

Pineapple Vinegar to Enhance Shelf Life of Carrot and Mango in Tanzania

Aldegunda Sylvester Matunda

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Master of Science in Life Science In Food Science and Technology

Sean F. O'Keefe Co-Chair
Kumar Mallikarjunan Co-Chair
Susan Duncan
Amanda Stewart
Richard Mongi

6/04/2015
Blacksburg, VA

Keywords: Pineapple, mango, carrot, vinegar, sensory evaluation, consumer acceptability, Vitamin A, Vitamin C:

Pineapple Vinegar to Enhance Shelf Life of Carrot and Mango in Tanzania

Aldegunda Sylvester Matunda

ABSTRACT

Fruits and vegetables are highly perishable, produced seasonally, and large quantities (about 50-60% of production) are wasted during high season due to poor handling and lack of cold storage in Tanzania. Processing excess pineapple into vinegar which can be used for preservation of other fruits and vegetables may be a helpful strategy for reducing losses. Vinegar was produced from pineapple juice supplemented with sugar to produce different degrees of Brix (13, 20 and 30) and was fermented with *Saccharomyces cerevisiae*, *Acetobacter pasteurianus*, and *Gluconobacter oxydans*. Levels of acetic acid were measured in the vinegar produced. High production (5.8%) of acetic acid was observed with pineapple juice concentrated to 13⁰ Brix with the combination of *Saccharomyces cerevisiae*, *A. pasteurianus* and *G. oxydans*.

The pineapple vinegar produced was used for preservation of carrot and mango. The pH of carrot pickle and mango chutney was monitored for three months. The pH of preserved carrot and mango was below 4 and no significant changes in pH were observed during three months storage at 29-32⁰C. Chemical analysis of vitamin A and vitamin C showed high losses of Vitamin A in carrot and increased vitamin A in mango, but losses of about 74% and 85% of vitamin C were observed in carrot and mango after processing.

Consumer sensory testing of pineapple vinegar, carrot pickle and mango chutney showed no significance different on overall consumer acceptability of products during storage. Pineapple vinegar can be used to rescue mango and carrots that would otherwise be lost, producing highly acceptable food products in Tanzania.

Acknowledgement

I sincerely appreciate USAID for sponsoring my study, iAGRI staff in Tanzania for their assistance, and Sokoine University for allowing me to use their lab facilities. Stewart Mwanyika, lab technician in the food science lab at Sokoine University, supported me greatly during lab work in Tanzania.

My committee members, Dr. Richard Mongi, Dr Suzan Duncan, Dr. Amanda Stewart, Dr. Kumar Malkarjunan, are thanked for their advice and contributions to my study; it was great to have each of them on my committee.

My thanks to Ken and Kim for their assistance in lab work at Virginia Tech; it was very helpful and grateful to work under your assistance.

Special appreciation to my advisor Dr. Sean O’Keefe for being my advisor; I am very grateful to work with him when I was in US and even when I was outside US he continued to provide the same assistance and support.

My special gratitude goes out to my husband, my son and my family for their encouragement and love during my study, especial when I was away from my country; it was nice to have them on my side.

My friends and everyone who helped me during my study, it was nice to have all of you on my side.

Dedication

I dedicate this work to my beloved son, Carrington Victor, for his patience and tolerance of my absence, which made it hard to concentrate on my studies. His love was my strength in whatever I did. My husband, with his love and support during my studies, made me feel strong in my work. My mother (Mary Matunda) for her prayers during my studies, my sisters (Avelina Matunda and Marytreza) for their love and encouragement during my studies, my mother (Agnes Muhabuki) for taking care of my son during my studies, keeping my son healthy and safe was encouraging me and strengthened me during my studies.

Abbreviations

FAO - Food Association Organization

MAFC - Ministry of Agriculture, Food Cooperatives.

Ho - Null hypothesis

Ha - Alternative hypothesis

pH- negative log of hydrogen ion concentration

WHO – World Health Organization

ATCC – American Type Culture Collection

USA – United State of America

SUA – Sokoine University of Agriculture

GAP – Good Agricultural Practices

GMP – Good Management Practices

GHP – Good Hygiene Practices

TSS – Total Soluble Solid

IRB – Institutional Review Board

NIMR – National Institute for Medical Research

THSD – Tukey’s Honest Significant Difference

AAB – Acetic Acid Bacteria

s.d – standard deviation

CV – Commercial Vinegar

A.p - *Acetobacter pasteurianus* bacteria

O – *Gluconobacter oxydans* bacteria

P₁₃ – Pineapple juice concentrated to 13 degree Brix

P₂₀ – Pineapple juice concentrated to 20 degree Brix

P₃₀ – Pineapple juice concentrated to 30 degree Brix

Table of Contents

Acknowledgement	Error! Bookmark not defined.
Dedication	iv
Abbreviations	v
List of figures	xi
List of tables	xii
Chapter 1	1
1.0 Introduction	1
1.1 Background information	1
1.2 Problem statement	2
1.3 Objective of the study	3
1.3.1. Specific objectives and hypotheses:	3
Chapter 2	5
2.0 Literature Review	5
2.1. Introduction	5
2.2 Fruits	6
2.2.1 Pineapple	6
2.2.2 Mango	6
2.2.3 Carrot	6
2.3 Post-harvest losses of fruits and vegetables in Tanzania	7
2.4 Vinegar	8
Chapter 3	10

3.0 Material and Methods	10
3.1. Study area.....	10
3.2 Raw materials.....	10
3.3 Vinegar Processing	10
3.4 Preserving carrot and mango with vinegar	13
3.5 Chemical analysis	17
3.5.1 Measurement of total soluble solids	17
3.5.2 Measurement of pH.....	17
3.5.5 Consumer sensory evaluation of pineapple vinegar	18
3.5.6 Statistical data analysis	20
Chapter 4.....	21
4.0 Results.....	21
4.1 Chemical analyses.....	21
4.1.1 Effect of total soluble solids on level of acetic acid in vinegar produced from pineapple.....	21
4.1.2. Impact of vinegar on vitamin A and C contents of preserved mango and carrot ...	28
4.1.2.1. Vitamin A.....	28
4.1.2.2. Vitamin C.....	30
4.2 Consumer acceptability of pineapple vinegar, mango and carrot preserved with pineapple vinegar	31
Chapter 5.....	36
5.0 Discussion.....	36
Chapter 6.....	44

Conclusions and Recommendations	44
References.....	45
APPENDICES	49
Appendix A: Demographic questionnaire.....	49
Appendix B: Score sheet (a).....	52
Appendix C: Score sheet (b).....	53
Appendix D: Work sheet (a).....	54
Appendix E: Work sheet (b).....	55
Appendix F. Score sheet for consumer sensory test on pineapple vinegar.....	56
Appendix G. Working Sheet on Consumer sensory test on pineapple vinegar.....	57
Appendix H. Distribution % of consumer acceptability on pineapple vinegar	58
Appendix I. Distribution % of consumer acceptability on commercial vinegar.....	59
Appendix J. Distribution % of consumer acceptability of pineapple carrot pickle	60
Appendix K. Distribution % of consumer acceptability on commercial carrot pickle.....	61
Appendix L. Distribution % of consumer acceptability on pineapple mango chutney	62
Appendix M. Distribution % of consumer acceptability on commercial mango chutney	63
Appendix N. Fresh pineapple	64
Appendix O. Fresh carrot.....	65
Appendix P. Fresh mango.....	66
Appendix Q. Processing of pineapple to extract juice.....	67
Appendix R. Alcohol fermentation.....	68
Appendix S. Acetic fermentation.....	69
Appendix T. Sample collection.....	70

Appendix U. Control vinegar.....	71
Appendix V. Consumer sensory test on pineapple vinegar.....	72
Appendix W. Preserved carrot (carrot pickle)	73
Appendix X. Preserved mango (mango chutney).....	74
Appendix Y. Consumer sensory test on carrot pickle and mango chutney	75

List of figures

Figure 1. Processing flow chart of pineapple vinegar production	12
Figure 2. Carrot pickle processing flow chart.....	15
Figure 3. Mango chutney processing.....	16
Figure 4. Demographic information	19
Figure 5. Impact of TSS on acetic production of pineapple vinegar	23
Figure 6. Impact of Bacteria on acetic production of pineapple vinegar.....	24
Figure 7. Impact of time on acetic production on pineapple vinegar	25
Figure 8. Impact of vinegar on pH of carrot pickle	26
Figure 9. Impact of vinegar on mango chutney	27
Figure 10. Impact of vinegar on vitamin A($\mu\text{g/g}$) on carrot pickle	28
Figure11. Impact of vinegar on vitamin A of mango chutney.....	29
Figure 12. Impact of vinegar on vitamin C of carrot pickle	30
Figure 13. Impact of vinegar on vitamin C of mango chutney.....	31
Figure 14. Consumer acceptability on pineapple vinegar.....	32
Figure15. Consumer acceptability of mango chutney	33
Figure 16. Consumer acceptability on carrot pickle	34

List of tables

Table 1 Level of acetic acid produced in four weeks of acetic fermentation. 22

Table 2. Overall mean score of consumer acceptability on pineapple vinegar, mango
chutney and carrot pickle 34

Chapter 1

1.0 Introduction

1.1 Background information

Agriculture is the backbone of the Tanzanian economy. Around half of the national income comes from agriculture. Agriculture is mostly used as a source of food and provides employment opportunities to most Tanzanians. Small-scale farming dominates in Tanzania, with farmers cultivating an average of 0.5 ha to 3.0 ha. Fruits and vegetables are among the crops produced in Tanzania for nutritional and economic purposes to fulfill family needs, such as paying school fees, buying clothes, and food ingredients. Tanzania is among the countries with favorable conditions for fruits and vegetables cultivation. For instance, it is the second largest mango producer in east Africa and is ranked the seventeenth largest producer of mangoes globally, with an annual production of 300,000 tons (Match Maker Associates 2011)

Fruit and vegetables play a key role in improving both nutrition and economic well-being of Tanzanians as they provide a wealth of essential nutrients, such as vitamins, minerals, antioxidants, fiber, and carbohydrates that improve diet quality (Kader and others 2001). Daily consumption of fruits and vegetables has been strongly associated with reduced risk of some major chronic, non-communicable diseases such as cardiovascular, diabetes, hypertension, and certain types of cancer. It has been reported that up to 2.7 million lives could potentially be saved each year with sufficient intake of fruits and vegetables (FAO 2003).

1.2 Problem statement

Despite Tanzania being richly endowed with a large variety of fruits and vegetables, their production is seasonal and the products are highly perishable. During the peak season (usually 3-4 months), markets are overwhelmed with fruits and vegetables due to their abundance. A post-harvest loss of 50-60% has been reported for fruits and vegetable due to deterioration of crop before they can be consumed in developing countries, Tanzania included (FAO 2009). Poverty and lack of knowledge, facilities and technology for handling and processing are among the major factors responsible for the losses. Only 10% of the produced fruits and vegetables are processed in Tanzania (MAFC 2009, Match Maker Associates 2011) while about 90% of the fruits and vegetables produced in Tanzania are consumed unprocessed. The loss of fruit and vegetable resources contributes to the country's health problems such as vitamin A deficiency and the increasing incidence of anemia in women, and in children less than five years old. The problem also contributes to the poor standard of living of farmers; no revenue is obtained from the wasted crops, but the farmers have already invested significantly in their production.

Adding value to the agricultural sector by rescuing these currently wasted crops would add significantly to the income of farmers and provide needed nutrients to the diet. Based on the high post-harvest losses and their associated nutritional and economic losses, there is a need to find appropriate and affordable technologies for extending the shelf life of agricultural products. Using vinegar, as a preservative agent for extending shelf life of fruits and vegetables, is one of the ways that economic losses can be

decreased. However, most of the vinegar, beverages, and spirits available in Tanzania are imported, which adds costs and reduces feasibility as preservative agent for resource-poor farmers. For instance, in 2004, beverages, spirits and vinegar represent the second largest export from South Africa to Tanzania. Over the period 2003-2004, the imports of beverages, spirits and vinegar grew by an estimated 54% with wine from fresh grapes and ethyl alcohol being the most imported products (Ramonyai and Konstant 2006). Information on the use of fruit vinegar for preservation of fruits and vegetables is limited.

Therefore, this work was conducted to develop and determine the nutritional value and potential of pineapple vinegar in preservation of carrots and mango in Tanzania.

1.3 Objective of the study

The general objective of this study was to develop and assess the nutritional value and potential of pineapple vinegar in preservation of carrots and mango in Tanzania.

1.3.1. Specific objectives and hypotheses:

- i. To assess the impact of total soluble solids on level of acetic acid in vinegar produced from pineapple.

Hypothesis: Ho: Level of acetic acid produced in pineapple vinegar at different degree of Brix will be the same with other vinegar in the market.

Ha: Level of acetic acid produced in pineapple vinegar at different degree of Brix will not be the same with other vinegar in the market.

- ii. To determine the pH of mango and carrot preserved using pineapple vinegar.

Hypothesis: Ho: A pH of mango and carrot preserved using pineapple vinegar will be the same.

Ha: A pH of mango and carrot preserved using pineapple vinegar will not be the same.

iii. To assess consumer acceptability of mango and carrot preserved with pineapple vinegar

Hypothesis: Ho: Preserved mango and carrot will be accepted by consumer.

Ha: Preserved mango and carrot will not be accepted by consumer.

iv. To determine contents of vitamins (A and C) in preserved mango and carrot.

Hypothesis: Ho: Pineapple vinegar will not affect the vitamin A and C of preserved mango and carrot.

Ha: Pineapple vinegar will affect the vitamin A and C of preserved mango and carrot.

Chapter 2

2.0 Literature Review

2.1. Introduction

In earlier times, people preserved their foods through fermentation to extend shelf life of food to make them available even during drought periods (FAO 2012). This implies that the fermentation is the one of the oldest methods used for food preservation even at village levels, where the technology is poor. Studies have shown that fermentation has been used for preserving fruits (including pineapple) and vegetables worldwide. Reddy and Reddy 2009 examined production of wine from mango and they found the mango wine had good acceptability, with novel aroma and taste characteristics compared to grape wine. Akubor 1995, Arumugam and Manikanda 2011 evaluated the chemical composition of fruit waste, pulp and peel and found that the fruits contains proteins, lipids, starch, fiber, polyphenols, and they reported that different fruits have different values of the components. Adesina and others 1992 analyzed the fermentation of mango juices and found that yeast isolated from the bottom of palm juice is most efficient for alcohol production. Ameyapoh and others (2010) studied the physiochemical characteristics of vinegar produced from local mangoes using *Sacharomyces cerevesiae*. In a model system of 20 ml of mango juice, 20 °Brix sugar and 10^6 yeast cells, they found that 22.4g L^{-1} of ethanol could be produced in 3 days, and 93% of this ethanol was then transformed into acetic acid in 12 days.

2.2 Fruits

2.2.1 Pineapple

Pineapple is among the tropical fruit grown in many countries in Africa. In Tanzania, the main growing regions include Rufiji, Kibaha, Tanga, Bagamoyo, Morogoro, Mwanza, Mbeya, Dar es Salaam, Tarime, and Sumbawanga (Horticonsults 1993). Mango is mainly used as fresh fruit and for producing juice and some mango used in making jam. Pineapple has been described as a fruit with good concentrations of vitamin C, manganese, as well as dietary fiber. Like most fruits and vegetables, pineapple is a good source of dietary fiber, which helps with digestion and lowers risk of certain diseases (cardiovascular diseases and cancer).

2.2.2 Mango

Mango is one of the most popular fruits and is sometimes called the king of the fruits. Mango has a unique flavor and taste, and is grown in the tropical regions from sub-Himalayan plains of India. In Tanzania, mango is mostly grown Tanga, Morogoro, Dar es Salaam, Pwani, Mbeya, Sumbawanga, Musoma, Shinyanga, Kilimanjaro, Dodoma, Mwanza and Mtwara. Most Tanzanian mango is used as fresh fruit, for juices, and very little is processed (Horticonsults 1993, Match 2008). Mango is a good source of vitamin A, flavanoids, dietary fiber, vitamin C and minerals. Studies have shown that high consumption of mango help to decrease risk of obesity, diabetes, overall mortality and heart disease.

2.2.3 Carrot

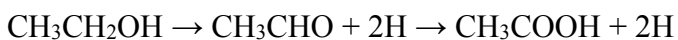
Carrot is among the vegetables where the taproot is the edible part of the plant. Carrot originated in Afghanistan, and was known by Greeks and Romans. Early uses were mainly medicinal, to cure stomach problems. Carrot was produced as a food crop in India, China and Japan by the 13th century. Now carrot is one of the most popular vegetables grown around the world. In Tanzania, main regions producing carrot include Oldonyo Sambu in the Arumeru District, Moshi Rural, West Kilimanjaro, Lushoto, Morogoro, Iringa and Mbeya (Horticonsults 1993). Carrot is mainly used as ingredient in cooking, although a little is used for juice. Carrot is highly regarded for beta-carotene and fiber contents, and is also a good source of antioxidants. Much research has discussed the health benefits of carrot, including reducing cholesterol, prevention of heart attacks, improving vision, health skin, improved digestion and boosted immune system.

2.3 Post-harvest losses of fruits and vegetables in Tanzania

A post-harvest loss of 50-60% has been reported for fruits and vegetable due to deterioration of crop before they can be consumed in developing countries, Tanzania included (FAO 2009). Poverty and lack of knowledge, facilities and technology for handling, storage and processing are among the major factors responsible for the losses. Only 10% of the produced fruits and vegetables are being processed in Tanzania (MAFC 2009, Match Maker Associates 2011) while about 90% of the fruits and vegetables produced in Tanzania are consumed unprocessed. Education on post harvest handling, value addition on fruits and vegetables could be the solution to minimize these losses.

2.4 Vinegar

Vinegar is produced in two successive biochemical processes, the first step is the primary fermentation of sugar into ethanol and the second step is the fermentation of ethanol to acetic acid. Vinegar has unique properties of being an aqueous clear liquid, which can either be with or without color depending on the raw materials used. Prescott and Dunn 1949 report that vinegar has a pH range 2-3.5 and acetic acid range of 4-6%. Fermentation to produce vinegar is an oxidative process in which *acetobacter* or other bacteria oxidize a diluted solution of ethanol to acetic acid in the presence of oxygen.



Kocher and others (2012), Webb (2007), Sugiyam and others (2003) and Kond and others (2001) reported that vinegar is a good food supplement because it improves digestion, adds flavor, and it reduces total plasma cholesterol and risk of cardiovascular disease. In developing countries where food processing technology and preservation are limited, vinegar can be used as an important ingredient for preserving fresh vegetables and fruits, enhancing shelf life. Vinegar preserves fruits and vegetable by lowering the pH of food, in other words, the food conditions becomes undesirable for harmful microorganisms to grow, hence the shelf life of food is increased (Marshall and Mejia 2011). In some countries such as Japan, USA and Canada, vinegar has been used mixed with fruit juice in treating a long list of disease (Lisa 2009). The Tanzania Ministry of Agriculture emphasized food preservation with vinegar as a value-added process for food

crops. As an immediate action for implementation, short-term training of farmers and extension workers was necessary (WHO/FAO, 2003).

Chapter 3

3.0 Material and Methods

3.1. Study area

This study was conducted at the Department of Food Science and Technology laboratory in Morogoro, Tanzania.

3.2 Raw materials.

Pineapples were purchased from a local market in Mwanza Municipality, Tanzania. Yeast (*Saccharomyces cerevisiae*), and bacteria (*Gluconobacter oxydans* and *Acetobacter pasteurianus*) were purchased from ATCC (Manassas, VA). Sugar and other ingredients were purchased in local markets in Morogoro Tanzania. Chemicals and reagents for chemical and microbiological analyses were obtained from the Department of Food Science Laboratory, SUA. Carrot and mango used in the tests of the produced vinegar were bought from local markets in Morogoro, Tanzania.

3.3 Vinegar Processing

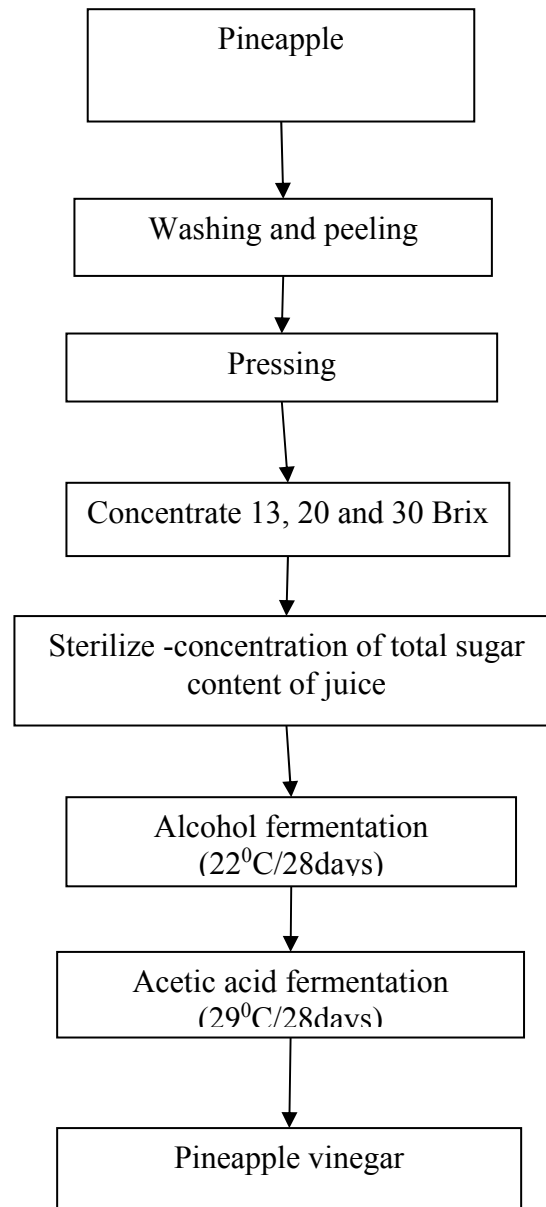
Basic safe food operating principles, such as good agricultural practices (GAP), good manufacturing practices (GMP) and good hygiene practices (GHP) were followed for the processing of pineapple to vinegar. Fermentation of pineapples to wine was conducted following the same steps of wine making as described by Ameyapoh 2010. In addition, the pineapple was further fermented by *Gluconobacter oxydans* and *Acetobacter pasteurianus* to produce acetic acid from the ethanol. Processing of vinegar was conducted at Food Science laboratory, Sokoine University of Agriculture (SUA).

Three samples of vinegars were processed from pineapple juice of 13⁰, 20⁰ and 30⁰ Brix replicated three times at the environmental temperature of 22⁰C.

The pineapples were drained followed by hand peeling using a knife, then chopping into small pieces and blended to extract juice. Total soluble solid of juice was measured using refractometer followed by dilution of 1:1 ratio of water and juice. Juice at 13⁰, 20⁰ and 30⁰ Brix were made by adding brown sugar. Fermentation of pineapples to wine was conducted following the same steps of wine making as described by Ameyapoh 2010.

In addition, the pineapple was further fermented by *Gluconobacter oxydans* and *Acetobacter pasteurianus* to produce acetic acid from the ethanol. Three samples of vinegars was processed from pineapple juice of 13⁰, 20⁰ and 30⁰ Brix replicated three times at the environmental temperature of 22⁰C. Alcohol fermentation was conducted for four weeks until the fermentation was done then followed by acetic acid fermentation at room temperature of 29⁰C for four weeks (Figure 1).

Figure 1. Processing flow chart of pineapple vinegar production



Analysis of acetic acid production was conducted every week for four week at Sokoine University Food Science lab. Titrations on vinegar using sodium hydroxide were used to determine the level of acetic acid produced on pineapple vinegar.

3.4 Preserving carrot and mango with vinegar

Both pineapple vinegar and commercial vinegar were used for increasing shelf life of processed carrot and mango. Carrot pickle was made using 2.75lb fresh carrot, 2 lb vinegar, 0.36 lb water, 0.72 lb sugar, 8 tsp mustard seed and 4 tsp celery seeds as ingredients. Carrot selection was done followed by washing using treated water, peeling and chopping into rounds that were approximately 0.5inch thick. Combination of water, vinegar, sugar and canning salt was done in a stock pot. The ingredients were brought to boil, and boiled for three minutes followed by addition of carrots to boiling solution, which was then simmered on reduced heat for about 10 minutes until half cooked. Mustard seed and celery was added into clean jars followed with hot carrots. Air bubbles were removed and jars pasteurized for 20 minutes. Carrot pickle was stored for three months. Basic food operating principles such good manufacturing practices (GMP) and good hygiene practices (GHP) were followed in each step, where pineapple vinegar of 5% level of acetic acid was used. Both carrot pickle and mango chutney were processed using commercial vinegar and pineapple vinegar. The processing flowcharts are shown in Figure 2 modified from Hearthmark 2010.

Mango chutney was made from fresh mango including 0.9 lb onions, 2.5 tbsp ginger, 1.5 tbsp fresh garlic, 1.62 lb sugar, 0.9 lb golden raisins, 1 tsp canning salt, 4 tsp chili powder and 1.08 lb vinegar. Unripe mango was selected, washed using treated water, peeling and chopped into 0.75inch cubes and cubes chopped into small pieces, onions were peeled, diced, garlic was chopped, ginger was grated. Sugar and vinegar were mixed in a stock pot brought to boil for 5 minutes, followed with addition of other ingredients then brought back to boil. It was simmered on reduced heat for 25 minutes.

Hot chutney was filled in jars then pasteurized in a water bath for 15 minutes stored for three months. Basic food principles such good manufacturing practices (GMP) and good hygiene practices (GHP) were followed in each step (Figure 3). Mango chutney was processed using pineapple vinegar and commercial vinegar as it was modified from Hearthmark 2010.

Figure 2. Carrot pickle processing flow chart

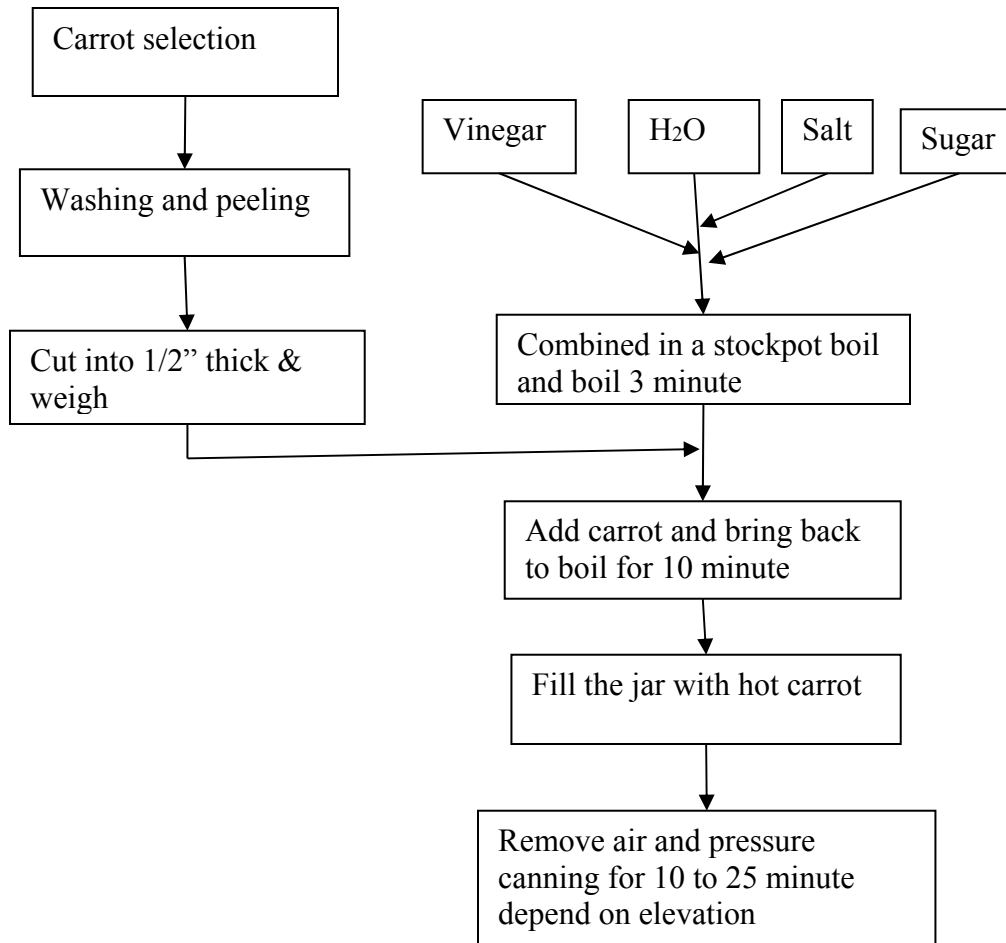
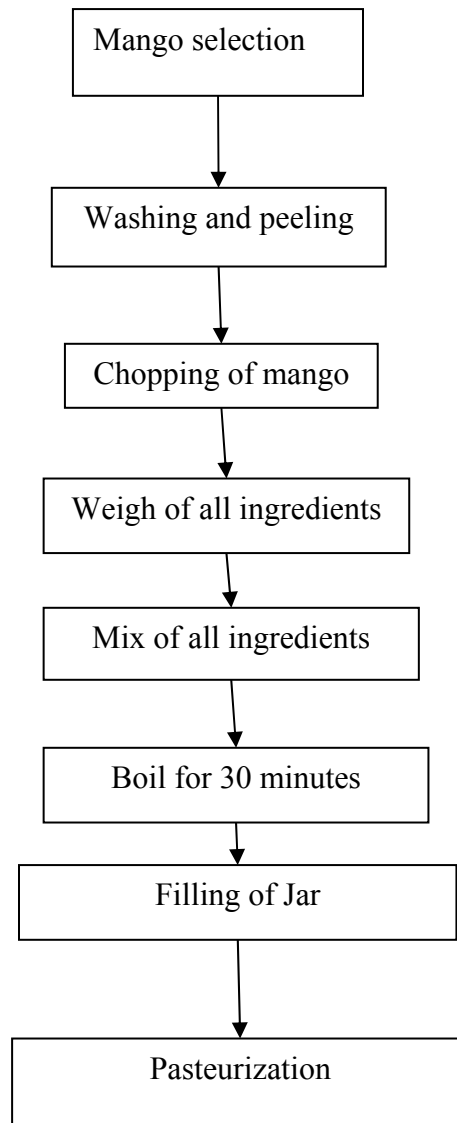


Figure 3. Mango chutney processing



After processing, both carrot pickle and mango chutney were stored at room temperature of 29-32 °C for three months.

3.5 Chemical analysis

3.5.1 Measurement of total soluble solids

Small samples of pineapple juice before fermentation was evaluated for total soluble solids content (TSS). Determination of total soluble solids (TSS) was done using refractometer (Ontago, China), measuring TSS as degree Brix in 0.1% graduations.

Three samples of pineapple juice were collected, drops of distilled water were used to clean the prism surface, and a drop of juice was placed on the prism surface, lid closed to get proper reading. The prism plate was wiped dry with a soft tissue and distilled water after every sample.

This was followed by measurement of pH, beta-carotene and vitamin C of preserved fruits and vegetables.

3.5.2 Measurement of pH

pH of carrot pickle and mango chutney was measured using a pH meter. The pH meter was calibrated using buffer solutions, samples were collected, and electrode was placed into food samples and cleaned after each sample, pH was taken for the period of three month.

3.5.3 Determination of beta carotene

Carrot pickle and mango chutney were collected and separately extracted using acetone. After extraction, samples were filtered, stored at low temperature, and absorbance measured using a spectrophotometer immediately after cooling.

3.5.4 Determination of vitamin C

Vitamin C of carrot pickle and mango chutney was evaluated using the chloroindolphénol titration method. Carrot pickle and mango chutney samples were separately blended (replicated three times). Each sample was placed into 10ml graduated cylinders followed by titration with shaking until reaching the end point. Reading was recorded for calculation of vitamin C contents; the titration was repeated thrice for each sample.

3.5.5 Consumer sensory evaluation of pineapple vinegar

A consumer study to determine the overall acceptability of pineapple vinegar, carrot pickle and mango chutney was conducted at the Department of Food Science lab using 69 panelists selected from population of student aged 18 years old and above who were willing to participate consumers. Prior to that, a letter of approval was obtained from (IRB no 14-894) Virginia Tech and National Institute for Medical Research (NIMR). Each panelist was provided with a consent form to read thoroughly and sign before sample presentation. Consumer sensory evaluation was conducted to determine overall consumer acceptability of pineapple vinegar, carrot pickle and mango chutney, Samples of vinegar were prepared 12 hrs before the sensory test; 5mls of vinegar was diluted in 1 litre of safe water stored at 4⁰C and served cold. Twenty ml of each sample was served in small containers coded by three random digits. Each panelist was provided with four samples (pineapple vinegar, commercial vinegar, combination of pineapple and commercial vinegar and water) in one set, was asked to taste the sample of pineapple vinegar to evaluate overall acceptability using hedonic scale (1 dislike most and 9 most liked, Meilgaard 2007). Between samples, each panelist was asked to rinse their palate

with crackers and water. Demographic information from each panelist was collected after tasting the product as it is shown in Figure 4.

Gender	
Male	64%
Female	36%
Age	
18-24	34%
25-34	54%
>35	12%
Status of panelist	
Undergraduates	78%
Graduates	18%
Staff	4%
Consumption rate of vinegar	
Never consume at all	6%
Monthly	66%
Weekly	24%
Daily	4%
Purchasing of vinegar	
Daily	5%
Weekly	32%
Monthly and rare	59%
Fruits and vegetables Preservation status	
Frequently	25%
Seasonal	67%
None	8%
Major preserved fruit	
Mango	30%

Figure 4. Demographic information

Mango chutney and carrot pickle were processed from fresh mango and carrots 12 hrs before the sensory test. Samples were packed and stored at 4 °C and were served cold. Sample of 20 g was presented to panelists in small containers coded with three random digit numbers and each panelist was asked to test the sample and rate the degree of liking using nine point hedonic scale (1 dislike most and 9 most liked as described by Meilgaard 2007). Crackers and water were provided to rinse their mouth between the tests to avoid carry over taste.

3.5.6 Statistical data analysis

Data were analyzed using JMP Software to determine significant differences between the main parameters. Means were separated by Tukey's Honest Significant difference (THSD) at $p < 0.05$. Values were presented as mean \pm SD and presented in tabular and graphical forms.

Chapter 4

4.0 Results

4.1 Chemical analyses

4.1.1 Effect of total soluble solids on level of acetic acid in vinegar produced from pineapple

Production of acetic acid in pineapple vinegar was influenced by degree of Brix of the pineapple juice and combination of bacteria used during the oxidation reaction (Table 1). The lower brix of 13 resulted in greater production of acetic acid in the presence of *Acetobacter pasteurianus* and the combination of *Gluconobacter oxydans* and *Acetobacter pasteurianus*. Acetic acid production increased from day 1 to day 28 of acetic fermentation for samples fermented with *Acetobacter pasteurianus* and the combination of *Gluconobacter oxydans* and *Acetobacter pasteurianus*. Only a small amount of acetic acid was observed in the rest of the samples. Production of acetic acid after one week of acetic acid fermentation showed significant differences between pineapple vinegar and commercial vinegar ($p = 0.0001$). Significant increased production of acetic acid was observed from two to four weeks of acetic acid fermentation (Tables 1), the highest level of acetic acid was mostly observed on the vinegar from 13⁰ Brix juice fermented with *Acetobacter pasteurianus* or the combination of *Gluconobacter oxydans* and *Acetobacter pasteurianus* (Tables 1). Significant differences in production of acetic acid between pineapple vinegars fermented with different Brix juice were observed. Production of acetic acid after one week of acetic acid fermentation was low, and there was little variation between samples of pineapple vinegar (Table 1). Increasing

acetic acid production was observed in pineapple vinegar samples with total soluble solid of 13⁰ Brix compared to other total soluble solids which did not have big impacts on acetic acid production (Tables 1). In assessing the impact of bacteria, TSS, time and interaction of these three factors on production of acetic acid in pineapple vinegar, results show that interaction of TSS*time and the interaction of TSS*bacteria significantly influence production of acetic acid in pineapple vinegar (p<0.0001).

Table 1 Level of acetic acid produced in four weeks of acetic fermentation.

Sample	1 st Week	2 nd Week	3 rd Week	4 th Week
CV ₂	4.92 ± 0.08 ^a	4.92 ± 0.08 ^a	4.92 ± 0.08 ^{ab}	4.92 ± 0.08 ^{bc}
CV ₃	4.76 ± 0.09 ^a	4.76 ± 0.09 ^a	4.76 ± 0.09 ^{ab}	4.76 ± 0.09 ^c
CV ₁	4.58 ± 0.21 ^a	4.58 ± 0.21 ^a	4.58 ± 0.21 ^{ab}	4.58 ± 0.21 ^c
P ₁₃ +A.p	0.42 ± 0.05 ^b	1.40 ± 0.37 ^c	3.02 ± 1.05 ^{bc}	5.273 ± 0.34 ^b
P ₁₃ + O	0.33 ± 0.01 ^{bc}	0.32 ± 0.02 ^d	0.68 ± 0.25 ^d	1.12 ± 0.16 ^d
P ₁₃ + O + A.p	0.37 ± 0.00 ^{bc}	2.39 ± 0.66 ^b	5.51 ± 1.33 ^a	5.89 ± 0.16 ^a
P ₂₀ + A.p	0.31 ± 0.02 ^{bc}	0.74 ± 0.25 ^{cd}	1.21 ± 1.48 ^{cd}	0.27 ± 0.07 ^e
P ₂₀ + O	0.29 ± 0.01 ^c	0.63 ± 0.014 ^d	0.30 ± 0.00 ^d	0.28 ± 0.007 ^e
P ₂₀ + O + A.p	0.34 ± 0.04 ^{bc}	0.26 ± 0.014 ^d	0.30 ± 0.014 ^d	0.31 ± 0.02 ^e
P ₃₀ + A.p	0.41 ± 0.06 ^{bc}	0.92 ± 0.012 ^{cd}	0.41 ± 0.12 ^d	0.35 ± 0.03 ^e
P ₃₀ + O	0.38 ± 0.00 ^{bc}	0.40 ± 0.014 ^d	0.38 ± 0.012 ^d	0.40 ± 0.03 ^e
P ₃₀ + O + A.p	0.38 ± 0.00 ^{bc}	0.36 ± 0.018 ^d	0.39 ± 0.007 ^d	0.33 ± 0.08 ^e

Mean values with different superscript values along the column are significantly different at p<0.05 (CV= Commercial vinegar, P13= pineapple juice concentrated 13 Brix, P20= pineapple juice concentrated 20 Brix, P30 = pineapple juice concentrated 30 Brix, A.p = Acetobacter pasteurianus bacteria, O = Gluconobacter oxydan bacteria)

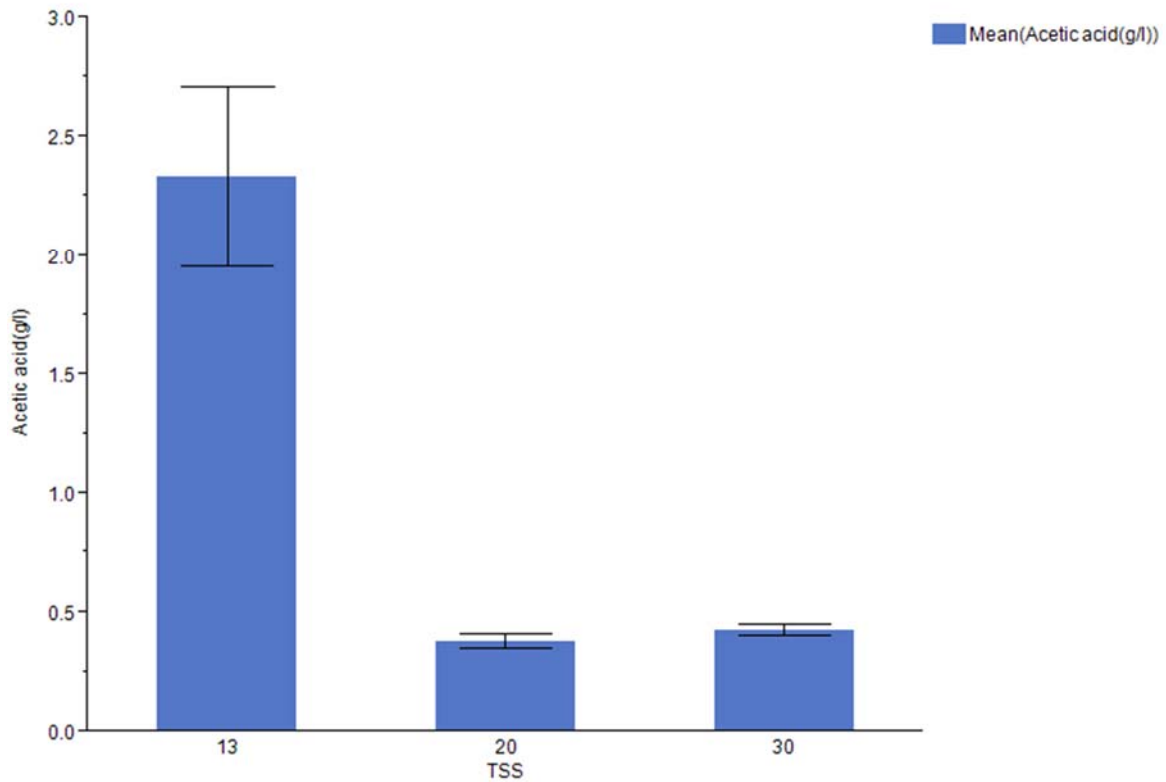


Figure 5. Impact of TSS on acetic production of pineapple vinegar

Figure 5 shows overall impact of total soluble solid (TSS) on the acetic acid production of pineapple vinegar, where by high production of acetic acid observed on pineapple juice concentrated to 13 degree Brix, lowest production of acetic acid observed on pineapple juice concentrated to 20 and 30 degree Brix. This result shows that there is significant different on production of acetic acid between different TSS.

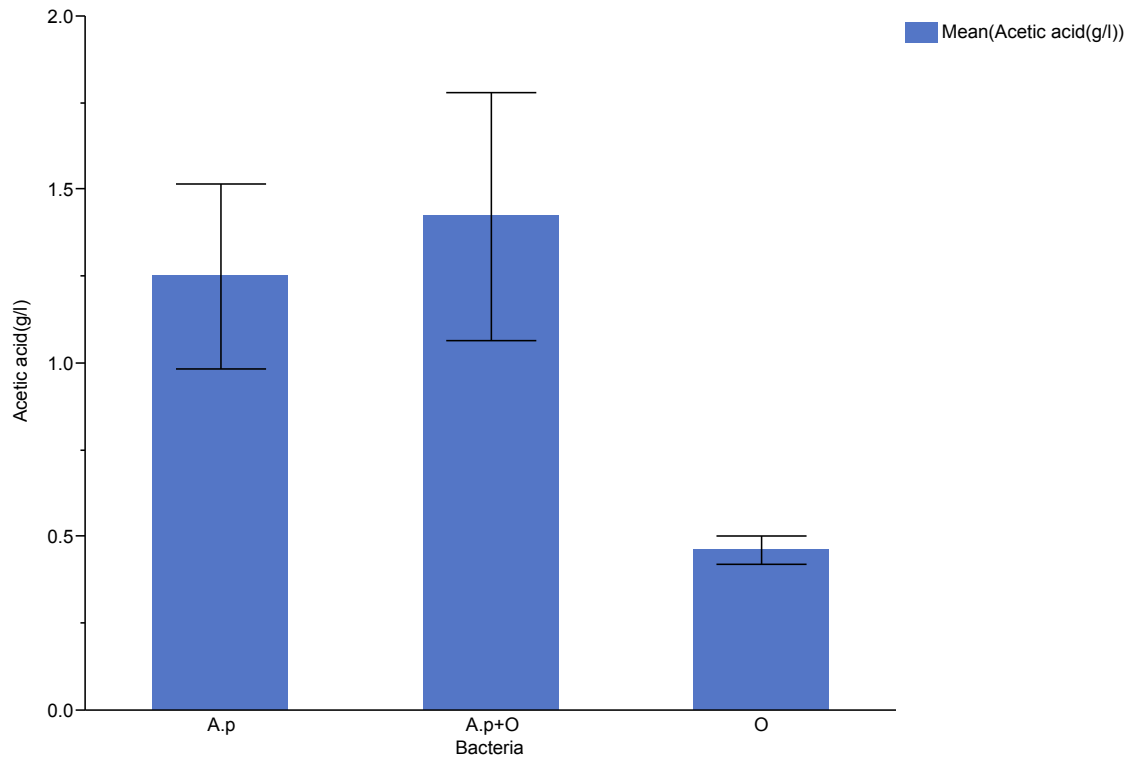


Figure 6. Impact of Bacteria on acetic production of pineapple vinegar

(Where by A.p= Acetobacter pasteurianus, O= Gluconobacter oxydans)

Figure 6 shows the impact of acetobacter bacteria on production of acetic acid on pineapple vinegar, result shows that there is significant different on production of acetic acid of pineapple vinegar between Acetobacter pasteurianus and Gluconobacter oxydans bacteria. High acetic production observed on combination of Acetobacter pasteurianus and Gluconobacter oxydans followed with Acetobacter pasteurianus, lowest acetic production observed on Gluconobacter oxydans.

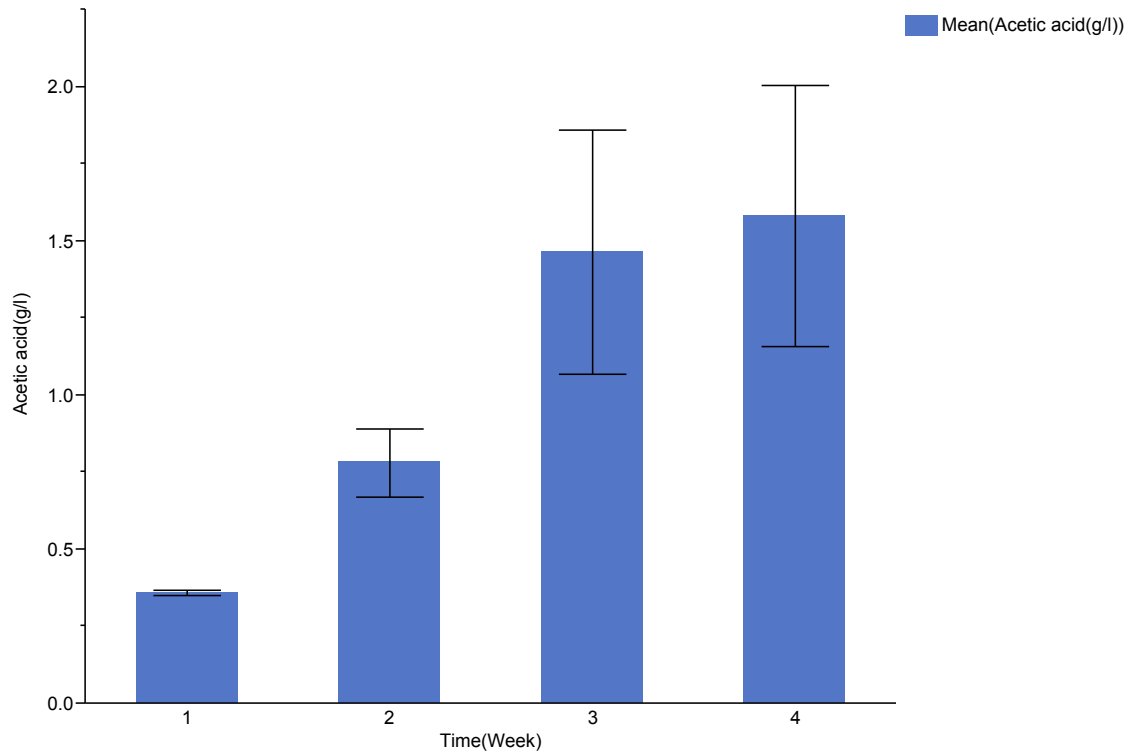


Figure 7. Impact of time on acetic production on pineapple vinegar

Figure 6 shows impact of time on acetic acid production of pineapple vinegar, result shows that there is significant different on acetic production with time of four weeks of pineapple vinegar production. Maximum acetic production observed at week 4 where by low production of acetic acid observed on first week of acetic fermentation.

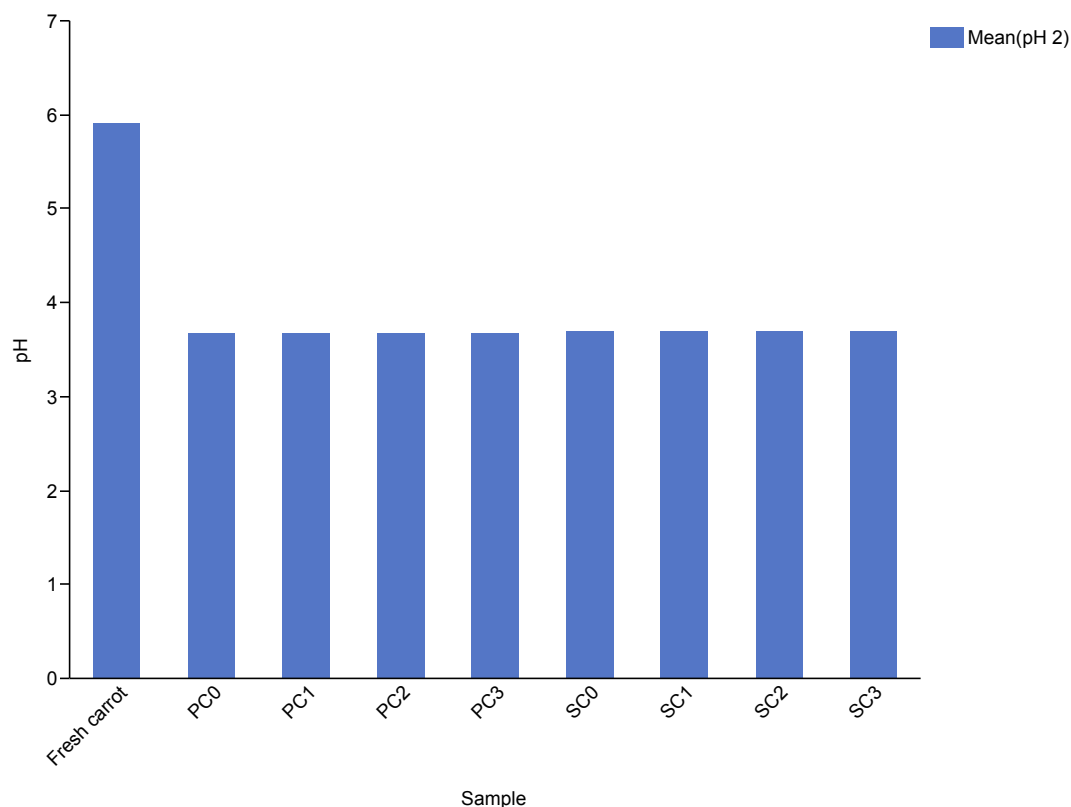


Figure 8. Impact of vinegar on pH of carrot pickle

(PC= pineapple carrot pickle, SC= Commercial carrot pickle, 0= day one, 1= first month of storage, 2= second month of storage, 3= third month of storage)

Figure 8 shows impact of vinegar on pH of carrot pickle for period of three month of storage. Result shows that there was a significant different in pH between preserved carrot and fresh carrot ($p < 0.0001$), but the pH of carrot pickle with pineapple vinegar was 3.57 while pH of carrot pickle with commercial vinegar was 3.78 ($p > .05$). There was no significant difference between pH of pineapple carrot pickle and that of commercial carrot pickle. The effect of time of storage (for three month) with change in pH of carrot pickle was not statistical significantly ($p = 0.30$).

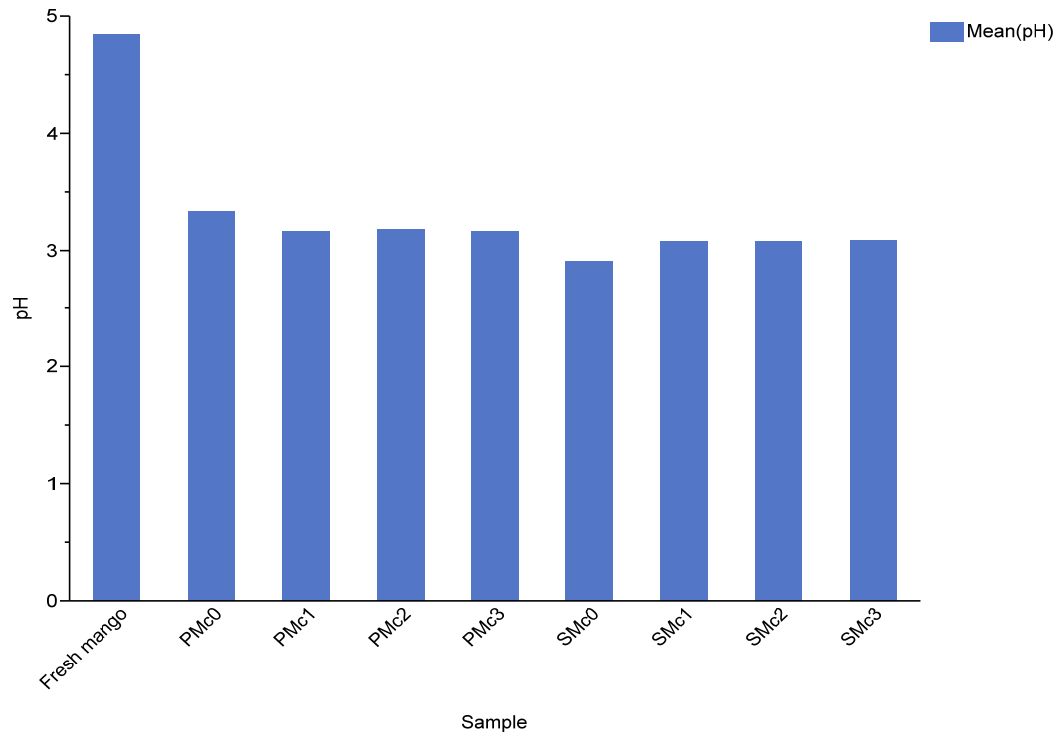


Figure 9. Impact of vinegar on mango chutney

(PMc= pineapple mango chutney, SMc= Commercial mango chutney, 0= day one, 1= first month of storage, 2= second month of storage, 3= third month of storage)

Figure 9 shows impact of vinegar on mango chutney for three month of storage. Result shows that there was statistically significantly a difference in pH of fresh mango and preserved mango chutney ($p < 0.0001$). Highest pH value observed on fresh carrot which was lowered to 3.24 & 3.15 pH of pineapple mango chutney and commercial mango chutney. Between pineapple mango chutney and commercial mango chutney, the observed p-value was 0.01. There was no significant change on pH of mango chutney processed using pineapple vinegar and that processed using commercial vinegar over three months of storage ($p=0.07$).

4.1.2. Impact of vinegar on vitamin A and C contents of preserved mango and carrot

4.1.2.1. Vitamin A

In comparing vitamin A on carrot pickle and mango chutney processed using pineapple vinegar compared to the commercial vinegar. Figure 10 shows the impact of vinegar on vitamin C content on carrot pickle, results shows that there was decreased vitamin A content of preserved carrot pickle from that of fresh for both carrot pickle processed using pineapple and commercial vinegar, and there was no significant difference in the vitamin A content of carrot pickle processed using pineapple and that processed using commercial vinegars ($p=0.9800$).

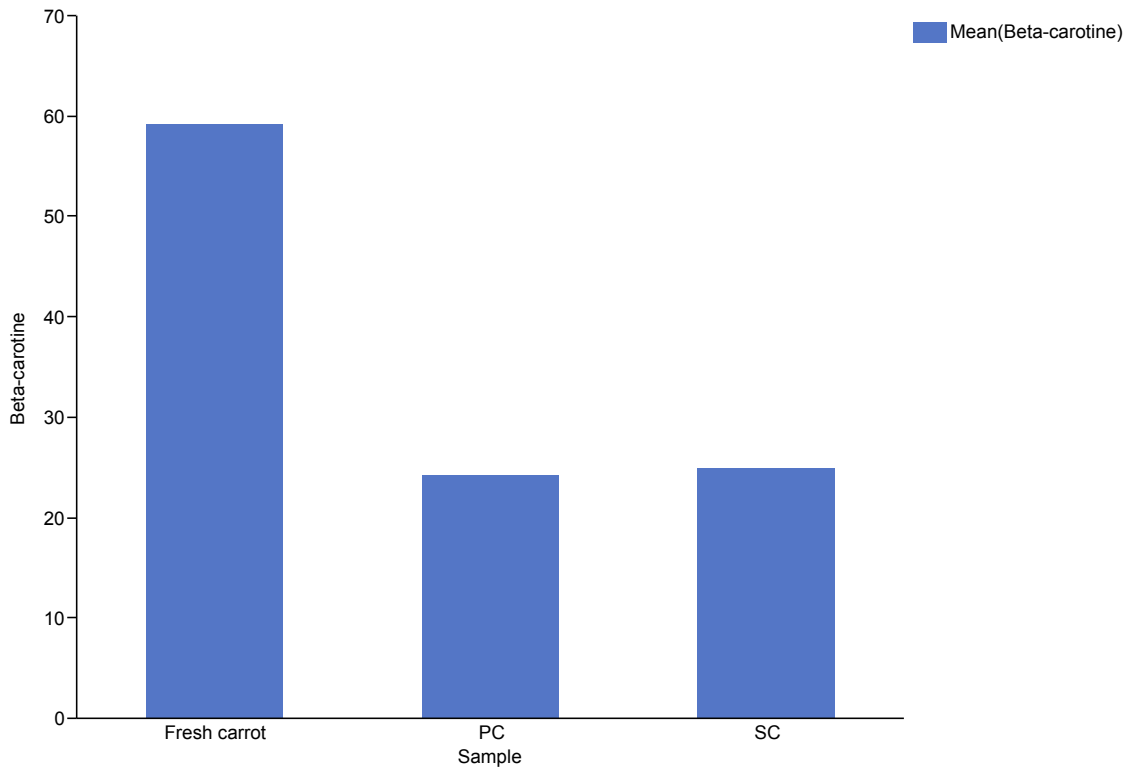


Figure 10. Impact of vinegar on vitamin A($\mu\text{g/g}$) on carrot pickle

(PC= pineapple carrot pickle, SC= Commercial carrot pickle)

Figure 11 shows impact of vinegar on vitamin A of mango chutney, Vitamin A content of mango chutney increased from that of fresh mango for both mango chutney with pineapple vinegar and mango chutney with commercial vinegar, but there was no significant different observed between mango chutney processed with pineapple vinegar and commercial vinegar ($p=0.1679$). Highest vitamin A content (beta-carotene) observed on mango chutney processed using commercial vinegar followed with that of mango chutney processed using pineapple vinegar, low vitamin A content observed on fresh mango.

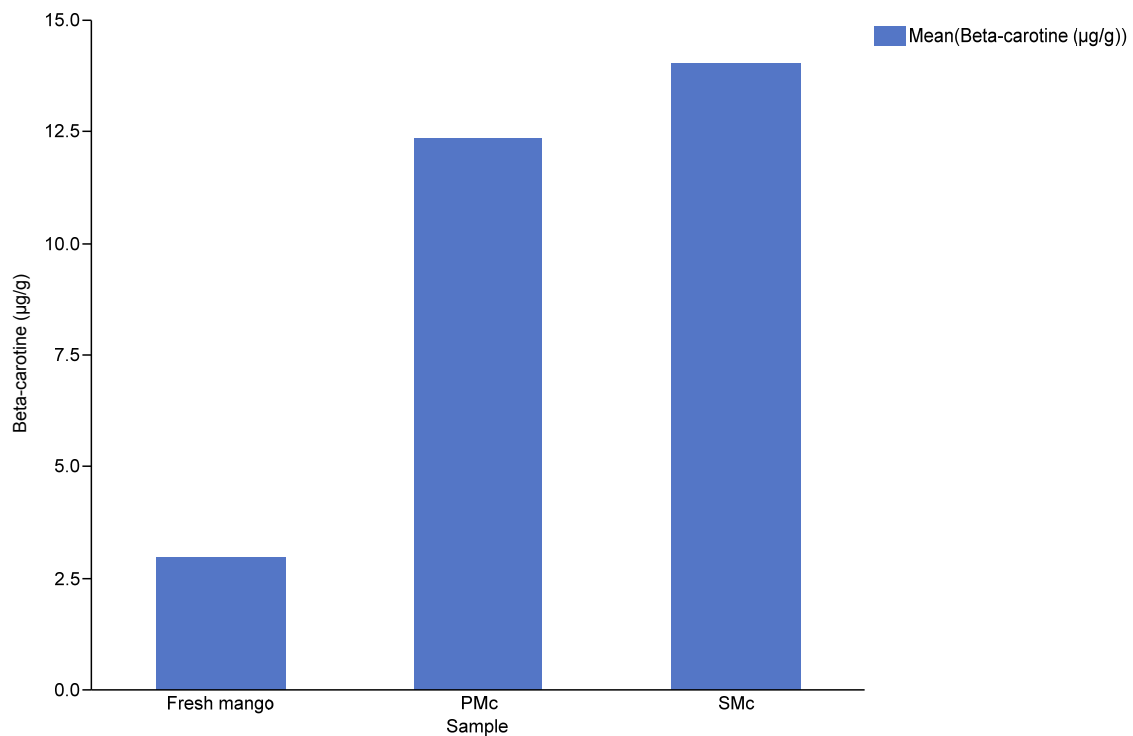


Figure11. Impact of vinegar on vitamin A of mango chutney

(PMc= Pineapple mango chutney, SMc= Commercial mango chutney)

4.1.2.2. Vitamin C

Figure 12 shows impact of vinegar on vitamin C of carrot pickle, results show that the vitamin C content of carrot pickle processed using both pineapple vinegar and commercial vinegar decreasing from fresh carrot and fresh mango , statistical there was no significance different in vitamin C content of carrot pickle processed using pineapple and commercial vinegars ($p=0.9061$).

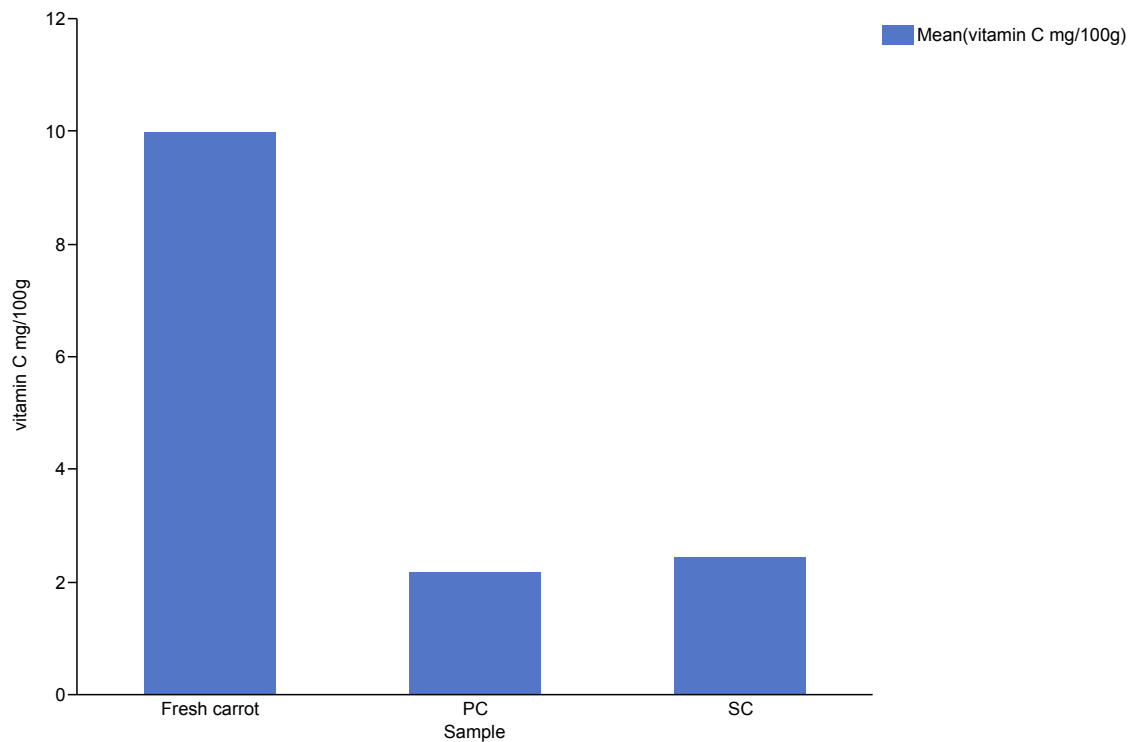


Figure 12. Impact of vinegar on vitamin C of carrot pickle

(PC = Pineapple carrot pickle, SC= commercial carrot pickle)

Figure 13 shows impact of vinegar on vitamin C content of mango chutney, Result shows that there was no significant different in vitamin C content of mango chutney processed using pineapple vinegar and that processed using commercial vinegar ($p=0.4920$). High vitamin C content was observed on fresh carrot followed by that of commercial mango chutney and that of pineapple mango chutney.

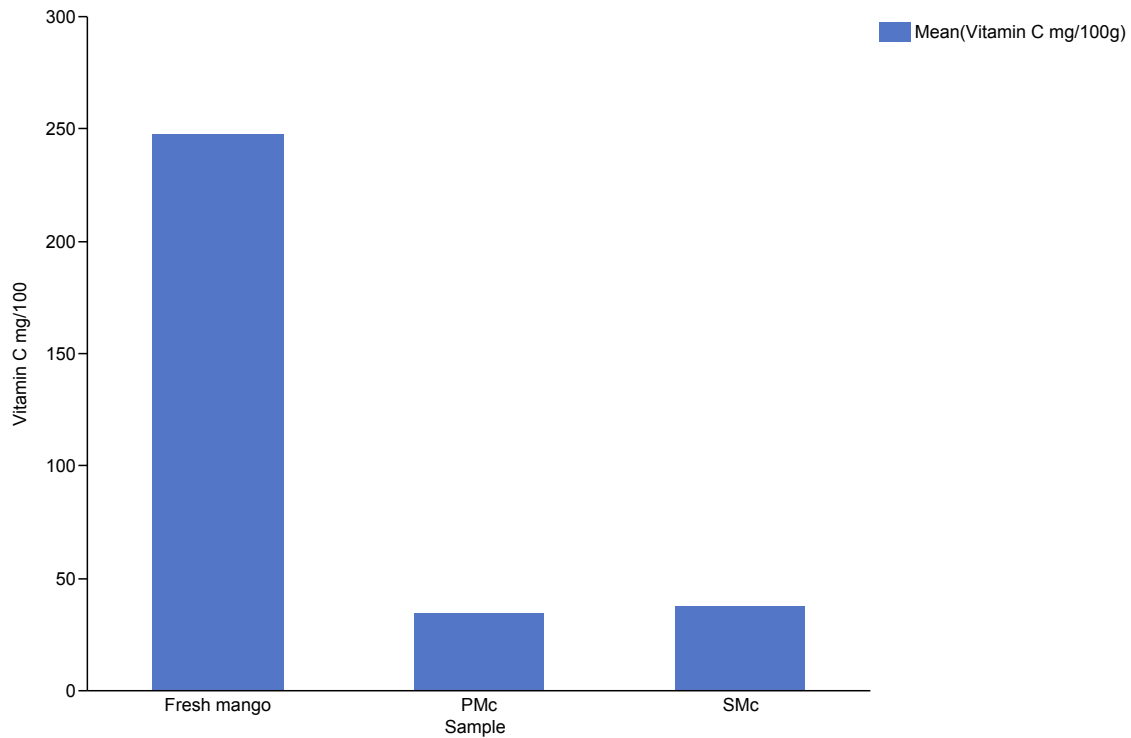


Figure 13. Impact of vinegar on vitamin C of mango chutney

(PMc= pineapple mango chutney, SMc= commercial mango chutney)

4.2 Consumer acceptability of pineapple vinegar, mango and carrot preserved with pineapple vinegar

Figure 14 shows consumer overall acceptability of pineapple vinegar, result shows that there was significant different on the acceptability of pineapple vinegar from that of commercial vinegar ($p = 0.028$), high degree of like was observed on pineapple vinegar which score 6.29 (hedonic scale) while commercial vinegar score 5.25(hedonic scale) table 2. About 93.6% of panelists expressed a high degree of like for pineapple mango chutney, 1.5% neither liked nor disliked and 4.7% dislike

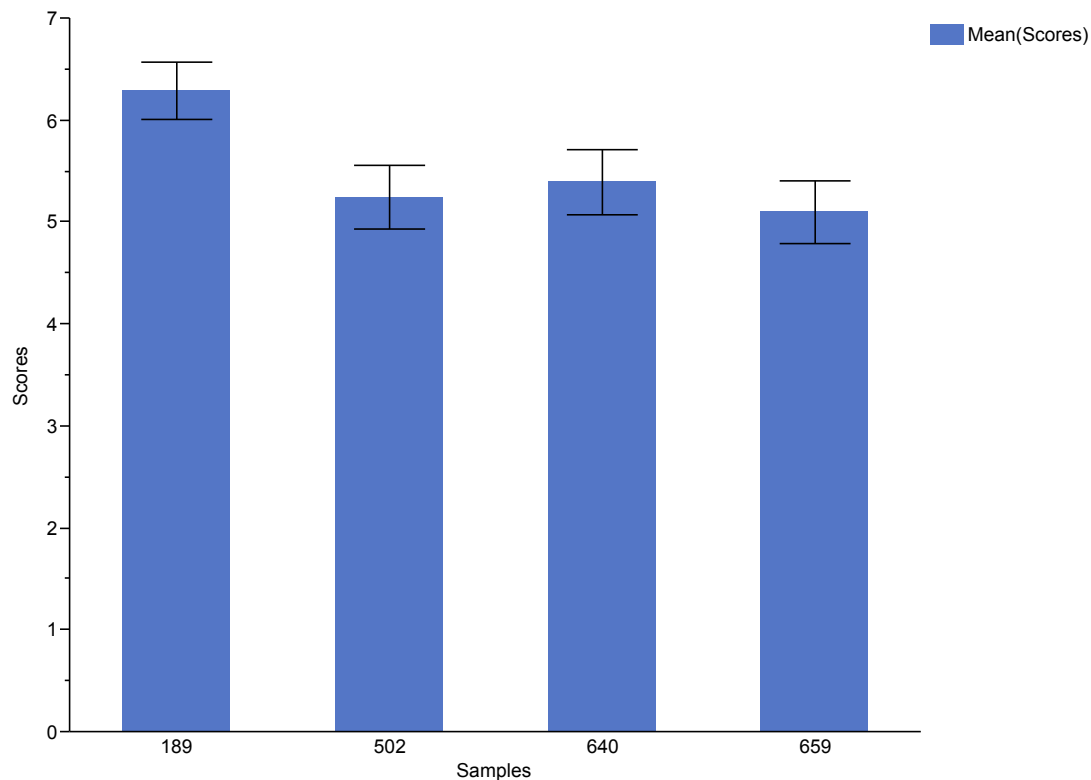


Figure 14. Consumer acceptability on pineapple vinegar

(189= pineapple vinegar, 502= commercial vinegar, 640= combination of pineapple and commercial vinegar, 659= plain water)

Table 14 shows consumer overall acceptability of mango chutney processed using pineapple vinegar, result shows that there was no significant difference in acceptability of mango chutney made between pineapple vinegar and commercial vinegar ($p = 0.63$). Also using t-test result shows that there was significant different on consumer acceptability between mango chutney processed using pineapple vinegar and that processed using commercial vinegar ($t = 0.0443^*$). Highest mean score of 7.24 (hedonic scale) was

observed on pineapple mango chutney, while 6.79 score was observed on commercial mango chutney (table 2).

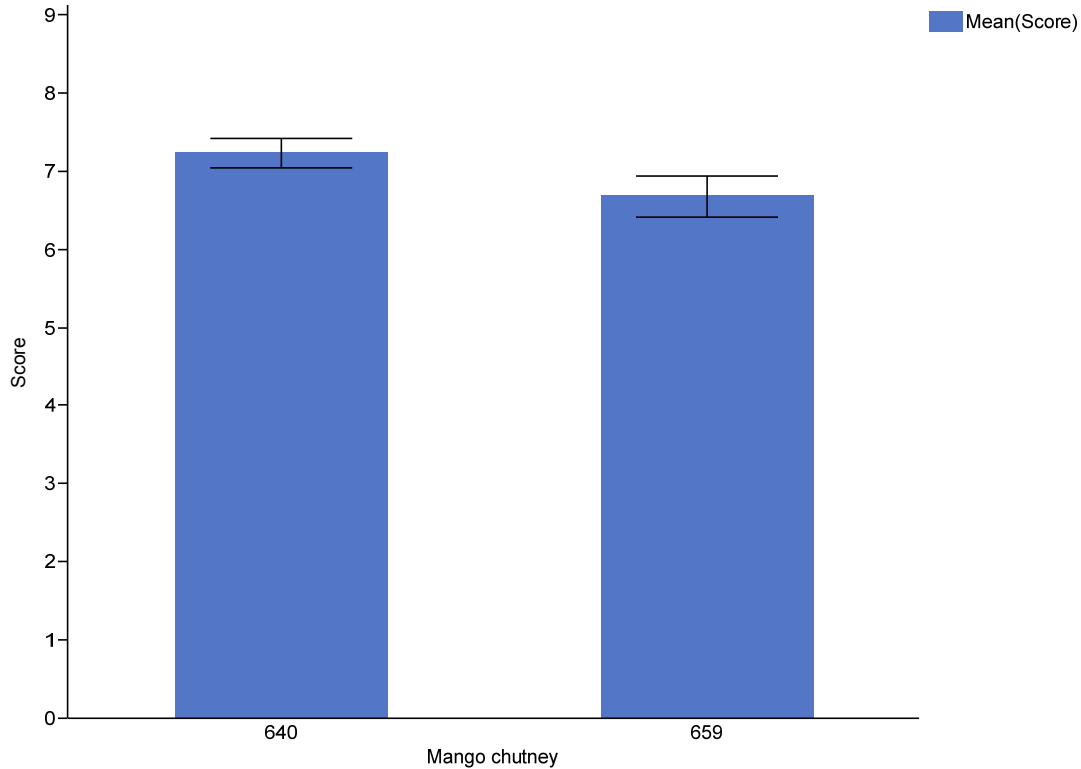


Figure15. Consumer acceptability of mango chutney

(640= pineapple mango chutney, 659= commercial mango chutney)

Figure 15 shows overall consumer acceptability on carrot pickle, result shows that there was no significant difference on acceptability of carrot pickle between carrot pickle processed using pineapple vinegar and that processed using commercial vinegar ($p=0.28$), same result was obtained using t-test which shows that no significant different on consumer acceptability between carrot pickle processed using pineapple vinegar and that processed using commercial vinegar ($t = 0.1416$). Pineapple carrot pickle was highly accepted with mean score 7.13 while carrot pickle processed with commercial vinegar was accepted by 6.79 score (table 2).

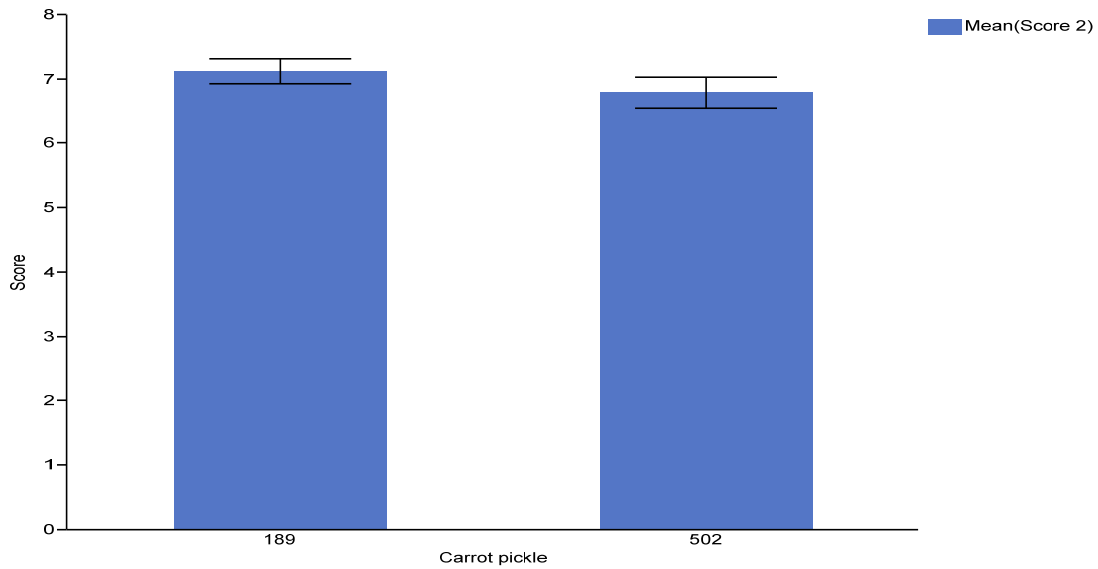


Figure 16. Consumer acceptability on carrot pickle

Table 2. Overall mean score of consumer acceptability on pineapple vinegar, mango chutney and carrot pickle

Sample	Mean score \pm s.d
Vinegar	
Pineapple vinegar	6.29 \pm 2.32
Commercial vinegar	5.25 \pm 2.57
Combination of pineapple and commercial vinegar	5.39 \pm 2.67
Plain water	5.10 \pm 2.50
Carrot pickle	
Carrot pickle (pineapple v.)	7.13 \pm 1.54
Carrot pickle (commercial v.)	6.79 \pm 1.91
Mango chutney	
Mango chutney (pineapple v.)	7.24 \pm 1.49

Mango chutney (commercial v.)

6.68 ± 2.09

(Hedonic scale ranging from dislike extremely = 1, like extremely = 9 was used on assessing consumer overall acceptability).

Chapter 5

5.0 Discussion

It was very important to determine which Brix level is likely to be more effective in pineapple vinegar production to be used by farmers at the village level in Tanzania. *Saccharomyces cerevisiae* yeast and *Acetobacter pasteurianus*, *Gluconobacter oxydans* (bacteria) were used for production of pineapple vinegar. *Saccharomyces cerevisiae* is commonly used yeast and recommended for production of fruit vinegar (Solieri and others 2009). Pineapple juice at 13, 20 or 30 °Brix was used with different bacteria. It was found that overall acetic acid production increased from 0.29-5.50 percent from day 1 to day 28 of acetic acid fermentation. The same result was observed on the study conducted by Sossou 2009 reported an increase in production of acetic acid from 1.1-4.5 percent between days 1-20 of acetic fermentation.

High production of acid was observed for pineapple juice at 13 Brix treated with *A. pasteurianus* and a combination of *A. pasteurianus* and *Gluconobacter oxydans*, ranging from 3.02 to 5.50 percent. Pineapple juice with high Brix contents (20 and 30) showed little production of acetic acid (ranged from 0.26 to 0.40). These values were not significantly different from one another but were significantly lower than vinegar content produced from pineapple juice of 13 Brix content. This result was supported by Sossou 2009 who has reported that the number of strains of acetic bacteria that are able to grow decreases with increased glucose, and at a concentration of 24% sugar, only small number of strains were able to grow. Since sugar is a dehydrating agent often used for preservation, it might have inhibited the growth of acetic bacteria, resulting in low

production of acetic acid in samples with high concentrations of sugar. In samples of 13 Brix pineapple juice, a high production of acetic acid was observed with combinations of the two bacteria *P. pasteurianus* + *G. oxydans*, followed by *A. pasteurianus*, and a low production of acetic acid was observed in pineapple juice fermented with *G. oxydans*. Solieri and others 2009 recommended microorganisms involved in vinegar production: *Acetobacter pasteurianus* was recommended for fruit vinegar while *Gluconobacter* spp was recommended for honey vinegar. Raspor and others 2008 reported *Gluconobacter oxydans* numbers decreased after alcoholic fermentation, and large numbers of acetic bacteria grow in the wine of 7 to 9% v/v alcohol, but if wine is too high in alcohol, above 9%, it needs to be appropriately diluted with water to lower the concentration of alcohol which inhibits the growth of AAB.

Ndoye and others 2006 reported acetic bacteria are gram negative, mostly aerobic, and commonly found in nature on different plants. Seventeen strains of *Acetobacter* bacteria were isolated from tropical fruits in sub-Saharan Africa and were used for industrial production of vinegar; more than half of the species identified belong to the genus *Acetobacter*, while remaining species were identified as *Gluconobacter*.

Impact of bacteria, TSS, time and interaction of these three factors on production of acetic acid in pineapple vinegar, results show that interaction of TSS*time and the interaction of TSS*bacteria significantly influence production of acetic acid in pineapple vinegar ($p < 0.0001$). Interaction effect of total soluble solid (TSS) and time on acetic acid production of pineapple shows that efficiency of acetic bacteria depend on total soluble solid and time, where by acetic acid production on pineapple vinegar increases with decrease in total soluble solid with time of bacteria adaption. Also interaction effect on

total soluble solid and bacteria on acetic acid production of pineapple vinegar shows that high acetic acid production was influenced with tolerance and efficiency of acetic bacteria on total soluble solid. Tesfaye and others 2000 describe that high concentration of alcohol which result from high total soluble solid had a negative influence on bacterial growth, hence result into poor production of vinegar. Vegas 2010 shows that acetic acid bacteria had successful shows maximum concentration of acetic acid production with time increase. Maal and Shafiee 2009 on interaction effect of ethanol concentration and temperature on strain and acetic acid production suggested that concentration of ethanol influences the temperature tolerance of strain and the sensitivity of strain to high temperature is increased and bacterium need more time to adapt to new stress condition.

Vinegar lowered the pH of preserved carrot (carrot pickle) and mango (mango chutney) to a pH of less than 4, which can help enhance the shelf life of the preserved foods by inhibiting the growth of harmful microorganisms. Vinegar lowers pH of foods where it is used as an ingredient because of its acetic acid content. There was no significant difference in pH of carrot pickle and mango chutney produced using pineapple and commercial vinegars, showing that the pineapple vinegar produced using low technology procedures would be as effective in preserving fruit as imported commercial vinegar. Sultan and others 2014 processed carrot pickle by lowering the pH to 4.47. Samples were stored for three months at 20⁰C to 32⁰C to monitor physical changes; they reported that physical properties such as color flavor and texture were well-retained. Khan and others 2005 reported that spoilage of oil pickle only occurred at pH 5.0 and above. The pH of the preserved carrot and mango was < 4.0 and would be expected to remain safe during storage. The quality of processed food is influenced by the quality of

ingredients used, so during the processing of carrot pickle and mango chutney, the quality of all ingredients was taken into consideration by following the principles of good agricultural practices (GAP), good manufacturing practices (GMP) and good hygiene practices (GHP). Acetic acid, sugar, salt and heat were applied in the processing of carrot and mango, and the pH was less than 4. Lee 2004 in a study of microbial safety of pickled fruits and vegetables reported that utilization of acetic acid, heat and salt contributed to the microbial safety of the preserved fruits and vegetables.

The mean score for the taste and overall acceptability of pineapple vinegar, carrot pickle and mango chutney are shown in Table 5. The mean score for overall acceptability in pineapple vinegar was 6.29 (like slightly), which was higher than the control vinegar, which was 5.25 (neither like nor dislike according to the hedonic scale), this was followed with 5.39 of combined pineapple and commercial vinegar and 5.10 for plain water which was lowest. High acceptability of pineapple vinegar was high influenced with 31% of panelist who like mostly, 22% panelist who like very much, 20% panelist who like slight, 19% panelist like extremely, 4% panelist neither like nor dislike and 1% panelist dislike the product very much (appendix H). Overall consumer acceptability on commercial vinegar was influenced with 27% panelist like most, 21% panelist like slightly, 20% panelist like very much, 10% panelist like extremely, 8% neither like nor dislike and 1% panelist dislike the product extremely(appendix I). Also multiple linear regression which was used to assess the impact of gender, rate of consumption, and age on the overall acceptability shows that vinegar rate of consumption had a significant influence on acceptability ($p < 0.0001$). From demographic information collected only 4.4% of panelists consume vinegar frequently, 26.5% consume vinegar once per month

and 64.7% rarely or never consumer vinegar which has influence result of overall consumer acceptability of vinegar, same reason was explained by Biachi and Duncan 2014 who reported that people who never consumed soymilk were less able to tell the difference between improved and control soymilk compared to regular soymilk users.

Consumer acceptability of carrot pickle and mango chutney processed using pineapple vinegar had mean scores of 7.13 for pineapple carrot pickle and 6.75 for commercial carrot pickle, this result was influenced with 35% panelist who like mostly, 30% panelist who like very much, 20% panelist who like extremely, 3% panelist who neither like nor dislike and 2% panelist who dislike much carrot pickle processed with pineapple vinegar (appendices J). On consumer acceptability of commercial carrot pickle the overall mean score of 6.75 which was low compare to that of pineapple carrot pickle was influenced by 35% panelist who like much, 31% panelist who like very much, 16% panelist at 9 score, 2% panelist neither like nor dislike the product and <4% panelist dislike the product (appendix K).

Overall consumer acceptability of mango chutney shows that mango chutney processed using pineapple vinegar was more accepted by consumer at 7.24 compared to that of mango chutney processed using commercial vinegar which scores 6.68. Overall mean score of mango chutney processed using pineapple vinegar was influenced by 33% panelists who like very much, 23% panelist who like extremely, 23% panelist who like mostly, 17% panelist who like slightly and 1% panelist who dislike the product mostly (appendix L). Also mean overall acceptability of mango chutney processed using commercial vinegar was influenced by 40% panelist who like very much, 28% panelist like mostly, 12% panelist extremely like and 2% panelist dislike mostly (appendix M).

There was no significant difference in the preference of carrot and mango preserved using pineapple vinegar compared to the control vinegar. As it has been mentioned above, although most of the panelists were not consumers of the vinegar, the panelist liked the products made from both pineapple and control vinegar.

The vitamin C contents of preserved carrot pickle decrease from 9.98 mg/100g in fresh carrot to 2.3 mg/100g, while that of fresh mango decrease from 247 to 36 mg/100g in preserved mango (mango chutney). Vitamin C is among the most important vitamins found in fruits and vegetables. The decreased level of vitamin C of preserved carrot and mango was most likely due to the heat treatment applied during processing of carrot pickle and mango chutney. The total loss of vitamin C in carrot pickle was 76% while loss of vitamin C of mango chutney was 85%. Amounts of vitamin C in preserved mango flours were 109.7 mg/g for green peel flour, 94.1 mg/g for green pulp, 52.5 mg/g for ripe peel flour and 71.4 mg/g for ripe pulp flour Aziz and others 2011. Sultana and others 2014 reported high loss of vitamin C in fermented carrot (carrot pickle); about 99%, his analysis vitamin C of fresh carrot was 8.56mg/100g while that of carrot pickle was 0.0001 mg/100g. Tressler and others 1936 showed effects of cooking on vitamin C content on peas, snap beans and cabbage, where around 1/3 of the vitamin C was dissolved in the cooking water after twenty minutes. This shows that cooking time and cooking temperature have influences on the loss of vitamin C content. Carrot and mango were processed for thirty minutes at low cooking temperatures which increase the losses of vitamin C. Maturity of fruits and vegetable also impacts the level of vitamin C. The high content of vitamin C in mangos in our study was likely affected by the maturity of

the mango used, because they were still unripe. Aziz 2012 showed green mango flours found to have higher vitamin C content compared to ripe mango flours.

In this study, vitamin A contents of the fresh and preserved fruit and vegetables were different; carrot Vitamin A decreased from 59.2 $\mu\text{g/g}$ – 24.5 $\mu\text{g/g}$ while mango was increased from 2.9 $\mu\text{g/g}$ – 13.0 $\mu\text{g/g}$. Heat treatment impacts the color of fruit and vegetables; color intensity of some fruits and vegetable increases while other fruits and vegetable decrease in color intensity on heat treatment Fellows 2009. Time of heating also impacts the color intensity of foods. This impact has been observed in this study where carrot pickle show depletion of its vitamin A compared to fresh carrot. The vitamin A content of mango was low compared to carrot because of the maturity of the mango which was unripe with just little yellow color, which was enhanced with combination with other ingredients like grape, onion, chilies, garlic and ginger on the recipe used. Aziz 2012 reported that the carotenoid level of mango increases with increase intensity of color during growth of mango, where by high carotenoid level was found on ripe pulp flours than in green mango flours.

According to FAO and WHO 2004 recommended dietary intake of vitamin A was distributed in age group as follow; 375RE for children of one year, 400RE for 1-3years children, 500RE for 4-6years, 800RE for female and pregnant women and 1300RE for lactating women. So from this study carrot pickle and mango chutney can be used to reduce vitamin A deficiency in children less than five years, pregnant women and lactating women by daily consumption of 97.9g carrot pickle for children of 1-3years, 122.4g carrot pickle for 4-6years children, 195.9g carrot pickle for pregnant women and 318.3g carrot pickle for lactating women. To get a recommended amount of vitamin A

from consumption of mango chutney, it will require 184.6g for 1-3years children, 230.7g for 4-6years children, 323g for pregnant women and 600g for lactating women.

Vitamin C recommended dietary intake was described with FAO and WHO 2004 as follow 30mg for 1-6years children, 55mg pregnant women and 70mg for lactating women daily. In order to reduce vitamin C deficiency in Tanzania mango chutney can be consumed as part of diet in every meal of Tanzanian, where by 83g of mango chutney for 1-6years children, 152.7g of mango chutney for pregnant women and 194.4 of mango chutney for lactating woman can be consumed to meet recommended intake of vitamin C. Also same amount of recommended vitamin C can be obtain by daily consumption of carrot pickle where by 1304.3g for 1-6years, 2319g for pregnant women and 3043g for lactating women.

Chapter 6

Conclusions and Recommendations

Concentration of sugar and type of bacteria impacted the production of acetic acid in pineapple vinegar production. This should be further studied for introducing vinegar production in Tanzania to enhance food security by lowering fruit and vegetable losses during high production season. From this study, results show that production of pineapple vinegar can be used to reduce fruit and vegetable losses.

References

- Adesina AA, Oguntimein GB and Obisanya MO. 1992.** Kinetic analysis of fermentation of mango juice. *Lebensm wiss, u.technol*, (26) 79-82(1993).
- Akubor PI. 1995.** The suitability of African bush mango juice for wine production. *Plant Food for Human Nutrition* 49: 213-219.
- Ameyapoh Y, Leveau JY, Karou SD, Bouix M, Sossou SK. and Souza CDe. 2010.** Vinegar Production from Togolese Local Variety of Mango *Mangifera indica* linn (*Anacardiaceae*) scialert.net/fulltext/?doi=pjbs.2010.132.137&org=11
- Arumugam R and Manikandan M. 2011.** Fermentation of Pretreated Hydrolyzate of Banana and Mango Fruit Wastes for Ethanol Production. *Asian J. Exp. Biol. Sci.* Vol 2(2).
- Aziz NAA, Wong LM, Bhat R and Cheng LH. 2012.** Evaluation of processed green and ripe mango peel and pulp flours (*Mangifera indica* var. Chokanan) in terms of chemical composition, antioxidant compounds and functional properties. *Journal of the Science of Food and Agriculture*, 92, p.557-563.
- FAO and WHO (2004)** Vitamin and Mineral requirements in human nutrition, Second edition, Rome Italy.
- FAO 2008.** "Commodity market review, commodity and trade division" Food and Agriculture Organization of the United Nations, Rome, 2010.
- FAO/WHO. 2004.** "Fruits and Vegetables for Health" workshop 1-3 September 2004, Kobe, Japan .
- Fellows PJ. 2009.** Food Processing Technology, Principles and Practices, 3rd edition, Elsevier.

- Horticonsults (ltd) 1993.** The Horticulture Industry in Tanzania, Under assignment by the United States Agency for International Development (USAID/Tanzania)
- Kader A, Department of Pomology and Davis UC. 2001.** Importance of fruits, nuts and vegetables in human nutrition and health. *Perrishables handling quarterly*, Issue No. 106, p. 4-6
- Khan SH, Muhammad F, Idrees I, Shafique M, Hussain I and Farooq1 H. 2005.** Some studies on spoilage fungi of pickle. *Journal of Agriculture and Social Science* Vol 1, No 1.
- James IF and Kuipers B. 2003.** *Agrodok 3 Preservation of fruit and vegetables.* Agromisa Foundation, Wagenigen, 4th edition. ISBN: 9077073302.
- Lee S Y. 2004.** Microbial safety of pickled fruits and vegetables and Hurdle Technology. *Journal of Food Safety* Vol 1, p. 21-32.
- Maal BK and Shafiee R. 2009.** Isolation and Identification of *Acetobactor* strain from Iranian White- Red Cherry with High Acetic Acid Productivity as a Potential strain for Cherry Vinegar Production in Food and Agriculture Biotechnology, *Word Academy of Science, Engineering and Technology*, Vol. 3, p. 06-23.
- Match Maker Associates ltd.2011.** Mango Value Chain Analysis (VAC) in Tanzania Final report January 2011.
- Mershall E and Mejia D. 2011.** Traditional fermented food and beverages for improved livelihoods. *Diversification booklet number 21*, Rome 2011.
- Ramonyai D and Konstant H. 2006.** Country profile of the republic of Tanzania (Agricultural trade), report presented to Common wealth.

Raspor P and Goranovic D. 2008. Biotechnological application of acetic acid bacteria.

Department of Food Science and Technology, University of Ljubljana, Ljubljana, Slovenia.

Reddy LV and Reddy OVS. 2009. Production, Optimization and characterization of
from mango (*Mangifera indica* Linn) .National production radiance, vol 8 (4). Pp
426-435.

Reddy LVA and Reddy OVS. 2010. Effect of fermentation conditions on yeast growth
and volatile composition of wine produced from mango (*Mangifera indica* L.)
fruit juice. Food and products processing 89 (20 II) 487-491

Reddy LVA and Reddy OVS. 2005. Production and characterization of wine from
mango fruits (*mangifera indica* L.). World journal of microbiology and
biotechnology (21): 1345- 1350.

Solieri L and Giudici P. 2009. Vinegars of the World, Springer V, Italy.

Sossou SK, Ameyapoh Y, Karou SD and Souza CD. 2009. Study of pineapple peelings
processing into vinegar by Biotechnology. Pakistan Journal of Biological Science.
12(11):859-865, 2009.

Sultana S, Iqbal A and Islam MN. 2014. Preservation of carrot, green chilli and brinjal
by fermentation and pickling. Department of Food Technology & Rural
Industries, Bangladesh Agricultural University. International Food Research
Journal 21(6): 2405-2412.

Tesfaye W, Parrilla GC and Troncoso MA. 2000. Set Up and Optimization of a
Laboratory Scale Fermentor for the Production of Wine Vinegar. Journal of the
Institute of Brewing 106, No 4, p.215-219.

Tressler DK, Mack GL and King CG. 1936. Factors influencing the vitamin C Content of vegetables. Chemistry Department, University of Pittsburgh, Pittsburgh, Pa.

Vegas C, Mateo E, Gonzales A, Jara C, Guillamon MJ, Poblet M, Torija J M and Mas A. 2010. Population Dynamic of Acetic Acid Bacteria during Traditional Wine Vinegar Production. International Journal of Food Microbiology, 138, p. 130-136, 2010.

Webb AD and Updated by stuff. 2007. Vinegar , Kirk-othmer Encyclopedia of chemical Technology.

WHO/FAO .2003. Dietary recommendations and report of joint WHO and FAO expert consultation on diet, nutrition and prevention of chronic disease. WHO technical report series 960.

APPENDICES

Appendix A: Demographic questionnaire

(Cycle which is appropriate)

1. Gender

- Female
- Male

2. Age group

- 18-24yrs
- 25-34yrs
- >35yrs

3. Which group do you fit

- Undergraduate
- Graduate
- Staff

4. How many time do you use vinegar

- Daily
- Once in week

- Once in month/ rare

5. What type of vinegar do you use? _____.

6. How often do you buy preserved fruits/vegetables

- Daily
- Once in week
- Once in month/rare

7. Do you preserve fruits and vegetables

- Yes
- No

If yes continue with number 8 -10

8. How often do you preserve

- Seasonally
- Frequently
- None

9. Which methods do you use in preserve fruits and vegetables

- Drying
- Salting/sugar
- Smoking
- Pickling
- Other
- None

10. Which fruits and vegetables do you preserve and why?

Pass the tray to investigator wait for another sample.

Appendix B: Score sheet (a)

Score sheet for consumer preference test

Panelist # _____ Date _____

Product: Preserved carrot.

Please taste the sample from left to right and check how much you like or dislike each one, use water and cracker after each test.

Sample code	189	502
like extremely	_____	_____
like very much	_____	_____
like moderately	_____	_____
like slightly	_____	_____
neither like nor dislike	_____	_____
dislike slightly	_____	_____
dislike moderately	_____	_____
dislike very much	_____	_____
dislike extremely	_____	_____

Comments:

Please pass the tray, wait for the next sample

Appendix C: Score sheet (b)

Score sheet for consumer preference test

Panelist # _____ Date _____

Product: Preserved mango

Please taste the sample from left to right and check how much you like or dislike each one, use water and cracker after each test.

Sample code	640	659
like extremely	_____	_____
like very much	_____	_____
like moderately	_____	_____
like slightly	_____	_____
neither like nor dislike	_____	_____
dislike slightly	_____	_____
dislike moderately	_____	_____
dislike very much	_____	_____
dislike extremely	_____	_____

Comments:

You are now done with the sensory testing, pass the questionnaire to the investigator and exit through the back down.

Appendix D: Work sheet (a)

Date _____	Worksheet _____	No _____	Test code _____															
<p>Post this sheet in the area where trays are prepared. Please follow this order when presenting the sample to panelist.</p>																		
<p>Type of sample: Preserved Carrot</p> <p>Type of test: Overall preference test</p>																		
<p>Sample identification: Code used for:</p>																		
<p>A: Lab code 189</p> <p>B: Lab code 502</p>																		
<p>Code serving containers as follows:</p> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Subject #</th> <th style="text-align: left;">Code in order</th> <th style="text-align: left;">Underlying</th> </tr> </thead> <tbody> <tr> <td>1, 5,9,13,17,21,25,29,31,37,41,45,49,53,57</td> <td>189 , 502</td> <td>AB</td> </tr> <tr> <td>2, 6,10,14,18,22,26,30,34,38,42,46,50,54,58</td> <td>502, 189</td> <td>BA</td> </tr> <tr> <td>3, 7,11,15,19,23,27,31,35,39,43,47,51,55,59</td> <td>189, 502</td> <td>AB</td> </tr> <tr> <td>4, 8,12,16,20,24,28,32,36,40,44,48,52,56,60</td> <td>502, 189</td> <td>BA</td> </tr> </tbody> </table>				Subject #	Code in order	Underlying	1, 5,9,13,17,21,25,29,31,37,41,45,49,53,57	189 , 502	AB	2, 6,10,14,18,22,26,30,34,38,42,46,50,54,58	502, 189	BA	3, 7,11,15,19,23,27,31,35,39,43,47,51,55,59	189, 502	AB	4, 8,12,16,20,24,28,32,36,40,44,48,52,56,60	502, 189	BA
Subject #	Code in order	Underlying																
1, 5,9,13,17,21,25,29,31,37,41,45,49,53,57	189 , 502	AB																
2, 6,10,14,18,22,26,30,34,38,42,46,50,54,58	502, 189	BA																
3, 7,11,15,19,23,27,31,35,39,43,47,51,55,59	189, 502	AB																
4, 8,12,16,20,24,28,32,36,40,44,48,52,56,60	502, 189	BA																

Appendix E: Work sheet (b)

Date _____ Worksheet _____ No _____ Test code _____															
Post this sheet in the area where trays are prepared. Please follow this order when presenting the sample to panelist.															
Type of sample: Preserved mango Type of test: Overall preference test															
Sample identification: Code used for:															
A: Lab code 640 B: Lab code 659															
Code serving containers as follows:															
<table border="1"> <thead> <tr> <th>Subject #</th> <th>Code in order</th> <th>Underlying</th> </tr> </thead> <tbody> <tr> <td>1, 5,9,13,17,21,25,29,31,37,41,45,49,53,57</td> <td>659 , 640</td> <td>BA</td> </tr> <tr> <td>2, 6,10,14,18,22,26,30,34,38,42,46,50,54,58</td> <td>640, 659</td> <td>AB</td> </tr> <tr> <td>3, 7,11,15,19,23,27,31,35,39,43,47,51,55,59</td> <td>659, 640</td> <td>BA</td> </tr> <tr> <td>4, 8,12,16,20,24,28,32,36,40,44,48,52,56,60</td> <td>640, 659</td> <td>AB</td> </tr> </tbody> </table>	Subject #	Code in order	Underlying	1, 5,9,13,17,21,25,29,31,37,41,45,49,53,57	659 , 640	BA	2, 6,10,14,18,22,26,30,34,38,42,46,50,54,58	640, 659	AB	3, 7,11,15,19,23,27,31,35,39,43,47,51,55,59	659, 640	BA	4, 8,12,16,20,24,28,32,36,40,44,48,52,56,60	640, 659	AB
Subject #	Code in order	Underlying													
1, 5,9,13,17,21,25,29,31,37,41,45,49,53,57	659 , 640	BA													
2, 6,10,14,18,22,26,30,34,38,42,46,50,54,58	640, 659	AB													
3, 7,11,15,19,23,27,31,35,39,43,47,51,55,59	659, 640	BA													
4, 8,12,16,20,24,28,32,36,40,44,48,52,56,60	640, 659	AB													

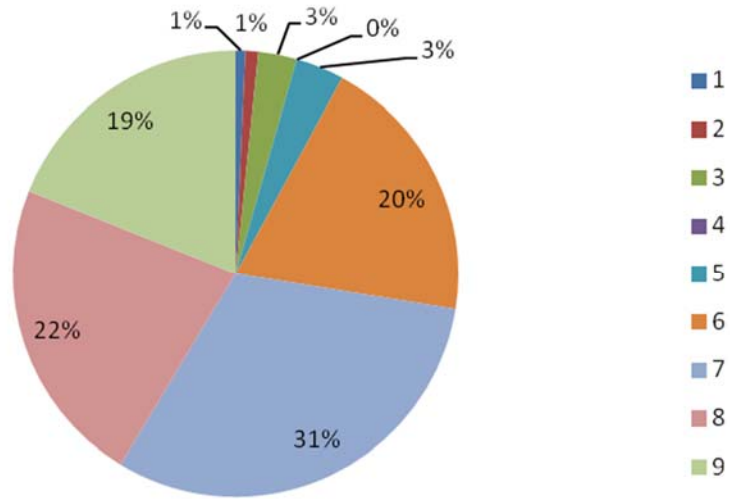
Appendix F. Score sheet for consumer sensory test on pineapple vinegar.

Score sheet for consumer preference test					
Panelist # _____	Date _____				
Product: Pineapple vinegar					
Please taste the sample from left to right and check how much you like or dislike each one, use water and cracker after each test.					
	Sample code	659	189	502	640
like extremely		_____	_____	_____	_____
like very much		_____	_____	_____	_____
like moderately		_____	_____	_____	_____
like slightly		_____	_____	_____	_____
neither like nor dislike		_____	_____	_____	_____
dislike slightly		_____	_____	_____	_____
dislike moderately		_____	_____	_____	_____
dislike very much		_____	_____	_____	_____
dislike extremely		_____	_____	_____	_____
Comments:					

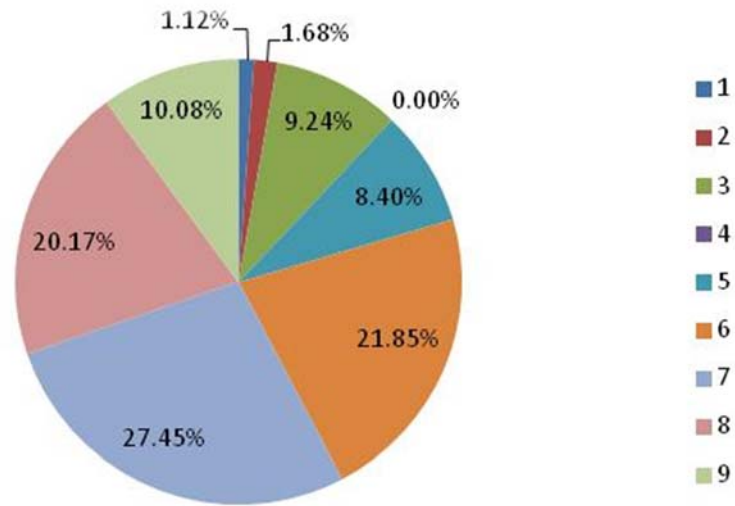
Appendix G. Working Sheet on Consumer sensory test on pineapple vinegar.

Four samples of vinegar.	
Vinegar A, B, C and D	
Sample presentation to the panelist is through randomize block design	
ABCD	
BCDA	
CDAB	
DABC	
Panelist	Sample presentation
1,5,9,13,21,25,29,33,37,41,45,49,53,57	189, 502, 640, 659
2,6,10,14,18,22,26,30,34,38,42,46,50,54,58	502, 640, 659, 189
3,7,11,15,19,23,27,31,35,39,43,47,51,55, 59	640, 659, 189, 502
4,8,12,16,20,24,28,32,36,40,44,48,52,56,60	659, 189, 502, 640

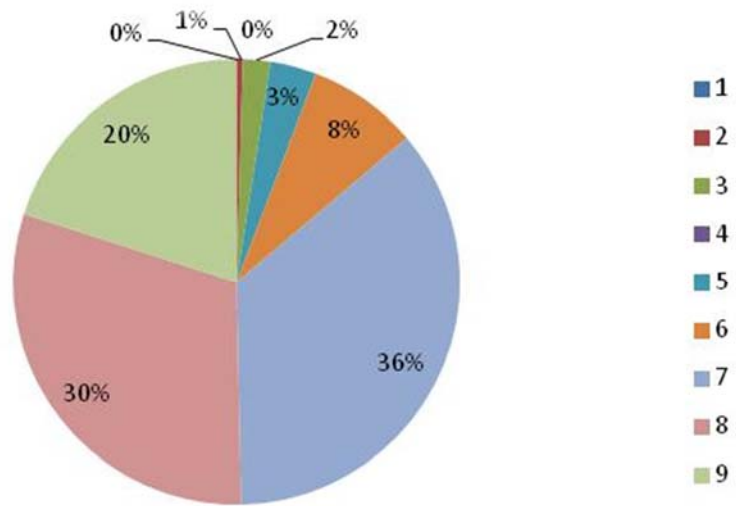
Appendix H. Distribution % of consumer acceptability on pineapple vinegar



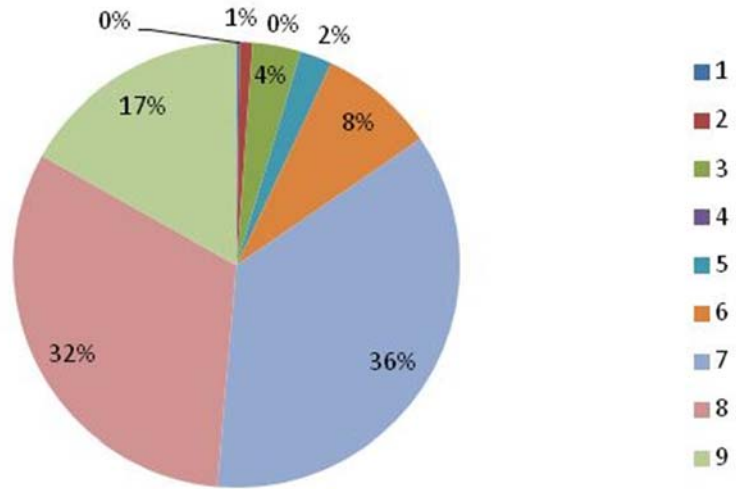
Appendix I. Distribution % of consumer acceptability on commercial vinegar



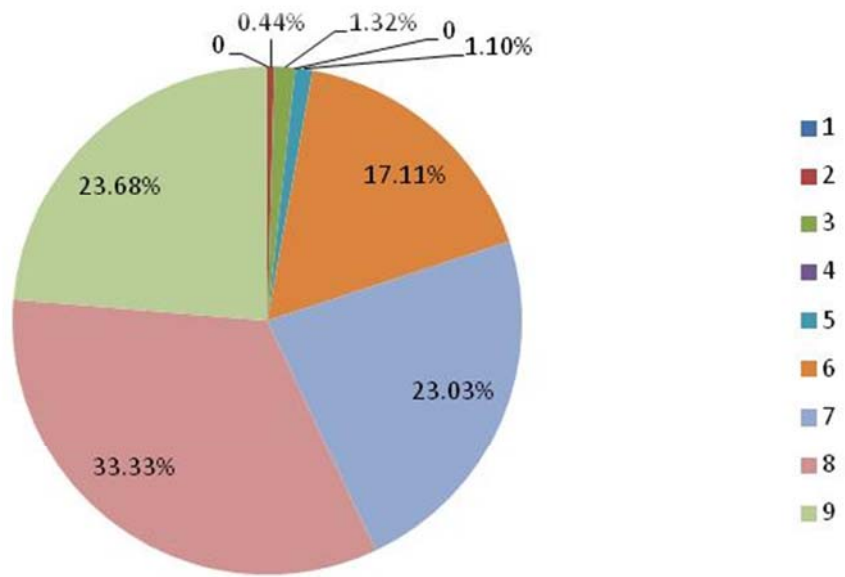
Appendix J. Distribution % of consumer acceptability of pineapple carrot pickle



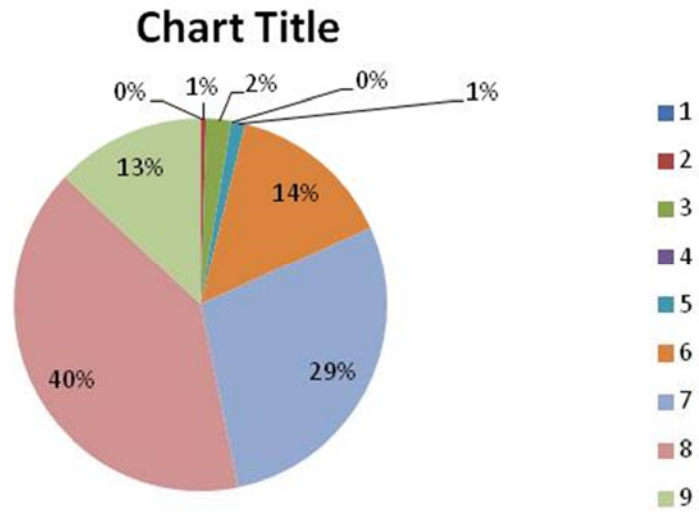
Appendix K. Distribution % of consumer acceptability on commercial carrot pickle



Appendix L. Distribution % of consumer acceptability on pineapple mango chutney



Appendix M. Distribution % of consumer acceptability on commercial mango chutney



Appendix N. Fresh pineapple



Appendix O. Fresh carrot



Appendix P. Fresh mango



Appendix Q. Processing of pineapple to extract juice.



Appendix R. Alcohol fermentation



Appendix S. Acetic fermentation



Appendix T. Sample collection



Appendix U. Control vinegar



Appendix V. Consumer sensory test on pineapple vinegar.



Appendex W. Preserved carrot (carrot pickle)



Appendix X. Preserved mango (mango chutney).



Appendix Y. Consumer sensory test on carrot pickle and mango chutney

