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Original article

Effect of storage at ambient temperature on quality of donut

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A R T I C L E I N F O

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This work was carried out to study the influence of storage time (1-7 days), on the quality of donut. Rheological properties, crumb and crust color and Donut's brain cavity were used as quality indicators. Results show that significant changes occurred on storage in all textural properties. The hardness, Gumminess and chewiness of the donut showed a significant increase with the time of storage. L* a* b* color parameters of crust don't change significantly. The most noticeable change in color parameters of crumb was observed in ΔE. Average diameter of donut's brain cavity decreased within the storage time of seven days. Average area of cavities decreased too but circularity of cavities increased. The best time for consumption of donut was calculated as 4.8 days in the based on simple kinetic model.

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1. Introduction

Donuts are fermented and fried sweet snacks. They are usually served in hotels, restaurants and snack bars in many countries all over the world as a convenient food and have become one of the most desirable snacks for every one due to their low manufacturing lost and ability to serve as a vehicle for important nutrients. Recently, donuts consumption has increased in Iran too (Rehman et al, 2007., Zolfaghari etal, 2011).

The donut market alone is a 3–4 billion$ business in the U.S. After baking and during the storage at ambient temperature, all bakery and bakery like products such as donuts undergo a series of chemical and physical changes which is totally referred as staling. Some of important changes associated with staling are the gradual increase in the hardness of the crumb, deterioration in flavor and aroma and loose of crust crispness (Tan &Mittal, 2006., Hallberg etal, 2006., Lebesi etal, 2011).

After frying, donuts are soft but when kept at ambient temperature they stale rapidly and become tough and rigid. Quality of fried donut depends on its color, shape, brightness aroma, flavor and nutrition value. Staling is a complex process. Starch is one of main component of donut and numerous studies indicated that changes in starch play a major role in bakery and bakery like products firmness. Donuts shelf-life is short and it is a serious problem because it can be costly to producer, distributor and consumer. Firming of crumb during storage is a common phenomenon and leads to a crumbly texture, and lowering consumer acceptance (ji etal, 2010., Hallberg etal, 2006., Noor aziah etal, 2012).

Staling is much slower in cakes than in breads that may be partly attributed to the higher fat and lower flour content of cakes and moreover to the lower starch level that is expected to delay the staling of cake. The aim of this research was to study the physical and rheological characteristics of donut that related to its staling, during 7-d storage (Lebesi etal, 2011).

2. Materials and Methods

2.1. Materials

Wheat flour (moisture 14% and protein 8.9%), sugar, salt and fresh whole eggs were purchased from local market. non-fat milk solid, yeast and shortening were supplied by Nanrazavi co.

2.2. Donut formulation and preparation

Donut samples were prepared by mixing ingredients according to the formulation (Table 1). Eggs were beaten at high speed for 1 min in a mixer, and then sugar was added and beaten at high speed for 1 min. The shortening and dry milk were added and mixed at low speed for 20 sec, and the dry ingredients were mixed for 45 sec on low. The dough was transferred to a cutting board. It was rolled to a thickness of about 1 cm and cut to ring shaped samples with dimensions of 8 cm diameter and 1cm thickness (shih etal, 2001., Vélez-Ruiz, 2003).

Table 1
Recipe for donut preparation.

Ingredient	**g**
Wheat flour	57.5
Egg	12
Sugar	25
Shortening, margarine	2
Milk, reconstituted nonfat dry	2
Yeast	1
Salt	0.5

A deep-fryer was used for the frying experiment. The heating was controlled using a temperature probe, The oil bath, filled to a depth of 15 cm with 2.5 L of nazgol vegetable oil, was heated at 180 $^{\circ}$C for 1 hour before use. The donuts were fried, with frequent flipping from side to side about every 60 sec, until they were fried completely (golden brown on the outside and well cooked on the inside) (shih etal, 2001).

2.3. Rheological characteristics

Donut samples were cut into 20×20×20 mm and compressed Texture of donut was measured using a Texture Analyzer (Model QTS Brookfield, UK). Texture profile analysis (TPA) consists of compressing the sample twice. From this test several texture parameters are derived such as hardness, cohesiveness, Chewiness and Gumminess. A 40×40 mm aluminum probe was used in TPA test to compress each sample to 75% of the sample length with a cross head speed of 60 mm/min in a 2-cycle test (Nasehi etal, 2009).

There are several ways to predict the shelf life of Food products (ahuja etal, 2012). At the present study To analyze the general quality change in donut, the following approach is used (eq 1):

$$\pm\frac{dQ}{dt} = kQ^n \quad \text{(Equation 1)}$$

Where Q is the (measured) quality index (e.g. color, texture, sensory attribute), t is time, k is the reaction rate constant, which is temperature dependent and n is the reaction order. For majority of foods, the time dependence relationships appear to be described by zero- or first order models (Olivera etal, 2011). In first-order reactions, the relationship between quality attribute and time is exponential and therefore eq(1) gives:

$$-\frac{dQ}{dt} = kQ \quad \text{(Equation 2)}$$

2.4. Volume and density of donut

Volume of the donut was measured using rapeseed displacement method. Three donuts were put in a metallic container with known volume (*V*). The container was topped up with rapeseed, the donuts removed and the volume of the rapeseed was noted (V_R). Volume (V_L) was then calculated according to following formula:

V_L (ml) = V - $V_{R.}$ (Equation 3)

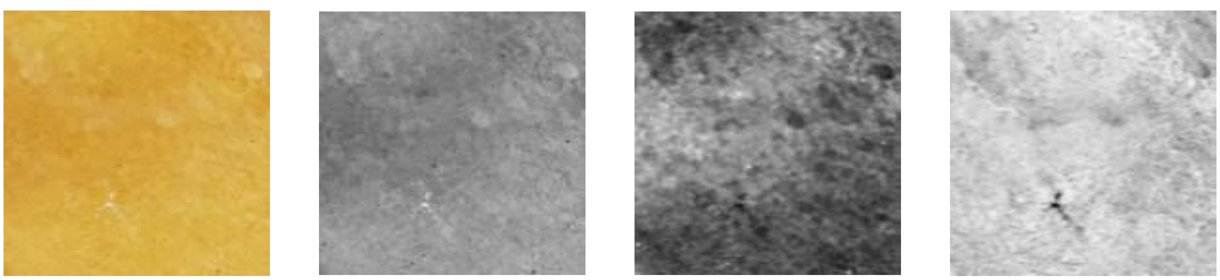
Then donuts were weighed on a digital scale, W (g). Density of donuts (ρ) was calculated as

ρ (g/ml) = W/V_L. (Equation 4)

2.5. Color

Donut's crust and crumb pictures were taken using a digital camera (model kanon, pawershot A520). The digital images were saved in JPEG format (Figure 1). The analysis of donut's crumb and crust color for obtaining the color parameters (L*a*b*) was performed using Analyze option in image J software (shahidi etal, 2012). where L* represents the lightness of colour, a* its position between red and green (or redness) and b* its position between yellow and blue (or yellowness). Tow replicates per storage time were recorded. Total color difference, ΔE, was calculated as:

$$\Delta E = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2} \quad \text{(Equation 5)}$$



1 2 3 4

Fig. 1. Steps of image processing to estimate L*a*b*of donut with Image J software. 1: Original image, 2: Parameter L*, 3: Parameter a*, 4: Parameter b*

2.6. Statistical analysis

Analysis of variance were computed using SPSS 16 software and The experimental groups were then separated statistically using Duncan's new multiple range tests (p<0.05).

3. Results and discussion

3.1. Texture

The results (Table 2) showed that significant changes occurred on storage in all textural properties. The hardness of the donut showed a significant ($P < 0.05$) increase with the time of storage, for example the hardness increased from 1883 g to 3735 g during storage for 7 days. These result is in agreement with those of other researchers who have showed increasing in hardness of bread during storage (Besbesa etal, 2011, Angioloni, 2009., Sourki etal, 2010). Gumminess and chewiness are parameters dependant on hardness, therefore, their values, both in donut samples during storage, followed a similar trend than that of hardness. Cohesiveness was not significantly changed during storage.

Table 2
textural properties of donut during storage.

day	Cohesiveness	Chewiness	Gumminess	Apparent modulus
1	0.37±0.01	12041±985	703±92	79±29
2	0.38±0.01	13734±4818	857±326	116±48
3	0.37±0.01	12834±2756	783±218	104±50
4	0.36±0.03	19928±8209	1197±416	143±50
7	0.34±0.01	23777±13653	1257±502	147±55

The results (Table 2) show the amount of apparent modulus during storage at ambient temperature. In general terms, a similar behavior can be observed for the different TPA parameters: a significant increase was registered with time, which was more pronounced during the 3th day of storage. As it was mentioned, in a previous work, the influence of the storage time was investigated.

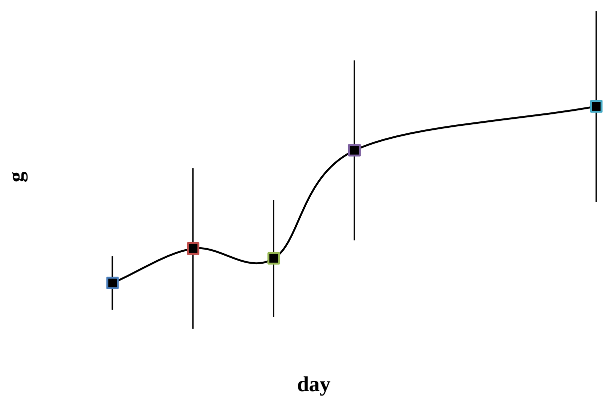


Fig. 2. Hardness of donut during storage.

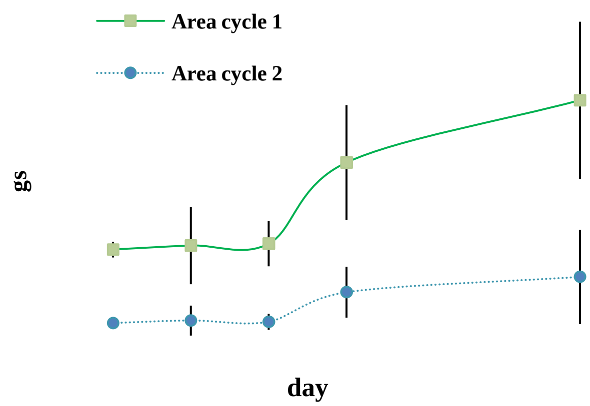


Fig. 3. Area cycle 1&2 during storage.

During storage time, the hardness of donut was the parameter that showed important variation, which can be obtained from the results of TPA test that mentioned before. Furthermore, such differences were detected by regular consumers and certainly affected the acceptability of the product. Therefore, hardness was selected as the critical quality index for storage of donut, and then, the quality loss kinetic model was obtained for the tested conditions. In this way, from the experimental data of instrumental (hardness) the corresponding quality loss kinetics was calculated. Hardness values were well adjusted using a modified first-order kinetic model:

$$H= q+b\times \exp(-kt) \qquad \text{(Equation 6)}$$

Where t is the storage time (day), H is the hardness at storage time t, and q, b, and k are kinetic constants. Table 3 shows the results of kinetic modeling for hardness including experimental values. Shelf life was determined when 25% of panellists rejected the donut samples (3000 g).

Table 3
Regression results for kinetic modelling of shelf life of donut.

Kinetic constants	**b**	**k**	**q**	**R-square**
value	3775	-0.0787	-2495	0.85

3.2. Colour

L* a* b* color parameters of crust and crumb of donuts during 7-d storage were presented in table 4 & 5. Each value is the average of three replications. The most noticeable change in crumb of donut was observed in ΔE, which increased from 0 to 5. It was found that L*, which is associated with lightness, decreased during storage time. On the other hand, b*, that is related to yellowness, did not present significant differences in the tested conditions, Furthermore a*, which is associated with redness, only a slight decrease during the seventh days of storage was observed.

Table 4
color parameters of crust.

day	**L***	**a***	**b***	**ΔE**
1	70±4	12±3	55±2	0
2	66±5	11±3	55±0	4
3	79±6	2±3	55±4	14
4	73±0	6±2	55±2	7
7	69±2	6±0	51±1	7

Table 5
color parameters of crumb.

day	**L***	**a***	**b***	**ΔE**
1	95±4	-10±1	23±2	0
2	95±1	-9±0	23±1	1
3	96±0	-12±0	24±0	2
4	95±0	-9±0	25±0	2
7	91±0	-8±0	24±0	5

3.3. Donut’s brain cavity

Table (6) shows the evolution of donut’s brain cavity during storage at ambient temperature. In donut samples, average diameter of donut’s brain cavity decreased within the storage time of seven days.

Table 6

properties of donut's brain cavity during storage.

day	average size	perim	circ
1	125±2	32±1	0.81±0.02
2	122±3	31.7±0.1	0.82±0.01
3	110±19	29.0±2.7	0.82±0.01
4	126±17	31.8±4.2	0.83±0.01
7	83±26	27.2±3.6	0.84±0

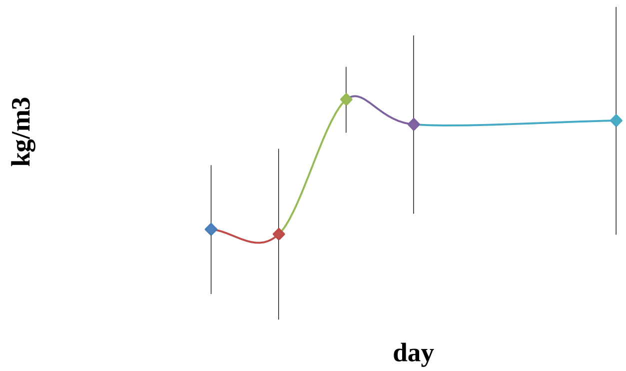


Fig. 4. Density of during storage.

Furthermore surface area of cavities decreased too but circularity of cavities increased. This indicates that during storage time, brain cavities have been shrinkage and their shapes is more similar to circle. These results are in agreement with previous works (fig 4) (Garimella Purna etal, 2011). In a study, the influence of the storage time on porosity of donut was investigated. Significant differences were found between fresh donuts and stored samples porosity. The porosity reduced during the storage time. Samples porosity was 30% lower than the initial porosity in the end of storage (ghaitaranpour etal, 2013).

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