MANAGING SHELF LIFE OF FOODS

Purwiyatno Hariyadi
http://phariyadi.staff.ipb.ac.id/

Guru Besar Rekayasa Proses Pangan
Dept Ilmu dan Teknologi Pangan, Fakultas Teknologi Pertanian
dan
Senior Scientist
Southeast Asian Food & Agricultural Science & Technology (SEAFAST) Center

CASE OF SHELF LIFE DETERMINATION

Informations needed:
• Quality critical factor(s)?
• Value of critical factor(s)
  • Maximum value (quality at the factory gate)
  • Minimum value of critical factor(s): minimum quality at the end of shelf-life
• Kinetic parameters for quality changes ($E_a$, $Q_{10}$)

1

Experiment & Analysis
• Emperical Analysis
CASE OF
SHELF LIFE DETERMINATION

KINETIC OF QUALITY CHANGE

A → B

\(-\frac{dA}{dt} = k A^n\)

Measure either loss of A, desirable quality marker, or production of B, undesirable quality marker

\[ A = \text{quality} \]
\[ t = \text{time} \]
\[ k = \text{rate constant} \]
\[ n = \text{reaction order} \]

CASE OF
SHELF LIFE DETERMINATION

KINETIC OF QUALITY CHANGE

Zero order (n=0) quality changes

\(\rightarrow -\frac{dA}{dt} = k A^n\)

\[ -\frac{dA}{dt} = k [A]^0 = k_Z \]

\[ \int_{A_0}^{A} -dA = \int_{0}^{t} k_Z d\ t \]

\[ -[A - A_0] = k_Z t \]

\[ A = A_0 - k_Z t \]
1 CASE OF SHELF LIFE DETERMINATION

KINETIC OF QUALITY CHANGE

Zero order (n=0) quality changes

\[ -\frac{dA}{dt} = k_z \rightarrow A = A_0 - k_z t \]

CASE OF SHELF LIFE DETERMINATION

If \( Q_s \) is quality level at the end of shelf life, then

\[ A_s = A_0 - k_z t_s \]

or

\[ t_s = \frac{(A_0 - A_s)}{k_z} \]

at which

\( t_s \) is shelf life of the product
CASE OF SHELF LIFE DETERMINATION

**KINETIC OF QUALITY CHANGE**

Zero order (n=0) quality changes

\[ -\frac{dA}{dt} = k_z \]

or,

\[ A = A_o - k_z t \]

Just Illustration:

- \( A_o = 100 \) units at time zero
- \( A = 60 \) units at 20 weeks
- What is \( k_z \) if quality change follow zero order?

Remember, \( k_z \) is a slope \( \frac{\Delta Y}{\Delta X} \)

\[ = \frac{(100-60)}{(20-0)} = \frac{40}{20} = 2 \text{ units per week} \]

Thus 2 units per week x 20 weeks is loss of 40 units (with 60 units of quality left)

---

CASE OF SHELF LIFE DETERMINATION

**KINETIC OF QUALITY CHANGE**

First order (n=1) quality changes

\[ -\frac{dA}{dt} = k_f A^1 \]

or,

\[ -\frac{dA}{dt} = k_f A \]

---

**CASE OF SHELF LIFE DETERMINATION**

**KINETIC OF QUALITY CHANGE**

First order (n=1) quality changes

\[ -\frac{dA}{dt} = k_f A^1 \]

or,

\[ -\frac{dA}{dt} = k_f A \]
KINETIC OF QUALITY CHANGE

First order (n=1) quality changes

\[ -\frac{dA}{dt} = k_f A^1 \quad \text{or,} \quad -\frac{dA}{dt} = k_f A \]

\[ \ln \left( \frac{A}{A_0} \right) = k_f t \]

\[ A = A_0 e^{-k_f t} \]

\[ \text{or; } \ln \left( \frac{A}{A_0} \right) = -k_f t \]

CASE OF SHELF LIFE DETERMINATION
CASE OF SHELF LIFE DETERMINATION

KINETIC OF QUALITY CHANGE

First order (n=1) quality changes
\[ -\frac{dA}{dt} = k_f A^1 \]
\[ \text{or, } -\frac{dA}{dt} = k_f A \]

CASE OF SHELF LIFE DETERMINATION

If \( A_s \) is A at the end of shelf life, then
\[ \ln \left( \frac{A_s}{A_0} \right) = -k_f t_s \]
Or
\[ t_s = \frac{\ln(A_0/A_s)}{k_f} \]
Or
\[ t_{1/2} = \frac{0.693}{k_f} \]
At which \( t_s \) is shelf life of product.
CASE OF SHELF LIFE DETERMINATION

KINETIC OF QUALITY CHANGE

First order (n=1) quality changes

\[-\frac{dA}{dt} = k_f A\]

\[-\ln(A/A_0) = k_f t\]

Just Illustration:

Ao = 100 units at time zero
A = 60 units at 20 weeks
What is \(k_f\) if quality changes follow first order?

Remember slope is \(\Delta Y/\Delta X\) but on Ln scale so

\[= \frac{\ln(60/100)}{(20-0)} = 0.51/20\]

\[= 0.02554 \text{ week}^{-1}\]

\[A = A_0 e^{-k_f t}\]

\[A = 100 \times e^{-0.02554 \times 20} = 100 \times e^{-0.511} = 60\]

CASE OF SHELF LIFE DETERMINATION

Examples of kinetic of quality change of selected product during storage/processing

Zero Order
- Overall quality of frozen food
- Non-enzimatic browning

First Order
- Vitamin loss/degradation
- Mikcorbial inactivation
- Oxidatif deterioration of color
- Thermal degradation of texture

Check on Literatures
2. **Shelf Life → Ingredient?**

- **Step 2**: Penentuan Spesifikasi Ingredien
- **Step 2**: Penentuan pengaruh pengolahan pada Q relative
- **Step 2**: Penentuan Spesifikasi Produk
- **Step 4**: Penentuan Spesifikasi Produk *tak-layak*

**Ingridient, Pengemas, dll (step 1)**

**Process 1**
- Manufacturing (step 2)

**Process 2**
- Packaging

**Transport (step 3)**

**Retail (step 4)**

**Process criteria:** e.g. pasteurisation or sterilisation time/temperature

**Product criteria:** pH, aw, salt, acid, etc = f(fungsionalitas, Q, R)

---

**Quality Limit**

- Quality I
- Quality II
- Quality III

**Ingridient Spec:**
- Acceptable spec by Industry
  - will affect the formulation

**Shelf Life**

- Quality Limit (expiration date)
  - set by supplier

**Storage Time**

- (months)

---

**Shelf Life → Ingredient?**

- Quality I
- Quality II
- Quality III

**Ingridient Spec:**
- Acceptable spec by Industry
  - will affect the formulation

**Quality Limit**

- Quality Limit (expiration date)
  - set by supplier

**Storage Time**

- (months)
2. **Shelf Life → Ingredient?**

Example → Formula: 10 kg/ton

- Quality I
- Quality II
- Quality III

Quality Limit (expiration date) set by supplier

Storage Time (months)

Q relative

0          2            4             6            8           10

Example → Formula: 11.1 kg/ton

- Quality I
- Quality II
- Quality III

Quality Limit (expiration date) set by supplier

Storage Time (months)

Q relative

0          2            4             6            8           10
2. **Shelf Life → Ingredient?**

- **Quality I**: Q relative = 100, 90, 80, 70, 60
- **Quality II**: Q relative = 12.5 kg/ton
- **Quality III**: Q relative = 14.3 kg/ton

**Storage Time (months)**: 0, 2, 4, 6, 8, 10

**Formula**: 12.5 kg/ton, 14.3 kg/ton

**Quality Limit (expiration date)**: set by supplier
2. **Shelf Life → Ingredient?**

**Ask the supplier:**
The Ingredients still “good” → Can the shelf life be extended?

**Formula → 14.3 kg/ton**

**Quality Limit (expiration date) set by supplier**

**Storage Time (months)**

---

**Theoretically ... Yes you can ...**

→ As long as the product you produce comply with regulation (Food Quality and Safety standard)

→ And ... if technically possible
2. **Shelf Life → Ingredient?**

**Theoretically ... Yes you can ...**
- As long as the product you produce comply with regulation (Food Quality and Safety standard)
- And ... if technically possible
- **Adjust formula** → 16.6 kg/ton

**Food Law:**

*PRESIDEN REPUBLIK INDONESIA*

**UNDANG-UNDANG REPUBLIK INDONESIA**

NOMOR 18 TAHUN 2012

TENTANG

PANGAN

DENGAN RAHMAT TUHAN YANG MAHA ESA

PRESIDEN REPUBLIK INDONESIA,
2. **Shelf Life → Ingredient? → Potential legal problem??**

**Food Law:**

(Pasal 90)

1. Setiap Orang dilarang mengedarkan Pangan tercemar.
2. Pangan tercemar sebagaimana dimaksud pada ayat (1) berupa Pangan yang:
   a. mengandung bahan beracun, berbahaya, atau yang dapat membahayakan kesehatan atau jiwa manusia;
   b. mengandung cemaran yang melampaui ambang batas maksimal yang ditetapkan;
   c. mengandung bahan yang dilarang digunakan dalam kegiatan atau proses Produksi Pangan;
   d. mengandung bahan yang kotor, busuk, tengik, terurai, atau mengandung bahan nabati atau hewani yang berpenyakit atau berasal dari bangkai;
   e. diproduksi dengan cara yang dilarang; dan/atau
   f. sudah kedaluwarsa.

(Pasal 99)

Setiap Orang dilarang menghapus, mencabut, menutup, mengganti label, melabel kembali, dan/atau menukar tanggal, bulan, dan tahun kedaluwarsa Pangan yang diedarkan.
3. Managing Shelf Life

Shelf-life is established within “Design” and managed through all stations.

- **DESIGN**
  - Products
  - Raw Materials
  - Packaging
  - Process
  - Safety net: HACCP and Allergens
  - Quality
  - Shelf-life incl. stor. & distr. conditions
  - Regulatory compl.

- **PROCURR**
  - Purchase to specs

- **CONVERT**
  - Finished product to specs

- **DISTRIBUTE**
  - Handle and store to specs

- **CUSTOMER**
  - Handle and store to specs

- **CONSUMER**
  - Handle and use to labels (ideally)

![Graph](image)

- **Shelf Life-1**
- **Q**
- **Quality Value**
  - Limit (critical) **Q**
  - Storage Time (months)

Purwiyatno Hariyadi
Web: phariyadi.staff.ipb.ac.id
Email: phariyadi@ipb.ac.id
3. Managing Shelf Life

1. Improve Initial Q ($Q_0$)

- **Shelf Life-1**
  - $Q_{0-1}$
  - Limit (critical) Q
- **Shelf Life-2**
  - $Q_{0-2}$
  - Limit (critical) Q

2. **Shelf Life-2**

3. **Shelf Life-1**

Managing Shelf Life

1. Improve Initial Q ($Q_0$)
Managing Shelf Life

3. 

2. Reduce the rate constant \(k\)

1. Identify weakes link?

1. Product characteristics
2. Processing technology
3. Packaging
4. Condition of storage, distribution & handling
Managing Shelf Life:
= Shelf Life is determined by the weakest link

1. Product characteristics (RM, ingredients)
   - nutrients, water ($a_w$), acids (pH), microbial load, etc

2. Processing technology
   - Temp (T) & Time (t)
   - Cleaning (4T)
   - Hygienic practices, etc.
Managing Shelf Life:

- Shelf Life is determined by the weakest link

Quality

Packaging
- WVTR?
- OTR?
- Light protection?
- Physical protection?

Shelf Life

Condition of storage, distribution, and handling
- T, RH, light?
- Handling practices?
- Transportation practices?
- Storage practices?
Managing Shelf Life:
= Shelf Life is determine by the weakest link

Responsibility of food Industry: Optimizing Shelf Life

Quality
1. Product characteristics
2. Processing technology
3. Packaging
4. Condition of storage, distribution& handling

Shelf Life

Manage these factors

Assurance that “at possible latest consumption the characteristics of food product are remain acceptable”

TERIMAKASIH

“YOU'RE WAITING TO SEE THE DOCTOR.... WHAT'S YOUR SHELF LIFE....?”