Journal of Dry Zone Agriculture

Volume 6, Number 2
2020

Faculty of Agriculture, University of Jaffna,
Sri Lanka

Journal of Dry Zone Agriculture, Vol. 6, No. 2, 2020

ISSN 2012-8673

Editorial Policies

The Journal of Dry Zone Agriculture (JDZA) publishes two issues in a volume annually with original research articles covering all aspects of dry zone agriculture. Authors preparing manuscripts should follow the instructions appearing at the end of this volume. All opinions reflect the views of the authors and are not necessarily the views of Faculty of Agriculture, University of Jaffna. Final decision of the acceptance or rejection of the papers is made by the editorial board. The JDZA is devoted to sustain the standard through a rigorous blind review along with strict ethical policies. The JDZA publishes original research works that have not been published in any form except abstract or not currently under consideration for publication elsewhere. Any violations of professional ethical codes such as plagiarism, fraudulent use of data and bogus claims of authorship are taken seriously by the editors. Authors are expected to acknowledge the funding sources. Copyright materials must be reproduced only with the permission and acknowledgement. Authors should ensure that text, equations or figures from published sources have been cited.

Published by the Faculty of Agriculture, University of Jaffna, Ariviyal Nagar, Kilinochchi, Sri Lanka.
URL: www.jdza.jfn.ac.lk

Editor's Note

It is a great pleasure and privilege to publish volume 06 of the Journal of Dry Zone Agriculture (JDZA) of Faculty of Agriculture, University of Jaffna, Sri Lanka. The objective of the JDZA is to publish up to date and high quality research findings, focusing on all aspects of agriculture related to the Dry Zone of Sri Lanka. Agriculture and crop yield from these areas are under high uncertainty due to the impact of climate change at recent times such as unexpected floods and prolonged severe drought. Therefore, mitigating climate change is the prioritized area to be considered near future since water will be a limited commodity in future.

This volume six consists of twenty six full research papers in two issues including five papers from abroad and twenty one papers from universities and important institute related to agriculture in Sri Lanka, which are selected from the abstracts presented at the 5th International Conference on Dry Zone Agriculture (ICDA 2019) and submitted research papers in year 2020. The research papers submitted to JDZA are not published previously in the same, or any other form or being considered for publication elsewhere. To ensure the quality of the research papers, all the papers were peer reviewed and finalized by the team of experts from the relevant field.

I would like to thank the contributions made by the authors, voluntary support given by the reviewers, associate editor, designing assistant and editorial board for their tireless efforts to finalize the research articles to this volume. Further, I would like to acknowledge the financial support provided by the WASO project to publish the journal during COVID 19 pandemic causing financial crisis all over the world. Without their financial support, publishing the journal is impossible this year. Editorial board members encourage to publish research articles related to Dry Zone Agriculture from abroad, different universities and institutes of Sri Lanka, containing new methodological approaches to disseminate the knowledge to farmers and community. Finally, I thank all who witnesses the release of this journal on the inaugural day of the 6th International Conference on Dry Zone Agriculture (ICDA 2020) in December, 2020.

Dr. (Mrs).Loha Pradheeban,
Editor-in-Chief.

List of Contents
JDZA 2020 Volume 6, Number 2

Journal of Dry Zone Agriculture, 2020, 6 (2): 01 - 07

ISSN 2012 – 8673

Up-scaling Water Saving Technologies in Rice Cultivation under Corporate Social Responsibility

Subbalakshmi, L., Anbumani, S. and Panneerselvam, S.
Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Abstract: Rice crop being the major consumer of water, the water use efficiency of growing rice crop is low compared to other field crops. The promising technologies on water saving in rice were advocated to the farmers on corporate social responsibility basis by upscale and popularization of these techniques among poor land holding farmers in rice growing locations of Villupuram district of Tamil Nadu State in India. The main objective of the study was to bring awareness among farmers on water saving technologies in rice production, thereby increasing water usage efficiency and enhanced grain yield. Field demonstrations were carried out in 25 locations each separately in Villupuram district for up scaling water saving technology in rice cultivation like System of Rice Intensification (SRI) and Alternate Wetting and Drying Irrigation (AWDI). SRI compared with conventional transplanted rice (CTR) and AWDI with flood irrigation as farmers' practice. The bio-metric observation data was recorded in the demonstration field plots. The average mean data was computed and used for analysis. SRI has showed higher yield attributes viz., Productive tillers (19) and 174 number of grains/panicle over CTR, besides enhanced water productivity of 0.63 kg/m^3 by minimizing the no. of irrigation to 19 and quantum of water requirement (9800 m^3/ha). Increase in the grain yields up to 19.44 percent over CTR obtained with water saving made the farmers confident on the water saving technologies. Among the irrigation methods *viz.,* flood irrigation and AWDI, 9.4 percent yield increase with 30.4 percent water saving as recorded under AWDI method of irrigation management in lowland rice cultivation. Popularization of water saving technologies in rice cultivation has created greater awareness on water quantification and need based water management among the farmers in the project area.

Keywords: Rice crop, Water saving technology, Up-scaling.

Corresponding Author: L.Subbalakshmi, kplokanadhan@yahoo.co.in

Introduction

Rice is a traditional food grain crop which is being grown from time immemorial in India which is predominantly grown in Tamil Nadu by accounting nearly 65% of the irrigated area. Of late, water scarcity due to climate change led variations in rainfall distribution and less profitability, the area under rice cultivation is shrinking every year with increasing productivity (Thiyagarajan, 2005). Surface water is key source of irrigation wherein irrigation tanks supports the rice farmers in their command area of traditional paddy growing zones in southern India. The paucity of water in the surface storage structures like tanks and reservoirs threatens the sustainability of lowland rice ecosystem. There is greater competition for sharing of the existing water resources from industrial and domestic sector which necessitate for economizing the water usage in agriculture sector. Decline in availability of water for rice farming has become a global concern and need water saving techniques with renewed attention (Bouman and Tuong, 2001). System of Rice Intensification is a resource efficient production system being adopted very well in Asian countries for the past one decade with promising results on rice productivity (Uphoff, 2013). Tamil Nadu Agricultural University has taken SRI and AWDI as one of the water saving technology in IOCL funded project with the objective of enhancing the crop and water productivity.

Material and Methods

Project was implemented in Villupuram district of Tamil Nadu under irrigated ecosystem to maximize the crop and water productivity by adoption of various water saving technologies as farmers participatory approach. North-east and South-west monsoons that contribute to the total annual rainfall. The normal rainfall of the district is 1213.3 mm.

The farmer's participatory demonstrations were conducted in 50 farmers holding in different villages of Viluppuram district during Samba season (September 18 to January 19). The soil type in the study area were clay loam, medium in available soil nitrogen, low to medium in available phosphorus and high in available potassium. Tank and wells are the key sources of irrigation. Water saving technologies like System of Rice Intensification and Alternate Wetting and Drying Irrigation were demonstrated in 0.4 hectare area by comparing with farmers existing practice in rice cultivation with same varieties.

1. *System of Rice Intensification (SRI)*

SRI demonstrations were conducted in 25 farmers holding in an area of 0.4 hectare which was compared with Conventional Transplanted Rice (CTR) @ 20 x 10 cm spacing. The major components of SRI *viz.,* lesser seed rate of 7.5 kg/ha grown in mat nursery transplanted at young age (14 - 15 days) as square planting of 25 x 25 cm with one

seedlings /hill, mechanical weeder for weeding (15, 30,45 DAT) and intermittent irrigation (2.5 cm depth) was adopted. Conventional transplanted rice (CTR) includes adoption of 30 - 35 days old seedlings planted at randomly with continuous submergence of irrigation water at 5 cm depth until harvest of the crop was practiced. Water quantification at field level based on the water depth study and number of irrigation in each treatment, to work out water productivity (Mishra and Saloke, 2010).

2. *Alternate Wetting and Drying Irrigation (AWDI)*

AWDI demonstrations were conducted in 25 farmers holding in an area of 0.4 hectare which was compared with Flood irrigation (continuous submergence of irrigation water). Alternate Wetting and Drying Irrigation (AWDI) is a water-saving technology that farmers can apply to reduce their irrigation water use in rice fields without decreasing yield. In AWD, irrigation water is applied, a few days after the disappearance of the ponded water. Hence, the field is alternately flooded and non-flooded. A practical way to implement AWD safely is by using a 'field water tube' (*Pani pipe*) to monitor the water depth on the field. After irrigation, the water depth will gradually decrease. When the water level in the water pipe has dropped to about 15 cm below the surface of the soil, irrigation should be applied to re-flood the field to a depth of about 2.5 cm.

The Field Water Tube (Pani pipe)

The field water tube is made up of 30 cm long plastic pipe and should have a diameter of 10 - 15 cm so that the water table is easily visible, and also it is easy to remove soil inside. Perforate the tube with many holes on all sides, so that water can flow readily in and out of the tube. Hammer the tube into the soil, so that 15 cm protrudes above the soil surface. Take care not to penetrate through the bottom of the plough pan**.** Remove the soil from inside the tube so that the bottom of the tube is visible (Plate 1).

Plate 1: Field water tube specification and field installation view

The biometric observations were taken in 5 plants per demonstration in the field at different stages and was pooled for statistical analysis. Demonstrations were conducted in Randomized Block Design with each farmer field taken as replication. Net income and benefit cost ratio were arrived based on the cost of cultivation per hectare with market grain price of Rs.14/kg rice to arrive at the gross income. The data were subjected for statistical analysis by following standard statistical method (Gomez and Gomez, 1984).

Results and Discussion

Demonstrations conducted with the active participation of farmers during 2018-19 to quantify the water saving and influence on cropproductivity in rice cultivation. Results emanated from the demonstrations are given hereunder along with the scientific relationship with the observed parameters taken at different stages are discussed appropriately.

Yield Attributes and Grain Yield

SRI Vs CTR

Results showed that SRI performed superior in terms of having 20 productive tillers/hill, 190 filled grains/panicle and grain yield of 6.17 t/ha over CTR of 9 productive tillers/hill, 149 grains/panicle and grain yield of 5.13 t/ha (Table 1). SRI cultivation has edge over the CTR to the tune of 19.4 % increased yield over CTR. Planting of young seedlings under optimal growing condition is responsible for accelerated growth rate in SRI plants as these make possible to complete more phyllochrons before entering into their reproductive phase. Completion of more phyllochrons at early stage resulted in more productive tillers per hill and grain number per panicle as grain yield. These results are in tandem with the findings of Nemoto *et al.,* 1995 and Pandian *et al.,* 2014. From the above results, also found that the conversion of tillering to productive tillers are more in SRI over conventional planting.

Table 1: Establishment methods on yield attributes and Grain yield (pooled value of 25 demonstrations

Establishment method	No. of productive tillers/hill	No.of grains/ panicle	Grain yield (t/ha)	Net income (Rs/ha)	BCR (Rs.)	Water Requirement (m^3/ha)	Water productivity (kg/m^3)	Litre of water/kg of grain producti
CTR	9	149	5.13	24,841	1.68	12,960	0.40	2,534
SRI	20	190	6.17	40,030	2.18	9,800	0.63	1,593
S.Ed	0.69	4.3	0.18	-	-	-	-	-
CD (p= 0.05)	1.4	9.4	0.39	-	-	-	-	-

The results found that, there was water saving up to 24 percent over conventional method of planting with flood irrigation. Water productivity also, worked out to find out the efficiency of water on grain yield and litres of water required to produce per kg of grain (Figure1). Under conventional method of rice cultivation, 2,534 litres of water is required to produce one kg of grain but 1,593 litres is sufficient in SRI. Higher yield from SRI crop establishment method has showed, higher net income Rs.40, 030 / ha with benefit cost ratio of Rs.2.18 than the conventional method of crop establishment. The incremental income of Rs.24, 841/- per hectare have been obtained through SRI method to produce per kg of grain under SRI (Table1). Ravichandran *et al.*, 2015 found that SRI has more economic gain over conventional planting of rice in Tamil Nadu.

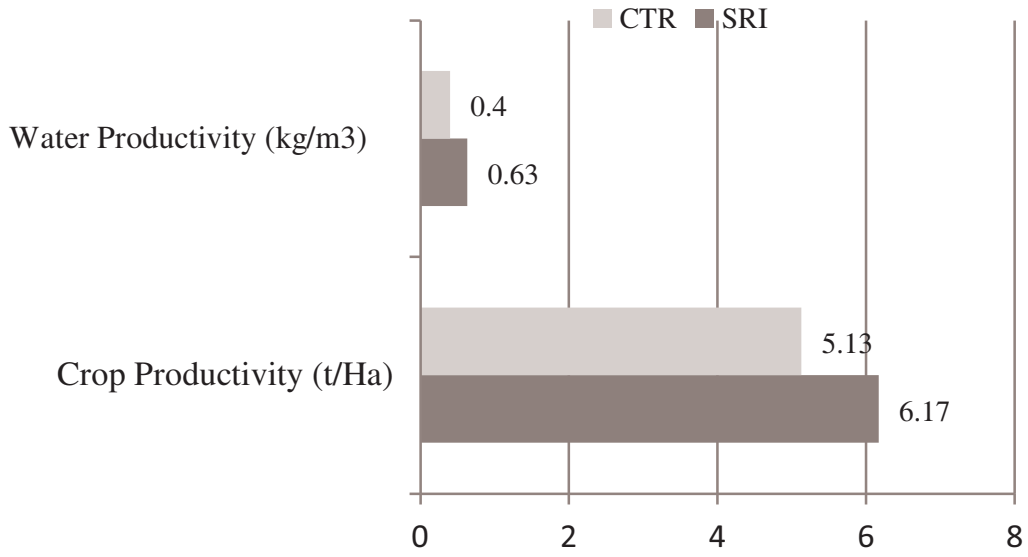


Figure 1: Crop and Water Productivity influenced by Crop establishment methods

AWDI Vs Flood Irrigation

Irrigation methods *viz.*, Flood irrigation and alternate wetting irrigation were demonstrated simultaneously in 25 farmers field and the accrued results showed that AWDI performed superior in terms of producing 15 productive tillers/hill, 180 filled grains/panicle and grain yield of 5.66 t/ha over flood irrigation in conventional method with 10 productive tillers/hill, 155 grains/ panicle and grain yield of 5.14t/ha (Table 2). AWDI has edge over the flood irrigation to the tune of 9.83% increased yield (Figure 2).

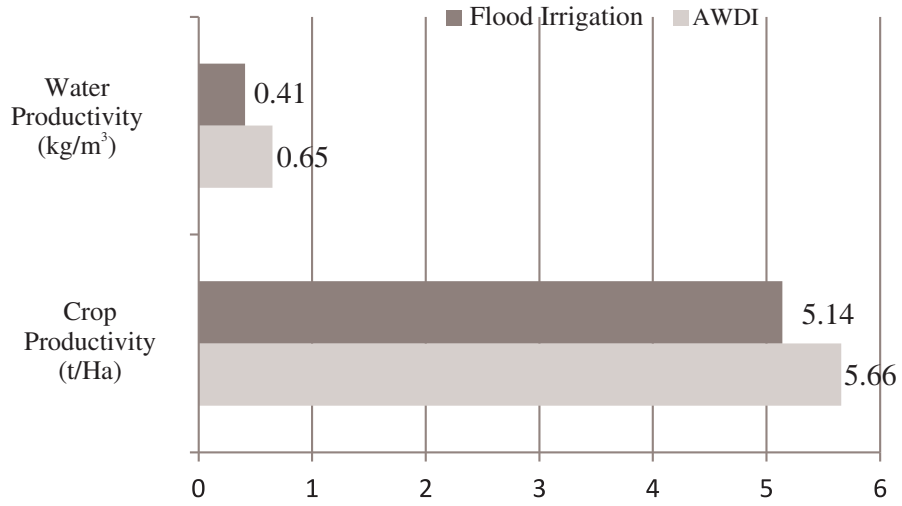


Figure 2: Crop and Water Productivity influenced by Irrigation Methods

Table 2: Irrigation methods on yield attributes and Grain yield (pooled value of 25 demonstrations)

Irrigation methods	No. of PT/hill	No.of grains/ panicle	Grain yield (t/ha)	Net income (Rs//ha)	BCR	Water Requirement (m^3/ha)	Water productivity (kg/m^3)
Flood irrigation	10	155	5.14	26,633	1.76	12,690	0.41
AWDI	15	180	5.66	32,863	1.94	8,750	0.65
CD (p= 0.05)	1.68	11.2	0.49	-	-	-	-

The results found that conversions of tillering to productive tillers were more in Alternate Wetting Drying Irrigation (AWDI) over continuous submergence of water. AWDI also owing more number of grains per panicle and 9.83 percent increased grain yield (Table 2). The shallow depth of irrigation as guided through field water tube facilitated the farmers to take decision on when to irrigate and how much to irrigate appropriately.

Simple and affordable tool (field water tube) is much useful for irrigation scheduling in rice cultivation, thereby saving of sizable quantity of irrigation water (3,940 m^3) over continuous submergence of water. An average of 25 plots harvested, recorded 30.94 percent water saving through Alternate Wetting Drying Irrigation than continuous submergence of water (Figure 2). Nyamai *et al*. 2012 opined that practice of alternate wetting and drying irrigation under SRI has potential to save water and maximized the productivity.

Higher grain yield from alternate wetting drying irrigation than continuous submergence of water has showed higher net income (Rs.32, 863/ha) and benefit cost ratio of Rs.1.94 than the conventional method of crop establishment. The

incremental income of Rs.6, 709/ha have been obtained through alternate wetting Drying Irrigation.

Conclusion

The water saving through adoption of the technologies helped the farmers to expand additional area under rice cultivation. Increase in the rice grain yields obtained made the farmers, confident on the water saving technologies and to address the water shortages in well irrigation system and also paved way for overall energy saving (electricity in particular) in rice cultivation.

Acknowledgement

The authors aregrateful to acknowledge the Indian Oil Corporation, Southern Region under Corporate Social Responsibility project and also express sincere thanks to the Director, Water Technology Centre, TNAU for the project implementation and support.

References

Bouman, B.A.M. and Tuong, T.P. 2001. Field water management to save and increase its productivity in irrigated lowland rice. Agric. Water Management, 49:11-30.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research (2nd Ed.). Wiley - Interscience Publication, John Wiley & sons, NY, USA.

Nemoto, K. Morita, S. Baba, T. 1995. Shoot and root development in rice related to the phyllochrons. *Crop Sci*. 35:24-29.

Mishra, A. and Saloke, V. 2010.The Efect of planting pattern and water regime on root morphology, physiology and grain yield of Rice. *J.Agron Crop sci*.196: 368-378.

Nyamai, M., Mati, B.M., Home, D.G., Odaongo, B. and Wanjogu, R. 2012. Improving land and water productivity in basin rice cultivation in Kenya through SRI. *Agr Eng*.14:1-9.

Pandian, B.J., Sampathkumar, T. and Chandrasekaran, R. 2014. System of Rice Intensification (SRI): Packages of technologies sustaining the production and increased the rice yield in Tamil Nadu, India, Irrigation Drainage Sys Eng. 3:115-120.

Ravichandran, V.K., Nayar, V. and Prakash, K.C. 2015. An Evaluation of the SRI on increasing yield, water productivity and profitability; Experiences from TN-IAMWARM Project. Irrigation Drainage Sys Eng.4:137-142.

Thiyagarajan, T.M. and Selvaraju, R. 2005. Water saving in rice cultivation in India. In: Hengsdijk H, Bindraban PS, editors. Water saving in rice production systems. Proceedings of an International workshop on water saving rice production systems at Nanjing University, China, April 2-4, 2005. PRI report no.33:15-45.

Uphof, N., Kassam, A. and Thakur, A. 2013. Challenges of increasing water saving and water productivity in the rice sector: Introduction to the system of rice intensification (SRI) and This Issue. Taiwan water Conservancy, 61:1 -13.

Journal of Dry Zone Agriculture, 2020, 6 (2): 08 - 14

ISSN 2012 – 8673

Pricing-to-Market and Exchange Rate Pass-Through in the Sri Lankan Crepe Rubber Export Markets

Madushika, P.J. and Sooriyakumar, K.
Department of Agricultural Economics, Faculty of Agriculture, University of Jaffna, Sri Lanka.

Abstract: This article analyses the impact of the pricing-to-market (PTM) strategy on the Sri Lankan crepe rubber. The fluctuation in the value of the Sri Lankan rupees can alter the prices of exported goods in terms of foreign currencies. This affects the Sri Lankan products either to be more or less expensive to the foreign buyers and consequently, it effects on export demand. Hence, analyzing the effects of PTM is an important element in assessing the relationship of the exchange rates and export prices of tradable goods. Within and between models of panel regression was used to analyse the exchange-rate-pass -through (ERPT) of Sri Lankan crepe rubber in the world market. The within model was used to analyse the short-run pricing-to-market and the between model was used to analyse the long-run pricing-to market. Data of eight export market destinations spans from 2003 to 2014 were used in the analysis. Results indicated that the short-run pricing-to market is a strategically viable plan to expand the Sri Lankan crepe rubber market via exchange rate pass through.

Keywords: Pricing-to-market, Exchange rate pass through (ERPT), Crepe rubber export, Regression, Panel data

Introduction

Rubber was first introduced to Sri Lanka in 1876 by then colonial rulers, the British. It is one of the country's major exports even today. In the year 2010 August, rubber was placed third in the composition of exports, behind textiles and garments and tea (CBSL, 2010). In the country where the contribution of GDP from the agriculture sector is 11.9 %, the rubber sector's contribution is 0.3 % (CBSL, 2010). So, it directly contributes to the economic country. Sri Lanka is very popular in the world market for crepe rubber. Which accounted for a higher percentage of the total exports of rubber products. Currently, Thailand, Indonesia, and Malaysia are major competitive

Corresponding Author: P.J.Madushika, Mjayasinghe770@gmail.com

exporters to Sri Lanka. Sri Lanka has to compete with these exporters, but the Sri Lanka rubber market is unstable in previous years. Hence, it is threatening to keep a steady international export market for Sri Lanka crepe rubber. In locally, crepe rubber industries have to adjust their production according to demand of product. It is difficult to take the production decision when demand frequently fluctuates. In addition, fluctuation in the value of the Sri Lankan rupees can alter the prices of exported goods in terms of foreign currencies. Therefore, it leads to the Sri Lankan products either more or less expensive to foreign buyers, and consequently affecting export demand. This unexpected fluctuation in exchange rates is usually accompanied by increasing export prices and decreasing trade volumes. So, it is important to analyses the viability of expanding the crepe rubber market. Therefore, this study is focused on determining the impact of ERPT in export market of Sri Lankan crepe rubber. Predict where the implementing exchange rate pass through is strategically viable plan to expand the export market or not.

Objectives

1. Determine the impact of exchange rate pass through in export market of Sri Lankan crepe rubber.
2. Predict where the implementing exchange rate pass through is strategically viable plan to expand the export market or not.

Hypothesis

- Fluctuation in value of the Sri Lankan rupees strategically viable plan to expand the market shares of crepe rubber export market in short run as well as in long run.

Materials and Methods

This study is primary bond on hypothesis of, fluctuation in value of Sri Lankan rupees strategically viable plan to expand the market shares in short run as well as in long run to analyses hypothesis, the Sri Lankan rubber industry ship its crepe rubber to more than 20 countries among the export destinations, 8 countries were selected for this study. Annual export income was obtained from exporting 1000kg of crepe rubber to 8 countries. The details were taken from the data span of export development board of Sri Lanka from 2003 to 2014, exchange rates were taken in directly from quotation and which were obtain from annual report publish by central bank of Sri Lanka. In here to analyze the data pricing to market model of Krugman (1986), Dornbusch (1987) and Knetter (1989) (hereafter KDK model) and their econometric methods were used.

$$\ln\left(-\frac{1}{T}\sum P_i\right) = \alpha + \beta \ln\left(-\frac{1}{T}\sum E_i\right) + u_i,\ Ii = 1,\ldots, N,$$

where β = a measure of pricing-to-market across export destination markets due to estimation of cross-sectional variables over the long- run, Ei reflects the market specific exchange rate of exporting

country i on time average. Results from country-level within regression can be interpreted as explaining transient pricing-to-market practices, since the specification focus on movements away from the estimate of the firm's constant unit export price. The coefficients generated by this specification explain which country variables are associated with deviations from the firm's average position. On the other hand, a significant coefficient in the exchange variable in the between estimator is more likely to be associated with a long- run pricing-to-market strategy. A coefficient of -1 on the exchange variable indicates a complete exchange rate pass through; 0 shows no pass-through. A body of literature on pricing to market model of Krugman (1986), Dornbusch (1987) and Knetter (1989) (hereafter KDK model) and their econometric methods were reviewed initially. These economic models are important and essential in that they yield an econometric model to estimate the PTM model for short-run analysis.

(1) $Q_{it} = f\,(E_{it}P_{it})\,v_{it}$, $i = 1, \ldots, N$ and $t = 1, \ldots, T$,

Where P_{it} is price in terms of the exporter's currency, E_{it} reflects the market specific exchange rate in period t, where the observations corresponding to the prices in country i are the market- specific exchange rate, and zero when there is no trade. v_{it} is a random variable that may shift demand in market i in period t.

The exporter's cost is given by

(2) $C_t = C\,(\sum Q_{it})\,\delta_t$, $t = 1, \ldots, T$,

Where C_t measures costs in the exporter's domestic currency units, which are summed over all destination markets, and δ_t is a random variable that may shift the cost function (e.g., changes in input prices) in period t. Substituting equation (1) for Q_{it} in equation (2), the maximiz ation problem becomes

(3) $\text{Max}\,\Pi = \sum [P_{it} f\,(E_{it}P_{it})\,v_{it}] - C\{\sum f[(E_{it}P_{it})\,v_{it}]\}\delta_t$

Differentiating equation (3) with respect to P_{it} and expressing in terms of elasticities, the first order conditions are

(4) $P_{it} = c_t \left(\dfrac{\varepsilon_t^i}{\varepsilon_t^i - 1} \right)$, $i = 1, \ldots, N$ and $t = 1, \ldots, T$,

Where c_t is the marginal cost of production in period t and and is the demand elasticity for imports in importing country i in period t. Equation (4) states that the price discriminating monopolist will equate marginal cost to marginal revenue in each market.

(5) $\ln P_{i,t} = \alpha + \sum \phi_t x_{t+} \sum \lambda_i x_i + \sum \beta_i \ln E_{i,t+} u_{i,t}$, $i = 1, \ldots, N$ and $t = 1, \ldots, T$,

where $P_{i,t}$ is the export unit value to market destination country i in period t; x_t is a dummy variable to cap the exporting country; $-_t$ measures the time effect corresponding to the t periods; λ_i measures the country effect corresponding to the individual i destination markets; βi measures the exchange rate pass-through for the individual i countries; and $u_{i,t}$ is error term. The two-way within regression model in equation (5) examines export pricing behavior across destination markets. The within estimator regresses

the country-specific deviations from the mean of the dependent variable on the country-specific deviations from the means of the independent variables as such:

$$(6)\ \ln(P_{i,t} - \frac{1}{T}\sum P_i) = \alpha + \beta \ln(E_{i,t} - \frac{1}{T}\sum E_i) + u_i,\ i = 1, \ldots, N \text{ and } t = 1, \ldots, T,$$

Where β = a measure of non-competitive pricing, because the estimator focuses on movements away from the estimates of complete exchange pass-through from year to year price. E_{it} reflects the market specific exchange rate in period *t*, where the observations corresponding to the prices in country *i* are the market-specific exchange rate, and zero otherwise.

In practice, one can take several steps to make equation (6) easily estimable. For example, take the data on individual country *i* as in

$$(7)\ \ P_{i,t} = \alpha + \beta E_{i,t} + v_i,\ i = 1, \ldots, N \text{ and } t = 1, \ldots, T,$$

The between estimator (cross sectional only) measures the long-run effects; it tells us the price discrimination. It regresses the mean of the dependent variable on the means of the independent variables as follows:

$$(8)\ \ln(\frac{1}{T}\sum P_i) = \alpha + \beta \ln(\frac{1}{T}\sum E_i) + u_i,\ Ii = 1, \ldots, N,$$

where β = a measure of pricing-to-market across export destination markets due to estimation of cross-sectional variables over the long- run, Ei reflects the market specific exchange rate of exporting country *i* on time average.

Results from country-level within regression can be interpreted as explaining transient pricing- to-market practices, since the specification focus on movements away from the estimate of the firm's constant unit export price. The coefficients generated by this specification explain which country variables are associated with deviations from the firm's average position. On the other hand, a significant coefficient in the exchange variable in the between estimator is more likely to be associated with a long-run pricing-to-market strategy. A coefficient of -1 on the exchange variable indicates a complete exchange rate pass through; 0 shows no pass-through. A coefficient between these two numbers suggests incomplete pass-through, indicating evidence of pricing-to- market. This decomposition enables us to show an individual evidence for a short-run pricing-to- market practice and a long-run pricing-to-market strategy separately. These dichotomized empirical results have not been documented in the previous monotonic pricing-to-market (PTM) research.

Our hypothesis is motivated by the literature and theory which suggests that the long-run impact on economic variables matters. All the previous pricing-to-market research in panel analysis used a within effects model, which only produces an estimate for a short-run pricing-to-market practice. Moreover, a significant short-run pricing-to-market estimate is not warranted to fully describe a long-run

pricing strategy in which expanding market shares might be one of solutions to a rising imbalance between Sri Lanka domestic crepe rubber production and domestic consumption.

Results and Discussion

The paper decomposes pricing-to-market activities into their cross-sectional (between regression) and time-series components (within regression). The significant negative coefficient in the within specification in Table 1 indicates that exchange-rate pass-through occurs for Sri Lankan crepe rubber exports. Export prices are adjusted downward by 1.6% for a 1% depreciation of the Sri Lankan rupees relative to the foreign currencies. There is insignificant "between" exchange rate coefficient parameter (p-value = 0.6086 not reported in Table 1).

Table 1: Within and Between Estimations for Impacts of Exchange Rates on Sri Lankan crepe rubber export prices: 2003 – 2014

	A	B	r^2
Within	0.5035078	-1.619415	0.1745
	0.43 **	-4.29 **	
Between	5.497071	-0.0118512	0.0464
	66.59	-0.54 **	

Note: Coefficients are elasticities and numbers in parentheses are t-statistics. ** indicates a statistical significance level of 5%.

In fact, expanding market-shares of crepe rubber exports by implementing exchange rates pass-through has been a strategically viable plan for short run, given the rising imbalance between Sri Lankan domestic crepe rubber production and consumption.

The conventional econometric model to examine exporter's price behavior across its destinations is a two-way within model of panel regression of exchange rates on export prices with time and country dummies. Findings of a significant coefficient parameter in the exchange rate variable on the conventional within model caught to be interpreted as evidence of short-run pricing-to-market only. On the other hand, between specifications produces a parameter estimate for long-run pricing-to-market behaviour.

This study found statistically significant coefficients in the within and insignificant coefficient in the between model, indicating that the pricing-to-market of Sri Lankan crepe rubber exporters across their export destinations are not both transient and persistently long. These results add

further evidence of pricing-to-market behavior in the exchange rate pass-through literature. Furthermore, the negative significant coefficients in the within models agree with what Davis *et al*. 2014 found and suggest that U.S. broiler meat exporters offer broiler meat at a partially-exchange-rate adjusted price to defend its market share in the selected destination markets, followed by a strong appreciation of U.S. dollar relative to the currencies of the importing countries.

The potential imbalance between rising Sri Lanka domestic production and stagnant domestic consumption could be a major concern, because a stagnant domestic consumption tends to put a downward pressure on price. Information on pricing-to-market behavior in the short-run could prove to be beneficial to the export industries in some other countries because it allows for better timing of decisions given volatile exchange rate changes.

Lastly, this study shows that in Sri Lanka, expanding of crepe rubber market is a viable strategy in short run. The potential imbalance between rising Sri Lanka domestic production and stagnant domestic consumption could be a major concern, because a stagnant domestic consumption tends to put a downward pressure on price. Information on pricing-to-market behavior in the long-run as well as in the short-run could prove to be beneficial to the export industries in some other countries because it allows for better timing of decisions given volatile exchange rate changes. Lastly, this study shows that in Sri Lanka, expanding of crepe rubber market is not a viable strategy in short run as well as in long run. Policy makers must be careful when evaluating policy impacts; policies may be ineffective in the short run or in the long run.

Conclusion

Expanding the market shares of crepe rubber exports by implementing exchange rates pass -through has been a strategically viable plan for short run. Depreciation Sri Lankan rupees will impact on export price of crepe rubber with in model regression suggests that short run pricing to market is viable for Sri Lankan crepe rubber export market but it is not viable for the long run.

References

Central Bank of Sri Lanka. 2014. Press Release, 1–7.

Central Bank of Sri Lanka. 2015. Annual Report.

Davis, C.G. and Harvey, D. 2015. Pricing-to-Market and Exchange Rate Pass-Through in the U.S. Broiler Meat Export Markets. 18:79–90.

Export Development Board, Sri Lanka. 2015. Performance Of The Export Sector Of Sri Lanka - 2014. (February): 1–14.

Export Development Board, S.L. 2014. Exploring

Federation of Chambers of Commerce and Industry of Sri Lanka. 2012. Annual Report.

Kumarasinghe, H., Edirisinghe, J.C. and Patalee, B. 2012. Role of human capital in technical efficiency increases: Evidence from a data envelopment analysis of rubber smallholdings in Gampaha district, *Journal of the Rubber Research Institute of Sri Lanka*. 92: 12-21.

Ministry of Enterprise Development and Investment Promotion. 2013. Progress Report -2013.pp.1-14. Carew, R., 2000. Pricing to Market Behavior: Evidence from Selected Canadian and U.S. Agri-Food Exports. *Journal of Agricultural and Resource Economics.* 25 (2): 578–595.

Ministry of Plantation Industries, Progress Report . 2013:1-34.

Ministry of Industrial Development. 2013. Progress Report.

Ministry of Plantation Industries. 2013. Progress Report.

Opportunities In The Chinese Market For Sri Lanka's Exports (2008-2013) :1-7.

Rubber Development Department. 2011. Performance Report , 1-65.

Small and Medium Enterprise Developers and Export Development Board. 2014. Annual Report.

Walter, D.P. 2015. Plantation industries. 1-10.

Wimalagunasekara, T.U., Edirisinghe J.C. and Wijesuriya, W. 2012. Neighbours' Influence on Farmer Adoption of Fertilizer Recommendations in Rubber Cultivation: Evidence from a Bayesian Spatial Autoregressive Probit Model *Journal of Rubber Research,* 7-20.

Journal of Dry Zone Agriculture, 2020, 6 (2): 15 - 29

ISSN 2012 – 8673

Groundwater Responses to Artificial Recharge of Rainwater in Badulla District in Sri Lanka

De Silva, C.S.[1] and Ariyananda, T.[2]

[1]Department of Agricultural and Plantation Engineering, Faculty of Engineering Technology, The Open University of Sri Lanka.

[2]Lanka Rainwater Harvesting Forum, New Parliament Road, Sri Jayawardenapura Kotte

Abstract: Two thirds of the country is considered a dry zone, where people face difficulties to access safe drinking water. According to the 2008 national census, pipe-borne water coverage in Sri Lanka is around 34%, with the rest of the population depending on local sources such as wells, hand pump tube wells, small scale rural water supply schemes, rain water harvesting tanks and surface water bodies: irrigation tanks, canals, streams and springs. It is believed that contamination of water sources, by industry and through agricultural waste and fertilizers, is the main cause of the growing water-related health problems in the country. Most of the Schools in Badulla District are mainly depend on groundwater wells for its uses. Major problems in using the groundwater wells was the decreasing well water levels during dry season and quality deterioration. Therefore this study was designed to use the overflow of the rainwater harvesting tank for artificial recharging to increase the groundwater levels. In total seven were selected in seven schools and overflow of the rainwater harvesting tank was diverted to these wells. Water levels in the well and the rainwater harvesting tanks were monitored at weekly intervals. In addition pH, electrical conductivity and total soluble salts were measured in weekly interval. Results showed that the groundwater level increased due to artificial recharging of rainwater during the year 2018 even though the annual average rainfall of year 2018 (1827.9 mm) was less than that of year 2017 (1924.5 mm). Further the pH, electrical conductivity and total soluble salts in rainwater harvested water were within the safe limits of 6.5 - 8.5, 1500 µS/cm and 500 mg/L. However the EC and TDS values of rainwater harvested water is much less than the well water, therefore artificial recharging by rainwater do not post any threat to the groundwater.

Keywords: Rainwater, Groundwater, Artificial recharge, Quality

Corresponding Author: C.S.De Silva, csded@ou.ac.lk

Introduction

Water is the essential resource, prevailing to ensure the existence of all living beings and proposing a part of larger ecosystem (UN-Water, 2015). Man has sustained even in deserts for thousands of years, and succeeded on it by the skillful management of vital and scarce resource; water. Even more, availability of sufficient water is an indication of development of a country (Weerarathna *et al.*, 2009). Therefore the sustainability of water should be ensured in order to sustain the existence of living creatures in the earth. The availability of water was balanced before the interference of human in the natural water cycle. But after the human intrusions such as deforestation, wetland drainage and other means of pollution, the balanced and favorable sequence started to collapse the water cycle and it has led the world towards water related issues (Charles, 2000). The ultimate reaction will be that one third of the world population is going to face hardships because of water scarcity. Within the globe, Asia is in the worst condition in the case of water availability because it consists 60% from the world total population but the availability of the water is only 36% from the total available water (UNESCO, 2003).

Available data portrays Sri Lanka as a country with either low scarcity or no water scarcity (Ariyananda, 2010). Even though some dry zone areas during the dry season face severe water shortages for safe and clean water. Statistically water supply of the country covers 78% of population in terms of drinking water. Within this, 35% only provided with structured piped water others are expected to depend on other water resources such as bore well and springs (Ariyananda, 2010). Due to population growth, limitation of water resources and climatic change, the availability of water is getting diminished and the demand for the safe and clean water is getting increased (Ariyananda, 2010). It is gradually getting in to a scenario of water scarcity and therefore need to think about tenable ways to strengthen the sustainability of available water.

Rain water is the primary water source and the annual rain fall of Sri Lanka is around 1800 mm through bi model rainfall. But more than 70% of total rainfall escapes to the sea as surface run off (Weerarathna *et al.*, 2009). Therefore saving the rainwater over the roof using proper technology for human consumption could be an ideal and sustainable way to get rid from the issues related to water. Such way of water collection and storage is called as “rain water harvesting”. This system is an age old technology and obviously a low cost system which could be made easily with the help of family labour. Even though Sri Lanka had a long history in rain water harvesting, such efforts had been lessened with the introduction of pipe supply and protected wells. Now the government and other

supporting NGO's are awaken to replenish the rain water harvesting sector, specifically the sector has started to work with more agility with the formation of rain water harvesting forum in 1996 (Weerarathna *et al*., 2009).

Groundwater is one of most precious natural resources of Sri Lanka. Communities in rural areas depend on groundwater with no expense to the State. When compared with surface water, groundwater is a hidden resource, which is more reliable and also less subject to the type of year-round variation as in the case with surface streams and rivers. Almost 80% of the rural populations in Sri Lanka rely on groundwater for their domestic needs today because of its excellent natural quality and sustained availability throughout the year. Main towns in the dry zone of Sri Lanka such as Jaffna, Mullaitivu, Kilinochchi, Polonnaruwa, Anuradhapura, Batticaloa, Mannar, Puttalam, Vavuniya depend almost 90 % on the groundwater supply (Panabokke and Perera, 2005). The composition of groundwater naturally reflects the underlying geology, the residence time in the rock, the previous composition of the groundwater and in some instances, the flow path. Due to the slower movement of groundwater as compared to that of surface water, the composition of the ground water shows a negligible variation with time for a given aquifer (Lerner *et al*., 1990). Communities in the rural areas use either shallow wells of 6 - 8 m deep or deep wells of 40 - 50 m deep. Mainly in shallow wells during monsoon/post-monsoon (*Maha* season) groundwater levels rise near to the ground surface as the recharge to the aquifer takes place during this season. During dry season (*Yala* season) groundwater level goes down due to abstraction, evapotranspiration and other losses such as seepage and percolation. Further it is aggravated when discharge rates are greater than there recharge rates. Seasonal fluctuation of groundwater is significantly correlated with precipitation, because the recharge into the groundwater system is considered entirely to be from rainfall infiltration and percolation.

Water quality refers to the chemical, physical, and biological of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. Water quality is important because it directly affects the health of the people, animals and plants that drink or otherwise utilize the water. When water quality is compromised, its usage puts users at risk of developing health complications. Water quality analysis is to measure the required parameters of water following standard method, to check whether they are in accordance with the standard. The qualities of groundwater resources vary naturally and widely depending on climate, season, and geology of bedrock as well as anthropogenic activities. Therefore, a regular check of its chemical quality is

required for assessing its suitability for different purposes and for quantitatively monitoring any future change. The chemical budget of major ions and heavy metals are important in determining the quality of groundwater. Total Dissolved salts (TDS) values are considered important in determining the usage of water and groundwater with high TDS values are not suitable for both irrigation and drinking purposes (Rajasooriya, 2002). Study of chemical budget of the major ions gains importance since it explains the origin of the ions in groundwater and the level of the contamination by natural as well as anthropogenic sources (Rajasooriyar, 2002).

Wells in the schools in Badulla was holding little water during the dry season and some wells get completely dried during dry season. Further the quality of the groundwater was not good because of the high concentration ions in groundwater during dry season. Adding more water to the well water may improve the water quality. Rainwater is free water received with good quality compared to the groundwater. Rainwater could be used effectively to artificially recharge ground water wells to improve the quantity as well as quality. This research project was designed to study the groundwater response to artificial recharge with rainwater in the study area for sustainable groundwater quantity and quality.

Background of the Study Area

Badulla is located in the southeast of Kandy, almost encircled by the Badulu Oya River, about 680 m (2,230 ft) above sea level and is surrounded by tea plantations. The city is overshadowed by the Namunukula range of mountains (highest peak 2,016 m (6,614 ft) above sea level). It was a base of a pre-colonial Sinhalese local prince (regional king) who ruled the area under the main King in Kandy before it became part of the British Empire. Later, it became one of the provincial administrative hubs of the British rulers. The city was the terminus of upcountry railway line built by the British in order to take mainly tea plantation products to Colombo. Badulla was an isolated village until the British built roads from Kandy and Nuwara Eliya in the mid19th century, as part of the growing plantation economy. By the 20th century Badulla had become a regional hub, with the British establishing it as the capital of Uva Wellassa, now known as the Uva Province. Badulla still has a number of British colonial buildings existing, including the Badulla railway station, St Mark's Church and the Old Welekade Market. Badulla district is one of the leading tea producing districts, second only behind the Nuwara-Eliya District. The town has grown steadily since the country's independence from approximately 13,000 in 1946, to 38,000 in 1977 and 47,587 in 2011. Badulla is a multi-national city with the ancient Muthiyangana Temple situated in its

heart. The Catholic Church has a diocese headquartered too in Badulla.

Climate

Rainfall

The climate is tropical in Badulla. There is significant rainfall in most months of the year. The short dry season has little effect on the overall climate. A lot of rain (rainy season) falls in the months of January, April, May, June, July, August, September, October, November and December. On average, October is the wettest month. On average, March is the driest month. The rainfall here is around 1885 mm | 74.2 inch per year. In Badulla, the summers are short, warm, and overcast; the winters are short, comfortable, wet, and mostly cloudy; and it is oppressive year round.

Temperature

During the month of January, February, March, April and May you are most likely to experience good weather with pleasant average temperatures that fall between 20 degrees Celsius (68 °F) and 25 degrees Celsius (77 °F).The months of January, February, March, April, May, June, July, August, September and December have a high chance of precipitation. The warmest month is April with an average maximum temperature of 22 °C (71 °F). The coldest month is February with an average maximum temperature of 18 °C (64 °F).October is the wet month. March is the driest month. The months January, February, March, April and May have a nice average temperature. On average, the warmest month is April. On average, the coolest month is August. The average annual maximum temperature is: 20 °C (68° F). The average annual minimum temperature is: 11 °C (51.8° F).

Soils

Badulla series is named as Red yellow Podsolic soils according to local classification. Badulla soil series form in ridge and valley land form with moderate to high relief from Demodara, Hali Ela, Badulla, Madulsima and Namankula range in the IM2 agro-ecological zone. Parent material of the soil is derived from feldspar rich decomposing rocks of the highland series (Coorey, 1984). Valleys that occur within this land form are V shaped and the bottom makes natural waterways. Solis are moderately deep to deep. These soils are extensively used for cultivation of Tea. Surface soils of this soil series are eroded. Soils on ridges and high relief are highly prone to mass movements. Some of the abandoned lands within this soil series are commercial pine plantations. Bed rock exposures and soil boulders are very common in the soil. Surface soil is dark yellowish brown in colour with sandy clay loam texture and medium size granular structure. The thickness of surface horizon is 20-30 cm thick depending on the physiographic position of the land form. Sub surface soil is dark yellowish brown to dark brown in

colour with sandy clay loam in texture and structure of sub surface soil is weak to moderate sub angular blocky.

Water Use

Community Based Water Projects are functioning in different functionality levels, offering services to 50279 of rural and estate population in Badulla district. Among total 447 Community Based Water Projects in Badulla district 210 are depended upon springs representing 46% beneficiaries depended upon Community Based Water Projects. Further 105 are depended upon common wells representing 27% of total beneficiaries among total CBO dependents (National Community Water Supply Department, 2018).

Groundwater Quality

Groundwater has an important source and the quality being measured by contamination of various parameters. Badulla municipal area has major water source from Badulla Oya, anyhow it was one of the important issues during the dry season, however in some cases people using groundwater for various purposes. National Water Supply and Drainage Board (2019) has done detailed study and the main purpose of that study was to determine current groundwater quality of Badulla municipality area and to compare with SLS drinking water standard to determine whether it is portable or not. In addition, to develop some hydro chemical distribution map of Badulla municipal area for further study. According to that 40 groundwater samples were collected randomly with GPS coordinates and analyzed for physiochemical parameters of EC, TDS, pH, Turbidity, Alkalinity, Total hardness, Chloride, Fluoride, Nitrate, Phosphate, Sculpture, Sodium, Potassium, Calcium, Magnesium, Iron, Manganese, Zinc. The relationship between resultant quality and SLS drinking water standards was compared and discussed. The analyzed quality results were interpreted using Visual MINTEQ to calculate the approximate ion species, precipitation of solid phases and the type of water was classified by plotting piper diagram using Rock ware AQ. QA. Hydro chemical distribution maps were developed using Arc GIS. The results have shown almost all the parameters were not exceeded SLS drinking water standard except phosphate and nitrate. This study was showed that Badulla municipality area had almost good groundwater quality anyhow the location of Badulla central and southern part had some problem of nitrate and phosphate from the results of few wells which was near to municipal dumping and agricultural land. Chemical speciation showed some relationship with phosphate, fluoride and manganese. According to the range and mineral species of fluoride and manganese, it will be an issue of fluoride and manganese in future. The main water type was calcium and non-dominant.

Methodology

In total seven wells in schools were selected randomly for this study in order to improve the groundwater levels and quality through artificial recharge using rainwater (Figure 1). All the wells were artificially recharged using overflow water of the rainwater harvesting tank. Rainwater from the roof is collected into the rainwater harvesting tank and the over flow of the rainwater harvesting tank was diverted to the well.

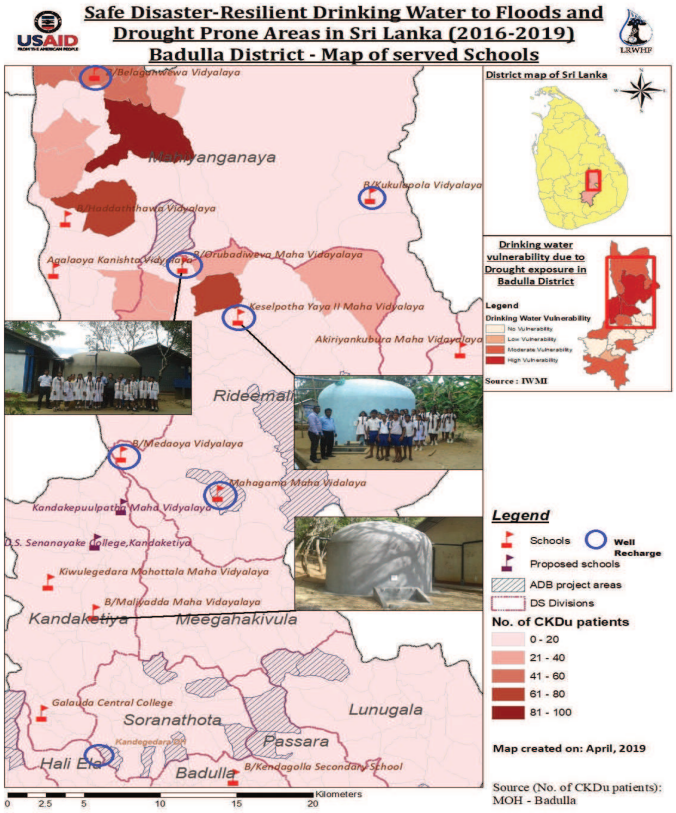


Figure 1: Location of the wells in the study site

All these wells were categorized into two groups based on the well depth (Table 1). Shallow wells are in less than 6.5 m depth, and deep wells are more than 6.5 m depth. Deepest well is having the depth of 9.75 m. The shallowest well is having the depth of 5.2 m. Well water levels below ground level (m) and water level in the rainwater harvesting tanks were monitored from May 2017 to May 2019 on weekly basis. Further well and rainwater harvesting tank water quality was also measured in weekly basis. Measured quality parameters were pH, electrical conductivity (µs/sec) and total dissolved Solids (mg/L). pH EC meter was used to measure pH and EC. Total dissolved solids were measured by Turbidity meter.

Table 1: Well details in the study area

Well Name	DSD/	GND	Well No	Well Depth(m)
Shallow Wells <6.5m depth				
Belaganwewa K.V.	Mahiyanganaya	Belaganwewa	B/ R.W.H - 06	5.2
Mahagama M. V.	Ridimaliyadda	Mahagama	B/ R.W.S - 01	6.1
Kukulapola K.V.	Mahiyanganaya	Kukulapola	B/ R.W.H - 05	6.2
Deep Wells > 6.5m depth				
Orubendiwewa M.V.	Ridimaliyadda	Sagabopura	B/ R.W.S - 03	9.7
Keselpothayaya II M. V.	Ridimaliyadda	Keselpotha	B/ R.W.S - 02	9.75
D.H. Kandegedara	Soranathota	Kandegedara	B/R.W.H - 04	8.2
Medaoya V.	Mahiyanganaya	Dadagolla	B/R.W.H - 07	7.3

Results and Discussion

Groundwater Level Responses to Artificial Recharge by Rainwater Harvesting.

Figure 2 (a) shows the rainfall, groundwater level fluctuation in the well and the water level in the rainwater harvesting tank in B/Mahagama Maha Vidyalaya in Ridimaliyadda. According to the figure the well water level was decreasing during dry season and reached the lowest point of 3.4 mbgl in October 2017. With the *Maha* season rains from October the well water level increased and reached the maximum point of 1.1 mbgl in December 2017. Average annual rainfall

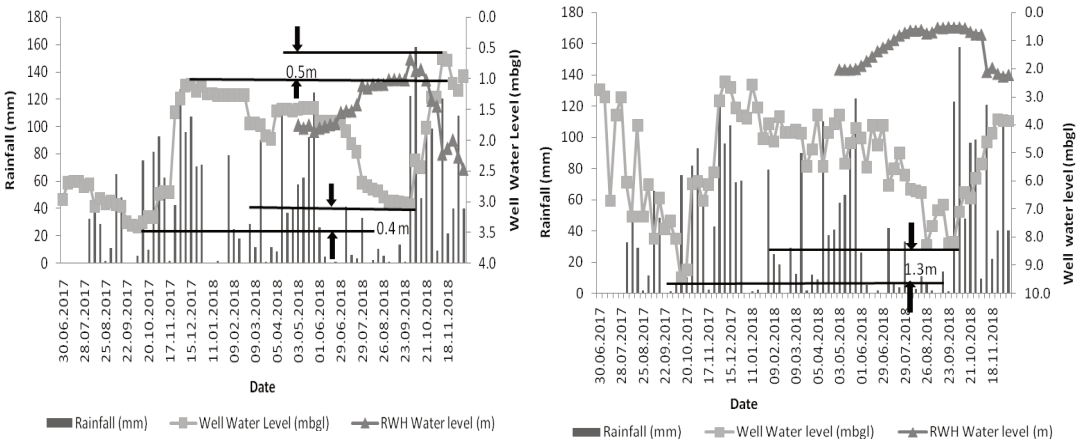


Figure 2 : Well water level (mbgl) and rainfall (mm) in (a) Mahagama Maha Vidyala well in Ridimaliyadda, Mahagama and (b) Orubendiwewa M. V.Ridimaliyadda, Sagabopura

for year 2017 was 1924.5 mm. Subsequently the well water levels decreased and reached the lowest point of 3 mbgl in end of September 2018. During the period from May 2018 to January 2019 there was rainwater in the rainwater harvesting (RWH) tank and this would have artificially recharged the well water levels and this may be the reason for 3mbgl in 2018 compared to 3.4 mbgl in 2017. This supports the fact that by recharging wells using rainwater harvested increase the well water level. In this study rainwater harvested water has raised the well water level by 0.4 m compared to the previous year 2017. Subsequently the well water level increased and reached the highest point of 0.665 mbgl in November 2018 which is almost 0.5 m higher than the previous year (2017) well water level. Average annual rainfall for year 2018 was 1827.9 mm. Even though the annual average rainfall for 2018 was almost 100mm less than the 2017 average rainfall (1924.5 mm), rainwater harvested water has increased the well water level higher than that in the year 2017 in both lowest and highest levels. Recharge calculated by water table fluctuation method using the groundwater table rise and the specific yield of the aquifer. Specific yield value based on the findings of De Silva and Rushton, (2007) was used in this study. Mikunthan and De Silva (2009) also agree with this water table fluctuation method and it was used in their study too. Therefore the recharge during year 2017 and 2018 was 132 mm and 140 mm respectively. Even though the annual average rainfall of 2018 is 100 mm less than that of 2017 the recharge was higher than that of 2017. It was mainly due to the overflow of rainwater harvested added to the well water. These results agree with the similar studies conducted in Kotawehara, Nikeveratiya by De Silva and Ariyananda (2006).

Due to the evaporation and extraction ground water will be depleted so the runoff water storage in ponds can be support to make an increment in ground water table by percolation. This was confirmed by a study carried out in Kotewehara in Nikawaretiya by De Silva and Ariyananda (2006). Similarly Sayana *et al*. 2010 did a similar study where the recharge structures were established in the St Peter's Engineering College Campus, India. The roof top water harvested and stored in the percolation pond in the study area as well as the recharge wells established in the campus. In a period of four years, the recharge is very effective in increasing the level of the water table in the study area. This case study brings to the light the importance of micro level management of water sources that may influence the sustainable management of water as common property resource.

Figure 2 (b) shows the well water level fluctuation in Orubendiwewa M. V., Ridimaliyadda, Sagabopura. According to the figure the well water level decreased

to the lowest point of 9.45 mbgl in October 2017. Then the well water level increased with *Maha* season rains and reached the highest point of 2.5mbgl in December 2017. Then the well water level decreased during dry season but it reached the lowest of point of 8.18mbgl in September 2018. From May 2018 to January 2019 there was water in the rainwater harvesting tank and because of the overflow and percolation the well water level did not reached the same level as in the previous year (2017). This is because the rainwater harvesting has increased the well water level successfully even though the annual average rainfall or year 2017 was less than the 2018. This result agrees with Sayana *et al*. (2010), that the rainwater harvesting increases the well water level effectively.

Well Water Quality

- *pH*

The pH of pure water is 7. In general, water with a pH lower than 7 is considered acidic, and with a pH greater than 7 is considered basic. The normal range for pH in surface water systems is 6.5 to 8.5, and the pH range for groundwater systems is between 6 and 8.5. Figure 3(a) shows the pH variation in all the selected wells in the study area. pH of the well water in all the wells in the study area is within the safe limit of 6.5-8.5. Soon after the *Maha* season rains the pH increased above the safe limit of 8.5 in few wells. pH of well water in the D.H Kandegedara falls below pH 6.5 during the month of April to October. The lowest pH observed D.H Kandegedara well water was 5.7 in April 2018.

- *Electrical Conductivity(µS/cm)*

Electrical conductivity of the wells in the study area during the study period is shown in Figure 3 (b). Electrical conductivity of all the wells is below the safe limit of 1500 µS/cm. But Kesalpothuyaya II showed the highest EC values.

- *Total Dissolved Solids (mg/L)*

Dissolved solids refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amounts of organic matter that are dissolved in water. Acceptable safe limit of TDS is 500mg/L. TDS values of the wells in the study area were below the safe limit of 500mg/L. But the TDS values were in the range of 100-300mg/L (Figure 3 (c)).

These harmful minerals accumulate because the body cannot excrete or utilize them. In most instances, TDS in the drinking water will not present a health problem but it's important to note, should TDS levels exceed 1000mg/L, the drinking water can be considered unfit for human consumption. It is recommended that people with kidney problem should drink pure water having TDS level below

100 mg/L for better recovery. In the study area there are CKDu patients therefore well water is not suitable for them to drink because the TDS values were above 100mg/L. There are ways to remove TDS through Reverse Osmosis (R.O.) Reverse Osmosis removes TDS by forcing the water, under pressure, through a synthetic membrane; Distillation. The process involves boiling water to produce water vapor and Deionization (DI). But RO water doesn't have many of the essential nutrients needed for health.

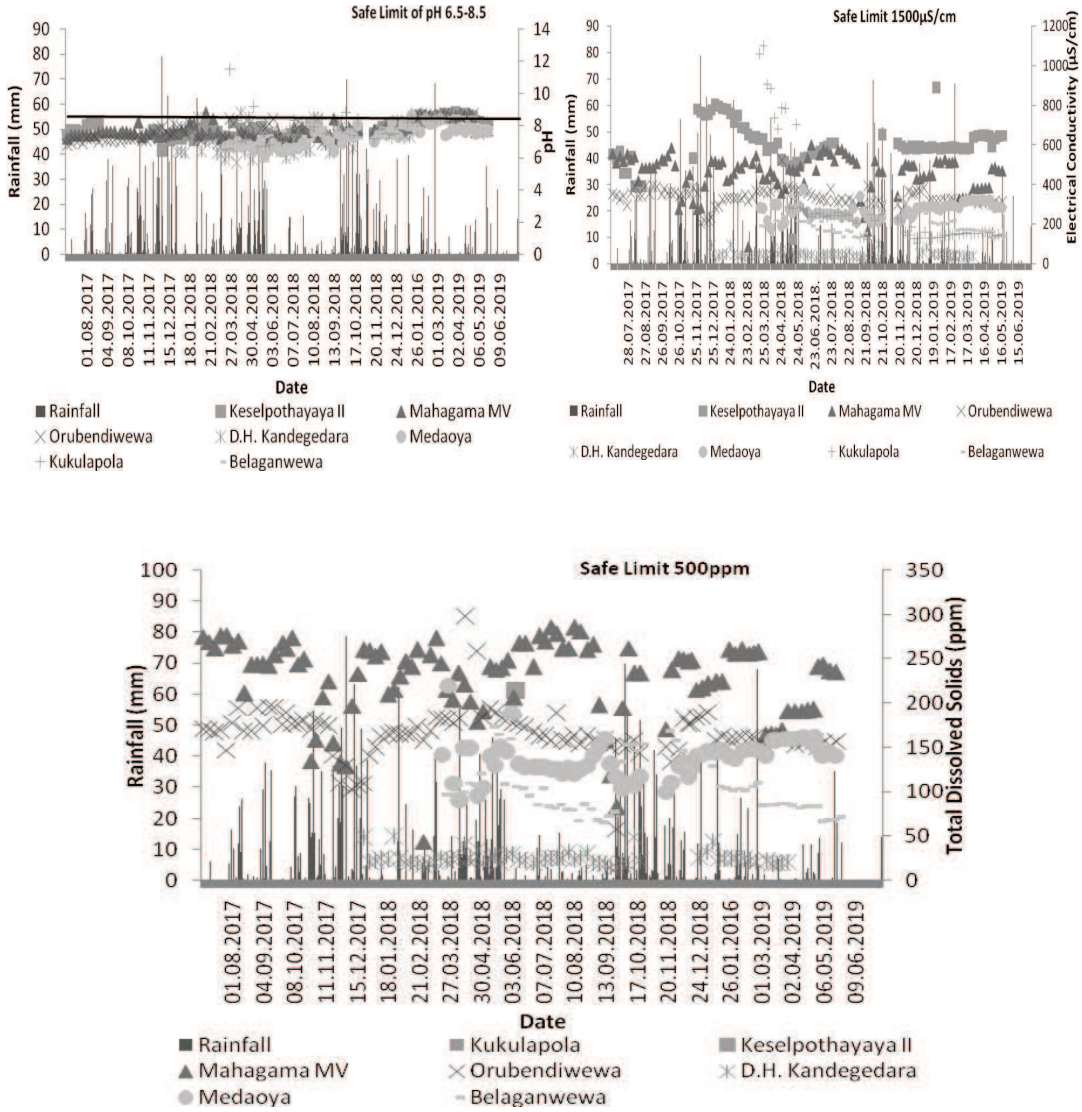


Figure 3 Temporal variation of (a) pH, (b) Electrical conductivity and (c) Total Soluble Solids of well water in the study area.

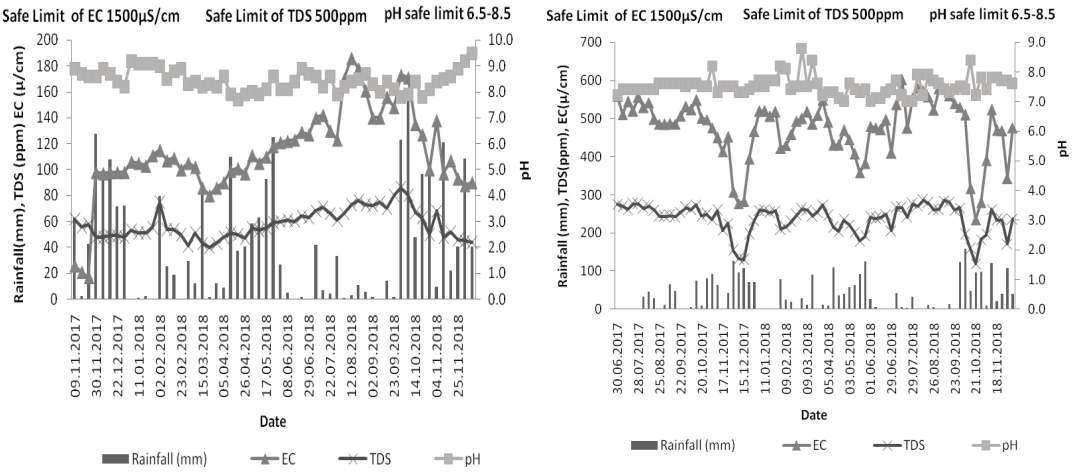


Figure 4: (a) Temporal variation of pH, EC and TDS in rainwater harvesting tank water and (b) Well water in Mahagama Maha Vidyalaya.

Rainwater Harvesting Tank Water Quality

• *pH*

In the study area pH of all the rainwater harvesting tank water in study area all locations was above the safe limit of 6.5-8.5. As an example rainwater harvesting tank water quality and well water quality in Mahagama Maha Vidyalaya are shown in Figure 4 (a) and (b). Some say the higher pH or alkaline water can help slow the aging process, regulate your body's pH level, and prevent chronic diseases like cancer. Because of this, some advocates of alkaline water believe it can neutralize the acid in your body. Normal drinking water generally has a neutral pH of 7. Alkaline water typically has a pH of 8 or 9.When you have kidney disease, it's more difficult for your kidneys to remove acid from your blood. Because of that, a high-alkaline diet, one that is low in acidic foods, may help people with kidney disease balance their pH levels. Therefore the pH in the Rainwater Harvesting Tank water quality is not a serious matter. The reason for high pH levels in the Rain water Tank is due to cement dissolving of the Ferro cement tank when they are newly constructed.

• *Electrical Conductivity (µS/cm)*

An electrical current results from the motion of electrically charged particles in response to forces that act on them from an applied electric field. Within most solid materials a current arise from the flow of electrons, which is called electronic conduction. In all conductors, semiconductors, and many insulated materials only electronic conduction exists, and the electrical conductivity is strongly dependent on the number of electrons available to participate to the conduction process. Most metals are extremely good conductors of electricity,

because of the large number of free electrons that can be excited in an empty and available energy state.

In water and ionic materials or fluids a net motion of charged ions can occur. This phenomenon produces an electric current and is called ionic conduction. Electrical conductivity in all the rainwater harvesting tank water in all locations was within the safe limit of 1500 µS/cm (Figure 4 and 5). Compared to the EC of Well water; Rainwater harvesting Tank water is better for consumption of CKDu patients in the study area because Rainwater Harvesting water have lower EC than that in well water.

- *Total Dissolved Solids (mg/L)*

Total dissolved solids (TDS) is a measure of the dissolved combined content of all inorganic and organic substances present in a liquid in molecular, ionized, or micro-granular (colloidal soil) suspended form. Generally, the operational definiti on is that the solids must be small enough to survive filtration through a filter with 2-micrometer (nominal size or smaller) pores. Total dissolved solids are normally discussed only for freshwater systems, as salinity includes some of the ions constituting the definition of TDS. Although TDS is not generally considered a primary pollutant (e.g. it is not deemed to be associated with health effects), it is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants. According to the results obtained in the study area, TDS of rainwater harvesting tank water in all locations are within the safe limit (Figure 4) of 500 mg/L to provide for palatability of drinking water. Results of this study show that the rainwater harvested water is in better quality than the well water quality in the study area. Further the TDS value of the rainwater harvesting tank in the study area is less than 100mg/L which is suitable for CKDu patients for quick recovery. EC values are also less in rainwater harvesting tank water than well water. In the study area there is considerable number of CKDu patients. Therefore rainwater with lower EC and TDS less than 100 mg/L is preferable for quick recovery of CKDu patients.

Conclusions

This study proves that using the rainwater harvested during wet season to recharge the groundwater wells is an appropriate methodology to increase the well water levels during dry period. If the rainwater is not harvested, most of the water would have lost as runoff and not contributed to groundwater recharge effectively. According to the study results groundwater levels increased where overflow of rainwater is diverted. Mainly Mahagama Maha Vidyalaya and Orubendiwewa Maha Vidyalaya wells showed increase in well water levels in year 2018. Since the volume of overflow rainwater is limited there is not much

difference in the recharge. Accordingly recharge during 2017 and 2018 were 132 mm and 140 mm respectively even though the annual average rainfall in 2018 (1827.9 mm) was less than the annual average rainfall in 2017 (1924.5 mm). Groundwater well quality and rainwater harvesting tank water quality were within the safe limit of pH, electrical conductivity and total dissolved solids. However the EC and TDS values in rainwater harvesting tank water were less than in well water. Rainwater harvesting tank water TDS was less than 100 mg/L which is acceptable for CKDu patients in the study area. Therefore rainwater harvested water quality is superior to the groundwater well quality in the study area. Therefore artificial recharging using rainwater harvested water is not posing any threats to well groundwater quality, but by artificial recharging groundwater wells by rainwater harvested water is improving the water quality of the groundwater wells.

Recommendations

This study results recommends the following;

- Introduce rainwater harvesting tank in all households in the Badulla area.
- Use the Rainwater harvested water drinking purposes as the ground water well quality is inferior to the rainwater harvested water.
- Strongly recommend to CKDu patients in the study area to us rainwater harvested for drinking purposes.

Acknowledgement

Authors acknowledge the USAID Grant No: AID - 383-A-16-00001 of the project, Safe Disaster – Resilient Drinking Water to Floods and Drought Prone Areas of Sri Lanka given to Lanka Rainwater Harvesting Forum to undertake this research study.

References

Ariyananda, T. 2010. Domestic rainwater harvesting as a water supply option in Sri Lanka. Hydro Nepal J. Water, Energy, 27–30.

De Silva, C.S. and Ariyananda, T. 2006. Impact of Rainfall Runoff harvesting in drought prone areas-A case study in Kotawehara of Sri Lanka. *Proceedings of the International Workshop on Rainwater harvesting,* 27-29 September 2006, Kandy, Sri Lanka. 96-102.

De Silva, C. S. and Rushton, K. R. 2007. Groundwater recharge estimating using improved soil moisture balance methodology for a tropical climate with distinct dry season. Hydrological Sciences Journal. 52(5): 1051-1067.

Charles, J. 2000. Anthropogenic distur bance of the terrestrial water cycle 50, 753–765.

Lerner, D. N., Issar, A. S. and Simmers, I. 1990 Groundwater Recharge. A Guide to Understanding and Estimating Natural Recharge. International Contributions to

Hydrogeology no. 8, Verlag Heinz Heise, Hanover, Germany.

Mikunthan, T. and Shanthi De Silva, C. 2009. Estimation of groundwater recharge in limestone aquifer using an improvedsoil moisture balance method: A case study in Jaffna district. Journal of Tropical Agricultural Research. 21 (1):51-61.

Panabokke, C.R. and Perera, A.P.G.R.L. 2005. Groundwater resources of Sri Lanka. Water Resources Board, Colombo, Sri Lanka. 78-90

Rajasooriyar. L. 2002, Groundwater quality in the valigamam region of the Jaffna Peninsula Sri Lanka Geological society special publication. 193(1): 181.

Sayana, E., Arunbabu, L., Mahesh Kumar, Ravichandran, S. and Karunakaran, K. 2010. Groundwater responses to artificial recharge of rainwater in Chennai, India: a case study in an educational institution campus. Indian Journal of Science and Technology, 3 (2): 56-90.

UNESCO. 2003. Water for People, Water for Life. World Water Dev. Rep. 36. pp 24-48.doi:10.1017/CBO9781107415324.004.

UN-Water. 2015. Water for a sustainable world. Pp 19-35. doi:10.1016/S1366-7017(02)00004-1.

Weerarathna, C., Weerasinghe, P., Deva, H., Aheeyar, M.., Jayantha, G., Ajith, P. and Neil, P. 2009. Rain Water Harvesting Practitioners Guide for Sri Lanka, 1st ed. Nugegoda. 12 - 19.

Journal of Dry Zone Agriculture, 2020, 6 (2): 30 - 41

ISSN 2012 – 8673

Market Contribution of Indigenous Poultry Farmer at Household Level

Lakshan, S. and Harisuthan, R.
Sri Lanka School of Agriculture, Kundasale, Kandy

Abstract: This study was broadly designed to analyze indigenous poultry market participation in Eravurpattu DS division in Batticaloa district. The study was mainly based on primary data obtained from a sample survey in four G.N Divisions in Eravurpattu DS Division. The simple random sampling technique was used to draw the sample and data were collected through pretested questionnaires. In addition to that, secondary data were also used. Data were analyzed using a statistical software, and descriptive statistics, frequencies and regression were done. Aspects of socioeconomic features of farmers, management practices, productivity of animals and socio economic determinants of poultry market participation decision were studied. Most of the indigenous chicken owners were females and practiced indigenous chicken farming as a part time work. Main purpose of Indigenous chicken rearing was both egg and meat production for 91% of farmers. It was found that high loss of birds due to improper housing/predation and disease attack were the major problems faced by chicken farmers. There is no organized marketing for indigenous chickens and eggs. However, middlemen, households and village shops were involved in the marketing activities. The main marketing channel was producer to consumer (75%) through households. The regression results showed that households' decision to participate in the poultry market was significantly ($p<0.05$) affected by sex of household head, bicycle ownership, market accessibility and source of market information. Further the results suggest that, establishment of effective market information service will enhance the sales of indigenous chicken farmers.

***Keywords*:** Indigenous, Sampling, Pretested, Regression, Socioeconomic, Determinants

Corresponding Author: S.Lakshan, lakshan1985@gmail.com

Introduction

The agriculture sector contributes 11.2% to the GDP of the country, 24 % of total export earnings and 33 % of national employment in Sri Lanka. Livestock is a sub sector of agriculture and accounts for 7.1% and 0.8 % of the agricultural and national GDP, respectively (CBSL, 2011). The most prominent sub sectors of the livestock sector are dairy and poultry, which provide employment and income to a majority of rural farmers (BOI, 2018). Indigenous chicken production in Batticaloa district has a high potential for poultry production. Village chicken, broilers, layers and ducks are mainly reared in this district. Considerable number of people is involving in village chicken rearing in this district. The production range is small scale at home level and is usually done as a part time occupation or a supplementary income. In Batticaloa district chicken meat is highly produced other than beef and mutton (DVS, Personal Communication, Batticaloa, 2018).

The village chicken are reared both in the rural and semi urban areas in the district. However, they are found very frequently in rural villages of Batticaloa district. The average flock size varies from 5-15 birds. More importantly, there are no commercial-level village chicken productions using intensive management practices as people do with exotic breeds. Birds are set free to scavenge during the day and kept in small houses in the night. According to the observations, house wives and children frequently have the responsibility in looking after the animals (District Statistical Information, Batticaloa, 2018).

Batticaloa district has 14 DS divisions. Eravur Pattu is one of the important DS divisions where indigenous chicken farming is done. Over 85% of the domesticated birds in Eravur Pattu are indigenous chicken providing meat and table eggs. They are frequently raised through the free range, backyard production system. There are an estimated 22,508 birds in Eravur Pattu with Indigenous Chicken being 85% of this number. Indigenous poultry production is an important activity for 75% of the rural population in Eravur Pattu and these birds are mostly kept for domestic consumption and sale (DAPH, Eravur pattu, 2018).

There are 39 G.N. Divisions in Eravur Pattu. Among those only 16 G.N Divisions are rearing backyard or home poultry or indigenous chicken farming at household. Kaluvankerny 1, Kaluvankerny 2, Palacholai and Sitttandi 4 consist highest number of Indigenous poultry farmers at household level. DAPH provides valuable advice and services to indigenous chicken rearing farmers such as training regarding the breeding, vaccination programme (V.S.Office, 2018).

Research Problem

There are many socio economic factors which affect the production, marketing, market participation and sales of indigenous chicken in rural household: Farming experience, family size, age, sex

and primary activity of household head, monthly household income, and education, number of children, breeds, bicycle ownership, market accessibility and market information.

Therefore this study was carried out to identify the factors that determine poultry market participation and sales of indigenous chicken farmers in GN range in Eravur Pattu DS division in Batticaloa District.

Objectives of the Study

1. To understand, the socioeconomic characteristics of the farmers who rear indigenous chicken,
2. To identify, understand the socioeconomic factors affecting the poultry market participation,
3. To identify the problems in indigenous chicken production and marketing.

Research Methodology

Selection of Sample

Kaluvankerny- (Akkarai), Kaluvankerny, Sittandy Part (Mathurenkulam) and Palacholai villages were selected Based on the degree of indigenous chicken production to collect the information. Then GN divisions were selected with degree of total number of indigenous chicken farming families from selected areas. Proportionate people size was selected from each GN divisions. Simple random sampling method was used to select the samples. The final sample comprised of 60 respondents.

Statistical Analysis

Multiple regression was done to analysis the data. Description of variables were given in Table 1.

Table 1: Description of the variables for poultry market participation in multiple regression

Variable name	Unit	Description
Dependent variable		
Poultry market participation = Y I	Yes = 1 No = 0	Categorical variable of whether HH sell live birds, chicken products(meat or eggs) or not
Independent variables		
Sex of household head = X1	Male = 1 Female=2	Categorical variable of whether the HH head is a male or female
Age of HH = X2	Years	Age of HH in years
Educational level = X3	Years	Years of schooling
Farming experience = X4	Years	Years of farming
Transport (bicycle ownership) = X5	Yes=1 No=2	Categorical variable of whether the HH own a bicycle or not
Market accessibility=X6	Yes=1 No=2	Categorical variable of whether the HH had market access or not
Availability of market information = X7	Yes=1 No = 2	Categorical variable of whether the HH has any source of information on poultry market.

Results and Discussion

The average age of indigenous chicken farmers in the study area was 35 years. Data revealed that all indigenous chicken farmers were females in this study area. There were no any male indigenous chicken farmers. All of the indigenous chicken farmers from this area were Hindu. The average farming experience of farmers was 6 years. The average family size of a household was 4 members. The average land size owned by poultry farmers was 2.3 acres. The average family income of the chicken farmers was Rs 13,900 per month (Table 2).

Table 2: Socio-economic status (N= 60) (Source: Field Survey Data, 2018)

Trait	Mean	Std. Deviation
1. Age (Years)	35.08	8.22
2. Farming experience (Years.)	6.10	3.31
3. Family size (No of HH members)	4.78	1.16
4. Income per month (Rs)	13900	3615.87
5. Land sized owned (Ac)	2.33	16.10

Educational level of farmers was determined by the years of schooling they had followed. It was observed from the survey that 35% of respondents were primary category, 65% of farmers had secondary category education. 35% of farmers have the experience of less than 6 years of schooling and 21.7% of farmers have 6-7 years of schooling 43.3% of farmers have the experience of greater than 7 years of schooling, respectively (Table 3). It was indicated by Saha (2003) that sufficient level of education is motivating the farmers to adopt the newer technologies.

Table 3: Schooling years of farmers (Education level of Farmers) (N=60) (Source: Field Survey Data, 2018).

Years of schooling	Number of farmers	Percentage
1. Less than 6 years	21	35
2. 6 - 7 years	13	21.7
3. More than 7 years	26	43.3
Total	60	100

The survey results indicated that farming was the major livelihood activity of 60 percent of respondents earned through agriculture activities. About 15 percent of respondents involve in other jobs such as government service and private sector. Rest 10 percent of the respondents involved in business activities (Table 4).

Table 4: Occupation of farmers (N=60) (Source: Field Survey Data, 2018)

Occupation	Frequency	Percentage (%)
1. Government	9	15
2. Private sector	9	15
3. Farming	36	60
4. Business	6	10
Total	60	100

Engaged in Indigenous Chicken Farming

When time spending with poultry rearing considered most of the farmers (94%) practiced part time. Only 6% of farmers practiced in full time because stable income cannot be obtained from village chicken rearing. It contributes fewer amounts of cost of living.

Farmer's Involvement in Indigenous Poultry

Survey revealed that all farmers reared indigenous chicken. Among those 51.7% of the farmers reared livestock other than indigenous chicken. Among those 21.7% of the farmers reared indigenous chicken with other poultry species such as layer and broiler. When indigenous chicken is reared with other breed, diseases are spread out quickly. Therefore, majority of farmers do not like to mix together.

Purpose of Rearing Indigenous Chicken

Purpose of rearing indigenous chicken varies among farmers. Survey revealed that main purpose of indigenous chicken rearing was both egg and meat for 91% of farmers, 9% of farmers said solely for egg purpose, main purpose of indigenous chicken was for their home consumption. In the survey area, high demand for indigenous chicken egg and meat exists because taste of this product is better than other poultry species product. Nobody rear for only Meat purpose. When indigenous chicken stopped laying egg it is sold for meat otherwise they use for home consumption

Indigenous Chicken Production

Free range system of production was practiced by the majority of chicken keeping households during the day. Surprisingly, a considerable proportion

(6.7%) of all households keeps chicken under confined (with roof) system during day. Confined (with roof) system was practiced by majority of household during night. Considerable proportion (13.3%) of household keeps chicken under free range system at night. Average flock size of household in this area was 25.83.

Dominant Breeds

Majority of surveyed people reared indigenous breed rearing (Table 5). Some of them had other breed. Indigenous breeds can be managed with low cost and disease attack is very low. In surveyed area people have not enough facilities to go for other breeds. Naked neck and normal indigenous chicken birds were commonly found in surveyed area.

Table 5: Chicken management practices

Variables	Percentage of farmers
a. Housing practices	
1. Day	
Free range	93.3
Confined (with roof)	6.7
2. Night	
Free range	13.3
Confined (with roof)	86.7
b. Feeding practices	
Kitchen waste	65
Grains	40

Indigenous chicken production is characterized by low input production systems (Alemu, 1995). The results in Table 5 indicated that the majority of indigenous chicken farmers used free range system during the day time (over 93.3%) and confined chicken at night (86.7%). There was no purposeful practice of feeding chicken while scavenging was the predominant way of feeding. In addition to scavenging, supplementary feeds (kitchen waste-65%, grains-40%) were provided to chicken when available. The all of indigenous chicken farmers used natural uncontrolled breeding for their chicken. The average unit cost of supplementary feed per kg was 75.00.

The average age of pullets at first laying was 5.78 months. The average number of eggs/clutch was 18 with an average 2 clutch/year. The average weight of adult male and female normal village chicken were 1.88 kg and 1.10 kg, respectively. These results showed that the production performance of indigenous chicken were comparatively low (Table 6).

Table 6: Productivity of indigenous chicken (N=6)

Variables	Mean	Std. Deviation
1. Age at first laying (Months)	5.78	0.48
2. Number of eggs per clutch	18.63	2.72
3. Number of clutch per year	2.50	0.50
4. Average marketing weight of male bird (kg)	1.88	0.21
5. Average marketing weight of female bird (kg)	1.10	0.20

However, Aberre (2000) revealed that despite the low productivity, indigenous chicken possess desirable characteristics such as thermo-tolerance, resistance to some diseases, good egg and meat flavor, presence of hard egg shells, high fertility and hatchability as well as high dressing percentage. Therefore, the indigenous chicken has the potential to improve in a rural setting while enhancing the livelihood of rural farm families.

Marketing of Indigenous Chicken

There is no organized marketing for indigenous chickens and eggs. Chickens are sold alive to meet family needs and most sales takes place at the home. 60% of the farmers said that they sold or consumed most of the cockerels and kept most of the young hens for breeding. The average price of adult male and female birds was Rs.906.50 and Rs.434.14 respectively. The average price of an egg was Rs.20.00. Average number of eggs used for home consumption per month was 31.85 and average number of eggs sold per month was 24.13.

The average annual income for the village chicken production per year is unstable because value of home consumption is high in village chicken farmers. Reason for this observation is mainly due to low production capacity of these village chicken breeds. Farmers try to fulfill their need rather than the sale that small number of egg as they have small number of village chickens compared commercial poultry farmer.

Market Participation

Survey results shows that 85 percent of indigenous chicken farmers were sell their products (live birds/eggs) to consumers through various channels as stated above. Rest 15 percent of the farmers did not sell their products at all; because they had large family size and that was leads to high home consumption.

Survey results shows that most of the (95%) household decision making for market participation (selling eggs, selling chicken, home consumption of eggs and chicken) was taken by house wives.

Market Accessibility

Data revealed that about 23.3 percent of the respondents had market accessibility. About 61.7 percent of respondents not had market accessibility.

Market Information

Data revealed that 45 percent of indigenous chicken farmers received market information from various sources. Data revealed that majority of the farmers (85%) had taken market information from ot herowners. About 31.7% of the market information had been obtained from Department of Animal Production and Health (Table 7).

Table 7: Market information sources (N=51) (Source: Survey Data (Multiple response), 2018

Source	Frequency	Percentage
1. From other owners	51	85%
2. DAPH	19	31.7%

Marketing Problems

Middlemen involvement and low price have been reported (85% of farmers) as a major marketing problem, while about 53.3 percent of indigenous chicken farmers had transport problems in selling their product. About 66.7 percent of farmers had reported low marketable output. Also 60 percent of farmers stated that lack of buyers. About 45 percent of farmers had lack of marketing information (Table 8).

Table 8: Problems in marketing of indigenous chicken (N=51)

Major problems	Number of respondents & percentage
1. Middle men restriction	51 (85%)
2. Road and transport facilities	32 (53.3%)
3. Low price	51 (85%)
4. Low marketable output	40 (66.7%)
5. Lack of buyers	36(60%)
6. Lack of marketing information	27(45%)

Table 9: Other production problems (N=60)

Problems	Number of respondents & Percentage
1. Not enough veterinary services	46 (76.7 %)
2. Loss of birds due to improper housing or predation or thief	49 (81.7 %)
3. Lack of financial assistance to develop their flock	38 (63.3 %)
4. Natural disasters	11 (18.3 %)
5. Disease attack	53 (88.3 %)

Among the respondents 76.7 percent of the farmers had stated that not enough veterinary services affect the indigenous chicken production. About 81.7 percent of farmers had reported high loss of birds due to improper housing, predation and thief. About 63.3 percent of farmers had reported lack of financial assistance to develop their flock size. Also 18.3, 88.3 percent of farmers stated that natural disasters such as flood (November to December) and disease attacks affect the indigenous chicken production, respectively (Table 9).

Table 10: Suggestions for improving indigenous poultry production (N=60)

Solution	Number of respondents
1. Provide enough veterinary facilities	32 (53.3 %)
2. Provide better transport facilities	33(55 %)
3. Provide subsidies and loan	27(45 %)
4. Provide proper marketing facilities	46 (76.6 %)

Respondents suggested many solutions for the problems they were facing. Among the solutions indicated 53.3% of the respondents suggested the solutions of providing enough veterinary services. At the same time 55%, 45% and 76.6% of the respondents suggested the solutions of providing better transport facilities, providing subsidies and proper marketing facilities (Table 10).

Health Care

Disease Prevention

Survey results shows that 65 percent of respondent farmers did not take any preventive measures at all; this was due to they had not faced any severe disease incidence. Say (1987) emphasized disease prevention through regular vaccination. Department of Animal Production and Health in Vantharumoolai and some other private shops such as pharmacies are providing vaccine to the farmers. Some of the farmers used some indigenous treatments for disease prevention.

Availability of Medicines and Drugs

Most of the indigenous chicken farmers (76.7%) do not get medicines and vaccine due to lack of availability of the

veterinary medicines in the market and high price. About 23.3% of farmers are getting medicines from Veterinary Office and other private shops. Indigenous chicken farmers don't have enough awareness regarding the usage of the medicines and drugs.

Socio Economic Factors Affecting Poultry Market Participation

The multiple regression results revealed that this model was significant at level of 5% (0.05) and the R^2 was 0.821 which implied that about 82.1% of the variation in indigenous poultry market participation was explained by the factors such as sex of household head, age of household head, education level of household head, farming experience, bicycle ownership, market accessibility and source of market information. Thus, indigenous poultry market participation significantly affected by sex of household head, bicycle ownership, market accessibility and source of market information (Table 11).

Table 11: Results for regression analysis of poultry market participation. (N=60, R^2=0.821, F value = 34.13)

	Variable	Coefficient	t
	(Constant)	0.314	1.673
1.	Sex of HH head	-0.106	2.001*
2.	Age	0.001	0.209
3.	Educational level	0.002	0.199
4.	Farming experience	0.003	0.435
5.	Transport (bicycle ownership)	0.151	3.495***
6.	Market accessibility	0.233	5.704***
7.	Source of market information	0.085	1.759*

Dependent variable: Poultry market participation,***Significance** at 10% level, ****Significance** at 5% level, *****Significance** at 1% level (Source: Data Analysis SPSS output)

The estimated model can be written as follows:

Y= 0.314 - 0.106 sex of HH head + 0.001 age of HH head + 0.002 educational level of HH head + 0.003 farming experience + 0.151 bicycle ownership+ 0.233 market accessibility + 0.085 source of market information.

The results confirmed that the decision of a household to participate in poultry market is influenced by sex of the household head. This result is consistent with the findings of Gebregziabher (2010) reported that participate in poultry market significantly affected with sex of household headship.

The results confirmed that the decision of a household to participate in poultry market significantly affected by bicycle ownership. This finding is consistent with the finding of Olwande and Mathenge (2010) that ownership of transport equipment was significantly affected with the agriculture market participation among poor rural households in Kenya.

Conclusions

From the study following conclusions can be arrived, Most of indigenous chicken farmers were female and they practiced indigenous chicken production as a part time job. Main purpose of indigenous chicken rearing was both egg and meat production. An average monthly income was Rs. 950.00. Middlemen restriction, transport facilities, low price and low marketable output were major marketing problems. Loss of birds due to improper housing; predation and thief, disease attack, not enough veterinary services and lack of financial assistance were major production problems. It was observed that indigenous poultry market participation was significantly affected by sex of household head, bicycle ownership, market accessibility and source of market information. Market information services have to be established and strengthened in order to improve the poultry market participation. Moreover, Attention should be paid to improve the market accessibility for indigenous chicken in the study area.

References

Abeykoon, M. N. D. F., Weerahewa, J. and Silva, G. L. L. P. 2013. Determinants of market participation by indigenous poultry farmers: a case study in Anuradha pura district in Sri Lanka. Tropical Agricultural Research, 24 (4): 347-361.

Abeykoon, M. N. D. F., Weerahewa, J., Weligamage, P. and Silva, G. L. L. P. 2014. Willingness to pay for chicks of different indigenous chicken types: an application of experimental auctions. Tropical Agricultural Research, 26(1):162-174.

Bulumulla, P. B. A. I. K., Silva, P. and Jianlin, H. 2011. Genetic diversity at Toll like receptor 7 (TLR7) gene of Sri Lankan indigenous chicken and Ceylon jungle fowl (*Gallus lafayetti*). Tropical Agricultural Research, 22(4): 367-373.

Characterization of the smallholder poultry marketing systems in rural Malawi: A case study of Malingunde Extension Planning Area. Livestock Research for Rural Development, 16 (12): 2004.

District Statistical Information, Batti caloa, 2018.

Ethiopian indigenous ('Angete-melata') chicken and their F1 crosses to long term heat stress. PhD thesis. Martin-Luther University, Halle-Wittenberg, Berlin, Germany. 182.

Farrell, D. J. 2000. The energy and protein needs of scavenging laying hens. Livestock Research for Rural Development, 12 (4).

Garces, A., Casey, N. H. and Horst, P. 2001. Productive performance of naked neck, frizzle and dwarf laying hens under various natural climates and two nutritional treatments. South African Journal of Animal Science, 31(3): 174.

Menge, S. K., Kosgey, M. A. and Kahi, J.W. 2007. Influence of prices on market participation decisions of indigenous poultry farmers in four districts of Eastern Province, Kenya. Journal of Agriculture and Social Research (JASR), 12(1):1-10.

Pym, B., Wegener, P., Wethli, E. and Young, M. 2009. Improving village chicken production: A manual for field workers and trainers. ACIAR Monograph No. 139. Australian Centre for International Agricultural Research, Canberra. http://www.aciar.gov.au/publication/ MN139.

Journal of Dry Zone Agriculture, 2020, 6 (2): 42 - 49

ISSN 2012 – 8673

Sustainable Waste Management: Green Concept of Black Solider Fly Larvae (*Hermetia illucens*) as Bio-degradable Waste Convertor; Comparison of Life Cycle and Growth Performances in Two Different Substrates.

Ellewidana, D.M.[1], Perera, N.P. [2], Pathirage, K.L. [1] and Magamage, M.P.S.[3]

[1] Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka

[2] Department of Export Agriculture, Faculty of Agricultural Sciences

[3] Department of Livestock Production, Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka, Sri Lanka

Abstract: Viable waste management using insects are in trend, nevertheless no significant practices available locally. The black soldier fly larvae (BSFL; Hermetia illucens) have proven successfully the decomposition of organic matter savagely, enriched with favorable amino acid source for animal feed. The study intended to compare the life cycle modalities of BSFL with two different substrates, swill (T1) and poultry starter feed (T2), by assessing the days taken for completion of life cycle, egg and larval characteristics and crude protein (CP) percentage under IM3 agro climatic region in Belihuloya, Sri Lanka. There was no substrate-dependent effect on the egg characteristics. The total time period taken to complete the life cycle in T2 (37 - 45 days) was quicker than the T1 (46 - 57 days). Substantial length and width variation in different larval instars were observed whereas higher values were recorded in T2 with compared to T1. The CP percentage of pre-pupae stage was 51.99% in T2 while 39.46% in T1. The latter instars of BSF larvae CP percentage were recorded as 48.88% and 33.11% in T2 and T1 respectively. In conclusion, poultry starter feed (T2) that consist of balanced nutrient composition could be used as the most appropriate substrate for early life cycle completion with compared to swill (T1). T2 may effectively utilize as artificial media for initial propagation of BSFL. Larva growth under T2 conditions recorded the highest CP levels but it need to be further studied prior to use as protein substitution in animal feed formulation.

Keywords: Black solider fly larvae, *Hermetia illucens*, Crude protein, Swill, Waste

Corresponding Author: D.M.Ellewidana, ewdmellawidana@gmail.com

Introduction

Solid waste management has become a terrific issue where all the nations are struggling to implement more effective methodologies to make sure cleanliness, healthy and productive nation coupling with globalization. It is having a positive correlation with waste generation and the raise of income levels among the population (Hoonweg *et al*., 2012). It is predicted that average waste generation is 0.74 kg /day person where global waste is expected to be raised to 3.4 billion tons by 2050 along with double population growth, especially in South Asia (Kaza *et al*., 2018). Unplanned urbanization is in trend where more than half of the generated waste is open dumped, creates the worst damage to the environment. According to the literature middle income countries counts 53% of food and green waste from their total waste (Kiran *et al*., 2014; Levis *et al*., 2010).

Emission of volatile odor from decomposing biodegradable waste has many adverse effects, especially animal waste. A higher greenhouse gas emission; ammonia in major and other volatile compounds are generated resulting severe health hazards. The people who live proximity to the waste collected areas are undergoing higher levels of depression, tension and anger (FAO, 2009 and Baskin *et al*., 2017).

Previous studies indicated that small and medium scale solid waste management using aerobic treatments prior to open dumping would be an appropriate method to a country like Sri Lanka, since more than 70% of the waste fraction is comprised with bio-degradable waste (Menikpura *et al*., 2012). Bio degradation using Black Soldier Fly Larvae (BSFL) is a proven success method worldwide (Diener *et al*., 2011). It is a harmless insect and widely spread in warmer areas of the world. Which is having a short complete life cycle with the especial ability of controlling house fly (Newton *et al*., 2005). The odor generated by bio waste inhibits the oviposition of house fly. They composed with natural antibiotics and able to reduce harmful bacteria like Escherichia coli 0157:H7 and Salmonella enterica (Erickson *et al*., 2004; van Huis *et al*., 2013; Sheppard *et al*., 1994). Few literatures presented their environmental impact by insect production (Salmone *et al*., 2016, Hackstein and Stumm, 1994; Oonincx *et al*., 2010).

The developing countries are mainly struggle to achieve the nutrient requirement where dietary preferences are shifting towards animal based products. The livestock production's profit is marginalized due to high expense of Crude Protein in animal feed which is accounting 60% -70 % of the total production cost. Another advancement is, BSFL are ferocious in transforming organic matter into livestock feed crude protein (Lalander *et al.*, 2019).

Same as globally, Sri Lanka also standing behind the waste processing requirement. Locally it is predicted that municipal

waste generation will be accelerated 1kg/person day by 2025 (Vidanarachchi *et al*., 2006). Most of the local waste management is carried out by local authorities and failed to provide sufficient waste management service due to lack of efficient procedure and skilled workforce. It results that approximately 90% of the collected waste is open dumped in an uncontrolled manner (Menikpura *et al*., 2012). Technology may not be the only solution since other effective alternative methods are in an urgent need (Kuruppuge *et al*., 2013).

Locally the livestock sector is a powerful tool in uplifting rural economy for centuries (Alahakoon *et al*., 2016). In Sri Lanka it is less known on BSFL production and lifecycle analysis. Since fewer literatures existed over insect life cycle assessments on this specific field, this study intends to compare the life cycle of BSF with the standard life cycle and growth performances in two different substrates conditions under Belihuloya IM3 agro ecological zone in Sri Lanka. Research outcomes serve best in sustainable insect production for environmental management and animal feed production.

Materials and Methods

For the BSF larvae breeding purpose, a special container was designed that facilitating aeration, leachate extraction, self-harvesting and corrugated surfaces for laying eggs with a dark atmosphere. 100% Swill (T1) and poultry starter feed (T2) were used using three replicates as experimental substrates. After initiation of brooding, swill was top up once in two days. Initially 700 g of poultry starter feed was mixed with Chlorine free water to de-crumble and made as pellet. Both substrates were stored in the dark and observed daily. Sufficiently moist state was ensured in both substrates.

Favorable breeding climatic requirements were maintained for BSF, ensuring the temperature range of 25 °C to 30 °C and relative humidity 50% to 80%. Since BSFL do not prefer direct sunlight the experiment set up was maintained under shade (Zhang, 2010; Givens *et al*., 2013).

Adult behavior and the larval performances of BSF were recorded daily in two different substrates. Special attention was paid towards the adult's oviposition behavior. Egg characteristics were evaluated by measuring the egg length using electron microscope and volume of egg mass using a ruler. The larval growth performances of both substrates were compared by measuring length and width of larval stages using three replicates. The life cycle completion days considering life stages were recorded respectively. In addition, the percentage of crude Protein percentage (CP%) was calculated performing Proximate analysis and multiplying the resulted Nitrogen percentage by 6.25 in terms of latter stages of larvae and the pre-pupae. All the parameters were statistically analyzed

for the standard deviation and Standard Error.

Results and Discussion

It was observed that the large number of egg masses (3 egg masses/day) were placed in poultry starter feed, with compared to small number of egg masses in swill (1-2 egg masses / day). Measurements of the average egg length was recorded around 1mm (Caruso et al., 2014) where 0.996 µm in swill (SD = 0.006) and 0.997 µm in poultry starter feed (SD = 0.007). The average eggs volume in swill was recorded as 0.973 eggs / mm3 (SD = 0.005) and in poultry starter feed with 0.95 eggs / mm^3 (SD = 0.024). The results showed that there was no substrate-dependent influence on egg characteristics, although the oviposition of the eggs showed their attraction to the smell of substrate.

The occurrence of the first instar larvae was registered in poultry starter feed after two days of oviposition, and swill substrate followed the hatching of the eggs after the third day of oviposition. The length of the first instar larvae was recorded as 932.49 µm (SD = 2.174) under swill subtrate where 893.668µm (SD = 0.611) length was recorded in poultry starter feed substrate.

Once the larval growth was initiated, there was a significant variation in larval length and width in terms of substrate specificity (Figures 1 and 2). Larval length measurements revealed that larvae brood in poultry starter feed indicated a higher larval length values than swill substrate. This may be due to high nutrient value of substrate supplement with poultry feed. There was a gradual increase in larval length from L1 to L5 in poultry starter feed. Even though larval length in swill also followed the same, a declining was encountered from L4 to L5.

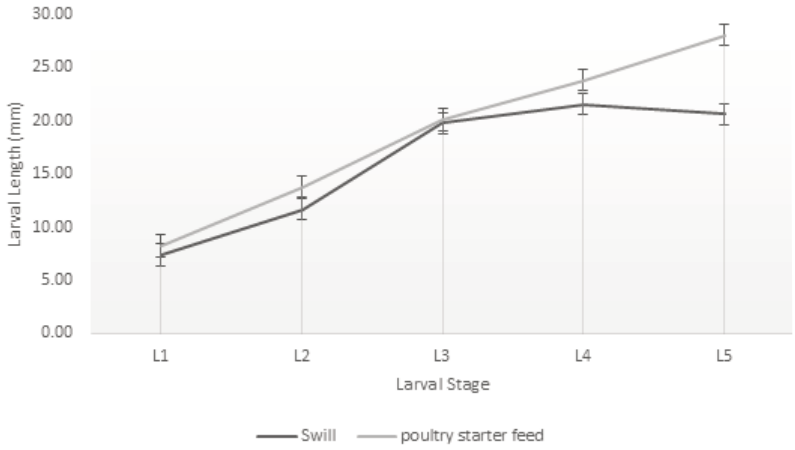


Figure 1: BSFL Larval length of different larval stages

Irrespective of brooding media the larval width was increased up to L3 stage. Nevertheless L1-L3 growth has increased in swill much slower phase than poultry starter feed. Poultry starter feed substrate has shown increased width between L3 and L4 with compare to the larvae brood in swill. The larval width was increased up to L4 and showed a decrease width in L4 to L5 in poultry starter feed. Larvae brood in swill has shown maximum growth up to L3 and started decreasing width from L3 to L5.

Irrespective of brooding media the widths of the various larval stages, increased up to L3, followed by steady growth up to L4. The increase in larval width was leveled in T1 from L3 to L4, followed by a decrease in growth to L5. The larvae brood in the T2 diet was wider than the T1 stage except the L3 stage.

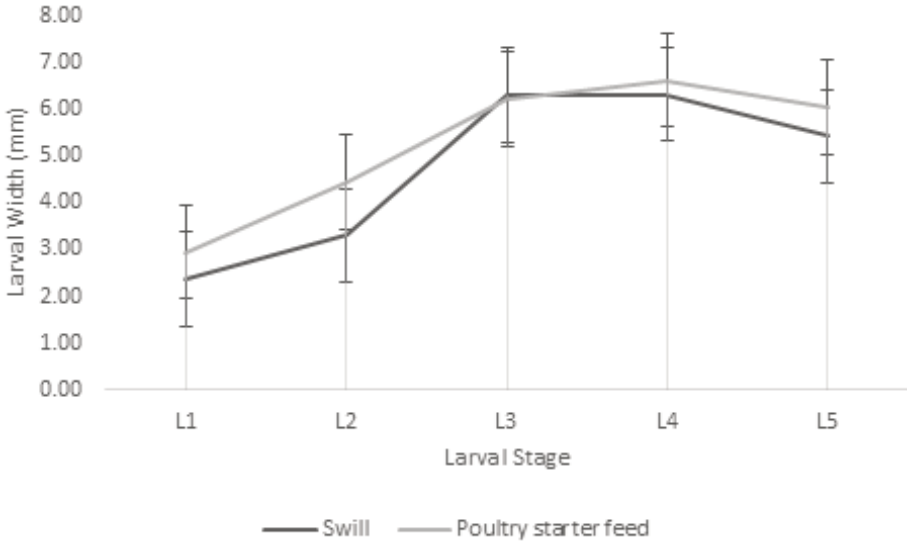


Figure 2: BSFL larval width of different larval stages

BSFL life cycle completion under poultry starter feed indicated early with compared to the swill. Five days were taken to initiate egg laying in poultry starter feed and 2 days to hatch and emergence of first instar. Further another 10-13 days were taken to attain 1st instar to 6th instar stage (Pre-pupae stage) in poultry starter feed. Time taken for emergence of pre-pupae to adult was exhibited 20 - 25 days. Collectively the total BSFL life cycle period brood in poultry starter feed was indicated around 37- 45 days.

Three days were taken to initiate laying eggs in swill. Eggs hatching were extended by another 3 days. After emergence of 1st instar at the 6th day of the experiment the larval stage continued up to 12 -16 days until attain the pre-pupae stage. From the pre-pupae stage to

emergence of adult stage the life cycle in swill recorded as 28 - 35 days. Collectively the BSFL life cycle completion in swill was exhibited 46 - 57 days.

The results envisaged that larvae brood in poultry starter feed showed an accelerated life cycle completion than swill. After 3 days of the experimental setup in which swill odor may influence the attraction of BSF to the substrate much earlier than poultry starter feed. Second incidence of oviposition was detected after 5 days of experimental setup where substrate odor emission was delayed. According to Caruso *et al.*, 2014, the standard life cycle is around 45 days. The proximate values indicated that pre-pupae stage, under swill substrate: 39.46% (SD= 0.84) crude protein and under poultry starter feed substrate: 51.99% (SD=2.22) crude protein was recorded. The CP levels were recorded in latter level instars 33.11% (SD= 1.68) and 48.88% (SD = 1.27) under swill and poultry starter feed respectively (Figure 3).

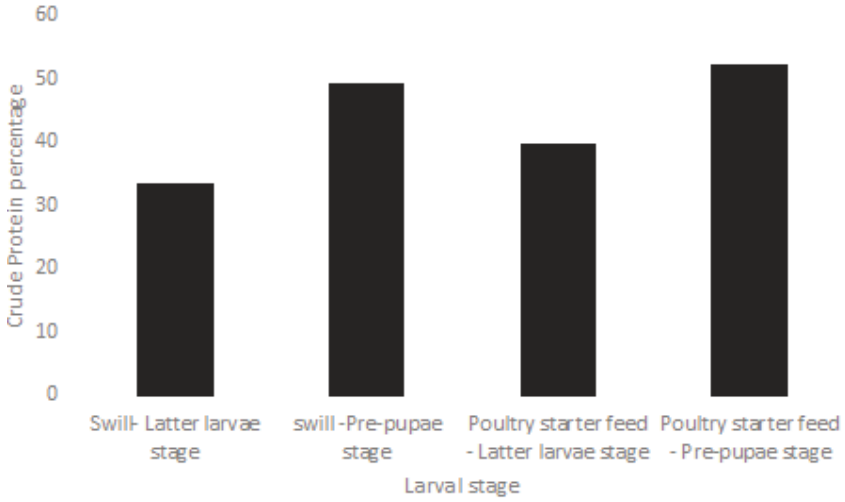


Figure 3: CP % of different life stages in different substrates

Conclusion

Results of the study revealed that, poultry starter feed envisioned the most suitable substrate for an accelerated life cycle compared to 100% swill and the standard BSFL life cycle. The higher nutrient composition of poultry starter feed enhanced the growth performances of larvae with respect to the 100% swill. The larvae brood in poultry starter feed was contained high levels of CP where other respective characteristics of larvae need to be further studied to substitute animal feed protein component.

Acknowledgment

We would be thankful for World Bank funded Accelerating Higher Education Expansion and Development – AHEAD project, RIC grant for funding the research project and the research team for their valuable involvement.

References

Alahakoon, A.U., Jo, C. and Jayasena, D.D. 2016. An overview of meat industry in Sri Lanka: A comprehensive review. Korean journal for food science of animal resources, 36(2):137.

Baskin, B. 2017. Why it's mainly giant companies that buy green power. *Wall Street Journal*, 21.

Caruso, D., Devic, E., Subamia, I.W., Talamond, P. and Baras, E. 2014. Technical handbook of domestication and production of Diptera black soldier fly (BSF), Hermetia illucens, Stratiomyidae.

Diener, S., Zurbrügg, C., Gutiérrez, F.R., Nguyen, D.H., Morel, A., Koottatep, T. and Tockner, K. 2011. Black soldier fly larvae for organic waste treatment—prospects and constraints. Proceedings of the Waste Safe, 2 :13-15.

Erickson, M.C., Islam, M., Sheppard, C., Liao, J. and Doyle, M.P. 2004 Reduction of Escherichia coli O157:H7 and Salmonella enterica serovar Enteritidis in chicken manure by larvae of the black soldier fly. J Food Prot. 67(4):685–90.

FAO. 2009. How to feed world in 2050.

Givens, M., Jeffay, N., Pierce, B., Robinson, W. and Mattox, J. 2013. The Black Soldier Fly How-to-Guide. University of North Carolina, USA, 4.

Hackstein, J.H. and Stumm, C.K., 1994. Methane production in terrestrial arthropods. Proceedings of the National Academy of Sciences, 91(12) : 5441-5445.

Hoornweg, D. and Bhada-Tata, P. 2012. What a waste: a global review of solid waste management, 15 :116.

Kaza, S., Yao, L., Bhada-Tata, P. and Van Woerden, F. 2018. What a waste 2.0: a global snapshot of solid waste management to 2050. The World Bank.

Kiran, E.U., Trzcinski, A.P., Ng, W.J. and Liu, Y. 2014. Bioconversion of food waste to energy: a review. Fuel, 134, 389-399.

Kuruppuge, R.H. and Karunarathna, A.K. 2013. Waste Management & Resource Utilisation. Waste Management & Resource Utilisation, 567.

Lalander, C., Diener, S., Zurbrügg, C. and Vinnerås, B. 2019. Effects of feedstock on larval development and process efficiency in waste treatment with black soldier fly (Hermetia illucens). *Journal of cleaner production*, 208 : 211-219.

Levis, J.W., Barlaz, M.A., Themelis, N.J. and Ulloa, P. 2010. Assessment of the state of food waste treatment in the United States and Canada. *Waste management*, 30(8-9) :1486-1494.

Salomone, R., Saija, G., Mondello, G., Giannetto, A., Fasulo, S. and Savastano, D. 2017. Environmental impact of food waste bioconversion by insects: application of life cycle assessment to process using Hermetia illucens. *Journal of Cleaner Production*, 140 :890-905.

Menikpura, S.N.M., Gheewala, S.H. and Bonnet, S. 2012. Sustainability assessment of municipal solid waste management in Sri Lanka: problems and prospects. *Journal of Material Cycles and Waste Management,* 14(3) :181-192.

Oonincx, D.G., Van Itterbeeck, J., Heetkamp, M.J., Van Den Brand, H., Van Loon, J.J. and Van Huis, A. 2010. An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *PloS one*, 5(12) :14445.

Van Huis, A., Van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G. and Vantomme, P., 2013. Edible insects: future prospects for food and feed security (No. 171). Food and Agriculture Organization of the United Nations.

Vidanaarachchi, C.K., Yuen, S.T. and Pilapitiya, S. 2006. Municipal solid waste management in the Southern Province of Sri Lanka: Problems, issues and challenges. *Waste Management*, 26(8) : 920-930

Zhang, J., Huang, L., He, J., Tomberlin, J.K., Li, J., Lei, C., Sun, M., Liu, Z. and Yu, Z. 2010. An artificial light source influences mating and oviposition of black soldier flies, Hermetia illucens. *Journal of insect science*, 10(1):1-7.

Journal of Dry Zone Agriculture, 2020, 6 (2) : 50 - 59

ISSN 2012 – 8673

Suitability of Different Rooting Media and Length of Cuttings on Growth and Yield Performance of Mint (*Mentha* spp.)

Priyatharshini, R., Pradheeban, L. and Nishanthan, K.
Department of Agronomy, Faculty of Agriculture, University of Jaffna, Sri Lanka

Abstract: Mint (*Mentha* spp) is an aromatic perennial herb. It belongs to the family Lamiaceae due to the specific aroma which is popular in world. It's not cultivated commercially in Northern part of Sri Lanka. The present experiment was conducted to evaluate the suitability of different rooting media and cutting lengths on growth and yield performance of Mint (*Mentha* spp) at Department of Agronomy, Faculty of Agriculture, Ariviyal Nagar, Kilinochchi during January to March 2019. Two factor factorial experiment was carried out in Complete Randomized Design (CRD) with five replicates, where factor one was rooting media and factor two was cutting length. Six potting media (cattle manure, compost, coir dust, partially burnt paddy husk, goat manure and top soil) and four length of cuttings (6 cm, 9 cm, 12 cm, and 15 cm) were used as treatment combinations. Weather, growth and yield parameters and chemical properties were recorded and data were analyzed in ANOVA using SAS 9.1 package. The means were compared by using Duncan Multiple Range Test. Management practices were performed according to the farmer practices. Growth parameters such as plant height, number of leaves, leaf area, branch number, root length and shoot length, yield parameters such as fresh weight of shoot, fresh weight of root and number of stolon) and chlorophyll content of the leaves were significantly different among rooting media and cutting length. The highest plant height, leaf area, length of shoot, fresh weight of shoot and number of stolon were recorded in the media contain goat manure. Number of leaves, number of branches, root length, fresh weight of root and chlorophyll content were highest in compost containing media. Compost and goat manure containing media showed best performance and gave the highest yield. Among these two media, goat manures gave more yield than compost containing media. Fifteen centimeter length of cutting showed the best performance and gave the highest yield. According to the results, it can be concluded, that 15 cm cutting planted in goat manure containing media is best for mint growth and yield in pots.

***Keywords*:** Lamiaceae, Length of cutting, Mint, Parameters, Rooting media

Corresponding Author: K.Nishanthan, knishanthan81@gmail.com

Introduction

Mint is an aromatic perennial herb and scientifically known as *Mentha*. The genus *Mentha* comprise 25 - 30 different species and known for its antimicrobial, antiviral and insecticidal activity (Karicheri and Antony, 2016). *Mentha* (Mint) belongs to Lamiaceae (Labitate) family and the order of Lamiales. It shows erect habit with short, branched, square stem and creeping rhizomes and produce long thin rhizomes commonly called as stolon and grow up to 60 to 100 cm in height.

Mint is an important leafy vegetable used in very small quantities for their distinct aroma due to the presence of essential oil and their ability to enhance the digestion. Essential oil of mint are extensively in toiletry, food and pharmaceutical industries due to its aromatic, stimulant and carminative nature. Its leaves are widely used for oil extraction, flavoring soups, sauces, beverages and in chutneys and for ayurvedic and unani medicines. It is small perennial herb a being grown as garden herb and cultivated extensively for food seasoning and household remedy. Mint is a shallow rooted plant and requires loose textured soil for easy penetration. It grows well in full sun light to partial shade and prefers well moist soil for its growth and development

Good container management and media composition are basic concept for the sufficient and quality yield. Good growing medium structure must be soft and porous enough for easy root penetration into medium and it able to provide nutrition, anchorage and support for the plant (Utobo *et al*., 2015). Different raw materials used for prepare the growing medium to achieve the correct balance of air and water holding capacity for plants to well growth and long term stability of medium (Bilderback *et al*, 2005).There is a need to select good growing medium rather than soil due to its infective nature (Egunjobi and Ekundare, 1981).

Many techniques are introduced to farmers with the aim of increasing production while considering suitable rooting media. In Sri Lanka, there are several studies conducted regarding mint propagation but very few is related to selection of media and size of the cuttings. None of the study was done in Northern part of Sri Lanka. By considering this gap, this present study was conducted to evaluate the effect of different rooting media and cuttings lengths on growth and yield performance of mint. The specified objective are,

1) To find the suitable medium for mint growing and its multiplication.
2) To identify the suitable length of mint cutting for yield optimization.

Material and Methods

The experiment was carried out at Faculty of Agriculture, Ariviyal Nagar, Kilinochchi during the period of January to May 2019 to evaluate the suitability of

different media and length of cuttings on growth and yield of mint (*Mentha* spp) in two factor factorial complete randomized design (CRD) with five replicates. In this experiment six rooting media and four length of cuttings were used as treatment combinations (Table 1). The rooting media was mixed in 1:1 ratio. According to the Rajeswara rao *et al*., 2001, the 9 cm cutting was used as control.

Table 1: Treatment Combinations of Different Rooting Media and Length of Cuttings

Treatments	**6 cm(L_1)**	**9 cm(L_2)**	**12 cm(L_3)**	**15 cm(L_4)**
Cattle manure + Top soil (M_1)	M_1L_1	M_1L_2	M_1L_3	M_1L_4
Compost + Top soil (M_2)	M_2L_1	M_2L_2	M_2L_3	M_2L_4
Coir dust+ Top soil (M_3)	M_3L_1	M_3L_2	M_3L_3	M_3L_4
Partially burnt paddy husk+Top soil (M_4)	M_4L_1	M_4L_2	M_4L_3	M_4L_4
Goat manure + Top soil (M_5)	M_5L_1	M_5L_2	M_5L_3	M_5L_4
Top soil (M_6)	M_6L_1	M_6L_2	M_6L_3	M_6L_4

Good quality planting materials were selected from Cargill's mint suppliers. The good quality reverse osmosis (RO) water was used for rooting for 7 days. Cattle manure, compost, coir dust, partially burnt paddy husk, goat manure was used for preparation with top soil in 1:1 ratio and treated with fungicide. Then media were cover by black polythene and incubated for 7 days. After 7 days pots were filled with media .Two cuttings were planted in each pot with the spacing of 10 cm. 50 % shade was provided to the plants. Pots were arranged in the spacing of 30 cm × 30 cm (Plate 1).

Plate1: Arrangement of Pots

Management practices were performed according to the farmer practices. Harvesting was done 60 days after planting in the pots, when the leaves reached proper maturity Growth parameters such as plant height, number of branches per plant, leaf area, shoot and root length, yield parameters such as fresh weight of shoot and root, and and quality parameter, chlorophyll content (SPAD value) were measured in the experiment. The ANOVA was performed by using the SAS 9.1 computer software package. Mean separation was done using Duncan's Multiple Range Test at p=0.05 level.

Results and Discussion

Growth Parameters

Plant Height

There is an interaction effect between rooting media and length of cuttings on plant height. Plant height was significantly differed between the rooting media and length of cutting (Figure 1).The highest height of 42.88 cm was recorded in 15 cm length of cutting (L_4) planted in the goat manure containing medium (M_5) and the lowest height of 17.26 cm was recorded in 6 cm length of cutting (L_1) planted in coir dust containing medium (M_3) on 8th week after planting .

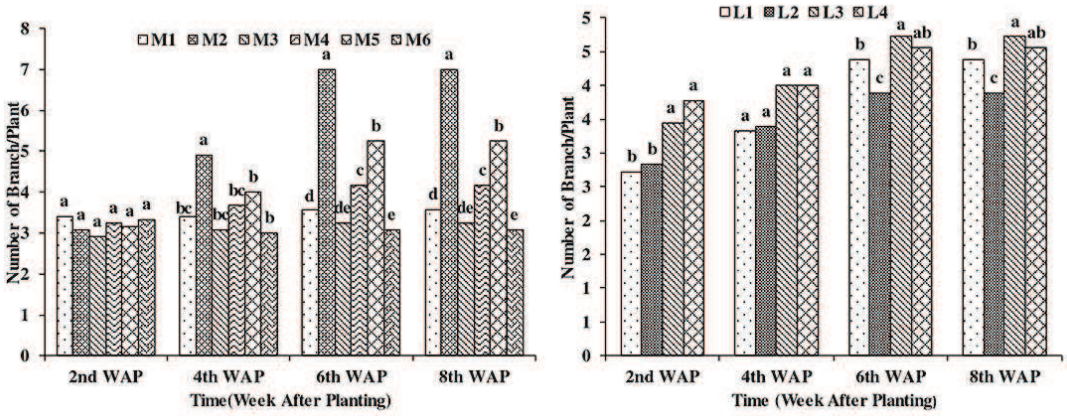


Figure 1: Average plant height of mint in different rooting media and length of cutting at two weeks interval. Means with the same letter within a given treatments are not significantly different at *p*=0.05.

Among the treatment combinations, 15 cm length of cutting (L_4) planted in the goat manure containing medium (M_5) was the best. Growth and yield parameters of amaranthus such as plant height, number of leaves, stem girth, marketable yield increased with level of goat manure (Akanni and Ojeniyi,2008). Kaymak *et al*, (2008) stated 15 and 20 cm cuttings showed better performance than the other treatments in mint.

Number of Leaves

The interaction between rooting media and length of cuttings on number of

leaves was significant (Figure 2). The maximum leaves number (238) was obtained in 15 cm length of cutting (L_4) planted in the compost containing media (M_2) and minimum (14) was obtained in 6 cm length of cutting (L_1) planted in coir dust containing media (M_3) on the 8th week after planting. Among the treatment combinations, 15cm length of cutting (L_4) planted in the compost containing media (M_2) was the best. Sanni, (2016) reported plant height, stem girth, number of leaves and leaf length were high in application of compost to *A.hybridus*.

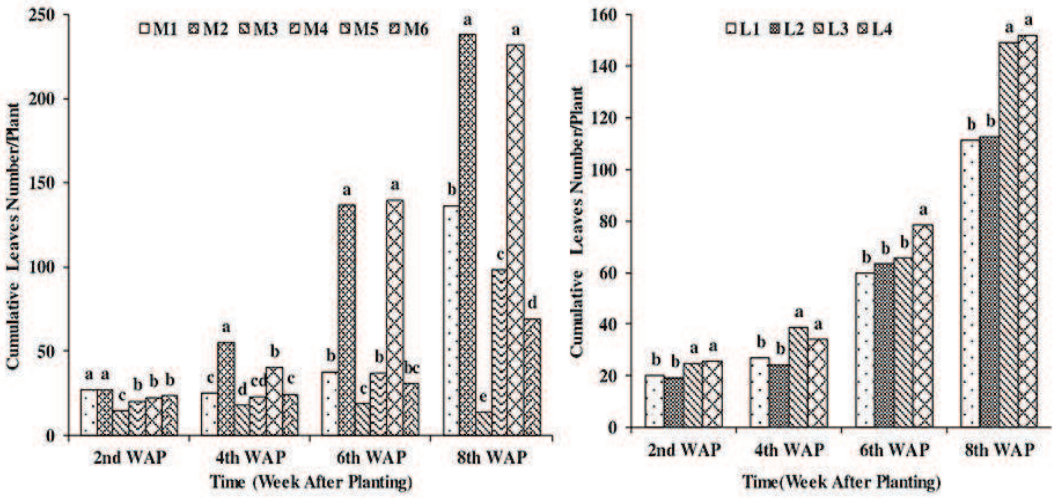


Figure 2: Effect of different rooting media & length of cutting on leaf number at weekly interval. Means with the same letter within a given treatments are not significantly different at p=0.05

Number of Branches

There was an interaction effect between rooting media and length of cuttings on number of branches(Figure 3).Among the treatment combinations, 12cm length of cutting (L_3) planted in the compost containing medium (M_2) was the best. Compare the rooting media and length of cutting the highest number of branches (7) was recorded in 12 cm length of cutting (L_3) planted in the compost containing media (M_2) and lowest (3) was recorded in 9cm length of cutting (L_2) planted in the coir dust containing media (M_3) on 8th week after planting Dada *et al*, (2017) stated application of compost to nutrient deficient soil promoted growth, fresh shoot, and dry matter yield of *A.cruentus*.

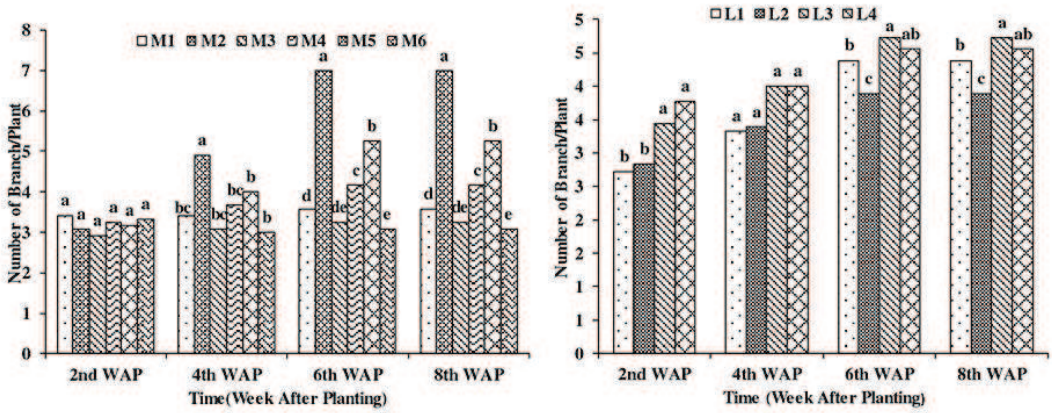


Figure 3: Effect of different rooting media & length of cutting on branch number of mint at biweekly interval. Means with the same letter within a given treatments are not significantly different at p=0.05

Leaf Area

There is an interaction effect between rooting media and length of cuttings on leaf area. Compare the rooting media and length of cutting the highest leaf area (18.87 cm^2) was recorded in 15 cm length of cutting (L_4) planted in the goat manure containing media (M_5) and lowest (3 cm^2) was recorded in 9cm length of cutting (L_2) planted in the coir dust containing media (M_3) on 8th week after planting. Among the treatment combinations, 15cm length of cutting planted (L_4) in the goat manure containing media (M_5) was the best. Odiete *et al.* (1999) had found similar result goat manure significantly improved growth and yield of okra, Amaranthus, celosia and maize in south west Nigeria.

Length of Root

There was an interaction effect between rooting media and length of cuttings on root length. Compare the rooting media and length of cutting, the maximum length of 31.18 cm was recorded in 9 cm length of cutting (L_2) planted in the compost containing media (M_2) and lowest length of 15.55 cm was recorded in 12 cm length of cutting (L_3) planted in the coir dust containing media (M_3).

Length of Shoot

There was an interaction effect between rooting media and length of cuttings on shoot length. There was significant difference among the media. Compare the rooting media, the maximum shoot length (46.75 cm) was recorded in 15 cm length of cutting (L_4) planted in the goat manure containing medium (M_5) and lowest (14.75 cm) was recorded in 6 cm length of cutting (L_1) planted in the coir dust containing medium (M_3).

In the study of Leif Marvin *et al.* (2015) revealed used of goat manure as raw material for compost was greatly influenced on fresh weight of leafy vegetable. According to the study of Awodun *et al*. (2007) that, goat manure was quite high in organic matter and had more N than K, Ca and Mg.

Fresh Weight of Shoot

There is an interaction effect between rooting media and length of cuttings(Figure 4).

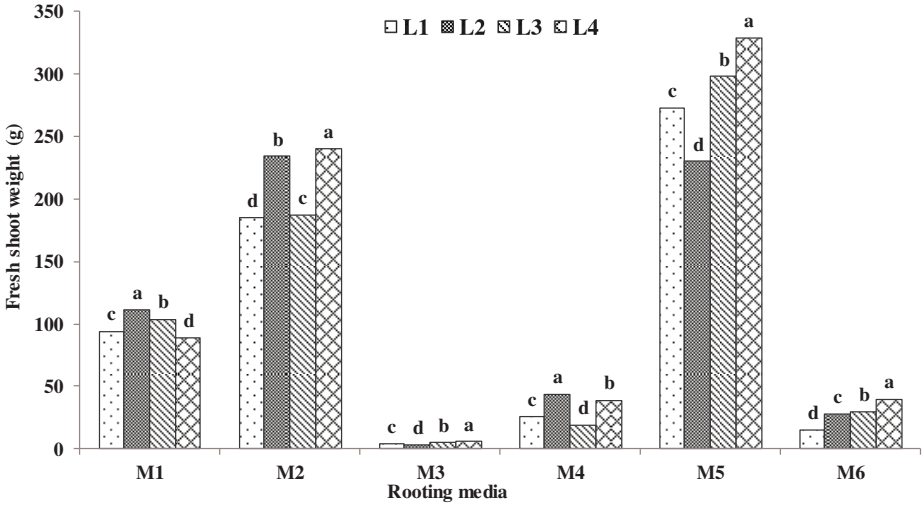


Figure 4: Effect of different rooting media on fresh weight of shoot for different length of cuttings. Means with the same letter within a given treatments are not significantly different at p=0.05

Compare the rooting media and length of cuttings, the highest fresh weight of shoot (286.42 g) was recorded in 15 cm length of cutting (L_4) planted in the goat manure containing medium (M_5) and lowest (6.17 g) was recorded in 6 cm length of cutting (L_3) planted in the coir dust containing medium (M_3). Among the treatment combinations, 15 cm length of cutting (L_4) planted in the goat manure (M_5) containing medium was the best. Seeiso and Materechera (2012) stated both cattle manure and goat manure improve growth and biomass yield of African indigenous leafy vegetables but the effect of goat manure was superior to that of cattle manure. Kaymak *et al.* (2008) reported 15 and 20 cm cuttings were showed better performance in mint growth.

Fresh Weight of Root

There is an interaction effect between rooting media and length of cutting in fresh weight of root(Figure 5). Compare the rooting media and length of cutting, the highest fresh weight of root (97.33 g) was recorded in 15 cm length of cutting (L_4) planted in compost containing

medium (M_2) and lowest (1.75 g) was recorded in 6cm length of cutting (L_1) planted in the coir dust containing medium (M_3). Among the treatment combinations, 15cm length of cutting planted in the compost containing media was the

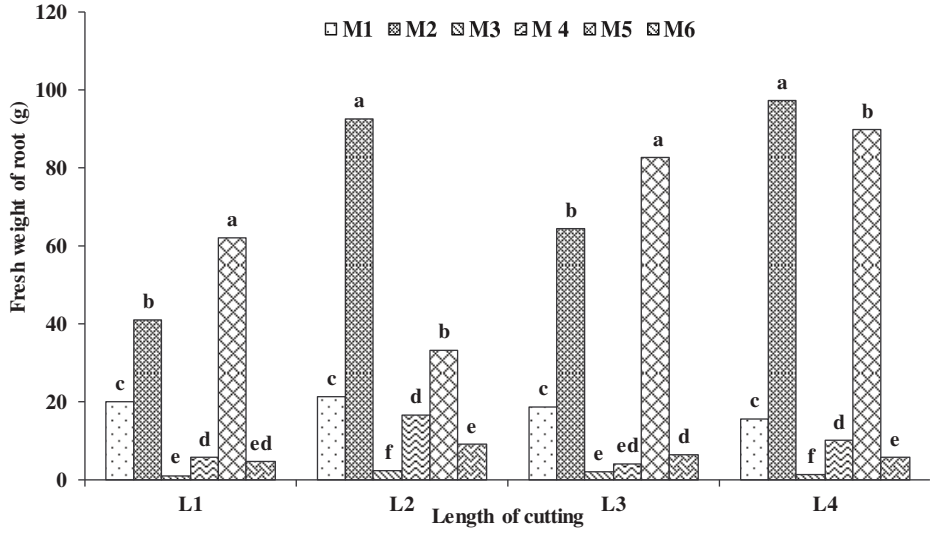


Figure 5: Effect of different length of cutting on fresh weight of root. Means with the same letter within a given treatments are not significantly different at p=0.05.

Number of Stolon

There is an interaction effect between rooting media and length of cuttings in number of stolon (Figure 6). Compare the rooting media and length of cutting the highest number of stolon (5) was recorded in 9 cm length of cutting (L_2) planted in goat manure containing media (M_5) and lowest (1.16) was recorded in 12 cm length of cutting (L_3) planted in the coir dust containing media (M_3).

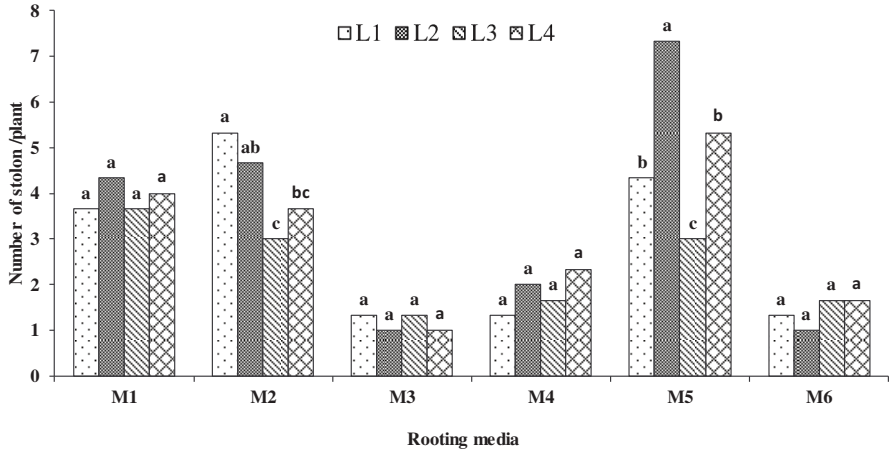


Figure 6: Effect of different rooting media on number of stolons. Means with the same letter within a given treatments are not significantly different at p=0.05

Quality Parameter

Chlorophyll Content

It was significantly differed between the rooting media. Compare the rooting media, the highest chlorophyll content (42.5 SPAD value) was recorded in compost containing medium (M_2).The highest chlorophyll content (37.16 SPAD value) was recorded in 15 cm length of cutting (L_4) on 7th week after planting. Among the treatment combinations, 15cm length of cutting planted in the compost containing media was the best. Akhtar *et al.* (2010) had reported linear relationship between quality of constituents of compost and vegetative development and nutrient uptake in lettuce and *Amaranthus*. Similarly, superior chlorophyll content recorded in compost suggests abundance synthesis by the leaves and other tissue resulting from nutrient supply and other precursors of chlorophyll.

Conclusions

Growth and yield performance of mint grown in pots were affected by the composition of rooting media and length of cuttings. It can be concluded that 15 cm length of cutting planted in the goat manure containing medium could be recommended as suitable length of cuttings and medium for obtaining quality and high yield in mint.

Suggestions

Carry out the research with the length of cutting should be more than 15 cm.Future research can be conduct in alternative media.

References

Akanni, D.I. and Ojeniyi, S.O. 2008. Residual Effect of Goat and Poultry Manures on Soil Properties Nutrient Content and Yield of Amanranthus in Southwest Nigeria. *Research Journal of Agronomy.* 2 (2):44-47.

Akhtar, J.M., Young, I., Irvine, R.J. and Sturrock, C. 2010 Assessing nitrogen supply potential and influence on growth of lettuce and amaranthus of different aged composts. Pak. J. Bot 42(1):527–536

Awodun, M.A., Omonijo, L.I. and Ojeniyi, S.O. 2007. Effect of Goat Dung and NPK Fertilizer on Soil and Leaf Nutrient Content, Growth and Yield of Pepper. International Journal of Soil Science, 2: 142-147.

Bilderback, T.E., Warren, S.L., Owen, J.J.S. and Albano, J.P. 2005. Healthy substrates need physicals too. Hort Technology. 15: 747-751.

Dada, O. A., Imade, F. and Anifowose, E. M. 2017. Growth and proximate composition of *Amaranthus cruentus* L. on poor soil amended with compost and arbuscular mycorrhiza fungi, International Journal of Recycling of Organic Waste in Agriculture. Springer Berlin Heidelberg, 6(3) : 195–202.

Egunjobi, O.A. and Ekundare, O.O. 1981. The cassava peeling as a soil amendment and its effects on maize yield in soil infested with *Pratylenchus bractyams*. Nig J Plant Prod 5 : 80-87.

Karicheri, R. and Antony, B. 2016. Antibacterial and Antibiofilm Activities of Peppermint (*Mentha piperita* Linn) and Menthol Mint (*Mentha arvensis* Linn) Essential Oils on Aggregatibacter Actinomycetemcomitans Isolated From Orodental Infections, European Journal of pharmaceutical and Medical Reasearch, 3 (7), pp. 37.

Karicheri, R. and Antony, B. 2016. Antibacterial and Antibiofilm Activities of Peppermint (*Mentha piperita* Linn) and Menthol Mint (*Mentha arvensis* Linn) Essential Oils on Aggregatibacter Actinomycetemcomitans Isolated From Orodental Infections, European Journal of pharmaceutical and Medical Reasearch, 3(7), pp. 37.

Kaymak, H.C., Yarali1, F., Guvenc, I. and Figen Donmez, M. 2008. The effect of inoculation with plant growth rhizobacteria (PGPR) on root formation of mint (*Mentha piperita* L.) cuttings African Journal of Biotechnology 7(24):4479-4483.

Odiete, I., Ojeniyi, S.O., Akinola, O.M. and Achor, A.A. 1999. Effect of goat dung on soil chemical composition and yield components of okra, amaranthus and maize. Proceedings of the 25th Conference of Soil Science Society of Nigeria, November 21-25, 1999, Benin, pp: 174-184.

Rajeswara Rao, B.R, Kaul, P.N., Syamasundar, K.V. and Ramesh, S. 2002. Water soluble fractions of rose-scented geranium *(Pelargonium* species) essential oil. Bioresource Technology 84: 243-246.

Sanni, K.O. 2016. Effect of compost, cow dung and NPK 15-15-15 fertilizer on growth and yield performance of Amaranth *(Amaranthus hybridus)*. International Journal of Advances in Scientific Research Volume 2(03): 076-082.

Seeiso, M.T. and Materechera, S.A. 2012. Yield Response of the African Indigenous Leafy Vegetable Cleome gynandra to applocation of Cattle and Goat Kraal Manure and Harvesting Techniques. J.Food Agric Environ,10,789 -794.

Journal of Dry Zone Agriculture, 2020, 6 (2): 60 - 67

ISSN 2012 – 8673

Prebiotic Potential of Resistant Starches and Dietary Fibers of Sri Lankan Traditional Rice Varieties and its Application in the Food Industry

Hettige, K.D.T., Jayarathna, G.E.D.A.M. and Wijewardane, R.M.N.A.
National Institute of Post-Harvest Management, Jayanthi Mawatha, Anuradhapura, Sri Lanka

Abstract: This study was conducted to investigate the prebiotic potential of selected traditional rice varieties by inoculating with probiotic bacterium *Lactobacillus plantarum.* Five traditional rice varieties; *Suwandel, Pachchaperumal, Kaluheenati, Kuruluthuda* and *Madathawalu* as treatments and *BG-358* as control, were used in flour form. Dietary fiber (DF) and resistant starch (RS) content of selected varieties were measured according to AOAC method 2009.01, 2011.25 and 2002.02. Modified culture media was prepared by combining *MRS* agar with rice flour in 4:1 ratio and *L.plantarum* was inoculated while inhibiting other bacterial growth using *ciprofloxacin.* Colony forming units (CFU) and prebiotic activity score (PAS) was calculated by inoculating *L. plantarum* as the probiotic and *Escherichia coli* was used as enteric bacteria. Rice idli mix was developed by using two rice varieties with highest PAS value and the best product was determined by a sensory evaluation with twenty five semi-trained panelists. According to the results of DF, RS, CFU and PAS evaluation, all traditional varieties were significantly higher ($p<0.05$) compared to control variety. *Kaluheenati* possesses significantly ($p<0.05$) the highest value of 6.97±0.03% and 2.53 ± 0.02% for DF and RS respectively. CFU were varied from 1.87 ± 0.04×10^7 to 2.58 ± 0.05 $\times 10^7$ and highest CFUs were reported in *Kaluheenati*. PAS was varied from 1.23 ± 0.01 to 1.46±0.02 and *Kaluheenati* was reported significantly higher ($p<0.05$) score compared to other traditional varieties. Best idli mix was combination of *kaluheenati* and *suwandel* in 1:1 ratio. The results revealed that *kaluheenati* has the highest DF, RS and higher PAS reflects traditional varieties have higher prebiotic potential.

***Keywords*:** Dietary fiber, Prebiotics, Probiotics, Resistant starch, Traditional rice

Corresponding Author: K.D.T.Hettige, kasun.hettige@gmail.com

Introduction

In Sri Lanka, nearly 2000 traditional rice varieties were cultivated in past (Rambu kwella and Priyankara, 2016) and nowadays in the market, we can see some of main traditional rice varieties such as "*suwandel*", "*kaluheenati*" *etc*. Today they have very high demand because of their organic cultivated nature, nutritive and medicinal value (Dharmasena, 2010). But cultivation is limited and also there is lack of investigation of their physio-chemical properties such as resistant starch content, the fermentation characteristics and the prebiotic potential of their dietary fiber fraction.

Resistant starch (RS) is the starch that escapes human small intestine digestion. It can be delivered to the lower gut for further microbial anaerobic fermentation (Topping *et al*., 2003).

Fermentation of RS and Dietary fiber (DF) by lower gut micro biota is one of the most important aspects to maintaining colon health. The human large intestine is heavily populated by numerous and diverse species of microorganism, which forming a complex micro flora community (Thursby and Juge, 2017). Colonic micro flora plays an important role in host health by maintaining the proper intestinal function, including development of immune system, inhibit the growth of pathogen and regulate metabolic pathway in the host (Mishra and Mishra, 2018).

Prebiotics are described as the indigestible carbohydrate which can improve a balanced intestinal micro flora, once administered orally as a food supplement. A prebiotic ingredient should resist towards the digestions in the upper gastrointestinal tract and be selectively fermented by intestinal micro flora associated with beneficial effects (Marko wiak and Slizewska, 2017). Traditional rice varieties can act as a vehicle to supply the fibers to human and there is a possibility of having a prebiotic potential of their fiber fraction. They are low in glycemic value and therefore can be recommend for the diabetic mellitus type 2 patients (Samaranayake *et al*., 2018).

The general aim of this study is to determine the prebiotic potential of resistant starches and dietary fibers of traditional rice varieties in Sri Lanka by calculating their prebiotic activity score.

Materials and Methods

In this research, used five traditional rice varieties; *Suwandel*, *Kaluheenati*, *Pachchaperumal*, *Kurulu thuda* and *Madathawalu*. Commercially cultivating *BG-358 samba* rice variety was selected as control. Each variety was purchased from Rice Research and Development Institute (RRDI) Sri Lanka.

Dietary fibers and resistant starches of traditional rice varieties were determined in the laboratory of National Institute of Post-Harvest Management (NIPHM) Sri

Lanka. Rice flour of the selected varieties was assessed for dietary fiber and resistant starch content. All samples were prepared in four replicates and the compositions were calculated as dry matter basis. Dietary fiber analysis was conducted according to the AOAC method 2009.01, 2011.25 and 2002.02 using the "*Megazyme* integrated total dietary fiber assay kit" (Bray, Ireland) and resistant starch analysis was conducted according to the AOAC method 2002.02 using the "*Megazyme* resistant starch assay kit" (Bray, Ireland).

The probiotic and prebiotic activities were conducted in the food microbiology laboratory of NIPHM. *Lactobacillus plantarum* was selected as the probiotic bacterium and use "*plantarum* probiotic culture" from "Green Living Australia" as the *L. plantarum* culture. Fermentation medium was prepared by combining De Man, Rogosa and Sharpe (MRS) agar with the flour of rice varieties. *Ciprofloxacin* antibiotic was used to selectively grow *L. plantarum* and inhibit the growth of other lactic acid bacteria based on the resistance of the *L. plantarum* to *ciprofloxacin* and its ability to produce acid from sorbitol (Bujalance *et al*., 2006). The modified medium was prepared by incorporating MRS agar and rice flour in 4:1 ratio. Weight of 60 g of MRS agar and 15 g of rice flour were dissolved in 1 liter of distilled water and added 5 mg of *ciprofloxacin*. Generally using non-prebiotic glucose media was used as the standard control to compare the prebiotic activity. The control medium was prepared using MRS agar and same amount of glucose instead of rice flour. The control and selected five varieties were used as the treatments of the experiment (Table 1).

Table 1: The experimental treatments of traditional rice varieties

Treatment	Fermentation Medium
T1	Standard medium (control)
T2	*Suwandel*
T3	*Kaluheenati*
T4	*Pachchaperumal*
T5	*Kurulu thuda*
T6	*Madathawalu*

Trial and error method was used to find out the exact ingredients of the fermentation medium. The developed mediums were inoculated with *L. plantarum* and incubated in an anaerobic culture jar (Anaerobic System Mark II) for 48 hours and microbial counts were calculated using standard plate count method.

Prebiotic Activity Score (PAS) was calculated by inoculating enteric bacteria, *Escherichia coli,* and compare the growth of *E. coli* with *L. plantarum*, according to the following equation (Fissore *et al*., 2015).

$$\left[\frac{(Probiotic\ log\ cfu/ml\ on\ prebiotic\ at\ 24\ hours - probiotic\ log\ cfu/ml\ on\ prebiotic\ at\ 0\ hours)}{(Probiotic\ log\ cfu/ml\ on\ glucose\ at\ 24\ hours - probiotic\ log\ cfu/ml\ on\ glucose\ at\ 0\ hours)}\right] - \left[\frac{(Enteric\ log\ cfu/ml\ on\ prebiotic\ at\ 24\ hours - enteric\ log\ cfu/ml\ on\ prebiotic\ at\ 0\ hours)}{(Enteric\ log\ cfu/ml\ on\ glucose\ at\ 24\ hours - enteric\ log\ cfu/ml\ on\ glucose\ at\ 0\ hours)}\right]$$

Rice *idli* mix from traditional rice was developed as the application of this study in food industry. The varieties with twohighest PAS values were used to develop rice *idli* mix. Best rice *idli* mix was selected by conducting a sensory evaluation was conducted in 5 point hedonic scale for 25 semi-trained panelists. Three recipes were developed as 100% of 1st variety, 100% of 2nd variety and 50% mix of both varieties. Appearance/ fluffiness, color, aroma, taste, sponginess, mouth feel and overall acceptability were used as the sensory parameters.

The best product selected from sensory analysis was analyzed for dietary fibers, resistant starches, CFUs of *L.plantarum* and PAS values. Steamed form of rice idli was used to analyze above parameters. Parametric data were analyzed using ANOVA in SPSS software and mean comparisons were performed using least significance difference test at $P<0.05$ significance level. Sensory data were analyzed using Friedman non parametric data in SPSS software.

Results and Discussion

All selected rice varieties possess significantly higher amounts of DF and RS compared to control rice variety; *BG 358*. Among them, *Kaluheenati* rice variety possesses significantly ($p<0.05$) the highest value of 6.97±0.03% and 2.53±0.02% for DF and RS respectively (Table 2). Generally red rice varieties have higher DF values because of its remaining outer layers (Abeysekera *et al*., 2017; Savitha and Singh, 2011). In this research, all the selected varieties were red rice varieties except *Suwandel* which possess a low glycemic index (GI) value compared to *BG 358*due to its higher DF and RS values (Hettiarachchi *et al*., 2016).

Colony forming units (CFU) of *L. plantarum* were calculated after 48 hours of anaerobic incubation period. The results of CFUs were indicated per 1 milliliter (ml) hence all rice varieties including the control medium, *BG 358* have higher CFU values more than the minimum therapeutic value of $1x10^6$ CFUs per ml (Ranadheera *et al*., 2012). The control medium, which has no rice flourwasn't consisting with DF or RS content. CFU of control medium was observed as 1.28 x 10^{7*} per 1 ml which is significantly ($p<0.05$) lower than all the other modified mediums developed from rice flour.

Table 2: Dietary fiber, resistant starch, colony forming units and prebiotic activity score values of selected traditional rice varieties

Variety	DF (%)	RS (%)	CFU(10^7)	PAS
BG 358	4.24 ± 0.02[a]	1.33 ± 0.03[a]	1.49 ± 0.03[a]	1.10 ± 0.02[a]
Suwandel	6.32 ± 0.01[b]	2.28 ± 0.01[b]	2.05 ± 0.03[b]	1.34 ± 0.01[b]
Kaluheenati	6.97 ± 0.03[c]	2.53 ± 0.02[c]	2.58 ± 0.05[c]	1.46 ± 0.02[c]
Pachchaperumal	6.71 ± 0.01[d]	2.24 ± 0.03[d]	2.33 ± 0.04[d]	1.32 ± 0.02[b]
Kuruluthuda	6.63 ± 0.02[e]	1.92 ± 0.01[e]	1.87 ± 0.04[e]	1.23 ± 0.01[e]
Madathawalu	6.56 ± 0.02[f]	2.11 ± 0.02[f]	2.06 ± 0.05[f]	1.24 ± 0.02[f]

*Values in the same column with different superscripts differ significantly ($p<0.05$). Each value represents mean ± SD with four replicates.

According to above table (Table 2), all rice varieties possess satisfactory fermentation characteristics with probiotic bacteria *L. plantarum*. CFU values of traditional rice varieties were significantly higher than the control variety *BG 358* (1.49 ± 0.03%) and *Kaluheenati* possess the highest CFU value (2.58 ± 0.05%). This result revealed that traditional varieties possess *L. plantarum* growth enhancing factors more than control variety.

DF and RS values of traditional rice varieties were significantly higher than control variety and it can be the reason for the higher CFU values of traditional varieties compared to control variety (Abeysekera *et al*., 2017). The prebiotic potential should be evaluated to justify whether there is a relationship to increase the CFU values by DF and RS content. Prebiotic activity score (PAS) was calculated to check the prebiotic potential of traditional rice varieties (Zhang *et al*., 2012).

The results of PAS revealed that all varieties including control variety have PAS values more than 1.0 ranging from 1.18 ± 0.02to 1.46 ± 0.02. But traditional varieties have significantly higher PAS compared to control variety (1.18 ± 0.02) and *Kaluheenati* has the significantly highest PAS value (1.46 ± 0.02). The PAS value is exceeding one means all varieties have some extend of prebiotic potential and traditional varieties have significantly higher prebiotic potential compared to control. DF value of *Suwandel* variety was lower than all other traditional varieties, but has higher PAS value due to its high amount of RS. Although RS is a component of DF, buthas much more influence on prebiotic potential than DF.

A B C

Plate 1: Rice *idli* made from traditional rice flour, A: 50% *Kaluheenati* and 50% *Suwandel,* B:100%*Suwandel,* C: 100% *Kaluheenati.*

In rice *idli* development, use top two varie ties of PAS value. Highest value was for *kaluheenati* variety. *Suwandel* and *pach chaperumal* both together possess the second highest value of PAS. In here use *suwandel* variety with *kaluheenati* to develop rice *idli*, because *suwandel* is a white variety and higher consumer accepta bility compared to *pachchaperumal* (Plate 1).

According to the sensory results, best rice *idli* mix was the combination of *Kaluheenati* and *Suwandel* in 1:1 ratio. Color, taste, sponginess and overall acceptability sensory parameters were significantly different while appearance, aroma and mouth feel parameters were significantly not different.

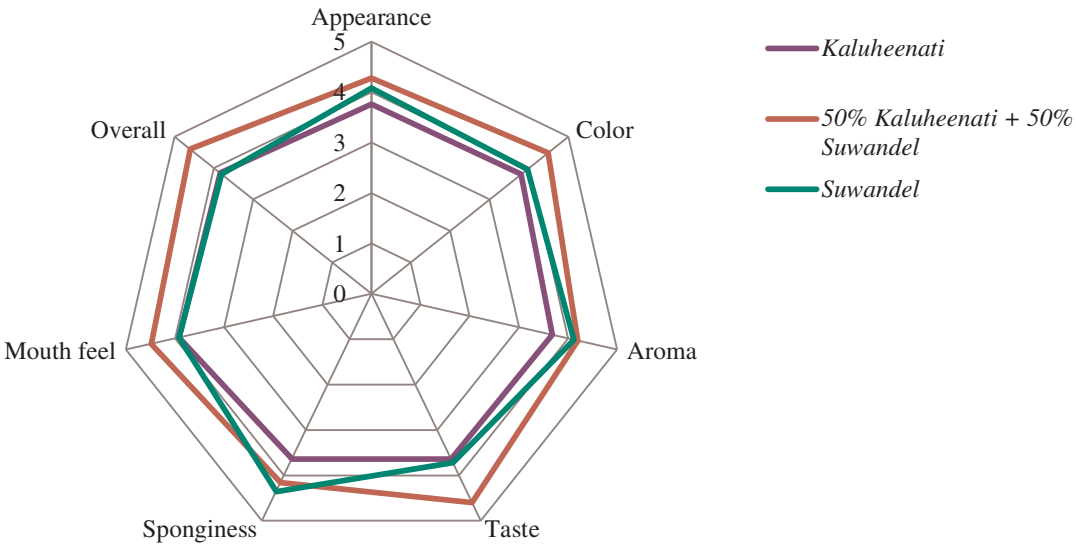


Figure 2: Sensory properties of rice idli made from traditional rice varieties.

The DF, RS, CFUs and PAS values of best rice *idli* mix after cooking were 6.73±0.04, 2.86±0.05, $3.02x10^7$ and 1.58±0.03 respectively. There was no any huge difference in DF content of cooked *idli* compared to raw rice flour. RS value drastically increased after cooking due to increase RS type 3 and type 5 (Ordonio and Matsuoka, 2016). Therefore CFU and PAS values also increased in cooked form compared to raw rice flour. Consuming rice *idli* mix after cooking provide considerable amounts of DF and RS and it provide good prebiotic source for the healthy gut micro flora in the host. Prebiotics enhance the growth and development of probiotics and it make a hostile environment to the pathogenic bacteria in the host's gut(Markowiak and Slizewska, 2017). Also consumption of higher DF and RS good for diabetes mellitus type 2 patients (Samaranayake *et al*., 2018).

Conclusion

According to the results of the study, the selected traditional varieties possess significantly higher amounts of DF and RS compared to newly improved and commercially cultivated varieties such as *BG 358*. High amount of DF and RS is good for diabetes mellitus type two patients due to its low GI value. The prebiotic activity score also significantly higher in traditional varieties compared to commercially cultivated varieties. Higher PAS reflects higher prebiotic potential in traditional varieties. RS has more influence on prebiotic potential compared to DF and higher RS containing varieties indicate higher prebiotic potential. *Kaluheenati* is the best traditional variety among other varietiesbecause of its highest DF, RS and PAS. Therefore, consuming traditional rice varieties gives health benefits towards consumer by providing prebiotics which enhance the growth and development of beneficial bacterial flora such as probiotics living in the human gut. Further *in vivo* study is required to evaluate extend of prebiotics in traditional rice to stimulate the growth of probiotic micro flora living in human gut ecosystem. The health benefits of traditional rice could be provided to the consumer by applying developed food products to the food industry.

References

Abeysekera, W.K.S.M., Arachchige, S.P.G., Ratnasooriya, W.D., Chandrase kharan, N.V. and Bentota, A.P. 2017. Physicochemical and nutritional properties of twenty three traditional rice (*Oryza sativa L.*) varieties of Sri Lanka. *J Coast Life Med*, 5:343-349.

Bujalance, C., Jiménez-Valera, M., Moreno, E. and Ruiz-Bravo, A. 2006. A selective differential medium for *Lactobacillus plantarum*. *Journal of Microbiological Methods*, 66(3):572-575.

Dharmasena, P.B. 2010.Traditional rice farming in Sri Lanka. Economic Review, 36(1&2):48-53.

Fissore, E.N., Santo Domingo, C., Gerschenson, L.N. and Giannuzzi, L. 2015. A study of the effect of dietary fiber fractions obtained from artichoke (*Cynara cardunculus* L. *var. scolymus*) on the growth of intestinal bacteria associated with health. Food & Function, 6(5):1667-1674.

Hettiarachchi, H.A.P.W., Ribeira, S.P., Prasantha, B.D.R. and Wickramasinghe, H.A.M. 2016. Diversity of physical and cooking quality characters of selected traditional and improved rice varieties in Sri Lanka. *Sri Lankan Journal of Biology*, 1(1):15-26.

Markowiak, P., and Śliżewska, K. 2017. Effects of Probiotics, Prebiotics, and Synbiotics on Human Health. Nutrients, 9(9):1021.

Mishra, P. and Mishra, S. K. 2018. Role of Microbial Flora and Probiotics in Host Immune Homeostasis. *Journal of Applied Pharmaceutical Science*, 8(10):136-149.

Ordonio, R. L. and Matsuoka, M. 2016. Increasing resistant starch content in rice for better consumer health. Proceedings of the National Academy of Sciences of the United States of America, 113(45): 12616–12618.

Rambukwella, R. and Priyankara, E.A.C. 2016. Production and Marketing of Traditional Rice Varieties in Selected Districts in Sri Lanka: Present Status and Future Prospects. Hector Kobbekaduwa Agrarian Research and Training Institute, 7-12.

Ranadheera, C.S., Evans, C.A., Adams, M.C. and Baines, S.K. 2012. Probiotic viability and physico-chemical and sensory properties of plain and stirred fruit yogurts made from goat's milk. Food Chemistry, 135(3):1411-1418.

Samaranayake, M.D.W., Abeysekera, W.K.S.M. and Ratnasooriya, W.D. 2018. Physicochemical and nutritional properties of long grain rice varieties of Sri Lanka. *Research Journal of Chemical*, 8(5):29-35.

Savitha, Y.S. and Singh, V. 2011. Status of dietary fiber contents in pigmented and non-pigmented rice varieties before and after parboiling. LWT-Food Science and Technology, 44(10):2180-2184.

Thursby, E. and Juge, N. 2017. Introdu ction to the human gut microbiota. *The Biochemical journal*, 474(11):1823–1836.

Topping, D.L., Fukushima, M. and Bird, A.R., 2003. Resistant starch as a prebiotic and symbiotic: state of the art. Proceedings of the Nutrition Society, 62(1):171-176.

Zhang, S., Hu, H., Wang, L., Liu, F. and Pan, S. 2018. Preparation and prebiotic potential of pectin oligosaccharides obtained from citrus peel pectin. Food chemistry, 244**:**232-237.

Journal of Dry Zone Agriculture, 2020, 6 (2): 68 - 78

ISSN 2012 – 8673

Analytical Method to Determine the Migrated Polymers from Edible Oils Adulterated with Polyethylene Terephthalate to Deep Fried Cassava Chips

Weerasinghe, T.M.A.N[1], Gunawardhane, C.R.[1], Jayathunge, K.G.L.R.[2], Thilakarathna, H.R.M.G.C.[3]

[1] National Institute of Post-Harvest Management, Anuradhapura, Sri Lanka

[2] Department of Biosystem Technology, Faculty of Technology, University of Sri Jayawardhanapura, Sri Lanka

[3] Department of Animal Science and Food Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka

Abstract: Non-branded deep fried manioc chips were evaluated by following a newly developed and validated method to determine the migration of Terephthalic acid (TPA) and Isophthalic acid (IPA) from the frying oils adulterated with pet bottles to make the snacks crisp and long last. Reporting method is comprised with soxhlet extraction of oils from deep fried manioc chip samples, solvent extraction of TPA and IPA using centrifuged oil samples, sample preparation for High Performance Liquid Chromatography (HPLC) injection and HPLC analysis of samples along with the Terephthalic and Isopthalic acid standard series. The percentage recovery range for TPA and IPA was in between 80-120% for manioc chip samples fried in edible oils incorporated with PET bottles. The results showed that the specific migration of TPA and IPA into the manioc chip samples conform to European Union legislation that identifies specific migration limits (SML). The intra day assays for TPA and IPA were expressed as Relative Standard Deviation (RSD) 5.123% and 2.015% respectively while inter-day precision assays for TPA and IPA were expressed as relative standard deviation (RSD) 2.089% and 2.105% respectively. Results highlighted that the data is tightly clustered around the mean with a good precision. Analytical curves for TPA and IPA were found to be linear over a wide concentration range (6ppb – 120ppb) with a correlation coefficient of 0.998 for TPA and 0.999 for IPA. The lower limit of quantification was determined to be 6 ppb, with a relative standard deviation lower than 10%. TPA and IPA in sample are well separated from each other and from the background oil. The study shows that the method presented in the methodology can be used as a suitable method for analytical determination of Terephtahlic acid and Isophthalic acid in deep fried crispy snacks like manioc chips with high precision and accuracy.

Keywords: Edible oils, Manioc chips, Isophthalic acid, Migration, Terphthalic acid

Corresponding Author: T.M.A.N.Weerasinghe, tmamandanw@yahoo.com

Introduction

Application of plastics in food packaging has largely increased during the last decades because of their availability and the enormous variety of these materials. In the last few decades, the simple long-chain polymer, polyethylene terephthalate (PET) has become one of the most common packaging polymers. Polyethylene terephthalate (PET) is a plastic material that has found increasing applications within the packaging field. It is a simple long-chain polymer, and its chemical inertness together with its physical properties has made it particularly suitable for food packaging applications. PET is a long-chain polymer that belongs to the generic family of polyesters (Brody and Marsh, 1997). PET has become a packaging material for many food products, particularly beverages. Being an inert material with good physical properties and glass-like transparency makes PET a good option for water packaging. Food Packaging is a rapidly evolving field. Besides keeping foods safe from contamination and retaining the nutritional properties and sensory characteristics of foods, packaging provides additional features that are important to consumers. Potential influence of these substances on product safety and quality remains in question as migrated compounds exceed the Maximum Allowable Limits in foods. Monomers and additives used in packaging materials are safety concern as they can be migrated from the package into food, creating hazardous conditions. The toxicity effects of isophthalic acid (IPA) and terephthalic acid, the migrants from PET packaging into foods has been demonstrated by many investigations. The EFSA fixed levels of Isophthalic acid (IPA) and Terephthalic acid (TPA) migration into foods from plastics of 5 and 7.5 mg kg^{-1} of food, respectively (Regulation 2011/10/EU).

Incorporation of PET bottles to edible oils which are being using for deep frying of crispy Snacks has become a strategy for crispy snack manufacturers to make the snacks crisper and long last. The tendency of monomer and oligomer migration increases when a plastic is exposed to high temperatures during thermal processing. Thus, Long term consumption of foods comprised with plastic migrant results mutations in cell structures which drives towards occurring of cancers in human bodies.

Hence, the objective of this experiment was to develop and validate an accurate method to quantify the migration of TPA and IPA from PET bottles to edible oils during deep frying of manioc chips and the quantification of TPA and IPA contamination in locally available non branded crispy snack samples in order to ensure the safety of consumption.

Materials and Methods

Experimental Location

Experiments were conducted at the

laboratories of National Institute of Post-Harvest Management, Anuradhapura.

Sample Preparation and Experimental Treatments

Commercially available deep fried manioc chip samples were purchased from the retail shops distributed island wide. The special focus was to collect non-branded deep fried manioc chip samples from small scale sellers/ manufacturers. Special attention was given to small scale sellers and manufactures because they have very limited access for the food safety and food sanitation measures as well as regulations imposed on food manufacturing and selling in order to ensure consumer safety. One hundred and fifty Small scale manufactured non branded deep fried manioc chip samples were drawn island wide and prepared thirty composite samples by mixing them. Analytical standards of TPA and IPA were purchased from Sigma Aldrich, USA. HPLC gradient-grade water, acetonitrile, and methanol (HPLC grade) solvents were purchased from Sigma Aldrich, USA. In this study method development and validation for analytical determination of migration of terephthalic acid and isophthalic acid into deep fried manioc chips have being conducted.

Instrumentation and Chromatographic Conditions

The method was performed on a HPLC system (Ultimate 3000, Thermo scientific, Germany) equipped with an Agilent G1311A quaternary pump and Agilent G1315A diode array detector. The determinations were performed with UV-Vis detector set at 242nm. The column was a Knauer C18 AQ column (250 mm, 5 µm particle diameter and 4.6 mm internal diameter). The column temperature was kept at 30 °C using an Agilent G1316A oven. The two mobile phases used for gradient HPLC elution were (A) H_2O buffered with 0.1 trifluoroacetic acid/acetonitrile (90:10, v/v) and (B) H_2O buffered with 0.1 trifluoroacetic acid/ acetonitrile (60:40, v/v) with the following proportions: A–B 90–10, 83–17, 75–25 and 60–40 at 0, 3, 6 and 12 min, respectively. The mobile phases were filtered through a 0.45 µm millipore membrane filter (model-FN 2545) and degassed with helium for 15 minutes before use. The flow rate was 1mLmin^{-1} and the volume of injection was 10µL (Khaneghah *et al*., 2013).

Standards and Calibration Curves

A mixed stock standard solution of 1000 ngmL^{-1} was prepared from TPA and IPA that were dissolved in methanol and was stored in the dark at refrigerator temperature (4 °C). Calibration standard solution series was prepared on the day of use at concentrations of 6, 12, 24, 60 and 120 ngmL^{-1} and calibration graphs were plotted using these concentrations of standard solutions.

The detection limit was defined as the concentration corresponding to a peak

height three times the baseline noise level. Recovery studies were carried out by spiking selected samples of oils with the blended standard solution (mix of TPA and IPA) at three concentrations (240, 750 and 1000 μg kg^{-1}). The spiked samples, as well as the controls, were analysed in triplicate experiments. Recovery rates (percent) were calculated by comparing peak area in the chromatogram with the peak area calculated from the standard calibration curves.

Oil Extraction from Manioc Chip Samples

Thirty homogeneous, composite samples were prepared from one hundred and fifty manioc chip samples drawn from island wide in order to reduce the time consumption of the procedure. Three replicates of each composite sample were analysed. Soxhlet Extractor was used for oil extraction with petroleum ether as the solvent and each sample was kept for 5 hours for oil extraction.

Extraction of Migrated Compounds

A mixture of methanol (1 mL), chloroform (3 mL) and NaOH (1 mL) was used for the extraction of migrated monomers from 1 g of oil sample. Centrifugation was done in order to extract migrated monomers into oils. After centrifugation (Hermle.Z326K Laborteknik GmbH, Germany) at 6000 rpm and at −3 °C for 20 min, the separated samples were analysed by HPLC.

Statistical Analysis

Statistical analysis was done with SPSS version 16.0 (SPSS Inc., Chicago, IL, USA) and Minitab version 16 (Minitab Inc., State College, PA, USA). The standard calibration curves were plotted using Excel 2016 (Microsoft, USA). The significance level was $P<0.05$.

Method Validation

Validation of an analytical procedure is to demonstrate that it is suitable for its intended purpose. Validation is a formal and systematic way to demonstrate suitability of the method to provide useful data to ensure that the process or the method gives satisfactory and consistent results within the scope of the process. The analytical methods refer to the way of performing the analysis. Linearity, accuracy, precision, limit of quantification and specificity were measured in order to validate the method.

Results and Discussion

Terephthalic acid and isophthalic acid are the two common migratable monomers in polyethylene terephthalate (PET). If the manioc chips are adulterated with PET bottles these two compounds should be detected during the experiments. In this study, a HPLC method for quantitative analysis of terephthalic acid (TPA) and isophthalic acid (IPA) in deep fried manioc chips was developed and validated. Simultaneous analysis of all island samples was done by using the validated method.

Accuracy

Accuracy can be expressed as the percent recovery of known amounts of TPA and IPA, added to a sample and it is one of the most important parameters of an analytical methodology. The recoveries were determined by adding known amounts of the TPA and IPA reference substances (6 ppb, 24 ppb and 120 ppb) to the oil sample which is previously tested for zero levels of TPA and IPA. The results presented in the following table (Table 1) refer to the average of triplicates for each concentration. Since the percentage recoveries remain in between 80 - 120% for each concentration, it can be concluded that the results are in good agreement with acceptable values for the validation of an analytical procedure (Britain, 1998).

Table 1: Analytical recovery of TPA and IPA mixed standard solution added to sample

Amount Added (ppb)	Recovery			
	TPA		IPA	
	ppb	Percentage	ppb	Percentage
6.00	4.744 ± 0.069	81.843 ± 1.469	5.142 ± 0.1671	85.7 ± 1.768
24.00	22.138 ± 0.1714	92.250 ± 0.703	22.998 ± 0.804	95.825 ± 0.983
120.00	112.04 ± 0.4514	93.372 ± 0.376	115.01 ± 0.795	95.841 ± 0.921

*ppb – parts per billion, TPA- Terephthalic Acid, IPA- Isophthalic Acid
Each value represents mean ± S.D of three replicates

Precision

The precision refers to the variability of the results in repeated analyses of the sample under identical experimental conditions. The method was validated by evaluating the intra- and inter-day precision. The precision was calculated from an average of six determinations of a homogeneous sample (USP, 2004). The intra day assays for TPA and IPA were expressed as Relative Standard Deviation (RSD) 5.123% and 2.015% respectively while inter-day precision assays for TPA and IPA were expressed as relative standard deviation (RSD) 2.089% and 2.105%, respectively, indicating that the data is tightly clustered around the mean and method presents a good precision (Brittain, 1998). The detailed precision data are shown at Table 2.

Table 2: Analysis of intra- and inter-day precision assays

Theoretical concentration	Concentration							
	Intraday TPA		Inter day TPA		Intraday IPA		Inter day I	
	ppb	%	ppb	%	ppb	%	ppb	%
7.0	5.7401	82.00	5.8321	83.31	5.8301	83.28	5.8211	83.15
7.0	6.1520	87.88	5.7511	82.15	5.9269	84.67	5.9123	84.46
7.0	5.7188	81.69	5.8200	83.14	5.9831	85.47	5.8272	83.24
7.0	5.8697	83.85	5.9820	85.45	5.7854	82.64	5.8113	83.01
7.0	5.9596	85.13	6.2712	89.58	5.7454	82.07	6.1120	87.31
7.0	6.2814	89.73	6.1230	87.47	5.8282	83.26	6.0230	86.04
Average	5.8869		5.9632		5.7998		5.9178	
Standard Deviation (ppb)	0.3016		0.1246		0.1169		0.1246	
Relative Standard Deviation (%)	5.123		2.089		2.015		2.105	

*ppb – parts per billion, TPA- Terephthalic Acid, IPA- Isophthalic Acid, %-Percentage

Linearity

The analytical curves for TPA acid and IPA acid standards were constructed by plotting the area under the curve (AUC) of the main peak versus migrant concentrations (|Table 3, 4, 5, and 6) It was found to be linear over a wide concentration range (6ppb – 120ppb) with a correlation coefficient of 0.998 for TPA and 0.999 for IPA. The straight line equations obtained from the experimental results were found to be:

$y = 0.029 - 0.121 \longrightarrow$ Equation for TPA

$y = 0.086 - 0.229 \longrightarrow$ Equation for IPA

The data were validated by analysis of variance, which demonstrated significant linear regression and non-significant deviation from linearity ($P < 0.05$). The Relative Standard Deviation of the slope and of the intercept of the three lines obtained for TPA standard were 12.1 % and 2.9%, respectively. The RSD of the slope and of the intercept of the three lines obtained for IPA standard were 22.9% and 8.6 % respectively.

Thus, this HPLC method can be considered to show adequate linearity in the concentration range (6 ppb-120 ppb) for quantitative analysis of TPA and IPA under the experimental conditions described.

Table 3: Linearity for TPA

Model summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.999[a]	.998	.998	.0666575

Table 4: Linearity for IPA

Model Summary			
R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
.999[a]	.999	.998	.1651860

Table 5: Coefficients for TPA

		Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
Model		**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**Lower Bound**	**Upper Bound**
1	(Constant)	-.121	.043		-2.798	.068	-.259	.017
	concentration	.029	.001	.999	40.731	.000	.027	.031

a. Dependent Variable: MAU

Table 6: Coefficients for IPA

		Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
Model		**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**Lower Bound**	**Upper Bound**
1	(Constant)	-.229	.107		-2.135	.122	-.570	.112
	concentration	.086	.002	.999	48.981	.000	.080	.091

a. Dependent Variable: MAU

Limit of Quantification

The lower limit of quantification was determined to be 6 ppb, with a relative standard deviation lower than 10%.

Specificity

HPLC chromatogram for sample loaded with TPA and IPA is shown in Figure 1. The results obtained from the chromatograms indicate that the retention times of the two compounds were between 11 and 15 min and peaks of solvents were eluted in about 1–2 min. Run time for the analysis of TPA and IPA was 20 min. TPA and IPA in sample are well separated from each other and from the background oil (Table 7 and 8) Following chromatogram illustrates that the extraction solvent did not critically interfere with the detection of the monomers.

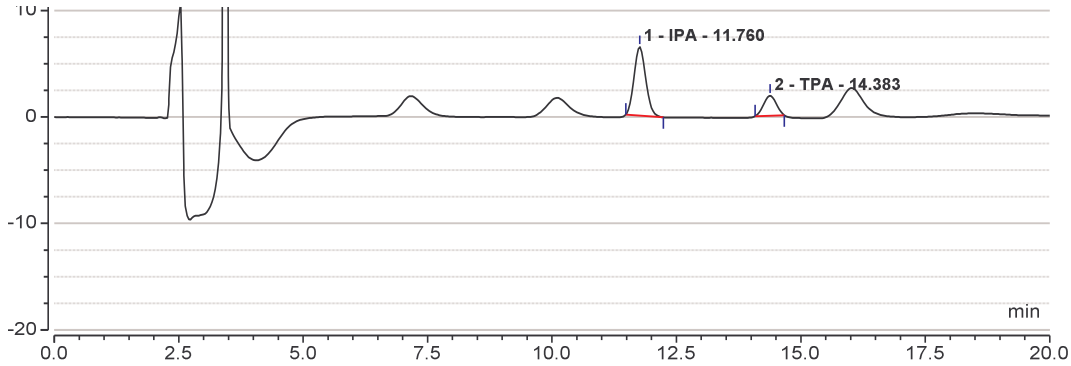


Figure 1: HPLC chromatogram for sample loaded with TPA and IPA

HPLC Analysis of All Island Samples

None of the samples collected island wide shows a positive result for TPA and /or IPA from HPLC Analysis.

Table 7: TPA Contamination for samples drawn island wide (30 composite samples prepared from 150 samples)

No	Injection name	Ret.Time min UV_VIS_1 IPA	Area mAU*min UV_VIS_1 IPA	Height mAU UV_VIS_1 IPA	Amount ppb UV_VIS_1 IPA	Real Area % UV_VIS_1 IPA	Peak type UV_VIS_1 IPA
1	Sample 1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2	Sample 2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
3	Sample 3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
4	Sample 4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
5	Sample 5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	Sample 6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
7	Sample 7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	Sample 8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
9	Sample 9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
10	Sample 10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
11	Sample 11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
12	Sample 12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
13	Sample 13	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
14	Sample 14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
15	Sample 15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
16	Sample 16	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
17	Sample 17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
18	Sample 18	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
19	Sample 19	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	Sample 20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	Sample 21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	Sample 22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
23	Sample 23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
24	Sample 24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
25	Sample 25	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
26	Sample 26	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
27	Sample 27	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
28	Sample 28	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
29	Sample 29	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
30	Sample 30	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Table 8: IPA Contamination for samples drawn island wide (30 composite samples prepared from 150 samples)

No	Injection name	Ret.Time min UV_VIS_1 IPA	Area mAU*min UV_VIS_1 IPA	Height mAU UV_VIS_1 IPA	Amount ppb UV_VIS_1 IPA	Real Area % UV_VIS_1 IPA	Peak type UV_VIS_1 IPA
1	Sample 1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2	Sample 2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
3	Sample 3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
4	Sample 4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
5	Sample 5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	Sample 6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
7	Sample 7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	Sample 8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
9	Sample 9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
10	Sample 10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
11	Sample 11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
12	Sample 12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
13	Sample 13	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
14	Sample 14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
15	Sample 15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
16	Sample 16	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
17	Sample 17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
18	Sample 18	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
19	Sample 19	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	Sample 20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	Sample 21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	Sample 22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
23	Sample 23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
24	Sample 24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
25	Sample 25	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
26	Sample 26	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
27	Sample 27	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
28	Sample 28	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
29	Sample 29	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
30	Sample 30	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Conclusion

The results obtained from the study show that the HPLC method presented, can be considered as a suitable method for the identification and quantification of terphthalic acid and is ophthalic acid migrated to edible oils used for deep frying of manioc chips. None of the sample drawn island wide were contaminated with TPA or IPA. Thus, they are generally safe for the consumption.

References

Brittain, H.G. 1998. Validação de métodosana líticosnão cromatográficos. *Pharm. Tech*. 6 :4-9.

Brody, A. L. and Marsh, K. S. 1997. Encyclopedia of Packaging Technology. ISBN 0-471-06397-5.

Brooks, D. W. and Giles, G. A. 2002. *PET Packaging Technology*. CRC Press, New York, pp. 27, 34, 65–70, 228–233.

Brussels, C.E.N. 1999. European Committee for Standardization (CEN), Materials and articles in contact with foodstuffs – plastics substances subject to limitation – Part 2: Determination of terephthalic acid in food simulants, ENV 13130-2. CEN, Brussels, 1–7.

Khaneghah, A. M., Limbo, S., Shoeibi, S. and Mazinani, S. 2013. HPLC Study of migration of terephthalic acid and isophthalic acid from PET bottles into edible oils. *Journal of the Science of Food and Agriculture* 94(11). DOI 10.1002/jsfa. 6540.

The United State Pharmacopoeia (USP 27) 2004. National Publishing Philadelphia, Asian Edn., 2622-2624.

Journal of Dry Zone Agriculture, 2020, 6 (2): 79 - 89

ISSN 2012 – 8673

Comparison of Nutritive Value in Fodder Species and Industrial By-products Available in Anuradhapura

Karunanayaka, R.H.W.M., Nayananjalie, W.A.D., Somasiri, S.C., Adikari, A.M.J.B., Weerasingha, W.V.V.R. and Kumari, M.A.A.P.
Department of Animal and Food Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka, Puliyankulama, Anuradhapura, Sri Lanka.

Abstract : This experiment intended to figure out the nutritive value of fodder species and industrial by-products for feeding ruminants in Anuradhpura. Fodder species; maize (*Zea mays*), sorghum (*Sorghum bicolour*), CO-3 (*Pennisetum purpureum* x *P. americanum*), gliricidia (*Gliricidia sepium*), and guinea grass (*Panicum maximum*) and agro-industrial by-products; rice (*Oryza sativa*) bran, coconut (*Cocos nucifera*) poonac, maize (*Zea mays*) meal and soya bean (*Glycine max*) meal (SBM) were analyzed for proximate composition, acid detergent fiber (ADF), neutral detergent fiber (NDF) and gross energy (GE). Nitrogen free extract (NFE), total digestible nutrients (TDN) and metabolizable energy (ME) were calculated. The data were analyzed using the one-way ANOVA procedure in SAS. The observed TDN, ME and GE of fodder species differed significantly ($p<0.05$).The highest ($p<0.05$) values of dry matter (DM), crude fat(EE), crude protein (CP), TDN, GE and ME were obtained for gliricidia. Guinea grass contained the highest ($p<0.05$) ADF and NDF contents compared to other fodder species. Sorghum and CO3 showed the highest ($p<0.05$) ash and crude fiber (CF) while the lowest ($p<0.05$) ash and CF were recorded in maize and gliricidia. The DMwas not significantly differed ($p>0.05$) in agro-industrial by-products. The highest ($p<0.05$) total ash, CP, TDN and MEwere reported in SBM while NFE was highest in maize meal. The highest ($p<0.05$) values of EE and GE contents were obtained for rice bran. The nutrient content observed in the feed ingredients in the present study, is in par with other references. According to the nutrient composition, these feed ingredients can be used for feeding ruminants and in the formulation of total mixed rations for dairy cows in Anuradhapura.

Keywords: Agro-industrial by-products, Fodder species, Gross energy, Nutrient comparison

Corresponding Author: W.A.D.Nayananjalie, nayananjalie@yahoo.com

Introduction

The livestock sector plays a major role in the Sri Lankan economy and it contributes around 0.7% to the National Gross Domestic Product (GDP) of the country (Central Bank Report, 2019).The national livestock population has been estimated as 1.08 million cattle, 0.30 million buffaloes, and 0.32 million goat/ sheep in 2019 (Depar tment of Census and Statistics, 2019). Under the livestock sector, cattle and buffaloes play a key role in the dairy industry in Sri Lanka. The current annual milk production has been estimated as 447.58 million liters in Sri Lanka and the number of milking cattle and buffaloes were estimated at 0.3 million and 0.09 million, respectively in 2019 (Department of Census and Statistics, 2019). As the climatic conditions in Sri Lanka vary widely, the breed of cattle to be reared varies depending on the agro-climatic zone. The agro-climatic zones in Sri Lanka are broadly classified into dry zone, coconut triangle, mid-country, and hill country (FAO, 1977). Anuradhapura district is located in North Central Province and it is classified under the dry zone. The livestock sector is also considered as a supplementary income source in the Anuradhapura district.

The fodder species play a vital role and it is the cheapest source of feed available for feeding ruminants in Sri Lanka (Premarathne and Samarasinghe, 2020). The most indispensable and basic input for efficient dairy production is the good quality fodder. The dairy industry in Sri Lanka primarily depends on natural pasture and fodder found on ravines, tank banks, uncultivated paddy fields, roadsides, and uncultivated public and private lands. Due to the abundance of natural grazing lands, the majority of dairy cattle is found in the dry zone of Sri Lanka (Houwers *et al*., 2015).They are mostly indigenous species and crossbred animals (Premarathne and Samarasinghe, 2020). However, the availability of the forage is seasonal, the yield depends onthe climate, cropping pattern, and soil conditions. Further, the quality of the forage is poor and it is not available in the required quantity thus resulting in low production of ruminants in the dry zone (Premarathne and Samarasinghe, 2020).The climatic condition and the irrigation facilities in the dry zone are favourable for cultivating forages like maize (*Zea mays*), sorghum (*Sorghum bicolour*), CO-3 (*Pennisetum purpureum* x *P. americanum*), gliricidia (*Gliricidia sepium*), and guinea grass (*Panicum maximum*) throughout the year. Maize is one of the major cereal crops; which has a higher-yielding potential and wider adaptability under fluctuating agro-climatic conditions (Sarmini and Premaratne, 2017). Maize is grown as a food and feed source in the dry and intermediate zones during the *Maha* season. It is considered as an ideal forage, because, it is rich in nutrients, highly palatable and high yielding and it helps to increase the body weight and milk quality in dairy cattle (Sattar *et al*., 1994).

Sorghum plays a vital roleas a forage crop under drought conditionsas it uses water efficiently and provides a higheryield (Sarmini and Premaratne, 2017). Further, sorghum has the ability to tiller and regrow after cutting, defoliation, and/or

browsing. CO-3 has special characters like high tillering ability, high yielding potential, high crude protein content, quick re-growth capacity, high palatability, free from other adverse factors, and resistance to pest and disease attacks (Premaratne and Premala 2006). Hence, CO-3 has been recommended for the small scale dairy farmers in Sri Lanka, due to its favourable characters (Premaratne and Premalal, 2006). Gliricidia is one of the major legume forage trees grown in tropical areas and it consists of high nutritive value, fast-growing ability and it can adapt to the different adversary climatic conditions. Gliricidia is widely used as a plant protein source for ruminants (Premarathne & Samarasinghe, 2020). However, it containsa high concentration of tannin and it affects negatively on rumen digestion (Ash, 1990). Therefore, it is not recommended to feed more than 20% of the animal's daily feed requirement. Guinea grass is a bush forming perennial grass that grows in warm areas and it can withstand continuous heavy grazing. It is a fast-growing leafy grass, palatable to dairy cattle with good nutritional value (Aganga and Tshwenyane, 2004).

Similarly, in Sri Lanka, rice (*Oryza sativa*) bran and coconut (*Cocos nucifera*) poonac are mostly used as agro-industrial by-products. According to the requirement, maize meal and soya bean (*Glycine max*) meal (SBM) can be fed as other agro-industrial by-products (Premarathne and Samarasinghe, 2020). Rice bran is a major industrial by-product, which is widely used as a cattle feed supplement in Sri Lanka. Rice bran refers to the mixture of aleurone and other layers removed from rice during the milling process (Shi *et al*., 2015). It is a good source of vitamin B-group,less expensive, contains a substantial amount of fat, protein, and metabolizable energy content (Rezaei, 2006). Coconut poonac is a by-product of the coconut oil manufacturing process and it is a residue left after the removal of oil from copra. In Sri Lanka, a high amount of coconut poonac has been used for livestock feeding(Silva, 1980). Maize is a primary source of energy supplement for ruminants (Premarathne and Samarasinghe, 2020). Maize meal contains less protein. Therefore, most farmers mix maize meal with high-quality forages and other ingredients such as soybean meal (www.feedipedia.org). Soybean meal is the by-product of the extraction of soya bean oiland iswidely used as a plant-based protein source in animal feeds in Sri Lanka (Premarathne and Samarasinghe, 2020). Hence, there is a potential to increase milk production by using a ration formulated with abovestated forages and agro-industrial by-products that are abundantly available in the dry zone of Sri Lanka. However, the nutritive value of the selected forages and industrial by-products should be known to determine the suitability for feeding and ration formulation for ruminants. Therefore, this experiment was aimedto figure out the nutritive value of fodder species and industrial by-products for feeding ruminants in Anuradhapura, Sri Lanka.

Materials and Methods

Sample Collection

Different feed ingredients available inthe Anuradhapura district (8.3114º N and

80.4037º E) were collected and the laboratory analysis was conducted at the Animal Science laboratory in the Faculty of Agriculture, Rajarata University of Sri Lanka, Puliyankulama, Anuradhapura from September 2019 to August 2020. The collected fodder species weremaize, sorghum, CO-3, guinea grass, gliricidia, and agro-industrial by-products; rice bran, maize meal, coconut poonac, and SBM. The agro-industrial by-products were purchased from milling centers in Anuradhapura. The whole plant of maize was harvested before the cob initiation and the guinea grass was harvested atthe pre-blooming stage. The whole plant of sorghum without seeds and CO-3 grass at the pre-blooming stage were collected. The leaves and twigs from the mature gliricidia trees we recollected for analysis.

Sample Preparation

Harvested fodder species were chopped by using a grass chopper and dried under shade. Industrial by-products were dried at 60 ºC and ground to a powder. Sub-samples of each chopped fodder speciesand by-products were dried to a constant weightat 60°Cin an oven (YCO-010, Taiwan) for dry matter (DM) determination. Dried samples were ground to pass through a 1 mm screen and stored in sample bottles at room temperature for nutrient analysis.

$$NFE\ (\%) = 100 - Ash\ (\%) - CF(\%) - EE(\%) - CP(\%)$$ (Kearl, 1982)

$$ME\ (Mcal/kg) = \left(\left(1.01x(TDN\%\ x\ 0.04409)\right) - 0.45\right)$$ (NRC,2001)

$$TDN\ (\%)(Dry\ forage\ and\ roughages) = -17.26 + 1.212(CP) + 0.8352\ (NFE) + 2.464\ (EE) + 0.4475(CF)$$

$$TDN\ (\%)(Energy\ feeds) = 40.26 + 0.1969\ (CP) + 0.4228\ (NFE) + 1.190(EE) - 0.1379(CF)$$

$$TDN\ (\%)(Protein\ supplements) = 40.32 + 0.5398\ (CP) + 0.4448\ (NFE) + 1.422\ )EE) - 0.7007\ (CF)$$

(Kearl, 1982)

Nutrient Analysis

The samples were then analyzed fortotal nitrogen (N), crude fiber (CF), ether extract (EE) and ash by using Kjeldahl unit (DK 20, Italy), fiber analyzer (FIWE3, Italy), soxhlet extractor (MIC ROSIL, India), and a muffle furnace (DMF-05, Korea), respectively according to protocols described by AOAC (2019). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were analyzed according to Van Soest (1991). The values were derived on a dry matter basis. Gross energy content was analyzed using a bomb calorimeter (C200 Auto, Germany).

Calculation of Crude Protein, Nitrogen-free extract and Energy Values

Crude protein (CP) was calculated as N% into 6.25. Nitrogen free extract (NFE), total digestible nutrients (TDN), and metabolizable energy (ME) values were calculated using the following equations.

Where, NFE- Nitrogen free extract, CF- Crude fiber, EE- Ether extract, CP- Crude protein, ME- Metabolizable energy and TDN- Total digestible nutrients.

Statistical Analysis

Five replicates were analysed from each sample. The nutrient data were statistically analyzed using one way ANOVA procedure using Statistical Software for Data Analysis (SAS), Ver 9.0 (SAS, 2002).

Result and Discussion

Chemical Composition of Fodder Species

The proximate composition of fodder species is presented in Table 1. The highest ($p<0.05$) values of DM, EE, and the lowest ($p<0.05$) CF, ADF percentages were obtained for gliricidia in the present study. The DM percentage of fodder species was ranging between 18.15± 1.01% and 25.10±0.78%.The findings of DM percentages for sorghum and CO-3 of the present study were higher than the reported values by Sarmini and Premaratne, (2017);15.55±0.02% for sorghum and 17.00±0.01% for CO-3, respectively in the north region of Sri Lanka. According to Sarmini and Premaratne (2017), DM percentage of maize (Pacific 984) was 32.73 ± 0.01% in the northern region of Sri Lanka and it was higher than the reported values of the present study. Heuze *et al*, (2017) observed CP, CF, EE, and ash content as 3.0 - 12.8%, 19.1 - 36.6%, 0.7 - 3.1%, and 2.5 - 11.8%, respectively for maize and present study results agree with these values. National Dairy Development Board (NDDB) in India reported that sorghum hay and maize hay contained CP, EE, CF, Ash, NDF, ADF, ME, NFE as 7.0%, 1.2%, 38.9%, 8.5%, 56.5%, 40.3%, 1900 kcal/g, 47.1% and 3.6%, 0.8%, 33.2%, 10.5%, 62.2%, 37.4%, 2100 kcal/g, 51.9%, respectively (NDDB, 2012). The slight variation in the contents of nutrients could depend on the variety, season, soil nutrient com position, and maturity stage. Further, Bandara *et al.,* (2016) reported that DM, CP, and CF content of sorghum in the 1st harvest were 22.1%, 11.63%, and 36.8%, respectively, and in 2nd harvest as 16.9%, 9.60%, and 35.8%,respectively. Therefore, the nutrient composition of sorghum varied with the harvesting interval.

Premaratne and Premalal (2006) reported a CP content of 15 –16% for CO-3 in the mid-country of Sri Lanka. The highest ($p<0.05$) and lowest ($p<0.05$) total ash contents were reported in CO-3 and Maize, respectively in the present study. According to Sampath *et al*. (2009), the ash content of gliricidia was 7.84%. However, Sarmini and Premaratne (2017) reported that the total ash contents of Maize, Sorghum,

Table 1: Chemical composition of fodder crops; gliricidia, guinea grass, CO3, sorghum, and maize (mean ± SE)

Component*	Fodder				
	Gliricidia	Guinea grass	CO3	Sorghum	Maize
DM (%)	25.10±0.78[a]	21.29±0.64[c]	18.15±1.01[d]	23.87±0.98[b]	23.33±0.77[b]
Ash (%)	8.51±1.15[bc]	9.64±0.61[ab]	10.21±1.77[a]	10.01±1.24[ab]	7.77±0.44[c]
EE (%)	3.96±0.62[a]	2.05±0.48[c]	2.95±0.82[b]	1.76±0.53[c]	1.90±0.33[c]
CP (%)	23.79±0.41[a]	5.76±0.21[d]	11.23±1.04[b]	8.83±0.30[c]	9.25±1.19[c]
CF (%)	26.37±5.48[d]	35.41±2.86[ab]	32.00±1.74[bc]	36.70±2.94[a]	30.27±1.41[cd]
NFE%	37.36±5.31[d]	47.13±2.47[ab]	43.50±2.78[bc]	42.70±3.30[c]	51.03±1.05[a]
ADF (%)	27.08±0.95[c]	46.78±3.25[a]	39.73±0.92[b]	36.70±2.94	39.19±1.48[b]
NDF (%)	30.76±1.52[d]	71.15±1.96[a]	60.02±1.05[c]	59.95±2.25[c]	63.07±2.88[b]
TDN%	64.34±1.40[a]	49.99±1.32[c]	54.36±2.26[b]	49.86±2.28[c]	54.53±0.64[b]
GE (kcal/g)	4060±5.54[a]	3630.6±35.63[c]	3228±20.80[e]	3879±25.80[b]	3575.6±90[d]
ME (kcal/g)	2420±0.26[a]	1780±0.25[c]	1980±0.42[b]	1780±0.43[c]	1990±0.12[b]

Differing superscripts within a rowindicate means that were significantly different ($p < 0.05$).

*DM-dry matter; EE-ether extract; CP-crude protein; CF-crude fibre; ADF-acid detergent fibre; NDF-neutral detergent fibre; TDN-total digestible nutrients; NFE; nitrogen free extract; ME- metabolizable energy

and CO-3 were 10.70±0.18%, 11.76±0.02%, and 16.06±0.01%, respectively and maize contained7.35±0.09% of CP. In support of the present findings, Somasiri *et al*., (2010) reported 26% of CF content for gliricidia cultivated in the intermediate zone of Sri Lanka. In contrast, Sarmini and Premaratne (2017) observed 35.15±0.60%, 38.28±0.14%, and 33.35±0.57% of CF contents for Maize, sorghum, and CO-3, respectively in the northern area. Aganga and Tshwenyane (2004) reported that the CF content of early bloom guinea grass in Tanzania was 39.6% and these findings were higher than the values observed in the present study. The NDF and ADF contents reported by Premaratne and Premalal, (2006) were 74 – 78% and 42-47%, respectively for CO-3. Musco *et al.,* (2016) found that the NDF and ADF contents of guinea grass were 50.80% and 38.85%, respectively. The findings of NFE percentages for CO-3 and sorghum of the present study were higher than the reported values by Pavithra *et al.* (2019); 37.4±0.04% for CO-3 and 37.7±0.06% for sorghum. According to the present study, gliricidia had significantly higher ($p<0.05$)gross energycontent (4060± 5.54 kcal/g) compared to the other fodder species and the lowest gross energy content (3228±20.80 kcal/g)was recorded in CO-3. Sampath *et al.* (2009), found that the gross energy contents of gliricidia and maize were 4330 and 3880kcal/g,

respectively. Pavithra *et al*., (2019) reported the gross energy content of CO-3 and sorghum, as 3580±0.00 and 3850±0.02 (kcal /g DM), respectively. Gliricidia had the highest ($p<0.05$) ME content compared to CO3 and Maize which inturn were higher ($p<0.05$) than guinea grass and sorghum.

Chemical Composition of Industrial By-products

The chemical composition of different industrial by-products is summarized in Table 2. The DM content of industrial by-products did not show any significant difference ($p>0.05$). The significantly higher total ash and CP contents were reported in SBM. Ravindran (1992), reviewed that the DM, ash, EE, CP, CF, and gross energy content of the SBM were 92.0%, 5.6%, 6.0%, 42.4%, 8.0%, and 4180 kcal/g, respectively. However, the variation of the nutrient content of SBM in the present study might be due to the genotypic variations, processing method, and environmental condition. According to the Somasiri *et al.,* (2010), the DM, CF, EE, CP, and ash content of coconut poonac were 92%, 10%, 9%, 21%, and 6%, respectively.

Rice bran had significantly higher ($p<0.05$) EE and gross energy contents compared to other industrial by-products in the present study. However, Sampath *et al*, (2009) reported ash, CP, ADF, and

Table 2: Chemical composition of industrial by-products; coconut poonac, maize meal, rice bran, and SBM (mean ± SE)

Component*	Industrial by-products			
	Coconut poonac	Maize meal	Rice bran	SBM
DM%	90.32±1.78^{a}	90.31±0.50^{a}	89.94±0.60^{a}	89.94±0.28^{a}
Ash%	3.97±035^{c}	0.64±0.22^{d}	5.72±0.78^{b}	8.52±0.79^{a}
EE%	7.31±0.56^{b}	3.36±0.63^{c}	10.96±1.04^{a}	2.38±0.68^{c}
CP%	19.40±0.44^{b}	9.36±0.14^{d}	11.99±0.19^{c}	50.99±0.43^{a}
CF%	10.45±1.82^{a}	3.56±0.74^{b}	9.93±0.59^{a}	4.08±1.11^{b}
NFE%	58.87±1.57^{c}	83.08±1.22^{a}	61.40±1.95^{b}	34.03±1.62^{d}
ADF (%)	31.08±4.52^{a}	3.94±0.99^{c}	8.75±0.82^{b}	8.10±0.32^{b}
NDF (%)	56.58±3.90^{a}	19.86±2.15^{b}	19.58±1.05^{b}	13.07±0.76^{c}
TDN%	80.05±2.26^{b}	80.74±0.38^{b}	80.25±0.64^{b}	83.50±2.09^{a}
GE (kcal/g)	3948.6±73.44^{b}	3469.6±19.00^{d}	4258.8±61.62^{a}	3739.6±39.10^{c}
ME (kcal/g)	3130±0.42^{b}	3160±0.07^{b}	3140±0.12^{b}	3280±0.39^{a}

Differing superscripts within a rowindicate means that were significantly different ($p< 0.05$).
*DM-dry matter; EE-ether extract; CP-crude protein; CF-crude fibre; ADF-acid detergent fibre; NDF-neutral detergent fibre; TDN-total digestible nutrients; NFE; nitrogen free extract; ME- metabolizable energy

NDF contents of rice bran as 4.58%, 16.68%, 16.77%, and 23.35%, respectively. The NDDB, (2012) has reported that rice bran contain CP, EE, CF, Ash, NDF, ADF, ME and NFE 14.0%, 14.0%, 12.0%, 11.8%, 19.4%, 15.0%, 2700 kcal/g, 49.2%, respectively. Different soil types and climatic conditions also affected the chemical composition of the rice bran (Shi *et al*., 2015). According to the NDDB, (2012) maize grain contained CP, EE, CF, Ash, NDF, ADF, ME and NFE as 9.0%, 4.2%, 2.0%, 2.0%, 15.6%, 3.5%, 3100 kcal/g and 81.6%, respectively. However, the reported values of ME and NFE for maize meal and rice bran by the NDDB (2012)were higher than the values observed in the present study. Ravindran (1992) observed 92.0%, 1.5%, 4.0%, 9.2% and 2.3%, of DM, ash, EE, CP and CF contents, respectively for maize grain. According to Abiose and Ikujenlola (2014), the chemical composition of maize meals differed due to the variety of maize and maturation stage. Coconut poonac contained significantly higher ($p<0.05$)CF and ADF contents compared toother industrial by-products in the present study. Rice bran had higher gross energy (4258.8±61.62 kcal/g) contents compared to the other feed sources and the lowest gross energy content was recorded in (3469.6±19.00 kcal/g) maize meal. However, the result of the present study did not agree with the finding of Ravindran (1992), who reviewed that the gross energy content of rice bran, coconut poonac, and SBM as 3710, 4220, and 4180 kcal/g, respectively. Sampath *et al*. (2009), reported the gross energy contents of maize and rice bran as 3880 and 3760 kcal/g, respectively. According to the Pavithra *et al*. (2019), the gross energy and NFE contents of coconut poonac, were 4300±0.01 kcal/g and 53.1±0.54% respectively. Soya bean meal had the highest ($p<0.05$) ME content compared to other ingredients in the present study. According to ME contents of maize grain, rice bran, SBM and Coconut poonac were 3100 kcal/g, 2700 kcal/g, 2500 kcal/g and 2300 kcal/g, respectively. The TDN contents reported by NDDB, (2012) was 85 – 90% for maize grain and 70 – 90% for rice bran. According to the NDDB (2012), the TDN content was ranged from 75% to 84% for SBM and it was depending upon the de-hulling and processing method.

Conclusion

The nutrient contents observed in the feed ingredients in the present study are in par with other references. According to the available nutrient composition, these feed ingredients can be used for feeding ruminants and in the formulation of total mixed rations (TMR) for dairy cows in Anuradhapura.

Acknowledgement

The authors wish to express sincere gratitude to Accelerating Higher Education Expansion and Development (AHEAD) operation project and World Bank group for funding for this work.

Academic and Non-academic staff members of Department of Animal and Food Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka are acknowledged for their assistance.

References

Abiose, S. H. and Ikujenlola, A. V. 2014. Comparison of chemical composition, functional properties and amino acids composition of quality protein maize and common maize (*Zea mays* L.). *African Journal of Food Science and Technology*, 5:81-89.

Aganga, A. A. and Tshwenyane, S. 2004. Potentials of guinea grass (*Panicum maximum*) as forage crop in livestock production, *Pakistan Journal of Nutrition*, 3: 1–4.

AOAC International. 2019. Official methods of analysis of AOAC international, 21st edition, Gaithersburg, MD, USA. 1-75.

Ash, A .J. 1990. The effect of suppleme ntation with leaves from the leguminous trees *Sesbania grandiflora*, *Albizia chinesis* and *Gliricidia sepium* on the intake and digestibility of guinea, *Journal of Animal Feed Science and Technology*, 28:225-232.

Bandara, P. G. G., Premalal, G. G. C. and Nayananjalie, W. A. D. 2016. Assessment of nutritive value of sorghum [*Sorghum bicolor* (L.) Moench] fodder in Sri Lanka, International *Journal of Livestock Research*, 6: 44-49.

Central bank report. 2019. Economic and social statistics of Sri Lanka. Janadhipathi mawatha, Colombo 01, Sri Lanka, 56.

Department of census and statistics. 2019. Annual report. Department of Animal Production and Health. Retrieved on April 05, 2020, from www.daph.gov.lk/web

FAO. 1977. Animal breeding selected articles from the world animal review. FAO, Rome, Italy, 139.

Feedipedia. 2020. Oil plant and by-products. Retrieved on March 19, 2020, from http://www.feedipedia.org.

Heuze, V., Tran, G., Edouard, N. and Lebas, F. 2017. Maize green forage. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO, Retrieved on April 05, 2020, from http://www.feedipedia.org.

Houwers, W., Wouters, B. and Vernooij, A. 2015. Sri Lanka fodder study; an overview of potential, bottlenecks and improvements to meet the rising demand for quality fodder in Sri Lanka. Lelystad, Wageningen University & Research center, Livestock Research, Livestock Research Report. 924.

Kearl, L. C. 1982. Nutrient requirements of ruminants in developing countries. International Feedstuff Institute, Agriculture

Export State., Utah State University, Logan, Utah, USA, 381.

Musco, N., Koura1, I. B., Tudisco, R., Awadjihè, G., Adjolohoun, S., Cutrignelli, M. I., Mollica, M. P., Houinato, M., Infascelli, F. and Calabrò, S. 2016. Nutritional Characteristics of forage grown in south of benin. *Asian Australas Journal of Animal Sciences,* 29:51-61.

NDDB (National Dairy Development Board). 2012. Nutritive value of commonly available feeds and fodders in India. National Dairy Development Board, Animal Nutrition Group, Anand, India, 1-112.

NRC (National Research Council) 2001. Nutrient requirements of dairy cattle, National Academy of Sciences, Washington, USA, 13.

Pavithra, S., Vidanarachchi, J. K., Sarmini, M. and Premaratne, S. 2019. Chemical composition and gross energy content of commonly available animal feedstuff in Sri Lanka. *Journal of Nutrient Sciences*, 47: 79-87.

Premaratne, S., and Premalal, G. G. C. 2006. Hybrid Napier (*Pennisetum perpureum* X *Pennisetum americarnum*) Var. CO-3: A resourceful fodder grass for dairy development in Sri Lanka. *The Journal of Agricultural Sciences*, 2: 22–33.

Premarathne, S. and Samarasinghe, K. 2020. Animal feed production in Sri Lanka: past present and future. Agricultural Research for Sustainable Food Systems in Sri Lanka, 12: 277-301.

Ravindran, V. 1992. Chemical composition and energy utilization values of common Sri Lankan feedstuff for growing pigs. *Journal of the National Science Council of Sri Lanka,* 20:91-98.

Rezaei, M. 2006. Utilization of mixed rice bran in laying hen diets. *Pakistan Journal of Biological Sciences,* 9: 1420–1423.

Sampath, W. A. K., Perera, A. N. F. and Prathapasinghe, G. A. 2009. Evaluation of an economical total mix ration for dairy cattle with locally available feed resources. *Wayamba Journal of Animal Science,* 578: 14-17.

Sarmini, M. and Premaratne, S. 2017. Yield and nutritional quality potential of three fodder grasses in the northern region of Sri Lanka. *Tropical Agricultural Research*. 28: 175 – 182.

SAS. 2002. Statistical Analyses System. Users Guide Statistics. SAS Institute Inc. Cary, North Carolina, USA, 59-67.

Sattar, M. A, Haque, M. F. and Rahman, M. M. 1994. Intercropping maize with broadcast rice at different row spacing. *Bangladesh Journal of Agriculture Research.* 19: 159-164.

Shi, C. X., Liu, Z. Y., Shi, M., Li, P., Zeng, Z. K., Liu, L., Huang, C. F., Zhu1, Z. P. and Li, D. F. 2015. Prediction of digestible and metabolizable energy content of rice bran fed to growing Pigs. *Asian Australian Journal of Animal Sciences*, 28: 654-661.

Silva, E. C. D. 1980. Suggested strategies for reducing the dependence of livestock industries on coconut poonac as a feed concentrate, *Journal of Ceylon Coconut Plantations,* 7: 36-43.

Somasiri, S. C., Premaratne, S., Gunathilake, H. A. J., and Abeysoma, H. A. 2010. Effect of gliricidia (*Gliricidia sepium*) leaf meal blocks on intake, live weight gain and milk yield of dairy cows. *Journal of Tropical Agricultural Research*, 22:76–83.

Van Soest, P. J., Robertson, J. B., and Lewis, B. A. 1991. Method of dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Sciences,* 74:3583-3597.

Journal of Dry Zone Agriculture, 2020, 6 (2): 90 - 96

ISSN 2012 – 8673

Phytoremediation Treatment of Farm Waste-Water by Selected Aquatic Plants

Kulanthini, K., Thusahanthy, A. and Prabhaharan, M.
Department of Agricultural Engineering, Faculty of Agriculture, University of Jaffna, Sri Lanka

Abstract: Wastewater management has a direct impact on the biological diversity of aquatic ecosystems. Disrupting the fundamental integrity of our life support systems. When water bodies receive excess nutrients especially nitrates and phosphates, these nutrients can stimulate excessive plant growth, which causes eutrophication including algal blooms. Eutrophication leads to oxygen depletion, decreased biodiversity, changes in species composition and dominance, and a severe reduction in water quality. Aquatic plants grow profusely in lakes and waterways all over the world and in recent decades their negative effects have been magnified by man's intensive use of water bodies. Eradication of the weeds has proved almost impossible and even reasonable control is difficult. Turning these weeds to productive use would be desirable if it would partly offset the costs involved in mechanical removal. These aquatic plants were growing on the waste-water in different range. Amount of Nitrate, phosphate, EC, TDS, pH changes were estimated and analyzed. Through this experiment 87.5% of Nitrate, 67% of phosphate was absorbed by the aquatic plants and 25% reduction of Ec and TDS was observed and alkaline pH changes to neutral. *Duckweed* and *Water hyacinth* are high pollutant removal efficiency and highest survival among these aquatic plants. *Azolla* performs the considerable reduction than others plants. Whereas *Salvinia* performs the lowest reduction rate compared to other aquatic plants. In addition to that *hydrila* performs the high reduction of water pH. In this study phytoremediated waste-water, which consists permissible level of pollutants can be used for the irrigation of farm plants without any physiological stress.

***Keywords*:** Phytoremediation, Eutrophication, Aquatic-weeds, *Waste*-water treatment.

Corresponding Author: M.Prabhaharan, aenpraba@gmail.com

Introduction

Wastewater is a combination of domestic, commercial, industrial, and agricultural discharge, which contains pollutants and contaminants, including nutrients, microorganisms, chemicals and other toxins. These pollutants can cause health and environmental problems when wastewater is released into body rivers improperly (Secretariat, 2014). On the other hands, the increase in the concentration of nutrients such as nitrogen and phosphorus in water causes eutrophication of surface water resources.

However, wastewater also contains reusable resources such as water, carbon and nutrients that could be recovered or reused. Therefore, they require appropriate treatments for removal of pollutants to meet the effluent regulatory standards prior to discharge to the environment. Natural treatment systems are not disposal practices, nor are they random applications of waste and wastewater in various habitats (Crawford, 2010).

Natural treatment systems are engineered facilities which utilize the capabilities of plants, soils, and the associated microbial populations to degrade and immobilize wastewater contaminants. Due to the numerous advantages presented by wastewater treatment systems using plants, a new research field has evolved for better understanding of the processes underlying the inter-relations between the different species of plants in effluent treatment. Phytoremediation has been increasingly used to clean up contaminated soil and water systems because of its lower costs and fewer negative effects than physical or chemical engineering approaches (Prasad and Freitas, 2003). The principles of phytoremediation system to clean up storm water includes identification and implementation of efficient aquatic plant systems; uptake of dissolved nutrients including N and P and metals by the growing plants, and the plants creating a favorable environment for a variety of complex chemical, biological and physical processes that contribute to the removal and degradation of nutrients (Billore *et al*., 1998).

Objective

To estimate the performance of nutrient removal from farm waste water by aquatic plants such as Hyacinth, Duckweed, Salvinia, Azolla and Hydrila.

Materials and Methods

Study Area

Kilinochchi is the main Agricultural district in Northern Province of Sri-Lanka. It does not have a single perennial river, seasonal streams and rivers. Traditional water storage was through built irrigation tanks.

The area belongs to the dry zone of Sri Lanka with low annual rainfall, cannot be supported without adequate replenishment of surface water storage. Waste water was selected according to the nutrient

content like pH, TDS, EC also analyzed to stabilize proper condition for plant growth. It has also contributed to nitrate and phosphate contamination which is now-a-days a matter of concern because of ground water scarcity.

Nitrate Sedimentation, surface-floating of solid-substances also avoided from the filtration of large particle food industry waste water, farm waste water, food packaging center waste waters also possible for the treatment. In select farm waste water as a waste water resource because of its essay availability in research place. Criteria is used in selecting Macrophytes, adaptability to local climate, tolerance to adverse climatic conditions, tolerance to adverse concent ration of pollutants, pollutants assimilative capacity, high rate of photosynthesis, high oxygen transport capability, resistance to pests/diseases, ease of management harvesting. Based on these criteria, the macrophytes were selected in the study water hyacinth (*Eichhornia crassipes*), duckweed (*Lemna spp.* and *Spirodela polyrrhiza,* W. Koch), salvinia (*Salvinia minima* baker), Azolla (*Azolla caroliniana*) and hydrilla ((*Hydrilla verticillata*).

Experimental set-up, Data Collection and Parameters Analysis

The raw farm waste water was collected from a nearby animal farm in water cans. Chemical parameters were measured pH, TDS, EC, nitrate, phosphate contents were measured by pH meter, calorimeters and spectrophotometer. After the propagating of the aquatic plants 4 days interval samples are collected and the measurement of pH, TDS, EC were done in the laboratory of department of Agricultural Engineering faculty of Agriculture. Further analysis in the water board located in Jaffna for nitrate measurement APHA4500-NO3-E, Adopted method and for phosphate measurement APHA 3500-P E Adopted method were adopted. Plant samples are Shoot (above-water plant part) and root tissue samples were oven dried at 38 °C for 48h, ground, and total NPK measurement was done.

Total Dissolve Solid, pH, Electrical Conductivity Measurements

The water samples were collected in 2 days intervals for sampling immediately. After sampling the rods of the HACH meter dipped in the samples with conical flask. The reading was recorded in the 2 days interval. A graph of the standards was plotted. The concentration of the unknown was driven from the graph. Potassium concentration of the each and every sample was calculated. Whereas the maximum growth, nutrient and COD removal efficiency of duckweed was observe at EC 1,000 µS cm-1 (*Jamshaid Iqbal* , 1999).

Results and Discussion

Results of water quality parameter changes during the phytoremediation of waste water were explained below.

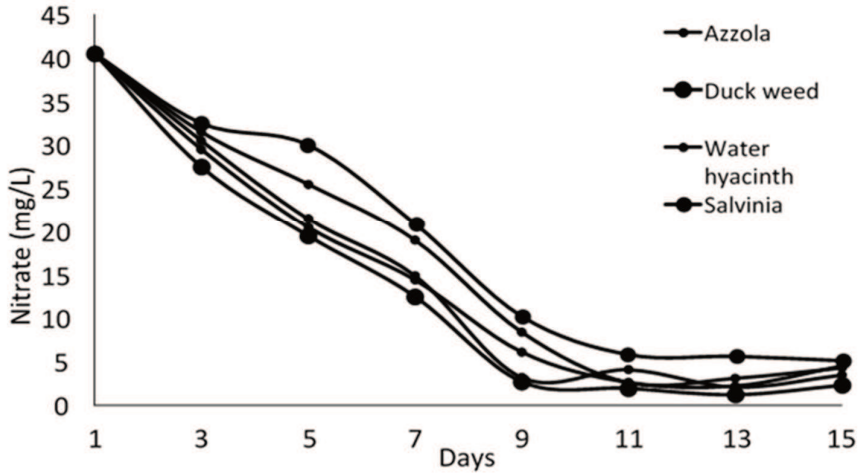


Figure 1: Variation in the nitrate content of the waste water in the time of remediation

Variation in the nitrate content of the waste water through the time of remediation process was shown in the Figure 1. Among the aquatic plant Duckweed performs the highest nitrate reduction rate and Salvinia perform lowest reduction rate. In addition to that water hyacinth also performs at the lowest reduction rate. Through the experiment efficient removal of nitrate content was reduced and ranged from 40mg/L to 5mg/L.

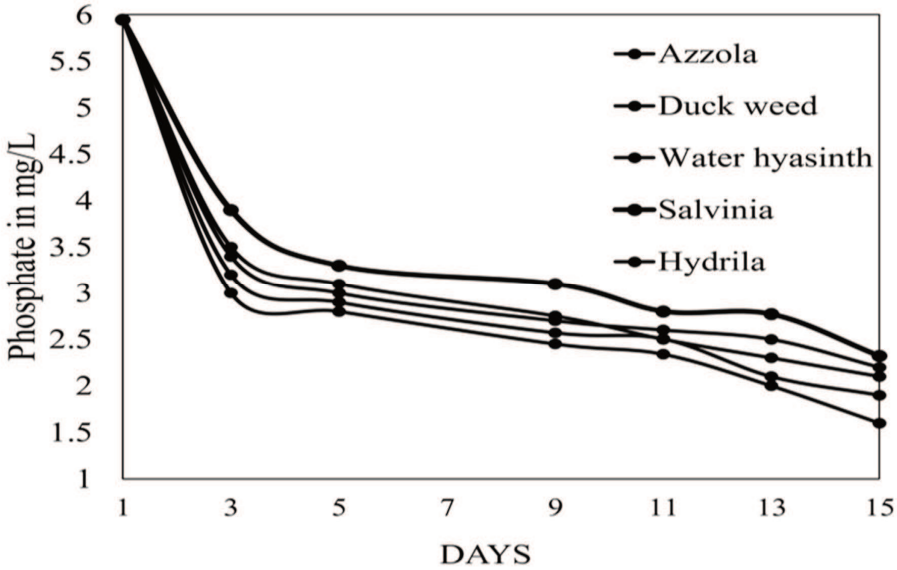


Figure 2: Variation in the phosphate content of the waste water in the time of remediation

Phosphate removal with time was shown in Figure 2. Among the aquatic pants tested Salvinia performed lowest reduction rate whereas the duckweed performed the highest reduction rate. Water hyacinth also performed higher reduction rate. During the absorption process Phosphate content decrease and it ranged from 6 mg/L to 2 mg/L.

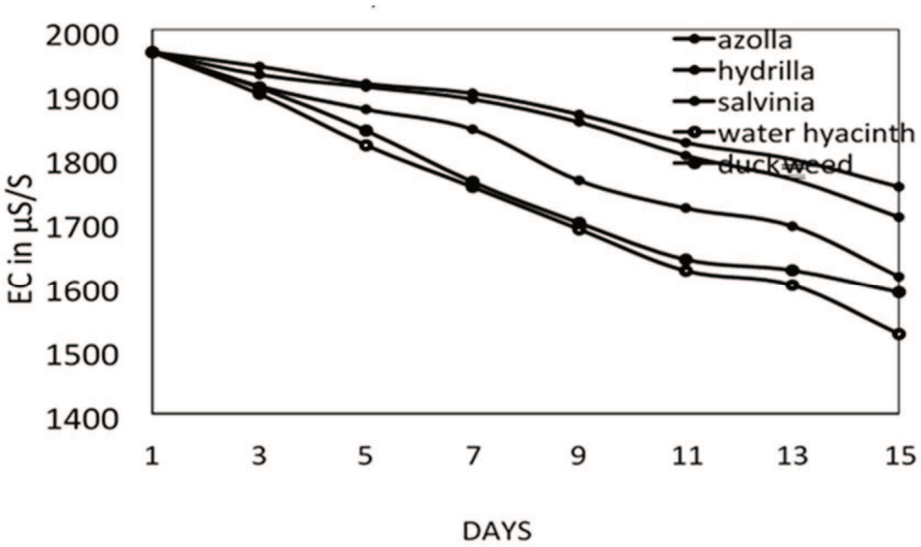


Figure 3: Variation in the electrical conductivity of the waste water in the time of remediation

The profiles of the Electrical conductivity in the phytoremediation process with selected aquatic plants was shown in Figure 3. Among the selected aquatic plant Water hyacinth and duck weed perform highest reduction rate. Whereas Salvinia performs lowest reduction rate compared to other aquatic plants. Study show that duckweed *(Lemna minor*) performed well.

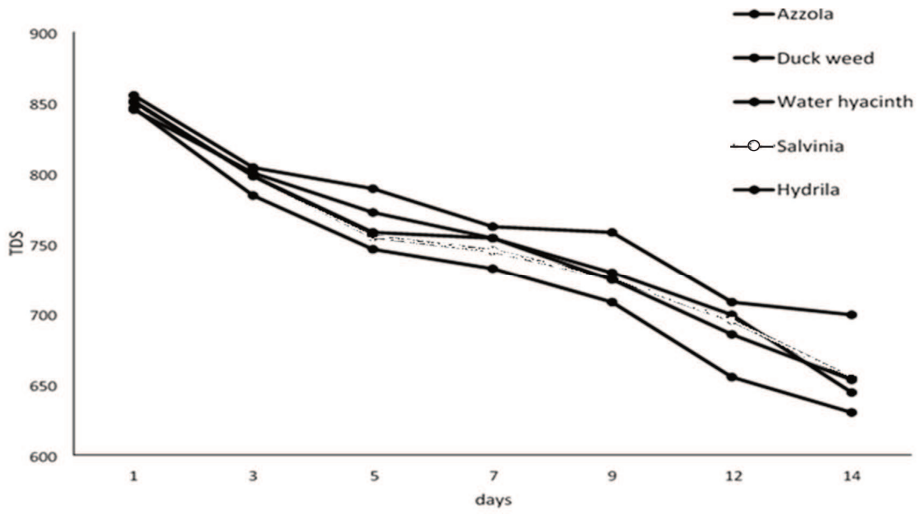


Figure 4: Changes in the total dissolve solid content of the waste water in the time of remediation

Figure 4 explained about the reduction in total dissolve solid content of the waste water. Water hyacinth perform highest reduction rate it ranged between 846 to 630 mg/l. Azola performs the lowest reduction rate than others plants. Duck weed also performs highest reduction than the other three plants. Water hyacinth is the efficient remover of the dissolve solid content among the selected aquatic plant.

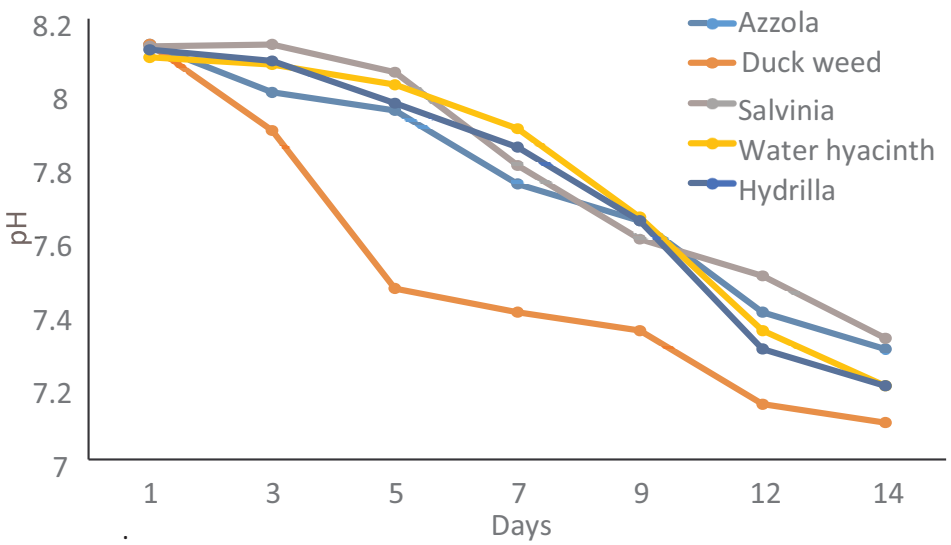


Figure 5: Changes in the pH content of the waste water in the time of remediation process

The pH of the environment has a profound effect on the rate of plant growth. pH affects the function of metabolic enzymes. Figure 5 showed the variation of pH in the phytoremediation treatment through the day. Based on that duck weed performs highest changes in pH, it reflect as near to natural. In addition to that hydrila and water hyacinth also perform the moderate changes. Salvinia perform the minimal change in the pH.

Conclusions

Among the Aquatic plants, Hyacinth, Duckweed, Salvinia, Azolla and Hydrila were purifying the waste-water in different range were estimated and analyzed. All the aquatic plants show better performance in water purification process. Through this experiment 87.5% of Nitrate, 67% of phosphate was absorbed by the aquatic plants and 25% reduction of EC and TDS was observed. Alkaline pH changes to neutral. Duckweed and Water Hyacinth are high removal efficiency and highest performance of survival among these plants. Azola performs the considerable reduction rate than others plants. Whereas Salvinia performs lowest reduction rate compared to other aquatic plants. In addition to that, hydrila performs the high reduction. In this study phyto-remediated waste water, which consists permissible level of pollutants can be used for the irrigation of farm plants without any physiological stress.

References

Abdul-Alghaffar, H. N. and Al-Dhamin, A.S. 2016. Phytoremediation of Chromium and Copper from Aqueous Solutions Using Hydrilla verticillata, *57*(1): 78–86.

Balcerzak, W. 2006. The protection of reservoir water against the eutrophication process. Pol J. of Environ. Stud, 15(6): 837-844.

Chislock, M.F., Doster, E. Zitomer, R.A. and Wilson, A.E. 2013. Eutrophication: Causes, consequences, and controls in aquatic ecosystems. Nature Education Knowledge, 4(4): 10.

Crawford. 2018. Wastewater Treatment by AzollaFiliculoides (A Study on Color, Odor, COD, Nitrate, and Phosphate Removal), 4(1), 69–76. https://doi.org/10.22059/poll.2017.236692.290

Prasad, M.N.V. and Freitas, H. 2003 Metal hyperaccumulation in plants - Biodiversity prospecting for phytoremediation technology. Electronic Journal of Biotechnology 6:275-321. Online electronic journal http://www.ejbiotechno logy.info/content/vo16/issue3/index. html

Jamshaid Iqbal. 1999. Phyto-remediation of dairy-waste water using constructed wetland. International Journal of Pharma and Bio Sciences, 3(3): 745-755.

Reemtsma, T., Weiss, T., Mueller, J., Petrovic, M., Gonzalez, S., Barcelo, D., Ventura, F. and Knepper, T. P. 2006, "Polar pollutants entry into the water cycle by municipal wastewater: a European perspective," Environ. Sci. Technol. 40 : 5451-5458.

Rizzo, L., Manaia, C., Merlin, C., Schwartz, T., Dagot, C., Ploy, M.C., Michael, I. and Fatta-Kassinos, D. 2013, "Urban wastewater treatment plants as hotspots for antibiotic resistant bacteria and genes spread into the environment: a review," Sci. Total Environ., 447:345-360.

Schwarzenbach, R.P., Escher, B.I., Fenner, K., Hofstetter, T.B., Johnson, C.A. and Wehrli, B. 2006, "The challenge of micro-pollutants in aquatic systems," Science, 313 : 1072-1077.

Topare, N. S., Attar, S. J. and Manfe, M. M. 2011 "Sewage/wastewater treatment technologies: a review," Sci. Revs. Chem. Common., 1 :18 – 24.

Journal of Dry Zone Agriculture, 2020, 6 (2): 97 - 104

ISSN 2012 – 8673

Testing and Evaluation of Double Layer Evaporative Cooler for Vegetables Preservation in North

Chamal, B.M., Prabhaharan, M. and Thusahanthy, A.
Department of Agricultural Engineering, Faculty of Agriculture, University of Jaffna, Sri Lanka.

Abstract: Sri Lanka is faced a problematic issue of post- harvest preservation and processing of agricultural produces. Introduction of cost effective method for storage of vegetables is necessary to maintain freshness until marketing. The evaporative cooling principle was introduced under the construction of cooling chamber system. Therefore low cost zero energy double layer cool chambers were designed using clay bricks, anthill clay. Space between double layers was filled with saw dust and charcoal separately and water circulated from top to bottom. The cool chambers were made to enhance the shelf life and minimize the weight loss of vegetables. Temperature and relative humidity inside and outside of chamber were measured in hourly intervals in day time. The samples of Spinach, brinjal and carrot were selected for evaluation. Weight loss was measured at hourly intervals to check the effectiveness of the design. Physiological weight loss for all selected vegetables was low for samples placed charcoal media cool-chamber than the saw dust media cool-chamber than outside. Evaporative cooler design tested by the regression analysis was implied to fit the relationship between log mean temperature ratio against time duration of cooling in saw dust media and charcoal media cool-chambers. The cooling rate (CR) was expressed by the equation, respectively. The relationship derived to charcoal media cool-chamber was $y= -0.015x + 0.063$ with regression value of R is 0.978 and saw dust media cool-chamber $y = -0.033x +0.079$ with regression value of R is 0.856. The cooling rate and efficiency were higher in charcoal as a filling media cooler. Since the regression value was more than 80%, in the both design. Design evaporative coolers are satisfied the requirements of safe storage.

Keywords: Evaporative cooler, Zero energy cooler, Double layer cool chamber.

Corresponding Author: M.Prabhaharan, aenpraba@gmail.com

Introduction

We all need vegetables in our daily requirements. Vegetables are perishable in nature so it grown and sold timely. When vegetable reaches the market it accommodate a lot of post-harvest process or operation like assembling, grading, storage, transportation and distribution. Huge postharvest losses can be minimized to a certain level by creating appropriate facilities for storage. Various types of storage structures and techniques have evolved with time to certify appropriate storage conditions. Most of them are still practiced to ensure safe storage and timely supply of vegetables. (Sharma, 2016).The respiration rate of a product strongly determines its postharvest life. The field heat of a freshly harvested crop is usually high, and should be removed as quickly as possible. Therefore, pre-cooling is depends in good temperature management. After harvest temperature is the single most important factor in maintaining quality in the storage of fruits and vegetables. The relative humidity is also important of the storage unit directly influences water loss in produce. Most fruit and vegetable crops retain better quality at high relative humidity (80–95 %). The cool temperatures in storage rooms help to reduce disease growth, but sanitation and other preventative methods are also required (Simon, O. and Odey, 2012).

Basically, evaporative cooling storage facility can extend the shelf life of vegetables for quite period of time if it is well designed and constructed. Evaporative cooling is the cheapest and simplest method as well as more efficient way for preserving vegetables (Kamaldeen *et al*., 2013). Evaporative cooling happens when dry hot air passes over a wet surface and the cooling efficiency depends on temperature, relative humidity and evaporation rate of the air around the facility (EL-dessouky *et al*., 2004). The evaporative cooled storage structure has proved to be useful for short term, on-farm storage of fruits and vegetables in hot and dry regions (Chopra, 2006). Good storage condition can be provided to vegetable produce through the use or adoption of evaporative cooling system. Consequently, there is need for simple and cheap means of preservation, such as evaporative cooling which is simple and does not require any external power supply (Tabrez and Chaurasia, 2014).

Specific Objective

To investigate the designperformance of double layer evaporative cooler for vegetables preservation.

Materials and Methods `

Site Selection for Experiment

The research was carried out at the Department of Agriculture Engineering, Faculty of Agriculture, University of Jaffna, Ariviyal Nagar, Kilinochchi, Sri Lanka.

Preliminary Data Collection on Meteorological Parameters

The study was conducted during January to July 2019. In Kilinochchi District varies from, mean monthly average rainfall in 12.5mm and 21.1mm , the average temperature /distribution is 23 ^{0}C and 26 ^{0}C and average relative humidity is 47% and 41%. Vegetables such as Brinjal, has high moisture content nearly 92% Spinach, Carrot has nearly 87% of moisture content and thin skin surface (Bastin, 1997).

Design Description

This research describes the improved design of cool chamber with its performance for preservation of vegetables with incorporation of locally available bio materials. In the initial study, a double walled cool chamber (double wall) based on evaporative cooling principle was constructed (Chaurasia *et al.,* 2002). The cool chamber utilized the water evaporation from the surrounded walls (vertical walls only) for the reduction of temperature hence which maintains high humidity. The data of temperature and humidity were recorded in different periods.

The cool chamber was also tested for storage of vegetables as compared to store in room. Further design of the cool chamber was improved by making the holes in both chambers by using drillers. These holes increased the evaporation rate of the cool chamber for faster cooling. Provisions were also made for water evaporation from both side of the cool chamber by providing suitable paths which further enhanced temperature reduction and retained high humidity in the chamber. Two cuboids double layer cooling chamber were built with same dimensions on the stage using clay and clay bricks. They were like tanks but they had double layers and there was spacing in between of double layers. The spacing between walls was filled with Sawdust for one cooling chamber and other chamber with Charcoal. The drainages were made on the top of those insulate materials to supply water.

Foundation of Cool Chambers

The shed was constructed using black polyphone and white gunny bags. The frame of the shed was made using box bar and wooden. This structure was permanently built using clay bricks with clay floors. First floor was built using one layer of bricks. Basement was built with length, width and height 210, 110 and 10 cm respectively. Outside of the basement was covered by clay. Both of cool chambers were built above the clay stage.

Double Layer Brick Wall

Clay bricks were used to build double layer walls. Clay bricks are having good properties of high porosity, good heat absorber and good surface for evaporation, and also easily available and cheap. The

height of walls are 50 cm. 10 cm gap was madebetween inside and outside walls. Sawdust and charcoal was filled the gap between the vertical walls up to 50 cm. The walls were constructed by using clay instead cement. It was graphically explained in Plate 1

Plate 1: Fabricated double-Layer evaporative Cool-Chambers

Sample Selection and Preparation

The chamber was sterilized by 200 ppm chlorinated water. Water was supplied to the cool chamber two times per day, 10 minutes is enough to saturate the porous layers by water circulation. Sample were stored as two methods in both of cool chambers separately. Samples were wrapped using wrapping papers. Other samples were kept without wrapping. Three replicates were used for both methods to correction of data analyzing.

Temperature and Relative Humidity Measurement

The temperature was measured by using wet and dry bulb thermometers. The temperature at all places in the Cool-Chamber was at the same time measured. The temperature at the middle layer was used as the inside temperature. The thermometer was placed at outside the cool chamber to measure outside temperature. The relative humidity of the Cool-Chamber was measured using "Psychometric Chart". All the temperatures were recorded at an hourly interval from 8.00 am to 5.00pm.

Determination of the Physiological Weight Loss (PWL)

Vegetables were kept in cool chambers as 2 types such as wrapping and unwrapping. Rapping polythene papers were used to rapping the vegetables. Digital electronic balance was used to get weight of vegetables. The readings were collected as daily interval. Charcoal and sawdust chambers data were collected separately.

Physiological Loss in Weight = (X1-X)/X1*10

Where *X1*- Initial weight of vegetable (g), *X*- Weight of vegetable at the next day (g).

The brick layers filled with saturated charcoal and sawdust were supplied moisture therefore inside air is saturated by water vapour coming from saturated charcoal and saw dust. It helps to keep inside air cool. The atmospheric relative humidity did not affect the chamber relative humidity. RH values are calculated normally using below equation.

$$\text{Relative Humidity} = \frac{\text{Amount of moisture in the cool chamber (m)}}{\text{Maximum amount of moisture that could exist in the Cool Chamber at a speci*ic temperature (M)}}$$

Temperature Ratio (CR)

Temperature ratio (CR) was calculated against proper time interval during cooling operation using flowing equation. The cooling rate was expressed by slope of the equation respectively. The regression vale was explained the efficiency of cooling.

Temperature Ratio (CR)= (Temperature at time (Db) – Ambient Tem (Db)) / (Initial Tem(Db)) - Ambient Tem (Db))

Results and Discussion

Temperature and Relative Humidity Variations

The relationship between temperature profile inside of cool chambers and ambient condition during experimental period (Figure 1 and 2). The temperature difference was high during noon because of high external temperature due to high solar intensity. Range of average temperatures inside Cool-Camber varied from 22°C to 24°C while ambient air temperature varied from 24°C to 31°C. Around 2 – 7^{0}Ctemperature gradient was recorded in sawdust mediacoolers throughout the experiment Figure 2.Range of average temperatures inside charcoal media Cool-Camber varied from 22°C to 24°C while ambient air temperature varied from 21.4°C to 22.5°C. Around 2.6 – 8.5°C temperature gradient was recorded throughout the experiment Figure 3.

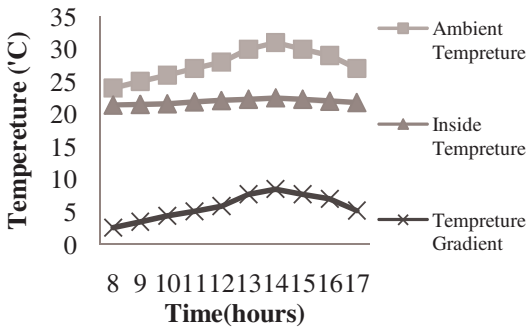


Figure 1: Temperature profile in sawdust cool-chamberand ambient condition

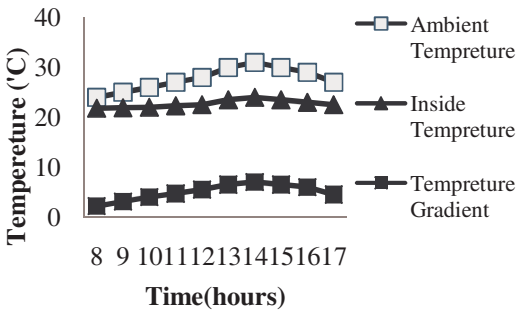


Figure 2: Temperature profile in charcoal cool-chamber and ambient condition.

Variation of Relative Humidity and RH Gradient in Saw Dust and Charcoal Chamber

The relative humidity of inside the Cool-Chamber varied from 85.75% to 94.89 % .while the outside RH varied from 79.41% to 91.96%.The RH gradient between inside and outside the sawdust Cool-Camber was found to be 2.93 % to 10.48%. These differences are shown in Figures 3 and 4. The Cool-Chamber inside relative humidity varied from 94.15 % to 97.43 % .while the outside RH varied from 79.41% to 91.96%. The RH gradient between inside and outside of the charcoal media Cool-Camber was found to be 3.73 % to 15.63%.

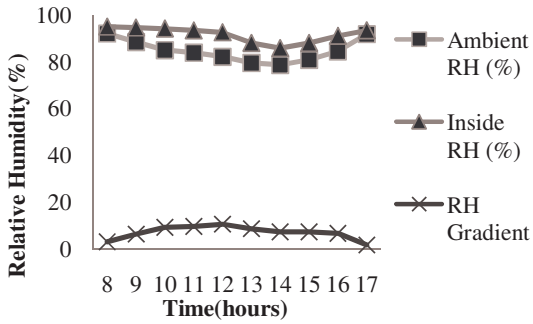


Figure 3: Relative Humidity in sawdust cool-chamber and ambient condition.

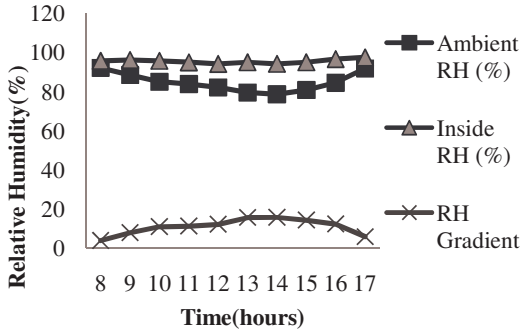


Figure 4: Relative humidity in charcoal cool -chamber and ambient condition

Physiological Weight Loss

Average weight loss of sample kept in Saw dust chamber is significantly different from the sample kept under Charcoal Chamber. Since there is a temperature difference between Cool-Chamber and ambient, weight loss of samples kept under restricted condition is low and this gives for samples fresh in appearance. Relationship between average weight loss percentage and keeping time kept under Saw dust and Charcoal Chambers. Significant difference in found in losses in weight between samples stored in Saw dust and Charcoal Chambers. When wrapped, the vegetables moisture loss of vegetables became low (Figure 5).

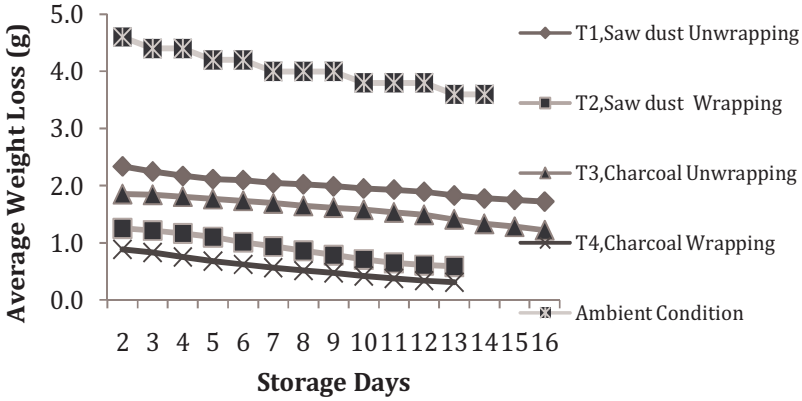


Figure 5: Weight losses pattern of selected Vegetables

When without wrapping condition Vegetables shelf life was increased than wrapping condition. Loss of moisture content is high at sawdust media cool-chamber Loss of moisture content is high at sawdust media cool-chamber, without wrapping in the beginning of storage due to fast respiration rate. It leads to higher weight loss percentage and it reduces thereafter due to the reduction in moisture content. Weight loss percentage of vegetables is nearly constant in both of chambers due to proper conditions for storage developed by water circulation.

Evaporative Cooler Performance Analysis of Saw Dust and Charcoal Media Chamber

The cooling rate was calculated by slope of the equation respectively (Figure 6 and 7). The regression vale was explained the efficiency of cooling. The relationship derived to charcoal media cool-chamber was $y = -0.015x + 0.063$ with regression value of 0.978 and saw dust media cool-chamber $y = -0.033x + 0.079$ with regression value of 0.856.The cooling rate and efficiency of cooling was high charcoal as filling media within double layer coolers. Since the R^2 value was more than 80%, the efficiency and design satisfy the requirement of dryer.

an evaporative cooling system for the preservation of fresh vegetables. African Journal of Food Science, 5(4) : 255-266.

Sharma, D. 2016. Analysis of post-harvest losses of vegetables with special reference to Jabalpur regulated market. JNKVV, 254-265.

Seth, I. M., Simon, O. and Odey. 2012. Evaluation of Pads and Geometrical Shapes for Constructing Evaporative Cooling System. Canadian Center of Science and Education : 120-135.

Thakur, B.C. and Dhingra, D.P. 1983. Parameters Influencing the Saturation Efficiency of an evaporative Rusten Cooler" University of Glasgow College of Agriculture Bulletin. No.115 : 56-65.

Thompson, F., Mitchell, F.G., Runsey, T.R., Kasmire. R.F. and Crisosto, C.H. 1999. Commercial cooling of fruits, vegetables, and flowers. UC Davis DANR Publications, 21: 56-61.

Umbarker, S.P, Bond, R.S. and Kalase M.N. 1991. Evaporative cooled storage stature for oranges (citrus), Indian J. Agric. Eng., 1(1): 26-32.

William Adebisi, Olosunde, Igbeka, J.C. and Taiwo Olufemi Olurin. 2009. Performance Evaluation of Absorbent Materials in Evaporative Cooling System for the Storage of Fruits and Vegetable. International Journal of Food Engineering, 1240-1255.

Journal of Dry Zone Agriculture, 2020, 6 (2): 105 - 116

ISSN 2012 – 8673

Farm-Level Adaptation to Climate Change and Impacts on Household Food Security: Evidence from the Dry Zone of Sri Lanka

Sithumini, S.D.P., Udugama, J.M.M. and Guruge, T.P.S.R.
Department of Agribusiness Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka.

Abstract: Climate change can have detrimental impacts on rural agricultural households. Farmers all over Sri Lanka are seen adopting numerous strategies to face the impacts of climate change. Climate change poses considerable challenges to all four dimensions of food security. Therefore, this study aims to explore climate related factors affecting the level of household food security of rural farmers. The study was conducted with 110 farmer families in the district of Anuradhapura. Data were collected through a structured questionnaire-based survey over a period of four months along with field observations. An ordered logistic regression was carried out in order to find out the influence of climate change adaptation and other related factors at farm-level on the household food security. Household food insecurity access scale was used to categorize the sample into different levels of food security. Results show that farmers who adopted climate change strategies are more food secure compared to those who did not adapt. Exposure to climate change and strong social networks also have a positive influence in leading these households to a higher level of food security. Certain socio-demographic factors such as the farmer's level of education and being a male-headed household were also positively associated with food security. The study therefore emphasizes the importance of stronger policies that can enhance farmer adaptation strategies through better accessibility to endowments such as alternative livelihoods, stronger social networks, awareness and better education for agricultural households.

Keyword: Climate change, Farm-level adaptation, Food security, Household

De Silva *et al*., 2007; Peiris *et al*., 2004; Wijeratne *et al*., 2007) while some have attempted to quantify the impacts in terms of yield loss and economic loss (Diyawadana *et al*., 2016; Fernando *et al*., 2007; Kalim, 2015; Seo *et al*., 2005; Wijeratne *et al*., 2007). The findings show that climate change impacts on the agricultural sector in Sri Lanka can be significantly reduced through appropriate adaptation strategies. Further, according to Esham and Garforth (2013), farmers perceive the ongoing climatic changes based on their experiences and take measures to address climate change and variability in five main categories i.e. crop management, land management, irrigation management, income diversification, and rituals.

Climate change has abundant impacts on food security. Food security refers to a situation that exists when all people at all times have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2006). Later the definition was conventionally subdivided into four main components i.e. (a) food availability: physical presence of food, (b) food access: ability of acquisition through production or purchase, (c) food utilization: the appropriate nutritional content of the food and the ability of the body to use it effectively and (d) stability: all four above dimension should be enduring without any fluctuations over time (FAO, 2011).

strategies at farm level. Thus, the purpose of the present study is to explore the influence of climate change adaptation at farm-level on the household food security. Specifically, the objectives of the study are: 1) to measure the degree household adaptation to climate change 2) to determine the relationship between food security and climate change adaptation in the farmer households and; 3) to make recommendations on effective interventions of government bodies and local farmer communities in the face of climate change.

Agriculture, Climate Change and Food Security in Sri Lanka

Agriculture is a vital sector in the Sri Lankan economy due to its significantly large contribution to the Gross Domestic Product and foreign exchange earnings. Agriculture plays a central role in ensuring food security. It could be seen that livelihood strategies of the most food insecure households in Sri Lanka are based on agriculture. Increasing impacts of climate change have threatened the agriculture sector thereby largely affecting the food security. Climatic changes such as increasing temperature, rainfall, floods as well as prolonged period of droughts have had detrimental effects on the staple food; rice as well as other crops. Unless climate challenges are met with proper adaptation and mitigation measures, agricultural production in the future is at stake resulting in serious challenges for the rising population.

Methodology

Data

Anuradhapura district in the dry zone is largely affected by drought and irregular patterns of rainfall. Agricultural production in the dry zone, particularly paddy is very much dependent of rainfall and availability of irrigation water. Thus, climatic changes can pose severe impacts of household food insecurity (Ministry of Environment, 2011). Anuradhapura district therefore was selected to collect data.

A pilot study was carried out with ten paddy farmer households selected from Thulana Grama-Niladhari (GN) Division in Rambawa Divisional Secretariat (DS) division. Ten farmer households were interviewed in order to gather the information. Initial questionnaire was revised using the gathered information. Sampling framework consisted of n=110 farmer households collected from five GN divisions in the Anuradhapura District. A stratified sampling technique was used to select the sample of farmers. The questionnaire was administered among the households. Pilot questionnaire was revised before eth actual survey.

The survey gathered information regarding household demographics; food availability; characteristics of the household; food consumption; dietary diversity; agricultural production; income and expenditure of the household. It posed several questions pertaining to how climate change was

HFIAS set of questions first poses an occurrence question. For example, "whether the condition of one of the four food security dimensions happened at all in the past four weeks". The respondents are given an option of yes or no as the answer. For example, whether in the past four weeks, have you had to worry that your household would not have enough food? If the respondent answers "yes" to an occurrence question, a frequency is then presented to determine whether the condition happened rarely (once or twice), sometimes (three to ten times) or often (more than ten times) in the past four weeks (Coates *et al*., 2007). A score, herein termed as HFIAS score was calculated from the set of statements. This score was used as the measure of the degree of food insecurity. The HFIAS score variable is calculated for each household by summing the codes for each occurrence question (Coates *et al*., 2007).

The four levels were categories according to the scores given for each question in the questionnaire (Table 1). According to this categorization, each household will be placed in one category.

1 = Food Secure
2 = Mildly Food Insecure
3 = Moderately Food Insecure
4 = Severely Food Insecure

HFIA category = 1 if [(Q1a=0 or Q1a=1) and Q2=0 and Q3=0 and Q4=0 and Q5=0 and Q6=0 and Q7=0 and Q8=0 and Q9=0]

A food secure household experiences none of the food insecurity conditions (Table 1). A mildly food insecure household worries about not having enough food sometimes or often, is usually unable to eat preferred foods, and/or eats a more monotonous diet than desired. But it does not cut back on quantity. A moderately food insecure household sacrifices quality of the meal more frequently, by eating a monotonous diet or undesirable foods sometimes or often and has started to cut back on quantity by reducing size of meals or number of meals, rarely or sometimes. A severely food insecure household has a tendency to cut back on meal size or number of meals often, and usually experience running out of food, going to bed hungry most of the days.

Factors that could affect the level of food security were explored using logit regression. These factors included degree of climate change adaptation, exposure to climate change and social network of the respondents. A set of statements reflecting each factor was included in the questionnaire and each statement was presented with a five-point Likert scale ranging from strongly agree (+1) to strongly disagree (+5). An index was calculated for each factor using the responses given for the statements on the Likert scale

Data Analysis

The relationship between the degree of household food security and the influencing factors was analysed using an Ordered

according to the HFIAS scale (Bilinsky *et al*., 2007). The regression model can be specified as below;

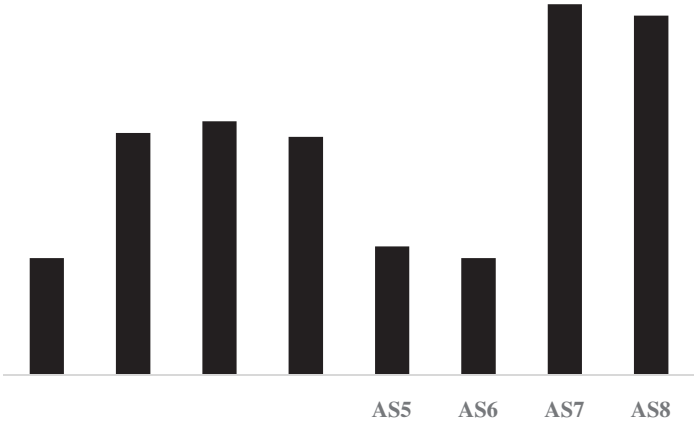
Where, dependent variable is the category of household food security (FSH) and the independent variables are; Social Network Index (SNI), Climate Change Adaptation Index (CAI), Exposure to Climate Change Index (ECI), Educational Level of the household head (EDL), Gender (GND), Household Income (HHI) and Type of Livelihood (LHT). The variables, CAI, ECI, SNI were included as indices.

Variables CAI, ECI and SNI were index values ranging from 0 to 1 where as gender, level of education, household income and age were included in the model as dummy variables. Indices were computed from responses on the scale.

Results and Discussion

Descriptive Statistics

Majority of the respondents in the sample were male (86%) and were in the age category, 40 - 60 years (63%). Nearly 47 % of the farmers had secondary education. Majority of the farmer households earned more than Rs. 60,000 per month. The sample consisted of 68% farmers who practiced climate change adaptation strategies. If a farmer practices more than eight strategies, the particular households was considered as an "adaptive" household.



Adaptation Strategy

		3.101	0.000**
		3.050	0.000**
CAI	-9.103	2.832	0.001**
ECI	-11.366	3.346	0.001**
		1.607	0.017**
		0.631	0.000**
	19.594	0.565	0.000**

households. Results show that the farmers who adapted climate change strategies were more likely to be food secure compared to those who did not. Furthermore, it was shown that climate change exposure was also a determinant of food security. Having a stronger social network strengthens the ability of a households' adaptive capacity thereby increasing the possibility of being food secure. Social networks also have a direct impact on food security as well. Results also show that socio demographic factors such as education can also influence the level of food security over most other factors.

Therefore, this study suggests policies to promote the adoption and practice of climate change adaptation strategies among rural farmers also as a mean of ensuring food security. It is imperative to increase the awareness about the importance of adaptation to climate changes, food security as well as the interrelationships. As the results revealed, education plays a vital factor in increasing the adaptive capacity as well as food security. Therefore, the government policies should pay more attention to awareness and education on the four dimensions of food security.

Another policy consideration could be to increase the capacity of adaptation, both in terms of climate change as well as food security challenges. Awareness and investment on coping strategies is key for these rural households. As the results show, strengthening the social networks

of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*. 19(2): 248–255.

De Silva, S.S., Abery, N.W. and Nguyen, T.T.T. 2007. Endemic freshwater finfish of Asia: distribution and conservation status. *Diversity and Distribution*. 13:172–184.

Diyawadana, D., Pathmarajah, S. and Gunawardena, E.R.N. 2016. Perception-driven Coping Strategies for Climate Change by Smallholder Farmers in Sri Lanka: A Case Study in Hakwatuna- oya Major Irrigation Scheme. *Tropical Agricultural Research*. 27: 336-349.

Esham, M. and Garforth, C. 2013. Climate change and agricultural adaptation in Sri Lanka. *Climate and Development*. 5(11): 66-76.

FAO. 2006. World Agriculture: Towards 2030/2050 – Interim Report. Chapter 2. Food security: concepts and measurement. Global Perspective Studies Unit, FAO, Rome, Italy.

FAO. 2011. The State of Food Insecurity of the World: How Does International Price Volatility Affect Domestic Economies and Food Security? FAO, WFP, IFAD, Rome, Italy.

Fernando, M.T.N., Zubair, L., Peiris, T.S.G., Ranasinghe, C.S. and Ratnasiri, J. 2007. Economic value of Climate Variability Impacts on Coconut Production in Sri Lanka. *AIACC Working Paper* No. 45. 1-9.

Fischer, G., Shah, M., Tubiello F.N. and Velhuizen, H.V. 2005. Socio-economic and climate change impacts on agriculture. *Philosophical transactions of the Royal Society*. 360: 2067-2083.

Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C. 2006. *Multivariate data Analysis with Readings*, Englewood Cliffs, New Jersey: Prentice Hall.

Henson, S. and Traill, B. 2000. Measuring perceived performance of the food system and consumer food-related welfare. *Journal of Agricultural Economics*. 51(3): 388 – 404.

Hertel, T.W., Burke, M.B. and Lobell, D.B. 2010. The poverty implications of climate-induced crop yield changes by 2030. *GTAP Working Paper* No. 59.

Hillig, Z. and Connell, J. 2018. Social capital in a crisis. *NGO Responses to the 2015 Nepalese Earthquakes, Asia Pacific Viewpoint*. 59(3): 309–322.

Jayasinghe-Mudalige, U.K and Udugama, J.M.M. 2014. Motives for Firms to Adopt Solid Waste Managmement Controls: The Case of Food Processing Sector in Sri Lanka. *Journal of Environmental Science and Management*. 17(1): 28-37.

Kalim, U. and Shah, H.B.D. 2015. Household capacity to adapt to climate change and implications for food security in Trinidad and Tobago. *Reg Environ Change*. 15:1379-1391.

Ministry of Environment in Sri Lanka, 2011/2012. *National Climate Change Adaptation for Sri Lanka 2011 to 2016*. Colombo, Sri Lanka. DOI:http: //dx.doi.org / 10.4038/jnsfsr.v38i2.2032.

Nakamura, M., Takahashi, T. and Vertinsky, I. 2001. Why Japanese firms choose to certify: a study of managerial responses to environmental issues. *Journal of Environmental Economics and Manag ement.* 42: 23-52.

Peiris, T.S.G., Wijeratne, M., Ranasinghe, C.S., Aanadacumaraswamy, A., Fernando, M.T.N., Jayakody, A. and Ratnasiri, J. 2004. Impact of Climate Change on Coconut and Tea Industry in Sri Lanka. Paper presented at 2nd AIACC Regional Workshop for Asia and the Pacific, Manila, Phillipines. 2-5

Shavell, S. 1987. Economic Analysis of Accident Law, Cambridge: Harvard University Press.

Seo, S.N., Mendelsohn, R. and Munasinghe, M. 2005. Climate Change Impacts on Agriculture Sri Lanka, Environment and Development Economics, 10:581 - 596.

Wijeratne, M. A., Anandacoomaraswamy, A., Amaratunge, M.K.S.L.D., Ratnasiri, J., Basnayake, B.R.S.B., Kalra, N. 2007. Assessment of Impact of Climate Change on Productivity of Tea (*Camellia sinensis* L.) Plantations in Sri Lanka. *Journal of the National Science Foundation of Sri Lanka*. 35(2): 119-126.

Journal of Dry Zone Agriculture, 2020, 6 (2): 117 - 128

ISSN 2012 – 8673

Farmers' Adaptation to Irrigation Water User Allocation: The LCC Irrigation System in Pakistan

Culas, R.J.
School of Agricultural and Wine Sciences, Charles Sturt University, Australia.

Abstract: Pakistan is facing the challenge to cope with decreasing agricultural productivity due to poor water quality (salinity) along the irrigation canal systems. Reallocation of water use between the head, middle and tail reaches of the distributaries in the canal systems can improve the groundwater quality (minimize salinity) as well as maximize crop productivity. This study employed a discrete choice model for analysing the socioeconomic and technological factors that can influence the farmers' adaptation to reallocation of water use (under an optimal water use scenario). Based on farm survey data collected during 2010 and 2012 cropping seasons at the Lower Chenab Canal (LCC) irrigation system in Pakistan, the following question was analysed *Can installation of tube wells at the head reach of the system to extract more groundwater help address the problem of poor water quality at the tail reach?* It was found that farmers who have more resources (land holding), experienced (aged) and membership with farmer organisation recognised the need to have more water, available for redistribution, through more groundwater extraction at the head reach of the system. Further the respondents in the study area were also asked to rank the options available to the farmers that can potentially improve their adaptation for the optimal water use scenario (reallocation). The ranking of the options indicated that majority of the farmers think that the best solution to the problem of water scarcity and its quality lies in water reallocation.

***Keywords*:** Groundwater, Water allocation, Farmers' adaptation, PROBIT model, Pakistan

groundwater tables are falling in these areas with a risk of saline water intrusion into fresh water aquifers which could make groundwater as unusable for irrigation.

Agricultural productivity in Pakistan is relatively low compared to other countries and it is limited by availability of sufficient water and its quality. The main sources of water for agriculture are rainfall (10 - 20%), cannel (surface) water (40%) and groundwater (40-50%). However, water scarcity is a major issue in Pakistan due to increased crop intensity which results in over extraction of groundwater, deepening of groundwater table and saline water intrusion. The issues confronted in relation to irrigation management are estimating (net) water availability, equitable distribution of water, and incentives/policy instruments for capacity building of the water sector and farmers. Groundwater management issues are both technical and legal, but they cannot be dealt without properly understanding the socioeconomics of farmers, their perspectives and the benefits involved. In Pakistan farmers have ownership of tube wells, however since groundwater is a common property resource, the Government can facilitate its management towards sustainable use.

An economic modelling approach for different water use scenarios have been developed to address the problem of inequality in water use and the impact of

up for the following question (dependent variable), *Can installation of tube wells at the head reach of the system to extract more groundwater help address the problem of poor water quality at the tail reach?* The results are discussed in relation to various socioeconomic and technological factors (explanatory variables) that can improve the current water use pattern and for the farmers' adaptation behaviour towards more equitable and sustainable water use practices.

Methodology and Data Analysis

The study area is in Punjab province, Pakistan and situated in the Lower Chenab Canal (LCC) irrigation system (Figure 1).

A baseline socioeconomic survey of irrigators along the head, middle, and tail reach of the LCC East irrigation system was conducted during 2010-11 and 2012-13 cropping sessions, respectively, as part of an ACIAR funded project (Culas *et al*., 2015). Three distributaries of the LCC East irrigation system, namely, Bhalak, Tarkhani, and Khikhi have been selected for the head, middle and tail reaches, respectively.

Table 1 presents the optimal water use scenario designed for the redistribution of water allocation following the economic modelling approach reported in Culas and Baig 2020, The optimal scenario suggests that when water use can be reallocated in terms of the percentages given for the canal and ground water, the

Figure 1: Location of the selected distributaries in the LCC East irrigation system

respectively. Whereas the optimal water use scenario implies that more groundwater should be used at the head distributary (30:70) and more canal water should be used at the tail distributary (70:30).

Table 1: Optimal water use scenarios (base scenarios are given in brackets) (%)

PROBIT models have been employed in a number of studies where the dependent variable is dichotomous in nature. For example, Bhandari and Pandey (2006) used PROBIT model to study the adoption of shallow tube wells in Nepal Terai; Khair *et al.* (2012) analysed PROBOT models to study the socioeconomic characters of farmers and groundwater markets in Balochistan, Pakistan.

Empirical Model and the Results

The empirical model analysed is detailed below. Farmers' response was recorded in terms of a binary response variable taking the value of '1' and '0' (as dependent variable). The models contain a list of explanatory variables where some of them are qualitative variables constructed in shape of dummy variables while the others are quantitative variables.

to adopt water-smart practices for groundwater management (Hussain *et al*., 2017; Zulfiqar and Thapa, 2018; Imran *et al*., 2019). Respondents were given multiple options to choose between them. Respondents who were using these technolo gies or ready to use these technologies were given the value '1' while rests of the respondents were given value '0'.

DACM: This is a quantitative variable developed from an index based on the ranking of the information sources (media) used by respondents. If respondent scored three or more, he was assigned a value '1' indicating access to the media while respondents scoring less than three were assigned a value '0' indicating no access to the media. In India, a positive and significant relationship between access to information and farm income was reported by many researchers (Birthal *et al*., 2015; Aryal *et al*., 2018; Sapkota *et al*., 2018) and Pakistan (Abid *et al*., 2015; Culas *et al.*, 2016).

DFO: Farmer organization were introduced in the area to take care of the operation and maintenance of the irrigation channels (from distributary to canal onward) in different irrigation circles in Punjab. These organizations were meant to make farmers responsible for handling the water related issues and can serve as a good proxy for the level of social responsibility and interaction among the farmers (Culas *et al.*, 2016; Aryal *et al*., 2018). So if the farmer was a

variables included in the analysis are explained below.

AGE: Age of the farmer is an important socioeconomic variable which has been widely used in the economic analysis to capture the social status of the respondent (Culas *et al*., 2016; Hussain *et al*., 2017; Abbas *et al*., 2017; Aryal *et al*., 2018). Many researchers have already explained the role of the age in decision making process and ability of the respondent to adapt to the changes. Age of farmer (in years) is used as a proxy for the experience of the farmer.
NSYEAR: Education has widely been accepted as a pivotal factor in influencing the adaptation, decision making and management skills of the respondent (Abbas *et al*., 2017; Aryal *et al*., 2018). Number of schooling years of the respondents was included in the analysis as a proxy for education.

FSZE: Family size is another important social indicator that has been included in the analysis. The impact of family size on behaviour and adaptation pattern has already been reported in literature ((Mponela *et al.*, 2016, Nkomoki *et al*., 2018; Kharti-Chhetri *et al*., 2016; Imran *et al.*, 2018). Number of the dependent family member of the respondents has been included in the analysis to capture their impact on the dependent variable.

LANDHOLDING: The other important variable that was included in the analysis was the size of operational land holding

The results for the PROBIT model are given in Table 3. The results are presented in relation to various socioeconomic factors that can potentially improve the current water use patterns and farmers' adaptation towards more equitable and sustainable water management practices in relation to the optimal water use scenario (reallocation) detailed above.

Estimates [b]		
Std. Error	**Z**	**Sig.**
.087	-1.369	.171
.063	1.312	.190

also asked to rank the alternative options (choices available) for improvement in the base scenario water use pattern if it was unacceptable to them. Six different options to improve the water distribution were offered to the respondents so that the equity issue in water use among the distributaries can be addressed. These options were ranging from less canal water use at the head distributary to water trading and pricing option.

Table 4 presents the ranking of the options offered to the farmers based on their opinion. The table is only showing the first ranked option by the respondents. The ranking shows that majority of the farmers think that the best solution to the problem of water scarcity and distribution in water use lies in water reallocation (Mekonnen *et al.,* 2016).

Table 4: Ranking options offered to the farmers

	Tarkhani		Khikhi		Total	
k	%	Rank	%	Rank	%	Ra

district in Pakistan. *Renewable Energy.* 107: 431-439.

Abid, M., Scheffran, J., Schneider, U.A. and Ashfaq, M. 2015. Farmers' perceptions of and adaptation strategies to climate change and their determinants: The case of Punjab province, Pakistan. *Earth System Dynamics.* 6:225-243.

Aryal, J.P., Rahut, D.B., Maharjan, S. and Erenstein, O. 2018. Factors affecting the adoption of multiple climate-smart agricultural practices in the Indo-Gangetic Plains of India. *Natural Resources Forum.* 42: 141-158.

Bhandari, H. and Pandey, S. (2006). Economics of groundwater irrigation: Some farm level evidences. *Journal of Agricultural and Applied Economics.* 38(1): 185-199.

Birthal, P. S., Kumar, S., Negi, D. S. and Roy, D. 2015. The impacts of information on returns from farming: Evidence from a nationally representative farm survey in India. *Agricultural Economics*. 46(4): 549-561.

Culas, R.J. and Baig, I. A. 2020. Impacts of irrigation water user allocation on water quality and crop productivity: The LCC irrigation system in Pakistan. *Irrigation and Drainage*. 69: 38-51.

Culas, R.J. 2019. User allocation and implica tion on water quality and farm

climate smart agriculture (CSA) through sustainable irrigation management on Resource use efficiency: A sustainable production alternative for cotton. *Land Use Policy.* 88: 104113.

Imran, M.A., Ali, A., Ashfaq, M., Hassan, S., Culas, R. and Ma, C. 2018. Impact of climate smart agriculture (CSA) practices on cotton production and livelihood of farmers in Punjab, Pakistan. *Sustainability.* 2018: 1-20.

Kanwar, R. 2010. Sustainable water systems for agriculture and 21st centruy challenges, in: Kang, M. S., (Eds.), Water and Agricultural Sustainability Strategies. Taylor and Francis Group, London, 3-19.

Khair, S. M., Mushtaq, S., Culas, R. and Hafeez, M. 2012. Groundwater markets under the water scarcity and declining water table conditions: The upland Balochistan region of Pakistan. *Agricultural Systems.* 107(1): 21-32.

Kharti-Chhetri, A., Aryal, J. P., Sapkota, T. B. and Khurana, R. 2016. Economic benefits of climate-smart agricultural practices to smallholder farmers in the Indo-Gangetic Plains of India. *Current Science*. 110: 1251-1256.

Mekonnen, D. K., Siddiqi, A. and Ringler, C. 2016. Drivers of groundwater use and technical efficiency of groundwater, canal water, and conjunctive use in Pakistan's

Pakistan, *Science of the Total Environment*. 666, 849-857.

Rosenzweig, M. R. and Evenson, R. 1977. Fertility, schooling, and the economic contribution of children of rural India: An econometric analysis, *Econometrica*. 45(5): 1065-1079.

Sapkota, T.B., Jat, M. L., Aryal, J. P., Jat, R.K. and Khatri-Chhetri, A. 2015. Climate change adaptation, greenhouse gas mitigation and economic profitability of conservation agriculture: Some examples from cereal systems of Indo-Gangetic Plains. *Journal of Integrative Agriculture*. 14: 1524-1533.

Tiwari, D. N., Loof, R. and Paudyal, G. N. 1999. Environmental–economic decision-making in lowland irrigated agriculture using multi-criteria analysis techniques. *Agricultural Systems*. 60(2): 99-112.

Zulfiqar, F. and Thapa, G. B. 2018. Determinants and intensity of adoption of "better cotton" as an innovative cleaner production alternative. *Journal of Cleaner Production*. 172: 3468-3478.

Dr. (Mrs) PABN Perumpuli, Dept of Food Science and Technology, Faculty of Agriculture, University of Ruhuna, Sri Lanka

Dr. (Mrs) S.H.P. Malkanthi, Department of Agribusiness Management, Faculty of Agriculture, Sabaragamuwa University of Sri Lanka.

Dr. (Mrs). C.A.K.Dissanayake, Department of Animal and Food Science, Faculty of Agriculture, University of Rajarata, Sri Lanka.

Dr. (Mrs). D.M.S.H. Disanayaka, Department of Agricultural Engineering and Soil Science, Faculty of Agriculture, University of Rajarata, Sri Lanka.

Dr. (Mrs). Kusum Wijesinghe, Department of Agribusiness Management, Faculty of Agriculture & Plantation Management, Wayamba University of Sri Lanka.

Dr. (Mrs).S.D.S.Hemachandra, Department of Agricultural Economics & Business management, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

Dr. (Mrs.) J. Nimalan, Department of Bio Science, Faculty of Applied Science, Vavuniya Campus, Sri Lanka.

Dr. (Ms). P.Korale Gedara, Department of Agricultural Economics & Business management, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

Dr. (Ms).S.A.C.N. Perera, Department of Agricultural Biology, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

Dr. A.D. Ampitiyawatta Asanga, Department of Export Agriculture, Faculty of Agricultural Sciences, Subragamuwa University of Sri Lanka.

Dr. D.M.S.B. Dissanayaka, Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

Dr. K.H Sarananda, Department of Biosystems Engineering, Faculty of Agriculture & Plantation Management, Wayamba University of Sri Lanka, Sri Lanka.

Prof. D.P.S.T.G Attanayaka, Department of Biotechnology, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka.

Dr. K.M.C. Fernando, Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Sri Lanka.

Dr. M.G.P.P. Mahindarathne, Department of Export Agriculture, Faculty of Animal Science and Export Agriculture, Uva Wellassa University, Sri Lanka

Dr. M.W.A.C.S. Wijetunga, Department of Export Agriculture, Faculty of Animal Science and Export Agriculture, Uva Wellassa University, Sri Lanka

Dr. Mrs. Niranjana Rodney Fernando, Department of Agricultural Biology, Faculty of Agriculture, Eastern University, Sri Lanka.

Dr. P. Sivarajah, Department of Agricultural Economics, Faculty of Agriculture, Eastern University, Sri Lanka.

Dr. S. Sivakumar, Department of Civil Engineering, Faculty of Engineering, University of Jaffna, Sri Lanka

Dr. Thiruvaran, Department of Civil Engineering, Faculty of Engineering, University of Jaffna, Sri Lanka

Dr. W. A. J. P. Wijesinghe, Department of Export Agriculture, Faculty of Animal Science and Export Agriculture, Uva Wellassa University, Sri Lanka.

Dr. W.L.I. Wijesekara, Department of Food Science and Technology, Faculty of Applied Sciences, University of Sri Jayawardenepura, Sri Lanka.

Dr.(Mrs). M.M.G.T. De Silva, Department of Civil Engineering, Faculty of Engineering, University of Peradeniya, Sri Lanka.

Dr.P.W.A.Perera, Department of Animal Science, Faculty of Agriculture, University of Ruhuna, Sri Lanka.

Dr.S.Pathmarajah, Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya.

Author Instructions

Script

The script should be free of errors and typewritten using double spacing throughout on one side A4 size white bond paper, leaving at least 3 cm margins on either side or liberal spacing at the top and bottom of each page. Sheets should be numbered consecutively.

Length and Style

The length of the paper should not exceed 15 A4 pages. Minimum number of pages should be 6 A4 pages. The style of writing should conform to acceptable English usage. Slang, jargon, unauthorized abbreviations, abbreviated phrasings and the like, should be avoided.

Manuscript Layout

Manuscript for article should be organized as follows: Title, Abstract, Keywords, Introduction, Materials and Methods, Results and Discussion, Conclusion, Acknowledgement and References. Pages should be numbered consecutively and arranged in the following order.

Page 1

Title Page

Include the title of paper, names and affiliations of all authors including e-mail address, telephone and fax number of corresponding author. Submitted manuscripts must list full names for all authors; that is, full first/given name(s), middle initial(s), and last/surname(s).Title should be concise, informative and typed in 'Sentence case' bold letters.

Page 2

Abstract:

No more than 250 words for full length articles. The abstract should not contain any references and should be able to stand on its use without modification in abstracting journals. It should outline objectives and methodology together with important results and conclusions.

Keywords

A maximum of six keywords may include the name of an organism (common and scientific), method or other words or phrases that represent the subject of the study.

Page 3 onwards

Main body

Introduction

It should be concise and well-focused to the research work done.

Materials and Methods

New methods may be described in detail with an indication of their limitations. Established methods can be mentioned with appropriate references. Sufficient detail should be included to allow direct repetition of the work by others. A paper reporting the results of the experimental investigations on human subjects or on animal must include a statement, under methods and materials, to the effect that the relevant national or other ethical guidelines have been adhered to. Statistical analyses done should be mentioned where applicable.

Results and Discussion

The results should be concisely and logically presented. Only data essential for the main conclusions emerging from the study should be included. Repetition of the same results in figures, tables or text should be avoided. Long discussions should be avoided. The discussion should deal with the interpretation of results. It should logically relate new findings of earlier ones.

Conclusion

Unqualified statements and conclusions not completely supported by data should be avoided. All hypotheses should be clearly identified as such.

Acknowledgement

Acknowledgements should be brief and made for funding sources, scientific and technical assistance and not for routine help in preparing manuscripts. If a significant part of the research was performed in an institution other than in those indicated by the authors' affiliations given in the title page, this fact should be acknowledged.

References

References to the literature must be indicated in the text and tables as following the general procedure. The reference should be in alphabetical order at the end of the manuscripts under the same caption. Unpublished data and personal communications should not be listed under reference but may be mentioned in the text. Reference to work 'in press' implies its acceptance for publication and may be listed under references. In each reference, all the initials of the author must be given after the

surname. The year of publication should follow the author name. This should be followed by the full title of the referred publication.

When journal articles are listed, the journal names should be given in full and it should be indicated in italics and followed by the volume number in bold type, the issue number in parentheses and then the inclusive pages. When books are listed, the order should be: author(s), year, book title, volume number, edition, pagination/inclusive pages, publisher and place of publication. The book title should be indicated in italics. When sections of a book are listed, the order should be: authors of section, year, title of the section, title of the book, edition, inclusive pages, publisher and place of publication.

Citation in the text

Cite references in the text by name and year in parentheses. Some examples:

…fully hydrogenated fats are blended with liquid oils as the feed stocks of interesterification (Zhang *et al*., 2000).

…. with low or zero trans fatty acids and the results were promising (Zhang *et al*., 2001; Zhang *et al*., 2006; Goli *et al*., 2008).

……trans-free margarine formulations and most widely used enzyme for the interesterification is Lipozyme TL IM (Ferreira-Dias, 2013).

…..fatty acids can be obtained by enzymatic interesterification (Huang and Akoh, 1994). This result was later contradicted by Becker and Seligman (1996).

Reference list

Journals articles

1. Single author

   Gil, A. 2002. Polyunsaturated fatty acids and inflammatory diseases. Biomedicine and Pharmacotherepy, 56:388–396.

2. Two authors

   Huang, K.H. and Akoh, C.C. 1994. Lipase-catalyzed incorporation of n-3 polyunsaturated fatty acids into vegetable oils. *Journal of the American Oil Chemists' Society*, 71:1277–1280.

3. More than two authors

Zhang, H., Xu, X., Mu, H., Nilsson, J., Adler-Nissen, J. and Høy, C.E. 2000. Lipozyme IM-catalyzed interesterification for the production of margarine fats in a 1 kg scale stirred tank reactor. *European Journal of Lipid Science and Technology*, 102:411–418.

Books and other monographs

4. Chapter in book

Gordon, M.H. 2001. The development of oxidative rancidity. In: Pokorny, J., Yanishlieva, N. and Gordon, M. (eds) Antioxidants in Food – Practical Applications. CRC Press, Washington, pp 7-225.

5. Web references

The full URL should be given with the date when the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given.

Abbreviations and Symbols

Unless common, these should be defined when first used, and not included in the abstract. The SI system of units should be used wherever possible. If measurements were made in units other than SI, the data should be reported in the same units followed by SI units in brackets. E.g. 5290 ft (1610m)

Formula and Equations

Equations should be typewritten and quadruple spaced. They should be started on the left margin on the number placed in parentheses to the right of the equation.

Nomenclature

Scientific names of plants and animals will be printed in italics, and should be either underlined or typed in italics in the manuscript. In the first citation, genus species and authority must be given. E.g. *Scirtothrips dorsalis* L. In later citation, the generic name may be abbreviated. E.g. *S. dorsalis*.