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A Comparative Assessment of the Quality of Minimally Processed Pineapples Sold in Wet Markets and Supermarkets of Mauritius

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Abstract

Pineapple is one of the most economically important fruit crops of Mauritius and is often sold after being minimally processed (MP). Unfortunately, minimally processed whole (MPW) and fresh-cut (MPC) pineapples are susceptible to microbial contamination that can compromise the quality of the products. It is therefore important that MP pineapples have optimal freshness, nutritional quality, and are free from microbial contamination which would otherwise constitute a public health hazard to the consumers. The main aim of this study was to assess the microbiological, nutritional, and physicochemical quality of MP pineapples sourced from wet markets and supermarkets. Samples of MPW and MPC pineapples collected from open markets and supermarkets were subjected to microbiological, pH, and vitamin C analyses. The MP pineapples were also challenged using the specific spoilage organism (SSO), *Pseudomonas fluorescens* and subsequently stored at either ambient or refrigeration temperature to simulate storage conditions of wet markets and supermarkets, respectively. Laboratory analyses revealed that the Total Viable Counts (TVC), pH, and vitamin C content for MPW and MPC pineapples sampled ranged from 4.8 – 5.5 Log CFU/g, 4.16 – 4.96, and 21.60 – 28.90 mg/100 g, respectively. Since the population density of TVC was less than 7 Log CFU/g, which usually marks the onset of microbiological spoilage, the products were

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considered to be of a satisfactory microbiological quality. Moreover, there was no statistically significant difference in the microbiological load, pH, and vitamin C content for pineapples sourced from markets and supermarkets. Taken together, this study reveals that MP pineapples sold in wet markets and supermarkets have a satisfactory microbiological, nutritional, and sensorial quality with a shelf-life of >7 hours and >5 days when stored at room (29°C) and refrigeration (4°C) temperatures, respectively.

Introduction

The tropical agro-climatic conditions of Mauritius make it very conducive for the production of a diverse range of fruits. One of the most economically important fruits is the pineapple, with an average annual production of 12,000 tonnes over an equivalent of 500 ha of land.[1] Mauritian pineapples are mainly acquired from two cultivars: the Queen Victoria and Smooth Cayenne pineapple.[2] Burhooa and Ranghoo-Sanmukhiya (2012) reported that the Queen Victoria cultivar is the variety that dominates the local and export market by virtue of its sweetness, fragrant smell, golden yellow flesh, vibrant tropical flavour, and year-round availability.[3]

Minimally processed (MP) fruits are becoming increasingly popular due to the convenient individual portioning and reduced preparation time.[4] In Mauritius, pineapples are typically served and consumed fresh after removal of the crown, rind, eyes, and core.[5] Consumers are becoming increasingly aware of the safety and quality of fresh pineapples, as well as the relationship between the production practice and the quality of these products.[2] They are thus increasingly pursuing assurances on freshness, taste, safety, traceability, health, and nutrition of the food they eat.[6] These factors collectively contribute to the overall perception of 'quality' and determines the degree of acceptability of the MP pineapples to the consumer. Quality of fresh fruits including pineapples can be assessed by five sensorial attributes: overall appearance, colour, aroma, texture, and taste. In addition to the five sensory traits, the acceptability of a fruit is also measured by a variety of quantifiable physicochemical and microbiological laboratory parameters.

The aim of this study was therefore to compare the quality of minimally processed whole pineapples (MPW) and minimally processed fresh-cut pineapples (MPC) sold in outlets of Mauritius as determined by subjective (consumer evaluation) and objective (laboratory analyses) assessments. The objectives were to determine the microbiological, physicochemical, and sensorial quality of MP pineapples sourced from different regions of Mauritius and to draw inferences on the acceptability of MP pineapples as determined by consumer evaluations, and laboratory analyses.

Materials and Methods

Sampling

Samples of MPW and MPC pineapples of the Queen Victoria cultivar, were chosen by customers and purchased from different regions of Mauritius and transported in an isothermal bag to the University of Mauritius' laboratory.

Microbiological Analyses

For microbiological analyses, 25 g of MPW and MPC pineapple samples were aseptically weighed and transferred to a stomacher bag. To the samples, 225 ml of Buffered Peptone Water (Oxoid, Hampshire, UK) was added. The mixture was blended in a stomacher machine (Stomacher 400, Seward, UK) for 2 minutes at 230 RPM. The homogenate was serially diluted and appropriate dilutions were plated. Plate Count Agar (Oxoid) was used to recover mesophilic aerobic bacteria following ISO 4833:2003,[7] Potato Dextrose Agar (Oxoid) was used to isolate yeasts and moulds following ISO 21527:2008,[8] De Man-Rogosa-Sharpe medium (Oxoid) for lactic acid bacteria,[9] Baird Parker Agar (HiMedia, Mumbai, India) for *Staphylococcus aureus* following ISO 6888-1:1999,[10] and finally, *Pseudomonas* Isolation Agar (HiMedia) for the recovery of *Pseudomonas* species.[11]

A culture of *Pseudomonas fluorescens* ATCC® 13525™ was inoculated on *Pseudomonas* Agar (HiMedia) and *Pseudomonas* CFC medium (HiMedia). Colonies appearing straw-coloured with a greenish tinge were presumed to be *P. fluorescens*. Presumptive isolates of *Pseudomonas* species were confirmed after microscopic examination and oxidase and catalase tests. Using a flame-sterilised

loop, a loopful of the culture was transferred into two test tubes, each containing 5ml of Nutrient Broth (HiMedia) and incubated at 30 ± 2 °C for 24 hours.

Physicochemical Analyses

Briefly, two pineapples that were either peeled (MPW) or peeled and cut (MPC) were homogenised in a juicer. The pH of the pineapple slurry was then measured with a pH meter (Mettler-Toledo, Greifensee, Switzerland) following the official method of analysis (AOAC, 1990).[12] Instrumental surface colour (CIE L* a* b*) was determined using a colorimeter (Konica Minolta CR - 410 Chroma Meter, Tokyo, Japan). Since a* values give an indication of the redness-greenness of a product, a* values were not of interest for this study. The moisture content of the pineapples was determined using the oven drying method by drying to constant weights at 105 °C. Water-activity of the samples was measured using a dew-point water activity meter (Novasina, Lachen, Switzerland). All the physicochemical analyses were carried out in two independent replicates.

Vitamin C Content Determination

Vitamin C content was determined by the Indophenol method adapted from the AOAC (1999) and Ceirwyn (1995).[13,14] Briefly, 25 g of pineapple slurry from individually homogenised MPW or MPC pineapples was mixed with 100 ml of 3% metaphosphoric acid-acetic, and the mixture subsequently filtered. The filtrate was then titrated against indophenol solution until a persistent light pink colour was obtained. The titre values were recorded and the mean was calculated. A blank titration was performed for which the titre value was also recorded.

Sensory Analysis

For sensory analysis, a questionnaire was designed and sensorial evaluation was conducted with ten untrained panellists to simulate naïve consumers. Samples of MPW and MPC pineapples were presented to the panellists in clean disposable plates and the latter were asked to rate the samples for the following sensory parameters: 'Overall Appearance', 'Aroma', 'Texture', and 'Colour'. A 9 - point hedonic scale ranging from '1 - Dislike Extremely' to '9 - Like Extremely' was used. The sums of scores of all ten panellists were then computed for each parameter. A scale was devised to assign the grades 'Good: 70-90', 'Fair: 50-69', 'Poor: 40-49', or 'Very Poor: 10-39' based on the summed scores.

Microbiological Shelf-Life Estimation of MPC Pineapples

For microbiological shelf-life estimation, whole pineapples were bought fresh from a wet market in the central region of Mauritius. In the laboratory, the samples were rinsed with sterile water. Using a flame-sterilised knife, the pineapples were peeled, and cut into identical-sized cubes weighing approximately 10 ± 1g and apportioned in 14 individual stomacher bags. A 125 µl aliquot of a late-log phase culture of *P. fluorescens* in nutrient broth was pipetted into each of the 14 bags containing the samples and pummelled gently to spread the inoculum evenly. Eight of the inoculated samples were subsequently kept at ambient temperature (28-29 °C) for up to 7 hours and analysed at hourly intervals to determine the population density of *P. fluorescens*. The remaining six stomacher bags were kept chilled at 4 °C for a period of 5 days and microbiologically analysed daily. The initial population density of the inoculum was approximately 5.0 Log CFU/g as determined by plating on *Pseudomonas* Isolation Agar. Growth data were then analysed as described in the section below.

Microbial Modelling

Online microbial modelling tools used in the project were ComBase Predictor (University of Tasmania/ USDA-ARS, Australia), Sym'Previus (ADRIA, France), and Integrated Pathogen Modeling Program (IPMP) 2013 (USDA-ARS, USA). ComBase is a predictive tool for important foodborne spoilage microorganisms.[15] Sym'Previus has a collection of models and data to be applied for quantifying microbial behaviour and determining shelf-life.[16] IPMP 2013 is a data analysis tool developed by the USDA, specifically designed to develop primary and secondary microbial growth models.[17] Growth data from the challenge study with *P. fluorescens* was fitted with the (a) Baranyi and Roberts model of ComBase, (b) linear model of ComBase, (c) linear model of Sym'Previus, and (d) linear model of IPMP 2013.

Data Analyses

All laboratory analyses were conducted in at least two replicates. Microbiological, physicochemical,

and vitamin C data were statistically analysed using Minitab Release 18 (Pennsylvania, USA). Overall significance was determined by subjecting the data to a one-way or two-way ANOVA. Significantly different means were separated using a Tukey's honest significant difference post-hoc test.

Results and Discussion

Microbiological Quality of MP Pineapples

Current results show that microbial counts of MPW and MPC pineapples varied with the degree of minimal processing (peeled *vs.* peeled and cut), the type of retail outlet (wet market *vs.* super-market), and to a lesser extent, on the geographical location of the markets and supermarkets (north, south, east, central, or central-north).

As shown in Table 1 below, the Total Viable Count (TVC) count for MPW and MPC pineapples fell in the range of 4.8-5.4 Log CFU/g and 5.2-5.5 Log CFU/g, respectively. Given that the TVC population density of 7.0 Log CFU / g is used as an index of food spoilage,[18] our results indicate that the pineapples were of sound microbiological quality. Moreover, none of the tested samples showed any visible evidence of spoilage. Contrary to the findings of

Table 1: Total Viable Counts (Log CFU / g) of MPW and MPC pineapples sourced from wet markets and supermarkets in different regions of Mauritius

Regions	MPW		MPC	
	Wet market	Supermarket	Wet market	Supermarket
South	5.4 ± 0.34^{aA}	5.2 ± 0.28^{aA}	5.5 ± 0.16^{aA}	5.2 ± 0.44^{aA}
Central	5.3 ± 0.24^{aA}	4.8 ± 0.32^{aA}	5.4 ± 0.60^{aA}	5.4 ± 0.77^{aA}
Central North	5.4 ± 0.23^{aA}	5.4 ± 0.44^{aA}	5.5 ± 0.26^{aA}	5.4 ± 0.34^{aA}
North	5.4 ± 0.17^{aA}	5.3 ± 0.02^{aA}	5.5 ± 0.50^{aA}	5.3 ± 0.07^{aA}
East	5.4 ± 0.46^{aA}	5.2 ± 0.44^{aA}	5.5 ± 0.11^{aA}	5.3 ± 0.14^{aA}

Results depict average values ± S.D of two replicates. Different lowercase superscript letters in the same row reveal significant differences ($P < 0.05$). Different uppercase superscript letters in the same column reveal significant differences ($P < 0.05$).

Table 2: Fungal counts (Log CFU / g) of MPW and MPC pineapples sourced from wet markets and supermarkets in different regions of Mauritius

Regions	MPW		MPC	
	Wet market	Supermarket	Wet market	Supermarket
South	5.9 ± 0.39^{aA}	5.8 ± 0.72^{aA}	6.0 ± 0.16^{aA}	5.9 ± 0.39^{aA}
Central	6.0 ± 0.34^{aA}	5.8 ± 0.90^{aA}	6.1 ± 0.34^{aA}	5.8 ± 0.72^{aA}
Central North	6.2 ± 0.14^{aA}	5.9 ± 0.18^{aA}	6.2 ± 0.29^{aA}	6.1 ± 0.12^{aA}
North	6.2 ± 0.39^{aA}	6.0 ± 0.34^{aA}	6.3 ± 0.34^{aA}	5.9 ± 0.39^{aA}
East	6.1 ± 0.52^{aA}	6.0 ± 0.62^{aA}	6.1 ± 0.24^{aA}	5.9 ± 0.55^{aA}

Results depict average values ± S.D of two replicates. Different lowercase superscript letters in the same row reveal significant differences ($P < 0.05$). Different uppercase superscript letters in the same column reveal significant differences ($P < 0.05$).

Jay (2005) who demonstrated that processing and packaging increased microbial incidence,[19] for this study, no significant difference (P = 0.98) in TVC was observed between MPC and MPW samples. Moreover, no significant differences were observed in the microbial load of MPW and MPC pineapples sold at either wet markets (P = 1.00) or supermarkets (P = 0.89).

Fungal counts for MPW and MPC pineapples fell in the range of 5.8 - 6.3 Log CFU/g (Table 2). According to Danyen *et al*. (2011), the acidic condition of pineapples does not hinder the growth of acid-tolerant fungi.[20] The high sugar content of pineapples also make them susceptible to fungal infection.[21] Fungal species that are known to grow on and spoil fresh fruits include *Fusarium, Cladosporium, Penicillium*, and *Alternaria*.[22] Those studies are consistent with findings of the present study where fungi were able to grow on cut pineapples displayed at either room temperature (wet markets) or refrigerated (supermarkets) temperature.

Table 3: Lactic Acid Bacteria count (Log CFU / g) in MPW and MPC pineapples sourced from wet markets and supermarkets in different regions of Mauritius

Regions	MPW		MPC	
	Wet market	Supermarket	Wet market	Supermarket
South	3.2 ± 0.27^{aA}	4.1 ± 0.36^{aA}	3.5 ± 0.95^{aA}	5.2 ± 0.37^{aA}
Central	4.6 ± 0.48^{aA}	2.7 ± 0.85^{aA}	3.8 ± 0.58^{aA}	3.9 ± 0.28^{aA}
Central North	3.9 ± 0.34^{aA}	4.3 ± 0.57^{aA}	2.8 ± 0.85^{aA}	3.9 ± 1.22^{aA}
North	3.1 ± 0.57^{aA}	2.9 ± 0.48^{aA}	3.2 ± 0.49^{aA}	4.1 ± 0.89^{aA}
East	3.6 ± 0.46^{aA}	4.0 ± 1.13^{aA}	4.4 ± 0.55^{aA}	3.2 ± 1.35^{aA}

Results depict average values ± S.D of two replicates. Different lowercase superscript letters in the same row reveal significant differences ($P < 0.05$). Different uppercase superscript letters in the same column reveal significant differences ($P < 0.05$).

Table 4: *Pseudomonas* species count (Log CFU / g) in MPW and MPC pineapples sourced from wet markets and supermarkets in different regions of Mauritius

Regions	MPW		MPC	
	Wet market	Supermarket	Wet market	Supermarket
South	4.7 ± 0.35^{aA}	2.8 ± 0.48^{aA}	4.4 ± 1.34^{aA}	3.3 ± 0.86^{aA}
Central	4.3 ± 0.64^{aA}	4.7 ± 0.73^{aAB}	3.6 ± 0.29^{aA}	4.5 ± 1.02^{aA}
Central North	3.2 ± 0.63^{aA}	5.9 ± 0.69^{bB}	5.2 ± 0.68^{abA}	4.8 ± 0.59^{abA}
North	3.1 ± 0.73^{aA}	2.9 ± 0.49^{aA}	3.9 ± 1.36^{aA}	4.1 ± 0.66^{aA}
East	4.1 ± 0.48^{aA}	4.0 ± 0.27^{aAB}	6.1 ± 1.05^{aA}	5.2 ± 0.17^{aA}

Results depict average values ± S.D of two replicates. Different lowercase superscript letters in the same row reveal significant differences ($P < 0.05$). Different uppercase superscript letters in the same column reveal significant differences ($P < 0.05$).

In the current study, lactic acid bacteria (LAB) counts of MPW and MPC pineapples varied considerably, ranging from 2.7 - 5.2 Log CFU/g (Table 3). The genera of LAB associated with the flora of fresh-cut fruits include *Lactobacillus, Leuconostoc, Pediococcus*, and *Lactococcus*.[22] Extensive growth of LAB can however result in fermentation and subsequent lactic acid production thereby lowering the pH and leading to off-flavour formation. Several authors have in fact noted the association between LAB growth and spoilage of fresh-cut fruits including pineapples when stored at 7 °C or above in a modified atmosphere.[23,24,25]

Staphylococcus aureus from MPW and MPC pineapples was consistently undetectable by plating (< 2 Log CFU/g), hence data are not shown. Even though staphylococci have been found on fruits and vegetables during processing, they are generally unable to proliferate in the presence of the more dominant lactic biota and this may explain the poor isolation of staphylococci.[26]

Pseudomonas species were isolated with population densities ranging from 2.8-6.1 Log CFU/g from MPW and MPC pineapples (Table 4). Fluorescent pseudomonads species are commonly known as important spoilage microorganisms of fresh-cut produce.[22] They can decay plant tissue at temperatures at or below 4 °C and have been found in a variety of frozen and refrigerated foods, including fresh produce.[27]

Taken together, mesophilic aerobes, fungi, LAB, and *Pseudomonas* species were detected at varying levels in MP pineapples sourced from the different retail outlets. The microbial load of MP pineapples usually reflects the sanitary quality of the processing steps and the microbiological conditions of the raw products at the time of processing.[26] However, no treatments during the production of MP fruits can ensure the total elimination of microorganisms on the surface of the produce since the flesh of pineapples represents a suitable matrix for most microorganisms by virtue of its high water activity and high sugar content.[22] Our results are also congruent with observations made by several other authors who indicated that the background microflora found on cut surfaces of MP fruits is diverse,[28] with a variety of fungi, spoilage, or otherwise innocuous bacteria.[29]

Physicochemical Quality of MP Pineapples

pH

The pH of MPW pineapples obtained from the different retail outlets ranged from 4.16 - 4.84 while the pH of MPC pineapples varied from 4.44 - 4.96 (Table 5). According to Gallota *et al.* (2018), cutting of fruits accelerates their respiration due to extensive wounding of the tissue.[30] This in turn increases the rate of catabolic activities involving acid breakdown which leads to an increase in pH.[31] It was noted that the pH of Queen Victoria pineapples from this study was considerably higher than pH of the same variety (3.62 - 3.95) determined by Khatoo (2008).[32]

Table 5: Mean pH of MPW and MPC pineapples sourced from wet markets and supermarkets in different regions of Mauritius

Regions	MPW		MPC	
	Wet market	Supermarket	Wet market	Supermarket
South	4.83 ± 0.025^{aA}	4.81 ± 0.015^{aA}	4.95 ± 0.020^{aA}	4.93 ± 0.021^{aA}
Central	4.85 ± 0.035^{aA}	4.82 ± 0.021^{aA}	4.96 ± 0.036^{aA}	4.95 ± 0.021^{aA}
Central North	4.84 ± 0.026^{aA}	4.84 ± 0.012^{aA}	4.94 ± 0.015^{aA}	4.93 ± 0.015^{aA}
North	4.26 ± 0.053^{aB}	4.24 ± 0.015^{aB}	4.95 ± 0.025^{bA}	4.93 ± 0.059^{bA}
East	4.17 ± 0.057^{aB}	4.16 ± 0.012^{aB}	4.44 ± 0.015^{aB}	4.85 ± 0.012^{bA}

Results depict average values ± S.D of two replicates. Different lowercase superscript letters in the same row reveal significant differences ($P < 0.05$). Different uppercase superscript letters in the same column reveal significant differences ($P < 0.05$).

Surface Colour

Instrumental evaluation using the CIE L*a*b* colour scale was used for colour references, based on L*, a*, and b* parameters and their derivative measurements (hue and chroma). Usually, an increase in L* value is correlated with the development of whiteness in samples, and a decrease in this parameter indicates browning development.[33]

From Table 6, L* values for MPW pineapples (73-75) were found to be significantly higher than their MPC counterparts (70-73) purchased from both wet markets (P = 0.00) and supermarkets (P = 0.00), thus indicating the loss of brightness after cutting. The lower L* values noted for MPC fruits could be due to enzymatic browning which is injurious to the quality maintenance of fresh-cut fruits.[34] As indicated by Crisosto *et al*. (2006), consumers usually assess the quality of fruits based on their specific colour and vividly coloured fresh-cut fruits tend to be perceived as 'fresh' by consumers.[35,36]

The b* values (Table 7) give an indication of the degree of yellowness to blueness; the highest b* value recorded was for MPC pineapples (51.71) sourced from the wet market of the northern region of Mauritius. The Queen Victoria variety of pineapple

Table 6: L* values of MPW and MPC pineapples sourced from wet markets and supermarkets in different regions of Mauritius

Regions	MPW		MPC	
	Wet market	Supermarket	Wet market	Supermarket
South	74.51 ± 0.15^{aA}	74.79 ± 0.20^{aA}	72.67 ± 0.32^{bA}	72.37 ± 0.21^{bA}
Central	73.62 ± 0.08^{aA}	74.27 ± 0.45^{aA}	71.63 ± 0.53^{bA}	71.42 ± 0.11^{bA}
Central North	74.64 ± 0.04^{aA}	74.77 ± 0.09^{aA}	73.17 ± 0.71^{abA}	72.81 ± 0.25^{bA}
North	73.93 ± 0.12^{abA}	74.12 ± 0.13^{aA}	72.55 ± 0.34^{bA}	72.38 ± 0.12^{bA}
East	74.75 ± 0.06^{aA}	74.61 ± 0.10^{aA}	72.77 ± 0.02^{bA}	72.47 ± 0.21^{bA}

Results depict average values ± S.D of two replicates. Different lowercase superscript letters in the same row reveal significant differences (P < 0.05). Different uppercase superscript letters in the same column reveal significant differences (P < 0.05).

Table 7: b* values of MPW and MPC pineapples sourced from wet markets and supermarkets in different regions of Mauritius

Regions	MPW		MPC	
	Wet market	Supermarket	Wet market	Supermarket
South	44.30 ± 0.33^{aA}	43.84 ± 0.22^{aA}	50.92 ± 0.70^{bA}	51.91 ± 0.10^{bA}
Central	44.70 ± 0.55^{aA}	43.92 ± 0.32^{aA}	50.87± 0.06^{bA}	50.95 ± 0.03^{bA}
Central North	44.32 ± 0.26^{aA}	43.95 ± 0.08^{aA}	50.95 ± 0.03^{bA}	50.91 ± 0.23^{bA}
North	44.25 ± 0.21^{aA}	43.90 ± 0.23^{aA}	51.71 ± 0.57^{bA}	50.91 ± 0.11^{bA}
East	43.78 ± 0.08^{aA}	43.67 ± 0.32^{aA}	50.75 ± 0.12^{bA}	50.92 ± 0.45^{bA}

Results depict average values ± S.D of two replicates. Different lowercase superscript letters in the same row reveal significant differences (P < 0.05). Different uppercase superscript letters in the same column reveal significant differences (P < 0.05).

is in fact known and appreciated for its bright yellow colour.[37] This study showed that MPC pineapples were significantly more yellowish (50.87-51.71) compared to MPW pineapples (43.67-44.70; P = 0.00). Pineapples samples with higher b* values are likely to have greater consumer acceptance.

Moisture Content

In this study, the moisture content for MPW was in the range of 78-84%, which, as expected, was significantly higher than MPC pineapples with 70-75% moisture content (Table 8; P = 0.00). Our results are similar to Ramallo and Mascheroni (2010) who found the moisture content of MP pineapples to be 72%.[38] Moisture content is an important marketing factor since water loss results in a wilted appearance, reduction in size, reduction in nutritional value, and loss of flavour.[39] Significantly higher moisture content was found in supermarkets as compared to wet markets for both MPW (P = 0.01) and MPC (P = 0.02) pineapples. This could be explained by the fact that supermarkets are enclosed areas while wet markets are open spaces where the fruits displayed are exposed to frequent air draughts. The difference could also be attributed to the display conditions of MP pineapples; in supermarkets, MPW pineapples were typically packaged in a transparent plastic bag with its ends tied with an elastic band as opposed

Table 8: Moisture content (%) of MPW and MPC pineapples sourced from wet markets and supermarkets in different regions of Mauritius

Regions	MPW		MPC	
	Wet market	Supermarket	Wet market	Supermarket
South	77.72 ± 0.49^{aA}	81.39 ± 0.56^{aA}	71.41 ± 1.05^{bA}	72.19 ± 1.41^{bA}
Central	81.72 ± 0.76^{aA}	82.43 ± 0.88^{aA}	74.84 ± 0.43^{bA}	75.24 ± 0.94^{bA}
Central North	80.39 ± 1.02^{aA}	81.24 ± 2.11^{aA}	72.51 ± 1.40^{bA}	74.11 ± 0.89^{bA}
North	79.21 ± 0.66^{aA}	80.95 ± 1.50^{aA}	70.29 ± 0.86^{bA}	74.13 ± 1.17^{bA}
East	80.44 ± 0.37^{aA}	83.73 ± 0.76^{aA}	73.53 ± 2.18^{bA}	75.39 ± 1.03^{bA}

Results depict average values ± S.D of two replicates. Different lowercase superscript letters in the same row reveal significant differences (P < 0.05). Different uppercase superscript letters in the same column reveal significant differences (P < 0.05).

Table 9: Vitamin C content (mg/100g) of MPW and MPC pineapples sourced from wet markets and supermarkets in different regions of Mauritius

Regions	MPW		MPC	
	Wet market	Supermarket	Wet market	Supermarket
South	28.99 ± 0.72^{aA}	26.08 ± 1.22^{abA}	24.37 ± 0.45^{bA}	23.33 ± 0.64^{bA}
Central	26.47 ± 1.12^{aA}	24.37 ± 0.85^{aA}	23.70 ± 1.21^{aA}	26.23 ± 0.48^{aA}
Central North	25.33 ± 0.73^{aA}	25.3 ± 1.33^{aA}	21.60 ± 0.73^{aA}	22.57 ± 1.77^{aA}
North	24.87 ± 1.68^{aA}	26.97 ± 0.58^{aA}	22.90 ± 0.49^{aA}	22.37 ± 0.87^{aA}
East	26.27 ± 0.95^{aA}	27.83 ± 1.68^{aA}	23.43 ± 1.54^{aA}	23.40 ± 0.56^{aA}

Results depict average values ± S.D of two replicates. Different lowercase superscript letters in the same row reveal significant differences (P < 0.05). Different uppercase superscript letters in the same column reveal significant differences (P < 0.05).

to wet markets where they were typically placed in open plastic bags.

Vitamin C Content

As shown in Table 9, the vitamin C content of MP pineapples varied from 21.60 to 28.99 mg/100 g. As stated by Saito *et al*. (2007), ascorbic acid is the vitamin that usually degrades most rapidly and can be used as an index for freshness.[40] Any type of cutting or bruising of the flesh will cause leaching of enzymes like ascorbate oxidase, which act on ascorbic acid when it comes into contact with oxygen.[41] This results in a loss in vitamin C, which gets converted to L-dehydroascorbic acid. Our findings are comparable with those of Uckiah *et al*. (2006) and Marrero and Kader (2006) who found that the average ascorbic acid content of freshly peeled pineapples of the Queen Victoria and the Smooth Cayenne variety (Cultivar SC3620) to be 24.8mg/100 mg and 26 mg/100g, respectively.[2,42]

Sensory Evaluation of MP Pineapples

The sensory test in this research focused on four attributes: 'Overall Appearance', 'Aroma', 'Texture', and 'Colour'.

Figures 1 and 2 compare the summed scores of all 10 panellists for the different sensory parameters for MPW and MPC pineapples, respectively. This study shows that MPC pineapples generally earned higher scores for aroma than their MPW counterparts by a maximum of 23 points. Aroma is often associated with volatile compounds synthesised when the pineapple flesh is exposed.[43] The texture of MPC pineapples (53-72 points) was also consistently better than that of MPW pineapples (50 - 65 points) purchased from the same retail outlets. In addition, we also noted consistently higher texture scores for MPC and MPW pineapples from supermarkets, which could be attributed to the temperature at which they are displayed during retailing. In this study, panellists were not asked to taste or chew the product; instead the data refer to the texture when the samples were picked up or touched, that is, the hand-feel rather than mouth-feel. Since consumers often expect fresh-cut products to be firm and crunchy,[44] firmness and texture can be used as additional indices of freshness and quality.[45,46]

Taken together, the 'Overall Appearance', 'Aroma', and 'Colour' of MPC pineapples were graded as 'Good' with their summed scores falling in the range of 70 - 90 points, although the 'Texture' attribute got a 'Fair' grade. On the other hand for MPW pineapples, only the 'Overall Appearance' was rated as 'Good' while 'Aroma', 'Colour', and 'Texture' obtained a 'Fair' grade.

Determination of Microbiological Shelf-Life of MP Pineapples

Shelf-life can be defined as the length of time that corresponds to a tolerable loss in quality of food products.[47] Sensory shelf-life and microbiological shelf-life of fresh-cut produce are usually analogous but differences can arise depending on the product type or extrinsic factors such as storage temperature.[48] *Pseudomonas* species are considered as one of the most important spoilage microorganisms in fresh-cut produce limiting its shelf-life.[49] According to Palleroni and Moore (2004), most members of

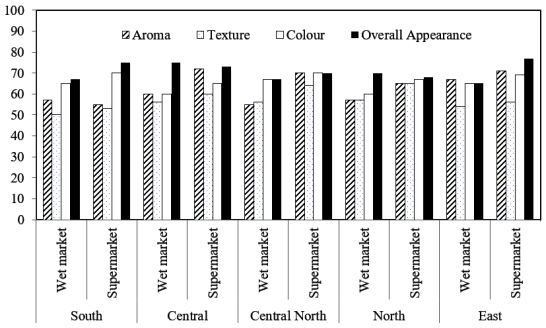

Fig. 1: Sensory scores for MPW pineapples sourced from wet markets and supermarkets in different regions of Mauritius

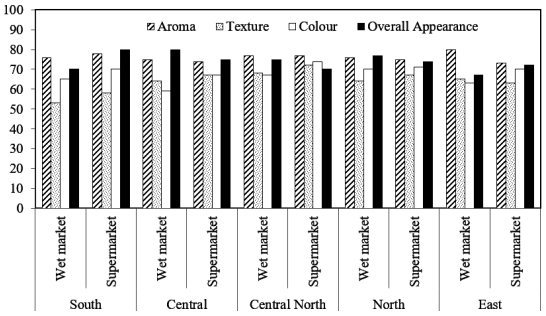

Fig. 2: Sensory scores for MPC pineapples sourced from wet markets and supermarkets in different regions of Mauritius

Group 1 pseudomonads are psychrotrophic and are commonly responsible for chilled food spoilage.[50]

Figures 3 and 4 depict the survival curves of *P. fluorescens* inoculated on MPC pineapples stored at room (29 °C) and refrigeration (4 °C) temperatures, respectively. The population of *P. fluorescens* from MPC pineapples decreased slightly over the 7-hour period from 5.0 Log CFU/g to 4.4 Log CFU/g while at 4 °C, the population decreased from 5.0 to 4.0 Log CFU/g when stored for up to 5 days. This decrease can be explained by the relatively high acidity (pH < 5), characteristic of pineapples. Moreover, the high percentage of unfermentable fibre, characteristic of pineapples, could have decreased the availability of nutrients for bacterial metabolism.[51] Hence, high acidity coupled with low nutrient availability could have inhibited the growth of *P. fluorescens* in pineapple flesh.

Since the population density of the SSO did not reach 7 Log CFU/g, which typically marks the onset of spoilage, the shelf-life of MP pineapples is estimated to be > 7 hours and > 5 days when stored at room and refrigeration temperatures, respectively. According to Barth *et al*. (2009), the shelf-life of

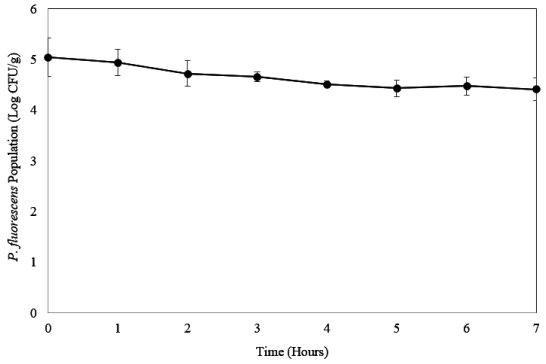

Fig. 3: Survival of *P. fluorescens* on MPC pineapples stored at room temperature (29 °C)

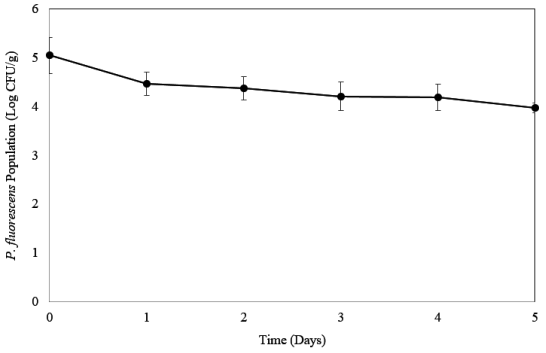

Fig. 4: Survival of *P. fluorescens* on MPC pineapples stored at refrigeration temperature (4 °C)

Table 10: Growth parameters extracted after fitting *P. fluorescens* growth data to different models

Software	Model	Temp. (°C)	μ_{max} (hr^{-1})	N_o (Log CFU/g)	y_{max} (Log CFU/g)	Goodness-of-fit Statistics
ComBase	Baranyi and Roberts	4	-0.158 ± 0.0237	4.488 ± 0.04	3.936 ± 0.0386	R^2 = 0.957
ComBase	Linear	4	-0.117 ± 0.0146	4.786 ± 0.0719	N/A	R^2 = 0.927
Sym'Previus	Zwietering	4	-0.011 ± 0.001	4.44 ± 0.04	N/A	R^2 = 0.942
IPMP 2013	Reduced growth, No lag	4	0.000 ± 0.147	4.822	3.8	RMSE = 0.074
IPMP 2013	Reduced growth, Baranyi	4	-0.04 ± 0.085	4.769 ± 0.034	N/A	RMSE = 0.039
ComBase	Baranyi and Roberts	29	-0.141 ± 0.0235	5.0487 ± 0.0396	4.44 ± 0.026	R^2 = 0.972
ComBase	Linear	29	-0.0922 ± 0.0125	4.976 ± 0.0522	N/A	R^2 = 0.885
Sym'Previus	Zwietering	29	N/A	N/A	N/A	N/A
IPMP 2013	Reduced growth, No lag	29	-0.144 ± 0.061	5.074 ± 0.034	4.144 ± 0.171	RMSE = 0.072
IPMP 2013	Reduced growth, Baranyi	29	-0.365 ± 0.058	5.072 ± 0.028	4.144 ± 0.171	RMSE = 0.072

μ_{max} – Maximum specific growth rate; N/A – Not available; N_o – Inoculation level of a batch culture; RMSE – Root-Mean-Square Error; Temp. – Temperature; y_{max} – Natural logarithm of maximum population density

fresh-cut fruits usually ranges from 1 to 35 days depending on storage temperatures, preparation methods, and packaging methods.[24] For instance, Joseph-Adekunle *et al*. (2010) showed that the onset of spoilage for fresh pineapples started on the third day of storage, with notable spoilage after 15 days, under ambient (27 °C) and intense (37 °C) heat storage conditions, while refrigerated (10 °C) pineapples remained unspoiled for up to 33 days.[52] In contrast, another study by Marrero and Kader (2001) reported the storage life of pineapple pieces from 4 days at 10 °C to over 2 weeks at 0 °C.[53]

The population data of *P. fluorescens* from the challenge study was fitted with ComBase Predictor, Sym'Previus, and IPMP 2013 with varying degrees of fit (R^2 ranging from 0.885 to 0.972). The growth rates extracted from the fitted functions ranged from -0.04 to -0.158 hr^{-1}. None of the growth rates determined by fitting the curves to the Baranyi and Roberts model of ComBase, linear model of ComBase, Sym'Previus, or IPMP were in agreement with the predicted growth rate obtained using the predictor module of ComBase. In fact, ComBase predictor yielded widely different growth rates of +0.044 and +0.433 hr^{-1} for pseudomonads when the pH was set at 5, starting population set at 5 Log CFU/g and temperature set at 4 °C and 29 °C, respectively. Hence, none of the modelling tools and fitting functions studied could be applied in shelf-life prediction of MP pineapple products (Table 10).

Conclusion

Taken together, this study revealed that MPW and MPC pineapples sourced from wet markets and supermarkets had a satisfactory microbiological, nutritional, and sensorial quality. Shelf-life challenge tests based on the development of the specific spoilage organism *P. fluorescens* demonstrated that the microbiological shelf-life of MP pineapples, under good storage practices, was > 7 hours when stored at ambient temperatures and > 5 days at refrigerated temperatures.

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Conflict of Interest

The authors declare that they have no conflict of interests.

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