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Shelf-life prediction for Indian mango roll using accelerated shelf-life testing (ASLT) shelf-life plot approach

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Abstract

Indian mango roll is a sweet and chewable after-meal sugar fix. It is prepared from the puree of Indian mango and dried to form a glossy sheet. Ripe raw Indian mango generally has a short shelf-life. Osmotic-dehydration is one way to extend the shelf-life of Indian mango. Changes in color and flavor were considered as critical aspects upon long-term storage at accelerated temperatures. This research aimed to predict the shelf-life of Indian mango roll with Accelerated Shelf-life Test methods. Indian mango rolls packed in 30 g stand up aluminum foil with polyethylene liner were stored at three different temperatures, 35°C and 45°C for temperature acceleration, and 30°C for the actual temperature for one hundred eighty (180) days. The storage of Indian mango roll at 30°C, 35°C, and 45°C is predicted until 255 days, 244 days, and 69 days, respectively, based on the test results for the conducted microbiological, physicochemical and sensory analyses. The results implied that the Indian mango roll can be stored long enough before becoming unfit for consumption or sale.

1. Introduction

Fruit rolls like mango roll, are dehydrated fruit products which are eaten as snacks or desserts. They are flexible sheets that have concentrated fruit flavor and nutritional aspects (Diamante *et al*., 2014). Mango roll is a traditional product prepared from ripe mango. Traditionally, sun drying is employed for preparing mango roll from ripe fruit pulp. Cabinet drying has also been carried out for making mango roll (Heikal *et al*., 1973).

In food processing and preservation, hurdle technology is a method that ensures microbial stability and safety of food as well as nutritional and sensory quality based on the application of several preservation factors (Leistner, 2000). The hurdles mainly used in food preservation include the use of preservatives, the type of packaging, temperature, water activity, and pH, among others (Lee, 2004).

Shelf-life is one of the most important aspects of assuring food safety and quality. According to IFST (1993), shelf-life is the period of time at which the food product will remain safe, and be certain to retain the desired sensory, chemical, physical, microbiological and functional characteristics and comply with the label declaration of nutritional data when stored under recommended conditions. The shelf-life of food is greatly affected by both the intrinsic and extrinsic factors. Intrinsic factors are a part of the food's system that cannot be controlled that includes pH, moisture content, water activity, nutrient content, antimicrobial agents, biological structures and oxidation/reduction potential. On the other hand, extrinsic factors are temperature, relative humidity, light, mechanical stresses including consumer handling, and the packaging properties (Singh and Cadwallader, 2002), presence of gases, physical stress, and other environmental parameters that can be controlled or changed to influence product's shelf-life.

Barberio (1986) reported that the actual shelf-life of a product depends on four major factors: formulation, processing, packaging, and storage conditions which are all critical and their relative importance depends on the perishability of the product. Accelerated Shelf-life Tests or ASLT refers to any method that is capable of evaluating product stability, based on data that is obtained in a significantly shorter period than the actual shelf-life of the product (Mizrahi, 2004). The procedure in ASLT is to store the finished product/package combination under some test abuse conditions, examine

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the product periodically until the end of shelf-life occurs; and use these results to estimate the product shelf-life under true distribution conditions.

Major quality parameters associated with dried foods are the changes in color, visual appearance, microbial population, texture, nutrients, and water activity. Hyun *et al*. (2019) studied the microbiological, physicochemical, and visual quality of dried persimmons during storage at various temperatures (-20, 4, 12, and 25°C) for 70 days to determine the product shelf-life. Grizotto *et al*. (2006) estimated shelf life of 168 days for the restructured dried papaya pulp at 25°C using ASLT. Under normal storage conditions, the shelf life of the product is estimated as 154 days based on the overall quality using the sensory results. However, the quality parameters for determining the accelerated shelf-life and, shelf-life, and quality of dried Indian mango roll have not been investigated so far. Therefore, the aim of this study is to predict the shelf -life of Indian mango roll with Accelerated Shelf-life test methods at various temperatures (30°C, 35°C, and 45°C) for 180 days.

2. Materials and methods

2.1 Indian mango roll preparation

Fresh, naturally ripened, firm Indian mangoes (4 months after flowering stage) were obtained from the vicinity of Pangasinan State University (PSU) Bayambang Campus. After sorting (overripe, damaged ones were discarded), Indian mangoes were washed thoroughly with water and peeled manually using a stainless knife. Mango puree was weighed, and sugar was added to it to adjust the total solids to 25°Bx and three (3) grams of an aqueous solution of citric acid (0.17% (w/w) per 100 g of the formulation was added to enhance the pectin-sugar-acid gelation. The mixture was heated for two minutes at 80°C. Then, sodium metabisulfite (0.1%, w/w), a preservative agent, was added. The mixture was then poured into stainless steel trays with plastic sheet in layers about 1.0 cm thick. Trays were loaded in the drier and dehydrated at 55°C for 15 hrs. Dried sheets were removed from the trays and transferred to a work surface previously dusted with confectioner's sugar. Each sheet was tightly rolled, cut into desired sizes, coated with confectioner's sugar and packed in aluminum foil with polyethylene (PE) liner, 10 cm x 15 cm, 30 g per pack, sealed and labeled (Domingo and Austria, 2017).

2.2 Temperature acceleration

Accelerated storage temperatures used were 35°C and 45°C. Samples were also stored at 30°C for one hundred eighty (180) days as the target storage period for the real-time shelf-life test. The sampling time was calculated using the formula:

$$Q_{10}^{\Delta/10} = ts_1/ts_2,$$

Where Q10 refers to temperature coefficient; Δ is the temperature difference between t_1 and t_2; ts_1 refers to the shelf-life at the lower temperature or target shelf-life and ts_2 is the shelf-life at the higher temperature. On the other hand, sampling frequency with the formula: $f_2 = f_1 Q_{10}^{\Delta/10}$ was also determined.

The shelf-life of the products at room temperature was estimated using shelf-life plot approach, derived from accelerated temperatures data, and was verified based on the actual end of shelf-life at room temperature.

For the sampling design, the selected Q_{10} value for mango roll was 1.5 related to flavor changes (Labuza, 1984), as its deteriorative reaction and the sampling frequencies or intervals at 45°C, 35°C and 30°C were 17 days, 26 days, and 31 days, respectively.

2.3 Microbial determination

For microbiological analysis, the tests used were Aerobic Plate Count (Maturin and Peeler, 2001), *Escherichia coli* count (Feng *et al*., 2001), Mold and Yeast Count (Tournas *et al*., 2001) and *Staphylococcus aureus* detection (Tallent *et al*., 2001).

2.4 Physical and chemical analyses

Proximate analyses were determined in terms of percent moisture content, crude fat, crude protein, and water activity using standard methods (AOAC, 2016). Subtracting the sum of fat content, protein content, ash content, and moisture from 100 gave the total carbohydrate content (Onyeike *et al*., 2000).

2.5 Sensory analysis

Sample was subjected to sensory evaluation using the Quality Scoring, Difference from the Control test, and the Acceptability and Preference test. Twenty (20) panelists whose ages range from 22 to 48 were selected and trained following the guidelines of ISO (1993). The method employed for mango roll was Quality Scoring focusing on the color, flavor, and overall acceptability score of the product. The test sample was compared to a control sample (mango roll sample stored at 4°C) and difference was significant at $p<0.01$. Once the test sample is significantly different from the control sample, it is then subjected to the acceptability test. If 50% of the panel rejected the sample for consumption, the testing ends (Hough, 2010).

2.6 Statistical analysis

The data were analyzed using the statistical package

PHStat and MegaStat in Microsoft Excel 2013.

3. Results and discussion

Table 1 shows that the microbiological test result for mango roll was negative for aerobic plate count and for mold and yeast count. The addition of citric acid and sodium metabisulphite contributed to the possible inhibition of microbial growth in this product. Oladapo *et al*. (2014) reported that the chemical preservatives (citric acid, potassium metabisulphite, sodium benzoate, ascorbic acid and potassium sorbate) are effective in the control of selected pathogenic bacteria such as *S. aureus, K. aerogens, P. mirabilis, P. aeruginosa* and *E. coli* that cause food poisoning and infection. In this study, mango roll was packed in an aluminum foil with PE liner that definitely protects the product from possible contamination. Cutter *et al*. (2002) reported that packaging materials have been developed specifically to prevent the deterioration of foods resulting from exposure to air, moisture, or pH changes associated with the food or the surrounding atmosphere. Both flexible and rigid packaging materials, alone or in combination with other preservations methods, have been developed to offer the necessary barrier, inactivation, and containment properties required for successful food packaging.

The mango roll sample that expired on day 69, day 244 and day 255 at 45°C, 35°C and 25-30°C respectively, remained acceptable on the microbiological level that is parallel to the obtained water activity result (Table 2). The effects of reduced water content in the environment upon microbial growth are usually described as functions of the water activity (a_w) of the medium decreases, mostly below about 0.98. It is well known that the rate of growth decreases as the a_w of the medium decreases, mostly below 0.98 (Casolari *et al*., 1978).

Mango roll is an intermediate-moisture food (IMF) that is defined as a shelf-stable food that contains between 15-50% moisture and a water activity between 0.60-0.85 (Jay, 2000). Table 2 shows that the a_w of mango roll is within the IMF a_w range and thus supported the obtained microbiological test result. Based on the conducted physicochemical analyses, the sample obtained the following results per 100 g sample: crude fat 3.44 g; crude protein 1.96 g; ash 1.06 g; and carbohydrate 63.37 g.

The mango roll sample was observed and evaluated through quality scoring. Initially, the attributes evaluated were sweetness, color, and overall score (acceptability as anchor descriptions) but these were changed to a more appropriate attribute: overall flavor, color, and overall acceptability score (poor – excellent). Every session, the sample was evaluated until there is a significant

Table 1. Microbiological test result for mango roll during shelf-life study.

Sample	Storage Temperature (°C)	Storage Time (Days)	Microbiological Test			
			[a]APC (CFU/g)	[b]TC/*E.coli* (MPN/g)	[c]*S.aureus* (CFU/g)	[d]MYC (CFU/g)
Mango roll		0	<10	<3.0	0	<10
	30°C	31	<10	-	-	<10
		62	<10	-	-	<10
		99	<10	-	-	<10
		108	<10	-	-	<10
		155	<10	-	-	<10
		202	<10	-	-	<10
		233	<10	-	-	<10
		255	<10	-	-	<10
	35°C	27	<10	-	-	<10
		78	<10	-	-	<10
		108	<10	-	-	<10
		155	<10	-	-	<10
		181	<10	-	-	<10
		218	<10	-	-	<10
		244	<10	-	-	<10
	45°C	34	<10	-	-	<10
		69	<10	-	-	<10

[a]Plates with no colonies or microbial growth, report as < 10 CFU/g or mL; Plates with counts of less than 25 colonies, report as < 250 CFU/g or mL

[b]MPN values per g or mL of sample and 95% confidence intervals; if 3 tubes are negative, report as <3.0 MPN/g or mL.

[c]Not detected in an amount of sample

[d]Plates with counts of less than 10 colonies, report as < 10 CFU/g or mL.

- No analysis

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Table 2. Moisture content and water activity (a_w) of mango roll stored at ambient and accelerated temperatures.

Sample	Storage Temperature (°C)	Storage Time (Days)	Moisture Content (%)	Water Activity (a_w)
Mango roll		0	7.36	0.617
	30°C	31	9.03	0.615
		62	12.17	0.623
		93	13.91	0.601
		126	17.12	0.547
		155	17.49	0.548
		202	17.49	0.535
		233	17.47	0.548
		255	17.49	0.549
	35°C	128	16.84	0.52
		155	-	0.523
		181	-	0.523
		218	-	0.521
		244	-	0.523
	45°C	69	-	0.514

difference ($p<0.01$) between the sample and the control in terms of overall acceptability score.

It was observed that the color of the sample is sometimes significantly different with control (sample stored at 4°C) on one session but not on the following session. It can be attributed to the innate difference in the appearance of the product due to many factors such as raw material characteristics (differences in color of raw mango). The color of the product is one of its important sensory attributes since it contributes to the deciding factor if the product is fit for consumption (Domingo and Austria, 2017)

The sensory score for color of the mango roll (Figure 1a) was observed to decrease over time in the two temperature settings (30°C and 45°C). The score range was zero (0) to ten (10), with zero correspondings to brownish-yellow while ten means bright yellow. The samples stored at 45°C have a higher rate of change in color as compared to the samples stored at 30°C and 35° C. The storage temperature affected the color of the product. One study found that the storage temperature of higher than 35°C increases the degradation of the carotenoids and color of the mango juice (Tantratian *et al*., 2018). The color scores fluctuate through time and can be attributed to the innate color of the product.

The overall flavor scores (0=none, 10=intense) of the sample (Figure 1b), also have a similar pattern as the color scores. The flavor scores of the samples stored at 45°C declined faster than the sample stored at 30°C and 35°C. The trained panels noted that the flavor changed to extremely sour profile similar to that of the tamarind as the effect of prolonged storage at high temperature. Higher storage temperature setting accelerated the rate of deterioration which resulted in changes in sensory profile (Mkandawire *et al*., 2016). The rate of decline of scores are faster on the samples stored at 45°C, followed by those at 35°C, and lastly those stored at 30°C.

For the overall acceptability score (Figure 1c), there is also a more rapid decrease of the score (0=poor, 10=excellent) at 45°C through time, followed by 35°C and 30°C. Also, similar patterns for the samples stored at room temperature and 35°C were observed. This is expected as both the color and the flavor scores of the sample directly affected the overall score of the product.

The first to have a significant difference with the control at Day 51 was the sample stored at 45°C. The samples were then subjected to acceptability test on Day 69 and results revealed that 73% of the trained consumer panels rejected the sample for consumption. Thus, the shelf-life testing for the sample at 45°C ended at Day 69. For the samples stored at 35°C and 30°C, the testing ended at Day 244 and Day 255, respectively.

The estimated shelf-life of mango roll at 30°C using the linear regression equation of the shelf-life plot (Figure 2) was 462 days (15 months) compared with the actual end of shelf-life which was 255 days (9 months). This result supported the sensory evaluation results mentioned above regarding the fluctuation of color scores through time and can be attributed to the innate color of the product, and other contributing intrinsic factors (such as differences in flavor of raw mango and preference of sensory panelists) that made the sensory panelists reject the samples at an earlier time.

The determined Q_{10} value of the deteriorative reaction using regressed values from shelf-life plot was 3.56 (discoloration).

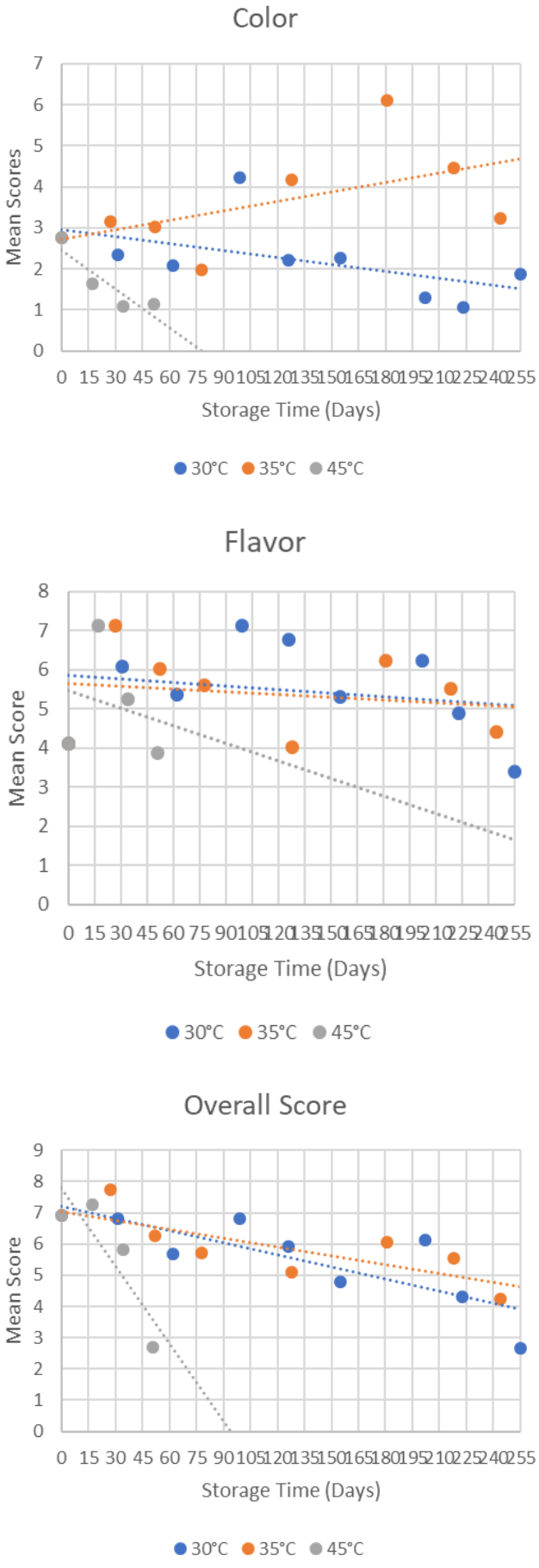

Figure 1. a) Color, b) flavor and c) overall acceptability mean scores of mango roll in different storage temperatures through time.

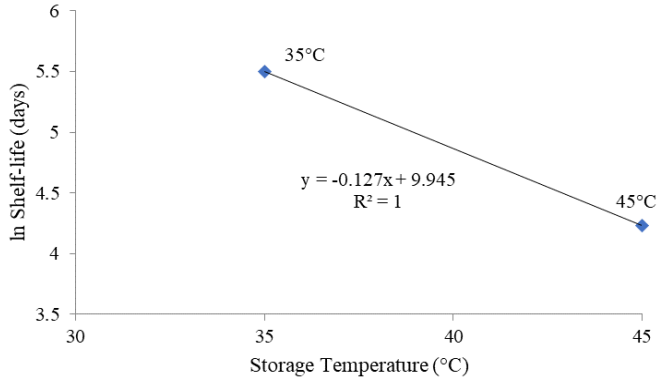

Figure 2. Shelf-life plot of Mango roll packed in 30 g aluminum foil with PE liner.

4. Conclusion

In this study, both actual and accelerated shelf-life test methods were used in the shelf-life evaluation of mango roll. The parameters used were physicochemical (moisture content and a_w), microbiological (aerobic plate count, mold and yeast count, total coliform/*E.coli* and *Staphylococcus aureus*), and sensory evaluation (quality scoring, acceptability test). The target shelf-life for Indian mango roll was one hundred eighty (180) days but based on the obtained physicochemical, microbiological, and organoleptic results, the determined shelf-life of mango roll packed in stand up aluminum foil with PE liner was 69 days, 244 days, and 255 days at 45°C, 35°C, and 30°C, respectively. Accelerated shelf-life testing is of great help to hasten the shelf-life determination of a certain product. But always be cautious with the intrinsic and extrinsic factors that influence the shelf-life of a product. Thus, a verification test should be done to compare the estimated shelf-life with the actual results of the study. Shelf-life testing of mango roll definitely provides important information to ensure that this food product is definitely safe and of high quality in terms of organoleptic properties.

Conflict of Interest

All authors declare that there is no conflict of interest regarding the publication of this paper.

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