



Impact of packaging materials and storage conditions on the shelf life and quality of biscuits

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Abstract

This research study examines the impact of packaging parameters, including thickness, surface area, and material quantity, on the shelf life of biscuits. An increase in the thickness of the packaging material significantly enhanced the shelf life of the product. This is attributed to the improved barrier properties, which reduce the permeation of moisture, oxygen, and other external factors that degrade product quality. Conversely, an increase in the surface area of the packaging led to a reduction in shelf life. Larger surface areas expose the product to greater environmental interactions, accelerating degradation processes. Slight increase in the quantity of material resulted in a marginal improvement in shelf life, suggesting that beyond a certain threshold, additional material has limited impact on preservation.

Keywords: Impact of packaging, shelf life, biscuits, moisture

Introduction

Biscuits, as one of the most widely consumed snack foods globally, are highly susceptible to quality degradation during storage due to factors such as moisture absorption, oxidative rancidity, and microbial spoilage (Manley, 2011) [7]. The shelf life and quality of biscuits are significantly influenced by the packaging materials used and the storage conditions they are subjected to. Effective packaging not only acts as a barrier against external environmental factors but also plays a crucial role in maintaining the texture, flavor, and nutritional value of the product (Robertson, 2016) [9]. Recent advancements in packaging technology have introduced a variety of materials, including plastic films, aluminum foil, biodegradable polymers, and nanocomposites, each offering unique properties to enhance product preservation (Marsh & Bugusu, 2007) [8]. For instance, high-barrier packaging materials with low oxygen and moisture permeability have been shown to extend the shelf life of biscuits by preventing staling and rancidity (Gomes *et al.*, 2020) [3]. Additionally, modified atmosphere packaging (MAP) and active packaging systems, which incorporate oxygen scavengers or moisture absorbers, have gained attention for their ability to maintain product freshness and quality over extended periods (Yildirim *et al.*, 2018) [12]. Storage conditions, such as temperature, relative humidity, and light exposure, also play a critical role in determining the shelf life of biscuits. Studies have shown that high humidity can lead to moisture absorption, resulting in softening and loss of crispness, while elevated temperatures can accelerate oxidative reactions, leading to rancidity and flavor deterioration (Sablani *et al.*, 2010) [10]. Furthermore, exposure to light, particularly UV light, can cause photo-oxidation of fats, further compromising product quality (Lund & Ray, 2017) [6].

Biscuits are manufactured in most countries of the world and although Britain led the industrialization of biscuits and

also popularized biscuits at least through her former colonies (Manely, 2001). On an average, Indians eat 0.48 kg every year, while Americans eat 4.02 kg. The annual sales turn over of a popular biscuit brand is 179.9 million kg (Anon, 2003) [1]. It is generally recognized that these products are cereal based and baked to a moisture content of less than 5% (Kumar, 2001) [4]. The cereal components is variously increased with two major ingredients, fat and sugar, but there after the possible composition is almost endless Prediction of shelf life of food product stored under different environmental condition is important. Shelf life depends on the large number of factors such as temperature, equilibrium relative humidity, oxygen partial pressure, light, package permeability and package configuration. The use of a computer to simulate a storage test provides a means to protect materials before actual storage testing. By performing these calculations rapidly, as only a computer can do much iteration are possible within a reasonable time, providing a power full support tool for packaging development. The simulations are accomplished by separating the product and packaging characteristics.

The product is analyzed for change that occur on exposure to the shelf life limiting parameter, which is identified as the mode of failure for the products. The packaging material is analyzed for its barriers properties against that parameter. The computer then used to combine the protective aspects of the package with the sensitive properties of product. It is possible to test the effect of different packages or conditions simply by entering the new variables.

Materials and Methods

It is evident from moisture sorption that for longer shelf life of biscuit which have to be stored under either humid or dry condition, they should be dried close to their lower critical moisture content level or higher critical moisture content levels respectively to allow the maximum possible moisture transfer.

A semi permeable film transports water vapour across its thickness by virtue of vapour pressure difference across the film (Fick's and Henry's Laws). The rate of transport of water is given by rearranging the variable.

$$\frac{dw}{dt} = \frac{KwA(P1-P2)}{X} \tag{1}$$

Where,

W = Weight of water transported across film, g

t = Time, days

Kw = Permeability of film, g mil/m² day mm Hg

X = Film thickness, mil

A = Area of film, m²

P₁ = External water vapour pressure, mm Hg

P₂ = Internal water vapour pressure, mm Hg

Eqn. (1) can be written in terms of moisture in the packages by substituting moisture content for the water transported as follow:

$$m = \frac{W}{Ws} \tag{2}$$

Where,

m = moisture content (g H₂O/g solids)

W = Weight of water transported across the packaging film, g

W_s = Dry weight of enclosed food, g

Hence, Eqn. (1) becomes

$$\left[\frac{dm}{dt} = \left[\frac{Kw}{X} \right] \left[\frac{A}{Ws} \right] (P1 - P2) \right] \tag{3}$$

Let a₁ and a₂ be external and internal water activity, respectively, Thus

$$a1 = \frac{P1}{Po} \text{ and } a2 = \frac{P2}{Po}$$

Where,

P₀ = Saturation pressure of water vapour at the given temperature, T.

By substituting P₁ and P₂, Eqn. (3) becomes

$$\frac{dm}{dt} = \frac{KwAPo}{(XWs)(a1 - a2)} \tag{4}$$

$$\Delta m = \{(Kw - A.P0)/(X.Ws)\} (a1 - a2) \Delta t \tag{5}$$

Where,

$$K = (Kw.A.P0)/(X.Ws) \tag{6}$$

In the Eqn. (5), only known is the internal package water activity, which is a function of material inside the package. The major resistance is in the film and it is assumed that rapidly equilibrates with the food. The internal water activity then is safely determined by water sorption isotherm

of the food. Eqn (5) implies that two packages have an identical behaviour as long as the coefficient K remain the same for both packages irrespective of the individual values of the constants.

With the help of developed model effect of packaging material thickness, surface area and weight of material on the shelf life of the food material were studied.

Results and Discussion

The effect of packaging material thickness on the shelf life of the biscuit was studied. Four different thicknesses that is 0.2, 0.6, 1.0, 1.4 mil (5, 15, 25, 35µ) were selected to see the effects (Table 1). All other parameters of model were kept constant except thickness. The table indicates that increase in thickness of packaging material increased the shelf life of product, because the WVTR decreased with increase in thickness. The effect of surface area of packaging material on shelf life of the food material was studied. All other parameters of model were kept constant except surface area. Table 2 shows that increase in surface area decreased the shelf life of biscuit. This finding is important because some time smaller quantity material is packed in bigger container.

Table 1: Effect of packaging material thickness on the moisture content of biscuit

Days	Thickness, (µ)			
	5	15	25	35
0	1.01	1.01	1.01	1.01
1	2.23	1.42	1.26	1.19
2	3.42	1.83	1.5	1.36
3	4.57	2.23	1.74	1.54
4	5.71	2.63	1.99	1.71
5		3.02	2.23	1.88
6		3.42	2.47	2.06
7		3.80	2.71	2.23
8		4.19	2.94	2.4
9		4.60	3.18	2.57
10		4.95	3.42	2.74
11		5.33	3.65	2.91
12			3.88	3.08
13			4.11	3.25
14			4.36	3.42
15			4.73	3.58
16			5.01	3.7
17				3.92
18				4.08
19				4.25
20				4.41
21				4.57
22				4.74
23				4.9
24				5.03

Data input

- Time Interval = 1(day)
- Thickness = 5,15,25,35 (µ)
- Water vapour permeability = 0.1843228 (g-mil/m² day mm Hg)
- Surface area = 0.0234 (m²)
- Weight of material = 75.175 (gm)
- Moisture content =1.01(%)
- Relative humidity = 90 (%)
- Temperature =38°C

Table 2: Effect of packaging material surface area on the moisture content of biscuit

Days	Area, (m ²)			
	0.0134	0.0234	0.0334	0.0434
0	1.01	1.01	1.01	1.01
1	1.24	1.42	1.59	1.77
2	1.48	1.83	2.17	2.51
3	1.71	2.23	2.74	3.15
4	1.94	2.63	3.3	3.97
5	2.17	3.02	3.86	4.68
6	2.4	3.42	4.41	5.38
7	2.63	3.8	4.95	
8	2.86	4.19	5.49	
9	3.08	4.57		
10	3.31	4.89		
11	3.53	5.33		
12	3.75			
13	3.98			
14	4.2			
15	4.42			
16	4.64			
17	4.85			
18	5.07			

Data input

Time Interval = 1(day)
 Thickness = 15 (μ)
 Water vapour permeability = 0.1843228 (g-mil/m² day mm Hg)
 Surface area = 0.0134, 0.0234, 0.0334, 0.0434 (m²)
 Weight of material = 75.175 (gm)
 Moisture content = 1.01(%)
 Relative humidity = 90 (%)
 Temperature = 38⁰C

Table 3: Effect of material weight on the moisture content of biscuit

Days	Weight (gm.)			
	65.175	75.175	85.175	95.175
0	1.01	1.01	1.01	1.01
1	1.48	1.42	1.37	1.33
2	1.95	1.83	1.73	1.65
3	2.41	2.23	2.09	1.97
4	2.87	2.63	2.44	2.29
5	3.32	3.02	2.79	2.61
6	3.77	3.42	3.14	2.92
7	4.22	3.80	3.48	3.23
8	4.66	4.19	3.83	3.54
9	5.10	4.57	4.17	3.85
10		4.89	4.51	4.15
11		5.33	4.84	4.45
12			5.18	4.76
13				5.06

Data input

Time Interval = 1(day)
 Thickness = 15 (μ)
 Water vapour permeability = 0.1843228 (g-mil/m² day mm Hg)
 Surface area = 0.0234 (m²)
 Weight of material = 75.175, 65.175, 85.175, 95.175 (gm)
 Moisture content = 1.01(%)
 Relative humidity = 90 (%)
 Temperature = 38⁰C

This study was carried out to see whether there was any effect of material weight packed in the packaging material on the shelf life. All other parameters were kept constant except material weight. With the increase in material weight, the shelf life of the product increased (Table 3).

Conclusion

Using the developed model, a simulation study was conducted to evaluate the effects of packaging material thickness, packaging material surface area, and material weight on the shelf life of biscuits, while keeping all other parameters constant. Increasing the thickness of the packaging material extended the shelf life of the biscuits, while a larger surface area of the packaging material resulted in a reduced shelf life. Additionally, a slight increase in the weight of the material was associated with a modest improvement in the shelf life of the biscuits.

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