Conference Proceedings

The 1st International Conference on Agriculture, Food Security and Safety

(AgroFood 2019)

07th-08th November 2019 | Colombo, Sri Lanka

Committee of the AgroFood 2019

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www.agrofoodconference.com

Book of Abstracts of the 1st International Conference on Agriculture, Food Security & Safety (AgroFood 2019)

Edited by Prof. Samih Abubaker and Dr. Asna Urooj

ISSN 2682-7158

Published by iConferences, No: 178/13/B6, Gamsabha Road, Kelanimulla, Angoda, 10620, Sri Lanka

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Fax: +94(0) 11 2419433

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MESSAGE FROM THE CONFERENCE CO-CHAIR AgroFood 2019

Food security is both a complex and challenging issue to resolve, it can happen when all people are able to access enough safe and nutritious food to meet their requirements for a healthy life. However, Food security faces a number of challenges across both production and consumption which research will be essential to solve. Many countries are facing the double burden of hunger and under-nutrition alongside overweight and obesity, with one in three people across the globe currently suffering from some form of malnutrition. World Food Day reminds us of the fragility of food security in the 21st century. Rising populations, rising incomes and changing diets coupled with falling water tables, increasing soil erosion and climate are the challenges the world today is facing to ensure Global Food Security. The International Conference on Agriculture, Food Security and Safety 2019 under the theme: "Global Food Security; Reality and Challenges" to be held on 7-8 Nov 2019 at Colombo is a great platform which brings together scientists, academia, policy makers, and all stake holders to address these challenges, increase coordination and collaboration on research and to facilitate its translation into policy and practice.

The Department of Studies in Food science and Nutrition, University of Mysore, India takes pride to participate in this event as an academic partner.

I wish all delegates a fruitful deliberations and the event a great success.

Dr. Asna Urooj
Professor and Chairperson of the post- graduate Department of Studies in Food science & Nutrition, University of Mysore, India
Conference Chairperson – AgroFood 2019

Table of Contents Page No

Proceeding of the International Conference on Agriculture, Food Security and Safety, Vol. 1, 2019, pp. 1-17

ISSN 2682-7158

Effect of Repeated Deep Frying on Oxidative Stability and Quality of Coconut Oil

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Abstract

This study was conducted to find the effect of repeated deep frying on the quality of coconut oil. Coconut oil was heated at 180°C for 20 minutes with or without food, for ten repeated frying cycles. Samples were tested for oxidative stability and physicochemical properties using standard methods. Free fatty acid content and thiobarbituric acid reactive substances (TBARS) increased significantly (p<0.05) while saponification value and iodine value decreased significantly (p<0.05) with increasing number of frying cycles. When oil was heated without food, peroxide value increased significantly (p<0.05) over the frying cycles. However, when oil was heated with food, peroxide value increased significantly (p<0.05) until the sixth cycle and thereafter decreased significantly (p<0.05) as a result of degradation of peroxides into secondary oxidation products. There were no significant (p>0.05) differences in the peroxide values and TBARS values when the oil was heated with or without food, since water released from the food acts as a barrier for oxygen and inhibits formation of peroxides and secondary oxidation products. Free fatty acid content increased significantly (p<0.05), only when oil was heated with food due to the hydrolysis of triglycerides in the presence of water. It indicates, repeated heating of coconut oil had a significantly (p<0.05) negative effect on its oxidative stability and physicochemical properties compared to the accepted limits. However, coconut oil can be used for maximum of 2-4 repeated deep frying cycles, while maintaining its quality under the specified limits of CODEX guidelines.

Keywords: deep frying, hydrolysis, oxidation and polymerization

Introduction

Fried foods are very famous and one of the most frequently consumed food throughout the world due to its desirable flavor, color and crispy texture (Boskou *et al*. 2006). Edible oil provides energy, essential fatty acid and serves as a carrier of fat soluble vitamins and it is an inevitable portion of our meal. Deep fat frying is one of the most commonly used methods for food processing from the ancient time since it is rapid and develops unique sensory characteristics (Sanibal and Mancini, 2004). During deep frying, food is completely immersed in hot oil at the temperature of 150 to 190°C with contact among oil, air and food (Romano *et al*. 2012). The oil is subjected to degradation during deep frying, as a result of the movement of water vapor and other compounds from food into the oil along with the combination of high frying temperature (Mellema, 2003). During repeated frying, oil is subjected to deteriorative chain reactions such as hydrolysis, thermal oxidation, isomerization and polymerization (Abiona et al. 2011). These changes contribute to the loss of essential fatty acids and development of objectionable flavor, color, odor and altered texture of fried foods, thus reducing palatability (Tian *et al*. 2000). The primary and secondary oxidative products produced by lipid oxidation are peroxides, hydroperoxides, aldehydes, ketones, acids and alcohols (Choe and Min, 2007). These compounds do not only affect the sensory quality of fried foods but also can cause potential hazards to human health and have adverse nutritional implications (Sanibal and Mancini, 2004).

A study has reported that coconut and coconut oil is the main source of fats and proteins consumed by most Sri Lankans which provide approximately 22% of calorie intake (Jayasekara, 2004). Sri Lanka is considered as the highest per capita consumer of coconut in the world with an average of 110 coconuts per annum (Peiris, 2004). Moreover, coconut oil is mainly consumed by rural areas of Sri Lanka, which comprise 70% of the total population. Recently the use of coconut oil for deep frying has become as a trend to reduce the health risks arising from trans fats because coconut oil is considered to be the most stable oil for deep frying due to the high level of saturation compared to other edible oils (Manchanda and Passi, 2016). In Sri Lanka, "*Vade*" is the most popular street food among local people and visitors. It is also frequently prepared in many households in Sri Lanka. For the preparation of "*Vade*" many street vendor use coconut oil and to reduce the expenses they use this coconut oil repeatedly until it is no longer suitable for consumption since the price of oil is increasing. In addition, some food industries like fast-food restaurants, hotels, etc. and many households also use frying oils repeatedly. This has become a common practice due to the low level of awareness among the public about the negative health and nutritional effects caused by the compounds generated during deep fat frying.

There are no any limits for the maximum number of cycles that the coconut oil can be used repeatedly and there is some evidence which emphasized the negative effects of reusing frying oils on the sensory and nutritional quality of fried food and about the safety concerns. Therefore, it is necessary to understand the oxidative and physicochemical changes that occur during repeated frying to monitor the quality and safety of fried products and to enhance the knowledge of the public, street vendors and food industries about the negative impacts of repeated usage of frying oil to maintain a healthy lifestyle. For the efficient usage of coconut oil by street vendors and food industries, it is important to determine the appropriate point between the usage of oil and the safety and quality of fried foods on the basis of the number of repeated frying. Studies conducted worldwide have reported the oxidative and physiochemical changes occur during repeated deep frying of several edible oils. However, no such research has been conducted in recent years to assess the oxidative and physicochemical changes occur in the coconut oil during repeated heating without any food and during repeated frying of "*Vade*" in Sri Lanka. Hence, the aim of this study was to explore the oxidative and physicochemical changes occur in the coconut oil samples collected from five different oil processing mills in Western and North Western province of Sri Lanka, during repeated heating without food and during repeated frying of "*Vade*" and to determine the maximum number of cycles that coconut oil can be used repeatedly to fry "*Vade*" in relation to food quality and safety.

Materials and Methods

This study was carried out at the Department of Food Science and Technology, Faculty of Agriculture, University of Peradeniya, Sri Lanka. A total of five coconut oil (copra oil) samples without any adulteration, of each 5 L were directly purchased from five different coconut oil processing mills located in the Western and North Western province of Sri Lanka. All the ingredients needed to prepare "*Vade*" batter were purchased from the local market in Kandy. All chemicals used in this study were of analytical grade with the highest purity available (> 99.5 %) and obtained from Sigma Aldrich, USA. A standard formulation was used to prepare the "*Vade*" batter for the repeated deep frying in all coconut oil samples.

Heating of Oil

The coconut oils were divided into two equal volumes of 2.5 L. The deep fat frying experiment was done as two parts. First was heating of oil without food and the second was heating of oil with food. In both, repeated heating of coconut oil was carried out in a stainless steel frying pan. A constant temperature was maintained throughout the heating process after heating the oil to a temperature of 180±5°C and heating was continued exactly for 20 minutes. When heating the oil with food, the prepared "*Vade*" batter was introduced into each coconut oil samples after bringing the temperature to 180±5°C and the ratio of oil to "*Vade*" batter was maintained as 10:3 (V/W). All coconut oil samples were reused for nine more frying cycles (ten frying cycles in total). Following each heating cycle, the oil was allowed to cool to room temperature. Triplicate samples (150 mL) were drawn at the end of each second, fourth, sixth and tenth cycle of repeated heating of all coconut oil samples without and with food in glass bottles. Sample bottles were sealed well and stored at refrigerator until chemical analysis. A control sample (150 mL) devoid of any heating or frying process was also collected as triplicate and it was used for comparative purpose.

Analysis of Oxidative and Physiochemical Changes in the Coconut Oil

To analyze the chemical changes in the oil, free fatty acid contents were determined according to the official method AACC (2000), saponification value was measured according to the official methods AOAC (2010a) with slight modification and the iodine value was determined according to Diop *et al*. (2014), which was based on ISO (2009). To analyze the oxidative changes in the oil, peroxide value of oil was measured according to the official methods AOAC (2010b), TBA value was measured using the TBARS assay according to the method described by Devasagayam *et al.* (2003) with some modifications. Trans fats were analyzed according to the AOCS (2017a). The color of the oil was measured using the spectrophotometric method as described by Elisavet and Pavel (2014) which was based on AOCS (1989).

Statistical Analysis

The data were analyzed using SAS software version 9.0. All measurements were performed in triplicate and results are expressed as mean±SD. The ANOVA tables were constructed using nested design and PROC GLM procedure. Duncan's multiple range test was used to determine significant differences at 0.05 significant levels.

Results and Discussion

Free Fatty Acid (FFA) content

FFA content reflects the number of fatty acids removed from triacylglycerol structure through hydrolysis and it is one of the indicators of oil deterioration, which mainly measures the degree of hydrolysis. The SLS (SLS 32:2002) and the Codex recommended standards for FFA content of coconut oil are 0.8 (maximum) and 0.3 g lauric acid per 100 g oil respectively. The mean FFA content of control coconut oil samples used in this study was 0.29±0.02 % FFA, thus it complied with these standards.

Figure 1 shows the changes in the FFA contents in the coconut oil samples over the repeated heating of oil without and with food. It was observed that the FFA contents in all coconut oil samples had increased significantly ($p<0.05$) with the number of frying cycles in both oils heated without food and with food.

Since Diop (2014) has shown that the FFAs can be formed as secondary oxidation products by the decomposition of primary oxidation products of lipid oxidation mainly hydroperoxides, the formation of FFAs in the oil heated without food could be mainly due to the oxidation because there was a less chance for the formation of FFAs through hydrolysis since no water was added to the oil along with the food. However, hydrolysis also might be occurred due to the moisture formed during other deterioration reactions and inherent moisture present in the coconut oil as it was not refined. But when heating the oil with food in addition to oxidation, hydrolysis of fatty acid also had taken place due to the presence of water and steam in the food, which reacted with triacylglycerides in the oil and produced free fatty acids. Sample 5 (S5) had significantly higher amount of FFA content, this could be due to the excessive heat treatment during processing or unintended addition of moisture into the oil during processing and storage or it might be adulterated with other crude oils.

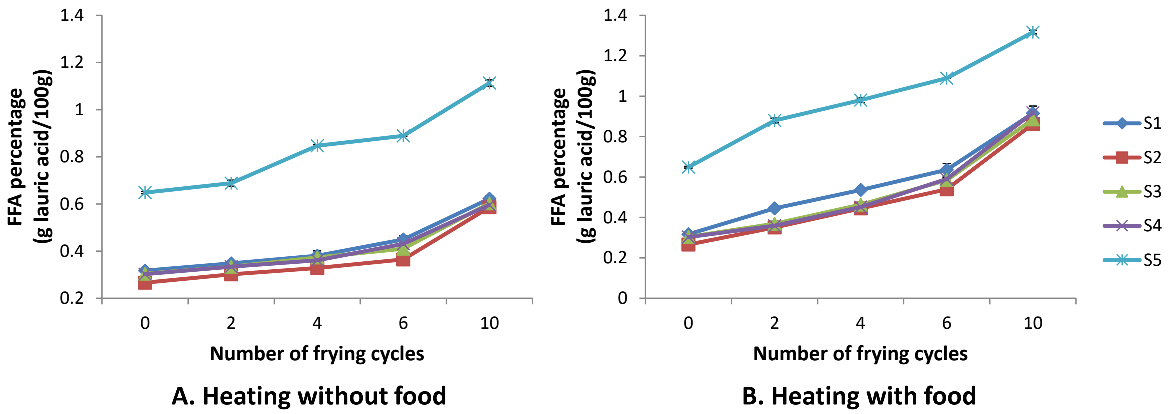

Figure 1 Changes in the free fatty acid contents in the coconut oil samples over repeated heating of oil without food (A) and heating of oil with food (B).
Five coconut oil samples (S1, S2, S3, S4 and S5) were repeatedly heated (at 180±5°C for 20 minutes) without food and with food *("Vade")* for ten cycles allowing cooling down to room temperature after each frying. FFA contents in the oil were determined after selected frying cycles (0, 2, 4, 6 and 10). FFA contents in all coconut oil samples had significantly ($p<0.05$) increased with the number of frying cycles. Sample 5 had significantly ($p<0.05$) higher FFA content compared to all other samples throughout.

The comparison of the mean FFA contents in the coconut oil samples (excluding the significantly different sample S5) over repeated frying cycles with and without food is shown in Figure 2. The mean FFA contents in coconut oil samples, when heated repeatedly with food were significantly higher ($p<0.05$) than that of oil heated without food. This was due to the rate of cleavage of double bonds in fatty acids of oil heated with food had increased rather than that of oil heated without food as a result of water and steam present in the food hydrolyzed the fatty acids in addition to oxidation and produced more numbers of free fatty acids in the oil. According to Chung *et al.* (2004), water is a weak nucleophile which caused the cleavage of ester linkage of triacylglycerol and produced di- and monoacylglycerols, glycerol and free fatty acids.

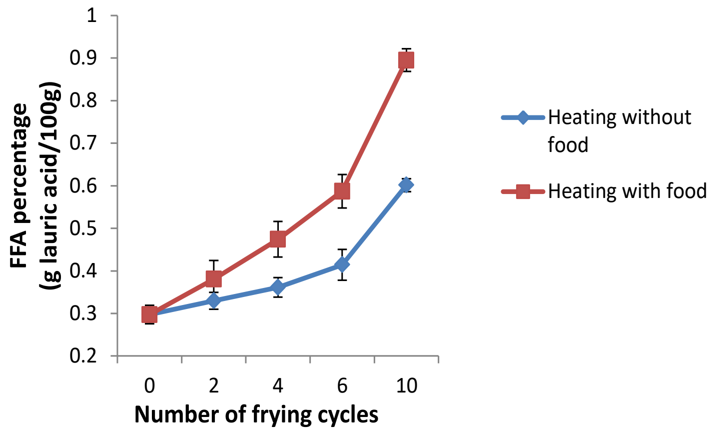

Figure 2 Comparison of mean FFA content in the coconut oil samples over repeated heating with and without food.

The mean±SD values of FFA contents of coconut oil samples (S1, S2, S3 and S4) excluding the significantly different sample S5 were calculated at the selected number of frying cycles (0, 2, 4, 6 and 10). The mean±SD value of FFA content of coconut oil samples heated with food was significantly (p<0.05) higher than that of samples heated without food. Different letters within a series show a significant difference at (p<0.05). The mean±SD values also had significantly (p<0.05) increased with the number of frying cycles in both samples heated with and without food.

Saponification value (SV)

Saponification value is used as an indicator of the molecular weight of triglycerides in oil, which is inversely proportional to the average weight or chain length of fatty acids in oil (Muhammad *et al.* 2011). The SLS (SLS 32:2002) and the Codex recommended standards for SV of coconut oil are 248-264 and 248-265 mg KOH/g respectively. In this study, the mean SV of control coconut oil samples was 253.46±8.23 mg KOH/g, it was acceptable as per these standards.

According to Figure 3, it was observed that the SV in each coconut oil sample had decreased significantly (p<0.05) with the increasing number of frying cycles when heated the oil without and with food. There was no significant (p>0.05) difference in the SV among the coconut oil samples. Since the SV is used to indicate the molecular weight of triglycerides in the oil, the decrease in the SV could be due to the breakage of ester bonds and decrease in the triglyceride content in the oil through hydrolysis and oxidation of fatty acids during heating.

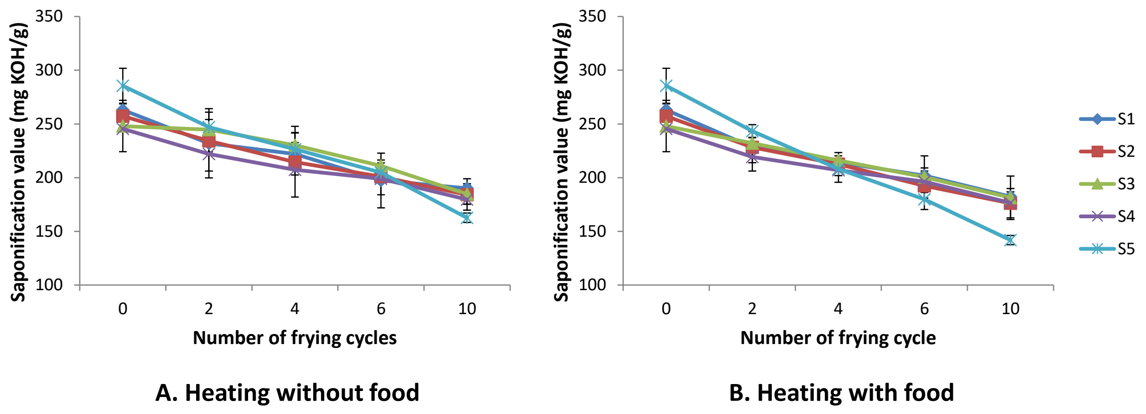

Figure 3 Changes in the saponification value in the coconut oil samples over repeated heating of oil without food (A) and heating of oil with food (B).
Five coconut oil samples (S1, S2, S3, S4 and S5) were repeatedly heated (at 180±5°C for 20 minutes) without food and with food *("Vade")* for ten cycles allowing cooling down to room temperature after each frying. Saponification values in the oil were determined after selected frying cycles (0, 2, 4, 6 and 10). Saponification value of all coconut oil samples had significantly (p<0.05) decreased with the number of frying cycles. No significant (p>0.05) difference in the saponification value among all coconut oil samples throughout.

Figure 4 illustrates the comparison of the mean saponification value of all five coconut oil samples over repeated heating of oil with and without food. The mean SV of oil heated with food was lesser than that of oil heated without food because when heating the oil with food, both hydrolysis and oxidation contribute to the breakage of ester bond, but there were no significant (p>0.05) difference in the mean SV between the oil heated without and with food. This could be due to the contribution of the hydrolysis for the breakage of the ester bond in the presence of food moisture was comparatively lower than that of the oxidation process.

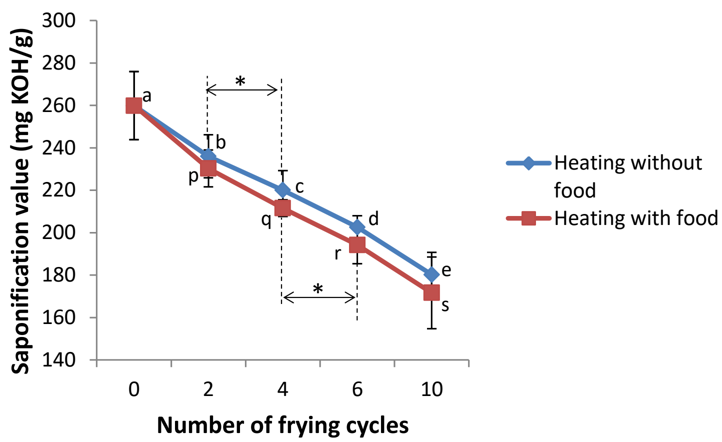

Figure 4 Comparison of mean saponification value in the coconut oil samples over repeated heating with and without food.
The mean±SD of saponification values of coconut oil samples (S1, S2, S3, S4 and S5) were calculated at the selected number of frying cycles (0, 2, 4, 6 and 10). Even though mean±SD

values of coconut oil samples heated with food are lower than that of samples heated without food, there were no significant (p>0.05) difference between samples heated with and without food. Different letters within a series show a significant difference at (p<0.05). The mean±SD values also had significantly (p<0.05) decreased with the number of frying cycles in both samples heated with and without food.

Iodine value (IV)

The iodine value (or iodine number) is a measure of the degree of unsaturation or the average number of double bonds in fats and oils (Chebet *et al*. 2016). The SLS (SLS 32:2002) and the Codex recommended standards for the iodine value of coconut oil are 7.5-9.5 and 6.3-10.6 g/100g I_2 respectively. The mean IV of the control coconut oil samples used in this study was 7.68±0.05 g/100g I_2, thus it complied with these standards.

The change in the iodine values of coconut oil during repeated deep frying of "*Vade*" is shown in Figure 5. It was observed that there was a significant (p<0.05) decrease in the IV of coconut oil with the increasing number of repeated frying cycles. The IV of the coconut oil sample before any frying process and after the second cycle of frying was not significantly (p>0.05) different, indicating the longer induction period of coconut oil. The IV after the fourth cycle of frying was significantly (p<0.05) lesser than the IV after the second cycle of frying. The IV value after the fourth and sixth cycle of frying were not significantly (p>0.05) different. However, the IV after the tenth cycle was significantly (p<0.05) lesser than the IV after the sixth cycle of repeated frying.

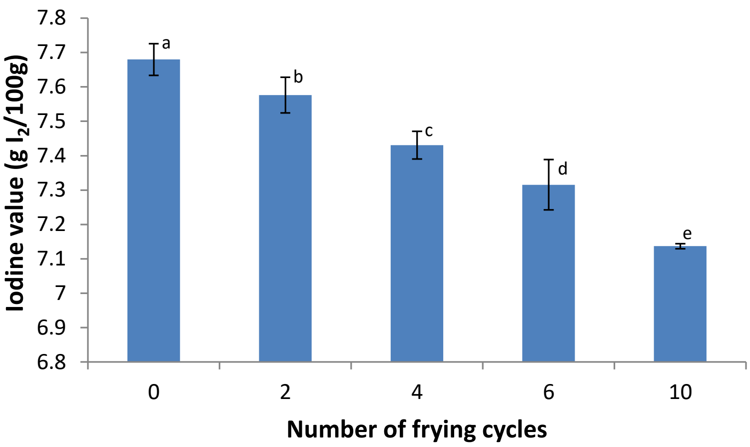

Figure 5 Changes in the iodine value in the coconut oil samples over repeated heating of oil with food.

Five coconut oil samples (S1, S2, S3, S4 and S5) were repeatedly heated (at 180±5°C for 20 minutes) with food ("*vade*") for ten cycles allowing cooling down to room temperature after each frying. Iodine values in the oil were determined after selected frying cycles (0, 2, 4, 6 and 10). The mean±SD of iodine values of samples (S1, S2, S3 and S4) excluding the significantly different sample S5 were calculated at each selected number of frying cycles. Different letters show a significant difference at (p<0.05). Mean±SD of iodine values of all coconut oil samples had significantly (p<0.05) decreased with the number of frying cycles.

Since Naz *et al*. (2004) shown that the decrease in the IV is an indication of lipid oxidation of oil, the decrease of IV of coconut oil was due to the reduction in the unsaturation or number of double bonds of the oil samples as a result of oxidation and polymerization of oil. Another study also reported that frying led to a decrease in the unsaturation for all types of oil and the decrease in IV was a result of complex physicochemical changes in fatty acids during frying which indicates the decrease in oxidation rate (Lalas, 2009).

Peroxide value (PV)

Lipids easily undergo oxidation which leads to deterioration of the quality and oxidative stability of lipids. The level of oxidation can be determined by quantifying the primary and secondary oxidative products generated in the oil sample. During the deep fat frying, the primary lipid oxidation products are hydroperoxides, which are generally expressed as peroxides. These peroxides are unstable organic compounds produced from triglycerides (Romano *et al*. 2012). The Codex recommended standards for PV of coconut oil is not more than 15 milliequivalents per kg. The mean PV of the control coconut oil samples used in this study was (3.36±0.95) mEq per kg, it was acceptable as per these standards.

Figure 6 illustrates the changes in the peroxide value of the coconut oil samples over repeated frying without and with food. Results revealed that PV had increased significantly ($p<0.05$) with the increasing number of frying cycles in all coconut oil samples heated without food, indicating a gradual oxidation of oils with time. The PV of coconut oil samples S2 and S4 had increased significantly ($p<0.05$) with the increasing number of frying cycles when heated the oil with food. Thus the level of oxidation gradually increased with frying cycles in the above two oil samples. It was observed that, in the coconut oil samples S1, S3 and S5 the PV had significantly increased until the sixth number of the frying cycle but after that, the PV had significantly decreased. The increase in the PV over the number of frying cycles was due to the formation of hydroperoxides as primary oxidation products by lipid oxidation at high temperature. As mentioned by Shahidi and Wanasundara, (2002), under the high frying temperature conditions the peroxides were unstable and decomposed rapidly to produce secondary oxidation products mainly carbonyl and aldehyde compounds which caused the PV to decrease after a certain number of frying cycles.

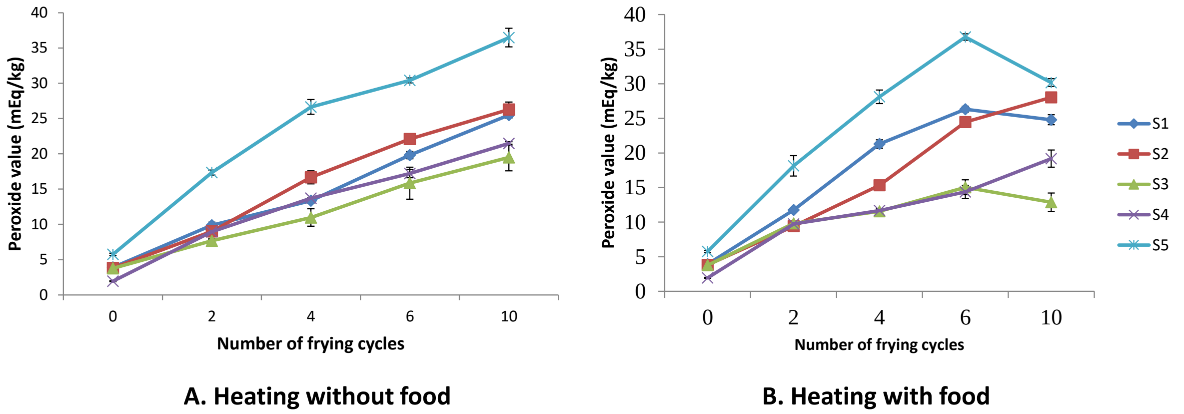

Figure 6 Changes in the peroxide value in the coconut oil samples over repeated heating of oil without food (A) and heating of oil with food (B).
Five coconut oil samples (S1, S2, S3, S4 and S5) were repeatedly heated (at 180±5°C for 20 minutes) without food and with food *("Vade")* for ten cycles allowing cooling down to

room temperature after each frying. Peroxide values in the oil were determined after selected frying cycles (0, 2, 4, 6 and 10). Peroxide value in all coconut oil samples heated without food had significantly (p<0.05) increased with the number of frying cycles. But when heated the oil with food, peroxide values of samples S2 and S4 had significantly (p<0.05) increased with the number of frying cycles and peroxide values of samples S1, S3 and S5 had significantly (p<0.05) increased until the sixth number of frying cycle, after that it had significantly (p<0.05) decreased. Sample 5 had significantly (p<0.05) higher peroxide value compared to all other samples throughout.

The comparison of the mean PV of all coconut oil samples over repeated heating cycles with and without food is shown in Figure 7. By comparing the mean PV of oil heated with and without food, it was found that the means were not significantly (p>0.05) different. The mean PV of oil samples heated with food was comparatively higher than that of oil samples heated without food until the fourth number of frying cycle. However, after the fourth cycle the mean PV of oil samples heated with food gradually became lower than that of oil heated without food. This was due to the decomposition of peroxides into secondary oxidation products when heated the oil with food, which can be observed in Figure 6, where PV of three coconut oil samples increased during the first period of frying until reached the peak and then started to decrease. Frankel (2005) reported that the oil become more deteriorated during intermittent repeated heat treatment compared with the continuous heat treatment as a result of new hydroperoxides form during cooling and storage of oil and these hydroperoxides undergo hydrolysis in the subsequent heating phase (Romano *et al*. 2012).

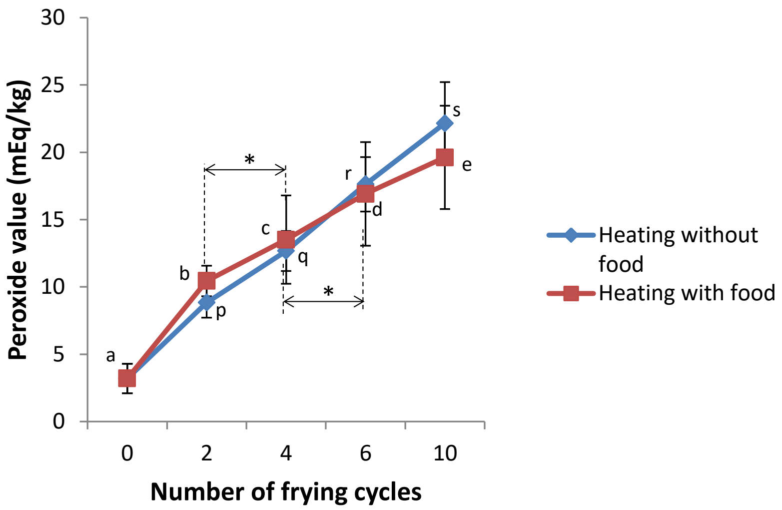

Figure 7 Comparison of mean peroxide value in the coconut oil samples over repeated heating with and without food.

The mean±SD peroxide values of coconut oil samples (S1, S2, S3 and S4) excluding the significantly different sample S5 were calculated at the selected number of frying cycles (0, 2, 4, 6 and 10). The mean±SD of coconut oil samples heated with food was significantly (p<0.05) higher than that of samples heated without food until the fourth number of the frying cycle after that mean±SD of samples heated without food was significantly (p<0.05) higher than that of samples heated with food. Different letters within a series show a significant difference at (p<0.05). The mean±SD values also had significantly (p<0.05) increased with the number of frying cycles in both samples heated with and without food.

2-Thiobarbituric Acid Reactive Substances (TBARS)

The 2-Thiobarbituric Acid Reactive Substances (TBARS) test measures the secondary oxidative products resulting from lipid oxidation mainly carbonyls which lead to the development of off flavor in oxidized oils (Shahidi and Bhanger, 2007). In this study, TBARS assay was used to measure the secondary oxidative products mainly malondialdehyde and related compounds. Malondialdehyde (MDA) is one of the mainly produced aldehydes during secondary lipid oxidation and it is very frequently used as oxidation marker.

The changes in the TBA value of the coconut oil samples over the repeated heating of oil with and without food are shown in Figure 8. It was observed that TBA values had significantly (p<0.05) increased with frying cycle in all coconut oil samples heated with and without food, indicating a gradual formation of secondary oxidative products in oils with time.

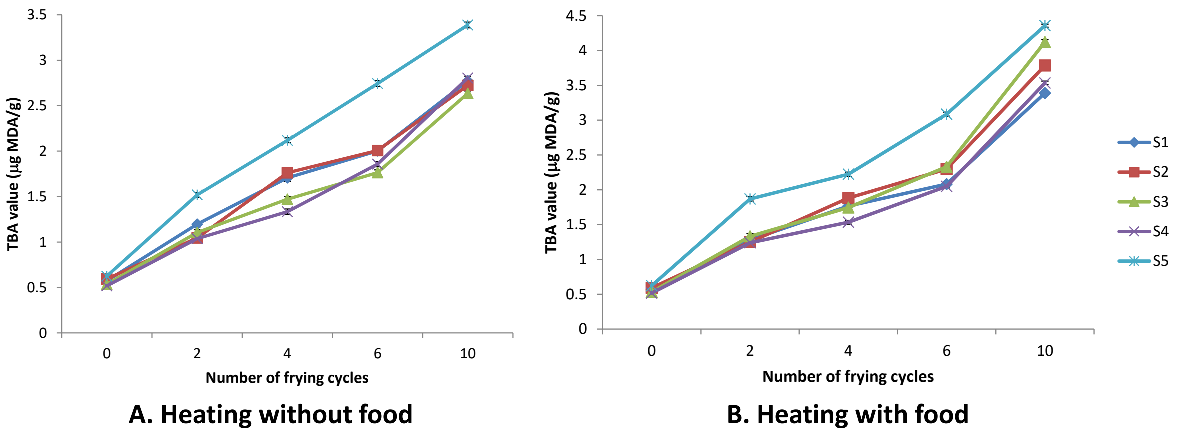

Figure 8 Changes in the TBA values in the coconut oil samples over repeated heating of oil without food (A) and heating of oil with food (B).
Five coconut oil samples (S1, S2, S3, S4 and S5) were repeatedly heated (at 180±5°C for 20 minutes) without food and with food *("Vade")* for ten cycles allowing cooling down to room temperature after each frying. TBA values in the oil were determined after selected frying cycles (0, 2, 4, 6 and 10). TBA values in all coconut oil samples had significantly (p<0.05) increased with the number of frying cycles. Sample 5 had significantly (p<0.05) higher TBA value compared to all other samples throughout.

Figure 9 shows the comparison of the mean TBA value of all coconut oil samples excluding the most deviated sample (sample 5) over repeated heating with and without food. It was observed that even though the mean TBA values of oil heated without food were lower than that of oil heated with food, there was no significant (p>0.05) difference between both. When heated oil with and without food, oils were undergone to thermal oxidation at high temperature, thus the TBA value of oil samples tended to increase with the number of frying cycles. When heated the oil with food, water was added to the oil along with the food which induced hydrolysis and formed more free fatty acids, these free fatty acids might easily undergone to thermal oxidation and might produce more primary and secondary oxidation products which lead to the high TBA value in the oil samples heated with food. But there was no significant differences between oil heated with and without food because the formed secondary products could be absorbed by the food and the amount of TBARS formed through the oxidation of free fatty acids produced by hydrolysis might be comparatively low.

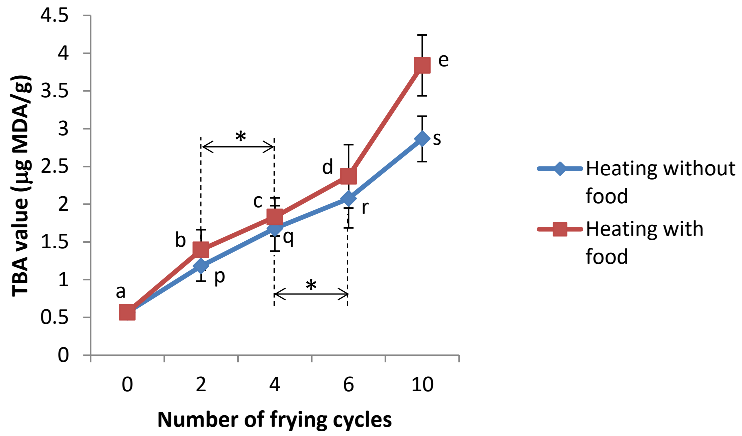

Figure 9 Comparison of mean TBA value in the coconut oil samples over repeated heating with and without food.

The mean±SD TBA values of coconut oil samples (S1, S2, S3 and S4) excluding the significantly different sample S5 were calculated at the selected number of frying cycles (0, 2, 4, 6 and 10). The mean±SD TBA values of coconut oil samples heated with food was significantly ($p<0.05$) higher than that of samples heated without food. Different letters within a series show a significant difference at ($p<0.05$). The mean±SD values also had significantly ($p<0.05$) increased with the number of frying cycles in both samples heated with and without food.

Trans-fats

Repeated using of frying oil lead to the thermoxidative degradation of the fatty acids, which results not only in quality changes in fried foods but also it leads to some safety issues. For example, temperature abused fat is hard to digest and consumption leads to diarrhea (Billek, 2000). Structural alterations mainly occurred by the changes in the double bond configuration and shifting of the double bond position within the fatty acids. Trans-fatty acids (TFA) are referred to as unsaturated fatty acids with at least one or more double bonds in the trans position. During deep fat frying, the cis configuration of fatty acids can be changed into trans configuration due to the breakage, shift and formation of C-C bonds. There are safety issues for human health contributed by high contents of trans fats in fried foods since they promote coronary heart diseases, increase the LDL cholesterol and triacylglycerol (TAG) levels and decrease the HDL cholesterol in the blood. There is some evidence that trans fats can cause systemic inflammation and sudden cardiac death (Mozaffarian *et al.* 2009).

The results showed that trans fat content was slightly changed with the number of frying cycles when heated the oil with food (Figure 10). However, the formation of trans fats was relatively low since coconut oil has about 92% of saturated fatty acids. Thus there was a less chance for the shifting of double bond to trans configuration and formation of trans fats.

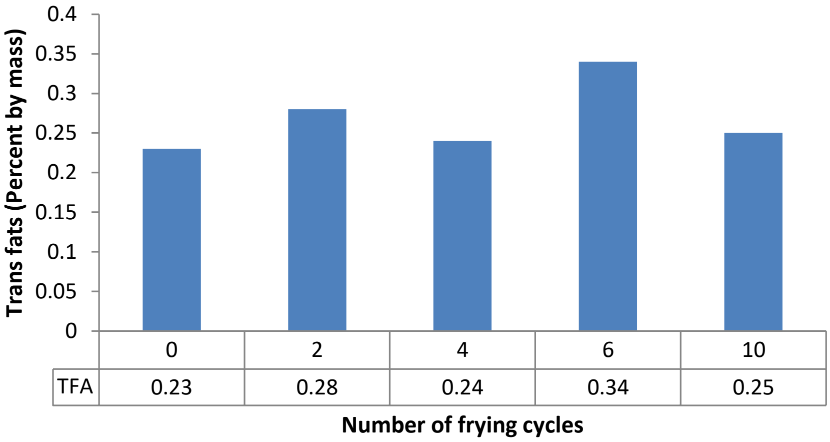

Figure 10 Changes in the trans fat content in the coconut oil samples over repeated heating of oil with food.

Five coconut oil samples (S1, S2, S3, S4 and S5) were repeatedly heated (at 180±5°C for 20 minutes) with food ("*Vade*") for ten cycles allowing cooling down to room temperature after each frying. Trans fat contents in the oil were determined after selected frying cycles (0, 2, 4, 6 and 10). The trans fat content showed a fluctuating change with the number of frying cycles.

Color - Photometric Color Index (PCI)

Color is a sensory property of edible oil which plays an important role both in the refining process and market place. It influences the perception of oil by consumers. The color of the oil is primarily caused by natural polyphenolic pigments, gossypol, chlorophyll, etc. and each pigment has an absorption spectrum with peaks at characteristic wavelengths.

According to Figure 11, the darkness of the coconut oil sample (S4) had increased after the second cycle of repeated heating of oil without food but after the second cycle, the dark color of the oil had gradually decreased until the tenth cycle. When heated the oil with food the darkness of the same oil sample (S4) had gradually increased until the fourth cycle and after that the dark color had gradually decreased. By comparing the color of the oil heating with and without food, it was observed that more dark color had developed in the oil heated with food than that of oil heated without food.

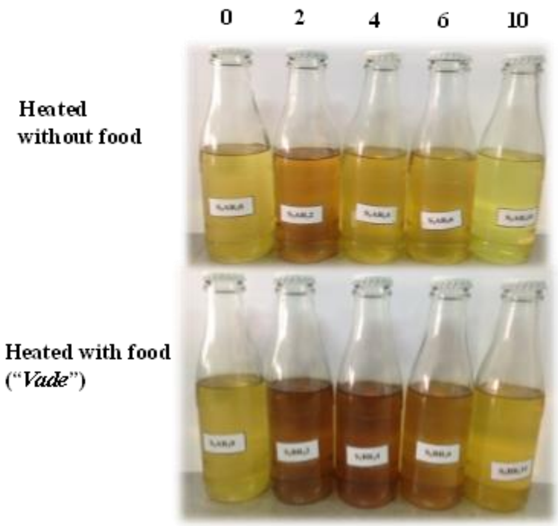

Figure 11 The changes in the visual color of the coconut oil sample (S2) over repeated heating of oil with and without food.

Five coconut oil samples (S1, S2, S3, S4 and S5) were repeatedly heated (at 180±5°C for 20 minutes) with food ("*Vade*") and without food for ten cycles allowing cooling down to room temperature after each frying. The color of the samples was visually inspected after selected frying cycles (0, 2, 4, 6 and 10). The color had changed with the number of frying cycles in oil heated with and without food. The oil heated with food showed a high color development than that of oil heated without food.

Table 1 shows the photometric color index (PCI) of coconut oil samples over repeated heating of oil without food. It was revealed that there were no significant (p>0.05) differences in PCI between the coconut oil samples when heated without food but sample 1 (S1) had a slightly lower mean±SD value of PCI than the other four samples. In each sample the PCI values showed a significant (p<0.05) difference over the number of heating cycles. Most of the samples showed maximum PCI at the second cycle of repeated heating and the PCI had increased significantly until the second cycle of frying but after that, the PCI had significantly reduced until the tenth cycle in all samples.

Table 1 Changes in the photometric color index (PCI) in the coconut oil samples over repeated heating without food

Number of frying cycles	Coconut oil Sample Number				
	S1	S2	S3	S4	S5
0	2.90 ± 0.45[a]	2.93 ± 0.08[c]	3.22 ± 0.19[b]	3.51 ± 0.02[b]	2.65 ± 0.03[c]
2	2.63 ± 0.05[a]	3.74 ± 0.16[a]	3.98 ± 0.27[a]	3.90 ± 0.24[a]	3.54 ± 0.09[a]
4	2.79 ± 0.38[a]	3.26 ± 0.06[b]	3.38 ± 0.04[b]	2.99 ± 0.16[c]	3.35 ± 0.19[a]
6	2.46 ± 0.09[a]	2.98 ± 0.01[c]	2.98 ± 0.06[b,c]	2.86 ± 0.02[c]	3.32 ± 0.06[a]
10	2.47 ± 0.19[a]	2.87 ± 0.17[c]	2.81 ± 0.05[c]	2.94 ± 0.04[c]	3.04 ± 0.04[b]

Mean± S.D value with the different letters within the same column is significantly different at (p<0.05).

As shown in Table 2, the PCI of coconut oil samples had changed significantly ($p<0.05$) with the number of cycles of repeated heating of oil with food. There were no significant differences ($p>0.05$) in PCI between the coconut oil samples but sample 2 (S2) and sample 4 (S4) had a slightly higher mean±SD of PCI than other three samples. Most of the samples showed maximum PCI at the fourth cycle of repeated heating and the PCI had increased significantly ($p<0.05$) until the fourth cycle of frying but after that, the PCI had significantly ($p<0.05$) reduced in all samples.

Table 2 Changes in the photometric color index (PCI) in the coconut oil samples over repeated heating with food

Number of frying cycles	Coconut oil Sample Number				
	S1	S2	S3	S4	S5
0	2.90 ± 0.45^{a}	2.93 ± 0.08^{d}	2.22 ± 0.19^{a}	2.51 ± 0.02^{b}	2.65 ± 0.03^{b}
2	3.11 ± 0.10^{a}	4.54 ± 0.15^{a}	2.84 ± 0.28^{a}	3.12 ± 0.14^{a}	3.24 ± 0.43^{a}
4	2.98 ± 0.08^{a}	4.67 ± 0.05^{a}	2.89 ± 0.20^{a}	4.57 ± 0.15^{b}	3.46 ± 0.17^{b}
6	2.87 ± 0.11^{a}	3.83 ± 0.01^{b}	2.81 ± 0.09^{a}	3.41 ± 0.39^{b,c}	2.90 ± 0.12^{a,b}
10	2.61 ± 0.17^{a}	3.35 ± 0.17^{c}	2.77 ± 0.09^{a}	2.87 ± 0.15^{c}	2.93 ± 0.09^{a,b}

Mean± S.D value with the different letters within the same column is significantly different at ($p<0.05$).

PCI was used as an index to assess the degradation of the oil. The increase in the PCI value during repeatedly heating could be due to the combination of oxidation and polymerization of unsaturated fatty acids in the frying medium. The color development in coconut oil was comparatively low; this might be due to the low amount of unsaturated fatty acids in the coconut oil. When heated the oil both with food and without food highest PCI was observed at the second and fourth cycle of frying, indicating higher oxidation. It was related to differential oxidation of oil during frying and accumulation of non-volatile compounds such as oxidized triacylglycerol and FFAs (Paul and Mittal, 1996).

By comparing the heating of oil with food and without food, it was observed that samples S2, S3, S4 and S5 had a significantly ($p<0.05$) high mean value of PCI when heated with food that that of oil heated without food, while the sample S1 did not show any significant ($p>0.05$) difference between the oil heated with and without food. Solubilization of unsaturated carbonyl compounds and non-polar compounds from foodstuff into the oil or Maillard browning reaction and caramelization at the high frying temperature as food containing sugar could be the reason for more darkening of oil when heated with food than that of oil heated without food. The decrease in the color after a certain cycle of repeated frying could be due to the accumulation and deposition of non-volatile compounds at the bottom of the frying pan which contributed to the color development in the oil during frying.

Conclusion and Recommendation

This study assessed and compared the changes in the oxidative stability and physicochemical properties of coconut oil samples following repeated deep frying using standard methods. The coconut oil samples collected from different oil processing mills had significantly ($p<0.05$) varying physicochemical properties and oxidative stability specifically free fatty acid content, iodine value, peroxide value and TBA value except for saponification value and color. The coconut oil samples devoid of any heating process had acceptable free fatty acid content, saponification value, acid value and peroxide value as per Codex and SLS standards. The results showed that deep frying of food in tested coconut oil had no significant (p>0.05) effect on its oxidative stability but significantly (p<0.05) increased its free fatty acid content than that of coconut oil heated without food. During frying of tested coconut oil reduced its physicochemical quality and oxidative stability significantly (p<0.05) with increasing frying cycles by increasing the free fatty acid content, peroxide value and TBA value, reducing the saponification value and iodine value and by changing the photometric color index and percentage changes of these parameters also increased over the number of frying cycles.

Therefore the negative quality and safety issues should be taken into consideration, when using the coconut oil repeatedly for frying of food ("*Vade*") by street vendors and households. According to this study, the coconut oil can be repeatedly used maximum for 2-4 cycles based on the CODEX and SLS standard for free fatty acids, saponification value, iodine value and peroxide value because these values were within the acceptable limits until the second to the fourth cycle of repeated frying. However, this limit is applicable only for foods which have similar composition of "Vade" frying in coconut oil. Therefore future analysis needs to be focus on frying of foods which have higher water, fat and protein content such as animal based food using different oil varieties

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Proceeding of the International Conference on Agriculture, Food Security and Safety, Vol. 1, 2019, pp. 18-29

ISSN 2682-7158

Safety Issues in Fresh Fruit and Vegetable Supply Chains in Sri Lanka: A Review

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Abstract: Safe food consumption across the globe has been overly threatened by food adulteration using harmful chemicals, which is detrimental to health. The practice is rampant in developing countries where many loopholes exist in the law enforcement paving way to various unscrupulous acts throughout the supply chains by various actors like farmers, collectors and traders, thereby controlling quality and assuring safety of fruits and vegetables in supply chains remain critical challenges. This paper reviews safety issues related to food adulteration in fruit and vegetable supply chains and institutional level measures to minimize quality and safety issues prevalent in fruit and vegetable supply chains particularly in Sri Lanka employing a literature survey and key informant interviews. It provides valuable insights identifying problematic areas related to food safety issues in fruit and vegetable sector in the country. Unregulated pesticide usage, poor awareness and technical know-how of the farming community, lack of sufficient national standards to measure food safety and absence of an integrated approach to ensure food safety were identified as major drawbacks. It emphasizes that the local food control mechanism does not have a farm to table approach. It underscores the need for a cost effective safety assurance system for consumer satisfaction and a separate market window to provide safe fruits and vegetables to consumers.

Keywords: Food Safety Issues, Fruits and Vegetables, Supply chains

Introduction

The fruit and vegetable sector is a force that promotes a healthy growth trend in the Sri Lankan agriculture with high potential for cultivating fruits and vegetables in for local and export markets. Hence development of this sector while improving the quality and safety of the products supplied to those markets is vital. However, fresh fruits and vegetables have recently been identified as a major source of pathogens and chemical contaminants that pose a potential threat to human health worldwide as the production process passes many stages before it gets to the market. Hence controlling quality and assuring safety of fruits and vegetables in supply chain has become a key challenge in Sri Lanka with various actors such as farmers, collectors and traders performing various unscrupulous acts throughout the supply chains, a grey area in food safety in Sri Lanka. On the other hand, when exploiting the export potential for fruits and vegetables strict adherence to stipulated international food safety and quality regulations is mandatory. Therefore, effective quality control systems are an essential component in the fresh and processed fruits and vegetables industry.

The present status of government registration of agro-chemicals and their impact on human health is not properly investigated. It appears that fresh fruits and vegetables being consumed by the people could have the levels of residues that far exceeded the Food and Agriculture Organization (FAO) recommended Maximum Residue Limits (MRL). Therefore, food safety issues need to be exhaustively investigated to find out the current levels of chemical residues in fruits and vegetables and whether the accepted residue regulations are violated. Lately, the number of patients with cancer, heart and kidney diseases records a sharp increase as a result of food adulteration, taking a heavy toll on public lives (Morol, 2014; cited in Hassan, 2014). This paper attempts to review the relevant literature, especially in the context of Sri Lanka, in relation to the present status of control of quality and safety of fruits and vegetables in horticultural chains. Hence, the objectives of this paper were as follows;

- To review the safety issues related to food adulterations in fruit and vegetable supply chains in the country
- To identify the institutional level measures to minimize quality and safety issues in fruit and vegetable supply chains in the country.

Methodology

A literature survey on research papers from peer–reviewed journals, conference proceedings, white papers and presentations from the studies related to safety issues of fruits and vegetable supply chains was carried out. Key informant and stakeholder interviews were conducted with officers in different government departments, research institutes and ministries (Table 1) to identify the role of those institutes to maintain quality and safety issues of fruit and vegetable supply chains.

Table 1 List of Key Informants

Ministry	Institute / Department
Ministry of Agriculture	Department of Agriculture
	Registrar of Pesticide
	National Plant Quarantine Service
Ministry of Health, Nutrition and Indigenous Medicine	Food Control Administrative Unit
	Medical Research Institute
	Government Analyst
	City Analyst, Colombo
Ministry of Technology and Research	Sri Lanka Standard Institute
	Industrial Technology Institute

Food Safety Hazards in Fruits and Vegetables

Fresh fruits and vegetables can become contaminated by biological hazards such as pathogenic organisms including bacteria, viruses and parasites, chemical hazards and physical hazards. Biological hazards in fresh produce occur due to micro-organisms such as bacteria, fungi (yeasts and moulds), protozoans, viruses and helminths (worms) which can also be termed as microbes. The primary sources of microbial contamination of fresh fruits and vegetables are; human and animal faeces (e.g. untreated manure/faeces or municipal bio solids and sewage fluids), contaminated water (agricultural and processing water), contaminated soil, dust, surroundings and handling equipment and poor sanitary practices throughout the production chain (contamination by humans or animals) (Ecobichon, 2001; cited in Din et al., 2011).

Fruits and vegetables can be contaminated with toxic chemicals from a variety of sources such as heavy metals, pesticide residues, contaminants and fungicides. Of all pesticide residues are ranked the top safety issue (Kader and Roll, 2004; cited in Din et al., 2011). Chemicals and single substances can pose a serious health hazard to the consumer if fresh fruit and vegetables are contaminated in significant concentrations. Contamination may be caused by either naturally occurring substances or by synthetic chemicals that may be added or are present during the agricultural production or post-harvest treatment and further processing. Presence of heavy metals such as arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr) in food is a dominant threat related to food safety. Data on the extent of exposure of the country's population to food contamination caused by toxic heavy metals is not widely available.

Physical hazards are foreign material in product that can cause injury. The high moisture content and soft texture of fruit and vegetable make them susceptible to mechanical injury which can occur at any stage from production to retail marketing. A small scratch or cut on produce surface results in increased respiration rate, heat production and fasten the ethylene production. The fruit or vegetable ultimately ends in senescence.

Pesticide Residues in Fruits and Vegetables

Like other crops, fruits and vegetables are attacked by pests and diseases during production and storage leading to damages that reduce the quality and the yield. In order to reduce the loss and maintain the quality of fruit and vegetable harvest, pesticides are used together with other pest management techniques during cropping to destroy pests and prevent disease incidence. Fewer farmers intentionally apply pesticides on harvested or crops just before harvesting as a strategy to extend storage lifespan of the harvest. Conversely, Sri Lanka's common farming practice heavily depends on mono cropping and monoculture, which usually triggers pest attacks and plant diseases; hence extensive agrochemical use is inevitable.

Chandrasekara et al. (1985) and Padmajani et al. (2014) highlighted malpractices and misuse of pesticides by farmers. It is observed that most of the farmers harvest their crops within seven to14 days after the final application of pesticides. Fewer farmers depend on the dealer advice for convenience without seeking advice of extension officers while some consult their neighbours to determine the type of pesticide to be used. Pesticide manufacturing companies have more influence on the farming community than the government does in pesticide selection and usage. Farmers tend to overdose pesticides disregarding the recommended levels stipulated by the Department of Agriculture. Most of the farmers apply pesticides to their crops prior to incidence of pests primarily owing to ignorance. Pesticides are applied arbitrarily disregarding the dosage and instructions given and harvesting is practised without observing the waiting periods. For bitter gourd, ridge gourd or snake gourd, the farmers have to apply pesticides closer to harvesting time as these vegetables are highly prone to pest attacks. However, if the pre-harvest interval is observed the crops will be over mature. Therefore, harvesting is performed in two to three days after application of pesticides (Chandrasekara et al., 1985). Moreover, it is further hastened if market prices are lucrative.

Dissanayake (2009) in a study on farmers' behaviour and habits with pesticide usage found that the farmers lack effective disposal methods for the empty containers ,which led to contamination of environmental resources. The above issues can be attributed to farmers' little knowledge on safe and efficient use of pesticides. Therefore, awareness and training of these farmers are key to resolve the issues in pesticide management.

Various forms of human-induced food adulteration during farm and industrial production and marketing are prevalent. An important human-induced safety concern is the presence of pesticide residues in food. The issues related to pesticides can be listed as follows;

- Administering overdose of pesticides

- Application of pesticides at shorter intervals
- Non-compliance to the withholding period (minimum duration between last application and harvesting)
- Application of cocktail of pesticides (mixing two or more pesticides together)
- Ignorance of the users
- Lack of motivation
- Lack of a vigorous media campaign
- Exploitation by the agents of the pesticide suppliers
- Absence of an effective monitoring system on pesticide usage

There is no long term systematic pesticide monitoring programme in Sri Lanka and a very few organized studies on contamination of food and water by pesticides have been carried out.

Lakshani et al. (2017) in a study to assess the concentration of pesticide residues in 90 samples of selected fruits and vegetables (tomato, cabbage and capsicum) found Diazinon, Chloropyrifos, Phenthoate, Prothiofos, Oxyfluorofen and Tebuconazole in 30 samples.

Meanwhile Dasika et al. (2012) in a study on apples, pears, grapes and guava and vegetables (brinjal, bell pepper) found Diphenylamine, Choloropyrifos, Thaibendazole and Malathion in "no wash" samples of apple. For grapes, fungicides Imazalil and Thiabendazole remains nearly 70% and 100% above the MRL and insecticide Phosmet 50% above MRL. For eggplant showed the most pesticides that have residue levels over the MRL and for bell peppers Chloropyrifos and Diphenylamine residues present 75-100% above MRL. The residue levels of most toxic pesticides were under MRL even before washing the samples of guava. In unwashed green pears, Choloropyrifos, Phosmet and Diphenylamine were present above MRL value.

Marasinghe et al. (2011) using 31 rice samples, 1,043 vegetable samples and 554 surface washed vegetables reported an analysis for organophosphates with 19, 125 and 15 detections of residues respectively. Chlorpyrifos, profenofos and diazinon were the most frequently detected organophosphates in rice, vegetables and surface washed vegetables with concentrations in the range of 2.6 x 103 to 5.0 x 106 ng/kg, 5.0 x 103 to 5.0 x 106 ng/kg and 1.2 x 104 to 1.0 x 105 ng/kg, respectively.

Dissanayake (2009) studied pesticide residue analysis of tomato by using Gas Chromatography/Mass Spectroscopy. The study found that Carbofuran, Mancozeb, Antracol, Polyram and Mancozeb and Carbaryl were present in both the peel and flesh of tomatoes. A study conducted on the Mahaweli River at Peradeniya has found pesticide residues (Illeperuma, 2000). Earlier a study conducted on pesticides by using gas chromatography and had found hydrocarbon residues in fruits and vegetables (Ramasundaram et al., 1979; cited in Illeperuma, 2000).

Zaneer (1998) in a study on leafy vegetables (*kankun, sarana*, *mukunuwenna* and *gotukola*) in Sri Lanka to check the presence of Endosulfan, Carbofuran, Chlorpyriphos, Quinalphos, Profenofos identified that immediately after spraying (in two hours) of pesticides, all the insecticides except Carbofuran were detected at high levels (20-65mg/kg). After 14 days of spraying it was low (0.5mg/kg) except in *gotukola* (5.5-11 mg/kg). It explained further that dip washing and heating in water to 800C did not significantly lower the residue levels.

Accordingly, food commodities particularly vegetables in Sri Lanka could contain pesticide residues at low levels but could reach unacceptable levels occasionally. Therefore, it is recommended that regular residue monitoring is necessary to identify the areas and crops contaminated with unacceptable residue levels which would ultimately lead to alter the use pattern of pesticides to minimize the dietary exposure. For this it is important to select more sensitive analytical techniques and equipment to reach the low limit of quantification (LOQ) than defined MRL while using the accreted laboratories for pesticide residue analysis to ensure the reliability of analytical results.

The total dietary intake of pesticide residues left on agricultural commodities is known as toxins and therefore it is desirable to reduce these residues. Maximum Residue Levels (MRLs) refer to the upper legal levels of a concentration for pesticide residues in or on food or feed based on good agricultural practices and to ensure the lowest possible consumer exposure. MRLs have been widely adopted across the globe and sometimes lead to confusions as acceptable residue levels differ from one country to another. Developed countries have adopted much higher standards. In the case of Sri Lanka, the use of pesticides is governed by the Control of Pesticides Act of 1980.

Fruit Ripening and Safety Issues

Using synthetic chemicals to induce ripening of climacteric fruits such as mango, banana, papaya, tomato and jackfruit is a persistent problem in Sri Lanka. Fewer non-climacteric fruits such as pineapple are also subject to ripening with chemicals. In commercial agriculture, induced fruit ripening is practised all over the world for uniform ripening, taste and quality. In developed countries, ethylene gas is used to induce ripening of climacteric fruits. In Sri Lanka, various liquid plant growth regulators containing ethephon as an active ingredient are sprayed on the fruits or the fruits are dipped in a solution of ripening chemicals. To meet consumer demand and other economic factors, different methods of artificial fruit ripening are in practice in Sri Lanka as opposed to the conventional ripening techniques such as using heat, light and smoking. Artificial ripening accelerates ripening, but affects the nutritional quality of the fruits. Consumption of fruits poses a risk as artificial ripening with different toxic chemicals is harmful to health. Although Section 26 of the Food (labeling and miscellaneous) Regulation of 1993 explicitly prohibits the use of calcium carbide— a chemical commonly used by collectors and traders for the production of acetylene to induce fruit ripening—which is widely used for the ripening of mangoes, papayas, durians and bananas in Sri Lanka. Calcium carbide treatment is banned as it contains traces of arsenic and phosphorous which are hazardous to human beings. Acetylene is not harmful if properly used. The dosage administered by traders normally exceeds the recommended level of 1g/kg of fruit (Amarakoon et al., 1999). The method used in the application of carbide is also hazardous to health, in that carbide pieces can be found among the heaps of fruit. 'Ethrel' is a harmless ripening agent which releases ethylene. This compound recommended by the Department of Agriculture in Sri Lanka is slowly gaining popularity among fruit collectors and traders for ripening bananas, mangoes and avocados (Fernando, 2006).

Transporting and distributing fruits from the farmers' orchards to consumers' baskets can take several days. During this period the naturally ripened fruits may become over ripen and inedible. Part of naturally ripened fruits can also be damaged due to harsh transportation conditions. It indeed increases economic loss for the fruit sellers and therefore, to minimize the loss, fruit sellers sometimes prefer collecting fruits before reaching full maturity and artificially ripen fruits. Among the widely used artificial ripening agents, ethylene and methyl jasmonate are reported as non-toxic for human consumption; however, they are relatively expensive. In many developing countries, low-cost chemicals such as calcium carbide, ethylene glycol and ethephon are reported to be the commonly used ripening agents. (Islam et al., 2016).

Industrial Technology Institute (ITI) in Sri Lanka recommends a minimal amount of ethrel diluted in water (1 ml per litre of water) and to place the containers filled with the solution around the room. The fruits are then stacked in the room and sodium hydroxide is added to the mixture. All ventilation to the room is then blocked off and the fruits will ripe in two days in the gas that is released.

Current Status of the Standards for Fruits and Vegetables and Testing Infrastructure

WTO's agreement on application of Sanitary and Phytosanitary (SPS) measures and agreement on Technical Barriers to Trade (TBT) have significantly altered the international environment for food safety. Failure to meet the standards and exporting poor quality food that is unfit for consumption to developed countries leads to rejection of shipments. SPS standards regulation in Sri Lanka has still not reached the international SPS standards particularly in terms of sanitary standards for fruits and vegetables. Further, interventions at the production/growing stage to ensure quality and safety are minimal.

Sri Lanka Food Act No.26 of 1980 is the main legislative document covering food safety within the country. The Food Act is basically implemented through Director Health Services and through local authorities and Medical Officer of Health (MOH) of the region. Twenty seven regulations are issued under the Food Act addressing different aspects of food and food safety. The Food Act of Sri Lanka is being revised and new standards are being introduced or the existing ones are being upgraded in line with international standards. Recently, Registrar of Pesticide has formulated Maximum Residue Levels for pesticides stipulated by law for fruits and vegetables to prohibit sale of fruits and vegetables containing residues of pesticides in excess of the permitted limits.

When chemicals or pesticides are used they should be in accordance with relevant legislations including the regulation made under the Food Act No. 26 of 1980, Consumers Affairs Authority Act No. 09 of 2003 and the Control of Pesticides Act No. 33 of 1980.

Good Agricultural Practices (GAP) for Fruits and Vegetables

As a solution for safety and quality issues in agriculture products, the Good Agricultural Practices (GAP) programme was introduced in 2015. Under this programme application of fertilizer, pesticide and weedicide, harvesting, processing, transportation, grading, packing, value addition, labeling, distribution and storage processes will be monitored by the Department of Agriculture (DOA). If farmers adopt recommended methods, a certificate will be issued. Farmers have to register for the programme before the start of the cultivation season. The programme targets agriculture exports and will be expanded to supermarkets and ordinary markets. Forty Counselors in Agri-business (CAB officers) and 40 technical assistants have been appointed by the Department of Agriculture, who are responsible for monitoring and promoting this programme among farmers. This will help control microbial, chemical and physical hazards associated with all stages from production to packaging of fruits and vegetables.

This was authorized for adoption by the Sri Lanka Standards Institution (SLSI) on 23/06/2016 (SLS 1523-1:2016). This standard should be used in conjunction with the SLS 1412 – Code of Hygienic

Practice for Fruits and Vegetables and the SLS 1465-Code of Practice for Use of Pesticides. SLS 1524: 2016 provides specific guidelines that help minimize microbial and chemical hazards of fresh leafy vegetables from production to consumer level. This code is also subject to the restrictions imposed under the Food Act No. 26 of 1980.

Organic Standards and Certification for Maintaining Quality for Export Market

A major market channel for organic produce in Sri Lanka is the export market. Bulk of the volume of organic agricultural products is exported. Major export destinations include the Europe, the USA, Japan and Australia. The Middle East is also a growing market. A few private sector organizations and non-governmental organizations are responsible for exporting organic food (Kariyawasam, 2007; cited in Vidanapathirana and Wijesooriya, 2014). Organic certification (external certification) is required to access distant and international organic markets. Organic standards have to be strictly followed. For meeting the requirement of the organic export sector in Sri Lanka, certification is carried out by foreign certification agencies. Two such certifying organizations (Control Union and Institute for Market Ecology-IMO) are involved in organic certification in the country. Organic is a form of labeling system granted for ecological production when the whole process is certified by an accredited third party organization. Without a third party guarantee on the compliance of set international standards on organic production methods, a product cannot be labeled, termed or called organic (Ranaweera, 2008; cited in Vidanapathirana and Wijesooriya, 2014).

The certification covers the whole chain of activities from production to processing, but the minimum requirement for export is to ensure the legal standards of the country of import are met. Certification leads to consumers trust in organic production system and products. Certification offers organic farming a distinct identity and credibility and makes market access easier (Prakash, 2003; cited in Vidanapathirana and Wijesooriya, 2014).

The Sri Lanka Standard Institute has developed the National Standard; SLS 1324: Sri Lanka Standard for Organic Agriculture Production and Processing in compliance with the EU requirements. These standards prescribe the methods of production, processing, handling, storage and transportation of organically produced agricultural products. A standard for organic agriculture defines how production system be managed, covering all aspects such as soil fertility and pest control with emphasis on proper recording and labeling. According to the country of import, the exporting companies have to follow different organic standards and the certification bodies operating in that particular country perform inspection and certification according to those standards. For the export market the quality of the organic food products needs to be assured from production to marketing. Hence, the exporters have to monitor the entire supply chain to assure whether the required standards for certified products are reached. Companies use different procedures to assess the quality of products (Vidanapathirana and Wijesooriya, 2014).

Institutional Environment to Monitor Food Safety of Fruits and Vegetables

In terms of food regulation two institutions coming under the government. i.e. Food Control Administrative Unit (FCAU) and Sri Lanka Standards Institute (SLSI) are in operation.

1. Food Inspection Service under Food Control Administrative Unit (FCAU)

Basically, the import inspections and the peripheral food inspection services are handled by FCAU in inspections of national food controlling. For food importations the Food and Drug Inspector is in charge of inspection services at ports for ensuring the compliance of imports to local regulations. The peripheral food inspection service is an important arm in local food controlling as it is responsible for inspections and auditing of a number of food operating bodies island wide. The regional food inspectors of Public Health Inspectors (PHIs) have been directed to conduct food inspections. The samples drawn are sent to food labs and the legal proceedings can be made only by the authorized officers recognized by the Food Act. Further, if PHIs need higher order assistance in their duty, support is derived from Food and Drug Inspectors appointed for each district.

The official inspection service under the FCAU lacks satisfactory coordination and integration with other government agencies of the local food chain. Especially the PHIs have no legal mandate to inspect the conditions of agricultural produce and their supplies. Also, the peripheral food inspectors of PHIs, have to accomplish a wide spectrum of work load in their duty pertaining to a large locality.

The FCAU has the legitimate mandate only to control items of food products, not agricultural produce. For instance, regulation of pesticide application, artificial ripening practices, plant quarantine, phytosanitary inspections, international trade of fresh fruits, vegetables and tea products are not within the mandate of Central Food Control Administration and an integrated approach for whole food chain does not exist (Madusanka, n.d).

National food controlling is scattered among diverse agencies of ministries. Therefore, the local food control mechanism does not have a farm- to- table approach. A common drawback in food inspection is the presence of multiple agency system of local food control system.

The Food Advisory Committee in Sri Lanka, appointed under the Food Act Controller, regulates all administrations of the Food Act, food related policy issues and new developments. Food Advisory Committee (FAC) consists of the representatives from the agencies implementing different aspects of the Act. It consists of authoritative representatives for food administration, national health, Sri Lanka Customs, Colombo Municipal Council, animal health and related food production institutes and several other members nominated by the minister. As per the Food (Amendment) Act No. 26 of 2011, FAC comprises 25 members.

2. Sri Lanka Standard Institute

The Sri Lanka Standards Institute (SLSI) prepares and publishes standards which are voluntary and it has no authority to make their standards mandatory. Currently Sri Lanka Standards are available only a limited types of fruits and vegetables; table potatoes, big onions, red onions, fresh bananas, fresh tomatoes and pineapples. The Sri Lanka Standard Institute formulated Sri Lanka Standard Specifications (SLS) for canned, processed fruits and vegetable products exported from Sri Lanka and make recommendations to the Department of Sri Lanka Customs. This scheme is based on the Gazette notification No. 1844/9 of 08 January 2014 under the Imports and Exports Control Act No.1 of 1969.

SLSI prepares standards in forms of product certifications and system certifications in relation to food industry. SLSI has imposed compulsory standards for seven food product categories produced locally including fresh fruit cordials, fruit cordial concentrates, fruit squash concentrates and fruit syrup concentrates, ready-to-serve (RTS) fruit drinks. The product inspections for those products are conducted by SLSI in collaboration with the Department of Customs. If a product found to be not in conformity with prescribed standards SLSI may take action to get products re-processed under supervision to return the consignment to the exporting country or else dispose it in an appropriate manner with assistance of the Department of Customs and Ports Authority (Madusanka, n.d).

3. National Plant Quarantine Service

According to the provision of Plant Protection Act no. 35 of 1999, the regulations are observed by the National Plant Quarantine Service (NPQS) of the Department of Agriculture in exporting and importing fruits and vegetables. For import of fruits a phytosanitary certificate issued by an authorized officer of the Plant Quarantine Service of the country of origin is compulsory. All the importers of fruit products are subjected to the regulations made under the Plant Protection Act. as given below;

- No plant or plant product can be imported without a valid permit obtained from the Director General of Agriculture.
- The consignment should not contain plant debris as packaging materials.
- Importation of fruit products are prohibited from tropical American countries.
- Fruit should be free of leaves and branches and also they should be securely packaged in cardboard or plastic cartons. Every consignment of fruit shall be transported to Sri Lanka by sea freight in cold storage at a temperature of 0^0C – 2.2^0C (32^0 – 36^0F).
- Caramel coated apples are not allowed to be imported from the USA.

When exporting fruits and vegetables, the consignment should arrive at the airport six hours early for cooling. During this period quarantine and the custom procedures are undertaken. When exporting plants and plant products plant quarantine requirements of the importing country should be met and the phytosanitary certificate issued by the NPQS should be obtained. PSC is issued;

- If the consignment is free from pest and diseases
- The consignment complies with the quarantine regulations of the importing country
- Consignment should be exported within 14 days from the date of issuing the phytosanitary certificate

4. Consumer Affairs Authority

Consumer Affairs Authority (CAA) is the apex government organization mandated to protect consumers' interest and to ensure fair market competition in Sri Lanka. It has been established under the Consumer Affairs Authority Act No. 09 of 2003. The Act has laid down legal provisions empowering CAA to take necessary action to safeguard the interests of consumers while maintaining effective competition among suppliers of products. It carries out legal proceedings in food controlling in reference to the legal provisions made by food regulatory acts (Food Act and SLSI Act). Import of food items is regulated by Import Export Control Act No.1, 1969, Food Regulations 2001 and Customs Ordinance and Customs Regulations.

The CAA in its food controlling role exerts the services of,

- Handling of consumer complaints
- Control of abusive trade practices

- Consumer education
- Empowerment of consumers
- Promotion of competition
- Market research and information

However, in food regulatory activities in Sri Lanka, CAA does not become as prominent as it lacks the required infrastructure of food controlling (e.g. laboratory facilities, analytical services, inspection services).

5. Analytical Services

The testing infrastructure in the country falls under different ministries. At present the two leading institutes providing standards certification and testing facilities for exporters (eg. HACCP) are Sri Lanka Standards Institute and the Industrial Technology Institute which fall under the purview of the Ministry of Technology and Research. In addition, three other laboratories fall under the purview of the Ministry of Health. The labs of the Registrar of pesticides and the labs of the Plant Quarantine Division fall under the purview of the Ministry of Agriculture. The Government Analyst Department which falls under the Ministry of Justice also conducts food testing. Private companies (eg. SGS Lanka Pvt Ltd) provide testing and certification facilities to exporters as well (Gunaruwan and De Silva, 2014).

Table 2 Official Food Control Laboratories

Ministry	Approved Analyst (Institutes/Departments)
Ministry of Justice	Government Analyst (Pesticide residues)
Ministry of Health (Environment and Occupational Health)	City Analyst, Colombo Municipal Council
	City Analyst - Kandy
	Medical Research Institute (MRI)
	National Institute of Health Sciences (NIHS) Labs- Kalutara, Anuradhapura, Kurunegala
Ministry of Agriculture	Registrar of Pesticide (ROP)
	National Plant Quarantine Service (NPQS)
Ministry of Technology and Research	Sri Lanka Standards Institute (SLSI)
	Industrial Technology Institute (ITI)
Private sector	SGS Lanka Pvt Ltd

Source: Author's Survey Information (2017)

Key Safety Issues in Fruit and Vegetable Supply Chains in Sri Lanka

- Extent to which the population is exposed to food contamination by toxic heavy metals is not widely available.
- Pesticide usage is not properly regulated due to ineffective legislation
- There is no long term systematic pesticide monitoring programme in Sri Lanka and little research has been carried out on contamination of fruit and vegetable

- The task of ensuring food safety is dispersed to a number of government agencies and departments
- The testing infrastructure in the country falls under different ministries.
- The official inspection service under the FCAU lacks satisfactory coordination and integration with other government agencies of the local food chain.

Conclusion

Safety of fruits and vegetables produced in Sri Lanka is in jeopardy due to improper pesticide use, poor methods and practices from the production to post-harvest measures. There is minimal interventions at different stages of the supply chains to ensure safety. The problem of contamination of food sources, especially vegetables by pesticide residues poses a serious challenge to public health. However, the extent to which the population of Sri Lanka is exposed to food contamination by toxic heavy metals is not widely available.

Steps to be taken to Assure Quality and Safety of Fruits and Vegetables

- Promoting and creating awareness for GAP programmes. Develop local market for GAP products.
- Development of Good Agricultural Practices (GAP), Good Manufacturing Practice (GMP) and Hazard Analysis Critical Control Point (HACCP) for economically important fruits and vegetables
- Improve testing and certification facilities
- Inter-sectoral coordination of food safety mechanisms
- Need research to develop easy-to-use practical test kits to identify chemicals
- Attitudinal change of farmers on pesticide usage. Farmers to be educated and trained on personal hygiene along with safe application of pesticides and efficient spray technology to prevent contamination in fields. Strengthening relationship between farmers and extension officers for selection of appropriate pesticides and dosage and providing training for farmers.
- Effective regulation on the quality of imported fruits is vital.
- The Registrar of Pesticide in a Gazette has stipulated Maximum Residue Levels (MRLs) for fruits and vegetables, hence new regulations can be introduced to prohibit sale of fruits and vegetables containing pesticide residues. Strict enforcement of the Pesticide Act and strengthening analytical capacity by upgrading the existing food laboratories to carry out pesticide residue analysis is needed.
- Assurance of food safety beginning from farmers through "Farm to Fork" approach is necessary in food control measures, which include farmers and growers, manufacturers and processors, food handlers and consumers.
- A single apex regulatory authority known as Food Safety and Standards Authority in Sri Lanka is needed to strengthen food safety regulations. Food Safety Act and food safety laws should be strengthened.

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Proceeding of the International Conference on Agriculture, Food Security and Safety, Vol. 1, 2019, pp. 30-44

ISSN 2682-7158

Analysis of the Factors Determining Farmers Adoption and Strategies for the Development of Single Origin Processing Scheme by Coffee Farmers

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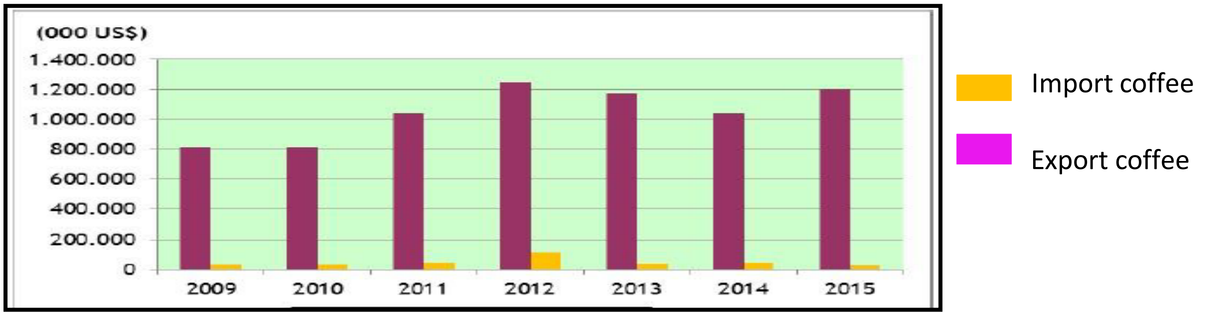
Abstract: Java Preanger coffee is one of GI coffees developed by local coffee producers in Indonesia. The coffee development could not give an equal economic benefit for the farmers, where the brand is mainly utilized by exporters. In order to support local coffee farmers getting a better economic benefit, the government introduce local concept through a Single Origin (SO) coffee program, where the farmers are allowed to process and brand the coffee by themselves. This paper aimed to analyze the factors affecting farmer's adoption to the program, followed by prioritizing strategies to develop further implementation. The ordered logit model is used to measure the probability of farmers in adopting the program with binary model 0 and 1 (1 if farmer adopt). As a result, dominant factors affecting farmer on adoption vary from (1) GI knowledge (odds ratio: 3.501), (2) socio-economic factor; gender (odds ratio: 3.397), farmer household number (odds ratio: 0.431), source of income (odds ratio: 2.779), age (odds ratio: 0.796), (3) geographic factor: existence of farmer neighborhood (odds ratio: 6.147), and (4) collective sharing (odds ratio: 3.061). Finally, there are some recommendations to be done consecutively as prioritized strategies; (1) farmer institution improvement (value: 0.430), (2) farmer technical skill development (value: 0.304), (3) financial access support (value: 0.112), (4), technology support (value: 0.105), and finally (6) marketing development (value: 0.48).

Keywords: Geographical Indication, coffee, farmer adoption, single origin (SO), Ordered logit model, AHP analysis.

I. Introduction

Indonesian coffee contributed as Indonesia's economic engine which was reflected on Indonesia coffee demand becoming the world-wide export commodity. Depicted on the figure 1 below, since the year of 2009, the progress of coffee exportation was going to stably increase with valuing 800.000 USD on the whole year of 2009 to be around 1.2 million USD within 2015.

Figure 1. The Development of Export and Import Indonesia Coffee



Source: Agriculture Ministry of Indonesia, 2016

Based on Indonesia government policy to maintain international market stability by keeping its coffee reputation, the government has initiated the program of Indication Geographic Certification (GI). This is an instrument that could be utilized by the producers to make coffee more exportable, recognizable, and trustworthy for consumer around the world which can lead to be more stable income for country's coffee producers (FAO, 2016). Furthermore, GI could offer opportunities to local farmer and sustainable rural development (Belletti and Marescotti, 2011 on Belleti G, 2014), by reducing an unfair competition through differentiation of the product and resulting the higher price. There are 4 elements of GI product which should be followed: (1) geographical area of production, (2) specific production means / methods, (3) specific product quality, and (4) name and reputation which differentiates the product from other products (FAO, 2010). On other hand, GI development has become exclusively a massive agenda by Indonesia government, since the case of Gayo Coffee, one of Indonesia coffee products, that had been claimed by international company (Holland company) and impacted to coffee export ban (Herviandi *et al*, 2017). Recently, there were lists of GI coffee products which produced from various regions of Indonesia producers as below table.

Table 1. List of Geographic Indication (GI) Coffee in Indonesia

No	Product's Name	Region	Year
1	Arabica Gayo	Aceh, Sumatera	2010
2	Arabica Simalungun	Simalungun Utara, Sumatera	2015
3	Robusta Lampung	Lampung, Sumatera	2014
4	Arabica Java Preanger	Bandung, West Java	2013
5	Java Arabica Sindoro-Sumbing	Temanggung, Central Java	2014
6	Arabica Ijen Raung	Raung, East Java	2013
7	Arabica Kintamani	Kintamani, Bali	2008
8	Arabica Kalosi Enrekang	Enrekang, South Sulawesi.	2013
9	Arabica Toraja	Toraja	2013
10	Arabica Flores Bajawa	Flores, Nusa Tenggara	2012

Source: Agricultural Ministry, 2016.

One of GI coffee certifications is Arabica Java Preanger coffee which is produced on Bandung City, Indonesia. Basically, as GI-certified coffee product, Java Preanger coffee is expected to become price discriminator for the small-scale farmer by its high attributional quality. Nevertheless, in fact, farmer has inequal benefit from the coffee value chain, in which roasters received 95.46% (Robusta) and 83.66% (Arabica) of the total economic rent (retailer excluded). Overall farmers enjoyed a small direct benefit (price) from this certification (Neilson, 2018; Astuti, 2015), due to the fact that there is no specific value chain applied as a distinctive to promote the price discrimination for the small-scale farmer. Otherwise, the GI farmers get the same value to produce GI product compared to the non-GI product, while the effort might be higher to produce the GI product. This non-differentiation of value chain has been happened because Indonesian value chain actors are still on the stage of "Nascent" (developing system), where the connection among producers is newly established or fragile and the GI product's reputation is weaker or more localized that gives consequences of less assured premiums (Treager et al, 2016). On other hand, if farmers could process and create a value-added coffee, the price could be higher varied around 50 dollars/kg within the national market (Putra and Yulius, 2015), as below table details.

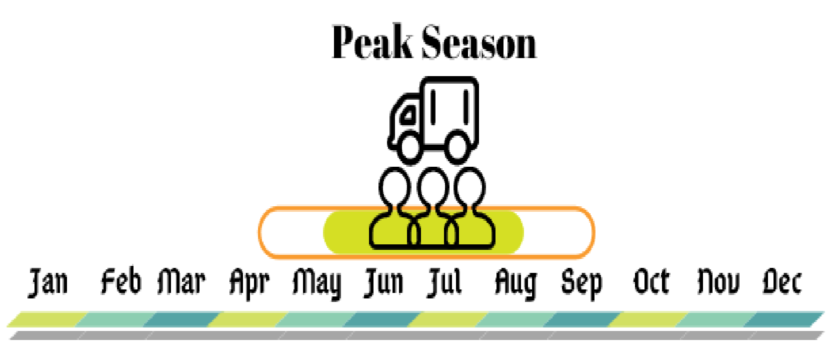
Table 2. Comparison Price of Coffee Product

No	Type of Coffee	Expected Benefit compared to Non- Processing	Expected Price / kg
1.	Red Cherry	-	< 1 dollar
2.	Green Bean	2-5 times higher	8-20 dollars
3.	Roasted Coffee	5-7 times higher	18-30 dollars
4.	Ground Coffee	7-10 times higher	45-55 dollars

Source: Department of plantation of West Java Province, 2017.

In fact, the price is not the only issue for Java Preanger coffee farmers, since the exporter will only come and stock during the peak season of coffee harvesting period (late of May to August). Afterwards, exporter will start exporting to their respected buyers. Thus, because small-coffee growers have lack of processing skill, this will emphasize their difficulties on the market after the peak season.

Figure 2. The Period of Exporter Absorption



Note: **Orange**: period of harvest, **Green**: period of exporter absorption

Source: Field observation, 2018.

To solve that problem, West Java Province has planned to run its new conception of business development model for coffee industry. Due to some ineffective of GI implementation, government has been introduced the concept of Single Origin (SO) Processing Scheme which could promote a local branding “trademark” to allocate more benefit for small-scale coffee growers by producing value-added coffee. This program basically is arranged to promote each regional’s potential coffees with more facilities to create and manage its product attribution. However, to implement this business model of coffee industry (SO Processing Scheme), there is a major government issue about the capacity building on how farmer adopt the new program, whether they could accept beneficially this concept or perform ineffective progress similar to GI. Since currently, farmers have highly dependency on exporter, thus, there are just small percentage of them who have already started the initiative of value-added product. From more than 300 farmer groups, there are only around 16 group of farmers who already developed in advanced the processing coffee products.

Thus, the pilot observation could become the key point before the full-package of implementation done by government, since the government has limitation on budget and human resources. Some farmer groups of total 16 groups could be identified to understand the basic factor in their willingness on processing coffee program as well as to observe the factors that could become the challenges to the adoption. Afterwards, in the final section, the government could consider some strategies to enhance further implementation by analysis model of AHP (analysis hierarchy process) to analyze the proper strategies on the Single Origin (SO) program implementation.

The research objectives were:

1. To analyze the factors affecting farmer to adopt The Single Origin (SO) Processing Scheme of Java Preanger Coffee;

2. To construct prioritized strategies in enhancing Single Origin (SO) Processing Scheme implementation by AHP analysis.

II. Literature Review

A. Theory diffusion of innovation

Basically, the adoption of single origin (SO) processing scheme idea is to give a new system on the local product to preserve or improve the product quality and price. Based on this innovation, this needs “Theory of Diffusion of Innovation” which is stated that innovation is an idea and practice or object that is perceived as a new way by an individual or group of people that adopt (Rogers, 2003 on Ngokkuen and Ulrike Grote, 2012). The new innovation adoption process generally begins with the small percentage of adopters (Jwaiffell and Al- Mothana, 2013).

B. Geographical indication (GI)

According to the U.S. Patent and Trademark Office, “Geographical Indications serve the same functions as trademarks, because like trademarks they are source identifiers, guarantees of quality, and are valuable business interests.” (Ferguson, 2006). A geographical indication (GI) is a name or sign used on certain products which corresponds to a specific geographical location or origin. The use of GI may act as a certification that the product possesses certain qualities, or enjoys a certain reputation, essentially attributable to their geographical origin (Rani and M. Kishor, 2013).

III. Methodology of Research

A. Analysis method

a.1 Order Logit Model

This research used the ordered logit model. Orinda, et al (2017) used probit/ logit analysis to evaluate the factor agricultural program. Meanwhile, Ngkokue and Ulrike (2012) used logit to evaluate the geographical indication adoption found that the level of adoption for the farmer could vary in different factors such as (1) technique, (2) socio-economics, and (3) overtime implementations. In this research, the predictor variables involved to measure what exactly the driven factor of farmers for their involvement in the program.

$$Ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k \quad \text{........ Equation (1)}$$

Y : 0 if farmer does not adopt the program

: 1 if farmer adopt the program

β0 : A constant (parameter)

x : factor affecting farmer's adoption choice

$yi = 0$, If $y^* i \leq 0$ Prob $(y=0|x) = Ø(-x^1 β)$

$yi = 1$, If $0 < y^* i \leq \mu 1$ Prob $(y=0|x) = Ø(\mu 1 - x^1 β) - Ø(-x^1 β)$

where yi = ordinal variable

μ = random factor

Model in this research can present below;

$$yi = β_0 + β_1 X_1 + β_2 X_2 + β_3 X_3 + β_4 X_4 + β_5 X_5 + β_6 X_6 + β_7 X_7 + β_8 X_8 + β_9 X_9 + β_{10} X_{10} + β_{11} X_{11} + ei$$

x1 : GI knowledge of farmer

x2 : Socio-economic factor

(1 if farmer satisfy on GI)

x3 : Spatial geographic

x4 : Relative advantage of the practice

x5 : Learnability characteristics of the adoption

x6 : Farmer organization and collective action

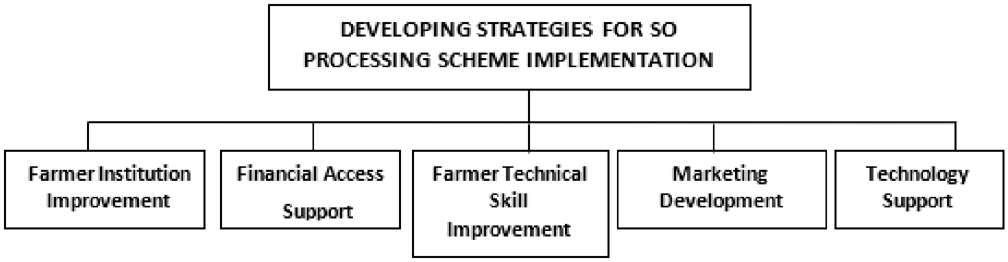
x7 : Public policy support

x8 : Environmental issue

a.2 Analysis Hierarchy Process (AHP) Model

This analysis purposed to evaluate the priority of strategies which could be performed as a policy recommendation for the government to structure the important agenda for the program.

Figure 3. Conceptual framework of AHP Analysis



B. Data Collection

b.1 Order Logit Analysis

The sampling method had been applied using (1) stratified sampling method; to collect the data from adopter and non-adopter farmer and (2) random sampling method; to collect sample both adopter and non-adopter as many as the minimum quota of sample.

Moreover, to find the minimum number of samples, it used the formula of:

$$n = \frac{N}{1 + N\alpha^2}$$ .... Eq (2)

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population
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From above formula, it calculated the total sample is about 134 farmers consisted from 3 region of cultivation area, as below.

Table 3. Distribution of sample size

	Cultivation Area	Total Farmer	Sample (20% per region)
Variant of GI Label	Malabar	211	42
	Tilu	257	52
	Patuha	201	40
Total		**669**	**134**

b.2 AHP Analysis

This research selected professionals on coffee business to get policy recommendation for the government, such as: (1) Farmer Group Leader, (2) Department of Agriculture of Bandung City, (3) Processor, (4) Commerce Department of Bandung, (5) Barista of Coffee, (6) GI organization protectors, and (7) Consumer.

IV. Result and Discussion

A. Ordered Logit Test

The logit analysed by running the model in SPSS 21. Based on the fitting model analysis, it was found the variables which could be performed as the fit model for this research.

a.1 Goodness of fit

a.1.1 Hosmer Lemeshow and Nagelkerke R Square test

Table 4. Hosmer and Lemeshow Test

Step	Chi-square	Df	Sig.
1	.397	8	.945

In this test, the model will be accepted if the sig. value is >0.05, while on the table there is 0.945 value which means the model is strong enough to explain the Y variable. On other hand, the Nagelkerke R2 valued as 0.973 which means that the model is fit and could represent as much as 97.3% of the variable fitness to measure the dependent variable in this research.

a.2 Factor Determining Farmers' Adoption on the SO Coffee Program

This model could be represented as below equation.

Table 5. Partial test of variable

Variables in the Equation

		B	S.E.	Wald	Sig.
Step 1[a]	VAR X1	16.926	7.725	4.801	.028*
	VAR X2.1	22.382	10.426	4.608	.032*
	VAR X2.2	-6.375	3.204	3.958	.047*

Note: * Statistically significance at level 95.

Variable explanation:
VarX1 (GI knowledge), X2.1 (gender), Var2.2 (farmer household number), Var2.3 (source of income), Var2.4 (education level), Var2.5 (age), Var2.6 (Total income/ season), Var2.7 (credit to exporter dummy), Var3.1 (Cultivation area), Var3.2 (Existence of neighborhood adopter), Var4 (Future profit perception), Var5 (perception of adoption easiness), Var6.1 (Farmer organization membership), Var6.2 (Collective sharing), Var6.3 (Personal trust), Var7.1 (Gov. extension visit), Var7.2 (Machinery support), Var7.3 (Marketing support), Var8.1 (Pest attack), Var8.2 (Climate change impact to production), Var9 (Farmer character), Var10.1 (Type of partnership), Var10.2 (Partnership experience), Var11 (Level of satisfaction on GI program).

VAR X2.3	15.905	6.571	5.859	.016*
VAR X2.4	3.879	3.754	1.068	.301
VAR X2.5	-.580	.213	7.453	.006*
VAR X2.6	.000	.000	.202	.653
VAR X2.7	-6.809	5.684	1.435	.231
VAR X3.1	7.321	3.939	3.454	.063
VAR X3.2	10.119	4.941	4.195	.041*
VAR X4	-5.162	3.898	1.754	.185
VAR X5	10.798	9.823	1.209	.272
VAR X6.1	-6.839	5.108	1.793	.181
VAR X6.2	5.147	8.481	.368	.044*
VAR X6.3	.523	10.063	.003	.959
VAR X7.1	-9.503	9.016	1.111	.292

VAR X7.2	5.509	4.678	1.387	.239
VAR X7.3	32.517	26511.638	.000	.999
VAR X8.1	.083	819.857	.000	1.000
VAR X8.2	5.243	6.832	.589	.443
VAR X9	-1.922	2994.622	.000	.999
VAR X10.1	-1.658	5829.392	.000	1.000
VAR X10.2	12.363	381.873	.001	.974
VAR X11	2.452	9.397	.068	.794
Constant	8.168	20814.969	.000	.048

Based on above total variables, it was calculated that only 7 variables were significance with the P-value was under the 0.05. These all variables were considered as the main factor to support the farmer to adopt the program of processing coffee. Meanwhile the other variables were not support to the farmer's adoption. Those 7 variables were the variable mostly related to socio-economic farmer (gender 0.032*, farmer household 0.047*, source of income 0.016*, and age 0.006*), existence of neighborhood adopter 0.041*, and collective sharing 0.044*, also GI knowledge 0.028*.

$$yi = 8.168 + 16.926_{X1} + 22.328_{X2.1} - 6.375_{X.2.2} + 15.905_{X2.3} + 3.879_{X2.4} - 0.580_{X2.5} - 0.000023_{X2.6} - 6.809_{X2.7} + 7.321_{X3.1} + 10.119_{X3.2} - 5.162_{X4} + 10.798_{X5} - 6.839_{X6.1} + 5.147_{X6.2} + 0.523_{X6.3} - 9.503_{X7.1} + 5.509_{X7.2} + 32.517_{X7.3} + 0.083_{X8.1} + 5.243_{X8.2} - 1.922_{X9} - 1.658_{X10.1} + 12.363_{X10.2} + 2.452_{X11} + ei \quad \ldots\ldots (3)$$

B. Analysis and Discussion

b.1 Ordered Logistic Analysis

To analyze the result, it used the odds ratio or Exp (B) value. As below table is the explanation.

Table 6. Partial test of variables in the Equation

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1[a]	VARX1	1.253	1.540	7.626	1	.006	3.501
	VARX2.1	1.223	1.735	5.922	1	.015	3.397
	VARX2.2	-.841	.548	2.356	1	.025	.431
	VARX2.3	1.022	1.820	10.947	1	.001	2.779
	VARX2.5	-.229	.077	8.786	1	.003	.796
	VARX3.2	1.816	1.157	2.465	1	.016	6.1472
	VARX6.2	1.119	.822	1.853	1	.013	3.061
	Constant	1.047	3.474	4.114	1	.043	2.8491

Variable explanation:

VarX1 (GI knowledge), X2.1 (gender), Var2.2 (farmer household number), Var2.3 (source of income), Var2.5 (age), Var3.2 (Existence of neighborhood adopter), Var6.2 (Collective sharing),

Based on above table, it could be stated that the variable X1 (GI knowledge) had the influence for farmer to adopt the program of coffee processing (Single origin coffee processing), with having odds ration as much as 3.501 and the beta (b) is positive (1.253), meaning that the more farmer understands the GI, the more farmer adopts the program. The farmer who know the GI program will be having the greater value to adopt the processing program as much as 3.501 times than the farmer who does not know about the GI knowledge. As of the identification, the reason revealed that if the farmer understands the GI, they already have the preliminary knowledge of creating the value addition product and understand the product quality in respect to the minimum standard and product attribution to be followed.

Varible X2.1 (gender) revealed that male farmers probably put more interest in the processing program, rather than the female. The male farmers have 3.397 times probability higher to adopt the program than the female farmer. In this case, the greater chance of male farmer to adopt the program of processing coffee product is because he has more capability of processing and higher skill by joining some sort of "barista training" provided by government and other related parties. For the female farmer, the least number of them join as the sortation control to grade the quality of coffee bean, only as grading control, which could determine the quality of taste and aroma of the coffee, however, their number is very limited since for that job desk is not needed massive number of human resources. Otherwise, for the male, it is very needed to include them in the processing program, since they are having more capability on (1) the extra power of resource, (2) capacity of conduct high exhausted farming controlling system such as (a) harvest distribution, (b) operating machinery system, and (c) drying system, and (3) their skill on processing which some of them have a competence as barista, while the female does not have.

Another important point which influence the farmer to adopt the program of processing is that X2.2 (farmer household number/ family member). This factor impacted to the probability of farmer adoption on the program as much as 0.431 point in the negative sign. If farmer has more family member, it would reduce the total amount of adoption probability about 0.431, while the less family member in one farmer's family, this could be greater probability of adoption by the family. Basically, the intention of family farmer to adopt the program of processing is due to the return benefit from the selling price (referred on table 2). However, since this implementation of program is still not yet reaching the whole farmers (producers) in the plantation area, thus, the benefit is not yet equally shared to the whole farmers within the plantation area. Thus, until now, to fulfill the family expense, some farmers may take non-farm business for alternative source of income in the family.

The variable X2.3 (source of income) significantly influenced the farmer to adopt the processing program. This was due to the fact most of the farmers are relied deeply on the sector of coffee business and concern totally without seeking any other differentiation of jobs. As the statistical result, the farmers who focused only in developing the coffee business by becoming the main source of income would have 2.779 greater chance to adopt compared to the one who does not rely on the coffee business. It was truly confirmed that if the farmer put coffee as the only source of income, he would concern more in the coffee plantation by such intensification and quality improvement to keep maintaining the product quality and total amount of harvest. Rather than doing differentiation on the jobs such as non-adopter farmer, they preferred to doing diversification by doing some kind of processing product of coffee. Thus, this could fulfill the daily expense of the farmer as an exchange of producing the value added from the processing coffee product. On other hand, as a common condition in Indonesia, basically, the farmer had been reaching the certain ages which needed some regeneration, impacted to the productivity which could be performed less. This was also happened in the coffee business with most of the farmer had been reaching the elder stage of farmer. Therefore, the older farmer in the coffee business would impact to the lower chance of them to adopt the program. As reflected on the logistic regression result, the variable X2.5 (age) influenced the farmer to adopt the program. The older farmer, the less of probability of them to adopt the program by 0.796. This was the truly fact that the older farmer had some sort of limitation in the extra source to manage the whole coffee processing, due to their human power was being reduced by the ages. Basically, the older farmer just focused on the plantation sector with growing and maintaining the coffee plant to produce the coffee cherry. While the younger could cover the job in processing area by helping sortation, pulping, roasting, grounding, and until the packaging as well as helping in the management of marketing, including operating the machinery and market place media on the internet.

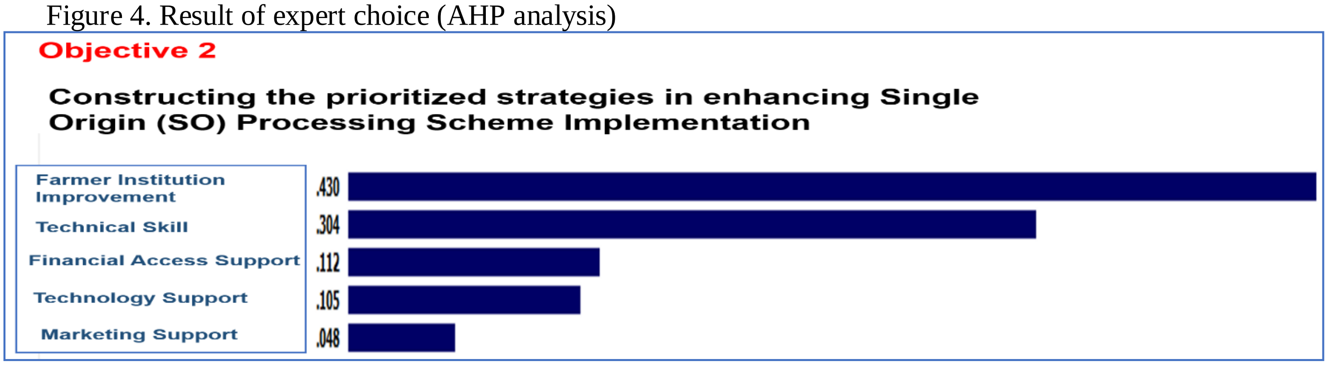
Importantly, to adopt the processing program, non-adopter farmers needed the assistance from another farmer. In this case, when the non-adopter farmers had the adopter farmer surrounding their areas, this could be possibly higher chance of adoption process, because the learning process and the extension process from the adopter farmer to non-adopter farmer (face-to-face extension). Based on it, the statistical result revealed that variable X3.2 (existence of neighbourhood adopter farmer) was significantly impacting to the program adoption for the farmer, by the value about 6.1472 times higher than if there is no adopter farmer in the neighbourhood area. The huge number of value (6.1472) means how important this variable (existence of neighbourhood adopter farmer) in the adoption process, because the extension service could be done daily and progressive to non-adopter farmer as they are in the same cultivation are which is having the same production characteristics. The value of face-to-face extension was becoming the weight point in the exchange sharing of knowledge and skill, since there was no any formal education which teach about "barista skill", thus the informal extension from adopter to non-adopter farmer could help them to understand the conception of coffee processing. On other hand, the benefit knowledge sharing was also becoming the main point in this neighbourhood exchange, because the adopter farmers could experience the process of value-added product and opening the new market channel which could be becoming an exceptional movement for the non-adopter farmer and influence their mindset about taking the risk on the new program of adoption, since most of the time, farmers are not willing to involve in the program due to risk on the profit return.

Finally, after having a knowledge and basic skill of processing, due to the neighbourhood extension, the farmers have to build the trust on the collective action. This collective action could determine the sustainability of the coffee processing product, by maintaining its uniqueness and market speciality. Thus, this variable X6.2 (collective sharing) had a strong influence for the farmer adoption in the single origin processing program by having odds ratio as much as 3.061. If the farmer in the group has the collective sharing and entrust each other in the processing to maintain the production quality from the beginning of germination, seedling, growing, harvesting, and processing, where they could share the resource such as machinery, marketing stuff, and input farming, so that they could reach the standard of product quality and sustain their uniqueness of attribution of the product.

b.2 AHP Analysis

Based on the AHP analysis, resulted some point which could be the preferable for government to take an action particularly in some section of strategies, as below is the detail of particular strategies to be noticed by the government.

Figure 4. Result of expert choice (AHP analysis)



As above result, it could be confirmed that the preferred strategy is having a linkage to the previous quantitative analysis which put the X3.2 (existence of neighborhood adopter) as the greatest factor (influencer) to the adoption process for non-adopter farmer (table 9), since on the above result is putting the farmer (1) institution improvement as the main consideration for the farmer to reform. In the case when non-adopter farmers had a group or cluster to develop processing product, it could react to the improvement of interest followed by the technical assistance from the group of adopter farmer. Looking backward on the table 8, it could be seen that variable X6.1 (farmer organization membership) is not having the real influence to the farmer adoption. However, this is due to the fact that not all the farmer group is becoming "the active group", otherwise, couples of groups are becoming "the non-active organization" which is not perform the function as a group, rather just activates during the time when the government wants to visit or inject the support, while afterwards it does not contain the business activity in exchange for that support. Thus, this linkage, put on how the (1) the farmer institution improvement as the main strategy to be prioritized as the top-first resolution from government by (0.430 weight value).

The second strategy was (2) technical skill to non-adopter farmer (0.304 weight value). It was truly important to know that the farmer basically was not coming from high level education, thus, the improvement of technical skill by the informal education or learning exchange was the logical solution to enhance the capability of smallholder coffee farmer to adapt steadily to the new program of value addition coffee processing. The government should consider about how to make the proper learning exchange in the technical area because this area is totally different than the area that had been done by most of farmer in cultivation and production. Here, this research considered to put in details strategies such as (a) leveling farmer leader barista skill which was selecting some of active farmer group leader in schooling to the certified barista in exchange to the barista competence, (b) sister partnership with other country broker (buyer); this idea generated based on the farmer leader keyperson, which currently has the sister partnership with its broker in the abroad. The function particularly was to check and balance the product quality and learn how the export consumer prefer to buy.

The other strategy was (3) financial access support (0.112 weight value) which could be enhanced once the farmer group is effectively starting to perform the processing. It could be noticed that once the group is existed to start produce the value-added coffee product, this group has a obligation to fulfill the payment to the farmer member who supplies the coffee to the group respected to the quality and quantity. In some case, the farmer group could not achieve to pay the farmer member's coffee produce due to the fact its financial stability is not much enough to pay the whole member production, otherwise, the buyer almost in every time just give the down payment as the deal before the product has been sent off. Thus, the assistance in credit allowance with government guarantee for the farmer must be the concern point for this strategy with the linkage relation to the bank and some of donor from respected company by the program of CSR. In other case (4) technology support strategy (0.105 weight value) may give an extra room for the farmer group to run the processing effectively and efficiently while the cost could be cheaper thanks to this help and by the time could substitute the cost to support the problem of financial aspect. Finally, on the point of (5) marketing support, which becomes the least strategy (0.48 weight value) that could be done by government. This strategy becomes the lowest one due to the fact that the market channel for coffee product in Bandung City is very opened. As observed, the market is continuously growing reflected to the new countless number of coffee shop including the development of new market channels such as retails and direct consumer chain, thanks to the 4.0 industry which enhance the usage of internet. Thus, for this strategy, the government is not putting the groundbreaking structure, otherwise just need to strengthen the market partnership and more “ease on doing business” for investment and marketing on the coffee industry.

V. Conclusion and recommendation

The research had been identified important factors of adoption in the program of single origin processing coffee, as follows: (1) GI knowledge with odds ratio 3.501 reflecting the more farmers have the understanding of GI knowledge, the more they were capable of adopting the SO program; (2) Gender with odds ratio 3.397 reflecting the male farmers have more chances in the program adoption; (3) Farmer household number with odds ratio 0.431 in negative sign, reflecting that if farmers have more family member, they would reduce the probability of adoption due to the risk on safety return; (4) Source of income with odds ratio 2.779 reflecting that if farmers have only coffee source of income, they would have greater chances of adoption, due to the willingness to focus in extracting the business by some of diversification; (5) Age with odds ratio 0.796 in negative sign, reflecting the older farmers, the lower chance of adoption, due to limited capacity of resource in conducting various aspect of management; (6) Existence of neighborhood adopter with odds ratio 6.1472, reflecting that the non-adopter farmers need the assistance of adopter farmer to do face-to-face extension in daily basis farming practice; (7) Collective sharing with odds ratio 3.061, reflecting that the more farmers gather in the effective group and share collectively the resource; human resource, machinery, input farming, management, the more farmers have greater chance to fast adopt the processing program

On other side, the recommendations to the government were; (1) Farmer institution improvement to reconstruct the farmers’ group; (2) Technical skill improvement, to improve the capability of farmer to the adoption program; (3) Financial access, as the solution to prepare the better absorption of the group to pay the farmer member who supplies the standardized production; (4) Technology support, through machinery and assistances, and finally; (5) Marketing support, to maintain the market promotion through integrated program partnership.

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Proceeding of the International Conference on Agriculture, Food Security and Safety, Vol. 1, 2019, pp. 45-56

ISSN 2682-7158

Pesticide Usage in Paddy Cultivation of Sri Lanka: Special Reference to Risk Perception of Farmers

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Abstract: Paddy cultivation plays vital role in Sri Lankan agriculture since rice is the staple food. Literature revealed that misuse and overuse of pesticides in paddy cultivation has led many health and environmental issues. Therefore, the overall objective of the study is to identify pesticide usage patterns in paddy cultivation based on technical aspects and farmer perception of risk. Multistage random sampling technique was employed in sample selection. The sample of 330 paddy farmers representing three climatic zones of Sri Lanka were surveyed using a structured questionnaire. According to the descriptive analysis, herbicides are the major category of pesticides use in Sri Lankan paddy cultivation irrespective of climatic zone and irrigation method. Majority of the surveyed farmers applied herbicide as an input. However, majority of farmers consider presence of substantial amount of pests or pest population before applying insecticides. Certainty Equivalent method and risk attitude scale was used to directly elicit farmer risk preferences. The results of risk attitude scale depicted that the relatively large group of farmers exhibit risk-averse behavior and it is consistent with risk attitude measures rooted in the expected utility approach by means of certainty equivalence. Risk premium of 0.0176 indicates that risk-averse behavior of Sri Lankan paddy farmers. Even though paddy farmers showed risk-averse behavior, there is a propensity to minimize pesticide usage through extension and training of integrated pest management techniques. Hence, national level protocol and monitoring mechanism are required, by incorporating the risk dimension of pest management and farmer risk perception.

Keywords: certainty equivalent method, paddy cultivation, pesticides, risk attitude

Introduction

Rice (*Oryza sativa*) is considered as one of the most important staple food for more than half of the world population (IRRI, 2006) and serious yield losses are caused annually due to pest and diseases (Akhtar *et al.*, 2009 ; Hu *et al.*, 2014). Paddy cultivation plays a vital role in Sri Lankan agriculture over the centuries. Paddy is cultivated as a wetland crop in all climatic zones in Sri Lanka during two major cultivation seasons namely *Maha* and *Yala*. Currently, around 0.792, million hectares of land cultivated in Sri Lanka for paddy and approximately 1.8 million farmers are engaged in paddy farming as a livelihood (Weerahewa *et al.*, 2010 ; Central Bank Report, 2018). More than 75 per cent of the paddy farmers are smallholders with a land area of less than one hectare and only around three per cent of farmers cultivate larger than two hectare of paddy lands (Department of Census and Statistics, 2002).

High rice production is an immediate requirement in the country to feed the ever-growing population. However, this task seems to be impossible due to various hindrances. As revealed by Amuwitagama (2002) the different kind of pest attacks is one of the major problems in the Sri Lankan paddy fields. Consequently, the significant evidences also proved that the paddy has shown the highest estimated percentage yield loss due to pest damages and that was 46.4 per cent per year (Zacharia and Tano, 2011). In addition, pesticides used in the paddy fields globally account for nearly 15 per cent of the total pesticides used for crop production (Agnihotri, 2000). The higher pesticide usage is a characteristic of risk-averse farmers who are wary of crop failure, while minimum pesticide usage is characterize by loss-averse farmers who are wary of health concerns (Liu and Huang, 2013).

Farmer risk preferences play an important role in agricultural production decisions (Feder, 1980). Risk and uncertainty are two terms which are basic to any decision-making framework. Further, risk can be defined as imperfect knowledge where the probabilities of the possible outcomes are known, and uncertainty exists when these probabilities are not known (Hardaker, 2004). Moreover, the risk in agricultural production can be exogenously caused by external factors or endogenously induced by farmer production decisions. Accordingly, Knight *et al.,* (2003), pest outbreaks are exogenously-caused risk while controlling pest outbreaks subject to risk and it is endogenously-induced.

Pesticide has become the most essential input in the modern agriculture and contributes to the productivity and the quality of the cultivated crop (Oerke, 2006; Verger and Boobis, 2013). However, overuse of pesticides has been led to many problems in worldwide such as environmental, ecological, health, social and economic problems. Sri Lanka also not exception of that (Nagenthirarajah and Thiruchelvam, 2008; Padmajani *et al.,* 2014).

It is ambiguous that indiscriminate use of pesticides by Sri Lankan paddy farmers is generally due to lack of knowledge or awareness on harmful effects of pesticides (Selvarajah and Thiruchelvam, 2007; Nagenthirarajah and Thiruchelvam, 2008). Further, misuse and overuse of pesticides in rice cultivation is a major issue (Munaweera and Jayasinghe, 2017). Farmers are reluctant to rely on technical recommendations as they perceive that risk of pest damages and consequent crop loss cannot be averted by available technical recommendations. Hence, information regarding farmer risk perception and behavior with regard to pesticide usage is a prerequisite for any policy intervention initiatives (Jin *et al.,* 2017).

Although many studies have shown impacts of pesticides on health and environment, farmers tend to use pesticides indiscriminately. It seems that farmers perceive less risk of health and environment in comparison to risk of crop loss. A major issue which always arises is whether farmers are willing to accept the risks of pesticide use in pursuit of the benefits. There are limited studies had been conducted on risk perception of crop loss and risk of health. Hence, this study is focused to identify pesticide usage patterns in paddy cultivation based on farmer risk perception.

Methodology

Methods of Data Collection

The study used both primary and secondary data. The primary data collection was done using a pre-tested structured questionnaire. In addition, primary data were collected through, key informant interviews and focus group discussions with Agriculture Instructors (AI) and Agriculture Research & Production Assistants (ARPAs). Secondary data were collected from Registrar of Pesticides, Department of Agriculture, Department of Census and Statistics and Central Bank of Sri Lanka.

Sampling Frame and Techniques

The field survey was covered, 330 paddy farmers who had cultivated paddy during 2017/2018 *Maha* season. Sample size was determined proportionate to the population and Multistage random sampling method was employed. In the first stage, ten districts which have highest number of paddy farmers were purposively selected from major paddy cultivating areas representing three climatic zones {Dry Zone (DZ), Intermediate Zone (IZ) and Wet Zone (WZ)}. In the second stage, two to three Divisional Secretariats (DS) were selected from each district based on, number of farmers, paddy sown extent and method of irrigation. In the third stage, two or three Agrarian Services Centers (ASC) were selected from each district based on number of farmers and paddy sown extent. In the fourth stage, two or three Grama Niladhari (GN) divisions were selected from each district based on number of farmers and paddy sown extent. In the final stage, paddy farmers were selected randomly from each GN division who cultivated under major, minor irrigation schemes and rain-fed.

Data Analysis

Descriptive statistics such as frequency and percentages were used to analyze socio demographic characteristics of paddy farmers and pesticide use patterns in paddy cultivation. Two methods were used to directly elicit farmer risk preferences (Penings and Garcia, 2001). One is derived from the expected utility framework and the other one is derived from responses to a multi - item scale (Churchill, 1995). In this study farmers risk preference or risk aversion was measured using Likert scale from -4 ("I strongly disagree") to +4 ("I strongly agree").

The expected utility model has been used extensively to investigate behavior under risk. In this study the certainty equivalence technique is employed to assess the utility function. Under the expected utility model, the research employed the certainty equivalent (CE) as a welfare measure, decomposing welfare effects into two parts: mean effects E(x) and the Arrow-Pratt risk premium R(x) (measuring the cost of risk) (Chavas and Shi, 2015). When the decision maker is risk-averse, his welfare and decisions generally depend on his risk exposure. According to Pratt (1964), the decision maker is risk- averse if U(y) is concave in y. When consider a decision maker facing certain two alternative management choices yielding either a consequence x_l or a less preferable consequence x_2, with equal probability. Obviously, the expected consequence E(x) of the two alternative choices is $(x_1 + x_2)/2$. The alternative management choices refer in this research are; Application of pesticides in current method of use (x_1) and Application of pesticides at ETL (x_2). (1) $E(x) = (x_1+x_2)/2 = (p)x_1 + (1-p)\ x_2$ with $x_1< x_2$.

The Certainty Equivalent (CE) defined in equation (3) includes two terms: mean output (Expected consequence) E(x), minus the risk premium, R(x), measuring the implicit cost of risk. As such, CE(x) in equation (2) is a risk-adjusted welfare measure for the producer, evaluated in units of x. Further, substituting in the expected utility model with the Von Neumann-Morgenstern utility (u) we can obtain $u(CE(p)) = pu(x_1) + (1-p)\ u(x_2)$. (2) $CE\ (x) = 1/(-c) * (\ln\ (e\text{-}cx_2 \text{-} e\text{-}cx_1)\text{-}\ln(c*(x_1\text{-}x_2)))$ (Keeney and Raiffa, 1976), (3) $CE(x) = E(x) – R(x)$.The cost of risk R(x) is obtained from equation (4) and it depends on both risk exposure due pest damage and health risk of pesticides and risk preferences represented by U(y). (4) $R(x) = E(x) – CE(x)$

For risk averse utility function, $u\ [px_1 + (1\text{-}p)\ x_2] > pu(x_1) + (1\text{-}P)\ u(x_2) = E(x) > CE(x)$ where $0<p<1$ (Keeney and Raiffa, 1976). In here researchers conducted the risk analysis under alternative risk preferences and assumed that the cost of risk R(x) will increase when the farmer become more risk averse. Further, according to Kahnemann and Tversky's Prospect Theory (1979) a positive difference between E(x) and CE(x) indicates risk-averse behavior while negative difference points to risk-seeking behavior. Finally, the researchers evaluate the mean yield E(x), risk premium R(x) and certainty equivalent CE(x). The CE(x) value shows the welfare effect of two alternative decisions. The risk premium R(x) shows the farmers willingness to indifference between two alternative approaches. In this research researches hypothesized that if farmers have same utility for two alternative management approaches there is a possibility to minimize the use of pesticides up to ETL.

Results and Discussion

Socio- economic Characteristics of the Surveyed Sample

Descriptive statistics revealed that about 95.8 per cent of the farmers were male. This result infers that the male farmers are mostly engaged in Sri Lankan paddy cultivation as their livelihood. With respect to the findings the average household size of all districts is around 4.09 and its accordance with the national statistics (Central Bank Report, 2018). The mean age of farmers in all districts is around 55.07 years. Further, majority (55.4%) of paddy farmers were above 55 years. Consequently, this result implies that most of the farmers who engaged in paddy cultivation were belong to old aged of the population and indicate that the lower participation level of young farmers in Sri Lankan paddy cultivation as an income generating activity.

Most of the respondents (39.1%) have 6-10 years of formal education and 28.5 per cent of farmers passed G.C.E. Ordinary Level Examination. According to the results only 12.7 per cent of farmers have completed their G.C.E Advanced Level Examination and have higher educational qualifications such as diplomas and degrees. Most of the respondents (38.8%) had 30-45 years of farming experience with an average of 30 years of farming experience. The result indicates that majority of the farmers are well experienced, and their farming experience is useful for identification of common pests and diseases in paddy cultivation. Farm sizes varied from less than 5 acres to over 10 acres, with an average of 2.23 acres. Further, vast majority (98.1%) of the paddy farmers are smallholders with a land area of less than one hectare and its accordance with the national statistics (Department of Census and Statistics, 2002). Consequently, pest management methods which have applied by farmers are different from farm to farm.

Pesticide Usage in Sri Lanka (Wet Zone, Dry Zone and Intermediate Zone)

The results shown in Table 1, reveal that paddy farmers apply herbicides as an essential input irrespective of climatic zone and method of irrigation. Insecticides are the second largest group of pesticides used whereas the fungicide usage is minimum in paddy cultivation compared to vegetable cultivation.

Table 1: Pesticide Usage in Irrigated and Rain-fed Systems

Type of Pesticide	Irrigated System		Rain-fed System	
	Responses	Percent of Cases*239	Responses	Percent of Cases*91
Herbicides	239	100.00	91	100.00
Insecticides	140	58.58	36	39.56
Fungicides	22	9.21	5	5.49

Source: Authors' own calculation based on field survey (2018)

Note: Total percentage of categories used for pesticide usage in Irrigated and Rain fed systems exceed 100, because many of the farmers in study area have multiple responses.

Pesticides Types Used in Sri Lankan Paddy Cultivation

A total of 66 pesticides types are found to be in use during the survey period (2017/2018 *Maha* season) and it includes 28 herbicides, 32 insecticides and 6 fungicides. Further, these trade names can be categorized into 30 active ingredients. Classification of commonly used pesticides and their toxicological class are shown in the (Table 2).

Table 2: Classification of Commonly Used Pesticides in Study Area

Active Ingredient	WHO Toxicity Class*	Farmer Use as Percentage
Herbicides		
MCPA	NC	48.5
Pretilachlor	U	34.5
Azimsulfuron	U	9.7
Bispyribac-sodium	NC	9.0

Insecticides		
Carbosulfan	Ⅱ	42.6
Fenobucarb	NC	19.3
Etofenprox	U	10.8
Thiamethoxam	NC	6.2
Fungicides		
Tebuconazole	Ⅲ	33.3
Hexaconazole	U	18.5
Carbendazim	U	11.1

Source: Authors' own compilation based on field survey (2018)

(* II: Moderately hazardous; III: Slightly hazardous; U: Unlikely to pose an acute hazard in normal use; NC: Not classified)

Farmers' Decision on Pesticide Application

Time of Insecticide Application

Majority of the paddy farmers (73.9%) applied insecticides considering the presence of pests or pest population since most of them are aware on Economic Threshold Levels (ETL)[1] by their own farming experiences and detrimental effects of excessive insecticide application. Alarmingly, 10.3 per cent of farmers applied insecticides in their paddy field before appearance of pests or symptoms as a preventive measure while seven per cent of farmers applied insecticide as a routine process. The existing literature has also provided the similar situations in Sri Lanka with respect to paddy cultivation (Amuwitagama, 2002 ; Munaweera and Jayasinghe, 2017).

Time of Herbicides Application

Herbicide application is more prominent in surveyed areas with irrespective of irrigated or rain-fed systems. Majority of the surveyed farmers (87.9%) applied herbicides as a routine process with or without emergence of weeds in their paddy fields. In generally, within 0 to 28 days after sowing herbicide applications are made by paddy farmers. About 10.6 per cent of sample farmers purposively applied herbicides after emergence of weeds in order to minimize the input cost and labor cost. It was observed that only 1.5 per cent of sample farmers applied weedicides during primary land preparation where majority of the sample farmers practiced mechanical and physical weed control methods.

Pesticide Application Patterns

It was observed that less than one per cent of the sample farmers applied herbicides before ploughing. However, majority of the farmers (43%) applied herbicides within 0 to 21 days after sowing/planting (DAS/DAP) in order to eliminate common annual grasses, sedges and broad-leaf weeds including *Echinochloa crus-galli* (Cockspur Grass, Barnyard grass/*Velmaruk)*, *Ischaemum rugosum*

[1] The economic threshold is defined as the pest density or amount of plant damage at which the marginal benefit of control just equals the marginal cost of control (Sexton *et al.*, 2007).

(*Gojarawalu/Kudu kedu*), *Cyperus difformis* (*Welhiriya*), *Cyperus iria* (*Thunessa*), *Fimbristylis spp*. (*Kudametta*), *Isachne globosa* (*Batadella*) and *Echinochloa glabrescens* (*Bajiri*).

Table 3: Stage of Pesticide Application in Paddy

Stage of Application	Type of Pesticide	Frequency	Percentage
Before ploughing (*Puran keteema*)	Herbicides	2	0.6
0 - 14 DAS/DAP	Herbicides	97	29.4
14 - 21 DAS/DAP	Herbicides/Insecticides/Fungicides	45	13.6
21 - 28 DAS/DAP	Insecticides/ Fungicides	12	3.6
One month AS/AP	Insecticides/ Fungicides	22	6.7
45 DAS/DAP (1.5 month)	Insecticides/ Fungicides	35	10.6
Two months AS/AP	Insecticides/ Fungicides	27	8.2
75 DAS/DAP (2.5 months)	Insecticides/ Fungicides	65	19.7
Three months AS/AP	Insecticides/ Fungicides	25	7.6

Source: Authors' own compilation based on field survey (2018)

Most of the insecticide and fungicide applications are made within 14-90 days in order to control rice insects and diseases. Common insects include as paddy bug (*Leptocorisa oratoria*), brown plant hopper (*Nilaparvata lugens*), rice thrips (*Stenchaetothrips biformis*) and stem borer (*Scirpophaga incertulas*) as well as fungal diseases like rice blast /*kola paaluwa* (*Magnaporthe grisea*). The results given in the Table 3, implies that the pesticide applications are made by responded farmers at different growth stages of paddy. This results also further confirms the findings of Amuwitagama (2002).

The study findings revealed that none of the farmers applied pesticides after threshing or during storage. Further, it was observed that some of the sample farmers (7.27%) have applied Imidacloprid for seed treatment in order to prevent pest and disease attacks that can be occurred in the future. These farmers reported that the application of Imidacloprid is a successful preventive measure to control Rice Thrips (*Stenchaetothrips biformis*) in paddy cultivation.

Farmers' Risk Perception on Pesticide Use

Agricultural production is exposed to various types of risk. Both weather shocks and unpredictable pest damages have significant impact on agricultural production. The choice of technology and management can provide options to reduce agricultural risk exposure. This study assesses production risk in agriculture using expected utility model. Under the expected utility model, the research employed the Certainty Equivalent (CE) as a welfare measure, decomposing welfare effects into two parts: mean effects and the Arrow-Pratt risk premium.

The results of the Certainty Equivalent (CE) analysis implies that the risk premium (cost of risk) varied between 0.0007 to 0.0553 in all three climatic zones and Mahaweli H area. Consequently, Table 4 indicates that the all island risk premium is 0.0176 and it implies that paddy farmers in Sri Lanka showing risk-averse behavior which is in accordance to Kahneman and Tversky's prospect theory (1979).

Table 4: Estimates of Mean Yield, Certainty Equivalent (CE) and the Cost of Risk under Selected Scenarios, (Tons/acre)

Description	**Estimates**				
	Dry Zone	**Wet Zone**	**Intermediate Zone**	**Mahaweli H**	**All Island**
Mean Yield	2.0343	1.3126	1.5112	2.4031	1.6907
Risk Premium	0.0376	0.0007	0.0224	0.0553	0.0176
CE	1.9967	1.3119	1.4887	2.3478	1.6731

Source: Authors' own calculation based on field survey (2018)

Risk Attitude Scales

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.559 showing that data is adequate for factor analysis. On the other hand, the value of Bartlett's test of sphericity was significant at the 95% confidence level ($X_2^2 = 408.32, p = 0.000$). Exploratory factor analysis on the statements of Table 5 produced eigenvalues for first two factors of 2 and 1.04. That implies that the results support a two-factor model where the first factor explained 49.99 per cent of the variation and second factor explained 26.097 per cent of the variation in the data. The first two statements in the Table 5 make up Scale 1; the last two statements make up Scale 2. Further, reliability of the Scale was 0.90 indicating a good reliability for the construct measurement. According to Hair *et al.*, (2014), the reliability scale ranges from 0 and 1, with higher values indicating greater reliability. Based on above mentioned risk attitude scales, paddy farmers were divided into risk-averse, risk neutral and risk seeking farmers. The split was based on the average sum of the score on the statements of the two scales. Farmers with negative sum scores were considered risk seeking and those with positive sum scores were considered risk-averse. Farmers with a sum score of zero were classified as risk neutral (Penings and Garcia, 2001).

Table 5: Statements Representing Farmer Risk Attitude

Statements	
1	When controlling pests, I am willing to take risks in order to realize higher average returns
2	I like taking some risk in cultivation
3	When controlling pests, I prefer pesticides application / any type of pest control methods which can certainly reduce crop loss
4	With respect to the conduct of cultivation, I don't like to take any risk by using innovative methods

Source: Authors' own compilation (2018)

The results in the Table 6 depicted that the relatively large group of farmers exhibit risk-averse behavior. However, for Scale 1 more farmers exhibit risk-averse behavior than in Scale 2. Further, this is consistent with the findings of the risk attitude measures rooted in the expected utility approach.

Table 6: Classification of Farmers' Attitudes based on the Sum Scores of the Risk Attitude Scales

Scale	Risk Averse (%)	Risk Neutral (%)	Risk Seeking (%)
Scale 1	83.7	4.2	12.1
Scale 2	37	35.6	27.4

Source: Authors' own calculation based on field survey (2018)

Health Risk due to Pesticides

Table 7: Risk Perception of Health

Risk perception	High	Average	Low	None
Frequency	234	60	26	10
Percentage	70.9	18.2	7.9	3.0

Source: Authors' own calculation based on field survey (2018)

Statement: How much health risk do you think that you are exposed while using pesticides in the farm.

According to the analysis 70.9 per cent farmers believe that when using pesticides, they are expose to high health risk while 18.2 per cent believe that pesticide use has an average risk. However, very few believe pesticides have low health risk while only three per cent believe that there is no health risk when using pesticides. Therefore, a great majority is aware of that use of pesticides causes a health risk. As stated by Liu and Huang (2013) loss-averse farmers who are wary of health concerns tend to use less amount of pesticides in their cultivations. Consequently, farmer perceptions of health risks are also expected to influence farmer behavior.

Environmental Risk due to Pesticides

As per the results of (Table 8) 66.4 per cent farmers believe that applying pesticides have high environmental risk while 21.5 per cent believe that the environmental risk is average. Very few believe pesticides have low or no environment risk. Therefore, a great majority of paddy farmers aware on risk of environment caused due to pesticides.

Table 8: Risk Perception of Environment

Risk perception	High	Average	Low	None
Frequency	219	71	32	8
Percentage	66.4	21.5	9.7	2.4

Source: Authors' own calculation based on field survey (2018)

Statement: How much environmental risk do you think that you are exposed to while using pesticide.

Conclusion

Herbicide is the major category of pesticide use in the Sri Lankan paddy cultivation irrespective of climatic zone and irrigation method. Majority of the paddy farmers (87.9%) applied herbicides as a routine practice. Insecticides are the second largest group of pesticides used by paddy farmers whereas the fungicide usage is comparatively low with respect to other crop cultivation. Majority of the paddy farmers (73.9%) applied insecticides considering the presence of substantial amount of pests or pest population since most of them are aware on ETL by their own farming experience and detrimental effects of excessive insecticide application. Further, farmers identify minimum pest population levels before they execute pest control measures.

According to the Certainty Equivalent analysis it was revealed that the all island risk premium is 0.0176 and it implies that the paddy farmers in Sri Lanka showing risk-averse behavior. The lesser increment in cost of risk indicate that the farmers have same utility for two alternative management approaches. Hence, there is a possibility to introduce ETL in pesticide application process as a pest management tool. Analysis of farmer risk perception revealed that the farmers believe that they are expose to high health risk (70.9 %) and environmental risk (66.4%) when using pesticides. Therefore, a great majority of paddy farmers are aware of health and environmental risk due to pesticides.

Recommendations

Severity of pest infestation, degree of crop tolerance and control measures are location specific. The Department of Agriculture has already developed the ETLs for several pests. However, it is necessary to test the acceptance of these threshold levels by paddy farmers. Further, farmer experience and attitude towards risk are the key elements of decision making in pest control. It is recommended to consider the risk dimension of pest management and farmer risk-averse behavior to design pesticide application thresholds that are consistent with farmer management goals. Consequently, implementing of extension and training programs are recommended with the consideration of risk-averse behavior of paddy farmers. Moreover, herbicides are the major category of pesticides use in Sri Lankan paddy cultivation regardless of paddy growing systems. Hence, further research efforts are recommended for identifying the economic impact of weeds in different rice growing systems.

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Proceeding of the International Conference on Agriculture, Food Security and Safety, Vol. 1, 2019, pp. 58-71

ISSN 2682-7158

Formulation and Nutrient Analysis of Vitamin C Enriched Red Wine Using Roselle (*Hibiscus sabdariffa*) and Peppermint (*Mentha piperita* L.)

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Abstract: Wine is considered as a functional fermented food which possess several health benifits. Much research has not been conducted yet to use wine as a vehicle for fortification. Therefore, the study has been undertaken focusing on improvement of the vitamin C content in red wine. Roselle (*Hibiscus sabdariffa*) and peppermint (*Mentha piperita* L.) extract were used for making the wine along with the main ingredients. Baker's yeast (*Saccharomyces cerevisiae*) was used for the fermentation process which was carried out for 28 days. Sensory evaluation was conducted in 9-point hedonic scale and mean scores showed the red wine variation with 10% roselle and 6% of peppermint extract (V2T3) was the best selected one. Mean scores of pH, SG and alcohol by volume % (ABV %) of V2T3 were 2.96, 1.006 and 10.73% respectively. The low pH content has made the microbial resistant and the alcohol content is also within permissible limits. It contains 0.163 ± 0.02 gm/100 ml protein, 2.667 ± 0.21gm/100ml carbohydrate, and 74.93 ± 1.25 mg/100ml GAE phenol, 141.20 ± 1.87 mg of catechin equivalents/l flavonoid and 0.0197 ± 0.001% of tannin. V2T3 contains 25.40mg/100ml of vitamin C whereas the standard red wine (T0) had only 1.91mg/100ml. The statistical F-test indicates that all the results are significant at 5% level. Shelf life study was done in two types of packaging (glass and PET bottles) for both T0 and V2T3. Results indicated that the microbial load is slightly on a higher side in PET bottle (bacterial count: 40.7±0.6 CFU/ml in glass bottle and 45.7±0.6 CFU/ml in plastic bottle; fungal count: 13.0±0.0 CFU/ml in glass bottle and 13.7±0.6 CFU/ml in plastic bottle at 6th week). Thus acceptable red wine is developed by fortifying it with roselle.

Keywords: Fermentation; Roselle; Wine; Vitamin C

Introduction

Wine is one of the functional fermented foods that possess many health benefits. Wine is produced by the fermentation of yeast that involves the conversion of sugar to alcohol. Generally, wine is made from grapes. Various varieties of grapes and yeasts strains are being used depending on the type of wines that need to be produced. Wine also acts as a nutrient supplement for seasonal fruits and vegetables. Use of fruits, flowers and vegetables, herbs which have various medicinal and nutritional values can be used as a substrate for wine production, thus the health benefits can widely be improved. *Hibiscus sabdariffa* which is commonly known as "Roselle, is an important medicinal plant native to India and Malaysia, it also grows widely in the tropics and subtropics regions. It is an annual dicotyledonous herbaceous shrub which belongs from family Malvaceae. The calyces of roselle are edible. It is commonly used as jellies, jam and beverages. Their uses have been reported in the preparation of tea and also fermented drinks in Egypt. Use of the red variety of roselle calyx has been reported to produce a drink in Sudan, Nigeria and West African francophone countries. According to folk medicine, an infusion made from the calyces of this flower is used as a diuretic and to treat gastrointestinal disorders, liver diseases, fever, hypercholesterolemia, and hypertension (Formagio *et al*. 2015). *Hibiscus* *sabdariffa* calyces are rich in anthocyanin and also contain various organic acids such as citric, malic and tartaric acids. Roselle calyx imparts various beneficial effects in human health which is mediated through its antioxidant property. The flowers of *Hibiscus sabdariffa* contain anthocyanin, flavonoids and polyphenols. The calyces are also rich in vitamins; especially ascorbic acid. Peppermint (*Mentha piperita* L.), is considered as a medicinal plant which has gained more attention from both food and pharmaceutical industries because it shows many health benefits to human society. It is a perennial aromatic herb belonging to the Lamiaceae (Labiatae) family. It is cultivated all over the world for its use in flavor, fragrance, medicinal, and pharmaceutical applications. . Some health benefits attributed to peppermint include antifungal, antimicrobial, antioxidant, antihaemolytic activities. Peppermint possess properties like, antiseptic, antiemetic, carminative, diaphoretic, analgesic. Vapour from peppermint oil is used as an inhalant for respiratory congestion. Peppermint is used in tea which helps to treat coughs, inflammation and bronchitis etc. Vitamin C, (also known as L-ascorbic acid), is an essential dietary component which is water-soluble in nature and is naturally present in some foods, If those are added to other food, it can turn into or can be used as a dietary supplement. Vitamin C is required for the biosynthesis of collagen, L-carnitine, and certain neurotransmitters; vitamin C is also involved in protein metabolism. Human beings are not able to synthesize vitamin C endogenously. Hence, vitamin C is an essential dietary component which can be obtained through food. Consumption of wines in the Indian market has been significantly increased. Also, wine is already considered as functional fermented food, on this account red wine can be chosen for value addition.

Materials and Method

Sample collection and preparation

Fresh grapes were purchased, destemmed, soaked in warm water and salt (NaCl) for 10 minutes, washed with clean water, dried in a clean muslin cloth and sorted. Grapes were weighed accurately for all the variations and crushed and mashed by a clean wooden muddler in a clean and dry vessel. Dried roselle petals are purchased from market and it is weighed accurately according to the calculated concentration of the respected variation and it is crushed and mashed along with the grapes nicely with the help of the muddler. Sugar (75g) and sterilized warm water (500ml) were added to the mixtures after this. Thus the total soluble solids (TSS) of the mashes were adjusted. Before inoculation, Potassium metabisulfite was added in the mashes to reduce the bacterial contamination. Commercially available baker's yeast (*Saccharomyces cerevisiae*) suspension (1g/l) is added to it and mixed well. The wine must was filled into sterilized fermentation jars and sealed airtight and left to incubate for 28 days at room temperature. After 28 days the filtration was done of each variation and the amount of extract obtained from each variation was measured by measuring cylinder. Peppermint extract was made from fresh peppermint leaves which were purchased from the market and destemmed, soaked in warm water and salt for 5 minutes, washed with clean water, dried in a clean muslin cloth and sorted. For each variation apart from control, around 10 gm leaves were measured and taken for crushing. The leaves were crushed uniformly by adding water. Afterward, it was added to 200 ml distilled water and boiled. It was separated with the assistance of filter paper. The extract was thus prepared and could now be included. The extract was made just before adding to wine to guarantee it was included when fresh.

Table 1 Composition of variations.

Product Code	Grapes(kg)	Roselle (%)	Peppermint extract (%)
T0 (Standard)	1	-	-
V1T1	1	5	2
V1T2	1	5	4
V1T3	1	5	6
V2T1	1	10	2
V2T2	1	10	4
V2T3	1	10	6
V3T1	1	15	2
V3T2	1	15	4
V3T3	1	15	6

Pasteurization and bottling

The clear wine was transferred into covered steel pots and pasteurized by heating to 70°C for 15 minutes and cooled to room temperature (25°C). No chemical was added for the clarification of wines. Cold wines were filled into pre-sterilized bottles and kept in room until needed for further analysis.

Determination of the physiochemical properties-

The pH and Total Soluble Solids (TSS) were measured according to the AOAC method. Specific gravity (SG) of different wine versions was determined according to the procedure of Balogu and Towobola, 2017. The percentage alcohol content was then calculated based on specific gravity chart given by American Society for Brewing Chemists.

Sensory evaluation

Each panelist received the wine sample in a random presentation order, a glass of water for rinsing consumption between samples. Coded samples were assessed organoleptically using a 9-point hedonic scale.

Proximate and Nutrient Analysis-

Protein (Lowry *et al*. 1951), Carbohydrates (Hedge and Hofreiter, 1962), Total Phenols (Mallick and Singh, 1980), Flavonoids (Debebe *et al.* 2016), Tannins (Mulani *et al.* 2016), Vitamin C (Nielsen, 2010) were measured.

Microbial analysis of the products (shelf life checking in glass bottles and plastic bottles)

The microbiological study was conducted for 6 weeks. Every test was carried out once in a week: 1st day, 7th day, 14th day, 21st day, 28th day, 35th day, 42nd day to check the difference of increase in the number of colony forming unit. Before a day of conducting analysis, petri plates and other tools such as pipette, micropipette etc. was autoclaved and kept in the incubator to ensure sterilization. Nutrient agar was used for pour plate (to determine bacterial colonies) and potato dextrose agar was used for spread plate (to determine fungal colonies). Serial dilution was done with the food sample in the test tubes. Triplicates of the sample were poured onto agar petri plates. Pour plate method was done using 1 ml of dilutions 10^{-7}, 10^{-8}, 10^{-9} and incubated at 37ºC for 24 hours. This is used to estimate colony forming unit (CFU) for bacteria. Spread plate method was done using 0.1ml of the dilutions 10^{-3}, 10^{-4}, 10^{-5} and incubated at room temperature (25ºC-28ºC) for 24 to 48 hours. This is used to estimate the fungal count of the food. The colony forming units were counted the next day for bacteria and the day after for fungi.

Results and Discussions

Physicochemical Properties

pH: The pH of wine is important to know as it plays a critical role in many aspects of winemaking, in particularly wine stability. pH influences microbiological stability, determines the effectiveness of sulfur dioxide and enzyme additions, influences the solubility of proteins and affects red wine colour and oxidative and browning reactions.

Product Code	Week 1	Week 2	Week 3	Week 4	Final pH
T0	3.53± 0.057	3.46 ± 0.057	3.36 ± 0.057	3.13± 0.057	3.2± 0.1
V1T1	3.16± 0.057	3.13± 0.057	3.09 ± 0.01	3.04± 0	3.01±0.1
V1T2	3.26± 0.057	3.16± 0.057	3.086 ± 0.01	3.07± 0.057	3.05± 0.005
V1T3	3.23± 0.057	3.13± 0.057	3.03±0.057	3.09± 0	3.06± 0.005
V2T1	3.09± 0.005	3.08± 0.057	3.04±0	3± 0.1	2.93± 0.005
V2T2	3.08± 0.015	3.06± 0.057	3.05± 0.01	2.99± 0.1	2.93± 0.057
V2T3	3.13± 0.06	3.08 ± 0.057	3.06± 0.011	2.99± 0.015	2.96± 0.057
V3T1	3.04± 0.017	3.01 ± 0.057	2.9± 0.011	2.89± 0.015	2.8± 0.1
V3T2	3.05± 0.01	3.003± 0.057	2.94± 0.011	2.85± 0.057	2.82± 0.1
V3T3	3.04± 0.011	3.01± 0.057	2.96±0.02	2.87± 0.057	2.84 ± 0.005

Table 2 Changes in pH during 4-week storage period.

Table 2 shows the weekly data of the pH for developed wines and it was observed that the wines are on acidic side (below 7) and in the variations the pH ranges from 2.8-3. The standard (T0) wine had a pH of 3.53± 0.057 on the first week fermentation which got decreased throughout the fermentation period and it got the final pH of 3.2± 0.1 after fermentation. T0 had the highest amount of pH. Amongst the variations V1T2 had the highest pH of 3.26± 0.057 and it obtained a final pH of 3.05± 0.005. The pH value of this variation is nearest to the standard (T0) wine. The variation (variation 3) which has the highest amount of roselle has showed to have the lowest initial pH. Both variation 2 and variation 3 obtained a final pH of <3 which is significantly lesser than T0. The significant trend which was observes here was the pH was decreasing gradually throughout the fermentation period. Due to the low pH values, the wines gave a crisp tart taste to the product and it also enhances the microbial resistance of the product. The values are comparable with the pH values on the final day were 3.0 and 3.07 at 20 °C and 30 °C respectively in roselle wine (Ifie *et al.* 2016). The pH of 3 varieties of Zobo drink ranges from 2.5-2.67 (Foline *et al.* 2011).

Total soluble solids (°Brix): TSS measures the sugar content of present in the wine. This is measured using a refractometer, and is referred to as the degrees Brix (°). This influences the conversion of sugar to alcohol by yeast strain during fermentation period. Table 3 shows the initial and final total soluble solids (TSS) of the developed wines. The addition of sugar at the beginning of fermentation is necessary to provide suitable conditions for the growth of yeast and fermenting the sugar into ethanol (Tatdao *et al.* 2014). The reduction in soluble solids of the must from 18.1 to 4.8 °Brix at day 12 of fermentation shows efficiency of the yeast during the fermentation of roselle wine (Ifie *et al.* 2012).

Table 3 Initial and final TSS.

Product Code	Initial TSS (Brix°)	Final TSS (Brix°)
T0	21.54	2.2
V1T1	19.31	2.01
V1T2	19.31	2.04
V1T3	19.31	2.03
V2T1	20.43	2.19
V2T2	20.43	2.02
V2T3	20.43	2.01
V3T1	20.88	2.18
V3T2	20.88	2.05
V3T3	20.88	2.03

Specific gravity and Alcohol by Volume % (ABV %): Table 4 shows the data for specific gravity (SG) of the developed wines. Final specific gravity is observed to be on a lower side than the initial specific gravity which is taken from the initial wine must. There is no significant trend observed in the specific gravity of wine. The standard wine had the highest initial SG of 1.09 amongst all the developed products, followed by variation 3 (1.087), variation 2 (1.085) and variation 1 (1.08). The table also depicts alcohol by volume % (ABV %) of the developed wines. The standard (T0) has showed to obtain the highest % of alcohol by volume % (ABV %) having an ABV of 11.27% which is almost near to the variations V3T2 (11.005%) and V3T3 (11.14%). The roselle wine contained 10.8% (w/v) alcohol after aging (Alobo & Offonry, 2009).

Product Code	Initial Specific Gravity	Final Specific Gravity	ABV%
T0	1.09	1.007	11.27717
V1T1	1.08	1.006	10.05435
V1T2	1.08	1.006	10.05435
V1T3	1.08	1.005	10.19022

V2T1	1.085	1.007	10.59783
V2T2	1.085	1.006	10.7337
V2T3	1.085	1.006	10.7337
V3T1	1.087	1.007	10.86957
V3T2	1.087	1.006	11.00543
V3T3	1.087	1.005	11.1413

Table 4 Specific gravity and Alcohol by Volume % (ABV %).

Sensory score analysis-

Table 5 depicts the product wise mean sensory scores. While considering the mean sensory score with respect to taste, the highest score (8.04 ± 0.94) was obtained by V2T3, followed by standard (T0) which obtains a mean score of 7.48 ± 1.64. Appearance, colour, aroma, taste and subtle taste factors like flavour of wine constitute the quality. Aroma and taste of wines are very complex and depend on number of factors such as cultivar, edaphic factors, vinification practices, fermentation and maturation. Primary aromas present in wines are fruity in nature and are grape-derived, whereas, secondary aromas arise from the fermentation of juice into wine and come from esters of alcohol and higher alcohols and a number of volatile compounds (Jackson R.S., 2016).

Table 5 Product wise mean sensory score

Product Code	Sensory Scores			
	Aroma	Taste	Mouth feel	Colour & Appearance
T0	7.20 ± 1.58	7.48 ± 1.64	7.44 ± 1.53	7.84 ± 1.18
V1T1	6.32 ± 1.15	5.48 ± 1.50	4.041 ±1.48	7.08 ± 1.22
V1T2	6.24 ± 1.09	5.96 ± 1.51	5.88 ± 1.04	7.12 ± 0.93
V1T3	6.12 ± 1.05	5.84 ± 1.11	5.68 ± 1.31	6.84 ± 1.28
V2T1	6.76 ± 1.30	6.96 ± 1.27	6.84 ± 1.03	7.60 ± 0.76
V2T2	7.04 ± 1.10	7.08 ± 1.19	7.00 ± 1.08	7.68 ± 0.69
V2T3	7.88 ± 1.01	8.04 ± 0.94	8.12 ± 0.83	8.24 ± 0.93
V3T1	5.60 ± 1.63	4.68 ± 1.35	4.72 ± 1.49	6.88 ± 1.59
V3T2	5.68 ± 1.41	4.60 ± 1.26	4.56 ± 1.45	6.84 ± 1.21
V3T3	5.68 ± 1.41	5.00 ± 1.47	4.88 ± 1.51	6.88 ± 1.13
F-Test	8.56*	20.64*	22.35*	5.01*
SEm±	0.2585	0.2676	0.2592	0.2245
CD at 5%	0.7166	0.7418	0.7185	0.6223

*Significant at 5 % Level, SEm: Standard Errors of mean, CD: Critical Difference

The table 6 depicts the overall mean acceptability scores with respect to the products. The highest overall mean acceptability scores were found to be higher in V2T3 (8.092±0.84), followed by T0 (7.512±1.38). The statistical scores between products were found to be statistically significant at 5% level (p<0.05, 20.30*).

Table 6 Sensory score of overall acceptance.

Products	Overall Acceptability Scores	
	Mean	SD
T0	7.512	1.38
V1T1	6.124	1.09
V1T2	6.260	1.01
V1T3	6.140	0.93
V2T1	7.064	0.90
V2T2	7.220	0.87
V2T3	8.092	0.84
V3T1	5.492	1.19
V3T2	5.444	0.90
V3T3	5.628	0.98
F-Test	20.30*	
SEm±	0.2040	
CD at 5%	0.5655	

*Significant at 5 % Level, SEm: Standard Errors of mean, CD: Critical Difference

Proximate and nutrient content analysis-

The results for following proximate and nutrient analysis are discussed as follows.

Comparison of the mean protein, carbohydrate (CHO) and phenol, flavonoid and tannin content between T0 and V2T3:

Table 7 Mean nutrient scores of T0 and V2T3 on protein, CHO and phenol, flavonoid and tannin.

Products	Scores (Mean ± SD)				
	Protein (gm/100ml)	CHO (gm/100ml)	Phenol (mg/100ml GAE)	Flavonoid (mg of catechin equivalents /l)	Tannin(%)
Standard (T0)	0.123 ± 0.02	2.200 ± 0.10	64.30 ± 0.85	113.47 ± 2.58	0.0307 ± 0.002

V2T3	0.163 ± 0.02	2.667 ± 0.21	74.93 ± 1.25	141.20 ± 1.87	0.0197 ± 0.001
F-Test	7.20*	12.25*	147.91*	227.71*	99.00*
SEm±	0.0105	0.0943	0.6191	1.3000	0.0157
CD at 5%	0.0414	0.1633	2.4306	5.1035	0.0615

*Significant at 5% level

Table 7 shows the mean protein content of T0 and V2T3. Mean protein content of the T0 was 0.123±0.02 gm/100ml and V2T3 was 0.163±0.02 gm/100ml. V2T3 has a mean protein content slightly higher than the standard. The statistical F-test indicates that the results are significant at 5% level (P<0.05, 7.20*). The protein content in most of the wines is negligible (Soni *et al*. 2009). Mean carbohydrate content of T0 was 2.2±0.1 gm/100ml and V2T3 was 2.667±0.21 gm/100ml. The statistical F-test indicates that the results are significant at 5% level (P<0.05, 12.25*). Mean phenol content of T0 was 64.3±0.85 mg /100ml GAE and V2T3 was 74.93±1.25 mg/100ml GAE. So, the total phenol content was higher than the standard. The statistical F-test indicates that the results are significant at 5% level (147.91*). Phenol content of wine can be improved by addition of new ingredients and also by using of various kind of wine making techniques. They have bactericidal and antioxidant properties that apparently protect consumers from cardiovascular diseases (Ribereau-Gayon *et al*. 2006). Mean Flavonoid content of T0 was 113.47±2.58 mg of catechin equivalents /l and V2T3 was 141.2±1.87mg of catechin equivalents /l. Developed wine contained more flavonoid than the standard wine. The statistical F-test indicates that the results are significant at 5% level (P<0.05, 227.71*). Studies have shown presence of flavonoid and phenolic compounds in roselle calyces which contributes to its antioxidant activity (Obouayeba *et al.* 2014). Tannin content of the standard was 0.030±0.0015 % and the best variation was 0.019±0.0011%. The statistical F-test indicates that the results are significant at 5% level (99.0). The tannin content was lesser in the developed product than the standard one. In preparation of red wine, the crushed grapes are used along with skin for extraction of colour and tannin content in wine. Tannins are very important chemical compounds in the grape berry and the corresponding wine, as they greatly influence the colour, taste and maturation potential of the wine (Nel, 2018).

Correlation between overall acceptability score and vitamin C content of standard (T0) and all the variations:

Table 8 depicts that V2T3 has the highest overall acceptability mean score and, vitamin C content of V2T3 25.40mg/100ml. The vitamin C content of V2T3 is comparable with the zobo drink made from bright red variety roselle prepared at 10 minutes in Nigeria, 26.12±1.62 mg/100ml (Bamishaiye *et al.* 2011). Compared to all the variations, control has the lowest amount of vitamin C, only (1.91mg/100ml). According to Indian Council of Medical Research, 2010, the daily recommended intake of vitamin C is 40mg/day. So, the best variation can provide with 63.5% of the RDA of vitamin C by one serving of it. A statistical analysis (Pearson's product-moment correlation) between sensory scores and vitamin C content of the wines were done and the data showed that the samples are negatively correlated (-0.430) and the p-value is >0.05. Hence, it can be concluded the correlation is moderately negative and there is no significant relationship between these two variables.

Table 8 Vitamin C and overall acceptability score.

Products	Scores	
	Vitamin C (mg/100ml)	Overall Acceptability
T0 (Standard)	1.913	7.512
V1T1	12.295	6.124
V1T2	12.842	6.260
V1T3	13.115	6.140
V2T1	24.590	7.064
V2T2	24.863	7.220
V2T3	25.410	8.092
V3T1	34.973	5.492
V3T2	35.246	5.444
V3T3	35.792	5.628
Correlation coefficient (r)	- 0.430	

*Significant at 5 % Level,

Shelf life study

Shelf life study is an integral component of a product development. The time of spoilage can be determined by storing the product at ambient condition. Microbial analysis was carried out to determine the quality of the fermented product by the standard plate count method.

Table 9a Mean scores of control and standard products on bacterial count (1st, 2nd and 3rd week).

Products	Scores (Mean ± SD)					
	1st Week		2nd Week		3rd Week	
	Glass	Plastic	Glass	Plastic	Glass	Plastic
T0	26.0±2.0	32.0±2.0	34.0±3.6	37.3±0.6	36.7±2.1	39.3±0.6
V2T3	22.3±0.6	30.7±1.5	27.0±1.7	34.7±0.6	31.7±2.3	38.0±1.0
F-Test	22.11*		13.99*		12.23*	
SEm±	0.9434		1.1790		0.9574	
CD at 5%	3.0764		3.8447		3.1222	

*Significant at 5 % Level

Table 9b Mean scores of control and standard products on bacterial count (4th, 5th, 6th week).

Products	Scores (Mean ± SD)					
	4th Week		5th Week		6th Week	
	Glass	Plastic	Glass	Plastic	Glass	Plastic

T0	39.7±1.5	43.7±1.2	41.3±1.2	45.3±2.5	42.3±0.6	49.7±2.1
V2T3	35.3±1.2	41.3±0.6	39.3±0.6	42.7±0.6	40.7±0.6	45.7±0.6
F-Test	27.83*		9.12*		35.56*	
SEm±	0.6658		0.8327		0.6658	
CD at 5%	2.1713		2.7153		2.1713	

*Significant at 5 % Level

Table 9a and table 9b shows the bacterial count for 6 weeks of T0 and V2T3 kept in glass bottles and plastic bottles. The bacterial count of both the products kept in glass and plastic bottles were observed and it was found to be less in glass bottles than plastic bottles in both T0 and V2T3. V2T3 has bacterial count of 40.7±0.6 CFU/ml in glass bottle and 45.7±0.6 CFU/ml in plastic bottle which is lesser than the T0 in both the cases. The statistical F-test score indicates that the results are significant at 5% level (P<0.05, 35.56*).

Table 10a Mean scores of control and standard products on fungal count (1st, 2nd ,3rd week).

Products	Scores (Mean ± SD)					
	1st Week		2nd Week		3rd Week	
	Glass	Plastic	Glass	Plastic	Glass	Plastic
T0	10.7±0.6	11.3±0.6	11.3±0.6	11.7±0.6	12.0±1.0	12.3±0.6
V2T3	10.3±0.6	11.0±1.0	11.7±0.6	12.0±0.0	12.0±0.0	12.7±0.6
F-Test	1.11 NS		0.89 NS		0.73 NS	
SEm±	0.4082		0.2887		0.3728	
CD at 5%	-		-		-	

*NS: Non-significant

Table 10b Mean scores of control and standard products on fungal count (4th, 5th 6th week).

Products	Scores (Mean ± SD)					
	4th Week		5th Week		6th Week	
	Glass	Plastic	Glass	Plastic	Glass	Plastic
T0	13.0±1.0	13.3±0.6	14.0±1.0	13.7±0.6	14.3±0.6	14.0±0.0
V2T3	12.3±0.6	13.0±0.0	12.7±0.6	13.3±0.6	13.0±0.0	13.7±0.6
F-Test	1.27 NS		1.94 NS		5.83*	
SEm±	0.3728		0.4082		0.2359	
CD at 5%	-		-		0.7694	

*Significant at 5 % Level, NS: Non-significant

Table 10a and table 10b shows the fungal count for 6 weeks of T0 and V2T3 kept in glass bottles and plastic bottles. The fungal count of the products kept in both glass and plastic bottles were observed and it was found that glass bottles have comparatively less fungal count than plastic bottles in both T0 and V2T3. V2T3 has lesser fungal count (13.0±0.0 CFU/ml in glass bottle and 13.7±0.6 CFU/ml in plastic bottle) as compared to T0. The statistical F-test score indicates that the results are significant at 5% level only at 6th week ($P<0.05$, 5.83*).

Conclusion

There are plenty of fruits, vegetables and edible flowers which are still underutilized though they can show positive health effects when consumed as it contains plenty of vitamins, minerals and also shows antioxidative properties. This study proves that acceptable wines can be prepared by addition of roselle and peppermint extract in the normal red wines if added in specific amount. The high acidity of the wines indicated that microbial spoilage resistance and storability can be improved when roselle is added to wine. Further studies are needed to check the antinutritional factors and mineral compositions of wine and also to check the parameters of the wine when aged for a longer time.

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Appendix

Table 1: Composition of variations.

Table 2: Weekly pH.

Table 3: Initial and final TSS.

Table 4: Specific gravity and Alcohol by Volume % (ABV %).

Table 5: Product wise mean sensory score

Table 6: Sensory score of overall acceptance.

Table 7: Mean nutrient scores of T0 and V2T3 on protein, CHO, phenol, flavonoid and tannin.

Table 8: Vitamin C and overall acceptability score.

Table 9 (a and b): Mean scores of Control and Standard Products on Bacterial count (1st – 6th week).

Table 10 (a and b): Mean scores of Control and Standard Products on Fungal count (1st – 6th week).