Biological Forum – An International Journal **(SI-AAEBSSD-2021) 13(3b): 129-133(2021)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Shelf Life Prediction of Canned Palmyra Palm Tender Fruit Endosperm using Accelerated Shelf Life Testing - Arrhenius Method

S.K. Mathanghi[1]*, S. Kanchana[2] and V. Perasiriyan[3]
[1]Assistant Professor, Department of Food Processing Technology, College of Food and Dairy Technology, Tamil Nadu Veterinary and Animal Sciences University, Chennai, India.
[2]Professor & Head, Department of Human Development and Family Studies, Community Science College and Research Institute, Tamil Nadu Agricultural University, Madurai, India.
[3] Professor & Head, Department of Food Business management, College of Food and Dairy Technology, Tamil Nadu Veterinary and Animal Sciences University, Chennai, India.

(Corresponding author: S.K. Mathanghi)*
(Received 01 July 2021, Accepted 29 September, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: This experiment is aimed at prediction of shelf life of canned Palmyra palm Tender Fruit Endosperm (PTFE) which is an essential step in launch of a new product to the consumer market. To determine the suitability of canned PTFE to support long-term storage during off seasons, accelerated shelf life studies were performed on representative samples kept in three different simulated temperatures 35ºC, 45ºC and 55ºC. The change in physical properties assessments were employed to establish shelf life endpoints for canned PTFE. Development of off-colour and presence of haze was observed through change in OD value of syrup and taste change was observed through TSS and pH values in accelerated conditions. The canned PTFE had F value of 10.19 minutes to reach the commercial sterility. The canning technology is an adaptable one where there is no usage of any chemical preservative and in a convenient package form; additionally the use of sterilization temperature and pressure combination extends the shelf life by reducing the microbial contamination. Arrhenius model used via mathematical projection predicted the shelf life as 9.3 months for canned PTFE.

Keywords: ASLT, Palmyra palm, Arrhenius method, Borassus flabellifer, shelf life.

INTRODUCTION

Shelf-life determination is most important one and it may vary from the lab or cottage scale condition to actual market environment. Prediction of shelf life is an essential criteria with which a product will remain satisfactorily safe to consume when stored under expected or directed condition. This accelerated study provides a rapid mean of quality control that can ensure zero detrimental changes to occur in uncertain storage conditions of food through distribution and in market.

All foods as a biological material follow a pattern of deterioration and it was influenced by the kinetics of the chemical reaction. To predict the shelf life of the long stored food products accelerated shelf life studies are preferred (Jafari *et al*., 2017).

Canned foods are a plausible option as a convenient food. Especially when the food product is seasonally oriented it can be heat processed and canned during glut season and stored for lean period or during scarcity (Drury *et al*. 2018.). With this perspective Palmyra palm tender Fruit Endosperms (PTFE) were processed in cans and shelf life was extended using thermal processing techniques. Palmyra palm Tender Fruit Endosperms called Nungu in Tamil and Taal in Hindi are thirst quenchers and replenishes the energy during hot summers in tropical, coastal and semi arid regions of India. But it is highly perishable because of its moisture content (above 86 %). Sterilization is the primary process in canning where filled cans are heat processed at higher temperatures to reach *bot-cook* values and ensure the product safety. As per the FSSAI guidelines, shelf-life of the product regarding safety, quality and nutrient of food has to be assessed for any product and to be mentioned mandatorily in the food package.

To ascertain the shelf life of the processed product in uncertain environmental conditions of the market, canned PTFE (Palmyra palm tender Fruit Endosperms) were subjected to accelerated temperatures and shelf-life was predicted using Arrhenius equation. Accelerated studies can quantify effect of temperature impact on the targeted parameter of the canned PTFE without the need for information on the actual temperature history of the product. This experiment establishes the schedule of distribution from the ware house to super market by calculating the end life of the product. Also defect in distribution systems and the damage of the processed product can be easily identifies and resolved to prevent the wastage. Many products stored at ambient conditions show longer shelf-life, making their experimental determination difficult. However, the existence of accelerated shelf-life tests represents an alternative, consisting of storage of product in an accelerated environment so as to hasten the rates of transformation (Breda *et al*., 2012). The main objective of the present experiment was to deem Arrhenius equation and parameter Q_{10} for estimating the shelf life of canned PTFE on three commercial quality indices such as OD value and Total Soluble Solids (TSS) of sugar syrup and pH value of PTFE. Also the capability of Arrhenius kinetic equation were tested for real long term storage conditions using accelerated storage data.

MATERIALS AND METHODS

Canning of PTFE. Three pieces round Open top sanitary (OTS) cans with EOE lids (from Metcan Pack Ltd, Mysuru) of 200 ml capacity chrome coated juice cans (211 × 300 can size) with 206 dia and 3.25" Ht were used for canning the PTFE. Pre-sterilized cans were filled with PTFEs and sugar syrup at 2:3 ratios (Mathanghi *et al*., 2020). Sealed using a double seamer and put that in retort for heat sterilization. Then the cans were heat sterilized at 121.1ºC at 15 psi since the PTFE processed comes under low acid fruit with a pH of 5.2.

Lethality value. Heat sufficiency in the sterilization process of canned PTFE in the temperature 121.1°C with 15 psi were recorded to find the lethality value to get rid of anaerobic organisms. The lethality value was observed using the data obtained from digital output from the retort autoclave machine based on improved general method. Sterility was expressed as an F_0-value were determined using general method or trapezoidal integration method given in (Holdsworth *and* Simpson, 2016), as in

$$F_0 = \int 10^{(T-Tref)/Z}.\mathrm{dt}$$

where, F_0 is the heat required for the commercial sterilization process, which is expressed as the equivalent heating time (in minutes) at a constant temperature of 121.1°C. *T* is the temperature at any given time; *T* ref is a reference processing temperature (121.1°C or 250°F), and z-value is 10°C.

Total plate count. Total plate count was enumerated using Plate Count Agar medium. 10 gram of the sample were mixed homogeneously and serially diluted using sterile water at 10^{-5} for fresh PTFE sample 10^{-3} for canned PTFE and 0.1 mL of appropriate dilutions were poured into plates in duplicates and further incubated aerobically at 30ºC for 48–72 h. Finally colonies were enumerated using colony counter. Commercial sterility tests were also performed to ensure the product safety by incubating the retort pouches at 35°C for 10 days and at 55°C for a minimum of 5 days.

Physicochemical indices of canned PTFE

Total Soluble Solids (TSS). It is based on the sugar concentration present in the samples and it was recorded as degree Brix using hand held refractometer (ERMA) at 20˚C (AOAC, 2019) taken in three replications with a measurement interval between 0% and 95 % and an accuracy of 0.1 % (Valverde-Miranda *et al*., 2021). The sugars and acids, together with small amounts of dissolved vitamins, fructans, proteins, pigments, phenolics, and minerals, are commonly referred to as soluble solids (Magwaza & Opara, 2015).

OD value of the sugar syrup. The OD value of the sugar syrup was directly related to the haze formation in the syrup which in an indication of spoilage, and it was obtained by filtering the syrup using muslin cloth (Supapvanich *et al*, 2011) and the absorbance of the solution were measured at 420 nm using a spectrophotometer (Shimadzu UV-mini 1240, North America)

pH of the canned PTFE. The pH of canned PTFE was measured by placing the electrode of a digital pH meter (Analog model 20 of Susima MP-1PLUS) inside the samples (Nundy, 2003). All the measurements were taken in triplicates.

Accelerated shelf life testing of canned PTFE

Temperature and time prediction of storage is the systematic kinetic modeling of shelf life dependence on the temperature of the food products that are calculated for the quality loss based on the response of temperature acceleration (Khasanov & Matveeva, 2020). Monitored temperature exposure along time for a processed product was experimented based on simulated conditions from the production at manufacturer, distribution, to the display shelf at the retail outlet and till it reaches the hands of consumers. To study the physico-chemical parameters of the canned PTFE, sample cans were kept in three different accelerated temperatures at 35, 45 and 55˚C. The tests were performed at every 10 days for 35˚C, at every 7 days at 45˚C and every 3 days at 55˚C(Jafari *et al*., 2017). Kinetic calculations Temperature dependence of different physicochemical reactions was simulated by Arrhenius equation:

$$Lnk = \ln k_0 - \frac{E_a}{RT}$$

where E_a, R, T, k and k_0 are activation energy of each reaction ($J.mol^{-1}$), universal gas constant (8.3145 $J.mol^{-1}.K^{-1}$), absolute temperature (K), rate constant of the reaction (day^{-1}), and pre-exponential factor (day^{-1}), respectively.

$$\frac{dQ}{dt} = k.Q^n$$

where, Q is the factor quality, t is the time, k is the rate constant depends on the temperature, n is the degree factor or order of the reaction. $\frac{dQ}{dt}$ is the change of Q factor per time unit.

$$t = \frac{(A_e - A_0)}{k}$$

$$t = \frac{ln\frac{A_e}{A_0}}{k}$$

t is the shelf life, A_e is the limitvalue, A_0 is the initial day value.

Accelerated Shelf Life Testing (ASLT) method with Arrhenius model were used in ascertaining the shelf life of canned PTFE based on physicochemical parameters. The storage of samples in extreme accelerated temperatures causes damage on food products at faster than thereal time. The shelf life was determined at 30ºC based on extrapolation of TSS and OD value of sugar syrup and pH of PTFE.

RESULTS AND DISCUSSION

Canning is a process of sterilization of food in hermetically sealed containers designed to kill the anaerobic microbes especially *Clostridium botulinum.* Canned PTFE were processed at the level of *Bot-cook* to ensure the safety from spore forming anaerobes. Sterilization degree is commonly represented as F value which means time in minutes at 121.1°C required to kill microbes and it depends on process temperature and Z value. The 12 D concept of 1 log reduction of microbes were followed according to the requirements of USFDA for canned food. In this experiment canned PTFE had F value of 10.19 minutes (Fig. 1). It means that the heating process of canned PTFE starts from early to the end is equal to constant temperature heating of 121.1°C for 10.19 minutes. Dewi *et al*., 2019, studied the Effect of Waiting Time and Process Temperature on the Quality of Commercially

Sterilized Flavored Liquid Milk and their findings showed that the use of processing temperature of 121.9˚C (F_0-value of 11.00-13.54 minutes) is consider to be the best alternative to produce commercially sterilized flavored liquid milk having waiting time up to 6 hours. F_0 value was measured by insertion of thermocouple needle into the coldest part of the can and heat transfer for solid materials is by conduction of heat and placed on the geometric spot of the can using D value as 10 and Z-value as 10.

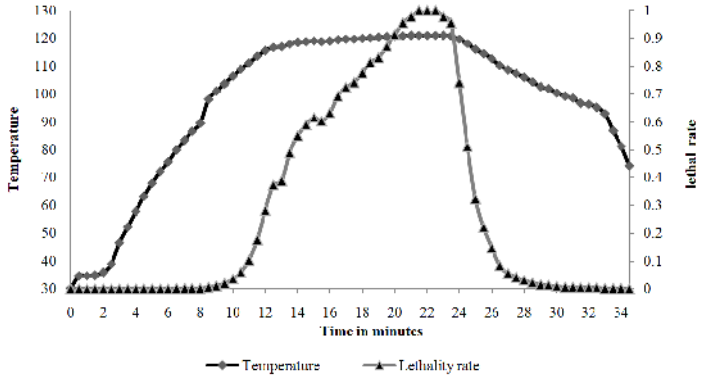

Fig. 1. Heat sufficiency in the sterilization process of canned palmyra palm tender fruit endosperm at 121.1°C for 15 minutes.

Microbial analysis of PTFE before and after sterilization of cans was performed and the results are produced in Table 1. There was a decrease in the TPC counts after heat sterilization. Microbes are responsible for chemical change in the canned food resulted in spoilage of foods and makes the safety at a bay even in minimal numbers. To ensure the safety of the canned PTFE, commercial sterility was also performed resulted negative for *Clostridium spp.* as mandated by FSSAI, India. The number of microbe counted by Standard Plate Count Procedure of TPC in the range of $1 \times 10^3 - 1 \times 10^5$CFU/ml is still classified as safe and acceptable for consumption based on the standard of FSSAI.

Table 1: Microbial analysis of fresh and canned Palmyra palm Tender Fruit Endosperm.

Sample	Microorganism total (CFU/g)
Fresh PTFE	$3.8 \pm 1.18 \times 10^5$
Canned PTFE	$1.8 \pm 0.85 \times 10^1$

The shelf-life of a food product is determined by establishing a quality index. For this purpose, the main quality parameter should be considered and also the degree of deterioration necessary to establish the end of the shelf-life (Sanjuán *et al*., 2004). The temperature range selected for the experiment is based on the tropical weather prevalent in south- Indian, tropical conditions and the limits were set for each parameter. The initial and corresponding values for 100 days of storage are given in Table 2. The TSS limit were ascertained as 40ºBx for low acid foods OD value limit taken as 0.4 and pH limit for PTFE was 4.5, beyond which it is considered acidic fruit and it becomes sour. The quality and shelf-life of the product is affected by extrinsic factors such as processing, packaging properties, temperature and relative humidity (RH) of the environmental air as well as intrinsic factors of the food such as acidity, available oxygen, additives, level of microbial contamination, redox potential and water activity (Escobedo-Avellaneda *et al*., 2012).

Table 2: Change in physicochemical parameters of canned PTFE during accelerated storage at temperature of 35, 45 and 55°C.

Time in days	Change in TSS (˚Bx)			Change in pH			Change in OD value		
	55˚C	45˚C	35˚C	55˚C	45˚C	35˚C	55˚C	45˚C	35˚C
0	46	46.5	46	5.7	5.78	5.68	0.05	0.05	0.06
10	45	45.5	45.7	5.52	5.63	5.5	0.061	0.064	0.0614
20	44.8	45.3	45.2	5.18	5.32	5.32	0.072	0.084	0.07
30	44.5	45	45	5.17	5.3	5.3	0.083	0.092	0.0758
40	44.3	44.8	44.8	5.05	5.2	5.2	0.098	0.116	0.088
50	44	44.5	44.5	5.01	5.19	5.2	0.126	0.138	0.0945
60	43.7	43.8	44.2	4.97	5.17	5.17	0.142	0.187	0.095
70	43.1	43.5	43.8	4.95	5.1	5.1	0.194	0.196	0.101
80	42.5	43	43.5	4.82	4.9	4.9	0.203	0.201	0.126
90	41.3	42.8	43.5	4.45	4.85	4.85	0.256	0.225	0.19
100	40.8	42	43.1	4.5	4.8	4.8	0.391	0.237	0.21

The selection of order of reaction was based on comparing the determination co-efficient in each of linear equation at the same temperature of zero order with first order kinetics. The reactions order with highest co-efficient of determination was selected for rate constant and shelf life was estimated. The kinetics of quality parameter change in TSS and pH over the accelerated storage conditions followed first order reaction whereas the change in OD value of sugar syrup follows zero order kinetics given in Table 3.

It was also observed the change in colour denoted by OD value was changed minimum and bearable compared to other parameters. Similar results was observed by Khasanov & Matveeva, (2020) in shelf life determination of functional beverages from carrots, grapes, blueberries and plant extracts of *Centella asiatica* and *Hoodiagordonii*. The Arrhenius equation determination was done by plotting Ln(k) versus 1/T for change in TSS, pH of PTFE and OD value of sugar syrup (Table 4).

From the linear equation of Arrhenius plot (Fig. 2) the extrapolation of normal storage temperature at 30ºC were estimated for each parameter (Giannakourou & Taoukis, 2020).

Table 3: ASLT relation of storage time and physicochemical parameters for canned PTFE at 0^{th} order and 1^{st} order reactions.

ASLT parameters	Temperature	R^2 value		k	Shelf-life at ASLT	
		0^{th} order reaction	1^{st} order reaction	Rate constant	Days	Months
TSS of syrup	35 ºC	0.9897	**0.9904**	0.0006	232.9	7.76
	45 ºC	0.9758	**0.9780**	0.0009	167.3	5.57
	55 ºC	0.9340	**0.9359**	0.0011	127.05	4.23
pH of PTFE	35 ºC	0.9466	**0.9501**	0.0015	155.3	5.1
	45 ºC	0.9226	**0.9315**	0.0017	140.1	4.6
	55 ºC	0.9143	**0.9150**	0.0021	112.6	3.75
OD value of syrup	35 ºC	**0.9378**	0.9121	0.008	425	14.16
	45 ºC	**0.9778**	0.9534	0.002	175	5.8
	55 ºC	**0.9858**	0.849	0.0029	120.7	4.02

Table 4: Kinetics rate of canned PTFE in ASLT storage temperatures 35, 45 and 55°C.

Temperature in Kelvin	Rate constant for TSS (1^{st} order)	1/T	Ln(k)
308.15	0.0006	0.003245	-7.418580903
318.15	0.0009	0.003143	-7.013115795
328.15	0.0011	0.003047	-6.812445099
	Rate constant for pH value (1^{st} order)		
308.15	0.0015	0.00325	-6.5023
318.15	0.0017	0.00314	-6.3771
328.15	0.0021	0.00305	-6.1658
	Rate constant for OD Value (0^{th} order)		
308.15	0.0008	0.003245	-7.1309
318.15	0.002	0.003143	-6.21461
328.15	0.0029	0.003047	-5.84304

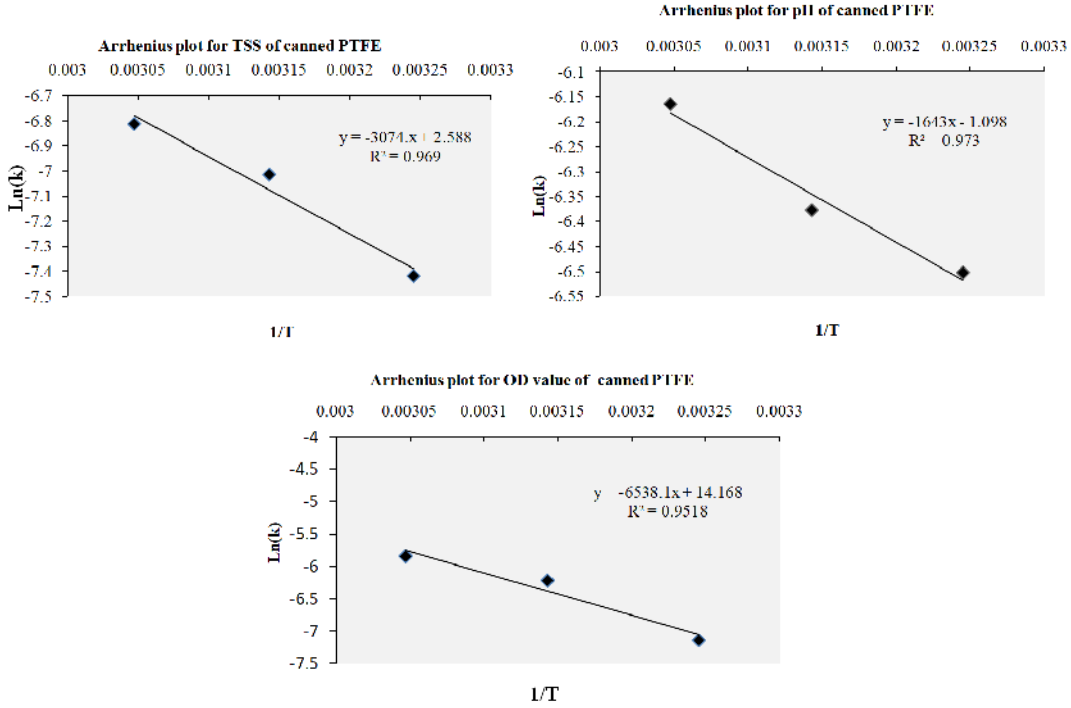

Fig. 2. Arrhenius plot of physicochemical indices of canned PTFE during storage.

Linear equation for TSS was y = -3074.4x + 2.5885; for extrapolation, the storage temperature in ambient condition say 30°C (303.15 K) was calculated. Resulted: Ln K = - 10.1415 (1/T) + 2.5885; K(303.15) = 0.0005. TSS critical point (A_e) was taken as 40 ºBX beyond which fermentation occurred and the initial TSS value used was 46ºBX.

$$\text{Shelf life} = \frac{ln\frac{A_e}{A_0}}{k}$$

Predicted shelf-life of canned PTFE is 279.52 days or 9.3 months

Using Arrhenius equation, k the reaction rate for TSS was 0.0005, for pH it was 0.00148 and for OD value of the syrup it was 0.00061. The resulted shelf-life based on Arrhenius plot was 9.3 months based on TSS value, 5.3 months based on pH value and 19 months based on OD value of the syrup at 30ºC. Out of these values TSS play significant role in managing the value chain with potential longer shelf life also taken as a critical parameter for quality control through non-destructive measurement method and could be possibly considered as an indicator to prevent food waste (Valverde-Miranda *et al*., 2021). If TSS goes below 40ºBx (October *et al*., 2018), it leads to spoilage of canned PTFE. So that parameter can be considered for shelf life as 9.3 months.

CONCLUSION

Prediction of shelf life of canned PTFE determined using Arrhenius model based on physicochemical parameters was 9.3 months which is considered a good time period for storage. Lethality time for canned PTFE was 10.19 minutes to reach the commercial sterility was ascertained. Canned PTFE will definitely implement a value addition strategy among the palmyra palm growers and industry populace also it can attract the consumers who are concerned about health and safety by promotion of canned PTFE without any addition of chemical preservatives.

Acknowledgement. The author wishes to give acknowledgement to Dr. N. Karpoora Sundara Pandian, Assistant Professor, Food Plant Operations, College of Food and Dairy Technology for providing the facility at right time for the smooth conduct of this experiment.

Conflict of Interest. None.

REFERENCES

AOAC (2019). *Official Methods of Analysis of AOAC International, Three-Volume Set, 21st Edition*. 21st edition. Rockville, Maryland: AOAC International.

Breda, C. A., Sanjinez-Argandoña, E. J., and Correia, C. de A. C. (2012). Shelf life of powdered Campomanesia adamantium pulp in controlled environments. *Food Chemistry*, *135*(4), 2960-2964. https://doi.org/10.1016/j.foodchem.2012.07.029

Dewi.N F, Purnomo. E.H and Hariyadi. P. (2019). Effect of Waiting Time and Process Temperature on the Quality of Commercially Sterilized Flavored Liquid Milk. *Jurnal Mutu Pangan*, *6*(1): 17-23. https://doi.org/10.29244/jmpi.2019.6.17

Drury, R. H., Brown, L. B., Williams, P., Eggett, D., and Richards, R. (2018). College Students' Understandings of, Perceptions Towards, and Usage of Canned Foods Based on Exposure to Canned Foods During Childhood.*Undergraduate Honors Theses*. 28.https://scholarsarchive.byu.edu/studentpub_uht/28

Escobedo-Avellaneda, Z., Velazquez, G., Torres, J. A., and Welti-Chanes, J. (2012). Inclusion of the variability of model parameters on shelf-life estimations for low and intermediate moisture vegetables. *LWT*, *47*(2): 364–370. https://doi.org/10.1016/j.lwt.2012.01.032

Giannakourou, M., and Taoukis, P. (2020). Holistic Approach to the Uncertainty in Shelf Life Prediction of Frozen Foods at Dynamic Cold Chain Conditions. *Foods*, *9*(6): 714. https://doi.org/10.3390/foods9060714

Holdsworth, S. D. and Simpson, R.(2016). Heat Penetration in Packaged Foods: In *Thermal Processing of Packaged Foods* , 161–195 Springer International Publishing.3rdEdn.https://doi.org/10.1007/978-3-319-24904-9

Jafari, S. M., Ganje, M., Dehnad, D., Ghanbari, V., and Hajitabar, J. (2017). Arrhenius equation modeling for the shelf life prediction of tomato paste containing a natural preservative. *Journal of the Science of Food and Agriculture*, *97*(15): 5216–5222. https://doi.org/10.1002/jsfa.8404

Khasanov, A., & Matveeva, N. (2020). Determination of the shelf life of a functional beverage by accelerated testing. *E3S Web of Conferences*, *164:* 01003. https://doi.org/10.1051/e3sconf/202016401003

Magwaza, L. S., and Opara, U. L. (2015). Analytical methods for determination of sugars and sweetness of horticultural products—A review. *Scientia Horticulturae*, (*184):* 179–192. https://doi.org/10.1016/j.scienta.2015.01.001

Mathanghi, S. K., Kanchana, S., Perasiriyan, V., Hemalatha, G., Vanniarajan, C., Kumutha, K., and Karthiayani, A. (2020). Relationship between Linear Combination of Variables in Retort Processing of Palmyra Palm Tender Fruit Endosperm (Borassus flabellifer). *International Journal of Current Microbiology and Applied Sciences*, *9*(12): 1099–1105. https://doi.org/10.20546/ijcmas.2020.912.132

Nundy D.C, 2003. Compendium of Analytical Methods, Volume 2. Determination of the pH of foods including foods in hermetically sealed containers. MFHPB-03. Health Canada, Food Section, Ottawa Laboratory (Carling), Canadian Food Inspection Agency. http://www.hc-sc.gc.ca/fn-an/resrech/analy-meth/microbio/volume2/mfhpb03-01-eng.php

October, F., Caleb, O. J., and Ndimba, B. K. (2018). Characterization of thirty-five apricot cultivars: Aptitude for processing and canning. *Acta Horticulturae*, *1201:* 139–144. https://doi.org/10.17660/ActaHortic.2018.1201.19

Sanjuán, N., Bon, J., Clemente, G., and Mulet, A. (2004). Changes in the quality of dehydrated broccoli florets during storage. *Journal of Food Engineering*, *62*(1): 15–21. https://doi.org/10.1016/S0260-8774(03)00165-1

Supapvanich, S., Pimsaga, J. and Srisujan, P. (2011). Physiochemical changes in fresh-cut wax apple (*Syzygium samarangenese* Blume Merrill & L.M. Perry) during storage. *Food Chemistry 127*: 912-917.https://doi.org/10.1016/j.foodchem.2011.01.058

Valverde-Miranda, D., Díaz-Pérez, M., Gómez-Galán, M., and Callejón-Ferre, Á. J. (2021). Total soluble solids and dry matter of cucumber as indicators of shelf life. *Postharvest Biology and Technology*, *180*: 111603. https://doi.org/10.1016/j.postharvbio.2021.111603