,7%	19	33,8

In one day at 90% RH lettuce seeds age as much as in one months at 30% RH

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Factors affecting longevity in storage

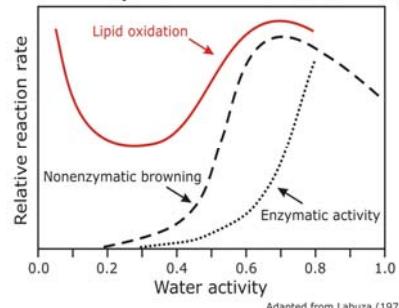
Type of deterioration during harvest, drying and storage:

- DNA damage,
- Protein oxidation,
- Lipid peroxidation
- Cell membrane damage
- Mitochondrial membrane damage
- ...

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Oxidative damage in food science

Food stability as a function of water activity



At low water activities lipid oxidation is enhanced

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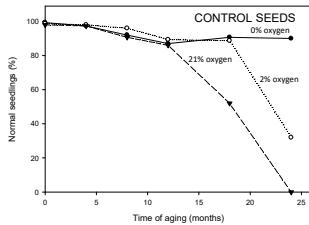
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The food industry packs seeds under anoxia



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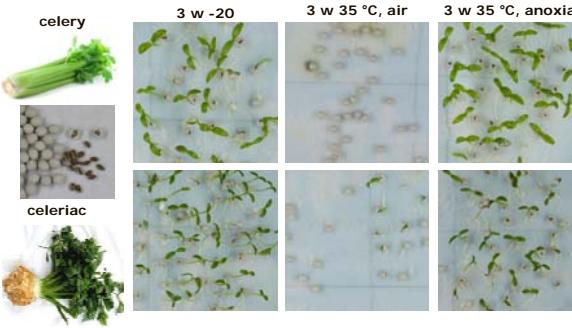
Oxygen and Seed Longevity



Reduced oxygen (0 or 2%) in the storage environment increased the longevity of lettuce seeds stored at 33% RH and 37°C.

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Do primed seeds survive longer under anoxia?



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Factors affecting longevity in storage:

Seed moisture content

Storage temperature

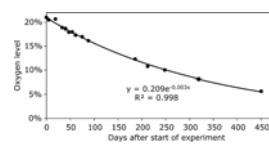
Storage atmosphere

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How to acquire low oxygen levels

- The container should be air (oxygen) tight
- Packaging under nitrogen or carbon dioxide gas
- Vacuum packaging
- Hermetic packaging

- Residual oxygen levels will decline



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GrainPro bags

- GrainPro (Philippines)
- Provides bags and coverings that have a very low permeability for moisture and oxygen
- Kills also insects
- www.grainpro.com
- <https://www.youtube.com/watch?v=iEb-Fs0TXC4>



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Summary: Seed Drying and Longevity

- Seeds have a finite lifetime
- Seeds absorb and lose moisture in response to the humidity of their environment
- Seed longevity is very sensitive to moisture content and temperature
- Packaging to prevent moisture absorption extends storage life
- Low temperatures extend storage life
- Low oxygen level extends lifetime (with dry seeds)
- Hermetic packaging prevents moisture uptake and oxygen entry
- Seed storage behaviour can be estimated (approximately) using the seed viability equation and species specific constants
- Seeds can deteriorate via diverse mechanisms; reactive oxygen species leading to membrane, DNA and protein oxidation is a likely common mechanism

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Contact

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<http://www.seedcentre.nl>
<http://internationalseedacademy.com>

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