MODELING THE SENSORY SHELF LIFE OF MANGO JUICE STORED AT UNCERTAIN CONDITION USING pH FACTOR

Tochukwu V. **Balogu***[1,2], Theophilus M. **Ikegwu**[1], Fatimah **Jubrin**[1], Chidinma **Akpadolu**[2]
Kenechi **Akpadolu**[2]
[1]Department of Microbiology, Ibrahim Badamasi Babangida University, Lapai, Nigeria
[2]Department of Food Science and Technology, Ibrahim Badamasi Babangida University, Lapai, Nigeria
*E-mail:tovin2009@yahoo.com

Abstract
Sensory shelf-life of mango juice stored at uncertain condition were modelled using responses of pH factor. Fresh mango juice without additives from healthy ripe mangoes fruits initially pre-heated (80^0 - 90^0C) for 10minutes for easy extraction of juice. Uncertainty factor of this study was premised on uncontrolled natural and artificial interfaces of four temperature dependent storage conditions: freezer (≤4°C), refrigerator (≤ 20°C), room temperature (25-27°C) and incubator (37°C). Sensory quality assessment by 100 panellists indicated a significant ($P<0.05$) compromise after 2nd day (≥48 hr), at declining order of taste, consistency, aroma and colour. Perhaps, the temperature of room and incubator conditions, encouraged microbial kinetics that consequentially altered the sensory qualities significantly ($P<0.05$), unlike freezer and refrigerator. Sensory models were generated from the hypothesis H_1: $E(Y|X=x) = \beta_0 + \beta_1x_1 + \beta_2x_2 + \beta_3x_3 + \beta_4x_4$, and resolved with fitted linear model hypothesis H_0: $E(Y|X=x) = \mu$; H_1: $E(Y|X=x) = \alpha + \beta$ ($r^2 = 1$). Predictable shelf-life ($P<0.05$) limit of pasteurized mango juice in freezer was approximately 50days, refrigerator (~45 days), room temperature (~25days) and incubator (~18 days). Remarkable similarities of sensory and pH trends, supported with resolved linear coefficient of $r^2 = 1$, basically portends pH as an ideal physiochemical factor that can predict the sensory quality of pasteurized mango juice beyond 95% precision. Conclusively, this study successfully demonstrated the possibility of modelling the sensory shelf-life of pasteurized mango juices dependent on pH factor only. Further merit of this model is the flexibility to accommodate uncertainty factors.

Keywords: Mango juice, shelf life, model, uncertainty, pH

Submitted: 30.11.2016 Reviewed: 16.03.2017 Accepted: 20.03.2017

1. INTRODUCTION

Mango (Mangifera indica) juice, like other fruits juices are nutritional beverage extracts of fruits in their natural concentrations or in processed forms. Most fruit juices contain sufficient nutrients that could support microbial growth. Several factors encourage, prevent or limit the microbial or sensory deterioration in juices; prominent among them are pH, handling, storage, temperature and preservatives. Mango fruits have been associated with major disease outbreak (Sivapalasingam *et al*., 2003) and this fact necessitates the need for instant wholesomeness evaluation of juices, which is the primary aim of this study. Although, home-made mango juice are preserved by pasteurization, yet are prone to spoilage by heat-resistant micro-organisms (Tribst *et al*., 2009), and more predisposed to rapid sensory deterioration that compromises the shelf-life.

Shelf life of products are determined by dates and are the responsibilities of manufacturer and regulatory agencies. These are dependent on thresholds of either microbiological safety, physical condition or organoleptic qualities (Franke, 2005). Many factors that influence shelf-life, could be categorized into intrinsic (water activity, pH, acidity, available O_2, preservatives, biochemical and microbial compositions) and extrinsic factors (Time–temperature, pressure, relative humidity, ultrasonic lights, packaging material, and handling procedures. (Charles-Rodríguez et al., 2007; Ceylan et al., 2004). Shelf-life of most home-made products unlike industrial products, are not standardised and are predisposed to uncertainty factors.

The essence of every predictive model is to predict future responses at any particular period. Existing predictive models are drawn mostly from laboratory-simulated assays that often fail due to weak precision. Recently, challenge test based models are becoming popular in food predictive shelf-life models (Balogu et al. 2014; Guerrero-Beltran et al., 2011). In predictive microbiology, sources of uncertainty and variability include: unknown exact initial microbial load or its composition, temperature and product composition, usually differs within the same product, between products and between subsequent batches. Others are scare monitoring parameters, or inability to neither measure them nor even simulate them in the laboratory (Balogu et al., 2014). Obviously, the preset conditions for shelf-life prediction of most mango juices(natural and processed) in developing nations are not strictly adhered to, due to the infrastructural deficiency, and consequently compromise the wholesomeness of the products even within the stated shelf-life. Thus, this study predicatively modelled the instant shelf-life of mango juice stored at uncertain conditions using pH factors.

2. MATERIALS AND METHODS

Sample Collection

A total 100kg of fresh ripped mango fruits obtained from Lapai LGA, Niger State, Nigeria,transported to Applied Microbiology Laboratory, IBB University, Lapai, in clean baskets. The mango fruits were sorted, washed and dried prior to juice extraction.

Extraction of Mango Juice

Crude extraction method was used by placing the mango fruits in water bath (80^{o}C) for 10 minutes, to soften the mango fruits for easy extraction of juices, and hygienically peeled the skin. Juices purees (syrup) extracted by pressing the skinless fruits to separate the seeds were diluted (20%) with distilled water (4:1 ratio), homogenized with electric blender for 10 – 15 minutes, sieved with muslin bag, pasteurized (60^{o}C) for 30minutes and bottled as mango juices for further analysis. Note: Puree was diluted to reduce the viscosity, which interferes with uniformity of physiochemical properties of samples.

Experimental Protocol

Mango juices were bottled in 350ml capacity white plastic bottles containing 300ml of juice. Eighty bottled of juices were randomly grouped into four units (20 bottles each) and stored in different conditions: freezer (≤4^{0}C), Refrigerator (≤ 20^{0}C), Incubator (37^{o}C), and Room temperature (25-27^{o}C) designed as FZ, RF, IC and RT respectively. Each of the bottled juices was vigorously agitated before sampling.

Microbial Analysis

Microbial counts were assessed periodicallyevery 3 days. From each storage units, three bottled juices were selected at random and 1ml from each of the bottle was serially diluted upto the 3rd and 4th folds. From these dilutions, 0.5ml was pour plated on nutrient agar, incubated at 37^{0}C for 24 - 48hrs and visible colonies were counted and expressed as Log10 cfu/mL (Cowan and Steel 2004).

Sensory Evaluation

The sensory evaluation of the wine were evaluated by 100 panellists (trained and untrained) selected from staffs and students of IBB University Lapai community, Each of the storage units(FZ, RF, IC and RT) were tagged with 25 panellists and five among them were randomly selected (permuted to evaluate not more than twice to limit biasness) for sampling. Within the 6 days assessment, sampling was done at 12hrs intervals using 5 mL each from five bottled juices (randomly selected) from each of the storage units (FZ, RF, IC and RT). Samples were evaluated with 5-point hedonic scales and data expressed as mean of five values.

Physicochemical Analysis

Similar protocol as detailed in sensory evaluation was used in physicochemical assessment (pH and temperature) of pasteurized mango fruit juices. At each sampling, five bottled juices (randomly selected) from each of the storage units (FZ, RF, IC and RT) were agitated vigorously and probes of pH meter and thermometer were dipped into the bottle content for 2 minutes (for stable reading). Recorded data were means of five values. (AOAC 1990).

Statistical Analysis

Data generated from sensory and physiochemical parameters were subjected to ANOVA, Duncan's Multiple Range Test and Post-hoc tests using SPSS software (version 20, 2014) Primary data modelled with Analyse-It for Microsoft excel statistical software version 4.60. All data were tested at 95% confidence level.

3. RESULT AND DISCUSSION

Daily sensory profile of mango juice stored at uncertain conditions indicate compromised quality after 2nd day. Taste and consistency parameters were significantly ($P<0.05$) disliked after 3rd day, aroma (5th day) and the least was colour on 6th day. (Fig. 1a-e). Among the different stored conditions, only incubator and room temperature environments significantly ($P<0.05$) compromised the sensory quality of mango juice (rating above 3), while freezer and refrigerator chambers had no significant impact on the sensory quality at the rating below 2 (Fig. 2). Obviously, low temperatures range of freezer and refrigerator reduced the microbial growth rate.

Bacterial profile of pasteurized mango juices at DAY-0 was standardized at 2.82Log10 cfu/ml. Dynamic of bacteria across all assessed storages conditions within 6 days period were progressive, though at different rates. FZ has the lowest rate of 18.7% (3.47Log10 cfu/mL), followed by RF 26.4% (3.83Log10 cfu/mL), RT was 38.1% (4.56Log10 cfu/mL) and IC was highest at 41.8 % (4.85Log10 cfu/mL) as shown in Fig. (3). Variables of all conditions were resolved (R^2 =1) into a linear equation: $y = 0.192(X) + 3.041$. This means that bacterial dynamics of pasteurized mango juice at uncertain conditions was modelled as Equ (1):

Bacterial Load = 0.192 **DAY** + 3.041 Equ (1)

Bacterial profile analyses were not the major scope of this study; however, the peculiar impact of microbial activities on pH and sensory properties of food (Valero et al., 2012 FAO 2017) necessitated the evaluation. Based on the resolved progressive bacterial dynamic model at different storage conditions, which were temperature dependent, validate the report of Tribst *et al*., (2009), Charles-Rodríguez et al., (2007) and Ceylan et al., (2004). These studies implicated temperature as one of the cardinal parameters that compromise stability of food shelf life. Obviously, this explains why most predictive food models generated from temperate regions could not achieve high precision outputs in tropics without correction factors.

Apparently, the stable sensory quality within 24hrs and progressive deterioration afterwards, invariably portrays the theory of lag and log phase of microbial kinetics in close system. Most organoleptic changes are dependent on the function of an active role played by enzymatic activities (FAO 2017, NAS 1985). Progressive increase of pH validates the theory that most spoilage microbes proliferate in less acidic environment (ACEnet 2001, Valero et al., 2012) by alcoholising the environment (Valero et al., 2012) especially in fermentation system (FAO 2017) . Sims and Morries (1987) observed an inverse proportion between pH and acidity, such that pH increases against decrease in acidity of grape juice during storage. This phenomenon validates the progressive increase of pH values observed in this study within six days assessment.

Sensory parameters of mango juice and shelf-life irrespective of the storage conditions were strongly correlated with R^2 = 0.98 (Fig. 4), premised on the hypothesis H1: $E(Y|X=x) = \beta 0$

+ $\beta 1x^1 + \beta 2x^2 + \beta 3x^3 + \beta 4x^4$ and modelled (eq. 2) as:

Day = -3.179 + 2.014 **Colour** + 1.893 **Aroma** - 0.8996 **consistency** - 0.1902 **Taste** (eq 2)

Most literatures in the review study of Balogu et al., (2014) and this study inclusive, modelled predictive shelf life of foods over time lag using data generated from physiochemical (pH, organic acids concentrations, water activity) and microbial parameters. However, within the purview of literatures, none to scanty models was predicated on sensory and pH qualities correlations, like this study.

Comparative data analysis of sensory and pH of mango juices response to the function of days, showed a significant similarity trend (Fig. 5a) and this observation was further strengthen with fitted model regression plot of pH and sensory data to achieve $R^2 = 1$, premised on the hypothesis: H0: $E(Y|X=x) = \mu$; H1: $E(Y|X=x) = \alpha + \beta$. (Fig. 5b), and the model equation (eq.3) as:

pH = 1.514 **Sensory** + 1.789 (Eq 3)

Similarly, the response trend of sensory and pH parameters to the different storage conditions were significantly ($P<0.05$) correlated (Fig. 6a). Further analysis with regression coefficient showed $R^2 = 1$, premised on the hypothesis: H0: $E(Y|X=x) = \mu$; H1: $E(Y|X=x) = \alpha + \beta$ (Fig. 6b) and modelled (eq. 4) as:

pH = 0.332 **Sensory** + 4.935 (Eq. 4)

The remarkable similarities of sensory and pH trends, supported with resolved linear coefficient of $r^2 = 1$, basically portends pH as an ideal physiochemical factor that can predict the sensory quality of pasteurized mango juice at precision of above 95%.

The maximum limit of these models to predict the shelf life of juice are dependent on the condition of storage, as predictable limit in freezer, refrigerator, room temperature and incubator facilities are ~50days, ~45days, ~30days and ~22days respectively (Fig. 7a,b,c,d). Valero et al. (2014) reported similar effect of temperature on model of microbial shelf life of milk products. However, most conceptual models are complex with secondary models (Hoffmann et al., 2008) unlike this study that utilized primary models.

4. CONCLUSION

Contrary to previous models (Blackburn 2000; Jaiswal and Jaiswal 2014; Gram *et al*., 2002), that attempt to predict microbial shelf life, this study successfully demonstrated the possibility of modelling the predictive sensory shelf-life of pasteurized mango juice using pH parameter only. Further merit of this model is the flexibility to accommodate uncertainty of temperature dependent factors.

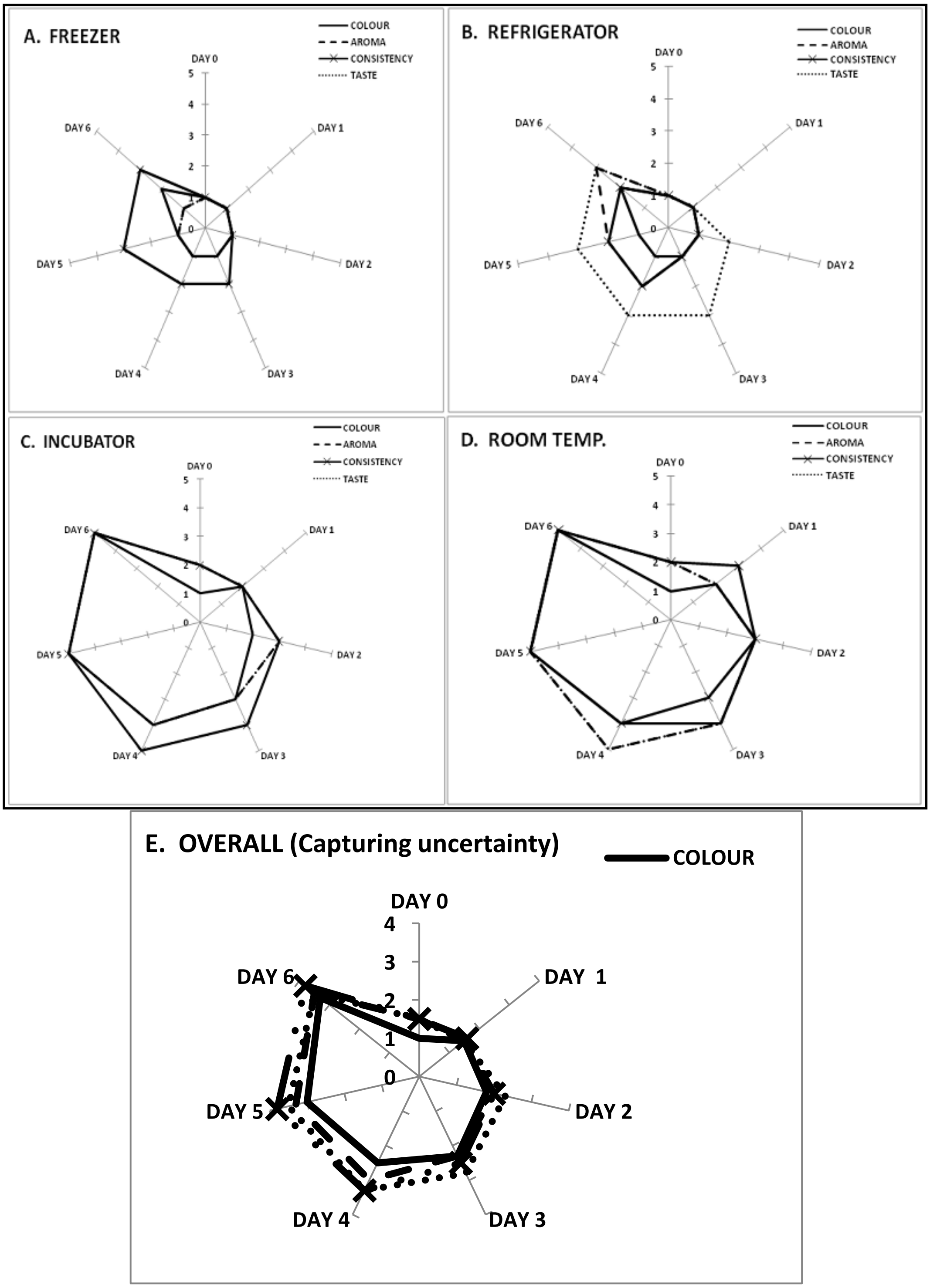

Fig. 1(a,b,c,d,e): Daily sensory profile of mango juice in uncertain storage conditions.
(NB: Alphabets A, B, C &D showed the effect of different storage conditions on sensory profile of pasteurized mango juice. Fig. 1e expressed the effect of overall conditions to reflect the uncertainty concept of this study).
Key: Sensory profile were based on 5-point Hedonic scale: [1 = very like, 2 = like, 3 = neutral, 4 = dislike, 5 = very dislike]

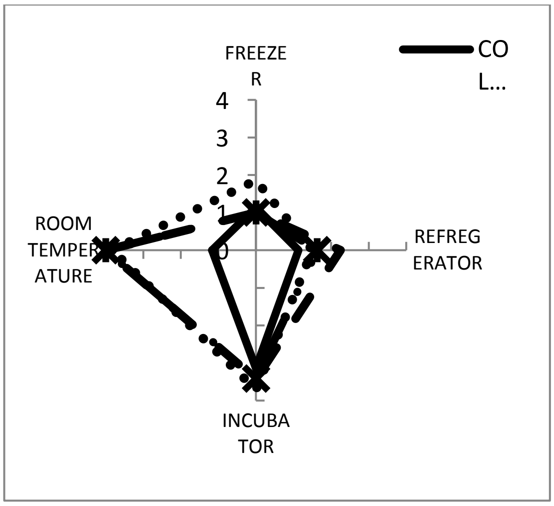

Fig 2: Effect of storage conditions on sensory profile of mango juice assessed for 6 days
Key: 5 – Hedonic scale: 1 = very like, 2 = like, 3 = neutral, 4 = dislike, 5 = very dislike.

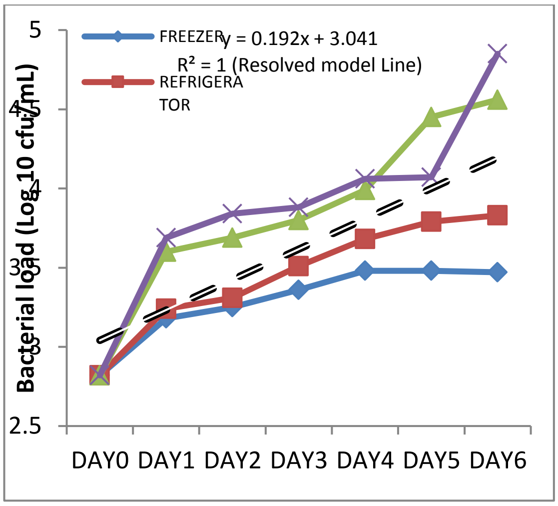

Fig. 3: Daily Bacterial profile of pasteurized mango juice in uncertain storage conditions

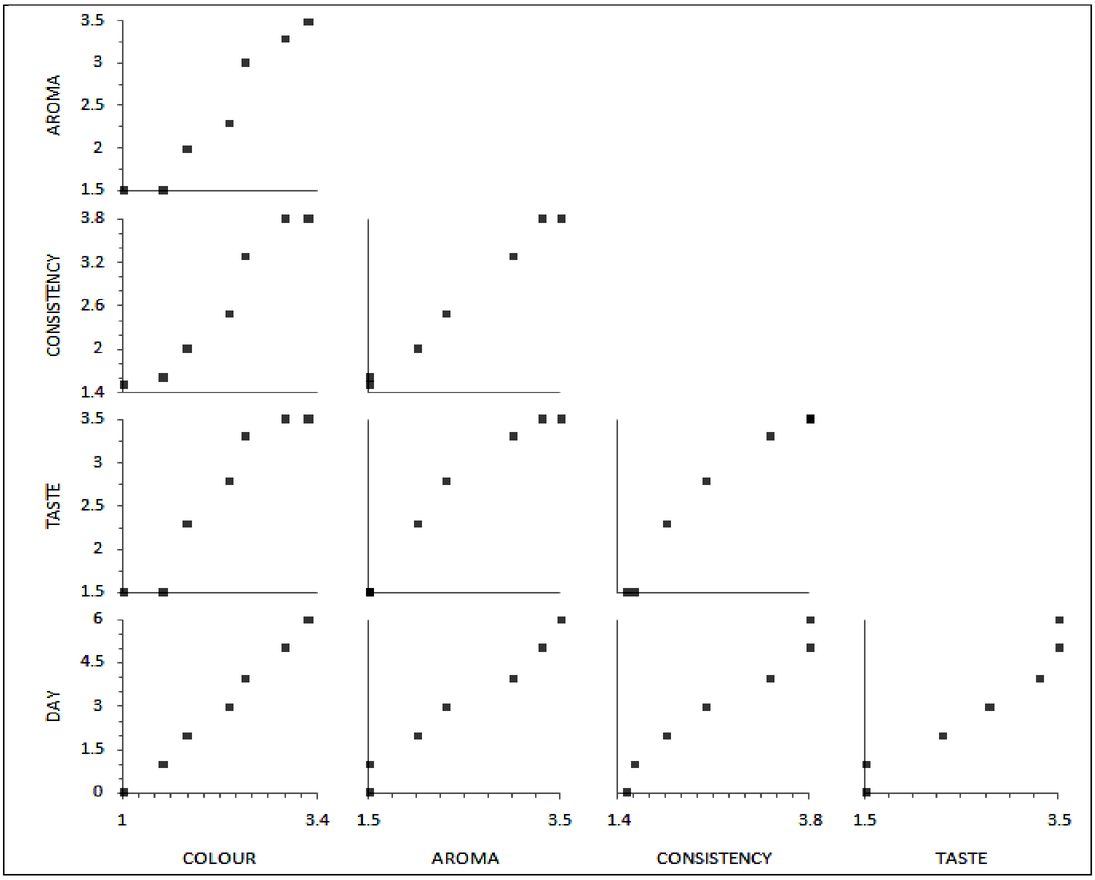

Fig. 4: Sensory parameters of mango juice qualities on daily factor.

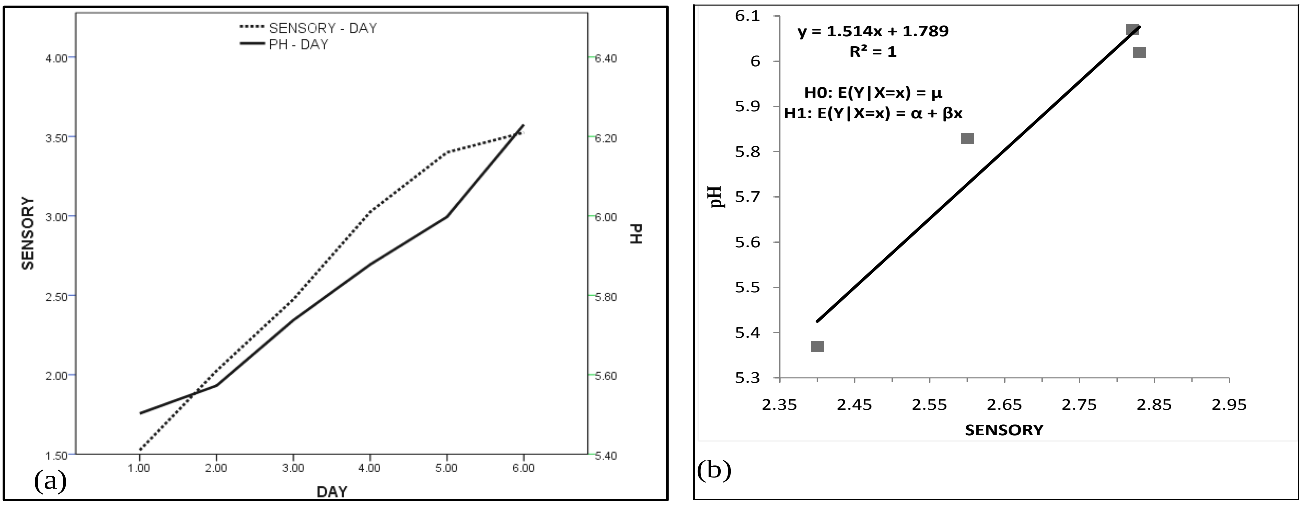

Fig.5 (a): Interpolation line responses of sensory and pH of Mango juice dependent on day
(b): Resolved model of pH and Sensory correlation based on the effect of Days

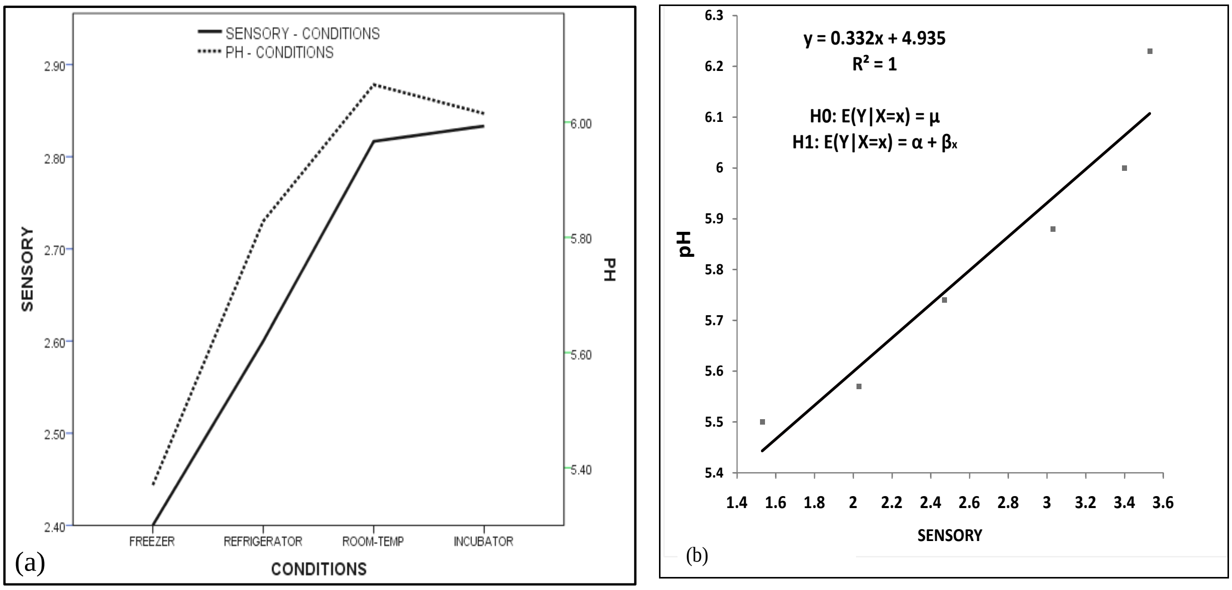

Fig. 6 (a): Interpolation line responses dependent on storage conditions of sensory and pH
(b): Resolved model of pH and Sensory based on the effect of storage conditions

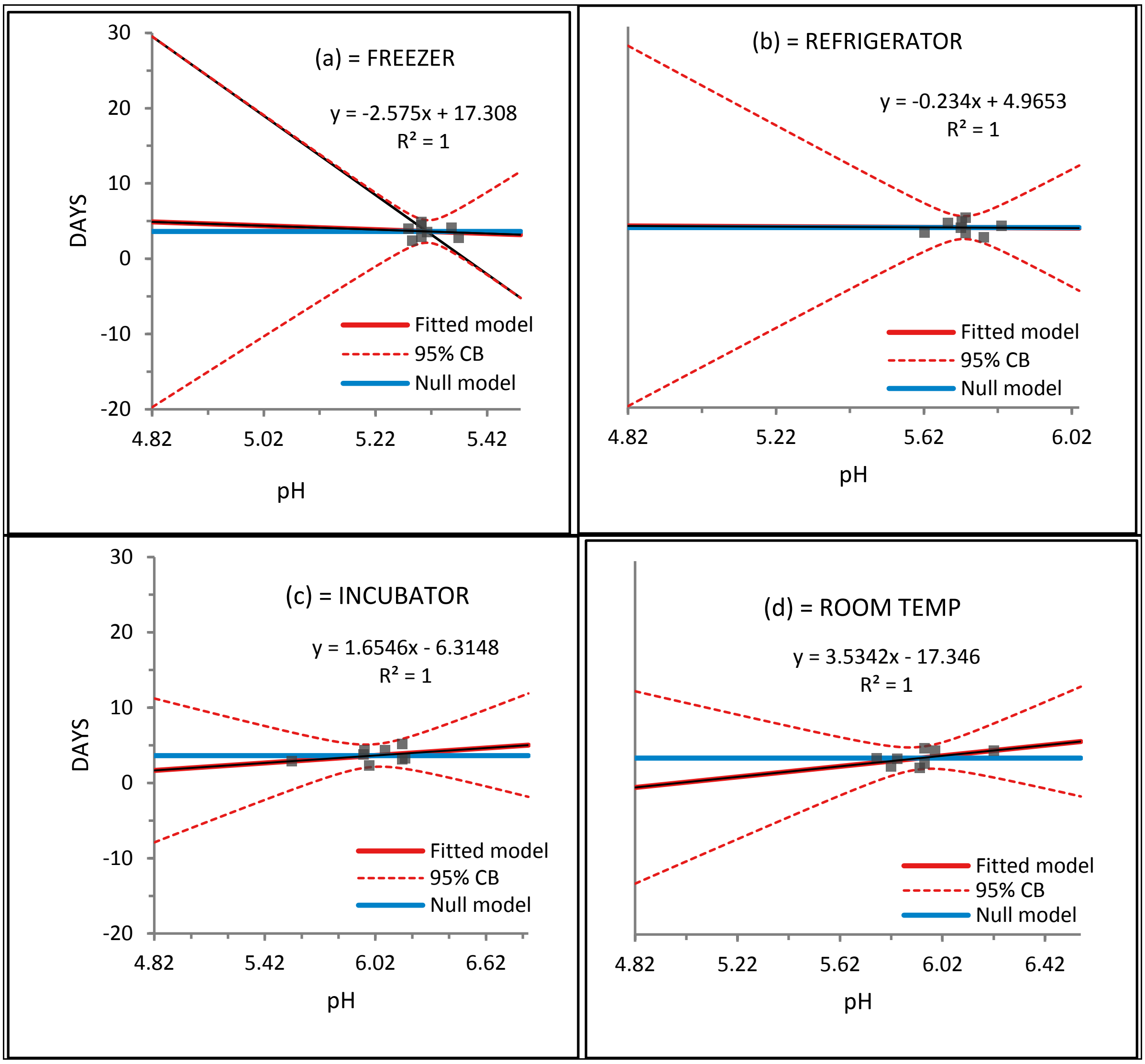

Fig. 7: Effect of storage temperature on the pH and Shelf-life of pasteurized mango

Maximum predictable shelf-life of mango juice ($P<0.05$) in freezer (~50days), refrigerator (~45 days), incubator (~18 days) and Room temperature (~25 days). Blue line = null model ; Red line = fitted model (95% confidence band).

5. REFERENCES

[1] ACEnet (2001). Shelf life and pH. Published February 1st, 2001 at http://t.acenetworks.org/warehouse/Shelf_Life_and _pH_Testing.pdf. Accessed 25/11/2016. pp2

[2] A.O.A.C. (1990). Official method of analysis. Vol. 11, 16th edition. Association of Official Analytical Chemists, Arlington, V.A.

[3] Balogu, T.V., Balogu, D.O., Akpanta, A.C., and Mohammed, S S.D. (2014). Predictive Microbiology Models (PPMs): Prospects on food safety, shelf-life and growth of Nigeria food industry. *Development of Science and Technology Research*. 3(1): 29-40.

[4] BlackBurn, C., (2000). Modelling shelf-life. The stability and shelf-life of food, 54-78.

[5] Ceylan, E., Fung, D.Y.C. & Sabah, J.R. (2004). Antimicrobial activity and synergistic effect of cinnamon with sodium benzoate or potassium sorbate in controlling *Escherichia coli* O157:H7 in apple juice, *J. Food Sci.* 69, 102–106.

[6] Charles-Rodríguez, A.V., Nevárez-Moorillón, G.V., Zhang, Q.H. & Ortega-Rivas E. (2007). Comparison of thermal processing and pulsed electric fields treatment in pasteurization of apple juice, *Food Bioprod Process* 85(2C): 93-97.

[7] Cowan, S. T. and Steel, K. J. (2004). Manual for the Identification of Medical Bacteria (3rd ed.). Cambridge University Press. London. 331pp.

[8] FAO (2017). Fermented frutis and vegetables. A global perspective. http://www.fao.org/docrep/x0560e/x0560e07.htm. Accessed on 14th March 2017

[9] Franke, A.A.; Cooney, R.V.; Henning S.M. and Custer, L.J. (2005). Bioavailability and antioxidant effects of orange juice components in humans. J Agric Food Chem., 53 (13): 5170–5178.

[10] Gram, L., and Dalgaard, P. (2002). Fish spoilage bacteria – problems and solutions. Current Opinion in Biotechnology, Vol. 13, pp, 262–266. ISSN 0958-1669.

[11] Guerrero-Beltran, J.A., Barbosa-Canovas, G.V. and Welti-Chanes, J. (2011). High hydrostatic pressure effect on natural microflora, *Saccharomyces cerevisiae, Escherichia coli*, and *Listeria Innocua* in navel orange juice, *International Journal of Food Engineering* 7 (1): Article number 14.

[12] Hofmann, A. F., Meysman, F. J. R., Soetaert, K. and Middelburg, J. J (2008). A step-by-step procedure for pH model construction in aquatic systems. Biogeosciences, 5, 227–251.

[13] Jaiswal, A. K. and Jaiswal, S. (2014). Modelling the effects of natural antimicrobials as food preservatives. In: Taylor M. (ed.)Handbook of Natural Antimicrobials for Food Safety and Quality. (pp. 259-284). Woodhead Publishing Limited, Cambridge, UK

[14] National Academy of Science : NAS (1985): Organoleptic examination *In:* An Evaluation of the Role of Microbiological Criteria for Foods and Food and food Ingredients. National Academy Press, Washington D. C. pp 112 - 113.

[15] Sims, C. A. and Morries, J. R. (1987). Effect of fruit maturity and processing methods on the quality of juices from french-Emerican hybrid wine grape cultivars. *American Journal Enology and Vitic*. 38(2) : 89 - 94.

[16] Sivapalasingam, S., Barrett, E., Kimura, A., Van Duyne, S., De Witt, W., Ying, M., Frisch, A. and Phan, Q. (2003). A multistate outbreak of Salmonella enterica serotype Newport infection linked to mango consumption: impact of water-dip disinfestation technology. *Clinical Infectious Disease* 37, 1585–1590.

[17] Tribst, A. A. L., Sant'Ana, A. S. and Massaguer, P. R. (2009) Review: microbiological quality and safety of fruit juices: past, present and future perspectives. *Critical Review of Microbiology* 35, 310–339.

[18] Valero,A., Carrasco, E., and García-Gimeno, R. M (2012). Principles and Methodologies for the Determination of Shelf-Life in Foods, Trends in Vital Food and Control Engineering, Prof. Ayman Amer Eissa (Ed.), ISBN: 978-953-51-0449-0, InTech, Available from:http://www.intechopen.com/books/trends-in-vitalfood-and-control-engineering/ principles-and-methodologies-for-the-determination-of-shelf-life-in-foods.