"Safe Food for Healthy Life"

PROCEEDINGS OF THE INTERNATIONAL RESEARCH SYMPOSIUM ON POSTHARVEST TECHNOLOGY

19th June, 2014

RESEARCH AND DEVELOPMENT CENTRE
INSTITUTE OF POST HARVEST TECHNOLOGY
JAYANTHI MAWATHA
ANURADHAPURA

MINISTRY OF AGRICULTURE

Indexed

PROCEEDINGS OF THE INTERNATIONAL RESEARCH SYMPOSIUM ON POSTHARVEST TECHNOLOGY

RESEARCH AND DEVELOPMENT CENTRE
INSTITUTE OF POST HARVEST TECHNOLOGY
JAYANTHI MAWATHA,
ANURADHAPURA,
SRI LANKA.

PROCEEDINGS OF THE INTERNATIONAL RESEARCH SYMPOSIUM ON POSTHARVEST TECHNOLOGY 2014

First Publication 2014

Published by
Research and Development Center
Institute of Postharvest Technology
Jayanthi Mawatha
Anuradhapura 50000
Sri Lanka.

Telephone:	0094(0)252222344, 2225765, 2225766
Fax:	0094(0)252220149, 2223983
Website:	www.ipht.lk
ISSN:	ISSN 2362-0943
Cover Page Design	Mr.C.R. Gunawardane
Printers	Wimal Printers (Pvt) Ltd, 561/86 E, New Bus Stand, 2nd Lane, Fair Road, Anuradhapura 50000, Sri lanka.
Editorial Board	Dr.B.M.K.S.Thilakarathne *(Editor- In- Chief)* Eng. H.M.A.P. Rathnayake Dr.W.A.H. Champa Mr.W.M.C.B.Wasala
Symposium Coordinators	Mr. D. P. C. Swarnasiri Eng. (Mrs.) D. P. Senanayake
Symposium Secretary	Dr (Mrs.) W.A H. Champa

Reaserch Paper Review Panel

Dr (Mrs). B.M.K.S. Thilakaratne
Mr. D. P. C. Swarnasiri
Eng. (Mrs.) D. P. Senanayake
Eng. H.M.A.P. Ratnayake
Dr. D.M.C.C.Gunathilake
Dr (Mrs.) W.A H. Champa
Dr. (Mrs.) R.M.N.A. Wijewardane
Mr. W.M.C.B. Wasala
Mr. C.R. Gunawardane
Mrs. H.S. Jayawardane
Eng. B.D.M.P. Bandara
Eng. T.M.R. Dissanayake
Mrs. C.A.K. Dissanayake
Eng. (Mrs.) D.M.S. P. Bandara
Mr. U.G. Chandrajith

Proceeding Sponsor: National Science Foundation, Sri Lanka

PREFACE

The Institute of Postharvest Technology (IPHT) proud to host its first International Symposium on Postharvest Technology under the theme *"Safe Food for Healthy Life"* on June 19, 2014 at the premises of Research and Development Center, Anuradhapura. In order to provide a better focus for the very broad area of postharvest technology the above theme was further divided into four specific subthemes namely, (1) Food and Nutrition, (2) Fresh Produce Quality and Safety; Handling, Packaging and Storage of Food Crops (3) Food Process Engineering and (4) Design of Postharvest Machinery. Scientists from both local and foreign institutes will present their research findings and the symposium demonstrates approximately thirty oral presentations. The proceedings incorporate extended abstracts of these presentations and the keynote speech. The chief guest Hon. Mahinda Yapa Abeywardene, Minister of Agriculture and the keynote speaker Dr. Keshavan Niranjan, Professor of Food Bio-Processing and the Editor-Journal of Food Engineering, University of Reading, United Kingdom will add glamour to this remarkable venture.

The symposium will provide a forum for researchers, academics, policymakers, graduate and postgraduate students to exchange research results and address issues in all aspects of postharvest technology of food crops, which may finally lead to advancement in science and technology. By organizing this symposium, our intention was to promote the stakeholder oriented research and development activities while encouraging utilization of consumer & eco friendly production practices throughout the supply and value chains so as to ensure public health.

At this juncture, on behalf of the organizing committee, I express my deepest sense of gratitude to chief guest, keynote speaker, chairpersons of each session, presenters and participants for their invaluable contribution rendered to make this event success. My heartfelt thank is also extended to internal scrutinizing panel for their professional input made on reviewing, editing and publishing the proceedings which will expand the body of scientific knowledge.

Dr. (Mrs) B.M.K.S.Tilakaratne
Editor In Chief
Director
Institute of Postharvest Technology

CONTENTS

Massage from the Chief Guest, Minister of Agriculture **v**
Hon. Mahinda Yapa Abeywardene

Massage from the Secretary, Ministry of Agriculture **vi**
Mr. R.M.D.B. Meegasmulla

Massage from the Chairman, Institute of Postharvest Technology **vii**
Mr Jagath Palitha Jayawarna

Keynote Speech **viii-xiv**
Dr. Keshavan Niranjan,
Professor of Food Bio-Processing and the Editor-Journal of Food Engineering,
University of Reading, United Kingdom

Paper Index

Food and Nutrition **5-50**

Fresh Produce Quality and Safety; Handling Packaging and Storage of Food Crops **51-97**

Food Process Engineering **98-130**

Design of Postharvest Machinery **131-159**

Appendix

MESSAGE FROM THE CHIEF GUEST

I am indeed privileged to be able to send this message for the "International Research Symposium on Postharvest Technology" convened to exchange new findings and views on global issues of postharvest technology.

Agriculture sector in Sri Lanka plays an important role in Sri Lankan economy contributing 11% to its GDP and providing employment opportunities to 31% of the labour force directly or indirectly. The state of agriculture sector at any given time is a fundamental factor that contribute in a large measure towards the economic prosperity of the country.

It gives me great deal of pleasure to mention that Sri Lanka has achieved self sufficiency in rice and maize at present. If Mother Nature bestows us with favorable climatic conditions, our farmers not only can produce of entire amount of rice and maize, required by the country, but can produce for export as well.

At present in Sri Lanka, about 30-40% of perishable and 10-15% of durables are lost during post production operations. Our attention should be focused to minimize these postharvest losses in an economical manner and such minimizing process should enable the farmers to earn high income and profit with their produce. Minimizing postharvest losses will be a win-win situation
for both supply chain stake- holders as well as consumers.

I see this symposium as crucial which will provide timely opportunity to exchange views and research findings on postharvest technology. I expect this symposium to be very productive in finding ways to minimize postharvest losses.

Hon. Mahinda Yapa Abeywardana
Minister of Agriculture.

MESSAGE FROM THE SECRETARY, MINISTRY OF AGRICULTURE

It gives me great contentment to send a message to the first international research symposium on postharvest technology organized by the Institute of Postharvest Technology (IPHT).

The theme "Safe Food for Healthy Life" is timely and very appropriate for the reason that the ministry of Agriculture plays an important role in promotion and popularization of safe foods which produced locally. As one of the main Institutions under purview this Ministry, contribution of IPHT to accomplish the aforesaid aspirations is highly appreciated.

I am convinced that the symposium will bestow with great prospects for Researchers to present their research findings, to put together the collaborations and to concentrate on the issue in their respective fields which may end results in the advancement of Science and Technology. I wish to express my gratitude and continued success, whilst applaud the efforts of organizing this first ever international Symposium.

R. M. D. B. Meegasmulla
Secretary,
Ministry of Agriculture

MESSAGE FROM THE CHAIRMAN

In accordance with *"Mahinda Chinthana"* programme of His Excellency the President Mr. Mahinda Rajapaksha and under the guidance of Hon. Minister of Agriculture, Mr. Mahinda Yapa Abeywardana, Sri Lanka became self- sufficiency in many agricultural commodities. Today even we have reached to the position of exporting the rice, maize etc.

Accordingly, today many people pay more attention on Post Harvest Technology. Therefore, great responsibility has been entrusted to our Institute. The Institute of Post Harvest Technology was established on 19th June 2000 under the Ministry of Agriculture. From onwards lots of innovations have been invented by the institute and these technologies have introduced locally and internationally.

After 12 years of the establishment of the institute, we have held a national research symposium for the first time, at Sri Lanka Foundation Institute, Colombo on 08th March 2012 under the guidance of Hon. Minister of Agriculture, Mr. Mahinda Yapa Abeywardana.

Going beyond that, we are about to hold an International Research Symposium on Postharvest Technology under the guidance of Hon. Minister of Agriculture, Mr. Mahinda Yapa Abeywardana and to the direction of the Secretary of Agriculture, Mr. R. M. D. B. Meegasmulla on 19th June 2014 and followed by postharvest machinery exhibition on 20th June 2014. I think it is my fortune to arrange such a symposium during my service of the IPHT.

I am very much grateful to Hon. Minister of Agriculture Mr. Mahinda Yapa Abeywardana and the secretary of agriculture Mr. R. M. D. B. Meegasmulla and staff of ministry for encouraging us to hold this International Research Symposium for the first time in Sri Lanka. Further, my special thanks goes to Dputy Chairman, Board of Directors, Chief Excusive Officer, Additional Directors, Research Officers, Mechanical Engineers, Extension Officers and all the other staff of the IPHT for their effort given to success this crucial event.

Jagath Palitha Jayawarna
Chairman
Institute of Postharvest Technology

KEYNOTE SPEECH

Challenges facing postharvest agroindustrial business: a view of the West

Prof. Keshavan Niranjan
Department of Food and Nutritional Sciences,
University of Reading, Whiteknights, PO Box 226, Reading RG6 6AP
United Kingdom

Introduction

Adding value to farm produce is imperative in every economy. However, there is a grotesque disparity between the extent of value added in the developing and developed economies. It would not be inaccurate to suggest that, typically, less than 10% of farm produce finds its way to factories in developing economies, whereas, this figure is as high as 70% in the developed economies of the West. Lack of value addition in the developing economies deprives farmers the opportunity of receiving a fair economic return and also leads to what is commonly known as *post-harvest wastage*. In the developed economies, the farmers do gain a much higher economic return, and, no doubt, post-harvest wastage, as we understand it, is substantially lower. However, it is arguable whether food wastage is any lower! It is now very well established that consumers in the West are buying food items, far in excess of what they consume. These items often end up in overloaded and poorly maintained kitchen refrigerators; ignored; and left to rot! Thus *post-harvest loss* is replaced by *post-purchase loss* in the developed world. Either way, precious natural resources are being wasted, which not only affects economic returns but also its fair distribution amongst the population.

Not only is the extent of food wastage significant, and more or less uniform, across the developing and developed economies, which the former must note, but there are a number of other observations concerning the role of technologists and engineers in the industrial world, which countries like Sri Lanka must note. Industrial agro-product manufacturers in the West find themselves at cross roads today because of profound changes in: the geographic regions in which they manufacture and sell their products, the manufacturing technology, the management culture of holding companies, consumer attitudes towards foods and food manufacturers, and the regulatory framework relating to manufacture as well as its environment impact. The aim of this paper is to highlight key challenges facing post-harvest agro-industrial part of the food chain, particularly in the West.

Technologists and engineers have traditionally confined themselves to running a manufacturing operation efficiently. This involves designing the processing steps, sizing equipment, making provision for process utilities (energy/steam/air etc), controlling and scheduling the operations in order to meet production targets. Food industry, just as most other industrial sectors, is finding itself at cross roads on account of the profound changes that have occurred over the last decade in the way industrial manufacture is carried out. This has thrown up a number of challenges which influence the way technology and engineering is applied to food manufacture. These challenges are posed by: *business dynamics*, *market forces*, the *manufacturing environment*, and *environmental issues*. The four categories of challenges are discussed below.

Challenges posed by business dynamics

There has been an unprecedented change in manufacturing philosophy induced by international trade agreements which have allowed, virtually, barrier-less flow of materials (natural as well as processed) across national boundaries. This has opened up the opportunity for manufactures to set up production units in those countries where production costs can be kept as low as possible, trading raw materials and finished products right across the globe. Developed economies have, more or less, priced themselves out of contention in respect of manufacturing, which is now increasingly being outsourced. As a direct consequence, the same state-of-the-art manufacturing methods - which were, until recently, associated exclusively with the developed world - are being employed anywhere in the world, regardless of the economic state of the country or region where manufacturing is practised. The key consideration for manufacturers is whether the technology can be implemented cost effectively or not in any given place; and technologists/engineers are expected to rise up to this challenge. This is in total contrast to the view that prevailed, say, twenty odd years ago, when each economy was expected to practise manufacturing methods that were appropriate to, or compatible with, its socio-economic needs; e.g. adoption of low automation levels in highly populated economies. Given the relatively low shelf-life of foods in relation to other commodities, outsourcing manufacture, especially to far off places, has been limited to those products which can endure travel and climatic changes, and yet offer adequate shelf stability. Although it is not possible to provide hard facts indicating the level of outsourcing in processed food manufacture, it is bound to be significant, especially if we consider products such as soft drinks, alcoholic drinks and confectionery. It is estimated that international food trade has more than quadrupled in the last five years.

Modern businesses constantly appear to be in a state of flux. There are changes being made all the time: some as a response to external events, and others, as proactive measures. Regardless, dealing with transients is an integral part of modern business culture. Business consolidation measures throughout the food chain, and pressures to outsource, have pushed processors to adopt *leaner* and *more efficient manufacturing methods*, which require a

process to be highly automated. It may be noted that automation can also result in better food safety standards as well as personnel safety standards. To what extent, a given process can be economically automated is an engineering challenge. Robots, for instance, are used for a variety of operations ranging from transportation within a plant to filling and packaging. These machines are fast, efficient and can handle high payloads. Introducing robots is, however, not easy, especially since food products vary tremendously in size, shape and texture. Automated systems capable of coping with such demands clearly cost. Technologists/Engineers have to develop cost-effective systems if the industry has to benefit from automation. There is, of course, a wider socio-economic challenge facing the engineer. Automation ends up competing with human effort. The question is whether social costs should be included in any cost-benefit exercise?

In recent years, businesses are taking a different approach to capital assets. They are more interested in the actual usage costs of equipment; not the purchase price. A number of food processors are not buying equipment to own it, but instead, they are leasing it from equipment suppliers. This strategy enables them to run their business without getting involved in matters relating to equipment maintenance and companies do not necessarily have to employ maintenance personnel. In other words, the processor buys the benefit of the equipment; not the equipment itself. Moreover, processors are interested in reliability of the equipment; not the complexity associated with it. Equipment manufacturers therefore have to seriously consider how to position themselves in an extremely competitive and demanding market.

Challenges posed by market forces

The influence of market on the engineering design of processes is absolutely critical. The food market in each country has its own idiosyncrasies. For example, in UK well over 60% of the grocery spend is through 4 major retailers; this follows market consolidation in the last couple of years. The market is also deflationary with decrease in at-home eating, and greater spending in restaurants. Prices of food commodities have not increased in real terms since the mid nineties. However, labour costs have gone up by roughly 3% p.a. with material costs going up by approximately 2.5% p.a. In such a environment, existing product lines cannot grow, and market advantage can only be maintained by regular introduction of new products. Further these products have to be priced competitively, since the processors are under enormous pressure from the relatively few, but very powerful retailers. In US alone, around six thousand new food and drink products were introduced in 2003. Professor Solke Bruin, in a recent address (Niranjan 2004), reported that innovation time has dropped from being around ten years in the seventies to about two years at present, which also demands the development of very strong brands to sustain product life cycle. Technologists/Engineers, therefore, have to design manufacturing lines which run in short campaigns to produce a wide variety of products. Equipment designs must therefore offer a

high degree of flexibility. At the same time they must run at increased speed and output, and possess higher efficiency. Other design features must include improved product handling, greater accuracy, simpler control and more versatile handling capabilities. The use of multi-functionally designed equipment, especially reactors, is common in the chemical industry (Stitt 2004), and it is desirable to exploit this concept fully in the context of food processing.

Most importantly, there has been a paradigm shift in food processing where the industry - which essentially aimed to adding value to farm produce after the second world war - is now consumer focussed. This has clearly moved manufacturing emphasis from *food preservation* towards consumer-driven *product development*. In terms of engineering, this has meant a clear shift from *process engineering* to *product engineering*. In other words, the starting point for process design is the consumers' expectations of product attributes. This is translated into the physico-chemical properties and microstructures, which the process design aims for.

Other consumer driven initiatives stem from their increasing intolerance of product quality and service failures. Consumers are also concerned about the traceability of the ingredients used in any product, and the longer-term health implications of the levels at which these ingredients are used. The issue of *traceability* came to the fore when health concerns associated with the use of genetically modified foods were raised. While, the levels at which ingredients such as salt, fat and sugar are added is a hot contemporary issue, especially with increasing evidence of their harmful effects on longer term health emerging, almost daily.

Traceability is taken to mean the path taken by a product as it goes through a food chain. Consumers demand technology which would enable them to trace the path taken by the food they have chosen during production. The manufacturers, on the other hand, require technology to link their produce to a path which provides them and others operating in the food chain with proof of origin. Although there are currently no regulations requiring the use of a computer-based system for traceability, it is clearly convenient to adopt distributed information technology to draw up traceability reports. Systems Technologists/ have risen to this challenge and there are papers published on this subject (Bello et al, 2004).
The food industry is taking the longer term effect of health very seriously, by reducing levels of salt, sugar and fats where possible. Changes in product formulation can significantly alter physico-chemical properties which, in turn, can adversely affect mouth-feel. The main engineering challenge in this area is to ensure that the healthier version of any product retains all other characteristics of the original brand. This will undoubtedly involve the application of product engineering principles. At the same time, it will also enable the manufacturer to offer *service* and *care* to the customers.

Challenges posed by the manufacturing environment

The manufacturing environment is itself changing. Quality management systems are being driven to the factory floor. This means data acquisition and management tools have to be integrated with individual machines, and efficient communication has to be established across the whole process. Data emerges from many sources: measuring sensors, on-line inspection and monitoring systems, production scheduling, process stoppage analysis systems, and also from product tagging systems. It is necessary to access data, interpret them, and interact with the process from a number of different levels; this places a significant emphasis on communications. The role of programmable logic controllers (PLC) which establish communication between machines, and human machine interface (HMI) which have better diagnostic and communication capabilities, are brought to the fore. Process control systems will therefore play an increasingly important role in ensuring that plant machinery are performing to their full potential. Even formal plant-wide strategies for managing food hygiene (usually in the form of the Hazard Analysis Critical Control Points (HACCP) system) are available. Control technology can confirm, for instance, that ingredients have been checked, used in accordance with the required recipe, processed according to a standard operating procedure (SOP), correctly labelled, and delivered (Bravington, 2000). A number of issues such as HACCP and Quality management systems are already enshrined in regulations in a number of countries. Moreover, processors are themselves volunteering to comply with internationally accepted standards such as ISO, because such accreditation enhances their credibility and enables them to trade across international borders. All these compliance requirements will make the task of process Technologists/ increasingly complex and place greater demand on them, not only to be better trained than at present, but also be better qualified in the first place, to face these challenges. A somewhat dated view on food engineering has been described by Niranjan (1994).

Challenges posed by the environmental issues

The increased culture of consumerism within our societies has escalated the problem of waste because of the use of disposable goods. Processed food wastes constitute one of the largest fractions of municipal wastes these days. Manufacturing processes operating under strict quality control, and retailing under stringent sell-by date regulations, has resulted in the generation of large volumes of food and packaging wastes. Wastes from food, drink and tobacco sectors constitute roughly 10% of the total industrial wastes in most developed countries. The food industry is facing increasing pressure to reduce its environmental impact, both from consumers and regulators.

Transferring food from the field to the plate involves a sophisticated production and supply chain, but for the purposes of waste production this can be simplified into three main steps: agriculture, food processors/manufacturers and the retail/commercial sector. Each of the sectors generates waste and wash water. Given the complexity of the food chain,

environmental impacts can occur at various points in the chain, even for a single food product. It is therefore necessary to take a holistic systems-based approach to tackle the problem, and undertake life cycle analysis which is now an integral part of engineering science.

Food processing wastes are multiphase systems with liquid wastes containing suspended solids, or solid wastes containing occluded water. The percentage waste - expressed in terms of the difference between the masses entering the plant and leaving it - is rather low, less than 4-5% in many cases (e.g. dairy processing plants). However, given the volumes involved, the overall impact on the environment can be significant. Technologists/Engineers must therefore design and develop processes which minimise the production of wastes as well as the water and energy consumed. It may be noted that the energy costs associated with food processing is relatively low in many operations, around 10% of overall costs. Therefore, there is little incentive to take measures which will reduce the overall energy consumed. However, manufacturers must not lose sight of the environmental impact (e.g. greenhouse effect) of consuming high levels of energy, even if this is affordable. Most governments have now made provision for a range of incentives, and indeed penalties, aimed at reducing the overall energy consumption. Engineering design cannot therefore consider process efficiencies independent of environmental issues as they have tended to do in the past.

The area of packaging wastes is yet another major environmental issue. Packaging is acknowledged to perform a number of useful functions. It acts as a physical barrier between a product and the external environment, thereby protecting it from external contamination and maintaining hygienic conditions; it protects and preserves the product during handling and transportation; it serves to attract the attention of consumers thereby giving the product a good market value; and it also serves to provide information on the product and instructions on how to use it. Despite these advantages, the environmental impact of packaging wastes is considerably high, and, in many cases, outweighs their benefits. Both consumers and governments are exerting enormous pressure on processors to cut down on the amount of packaging used, and use biodegradable or compostable materials. The challenge facing an engineer is to balance the utility of a packaging against its environmental impact after the product is consumed.

Advice to agroindustrial technologists and engineers

It is evident from the above discussion that technologists and engineers will be dealing with rapidly variant transients all the time. These transients may result from changes in the business environment, the nature of market forces, the manufacturing environment, or environmental pressures. Technologists and engineers have to be better trained than ever to

cope with such pressures, and equip themselves with skills which are, more often than not, excluded from university curricula.

REFERENCES

Bello LL, O Mirabella and N Torrisi (2004). Modelling traceability systems in food manufacturing chains, <http://www.hemswell.lincoln.ac.uk/ dnutter/wetice04/final-lobello.pdf>

Bravington C (2000). Personal Communication

Niranjan K (1994). Chemical engineering principles and food processing. Trends in Food Science and Technology. 5(1):20 – 23.

Niranjan K (2004). Conference Report, Transactions of the institution of chemical engineers part C. 82:255-256.

Stitt E H (2004). Multifunctional reactors, up to a point lord copper, Chemical engineering research and design, 82:129–139.

Paper Index

FOOD AND NUTRITION

Development and quality evaluation of instant rice noodles (cup noodle) **5-8**
UG Chandrajith, DMSP Bandara, KGLR Jayathunge and BMKS Thilakaratne

Development of a rice flour based deep fried cracker and evaluation of its storability **9-13**
HS Jayawardene and BMKSThilakarathne

Development of dehydrated murunga leaves fortified nutri-mix **14-18**
BMKS Tilakaratne, MKU Arachchi, KMS Wimalasiri and DGNG Wijesinghe

Glycaemic index and glycaemic load of rotti prepared with soy and rice flours **19-22**
MPMSH Perera, R Sivakanesan, DTDJ Abeysekara and K.H. Sarananda

Sensory qualities of flavoured and non flavoured cashew apple (*Anacardium occidentale* L.) syrup **23-26**
RKBNR Randeni, MDK Vithana and SJBA Jayasekara

Determination of selenium content in cereals and legume seeds grown in Sri Lanka **27-32**
PA Buwaneka, DSM de Silva, S Wimalasena and AT Kannangara

Development of murunga leaves (*Moringa oleifera*) based bread spread **33-41**
BMKS Thilakaratne, AAMT Gunasekara, NWIA Jayawardana and GAS Ginigaddara

Quality evaluation of locally produced rice available in the open market of Sri Lanka : A casestudy 2012 **42-47**
DPC Swarnasiri

Institutional development for successful implementation of sanitary and phytosanitary (SPS) agreement in Sri Lanka **48-50**
SMRS Semasinghe, I Wickramasinge and PNRJ Amunugoda

Fresh Produce Quality and Safety; Handling, Packaging and Storage of Food Crops

Use of safe packaging for vegetable transportation on main supply chains in Sri Lanka **52-56**
CR Gunawardhane, WMCB Wasala, CAK Dissanayake, RMNA Wijewardhana, UG Chandhrajith and BMKS Thialakarathne

Reduction of postharvest losses in leeks (*Allium porum*) during transportation using wooden bulk packages **57-61**
RMNA Wijewardane, GD Senevirathne, NWIA Jayawardana, TMR Dissanayake' WMCB Wasala and BMKS Thilakarathne

Assessment of postharvest losses and quality deteriorations of banana fruits during supply chain activities in Sri Lanka **62-66**
WMCB Wasala, CR Gunawardhane, WAH Champa, RMNA Wijewardhane, RMRNK Rathnayake, UG Chandrajith and BMKS Thilakarathne

Evaluation of big onion size grading machine **67-72**
DMCC Gunathilake and KB Palipane

Development of an appropriate methodology for extending shelf life of cassava (*Manihot esculenta* Crantz) **73-78**
WAH.Champa, RMRNK Ratnayake and BMKS Thilakarathne

Postharvest keeping quality and some nutritional aspects of *Trianthema portulacastrum* L. - an under-utilized leafy vegetable in Sri Lanka **79-83**
EGCK Priyadarshika, WAM Daundasekera and P Malathy

Postharvest losses of the potato marketing channel: a case of food waste foot printing **84-87**
HKN Darshika, SNM Wickramarathna and DAM De Silva

Preharvest foliar sprays of salicylic acid enhance berry quality of table grapes (*Vitis vinifera* L.) cv. Flame Seedless. **88-92**
WAH Champa, MIS Gill, BVC Mahajan, NK Arora and S Bedi

Effect of sodium bicarbonate and ammonium bicarbonate on anthracnose fruit rot of tomato caused by *Colletotrichum cocodes* **93-98**
RMRNK Rathnayake, WMCB Wasala, CAK Dissanayake, CR Gunawardhane, UG Chandrajith and BMKS Thilakarathne

Food Process Engineering

The role of pre-gelatinization on quality improvement of rice flour **99-103**
DMSP Bandara, CR Gunawardane, TMR Dissanayake, BMKS Thilakaratne and HMAP Rathnayake

Prediction of suitable isotherm model to treat paddy soaking wastewater using paddy husk charcoal **104-109**
SMWTPK Ariyarathna and R Shanthini

The performance analysis of far infrared emission on rice flour gelatinization **110-113**
G Abhiram and KSP Amaratunga

Model for internal porosity development of different shaped foods **114-120**
Wijitha Senadeera

Far-infrared drying of stored coriander (*Coriandrum sativum* L.) up to grinding moisture content **121-124**
AJ Fernando, KSP Amaratunga and LBMDL Priyadarshana

A novel approach for numerical simulation of plant tissue shrinkage during drying **125-130**
HCP Karunasena, W Senadeera, RJ Brown and YT Gu

Design of Postharvest Machinery

Development of continuous type paddy cooker **132-135**
TMR Dissanayake, DMSP Bandara, HMAP Rathnayake and DP Senanayake

Design and development of an energy efficient vibrated flour sifter for the rice flour industry **136-139**
HMAP Rathnayake, TMR Dissanayake, DMSP Bandara, DP Senanayake and BMKS Thilakarathna

Design and development of a low cost grain flour blending equipment **140-145**
BDMPB Dissanayake, HS Jayawardena and BMKS Thilakarathne

Development and testing of pedal-cum-motor operated paddy cleaner **146-150**
DP Senanayaka, HMAP Rathnayake, BDMP Bandara and TMR Dissanayake

Evaluation of medium scale IPHT maize thresher **151-154**
HMAP Rathnayake, DP Senanayake BDMPB Dissanayake, DMSP Bandara, KB Palipane and BMKS Thilakaratne

Evaluation of rasp bar mill for size reduction of maize **155-159**
DP Senanayaka, HMAP Rathnayake, BMKS Thilakarathne, BDMP Bandara and TMR Dissanayake

Food and Nutrition

Development and quality evaluation of instant rice noodles (cup noodles)

UG Chandrajith*, DMSP Bandara, KGLR Jayathunge and BMKS Thilakaratne
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka
*Corresponding author: chandrajith22@yahoo.com

ABSTRACT

Noodle is one of the main food item widely consumed throughout the world and their global consumption is second only to bread. The instant noodle market is growing fast in Asian countries and is gaining popularity in the western market. Wheat flour which is usually used for making instant noodles is poor in essential amino acid lysine. A few amount of instant rice noodles available in the Sri Lankan market but ther are also not in the form of ready to use cup noodles. Sri Lankan rice self-sufficiency rate was increased within last five years due to excess paddy production. It is important to introduce rice based novel food items such as instant cup noodle which helps to process excess paddy harvest in Sri Lanka. Instant cup rice noodles could be a good solution for people with busy lifestyle to have nutritious meal in morning time since product can be prepared within 3 min by adding boiling water only. This study reveals that the product is at acceptable level 4.83 out of 5.00 in sensory evaluations and cooking loss was 10.18%.

Keywords: Instant rice noodles, cup noodle, rice based product

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food in Sri Lanka and it provides 45% calorie and 40% total protein requirement of an average Sri Lankan (Fari *et al.* 2011). Sri Lankan rice self-sufficiency rates were increased figure from 100.65% to 113.91% since 2005 to 2010 which show increment in self-sufficiency within five years (www.statistics.gov.lk). Paddy production in 2011 *Yala* season had been increased by around 12.4% and it was around 1.88 million metric tons which was a highest production ever recorded in any *Yala* season (www.cbsl.gov.lk). According to the statistic, the rice production is becoming a surplus, therefore, it is a must go for different foods based on rice.

Noodles are widely consumed throughout the world and their global consumption is second only to bread. The instant noodle market is growing fast in Asian countries and is gaining popularity in the western market. Wheat flour which is usually used for making instant noodles is poor in essential amino acid lysine (Jayasena *et al.* 2008).

Although the different kind of rice flour noodle available in Sri Lankan market, an instant cup noodle is not available. Therefore, this research project aims to fill this gap by developing an instant rice noodle that could be prepared within two minutes without boiling.

MATERIALS AND METHOD

Homogeneous bulk sample of long white type paddy (BG 358) was used for the experiment. The brown rice was obtained by de-husking paddy in a rubber roll sheller. Brown rice was polished by the combination of abrasive and friction polishers. The bran removal percentage was kept around 60% for the experiment. Polished rice was ground using abrasive stone horizontal mill and sieved with 120 μ vibro sifter. Salt and water were used to make the rice noodle dough. Laboratory scale noodle extruding machine (Omega J8004) was used for extrusion and laboratory scale deep fryer (Singer 2.5 L) was used for frying. Noodle extrusion was tested with three different dies in three pore sizes such as 1.0, 1.5 and 2.0 mm. Rice noodles were prepared in the laboratory using 500 g rice flour, 7.5 g table salt (1.5% flour base) and 425 ml potable water (85% flour base) according to preliminary studies.

First, mixture of rice flour (500 g) and salt (7.5 g) was prepared using a hand mixer. Dough was prepared gradually adding 425 ml of water to the flour mixture and kneaded well until water dispersed even in the dough. Two types of noodles in two diameters were prepared for testing using 1.5 and 2.0 mm dies since 1.0 mm die did not produce noodle in prefered quality. Noodles were steamed for 10, 20 and 30 min and kept in cold water at 20 °C for 5 min. Noodle strands were drained off and fried in a deep fryer for 45 seconds at 165 °C for all above treatments. Fried noodles were kept at 50 °C for 2 h in an oven for drying. The process diagram is shown in Figure 1.

Dried noodle were cooked adding boiling water and cooking time was determined placing the noodle strands between two glass plates until white core disappeared. Quality of the product under three different steaming conditions were evaluated for fat percentage, moisture content, colour, rehydration time and cooking loss. Sensory evaluation of cooked rice noodles were done by 30 untrained panelists.

RESULTS AND DISCUSSION

The results of quality evaluation of instant rice noodles are presented in Table 1. There were significant differences in color of uncooked noodles, fat percentage, and moisture percentage, rehydration time, cooking loss and overall acceptability of sensory evaluation after rehydration. According to the sensory evaluation, the acceptable level is highest in T_5. Compared to the 2.0 mm die size, the acceptability results in three treatments; 15, 20, 30 min steaming time are significantly different from the results obtained from 1.5 mm die. Therefore, among the three different dies *i.e.* 1, 1.5 and 2mm, the best die size is 1.5 mm.

When consider the cooking loss, the lowest was recorded for 20 min steaming time (T_5). Similarly, best result for rehydration time is given for 20 min steaming time treatment among the 1.5 mm die (T_5). The moisture content is also in acceptable level in treatment 'T_5' and that is not significance from result in 1.5 mm die. Fat content and color value were not significant. According to literature, fat content for instant rice noodle is around 17%. The fat content of the studied samples were also in between 17.01 to 17.47%. Color value of uncooked noodles is a very important quality parameter for consumer attraction. Highest

lightness value was recorded with 2.0 mm die and 15 min steaming time (T_1) which was not significant with the 1.5 mm die and 20 min steaming time in (T_5).

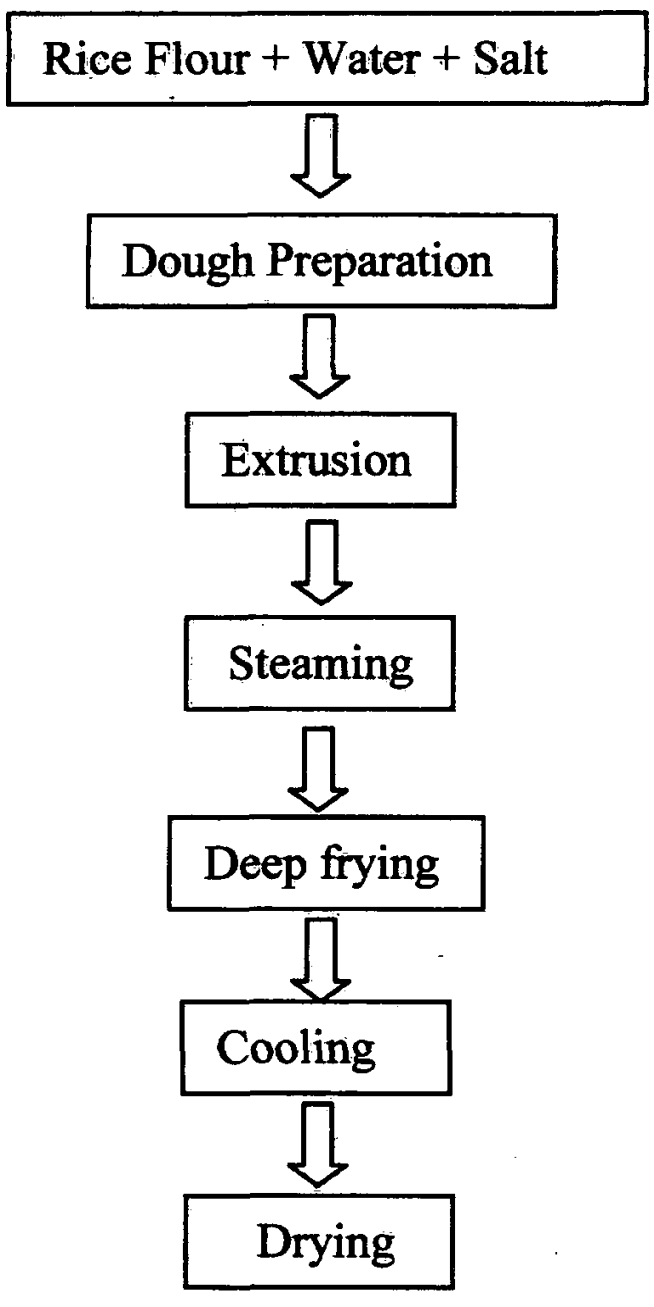


Fig. 1. The process of developed instant noodles

Table 1. Quality evaluation of three different steaming times of noodles strands produced by 2.0 mm and 1.5 mm noodle dies

Die Size (mm)	Steaming time (min)	Color (L*)	Fat (%)	MC (%)	RHT (min)	Cooking loss (%)	Overall acceptability
2.0	15 (T_1)	67.44^{a}	22.88^{a}	8.83^{a}	7.00^{a}	15.40^{a}	2.76^{e}
	20 (T_2)	66.01^{ab}	22.17^{a}	8.58^{abc}	6.00^{b}	8.97^{de}	3.66^{d}
	30 (T_3)	65.79^{ab}	21.77^{a}	8.71^{ab}	6.00^{b}	9.79^{cd}	3.90^{c}
1.5	15 (T_4)	65.08^{b}	17.47^{b}	8.16^{abc}	4.00^{c}	10.95^{b}	4.66^{ab}
	20 (T_5)	$\mathbf{65.39^{ab}}$	$\mathbf{17.09^{b}}$	$\mathbf{7.76^{c}}$	$\mathbf{3.00^{d}}$	$\mathbf{10.18^{bc}}$	$\mathbf{4.83^{a}}$
	30 (T_6)	64.05^{b}	17.01^{b}	7.88^{bc}	3.00^{d}	8.39^{e}	4.63^{b}

MC: moisture content, RHT: rehydration time; means within the same column bearing different superscripts are significantly ($p<0.05$) different. T_1, T_2, T_3 - three different steaming times of 2.0 mm die and T_4, T_5, T_6 - three different steaming time of 1.5 mm die.

CONCLUSION

This study reveals that using a Sri Lankan paddy variety as the raw material, an instant cup noodle could be performed in acceptable level. It may guide to introduce a new product development in commercial scale and solution for the rice surplus in Sri Lanka.

REFERENCES

Central bank of Sri Lanka. http://www.cbsl.gov.lk/pics_n_docs/10_pub/_docs/efr/annual_report/AR2011/English/English/6_Chapter_02.pdf [Accessed 02nd October 2013]

Department of census and statistics, Sri Lanka, Agriculture and environment statistics division. http://www.statistics.gov.lk/agriculture/Paddy%20Statistics/PaddyStatsPages/SelfsufficiencyRateofRice.html [Accessed 02nd October 2013]

Fari MJM, Rajapaksa D and Ranaweera KKDS (2011).Quality characteristics of noodles made from selected varieties of Sri Lankan rice with different physic chemical characteristics. J Natn Sci Foundation Sri Lanka 39(1):53-60.

Jayasena V, Leung P and Nasar-abbas SM (2008). Development and quality evaluation of Luip-fortified instant noodles. Proceedings of the 12th international Lupin conference. pp 473-477.

Pathiraje PMHD, Madhujith WMT, Chandrasekara A and Nissanka SP (2010).The Effect of rice variety and parboiling on in vivo glycemic response.Tropical Agricultural Research. Vol. 22 (1) 26 - 33.

Development of a rice flour based deep fried cracker and evaluation of its storability

HS Jayawrdene* and BMKS Thilakarathne
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka
*Corresponding author: hemanthika@hotmail.com

ABSTRACT

Utilization of rice flour in the commercial food processing industry in Sri Lanka is limited to few products. Therefore the purpose of this research was to develop a deep fried cracker using rice flour as the main ingredient and to evaluate the shelf life stability of the product.

Preliminary studies were carried out to determine the optimum formulation for rice cracker and develop a process for cracker production. A cracker was prepared with high organoleptic acceptability using rice flour (85%), wheat flour (5%), corn flour (10%), carboxymethyl cellulose (1%), salt (2%), pepper (1%), sugar (2%), and coconut oil (5%), as ingredients. The dough which prepared with above mix was sheeted (1cm thickness), steamed (95-98 °C, 45 min), then cooled to room temperature and placed in a refrigerator (5 °C, 10 h.). Then sliced (25 x 12 x 1.5 mm), oven dried (55 °C, 3 h) and deep fried in oil (220 °C, 5 s).

The storability of the product was tested with two types of packaging materials (polypropylene and oriented polypropylene/metalized cast polypropylene laminated bags) under ambient conditions (31±3 °C, 70±5% RH). During storage period physico-chemical, microbiological, and sensory qualities of the samples were evaluated monthly up to three months. Study revealed that deep fried cracker could be formulated using rice flour as the major ingredient and could be stored more than three months in oriented polypropylene/metalized cast polypropylene laminated packaging material without altering the sensory characteristics.

Keywords: Deep fried cracker, packaging material, rice flour, shelf life

INTRODUCTION

In Sri Lanka rice being the staple food and the single most important crop occupying nearly 1.2 million ha (Central Bank report, 2013) of the land. During last decades, Sri Lanka has achieved substantial progress in rice production and now almost in self-sufficiency stage. This production rise has been attributed to increased area under cultivation, increased irrigation, improved seed varieties, increased fertilizer application and higher prices for rice. Paddy production in 2013 was 4.6 million t and the annual average paddy yield is increasing over the past decade.

Rice is the staple food in Sri Lanka. But most commercial flour based food products are based on the wheat flour, which is imported. Use of rice flour is still limited to traditional

food items. In 2013 the government has spent Rs. million 40098 to import about 895000 t of wheat (Central Bank report, 2013). Therefore it is important to develop and introduce rice based products with regard to saving foreign exchange, to increase the rice farmers' income by increasing value, and also considering the health benefits to the human.

Snack foods are a significant part of the food industry and commercial rice based snacks are very limited. Biscuits, bites, extruded snacks, are some of the most dominant snacks in Sri Lanka and most of them are based on wheat flour. But in foreign countries rice based snacks are very popular and they are based on low amylose and waxy rice varieties. In Sri Lanka mostly cultivates and consumes high amylose rice varieties. This limits the beneficial effects given by low amylose and waxy rice varieties that giving high puffing ability and soft texture characteristics which are important in snacks. So the aim of this study was to enhance the utilization of rice grown in Sri Lanka by developing a rice based cracker using a local high amylose rice variety.

MATERIALS AND METHODS

Raw materials: A white, long paddy variety (BG 352) was selected for this study and purchased from the seed farm, Mahailukpallama, Anuradhapura. The other ingredients, wheat flour, corn flour, carboxymethyl cellulose, sugar, salt, pepper, coconut oil palm oil, and colouring were purchased from the local market. All chemicals ware on analytical grade and used as such without purification.

Formulation development: Preliminary studies were carried out to determine the optimum formulation for rice cracker and also to determine the production process. The optimum formulation for cracker preparation was selected by sensory evaluation tests. The selected formulation is, rice flour [ground by passing three times in a pin mill (FFC - 45), particle size < 150 Ч m] (85%), wheat flour (5%), corn flour (10%), carboxymethyl cellulose (1%), salt (2%), pepper (1%), sugar (2%), coconut oil (5%), water (54% by total weight).

Preparation method: Rice flour, wheat flour, corn flour, and carboxy methyl cellulose were mixed well with using a mixing machine. Salt and sugar were mixed with water and added to the above mix little by little while mixing. Finally oil was added and mixed for 15 min. The kneaded dough was sheeted (1cm thickness) on a wet cotton cloth and placed in a steamer for 45 min. at 95-98 °C. Then taken out of the steamer and cooled to room temperature and placed in a refrigerator at approximately 5 °C for 10 h. Then it was sliced (25 x12 x 1.5 mm) and oven dried at 55 °C for 3 h. The dried slices were deep fried in oil at 220 °C for 5 s.

Sensory evaluation: The five point hedonic test (1- dislike extremely, 5 - like extremely) was used to evaluate the sensory quality of the product. The Sensory attributes evaluated were colour, crispiness, odour, taste, texture, and overall acceptability.

Storage study: The storage studies were conducted using two different packaging materials [polypropylene (PP) (75μm) and oriented polypropylene/metalized cast polypropylene (OPP/MCPP) (20μm /25μm) laminated bags.] as treatments in a completely randomized

design with triplicates for each material. The packages were stored under ambient conditions (31±3 °C, 70±5 % RH) for three months. Samples were analyzed at one month interval for moisture, free fatty acid, total plate count, and sensory quality.

Physico-chemical analysis: Moisture was determined in triplicates according to AOAC (2000) procedures. The free fatty acid content (FFA) (as palmitic acid) of the product oil was determined in triplicates according to the method of SLS 251:1991.

Microbiological analysis: Micro biological quality (total plate counts) was determined in triplicates by the methods of SLS: 516-part 1.

Statistical analysis: Randomized complete block design was used to evaluate the sensory effects and data were analyzed by the Friedman test of the MINITAB statistical package. Mean comparisons were done by using Duncan's multiple range tests. Completely randomized design (CRD) was used to evaluate the physicochemical parameters and data were analyzed by SAS statistical package (SAS Institute Inc. 2000) using ANOVA.

RESULTS AND DISCUSSION

Storage study: After three months of storage period, deep oil fried plain crackers in PP package showed significant increase of moisture content compared to OPP/MCPP package. Samples in OPP/MCPP package showed least increase of moister content (Table 1).

Samples in PP package exceeded the maximum allowable moisture content (6%) for ready to serve extruded snacks as in SLS 1162:1997. However samples in PP and OPP/MCPP could be kept up to 2 months and more than 3 months respectively under safe moisture levels.

The slight increase observed in FFA content of the oil in the cracker during storage period in both packaging materials was significantly increased after one month of storage period (Table 2). However the FFA contents of the product oil in both packaging materials remained less than 1% (maximum allowable level for cookies according to SLS 251:1991).

Table 1. Moisture content (%) of deep oil fried cracker during storage

	Storage period (Months)			
Packaging material	**0**	**1**	**2**	**3**
PP	2.3^{f}	4.6^{c}	5.7^{b}	6.3^{a}
OPP/MCPP	2.3^{f}	2.4^{f}	2.6^{e}	2.8^{d}

Values followed by different letter within columns and rows are significantly different at $p< 0.05$, according to least significant difference test.

Table 2. Free fatty acid (FFA) content (%) as palmitic acid of the product oil during storage

Packaging material	Storage period (months)			
	0	1	2	3
PP	0.41[d]	0.42[d]	0.48[b]	0.50[a]
OPP/MCPP	0.41[d]	0.42[d]	0.45[c]	0.47[b]

Values followed by different letter within columns and rows are significantly different at $p< 0.05$, according to least significant difference test.

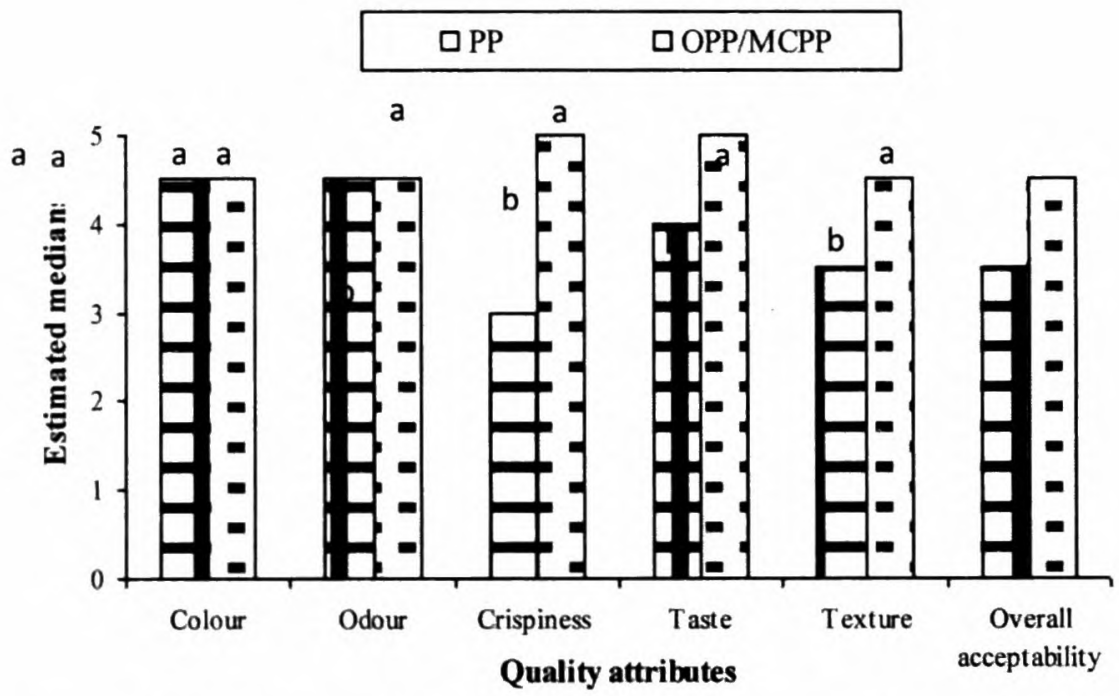


Fig. 1. Estimated median values for sensory quality attributes of deep oil fried cracker, after 1month of storage period

Figures 1 and 2 show the results of sensory evaluation tests during the storage periods of 1 and 3 months periods respectively. The sensory acceptability tests revealed, there were significant differences among the samples after 3 months of storage period for the quality parameters of crispiness, texture and overall acceptability. Samples in OPP/MCPP packaging material got high estimated medians for those parameters. This was indicating that OPP/MCPP packaging material as the best material compared to PP material for packaging of the deep fried cracker.

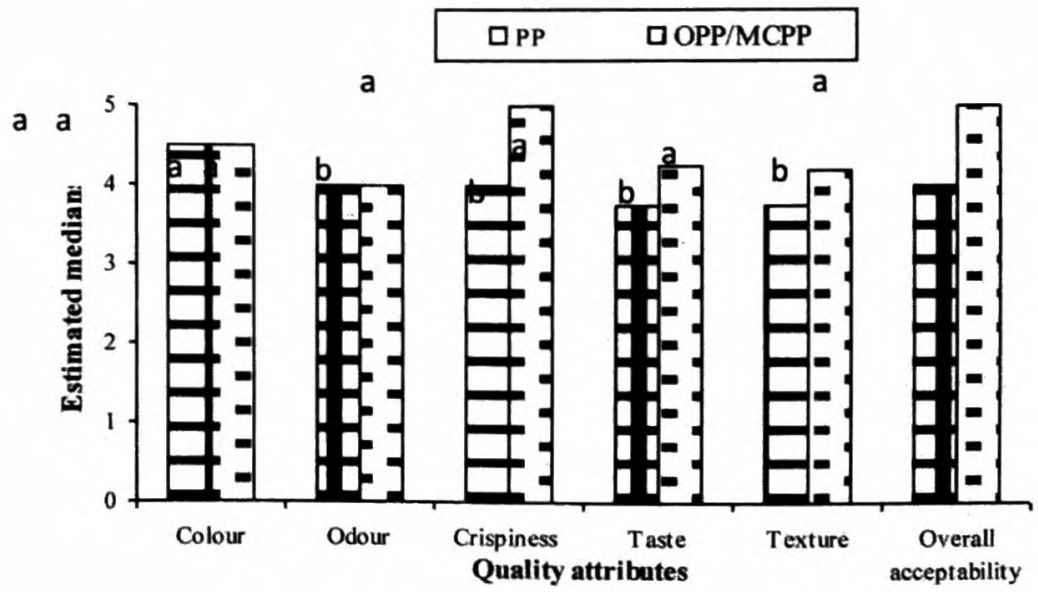


Fig. 2. Estimated median values for sensory quality attributes of deep oil fried cracker, after 3months of storage period

The cracker contained low level of microbial population at initial stage of storage (1 x 10^2 cfu/g). After three months period, samples in PP, and OPP/MCPP packages contained 9 x 10^2 cfu/g and 7 x 10^2 cfu/g respectively. According to SLS 1162:1997, the border line limit of acceptability for ready to eat extruded snacks is < 1 x 10^4 cfu/g and comparing to this limit the aerobic plate counts of the samples in all two types of packages were within safe level.

CONCLUSION

Rice flour based deep fried cracker could be formulated with highly acceptable sensory characteristics. Product could be stored safely for more than three months in OPP/MCPP packaging material without altering the sensory characteristics.

REFERENCES

AOAC. (2000). Official methods of analysis. Association of official analytical chemists, Washington DC.

Central bank of Sri Lanka. Anual report (2013).

SAS. (1994). Statistical procedures. Cary, NC, USA: SAS institute Inc.

SLS 516. (1991). Microbiological test methods, part 1- general guidance for enumeration of microorganisms colony count technique. Sri Lanka standards institute. 2 – 13.

SLS 1162. (1997). Specifications for ready to eat extruded snacks. Sri Lanka standards institute.

Development of dehydrated murunga leaves fortified nutri-mix

BMKS Tilakaratne*[1], MKU Arachchi[2], KMS Wimalasiri[2] and DGNG Wijesinghe[2]
[1] Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka
[2] Department of Food Science and Technology, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka
*Corresponding author: sikha45@yahoo.com

ABSTRACT

Nutri-mix is an instant food type that can be a good suppliment of essential vitamins and minarals which is contributing to recommended daily intake. Murunga leaves and pumpkins are commonly found in almost all areas in Sri Lanka, and they can be used as good replacements for traditional ingredients in nutria-mix without altering their nutritional content. As these crops are underutilized in Sri Lankan context, this study was carried out in order to introduce a new path to get the maximum use.

As treatments, four recipes were prepared changing the percentage of dehydrated murunga leaves powder (t_1 =2%, t_2 = 3% ,t_3= 4% , t_4= 5%) and dehydrated pumpkin powder (t_1 =18% , t_2 = 17% ,t_3= 16% , t_4= 15%).Then a constant precentage of brown rice (60%) and mung been (20%) was added to develop the nuti- mix. Sensory evaluation of four samples was conducted using thirty untrained panelists using a five point hedonic scale. The result show that the treatments were significantly different ($p< 0.05$) Treatement 2 (3% murunga powder and 17% pumpkin powder)got the highest median scores for all sensory attributes while treatment 4 (5% murunga powder and 15% pumpkin powder) showed the lowest median score.Thererfore treatment 2 was selected as the best ingredient combination for nuti- mix as it showed significantly higher sensory attributes among the others.

Keywords: Murunga leaves, nutri mix, pumpkin powder

INTRODUCTION

Nutri–mix is an instant food that can be good supplemant for essential vitamins and minerals to achieve recommended daily intake. It matches well with the busy life style of the pepole at present and an easy way of providing nutrients.various ingeredients are used to prepare different Nutri –mix in Sri Lanka to provide different nutrients to people eg: corn, soya, rice, green gram. There are several alternative and cheap ingredients readily available and wasted in huge amounts in the Sri Lankan context. In this research, murunga leaves, pumpkin, brown rice and mung been were selected to prepare a nutria-mix.

Murunga (*Moringa oleifera*) which belongs to the family Moringacea is a popular dry zone, home garden vegetable crop. This grows well in the areas such as Jaffna, Kalpitiya, Mannar, Puttalam and Hambantota. In Sri Lanka there is no large scale commercial cultivation of murunga and therefore, this crop is considered as an underutilized crop. Several varieties of murunga such as Rann Murunga (local variety), Jaffna and Chavakachcheri Murunga are grown in Sri Lanka (Ramachandren *et al.* 1987). In addition, several hybrid types such as Kalpitiya , V 19 and V 16 have been introduced. Partially matured pods, leaves and flowers can be used as medicines, animal fodder and seeds for oil extraction, water purification, cosmetic production, agro forestry and also in live fences. *Murunga* leaves contained high amount of protein, calcium, magnesium, potassium, iron, vitamin A, choline, thaimine, vitamin C and valine.

At present, the majority of women in Sri Lanka are employed and they have busy life style.Therefore, they look for products, which are convenient and time saving. Low cost murunga leaves based nutri –mix is one of the options among them which consist of high amount of nutrients.

Pumpkin is a cheap vegetable available all over the country, but high in nutrients. It is a source of dietary fiber, anti – oxidant, vitamins and minerals. Mungbean is widely produced and consumed in Sri Lanka. Mungbeans have tremendous nutritional value. Therefore, it is commonly referred as nutritional power house. It is easily digestible and prevents health problems. It is a good source of Vitamin B, C, E, and K.

Brown rice is higher in nutritional constituent compared to milled rice. Considering the above context, this study was carried out to develop a nutria-mix using dried *Murunga* leaves powder, pumpkin powder , brown rice and mungbean powder with the aims of popularize the murunga leaves based products also to find out the economies of the developed product.

MATERIALS AND METHODS

Location: The Study was carried out at the food processing laboratory of the Institute of Post Harvest Technology (IPHT), Anuradhapura.

Sample Collection: Murunga leaves were picked from the farm of the Institute of Post Harvest Technology and brown rice, mungbean and pumpkin were purchased from the market, Anuradhapura.

Selection of suitable samples: Picked leaves and purchased brown rice, mungbean and pumpkin were brought to IPHT food labotory. All damaged, ripened, diseased and immature leaves were removed during sorting. Diseased and damaged pumpkin parts were removed during peeling.

Preparation of samples: Murunga leaves were dipped in sodium metabi sulphite (SMS) containing water (1g/ L) for three min. Then blanching was done for 3 min at 60 ^{0}C (1g SMS/L). Pumpkins were peeled out and cut in to slices (2 mm) and were dipped in SMS water (1g/L) for three minutes. Then washed pumpkins were put on cotton cloth and made a

bunch. Blanching was done for 3-5 min at 60 ^{0}C (1g SMS/L). Mungbean were washed with water and then dipped in water for 6 h. After that, water was removed and covered with wet cotton cloth for 12 h. Brown rice was put in a laboratory grinder and sieved using 150 µm mesh.

Dehydration process: Dehydration of murunga leaves was done at 45 ^{0}C for 4 h in an oven. Dehydration of pumpkin was carried out at 50 ^{0}C for 6 h in an oven. Dehydration of mung bean was carried out at 50 ^{0}C for 6 h in an oven. After dehydration, dried murunga leaves, dried pumpkin and dried mung bean were ground and packed in polyethene bags. Mung beans were washed, dried in the oven at 55 ^{0}C for 4 h followed by toasting and ground for making into powder and sieved and packed in polythene bag. Red paddy was dehusked and prepared the brown rice and followd by grinding to prepare brown rice flour.

Table 1: Treatment combinations used in experiment 1

Ingredients	T- 1	T- 2	T- 3	T- 4
Dehydrated murunga leaf powder (%)	4	8	12	16
Dehydrated pumpkin powder (%)	16	12	8	4

*60% brown rice powder and 20% mungbean powder were added in equal amounts to all the treatments

Proximate composition analysis: Crude protein, crude fat, crude fiber, starch and total ash and moisture content were determined using the standards methods (AOAC, 2005).

RESULTS AND DISCUSSION

Results of sensory evaluation 1

For the color, treatment one obtained a significantly higher median value while the lowest ($P\leq0.05$) was obtained by treatment four. Overall acceptability is also the highest ($P<0.05$) in the combination of 4% murunga leaf powder and 16% dehydrated pumpkin powder supplemented nutri-mix. The lowest ($P<0.05$) overall acceptability was obtained by treatment four where 16% dehydrated murunga leaves powder and 4% dehydrated pumpkin powder was supplemented. Moreover there was no significant different in taste and odour among the treatment 2 and treatment 3.

Table 2. Effect of different combinations of dehydrated murunga leaves powder and dehydrated pumpkin powder of the first sensory evaluation

Sensory attributes	Treatment			
	T1	T2	T3	T4
Colour	4.4^{a}	3.5^{b}	2.5^{c}	1.8^{c}
Taste	4.6^{a}	2.8^{c}	2.6^{c}	1.6^{c}
Odour	3.4^{b}	$3.9^{a,b}$	3.4^{b}	2.1^{c}
Overall acceptance	4.4^{a}	$2.8^{b,c}$	2.5^{c}	1.9^{c}

Different letters within each row indicate significant differences at ($P<0.05$)

Treatments 2, 3 and 4 were rejected due to significant lower consumer acceptability. Furthermore, different ratios of dehydrated murunga leaves powder and dehydrated pumpkin powder were allocated to the nutri mix for next sensory evaluation near to the ratio of treatment one.

Results of sensory evaluation 2

Table 3. Effect of different combinations of dehydrated murunga leaves powder and dehydrated pumpkin powder in the second sensory evaluation

Sensory attributes	Treatment			
	T1	T2	T3	T4
Colour	3.2^{b}	4.4^{a}	3.9^{b}	2.7^{c}
Taste	4.2^{ab}	4.9^{a}	3.9^{b}	2.9^{c}
Odour	4.7^{a}	4^{b}	3.7^{b}	2^{c}
Overall acceptance	4.1^{ab}	4.8^{a}	3.6^{b}	2.1^{c}

Different letters within each row indicate significant differences at ($P<0.05$)

T_1 – 2% dehydrated murunga leaves powder, 18% dehydrated pumpkin powder, 60% brown rice powder, and 20% dehydrated mungbean powder

T_2 – 3% dehydrated murunga leaves powder, 17% dehydrated pumpkin powder, 60% brown rice powder, and 20% dehydrated mungbean powder

T_3 – 4% dehydrated murunga leaves powder, 16% dehydrated pumpkin powder, 60% brown rice powder, and 20% dehydrated mungbean powder

T_4 – 5% dehydrated murunga leaves powder, 15% dehydrated pumpkinpPowder, 60% brown rice powder, and 20% dehydrated mungbean powder.

Odour of the 2% dehydrated murunga leaves powder supplemented nutria-mix was higher ($P<0.05$) than other treatments. That may be due to least amount of dehydrated murunga leaves powder addition where that has lowest leafy odour. Furthermore, colour, taste and overall acceptability of treament two where 3% dehydrated murunga leaves powder and 17% dehydrated pumpkin powder supplemented nutri-mix showed significantly higher median values. Even in the second sensory evaluation result, higher Murunga leaves powder supplemented nutri mix showed the significantly lower consumer acceptability. Thus, that emphasized consumer acceptability would be gradually decreased with the increases of supplemented murunga leaves powder for nutria-mix.

CONCLUSION

The best combination of ingredients for the preparation of nutri-mix is 3% dehydrated murunga leaves powder, 17% dehydrated pumpkin powder, 60% brown rice powder and 20% dehydrated mungbean powder. It contained 28% protein, 14% fibre, 3% fat, 43% starch and 12% moisture. With high amount of vitamin A other nutrients. Ingradient cost was estimated as Rs. 35.00 to prepare 100 g of nutri-mix. If this product is mixed with 5% sugar and 10 % desicated cococnut can be used as instant ready to serve nutria-mix.

REFERENCES

National Research Council (2006). "Moringa" Lost Crops of Africa, National Academic Press, 247pp

Ramachaadran C, Peter KV, Gopalkrishnan P K (1987). Drumstick (*Moringa olefera*) A Multi Purpose Indian Vegetable., Economic Botany, New York Botanical Gaeden – Bronx, 34.

Food and Agriculture Organization of the United Nations (1999). The Vegetable Sector in Thailand [online]. [Accessed on 05.07.2011]. Available at http://en.wikipedia.org/wiki/Moringa oleifera

Heldman D R and Hartel RW (1998). Principles of food processing, Aspen Publishers, 34-177pp

Champagne ET, Wood DF, Juliano BO, Bechtel DB (2004). The rice grain and its gross composition. In: Champagne ET (Ed.) Rice: Chemistry and Technology, III[rd] ed. AACC, St. Paul, MN, pp. 77-107.

Kunse OR, Lan Y and Wratten FT (1970). Physical and mechanical properties of rice, *Rice Chemistry and Technology*, Ed., Champagne, E. T., American Association of Central Chemists, Inc, Monnesota, U. S. A., pp 191-195, 210-211.

Pomeranz Y and Meloan CE (1982). Food Analysis Theory and Practice, The AVI Publishing Company, 521-560pp

Glycaemic index and glycaemic load of rotti prepared with soy and rice flours

MPMSH. Perera[1*], R Sivakanesan[2], DTDJ Abeysekara[3] and KH Sarananda[4]
[1] Post Graduate Institute of Agriculture, University of Peradeniya
[2] Department of Biochemistry, Faculty of Medicine, University of Peradeniya
[3] Lakeside Adventist Hospital, Kandy
[4] Horticultural Researche & Development Institute, Department of Agriculture, Gannoruwa, Peradeniya
*Corresponding author: mpmshpp@yahoo.com

ABSTRACT

Soy incorporated foods have low glycaemic index and consumption of soya increase insulin sensitivity and improve glycaemic control. Therefore this study was conducted to evaluate the glycaemic index and feasibility of incorporating soy flour into rotti as a breakfast foods. Rice flour (BG 352) and Soybean (PB-1) were used to prepare rotti with 25% soy flour and 75% rice flour mixture. The Glycaemic Index was 36.04±1.9 and Glycaemic load was 4.32 therefore this can be used as a low glycaemic food for type 2 Diabetics.

Keywords: Carbohydrates, glycaemic index, glycaemic load, rice flour, soy flour.

INTRODUCTION

Sri Lankan breakfast foods are generally made from either rice (*Oryza sativa*) flour or wheat (*Triticum sativum)* flour. Feasibility of incorporating 25% soy flour into rotti was done and sensory evaluation indicated that rotti made with partial replacement of soy flour was acceptable (Perera *et al.* 2013). Soy incorporated rotti had 9.5% fat, 19.6% protein and 28.5% available carbohydrate content (Perera *et al.,* 2014). Present study was conducted to estimate the glycaemic index (GI) and glycaemic load (GL) of soy incorporated rotti.

MATERIALS AND METHODS

Raw materials: Red raw rice (BG 352) was obtained from Rice Research and Development Institute, Bathalagoda. Soy bean (PB-1) variety was purchased from Pelwehera farm, Department of Agriculture, Dambulla, Sri Lanka.

Preparation of soy bean flour and rice flour: Soybean seeds were processed into flour using the method of Wolf and Cowan (1981) at the Food Research Unit, Gannoruwa and the processing ensured effective removal of most anti-nutritional factors. Paddy variety BG 352 was milled to 7% polishing rate at the Institute of Post Harvest Technology, Anuradhapuraya and it was processed into flour at the Food Research Unit, Gannoruwa. Soy and rice flour were packed in 350 gauge polypropylene bags and stored at room temperature.

Preparation of rotti: A mixture of flour (25% soy flour and 75% rice flour), required amounts of salt, boiled cooled water and grated coconut were mixed thoroughly and the dough was divided into small balls, flattened to get a round shaped rotti. Rotti were placed on a circular rotti pan and heated on a mild blue-flame for 10 minutes.

Determination of glycaemic index: Glycaemic index (GI) was estimated with healthy individuals (n=13) employed at the Food Research Unit, Gannoruwa. The study procedure was explained to the subjects and their informed written consent was obtained. D-Glucose (Boi Labs, Kottala Road, Veyangoda, Sri Lanka) was used as the standard. Determination of GI and calculation of glycaemic load (GL) were carried out according to the method described by Wolver *et al.* (1995). Approval for the study was obtained from the Ethical Review Committee, Faculty of Medicine, University of Peradeniya, Sri Lanka (2012/EC/09).

Statistical Analysis: The GL, GI and Incremental Area Under Curve (IAUC) values were calculated using Microsoft Office Excel (2007).

RESULTS AND DISCUSSION

Demographic data of study subjects: All study subjects had normal body mass index, systolic and diastolic blood pressure, fasting and random blood glucose concentrations according to WHO (2006) criteria, (Table 1). Past medical history and drug history were obtained and no history of non communicable diseases was found.

Table 1. Demographic data of study subjects

Mean± SD*						
Age (years)	**BMI (kg/m^2)**	**Systolic blood pressure (mm/Hg)**	**Diastolic blood pressure (mm/Hg)**	**Pulse/min**	**FBGC (mg/dl)**	**RBGC (mg/dl)**
26.1 ± 1.8	22.1±1.8	118.9±4.8	77.2±4.5	75.3±2.3	90.6±9.2	120.6±1.7

FBGC: fasting blood sugar concentrations, RBGC: random blood sugar concentrations, number of replicates=13

Glycaemic response to standard and soy incorporated rotti: Glycaemic response to standard and soy incorporated rotti is illustrated in Figure 1. Soy incorporated rotti had slow increase in postprandial capillary blood glucose concentration compared to standard.

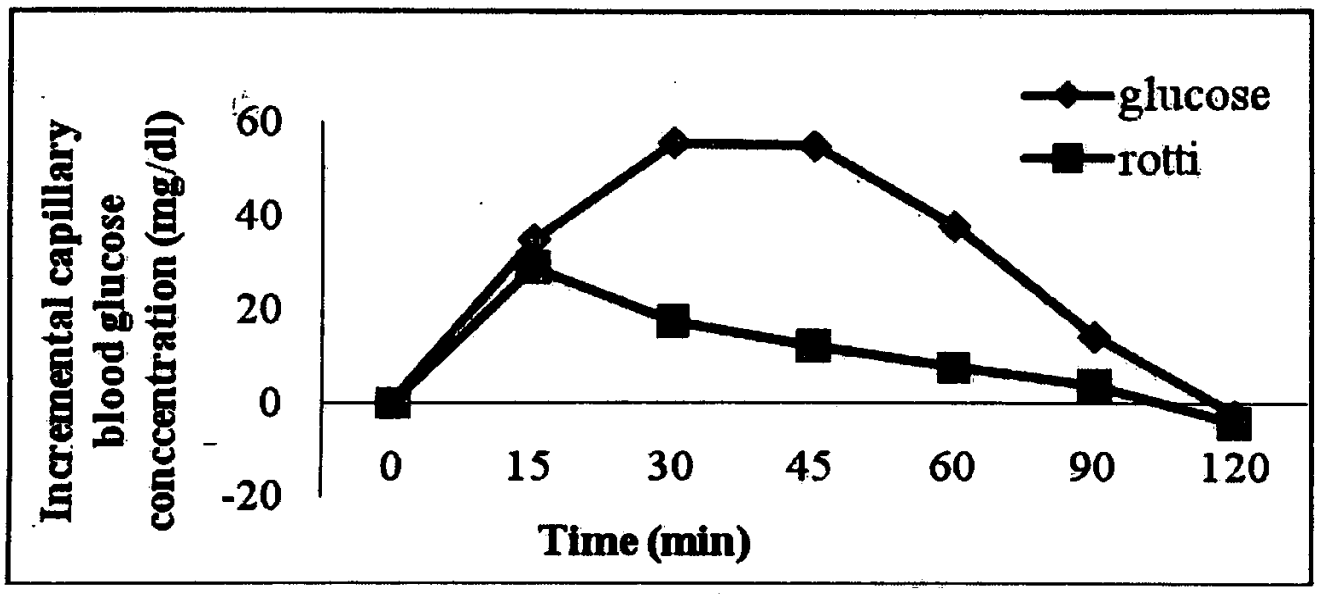


Fig. 1. Glycaemic response to standard and soy incorporated rotti

Glycaemic index (GI) and glycaemic load (GL) of soy incorporated rotti: Available carbohydrate content, meal size and glycaemic index of soy incorporated rotti are given in Table 2.

Table 2. Available carbohydrate content, meal size (cooked weight) glycaemic index and glycaemic load of soy incorporated rotti

Available carbohydrate (g/100g)*	Meal size (g)	GI**	GL**
28.47±1.4	244.1	36.04±1.9	4.32±1.9

*number of replicates=13, ** number of replicates=6

Rotti made with 25% soy in combination with 75% rice flour had a GI of 36.04±1.9 and a GL of 4.32±1.9. Foods are classified as low GI (55 or less), medium GI (55 to 70) and high GI (70 or greater) (Atkinson *et al.* 2008). GI of soy beans and soy milk are 16±1 and 34±4 respectively (Atkinson *et al.* 2008). Widanagamage *et al.* (2009) observed that rotti made with 100% wheat flour had 72±6 of GI and made with 100% rice flour had 69±7 of GI. Therefore soy incorporated rotti could be regarded as a low GI food may prove beneficial (Jenkins *et al.* 2002).

CONCLUSION

In conclusion, rotti made with 25% of soy bean flour and 75% rice flour had a GI of 36.04±1.9.

ACKNOWLEDGEMENT

The great assistance provided by the staff of Food Research Unit, Gannoruwa, Institute of Post Harvest Technology, Anuradhapuraya and Rice Research and Development Institute, Bathalagoda are highly acknowledged for their support, and commitment to make this study a success.

REFERENCES

Atkinson FS, Foster-Powell K and Brand-Miller JC (2008). International table of glycaemic index and glycaemic load values. Diabetes Care. 31, 2281-2283.

David JA, Jenkins CWC, Kendall L, SA Augustin, Silvia Franceschi, Maryam Hamidi, Augustine Marchi., Alexandra L. Jenkins and Mette Axelsen (2002). Glycemic index: overview of implications in health and disease. American Journal of Clinical Nutrition. 76, 266s-273s.

Perera MPMSH, Sivakanesan R, Abeysekara DT D J and Sarananda KH (2012). Sensory evaluation of traditional breakfast food substituted with soy flour and rice flour. Book of abstract of the Peradniya University Research Session. Sri Lanka. 17, 137.

Perera MPMSH, Sivakanesan R, Abeysekara DT D J and Sarananda KH (2014). Sensory evaluation, Proximate Composition and Available Carbohydrate Content of Soy Flour Incorporated Cereal Basede Traditional Sri Lankan Breakfast Foods. International Journal of Research in Agriculture and Food Sciences. 4, 10-18.

Thomas MS, Wolever David, JA Jenkins, Alexandra L. Jenkins, Robert G. Josse (1991). Glycaemic index methodology and clinical implications. American Journal of Clinical Nutrition, 54, 246-254.

Widanagamage RD, Ekanayaka S and Welihinda J (2009). Carbohydrate-rich foods; glycaemic indices and the effect of constituent macronutrients. International Journal of Food Science and Nutrition. 60, 4, 215-223

Wolf WJ and Cowan JC (1981). Soybeans as a food source. P: 46-77. CRC Press, Peoria, Illinois, USA.

World Health Organization (2006). Definition and Diagnosis of Diabetes Mellitus and Intermediate Hyperglycaemia, Report of WHO and IDF consultation.1-46.

Sensory qualities of flavoured and non flavoured cashew apple (*Anacardium occidentale* L.) syrup

RKBNR Randeni, MDK Vithana and SJBA Jayasekera
Department of Horticulture and Landscape Gardening, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila (NWP)
*Corresponding author: bimbarandeni@yahoo.com

ABSTRACT

Cashew apple products do not have much popularity among Sri Lankans because of the lack of awareness about cashew apple preservation. After the nuts are harvested, a large quantity of cashew apples is currently being wasted. Therefore, this study was carried out to develop syrup from cashew apple and evaluate its quality attributes including consumer acceptance. The juice was extracted manually by pressing cashew apple pieces and by grinding with peel using an electric grinder. Syrups were made using either cashew apples subjected to astringency reducing treatment, or from non-treated cashew apple, both with or without peel separately. A sensory evaluation was carried out to check the consumer acceptance. The data were analyzed using non-parametric Freidman and Mann-Whitney tests. The strawberry flavoured syrup made using peeled cashew apples subjected to astringency reducing treatment showed the highest acceptance with 'like very much' (rank 8). Lowest acceptance ranks were recorded for all sensory attributes for the with-peel non floured syrup. Refrigeration at 4°C increased the storage time and shelf life of cashew syrup.

Keywords: Astringency, cashew apple, flavours, sensory evaluation, syrup

INTRODUCTION

Cashew (*Anacardium occidentale* L.) is one of the most important cash crop in Sri Lanka, which generates significant foreign exchange through its kernel and cashew nut shell liquid (CNSL). Cashew apple is another major component of cashew fruit. The Vitamin C content in cashew apple juice is 261 mg /100 ml, which is 5 times that of orange and 12 times that of pineapple (Mini *et al.* 2005). Cashew apple has been found to cure stomach disorders and sore throat (Olunloya 1996). It has antimicrobial activity against the bacteria *Helicobacter pylori* which causes gastric disease (Kubo *et al.* 1999). However, in Sri Lanka, cashew apples is a highly underutilized and the fruits spoil in orchards under the trees due to unawareness among people about nutritional and medicinal value of this fruit and also due to lack of knowledge on technology of cashew apple preservation.

Cashew apple can be eaten as a fresh fruit or can be used for preparation of different non-fermented and fermented products such as juice, syrup, jam, chutney, liquor, wine, brandy, vinegar, etc. However, astringency, perishable nature and transportation problems hinder the utilization of cashew apple. The astringent and acrid properties in cashew apple produce a rough unpleasant and biting sensation on the tongue and throat.

In Sri Lanka, no research study and / or a developmental process has been conducted on cashew apple preservation. Therefore, this study was carried out to develop cashew apple syrup and evaluate its quality attributes and consumer acceptance. This effort aims to minimize the wastage of cashew apple while improving the economy of rural communities by creating an additional source of income.

MATERIALS AND METHODS

The study was carried out at the Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila from April to August, 2011. Cashew apple samples were manually harvested from the Cashew Seed Garden of Sri Lanka Cashew Corporation, Eluwankulama.

Astringency reducing treatment on cashew apple syrup: Syrup was made using either cashew apple subjected to astringency reducing treatment or using untreated cashew apples. As an astringency reducing treatment, Cashew apples were thoroughly washed, immersed in a boiling solution of common salt (3%) for 5 minutes and rinsed with fresh water.

Syrup preparation: The juice was extracted manually by pressing cashew apple pieces using an equipment and by grinding the pieces using an electric grinder. Then, the juice was strained through a muslin cloth. Cooked, powdered sago was added at the rate of 1.4 g /L of juice. The mixture was stirred for 2 min and strained through a muslin cloth. One kg of sugar, 20 g of citric acid and 0.08% sodium benzoate were added to 1 L of juice. Sodium benzoate was dissolved in a small volume of warm water before adding to the mixture. All the ingredients were thoroughly mixed and the mixture was heated to 90°C for 1 minute (Mini *et al.* 2005). Samples were prepared as pineapple flavoured, strawberry flavoured and non flavoured. Pink (0.75 ml/L) and yellow (4 ml/L) colours were added to strawberry and pineapple flavoured syrup, respectively. The syrup was collected in sterilized glass bottles, sealed and stored at room temperature (30°C) or in a refrigerator at 4°C for 2 months.

Sensory evaluation and statistical analysis: Sensory evaluation was conducted using 20 non-trained panelist for the diluted syrup (syrup : water, 1 : 5), where the panelists were asked to rate colour, smell, taste, astringency, overall quality and the purchasing intention using a structured nine-point hedonic scale (Peryam and Pilgrim 1957). Data were analyzed using the non-parametric Mann-Whitney and Friedman tests with Minitab 15 statistical package.

RESULTS AND DISCUSSION

Samples both non-treated and treated for astringency, from pineapple, strawberry and non flavoured treatments were compared using non-parametric Mann-Whitney test. Significant differences were shown only between strawberry flavoured syrups, treated or non-treated for astringency, for the overall quality ($P = 0.0472$) and purchasing intention ($P = 0.0514$). Acceptance rank for overall quality and purchasing intention of treated sample was recorded as 'like very much' (rank 8) and 'like moderately' (rank 7) for the non treated samples, respectively.

Sensory attributes of all the treatments were significantly different (Table 1). Astringency-reducing treatment had no considerable effect on the colour and smell of the syrup. The strawberry flavoured syrup subjected to astringency-reducing treatment was recorded as the best syrup, according to the ranking of the panelists.

Table 1. Median level of acceptance ranks for all treatments from syrup without peel

Sensory attributes	Pineapple flavoured		Strawberry flavoured		Non flavoured	
	TRA	NT	TRA	NT	TRA	NT
*Colour	7	7	8	7	5	5
*Smell	6	6	7	7	6	5
*Taste	7	6	7	6	6	5
*Astringency	7	6	7	7	6	5
*Overall quality	7	6	8	7	6	6
*Purchasing intention	7	6	8	7	6	5

TRA: treated to reduce astringency, NT: non treated * Significant at 0.001 level.

Lowest acceptance ranks were recorded for all the sensory attributes for with-peel non flavoured syrups (Table 2). The reasons could be the off flavour, colour and more astringency resulted when the juice was obtained by grinding cashew apple pieces with peel. A higher level of sedimentation was also observed in this sample which too is a negative quality attribute. Although siphoning was done it reduced sedimentation only up to a limited extent.

According to the visual observation during storage period, the colour of the syrup stored under room temperature changed when compared to the refrigerated syrup. The mixing of fruit enzymes with substrate and air can rapidly initiate enzymatic browning. Phenolic compounds, polyphenol oxidase and oxygen react to darken many juices. Many other enzymes active in juice are capable of destroying ascorbic acid, modifying pectin and affecting colour, flavour and texture. Therefore, rapid processing and the use of heat or enzyme inhibitors are necessary. Another storage limiting factor affecting most juices is the common sugar-amine or Maillard reaction in which reducing sugars and amines, slowly go through a series of steps to form brown pigments. Low temperature greatly retards Maillard browning, but does not completely stop these undesirable reactions. Therefore, refrigerated syrup was appropriate for consumption.

Table 2. Grand median of acceptance of with-peel non flavoured syrups after the period of storage

Sensory attributes	After 1 week	After 1 month	After 2 months
Colour	6	6	5
Smell	5	5	4
Taste	6	6	5
Astringency	6	6	6
Overall quality	6	6	6
Purchasing intention	6	6	5

CONCLUSION

Application of astringency-reducing treatment for syrup preparation procedure can be used to cut down the unpleasant biting sensation on throat when drinking a glass of syrup. Strawberry flavoured syrup treated for astringency was the best syrup and overall quality was scored as 'like very much'. Lowest acceptance rank was obtained for the "with-peel, non flavoured" syrup due to the unfavourable changes of aroma and taste of this syrup during storage. Refrigerated condition (4°C) was preferred over room temperature to store cashew apple syrup for a 2 months period without development of off colours.

REFERENCES

Kubo J, Lee JR and Kubo I (1999). Anti-*Helicobacter pylori* agents from the cashew apple. Journal of Agricultural and Food Chemistry, **47**: 533–537.

Mini C, Mathew J and Augustine A (2005). *Technologies for Cashew Apple Processing*. 2nd edition. Kerala Agricultural University, Mannuthy, Thrissur.

Olunloyo OA (1996). Marketing outlets for cashew nuts. In Proceedings of the national workshop on Cashew Production Technology. 26-29 March, 1996. Cocoa Research Institute of Nigeria.

Peryam DR and Pilgrim FJ (1957). Hedonic scale method of measuring food preferences. Food Technology, 11: 9–14.

Determination of selenium content in cereals and legume seeds grown in Sri Lanka

PA Buwaneka*, DSM de Silva, S Wimalasena and AT Kannangara
Department of Chemistry, University of Kelaniya
* Corresponding author:pawanthibuwaneka@yahoo.com

ABSTRACT

Selenium is considered as an essential micro-nutrient. Cereals and legumes play a vital role in nutrition of people in Sri Lanka as they consume food mainly of plant origin. Samples for the study were collected from farms located in Wariyapola, Elahara, Kilinochchi and Mattala. The study was carried out on *Vigna sinensis* (*Eng.* Cowpea), *Vigna radiata* (*Eng.* Greengrams), *Glycine max* (*Eng.* Soybeans), *Eleusine coracane* (*Eng.* Millet), *Vigna mungo* (*Eng.* Blackgram) and *Zea mays* (*Eng.* Maize). Selenium was determined using Hydride Generation Atomic Absorption Spectrometer, after digesting with nitric acid. Selenium content (dry weight basis) in cereals and legumes were in the range of 15.85 - 76.01 µg/kg. Highest concentration of selenium was observed in *G. max* (51.87 - 76.01 µg/kg) while *V. sinensis* had the second highest content (34.19 - 52.21 µg/kg). The variations of selenium content within the sub species of *V. sinensis* (MI 35, Bombe, Vijaya, Dhawala, Alintan, Waruni), *V. radiata* (Ari, MI 05, MI 06, Harsha), *V. mungo* (Anuradha, MI 01), *G. max* (PB 01, PM 25) and *E. coracane* (Ravana, Oshadha) were also studied for the samples obtained from Wariyapola. According to the results obtained the highest content of selenium was observed in the sub species of Vijaya, MI 05, MI 01, PM 25 and Ravana, which belonged to *V. sinensis, V.radiata, V. mungo, G. max* and *E. coracane* respectively.

Keywords: Cereal grains, legume seeds, selenium content, sub species of cereals

INTRODUCTION

Selenium is an essential micro-nutrient for human. It enters our body from the food consumed by us, mainly meat, sea food, milk, egg, vegetables and cereals (Montes-Bay´on *et al.* 2006). The function of selenium is carried out by selenoproteins that has selenocysteine, selenomethionine and methyl selenocysteine. During protein synthesis, these amino acids randomly get incorporated into proteins replacing methionine. These proteins are called selenium-binding proteins and they are different from true selenoproteins (Montes-Bay´on *et al.* 2006).

Glutathione peroxidase is the first true selenoprotein identified and it oxidizes reduced glutathione, as well as reduces hydrogen peroxide to water (Montes-Bay´on *et al.* 2006). This prevents lipid peroxidation and cellular damage by acting as antioxidants, and prevents degenerative diseases and aging. The relationship between selenium and vitamin E came to light with the discovery of the ability of selenium to prevent liver necrosis. The overlapping roles of these two nutrients are illustrated by the efficacy of selenium and vitamin E in preventing lipid peroxidation (Sunde 2006). More over selenium is essential for the synthesis of thyroxin which is the active thyroid hormone. Deficiency of selenium effects

functioning of thyroid gland while adequate amount of selenium helps in preventing some of the neurologic effects of iodine deficiency (Yang 1987 and Rayman 2000).

Selenium shows dual characters in biological function as the range in which selenium is toxic and resulting deficiency in animal is rather narrow (25 µg/day - 400 µg/day for person). Daily requirement of selenium for adult male and female is 55 µg/day. If the selenium concentration is hundred times higher than that required for physiological functions, it becomes toxic. Inorganic selenium and selenium incorporated amino acids are highly toxic while the methylated forms such as trimethylselenium chloride and dimethylselenides are three times less toxic. The most toxic form of selenium is hydrogen selenide. (Sunde 2006). It is a chemo preventive agent for prostate, lungs, colorectal, multiple and stomach cancer. Selenium also has the ability to act against progression of HIV virus (Sunde 2006). Keshan disease and Kashin-beck diseases are caused due to the selenium deficiency (Sunde 2006). Amount of selenium that is taken by the body is determined by the variety of food consumed and the selenium level in the soil of the area where food is obtained.

The amounts of selenium in foods, which are commonly consumed by the people of other countries, have been carried out, but not by those in Sri Lanka. In most of the South Asian countries, *Vigna sinensis* (*Eng.* cowpea), *Vigna radiata* (*Eng.* greengrams), *Glycine max* (*Eng.* soybeans), *Eleusine coracane* (*Eng.* millet), *Vigna mungo* (*Eng.* blackgram) and *Zea mays* (*Eng.* maize) are the commonly consumed cereals and legume seeds, but studies carried out on selenium content in these varieties are rare. Only available data on selenium content in cereals are from Thailand (Kongkachuichai *et al.* 2005). The main objective of this study was to determine whether cereals and legumes could be used as sources of selenium in Sri Lankan diet and introduce one or several varieties as rich source of selenium. Further this study focused on deducing the variation of selenium content in the sub varieties of cereals, in order to deduce whether a correlation exists between selenium content and sampling sites.

Further, in this study the variation in the selenium content within the sub species of *V. sinensis* (MI 35, Bombe, Vijaya, Dhawala, Alintan, Waruni), *V. radiata* (Ari, MI 05, MI 06, Harsha), *V. mungo* (Anuradha, MI 01), *G. max* (PB 01, PM 25) and *E. coracane* (Ravana, Oshadha) were also studied for the samples obtained from Wariyapola. The sub species were identified by the Sri Lanka School of Agriculture, Wariyapola.

MATERIALS AND METHODS

Sampling: Samples of cereals and legumes namely *V. sinensis, V.radiata, V. mungo, G. max, E. coracane* and *Z. mays* were collected from the small and large scale farms located in Elahera, Mattala, Kilinochchi and Wariyapola . Sub species of *V. sinensis* (MI 35, Bombe, Vijaya, Dhawala, Alintan, Waruni), *V. radiata* (Ari, MI 05, MI 06, Harsha), *V. mungo* (Anuradha, MI 01), *G. max* (PB 01, PM 25) and *E. coracane* (Ravana, Oshadha) were collected from Wariyapola. The sampling period was May 2013 to September 2013.

Methodology: The experiment was carried out in a laboratory of the Department of Chemistry, University of Kelaniya, Sri Lanka. Foreign matter and damaged seeds were removed by visual inspection and powdered using motor and pestle. Each sample was prepared in triplicate.

Samples (~5.0000 g) were oven dried at ~80°C till a constant weight was obtained (~5 hrs). Ground samples (2.5000 g) were digested with conc. nitric acid (30.00 mL) at 95°C for 2 hours and cooled to room temperature. De-ionized water (4.0 mL) and 60% hydrogen peroxide (6.0 mL) were added and heated to 60°C for twenty minutes. The addition of hydrogen peroxide was continued with warming until effervescence ceased. The solution was concentrated by heating at 80±5°C. It was further heated at 70°C with concentrated HCl for 30 min, and made upto 50.00 mL mark in a volumetric flask with de-ionized water. The extract was analyzed using Hydride Generation Atomic Absorption Spectrometry after optimizing the condition for the determination. The obtained data for the selenium concentrations were analyzed using one way ANOVA and TUCKY's pair wise comparison at 95% confidence level.

RESULTS AND DISCUSSION

The moisture content of all the samples was lower than 10%. The results of the present study indicated that *G. max* had the highest selenium content, while *V. mungo* had the lowest selenium content (Figure 1). There was no significant difference in selenium content in the samples belonging to the sub species of *V. sinensis* Significant difference in the selenium content was not observed in the sub species, Ari, MI 05 and MI 06 belonging to *V.radiata* but the concentration in the sub species Harsha showed a significant difference.

The highest selenium containing sub species of *V. sinensis, V.radiata, V. mungo, G. max* and *E. coracane* were Vijaya, MI 05, MI 01, PM 25 and Ravana respectively.

The variation in the selenium content in cereals and legumes with respect to the sampling sites (Wariyapola, Kilinochchi, Elahara and Mattala) were also determined. The highest selenium content in samples analyzed from the four sites was in *G. max*. The highest concentration of selenium was observed from Kilinochchi (74.95 µg/kg) and lowest concentration was from Elahara (51.87 µg/kg). The lowest selenium content was in *V. mungo* obtained from Wariyapola (17.91 µg/kg).

Statistical analysis showed ($p>0.05$) that except for *V. radiata* all other species showed significant difference in selenium concentrations with respect to sampling sites (Table 2).

A correlation between the selenium content and the sampling sites was not observed. Except for *G. max* all samples collected from Wariyapola showed the lowest selenium content compared with those from other area.

Table 1. Selenium contents in subspecies of cereals and legumes

Species	Sub species	Se concentration (µg/kg)*
Vigna sinensis (Cowpea)	MI 35	34.19 (±6.26)[a]
	Bomba	38.75 (±4.45)[a]
	Vijaya	45.60 (±2.62)[a]
	Dhawala	45.63 (±1.33)[a]
	Alintan	39.79 (±1.42)[a]
	Waruni	39.18 (±2.59)[a]
Vigna radiata (Greengrams)	Ari	29.59(±2.68)[a]
	MI 05	37.10 (±3.44)[a]
	MI 06	32.35 (±5.23)[a]
	Harsha	15.85 (±3.80)[b]
Vigna mungo (Blackgram)	Anuradha	17.91 (±2.19)[a]
	MI 01	25.24 (±2.28)[b]
Glycine max (Soybeans)	PB 01	60.99 (±2.87)[a]
	PM 25	76.01 (±8.62)[b]
Eleusine coracane (Millet)	Ravana	45.77 (±7.32)[a]
	Oshadha	18.92 (±4.61)[b]

*Mean ± standard deviation of determination carried out in triplicates,*means with the same letters in the column do not differ significantly when statistically analyzed by one way ANOVA and TUCKY's pair wise comparison test.

Table 2. Selenium content in cereals and legumes from different sites

Cereals & legumes	Average selenium content (µg/kg)*			
	Wariyapola	**Kilinochchi**	**Elahara**	**Mattala**
Vigna sinensis	39.79 (±1.42)[a]	52.21 (±5.50)[b]	51.35 (±5.19)[b]	42.29 (±1.98)[b]
Vigna radiata	29.59 (±2.68)[a]	32.28 (±2.47)[a]	32.99 (±2.15)[a]	ND
Glycine max	60.99 (±2.87)[a]	74.95 (±4.65)[b]	51.87 (±3.87)[c]	ND
Vigna mungo	17.91 (±2.19)[a]	48.85 (±13.40)[b]	ND	ND
Zea mays	18.46 (±3.92)[a]	ND	ND	49.29 (±2.86)[b]

ND – Not determined as samples were not available,*mean ± standard deviation of determination carried out in triplicates,*means with the same letter in the row do not differ significantly when statistically analyzed by one way ANOVA and TUCKY's pair wise comparison test.

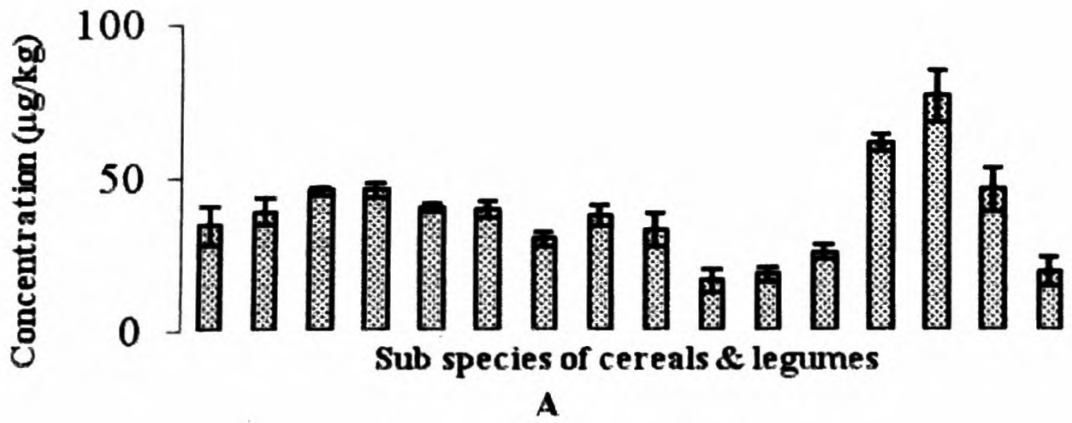


Fig. 1. A: Selenium concentrations (µg/kg) *vs* sub species of cereals & legumes from Wariyapola, B: Selenium concentrations *vs* species of cereals and legumes according to their sampling sites

CONCLUSIONS

All the cereals and legume seeds that were analyzed in this study were found to be good sources of selenium. The concentrations of selenium in the cereals analyzed were in the range of 15.85 - 76.01 µg/kg. *G. max* (soybean) contained the highest amount of selenium. A significant difference in selenium content in the sub species of cereals and legumes was observed except for *V. sinensis*. The highest selenium containing sub species for *V. sinensis, V.radiata, V. mungo, G. max* and *E. coracane* were Vijaya, MI 05, MI 01, PM 25 and Ravana respectively. A correlation between selenium content and sampling sites was not seen.

REFERENCES

Montes-Bay´on M, Jos´e D´ıaz Molet M, Blanco Gonz´alez E, Sanz-Medel A (2006). Evaluation of different sample extraction strategies for selenium determination in selenium-enriched plants (*Allium sativum* and *Brassica juncea*) and Se speciation by HPLC-ICP-MS. *Talanta*. 68, 1287-1293.

Sunde RA (2006). Selenium. In: R.M. *Present Knowledge in Nutrition*. 9th ed., Bowman, B.A. and Russell, Washington, D. C: ILSI Press. p480-497.

Yang GQ (1987). Research on Se-related problems in human health in China. *Proc. Int. Symp. Selenium Biol. Med.*, 3rd Edition, 9.

Rayman MP (2000). The importance of selenium in human health. *Lancet,* **356**. 233-241.

Kongkachuichai R, Polngam J, Puwastien P, Sirichakwal PP (2005). Selenium content of Thai foods. *Journal of food composition and analysis*. **18**, 47-59.

Development of murunga leaves (*Moringa oleifera*) based bread spread

BMKSThilakaratne,[*1] AAMT Gunasekara[2], NWIA Jayawardana[2] and GAS Ginigaddara[2]

[1] Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka

[2]Faculty of Agriculture, University of Rajarata, Puliyankulama, Anuradhapura 50000, Sri Lanka.

Corresponding author: sikha45@yahoo.com

ABSTRACT

Murunga leaves contain a high amount of protein, calcium, magnesium, phosphorous, iron, vitamin A, choline, thiamine, vitamin C and valine. This study was carried out to develop a bread spread with dehydrated murunga leaves powder which is considered as an underutilized plant in Sri Lanka. As treatments four recipes were prepared changing the percentage of dehydrated *murunga* leaves powder (t_1=35%,t_2=40% ,t_3=45%, t_4= 50%) and dehydrated carrot powder (t_1=15%,t_2=10% ,t_3=5%, t_4= 0%). Sensory evaluation of four samples was conducted by thirty untrained panelists using a five point hedonic scale. The results were analyzed using complete randomized design in factorial experiments. The best recipe out of all treatments was 45% of murunga leaves 5% of carrot powder 35% of margarine, 8.4% of onion 3% of vinegar 1.2% of mustard 1.2% pepper and 1.2% salt. The selected recipe from the sensory evaluation was stored in two packaging materials (glass bottles, polypropylene cups) and stored at two storage conditions, ambient (28-30 °C, 65%-75 RH %) and refrigerated (7-9 °C, 75-80% RH) for three months period. Moisture content, acidity, pH, rancidity, microbial count and sensory acceptability of the product were determined in one month interval using standard methods. Decrease in acidity, increase in pH and moisture were observed in the sample stored in polypropylene cups at ambient condition after one month and microbial count was higher than the standard limit specified by the Sri Lanka Standards Institution of margarine. Also the same result was observed in the samples stored in polypropylene cups at refrigerated condition after two months. There was significant difference (P= 0.05) in moisture content and pH during three months of storage in the samples stored in glass bottles at refrigerated condition and ambient condition while there was no significant difference in titratable acidity at 1st month in the sample stored in glass bottles at refrigerated condition and ambient condition . However, the coliform count was nil in all conditions up to the three months of the storage period. The study revealed that good quality bread spread could be prepared by using dehydrated murunga leaves powder and can be kept for three months period at ambient and refrigerated condition in glass bottles without quality deterioration.

Keywords: Bread spread, carrot powder, murunga leaves.

INTRODUCTION

Murunga (*Moringa oleifera*) which belongs to family Moringacea is a popular dry zone home garden vegetable crop in Sri Lanka. Several varieties of murunga such as Rann Murunga (local variety), Jaffna and Chavakachcheri are growing in Sri Lanka (Ramachandran *et al.* 1987). In addition, several hybrid types such as Kalpitiya , V 19 and V 16 have been introduced. Partially matured pods, leaves and flowers can be used as medicines, animal fodder and seeds for oil extraction, water purification, cosmetic production, agro forestry and also in leave fences.

At present, the majority of women in Sri Lanka are employed and they have busy life style. Therefore, they look for products, which are convenient and time saving. Nowadays, there is high demand for instant food. Bread spread is one of the instant food items, which match with the busy life style of the people and easy way of providing nutrients. Development of low cost murunga leaves based bread spread consists of high amount of nutrients and availability of murunga tree in Sri Lanka is very high. Using Murunga leaves based bread spread can reduce time consuming and can get high amount of nutrients at low cost. Considering the above context, this study was carried out to develop a Bread spread using dried Murunga Leaves powder with the objectives of evaluates its physico- chemical parameters and organoleptic properties, storability and the economies of the developed product.

MATERIALS AND METHODS

This study was carried out at Food Laboratory, Institute of Post Harvest Technology, Jayanthi mawatha, Anuradhapura. Murunga Leaves were picked from the farm of the Institute of Post Harvest Technology.

Preliminary Studies: Preliminary studies were carried out to develop the recipes of bread spread prepared from dehydrated murunga leaves powder. The ratios between murunga leaves powder and carrot powder were changed while keeping other ingredients constant as shown in the Table 1.The sensory evaluation test was conducted to find out the best treatment and the selected treatment was further developed. Sensory evaluation was done using 30 untrained panelist using 5 point Hedonic scales.

Preparation of the bread spread: Water was added to the dehydrated *Murunga* leaves powder, carrot powder and pepper powder with 4:1 ratio according to the trial and error method, in order to rehydration of the *Murunga* leaves powder, carrot powder and pepper powder and this was mixed according to the recipe using a spoon for the preparation for the *Murunga* mixture. Prepared *Murunga* mixture was heated up to 80 ^{0}C for three minutes in an open pan. Then margarine mix was prepared by mixing mustard powder, and vinegar. *Murunga* and margarine mixture was mixed together by using an electrical beater. When the temperature of the *Murunga* mixture below 35 ^{0}C Citric acid was added to the mixture to the bring PH down. The prepared spread was filled in to the previously sterilized glass

bottle and polypropylene cups. Immediately after filling in to the bottles and cups capping was done.

Table 1. Composition of preliminary recipes as a percentage

Ingredients	T- 1	T- 2	T- 3	T- 4
Dehydrated murunga leaf powder	35	40	45	50
Dehydrated carrot powder	15	10	05	0
Margarine	35	35	35	35
Onion	8.4	8.4	8.4	8.4
Vinegar	3	3	3	3
Mustard past	1.2	1.2	1.2	1.2
Pepper powder	1.2	1.2	1.2	1.2
Salt	1.2	1.2	1.2	1.2

Sensory Evaluation: A sensory evaluation was carried out to find out the best treatment out of all four preliminary treatments and to find out the best treatment from the further developed recipes using a sensory panel consisting 30 untrained panelists from the Institute of Post Harvest Technology. The color, odor, flavor, spread ability were evaluated using a five point Hedonic scale.

Physiochemical analysis of the bread spread: Five samples from the selected recipes were tested for following physio-chemical parameters, such as pH (using the electronic pH meter. Motel 230A+), Acidity and Moisture content (as describe in the Manual of the analysis of Fruit and vegetable product by Ranganna (1977), Rancidity was determined by recording the peroxide value, Ranganna 1977).

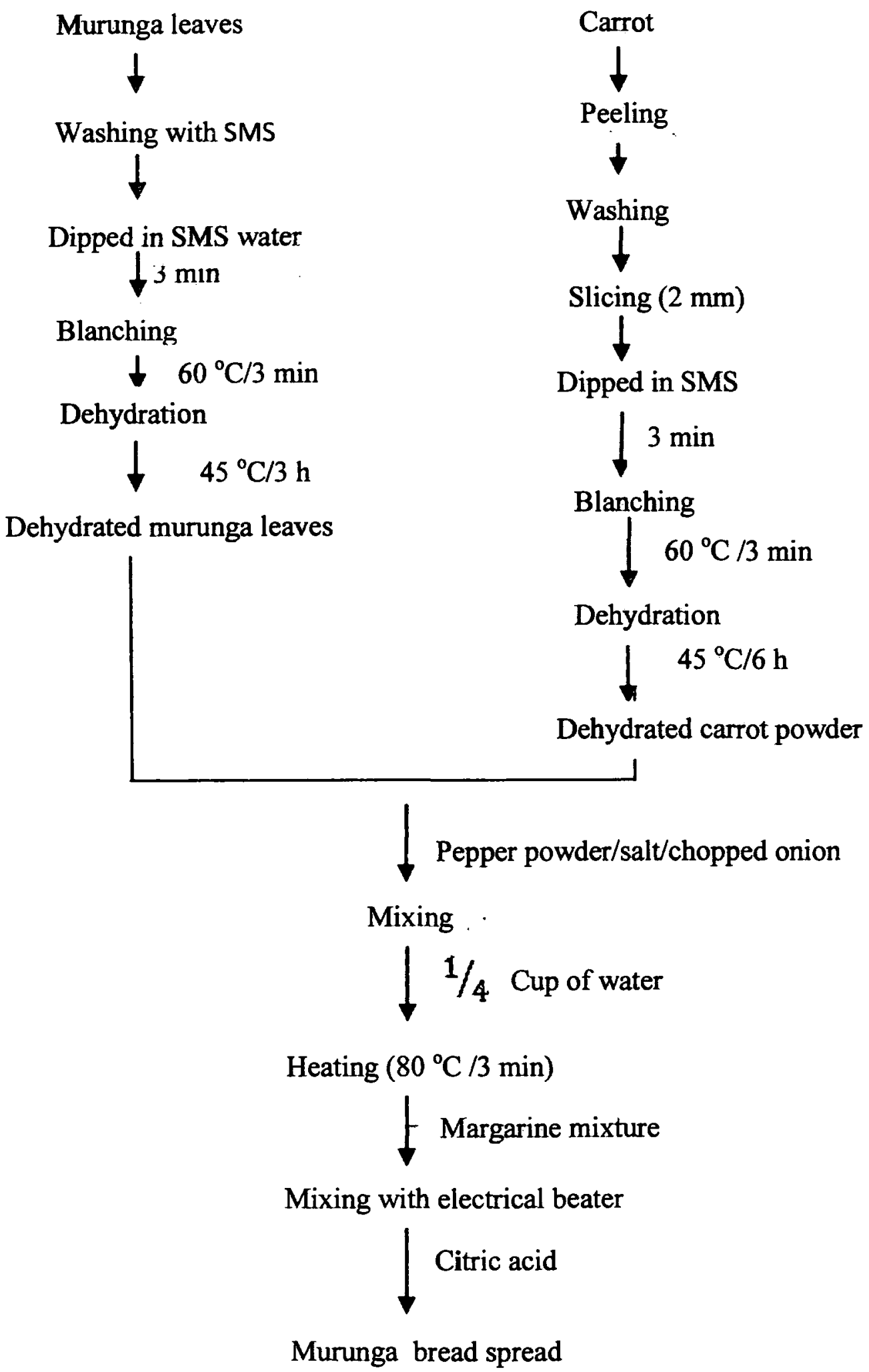


Fig. 1. Procedure for the preparation of bread spread

Microbiological study: Total plate count and coliform count of the selected product were tested according to the methods descried in the Essentials of Food Microbiology. (Garbutt 1977).

Shelf life evaluation: The selected recipe (Table 2) was stored in two storage condition (ambient condition and refrigerated condition) for three months period. Four replicates were prepared each treatment. The ambient condition was the existing temperature in the storage room refrigerated condition was 5 °C temperature. Acidity, pH, rancidity, moisture content microbial quality and sensory evaluation were measured at one month interval for three months.

Data analysis: Data of the sensory Evaluation was tested using non parametric Friedman Test with statistical software Minitab. Data of storage study was tested using complete Randomized Design in Factorial Experiments using SAS system.

RESULTS AND DISCUSSION

Sensory Evaluation of preliminary tests: Four products were prepared using four different recipes. Sensory evaluation was carried out to find out the best recipe for *Murunga* leaves Powder based bread spread. The sum of ranks for each sensory attribute of the four products was evaluated.

Table 1. Sums of ranks for sensory evaluation of each product

Sensory attribute	Sums of ranks			
	T- 1	T- 2	T- 3	T- 4
Colour	79	68.5	81	71.5
Odour	80	71.5	87.5	61
Texture	89	62	71	78
Flavor	78	67.5	78	76.5
Spread ability	70	76	78	76
overall acceptability	78	62.5	92	67.5

The color of dehydrated murunga leaves powder based bread spread was green in color and there was a soft texture in all four Treatments. Margarine was added to the bread spread to increase the spreading ability and to enhance the flavor of the product. According to the sensory evaluation results, Treatment 3 showed the highest sums of ranks and it was used for storage studies. It contained 45% dehydrated Murunga leaves powder 5% Carrot powder. Treatment 4 was not selected because it contained 50% *Murunga* leaves powder and no Carrot powder. So overall acceptability for this sample was low. Treatment 3 was selected as the best because it had highest sums of ranks and also it contained high amount of nutrients. Carrot Powder was used to reduce the Strong flavor of *Murunga* leaves powder and also it contained high amount of nutrients. But sum panelists comment that the strong flavor in the Murunga leaves were prominent in all four Treatments even with the added carrot powder.

Physiochemical analysis during storage

pH: Increase of pH was observed with the time in the all samples during storage study. Frazier and West off mentioned that many of the organic acid usually occurring in foods as

salts are oxidized by organisms to Carbonate, causing the medium to become more alkaline. This may be the reason for increasing of pH at the product stored in polypropylene cups at ambient condition. There was significant difference (a=0.05) in pH of the bread spread stored in polypropylene cups and glass bottles at both conditions during the 3 months.

Table 2. Variation of pH of the product at two different storage conditions for three month

Storage condition	Just after	1st month	2nd month	3rd month
Cup ambient	4.15	5.19^{a}	-	-
Cup fridge	4.15	4.38^{b}	4.39^{b}	-
Glass ambient	4.15	4.35^{a}	4.18^{a}	4.35^{a}
Glass fridge	4.15	4.32^{b}	4.11^{b}	4.32^{b}

Figures with the same superscripts are not significantly different (P=0.05) along the same column.

Acidity: Titratable acidity was decreased during storage in all four samples. there was significant difference (a=0.05) in acidity of the bread spread stored in polypropylene cups at ambient during first month while there is no significantly difference in acidity in glass bottle at ambient and refrigerated conditions. There was significant difference in all for samples at 2nd month 3rd month in all samples. In all Samples pH was increased. So medium became alkaline. Therefore acidity was decreased during storage period in all samples.

Table 3. Variation of acidity of the product in polypropylene cups and glass packaging material at two different conditions for three month

Storage condition	Just after	1st month	2nd month	3rd month
Cup ambient	0.87	0.082^{a}	-	-
Cup fridge	0.87	0.078^{b}	0.072^{b}	-
Glass ambient	0.87	0.068^{a}	0.068^{a}	0.065^{a}
Glass fridge	0.87	0.068^{a}	0.063^{b}	0.061^{b}

Figures with the same superscripts are not significantly difference (P=0.05) along the same row.

Moisture content: The moisture content increased in all for samples during the storage period. There was a significantly difference (a=0.05) in Moisture content of all the sample during the storage period except the samples stored in glass bottle at ambient condition and refrigerated condition and at 2nd month. The moisture content was highly increased in the sample stored at polypropylene cups at ambient condition. In this sample there were high amount of microbes. They produce Moisture from their metabolic reactions. Also through polypropylene cups moisture may be transferred to the product. Therefore, moisture content of this sample has highly increased.

Table 4. Variation of the Moisture content product in polypropylene cups and glass packaging material at two different conditions for 03 month.

Storage condition	Just after	1st month	2nd month	3rd month
Cup ambient	71.6	76.17[a]	-	-
Cup fridge	71.6	72.23[b]	72.53[b]	72.2 [b]
Glass ambient	71.6	71.67[a]	72.66[a]	72.87[a]
Glass fridge -	71.6	72.20[b]	72.63[b]	72.70[b]

Figures with the same superscripts are not significantly difference (P=0.05) along the same row.

Rancidity: During storage period of three months no value could be obtained for the rancidity. This revealed that no fat oxidation has taken place in the product during storage. The glass bottles were sealed after pouring the product so oxygen couldn't enter to the product. Therefore no fat oxidation was observed.

Microbiological evaluation of ambient and refrigerated conditions during storage study: At the first month the samples stored in polypropylene cups at ambient condition, microbial count was higher than the standard limit specified by the Sri Lanka standards institution for margarine (10,000 CFU/g) and after two months the sample stored in polypropylene cups at refrigerated condition , microbial count was higher than the standard limit specified by the Sri Lanka standards institution for margarine the microbial count in the samples stored in glass bottles in both conditions were less than the standards limit specified by the Sri Lanka standards for margarine. So these two products were safe for 03 months of storage period because microbial count in this 02 samples were less than the SLS standardsfor margarine.

Table 5. Variation of the microbial count of the product at to different storage conditions for 03 months

Storage condition	Just after	1st month	2nd month	3rd month
Cup ambient	$4.09x10^3$	$9.00x10^4$	-	-
Cup fridge	$4.09x10^3$	$8.18x10^3$	$4.09X10^4$	-
Glass ambient	$4.09x10^3$	$4.09X10^4$	$8.18x10^3$	$8.13X10^3$
Glass fridge	$4.09x10^3$	$8.18x10^3$	$8.18x10^3$	$8.18x10^3$

Sensory Evaluation during storage study: Sensory evaluation was conducted to find out the acceptability of the storage product compared to the freshly prepared sample. But the product stored at ambient condition was not in a suitable condition for a Sensory Evaluation due to gas formation, increase in pH and higher level of microbial count in the first month and the sample stored in polypropylene cups at refrigerated condition was not suitable for sensory evaluation after second month. So sensory evaluation was conducted only for sample stored in glass bottles under both conditions.

Table 6. Sums of ranks for sensory evaluation of sample in first month

Sensory attribute	Sums of ranks			
	T- 1	T- 2	T- 3	T- 4
Colour	78.5	72.0	74.5	75.5
Odour	84.5	40.0	88.0	87.5
Texture	83.5	38.0	89.5	89.0
Flavor	83.5	38.5	90.0	88.0
Spread ability	82.5	40.0	88.0	89.5
overall acceptability	80.5	35.0	91.5	93.0

Table 7. Sums of ranks for sensory evaluation of sample in second month

Sensory attribute	Sums of ranks		
	T- 1	T- 2	T- 3
Colour	67.0	60.5	52.5
Odour	62.5	58.5	59.0
Texture	63.5	57.5	59.0
Flavor	66.0	61.5	52.5
Spread ability	70.0	59.5	50.5
overall acceptability	64.0	58.0	58.0

Table 8. Sums of ranks for sensory evaluation of sample in third month

Sensory attribute	Sums of ranks		
	T- 1	T- 2	T- 3
Colour	62.0	59.5	58.5
Odour	62.0	57.0	61.0
Texture	63.5	57.5	59.0
Flavor	66.0	56.5	57.5
Spread ability	71.0	57.5	51.5
overall acceptability	65.0	57.0	58.0

T-1 - freshly prepared sample, T-2 - sample in polypropylene cup at refrigerated conditions, T-3 - sample in glass bottle at ambient condition, T-4 - sample in glass bottle at refrigerated condition.

According to the sensory evolution results, the sample in glass bottle at refrigerated condition had highest sums of ranks. Both samples were accepted by the panelists and these two samples were safe for consumption during three months period.

Cost analysis: The ingredient of 100g of murunga bread spread was Rs.49.00.

Table 8. Cost of ingredients

Ingredients	Cost
Murunga Leaves power	-
Carrot Powder	20
Margarine	17.50
Onion	1.00
Vinegar	1.00
Mustard paste	1.00
Pepper power	6.00
Salt	1.00
Miscellaneous cost	6.00
Total	49.00

CONCLUSION

Dehydrated murunga leaves powder could be used to develop a bread spread. The recipe containing 40% dehydrated murunga leaves powder ,10% carrot powder, 35% margarine, 8.4% chopped onion, 3% Vinegar, 1.2%, Mustard powder, 1.2% pepper powder, 1.2 % salt was found to be the best formulation among others. Ingredient cost is estimated as Rs. 49/= to preparation of 100g of the product. The Developed bread spread could be stored in glass jars under ambient condition and refrigerated conditions for 03 months period without quality deterioration.

REFERENCES

Babu SC (2000). Rural nutrition interventions with indigenous plant foods: a casestudy of vitamin deficiency in Malawi. International Food Polic Research Institute, Washington, Biotechnology, Agronomy Soc, Environ. 4 (3):169

Borgstrom G (1968). Principles of Food Science, Food microbiology and biochemistry, the Macmillan Company, London 13-185 pp

Jayaweera DMA (1982). Medicinal Plants (Indigenous and Exotic used in Ceylon), Publication of the National Science council of Sri Lanka

Meilgaard MC, Civilly GV and Carr BT (2007). Sensory Evaluation Techniques, CRC Press, 7-60pp

National Research Council (2006) "Moring" Lost crops of Africa, National Academic Press, 247 pp

Ramachandran C, Peter KV and Gopalkrishnan PK (1987). Drumstick (*Moringa oleifera*) multipurpose Indian vegetable., Economic botany, New York Botanical Garden-Bronx,34.

Pomeranz Y and Melon C E (1982) Food Analysis Theory and Practice, the AVI Publishing Company, 521-560p

Quality evaluation of locally produced rice available in the open market of Sri Lanka: A case study 2012

DPC Swarnasiri*
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka
*Corresponding author: swarnasiri2004@yahoo.com

ABSTRACT

More than half of the world population consumes rice as their staple food and demand of rice increase with growth of population. The per-capita rice consumption of Sri Lanka was 86.8 kg in 1973 and it was 116.0 kg in 2012. The objective of the study was to find out the quality of rice available in the local market of Sri Lanka in the year 2012. The study covered all the districts and collected 625 locally produced rice samples from normal and the super markets of Sri Lanka. The physical quality evaluation parameters such as moisture content, foreign matters, discolored grain, broken grains, paddy seeds in one kg of rice, odour were analyzed at the laboratory of IPHT. Some selected, slightly color changed, 25 rice samples analyzed for quantitative analyze of Afla-toxin at the Industrial Technology Institute (ITI). The rice samples graded according to the SLSI rice grading system of 1986.

The results showed that raw rice available in the market were 2% of premium, 10% of grade I, 15% of grade II, 16% of grade III and 57% was substandard level. According to the study, there were 3% of Grade I, 32% of Grade II and 13% of Grade III locally produced parboiled rice in the open market and the remaining 52% of parboiled rice was in substandard level.

Keywords: Paddy, raw rice, parboiled rice, quality

INTRODUCTION

Rice is the highly demanding consumable item in the open market of Sri Lanka. Annual total production of paddy increased gradually after introduction the fertilizer subsidy scheme and increase of cultivated land area after the peaceful situation of Northern and Eastern provinces of Sri Lanka. The total annual paddy production is 4.2 million metric tons in year 2012 and it was exceeding our annual requirement by 13% (Annual Report 2012, Central Bank Sri Lanka). As the staple food of Sri Lankans, the per capita rice consumption also increases gradually (Table 1). It is important to evaluate quality of locally produced rice with increasing paddy production and high per capita rice consumption. The excess amount produced need to be introduced foreign markets and it is important to promote production of premium or grade I rice.

Table 1. Per capita rice consumption

Year	Quantity (kg)
1973	**86.80**
1979	**90.90**
1982	**101.30**
1987	**103.60**
1997	**106.14**
2004	**106.21**
2008	**110.00**
2012	**116.00**

Source: Central Bank of Sri Lanka

In 1984, the Sri Lanka Standard Institute in collaboration with Rice Processing Research and Development Center (Presently Institute of Post Harvest Technology) established grading system for raw rice and parboiled rice. The rice grading system consists of five quality parameters and standards for grading into four grades namely Premium, Gr (Grade) I, Gr II, Gr III for both raw and parboiled rice (Table 2 & 3).

Table 2. Requirements for raw milled rice (SLS 633 :1984)

Characteristics	Requirements for grades			
	Premium	**Grade I**	**Grade II**	**Grade III**
Moisture content (% by mass max)	14.0	14.0	14.0	14.0
Foreign matter (% by mass max)	0.2	0.5	1.0	1.5
Type admixture (% by mass max)	Nil	2.0	6.0	10.0
Damage grains (% by mass max)	Nil	1.0	2.0	4.0
Broken grains (% by mass max)	10.0	20.0	35.0	45.0
Paddy seeds (grains/kg of rice max)	Nil	10	30	50

The study was conducted in the year 2000 showed that 15% of raw rice and 24% of parboiled rice can be graded according to SLSI standards. Some physical quality parameters, moisture content, foreign matter, discolored grain and broken grains were not in up to standard. The study conducted in the year 2008 showed that 41% of raw rice and 37% of parboiled rice can be graded according to SLSI standards. It was also revealed that 3, 13 and 25% of locally produced raw rice fall into Grade I, Grade II, Grade III respectively. The year 2008 results showed that 3, 18 and 16% of the parboiled rice samples out of graded 37%, fell into Grade I, Grade II, Grade III respectively according to SLSI standards.

Table 3. Requirements for parboiled milled rice (SLS 633 :1984)

Characteristics	Requirements for grades			
	Premium	**Grade I**	**Grade II**	**Grade III**
Moisture content (% by mass max)	14.0	14.0	15.0	15.0
Foreign matter (% by mass max)	0.2	0.5	1.0	1.5
Type Admixture (% by mass max)	0.2	2.0	6.0	10.0
Damage grains (% by mass max)	0.5	2.0	4.0	5.0
Broken grains (% by mass max)	1.0	5.0	15.0	20.0
Paddy Seeds (grains/kg of rice max)	Nil	10	25	50

The author of the study evaluated locally available rice in the year 2000 and 2008, at that period Sri Lanka was not self sufficient in rice. Early 1980s , the rice available in Sri Lanka had inferior quality rice and most of the rice mills had two or three machinery such as a paddy cleaner to clean paddy, a dehusker to dehusk cleaned paddy and polisher to polish brown rice. The rice obtained from traditional rice mills consist of foreign matters, paddy seeds, discolored grains and high percentage of broken grains.

The objective of the study was to find out the quality of rice available in the local market of Sri Lanka and thereby evaluate how much percentage of rice falls in to each grade according to the SLSI grading system. The results can be used to identify and improve some quality standard of locally produce rice.

MATERIALS AND METHODS

The study covered all the districts and collected 625 locally produced rice samples from normal and the super markets of Sri Lanka. The samples consisted of White and Red colored, Long and Short type rice of Raw and Parboiled forms and each sample was 500 g of rice. The physical quality evaluation parameters such as moisture content, foreign matters, discolored grain, broken grains, paddy seeds in one kg of rice, odour were analyzed at the laboratory of IPHT. Some selected, slightly color changed, 25 parboiled rice samples analyzed for quantitative analyze of Afla-toxin at the Industrial Technology Institute (ITI). The rice samples graded according to the SLSI rice grading system of 1986.

RESULTS AND DISCUSSION

Quality of locally produce raw rice available in the open market of Sri Lanka: The results showed that 2% of premium grade and 10% of grade I raw rice were available in the open market of Sri Lanka. Some Middle East and African countries imported rice quality requirements tally with the premium grade and Grade I standards of the SLSI of Sri Lanka. It has been indicated that 12 % of rice available in open market is suitable for export market

of some countries. The balance amount of raw rice was fallen into 15 % of Grade II, 16 % of Grade III and 57 % of substandard or ungraded level, which means 43% of locally produce raw rice available in open market of Sri Lanka can be graded according to the SLSI standards (Table 4).

It is important to compare results obtained in the previous studies conducted in the year 2000 and 2008. In the year 2000, there were no premium and Grade I locally produced raw rice, but there were 2% of Grade II and 13% of Grade III locally produce raw rice available in Sri Lanka. There was 85 % substandard level or ungraded raw rice in the market of Sri Lanka. The results of 2008 revealed that there were 3% of Grade I, 13% of Grade II and 25% of Grade III rice can be graded in the locally produced raw rice. The substandard level raw rice was 59%.

Table 4. Rice graded according to the SLS requirements in three studies

Year	Raw rice					Parboiled rice				
	P	Gr I	Gr II	Gr III	SG	P	Gr I	Gr II	Gr III	SG
2000	-	-	2.0	13.0	85.0	-	-	9.0	15.0	76.0
2008	-	3.0	13.0	25.0	59.0	-	3.0	18.0	16.0	63.0
2012	2.0	10.0	15.0	16.0	57.0	-	3.0	32.0	13.0	52.0

P-premium, Gr-grade, SG-Substandard grade

The results of the three studies showed that the amount of raw rice which can be graded according to the SLSI grading system was gradually increased from 15% , 41% and 43% in the year 2000, 2008 and 2012 respectively. The substandard raw rice decreased from 85% , 59% and 57% of the same years respectively (Figure 1).

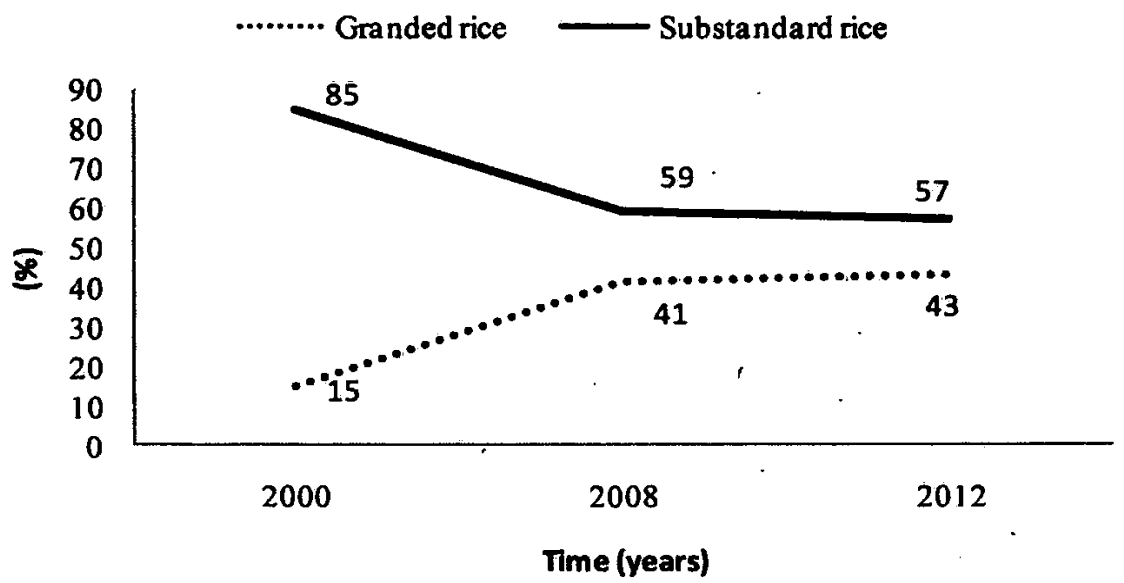


Fig.1. Variation in quality of raw rice during 2000 to 2012

Quality of locally produce parboiled rice available in the open market of Sri Lanka: The consumption of parboiled rice is 60 % of the total rice consumption of Sri Lanka. It is high in paddy producing areas and upcountry compared to other areas. The quality evaluation results of the study showed that 48 % of parboiled rice fall in to Grade I , Grade

II and Grade III of the SLSI Grading system. According to the results, there was no premium grade parboiled rice available in the market. Some quality parameters of parboiled rice such as moisture content, presence of discolored grain were the reasons for falling in to lower grades when grading the parboiled rice. According to the study, there were 3% of Grade I, 32% of Grade II and 13% of Grade III locally produced parboiled rice in the open market and the remaining 52% of parboiled rice was in substandard level (Figure 2).

According to the results of the quantitative analysis of aflatoxin of 25 parboiled rice samples showed that the level was below the critical level.The physical analysis results of the study can be compared with the results of the studies conducted in 2000 and 2008. The results of the year 2000 revealed that, 9% of Grade II and 15% of Grade III parboiled rice can be graded according to the SLSI grading system. That indicated 76% of parboiled rice was in substandard grade, but in the year 2008 results showed that substandard rice reduced to 63% while gradable rice increased to 37%. There were 3% of Grade I , 18% of Grade II and 16% of Grade III parboiled rice available in the open market of Sri Lanka. In 2012, the gradable parboiled rice increased to 48%. The year 2012 results have shown that drying parboiled rice to moisture content 14 % or below and reducing discolored rice percentage of parboiled rice, the quality of locally produced parboiled rice can be uplifted to higher grade categories.

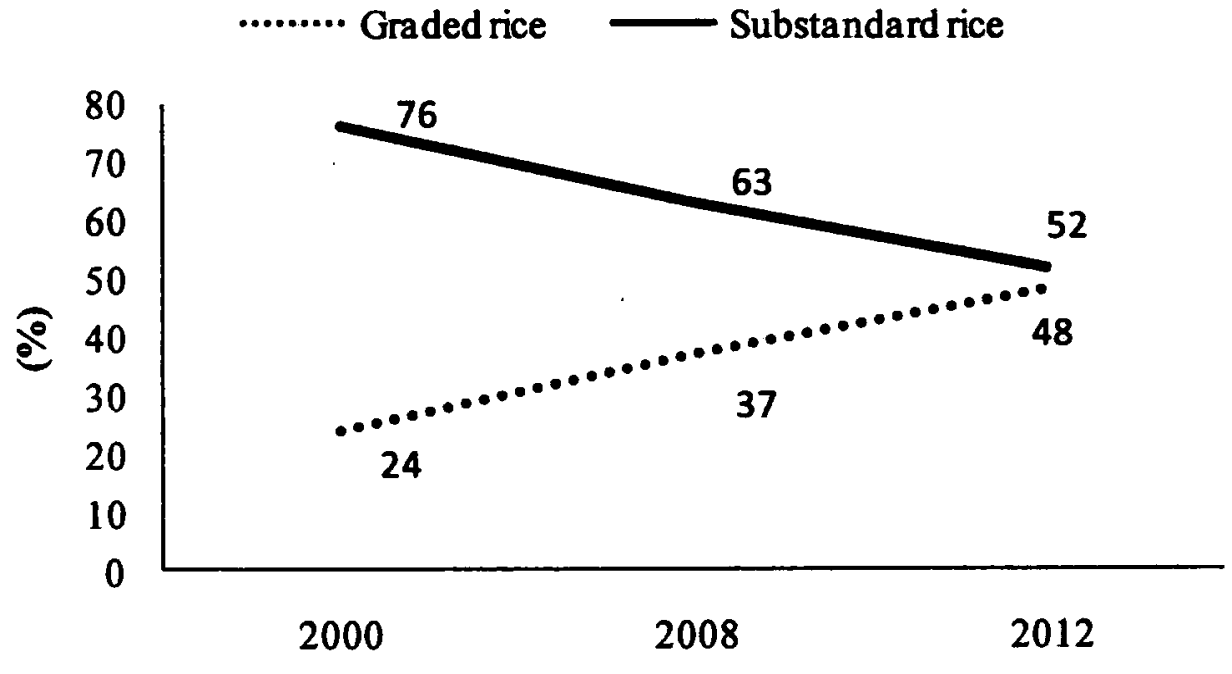


Fig.2. Variation in quality of parboiled rice during 2000 to 2012

CONCLUSION

The quality of the locally produced raw and parboiled rice has been improved gradually in the local market. The results showed that raw rice available in the market were 2% of premium, 10% of grade I, 15% of grade II, 16% of grade III and 57% was substandard level. According to the study, there were 3% of Grade I , 32% of Grade II and 13% of Grade III locally produced parboiled rice in the open market and the remaining 52% of parboiled rice was in substandard level. The moisture content and the broken grain percentage are the

critical factors which reduced the quality of the rice available in the local market in the recent past. If the rice millers target to export markets they can improve their rice quality further and produce Grade I and premium quality rice.

REFERENCES

Annual report 2000, Central Bank of Sri Lanka.

Annual report 2008, Central Bank of Sri Lanka.

Annual report 2012, Central Bank of Sri Lanka.

Sri Lanka Standards 633, 1984, Sri Lanka Standard Institute.

Swarnasiri DPC, Palipane KB (2000). Quality evaluation of locally produced rice available in open market of Sri Lanka.

Swarnasiri DPC (2008) Quality evaluation of locally produced rice available in open market of Sri Lanka.

Institutional development for successful implementation of sanitary and phytosanitary (SPS) agreement in Sri Lanka

SMRS Semasinghe[1], I Wickramasinge[1] and PNRJ Amunugoda[2]*

[1]Department of Food Science and Technology, Faculty of Applied Science, University of Sri Jayawardanepura, Sri Lanka

[2] Food Technology Section, Industrial Technology Institute, 363, Bauddhaloka Mawatha, Colombo 07, Sri Lanka.

*Corresponding author: neville@iti.lk

ABSTRACT

An effective sanitary and phytosanitary (SPS) regime can spur economic growth. As traditional trade barriers continue to decline, SPS related food safety standards become a tool to protect trade blocks. Sri Lanka's food supply chain recently more focused on export. However, food safety compliance strategies are not sufficient, reflecting necessity to upgrade SPS management capacity. A semi detailed surveys was carried out to evaluate SPS coordination mechanism. A mixed approach consisted of documentary, inventory analyses and semi-directive interviews to assess the impact of SPS issues and implementation. Results showed that Sri Lanka faces upcoming and eminent problems due to weaker coordination. SPS notifications, number of inspection and testing bodies to meet the requirement show little increases. The knowledge of officials of the SPS agreement is average (50%) and showed low awareness and lack of coordination adapted by the National Notification Authority. National Enquiry Point is weaker in providing of SPS information. Recommendations were made to upgrade the SPS regime by establishing a new national agenda, establishing a National Coordination Committee and Trade Meetings.

Keywords: Export led-industrialization, food safety compliance, national coordination, SPS regime, trade barriers.

INTRODUCTION

SPS measures and related national organizations promote food safety, animal health and plant protection in domestic and international trade by developing, approving and recommending standards and guidelines. SPS has become a important issue in international trading of Sri Lanka since demand for more stringent SPS requirements by developed countries following their growing incomes and health consciousness. Assessing the scientific justification that other countries offer for their SPS standards is crucial and therefore SPS measures function as a 'catalyst' for competitive repositioning land enhanced export performance. These standards and requirements are subject to frequent changes, and are often difficult and costly to meet thus created in market failure and unwanted trade embargo. Thus, there is a growing demand in Sri Lanka to upgrade its SPS management capacity for export led- industrialization. In Sri Lanka, the World Trade Organization (WTO) agreement on the application of SPS measures entered into force with the establishment of the WTO on 1st January 1995. The basic aim of the SPS agreement is to

maintain the sovereign right of any government to provide the level of 35 health protection it deems appropriate, but to ensure that these rights are not misused for protectionist 36 purposes and not to establish hurdle to international trade. In Sri Lanka, the main areas covered under 37 the SPS Agreement are carried out by Department of Food Control, Department of Animal Production 38 and Health and National Plant Quarantine Service. The Ministry of Health is the steering body for implementing national level notification requirements of the SPS Agreement. The objective of the survey therefore was to evaluate the existing coordination mechanism among the responsible organizations for effective implementation and participation of SPS measures in food export, thus to 42 giving recommendations for better institutional development for successful implementation of SPS agreement in Sri Lanka.

MATERIALS AND METHODS

In the design of the study, mixed approach (Neeliah *et al.* 2011) consisted of documentary and inventory analyses (Otsuki *et al.* 2001, Disder *et al.* 2008) and survey based semi-directive interviews (Henson *et al.* 1999) using a questionnaire, were used to gather information. The documentary analysis based on literature was done to review the impact of Sri Lanka SPS measures on food export. Information was collected from the WTO website and relevant ministries' reports of food hygiene inspections carried out for assessing the compliance of food safety control measures and trade barriers to exports. The inventory analysis was carried out to assess the capacity, and available institutional and infrastructures to facilitate for application of SPS measures. The inventory based approach can be used in a qualitative and a quantitative perspective to determine the importance of domestic regulations as trade barriers. Therefore the inventory-based approach was based on (1) data on regulations, (2) data on frequency of detentions. Under the inventory based approach, analyses of food safety notifications by Sri Lanka pertain to exports were compiled. Publications and notifications of WTO provided the major source for understanding the WTO SPS agreement and identifying the requirements for its implementation and related issues. The common information of the current situation of developing countries and available systems to manage the SPS activities are abstracted. The purpose of the qualitative interview was to get an in-depth insight of the issues surrounding. Data were collected using classical preset questionnaire to identify institutional framework for SPS management involved in food safety, animal and plant health to evaluate strength of linkage and coordination. Central food control unit of Ministry of Health, Department of Animal Production and Health of the Ministry of Lives Stock, Department of fisheries of the Ministry of Fisheries, Seed Certification and Plant Protection Center, National Plant Quarantine Services, Registrar of Pesticide and Food Research Unit of the Ministry of Agriculture were the key informant's organizations. Verbal guidance was given to key informants before filling the questioner. A sample of randomly selected fifty officials was given the specific questionnaire.

RESULTS AND DISCUSSION

Documentary analysis showed that there are satisfactory regulatory controls in Sri Lanka in terms of food trade. Analysis of the impact of SPS management responsibilities and

coordination mechanism on exporting food products shows that Sri Lanka still faces upcoming problems. Performances of SPS measures are vary from product to product and exporter to exporter leaving many problems to SMEs. Sri Lanka showed weaker coordination and implementation problem of SPS measures towards achieving goals under complex financial and existing poor infra structures facilities that leads to compliance issues. Inventory analysis of SPS notifications showed that Sri Lanka is in significantly lower stage compared to developed countries which severely affects export food market with upcoming WTO and private standards. Annual notification intensity was poor and showed lack in persistence, however shows increasing trend. Number of regulatory, inspection bodies and laboratories are low and must be improved. Semi directive interviews provided enough qualitative background to better contextualize and explain the findings from the documentary and inventory analyses on impact. Some findings provided a quantitative indication of the negative effects of SPSmeasures. Results showed that about 50% of officials showing awareness in the SPS activities and SPS measures implementation. Even though there is an improvement in the consciousness of existing regulations, the number and awareness of regulations is minimal in comparison. Out of total, 58% of the population is lack in coordination with the National Notification Authority. This indicated that the National Enquiry Point is lacking in exact support to members to easily collect trade and SPS related information regarding the critical SPS issues leading to lose of trade opportunities. Out of total, 52% of officials suggested to establish a clear and coherent national agenda for addressing SPS issues.

There were 48% preference to establish a National Coordination Committee and 32% suggested to organizing Trade Meetings. Thus, the average sample population showed their interest to improve the current coordination among the responsible and related organizations for effective implementation and participation of SPS measures. It is Recommendations were made to establish a clear national agenda, guidelines for addressing SPS issues, improving in coordination committee, establishing a proper coordination mechanism among responsible organizations and organizing trade meetings.

REFERENCES

Disdier ACE, Fontagne L and Mimouni M (2008). The impact of regulations on agricultural trade: evidence from the SPS and TBT Agreements.

Henson S, Loader R, Swinbank A and Bredahl, M. (1999). The impact of sanitary and phytosanitary measures on developing country exports of agricultural and food products. In: Proceedings of the conference on agriculture and the new trade agenda in the WTO 2000 negotiations,1-2 October 1999 Geneva, Switzerland.

Neeliah SA, Neeliah H and Goburdhun D (2011). Sanitary and phytosanitary issues for fishery exports to the European Union: A Mauritian insight Journal of Development and Agricultural Economics Vol. 3(2), pp 56-68, February 2011.

Otsuki T, Wilson JS, Sewadeh M (2001). Saving two in a billion: quantifying the trade effect of European food safety standards on African exports. Fd. Pol., 26(5): 495-514

Fresh produce quality and safety; handling packaging and storage of food crops

Use of safe packaging for vegetable transportation on main supply chains in Sri Lanka

CR Gunawardhane, WMCB Wasala, CAK Dissanayake, RMNA Wijewardhana, UG Chandhrajith and BMKS Thialakarathne
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka
*Corresponding author:crohan74@yahoo.com

ABSTRACT

A study was carried out to determine the technical feasibility of use of safe packaging for cabbage, carrot, beet and luffa which are major vegetables where the harvest is handled in very large quantities. They are excluded from the regulation which vegetables should be transported in safe packages. The study was conducted through supply four chains Dambulla to Colombo, Thambuttegama to Colombo, Nuwaraeliya to Colombo and Jaffna to Dambulla. Plastic crates and polysacks bags were used as packaging types. Vegetables transported by farmers were selected randomly at wholesale markets of the starting point, then packed in polysack bags and plastic crates and transported to destinations. Weight loss, colour change, visual quality, firmness, TSS and disease incidence of produce were measured at end points. After two days, these parameters of vegetables transported in both packaging types were measured to determine loss occur at retailer and consumer stages.
At the stating markets damaged up to certain extent of vegetables were observed. Results indicated that mechanical damage was the main cause for postharvest losses of vegetables. The study reveals that postharvest losses of beet transported in polysacks and plastic crates did not show considerable difference. But transport loss of cabbage, carrot and luffa can be reduced using plastic crates. Overall visual quality of vegetables also was better when transporting in plastic crates. Fungal infections were observed at retailer/consumer level for long bean and okra transported in both packages. Loss of produce firmness was significantly higher of vegetables transported in polysacks compared to plastic crates. The use of plastic crates reduced the transport loss of cabbage by 5.8%,, carrot by 15.8% and luffa by 14.7%, and also preserve the quality parameters of vegetables during post production handling.

Keywords: Mechanical damage, safe packaging, vegetable transportation, weight loss

INTRODUCTION

The postharvest loss of perishables lies between 30-40%, of which could have been used in reducing poverty and hunger, malnutrition and loss of export earnings of the country (Wasala *et al.* 2012). Therefore, feeding the population will surely be one of the major challenges that merit urgent attention. Minimization of postharvest losses of already produced food is more effective than increasing production to compensate for these losses.
As reported by Jayathunge *et al.* (2003) the major cause for postharvest loss is due to use of improper packaging during the transportation and further mentioned that transport loss of vegetables can be reduced from 20-30% to 5-7% using safe packaging. In order to prevent serious post harvest losses of fruits and vegetables and to supply quality produce for

consumers, government brought a regulation which fruits and vegetables should be transported in safe packages to minimize postharvest losses. But considering objections came from farmers and bulk transporters, government has now limited this regulation for eleven vegetables and eight fruits, But Cabbage, Carrots, Beet, and Luffa are excluded from this regulation which is handled in very large quantities. Further they are available in any market throughout the year. Use of safe packaging for these crops also is a very important step to minimize the postharvest losses in the country. Therefore, this research was carried out with the objectives of studying the technical feasibility of use of safe packaging for these four economically important crops during bulk transportation.

MATERIALS AND METHODS

Cabbage, Carrots, Beet, and Luffa were selected for this study considering their economic importance. The study was conducted through four major supply chains in Sri Lanka as follows,

Nuwara Eliya → Colombo
Dambulla → Colombo
Tambuththegama → Colombo
Jaffna → Dambulla

Plastic crates and conventional polysack bags were used as packaging types for study. Vegetable samples transported to Nuwaraeliya, Dambulla, Tambuththegama and Jaffna wholesale markets/dedicated economic centres by farmers or collectors were randomly selected. Sample size for one vegetable type was 250 kg – 300 kg. Initial weight, mechanical damages, colour, internal and external temperature and external appearance of vegetables were measured. Those vegetable samples were packed in polysack bags and plastic crates separately and placed in a truck at different layers (different heights) and then transported to above mentioned destinations at ambient condition. Vegetables samples packed in two packaging types were collected at the destination markets. After transportation, mechanical damages, physiological loss in weight losses due diseases were measured. Changes of colour and visual quality of vegetables were determined by visual observation as mentioned by Karder and Cantwell (2007). Firmness was measured using a fruit firmness tester with a cylindrical shape probe of 4 mm in diameter. Then vegetable samples were stored for two day at ambient condition and all the above mentioned parameters were measured again to determine losses occur at retailer and consumer level. Data gathered were analyzed using Analysis of Variance (ANOVA) by statistical system (SAS, 1994). Differences between treatments means were compared using Duncan's Multiple Range Test (DMRT) at $p < 0.05$.

RESULTS AND DISCUSSION

Postharvest loses: Postharvest losses of cabbage, carrots, beet, and luffa at different stages and transported in plastic crates and polysack bags are shown in table 1. Damaged vegetables up to certain extend were at initial stages in the supply chains. Results showed that post harvest losses of cabbage, carrot and luffa due to mechanical damages, transported in plastic containers were significantly lower than in polysack bags at both stages.

Table 1.Postharvest losses of vegetables

Vegetables	Transporter		Retailer/Consumer (after 2 days)		Total loss	
	PS(%)	PC(%)	PS(%)	PC(%)	PS(%)	PC(%)
Cabbage						
Mechanical damages (%)	10.4[a]	8.4[b]	10.82[a]	6.95[b]	21.22[a]	15.35[b]
PLW (%)	2.9[a]	3.1[a]	4.5[a]	4.3[a]	7.4[a]	7.4[a]
Carrots						
Mechanical damages (%)	13.5[a]	5.4[b]	13.4[a]	5.7[b]	26.9[a]	11.1[b]
PLW (%)	5.2[a]	2.9[b]	5.5[a]	2.5[b]	10.7[a]	5.4[b]
Beet						
Mechanical damages (%)						
PLW (%)	3.2[a]	2.7[a]	2.4[a]	2.4[a]	5.6[a]	5.1[a]
Luffa						
Mechanical damages (%)	19.3[a]	8.7[b]	8.8[a]	4.7[b]	28.1[a]	13.4[b]
PLW (%)	6.6[a]	3.4[b]	8.8[a]	6.9[a]	15.4[a]	10.3[b]

Values with same letters within same raw at one point are not significantly different, PLW: physiological loss of weight, PS: polysack bags, PC: plastic crates

Mechanical damages of beet root transported in both packaging method were not significantly difference through the supply chains.

Physiological loss in weight (PLW): PLW of carrot and luffa transported in plastic crates showed significantly lower values compared to these vegetables packed in polysacks while other two vegetables did not show any difference in both packaging methods. Gast and Flores (1991) reported that when PLW of fruits and vegetables is more than 10%, the produce should be discarded because with the loss of moisture it loses its freshness significantly.

Colour changes: At the retailer and consumer stage, luffa slightly had become yellow colour and on cabbage outer surface brownish patches were observed specially of cabbages transported using polysack bags. Fungal infections were observed at retailer and consumer level for carrot , luffa and cabbaged transported in both packages. But fungal infections were prominent on wounded areas of vegetables due mechanical injuries.

Overall visual quality of vegetables: At initial stages of the selected supply chains, visual quality ratings (VQR) of vegetables were Good condition (minor symptoms of deterioration) because minor physical injuries were observed. At retailer and consumer stages VQR of cabbage, luffa and carrots transported in polysacks was poor (Serious deterioration, limit of usability) and fair (Deterioration evident, but not serious, limit of salability) in plastic crates. But beet transported in plastic crates and polysack was fair (deterioration evident, but not serious, limit of salability). Anwar and Malik (2006) reported that the use of proper packaging has maitained the quality of produce during handling.

Firmness: Firmness is a quality attribute that is critical in determining the acceptability of vegetables. As shown in table 2, firmness of all four vegetables transported in both packages was not significantly different after the transportation. Firmness of cabbage, carrots and luffa transported in polysacks was lower than to crops packed in plastic crates at retailer/consumer stage. These results indicate that quality deterioration is higher when vegetables are transported in polysacks (Istella *et al*. 2006).

Table 2. Changing of quality parameters of vegetables

Vegetables	Transporter		Retailer/Consumer (after 2 days)	
	PS(%)	PC(%)	PS(%)	PC(%)
Cabbage				
Firmness (N)	73.9[a]	76.1[a]	63.6[b]	68.9[a] 5.6[a]
TSS (brix)	5.2[a]	5.13[a]	5.2[a]	
Carrots				
Firmness (N)	144.1[a]	144.2[a]	126.3[b]	134.1[a]
TSS (brix)	8.5[a]	7.4[a]	9.2[a]	8.2[b]
Beet				
Firmness (N)	125.9[a]	131.1[a]	97.4[b]	122.6[a]
TSS (brix)	5.9[a]	5.1[a]	6.9[a]	6.2[b]
Luffa				
Firmness (N)	34.6[a]	34.1[a]	32.35[b]	49.52[a]
TSS (brix)	4.0[a]	3.6[a]	4.3[a]	4.0[a]

Values with same letters within same raw at one point are not significantly different
TSS -Total soluble solids

Total soluble solids (TSS): TSS of carrot and beet transported in polysacks was significantly higher than that in plastic crates at retailer/consumer stage.

CONCLUSION

The study reveals that postharvest losses of beet transported in polysacks and plastic crates was not significantly difference. Transport loss of cabbage, carrot and luffa can considerably be reduced by using safe packaging techniques. The use of plastic crates reduced the transport loss of cabbage by 5.8%, carrot by 15.8% and luffa by 14.7%, and also preserve the quality parameters of vegetables during post production handling.

REFERENCES

Anwar M and Malik AU (2006). Hot water treatment affects ripening quality and storage life of mango (*Mangifera indica* L.), Pakistan J. Agric. Sci., 44:23-30.

Gast KLB and Flores R (1991). Post harvest management of commercial horticulture crops, The Journal of the agric. research, 7(2):12-18.

Istella S1, Muha V and Terbel I (2006). Storage ability and differences of carrot varieties defined by firmness changes measured with new non-destructive acoustic method, International Journal of Horticultural Science, 12 (1): 37–40.

Karder AA and Cantwell M (2007). Produce quality rating scales and colour charts, Post harvest technology research and information center, UC Davis University, CA, USA.

Jayathunge KGLR, Wasala WMCB, Rathnayake HMAP, Gunawardhana CR, Samarakoon HC, Fernando MD and Palipane KB (2003). Evaluation of different types of packages for handling and transportation of vegetables, IPHT technical note 2003-1.

Wasala WMCB, Gunawardhane CR, Rathnayake RMRNK, Wijewardhana, RMNA, Jayathunge KGLR, Thialakarathne BMKS and Wijerathne, DBT (2012). Study on feasibility of safe packaging for economically important vegetable transportation, proc. of International symposium on Agriculture and Environment, University of Ruhuna Sri Lanka: 258-260.

Reduction of postharvest losses in leeks (*Allium porum*) during transportation using wooden bulk packages

RMNA Wijewardane, [1*], GD Senevirathne[2], NWIA Jayawardana[2], TMR Dissanayake[1], WMCB Wasala[1] and BMKS Thilakarathne [1]

[1] Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura, Sri Lanka

[2] Faculty of Agriculture, Rajarata University of Sri Lanka, Anuradhapura

*Corresponding author: nilanthiwijewardana@yahoo.com

ABSTRACT

Leek (*Allium porum)* is an economically important vegetable which occupies a prominent position among vegetables grown in Sri Lanka. Due to variation in length, presently available packages are not suitable for leeks transportation and reported annual postharvest loss was 15.7%. This study evaluated the suitability of wooden bulk packages for leek transportation from Nuwara Eliya to Dambulla supply chain. The treatments used; T_1-75cm x 45cm x25cm with filling height 20cm , T_2- 75cm x 45cm x30cm with filling height 25cm, T_3-75cm x 45cm x 25cm with filling height 20cm, T_4- 75cm x 45cm x 30cm with filling height 25cm and T_5-80cm x 45cm 30cm cover with plastic coated wire on four sides with filling height 25cm. Existing transportation package which wrapped with poly sack and tight with a rope at the middle (T_6) was used as control. During transportation in package temperature, RH%, respiration rate and ethylene production were measured in four hours interval .To evaluate the quality of the produce; weight loss %, visual quality rating (VQR), Physical damages, wilting rate, were measured before and after transportation. Among the packaging methods tested, T_2- 75cm x 45cm x30cm with filling height 25cm showed better performances by reducing wilting %, physical damage and weight loss (%) while retaining higher in visual quality rating.

Keywords: Bulk package, leek *(Allium porum),* postharvest loss, storage life, transportation

INTRODUCTION

Leeks (*Allium porum L.*) one of the largely consume temperate vegetable can be grown upcountry wet zones on well drained soils, and are tolerant to wet weather and frost cover. Nuwara Eliya is the highest producing area within the country and during yala season it produced 9,244 metric tons under area of cultivation 585 ha in 2009/2010 (Dept.of Census and Statistics, 2010). Owing to its characteristic shape, structure and soft texture, associated with high moisture content, leeks is more susceptible to physical damages and during transportation losses will be accelerated due to improper infrastructure facilities, poor road accessibility and high climatic variation. Environmental factors such as relative humidity, O_2 concentration, increasing temperature can trigger the several reaction mechanisms that may lead to produce degradation. Sri Lankan vegetable sector was experienced around 30% to 40% post harvest losses and studies have been shown that 48% postharvest losses are occurred during transportation and distribution process (Ekanayake *et al.* 2009).

In Sri Lanka transportation of fresh vegetable is mainly done by open trucks from producing areas to the specific markets. Leeks are being cultivated in upcountry areas, and the produce has to be transported to economic centers, like Colombo manning market, Narahenpita and Dambulla economic centers. Due to variation in length of available leek varieties, present packages are not suitable for transportation and thus lead to use of improper packages like poly sacks. Those conditions contribute to serious post harvest losses, mainly due to physical damages like surface injuries, impact, bruising, and vibration which lead to product deterioration. Sri Lankan vegetable sector experienced around 15.7% postharvest losses annually due to use of poly-sacks for leeks transportation. Due to those reasons it is important to introduce suitable packages for handling and transportation of fresh leeks. The study was conducted to design and evaluate the suitability of developed bulk package for handling and transportation of fresh leeks.

MATERIAL AND METHODS

Fresh leeks were manually harvested at commercial maturity stage (based on stem diameter) from a farmer field at Nuwara Eliya during morning part of the day. There were six types of treatments (including existing packaging system), T_1-75cm x 45cm x25cm with filling height 20cm , T_2- 75cm x 45cm x30cm with filling height 25cm, T_3-75cm x 45cm x 25cm with filling height 20cm, T_4- 75cm x 45cm x 30cm with filling height 25cm and T_5-80cm x 45cm 30cm cover with plastic coated wire on four sides with filling height 25cm and control (T_6). It was loaded into partially covered vegetable transporting vehicle for transportation from Nuwara-Eliya to Dambulla for about 432 Km. The quality of the produce was evaluated by measuring weight loss % , wilting rating ; (1- None, 2- slight, not objectionable , 3- moderate, becoming objectionable , 4- severe, definitely objectionable, 5- extreme, not acceptable under normal condition), visual quality rating (VQR) ;(9- excellent, essentially no symptoms of deterioration., 7- good, minor symptoms of deterioration, not objectionable, 5- fair, deterioration evident, but not serious, limit of usability,3- poor, serious deterioration limit of usability,1- extremely poor, not usable) , physical damage ; (1- none, no symptoms of any physical injuries, 2- slight, minor symptoms of injury which would not affect retail price, 3- moderate, symptoms of physical injury are evident, retail price may be affected 4- severe, serious physical injuries, not marketable without substantial price reduction, 5- extreme, unusable, no market value) according to Postharvest Horticulture Series No.23-CD in random samples before and after transportation. During transportation in package temperature, RH%, respiration rate and ethylene production were measured in four hours interval.

Data Analysis: Parametric data were analyzed with ANOVA in Completely Randomized Design (CRD) using SAS statistical computer software. Means were separated using Least Significant Difference (LSD). Non parametric data were analyzed by Friedman test using MINITAB statistical package.

RESULTS AND DISCUSSION

Quality changes in Leek during transportation: Weight loss (%) and Wilting rating of leek vary with packing methods during transportation (Table 1). Treatment (T_2) showed the

lowest mean weight loss (1.24%) compared to control (6.00%). The higher value of weight loss % may be due to higher crop loss (physical damages) as a reason of using improper packages. The lowest wilting score was observed in T_2 and T_5. Severe loss of wilting (6.33) was observed in leek which transported using poly-sack, due to the unrestricted transpiration and evaporation. The rate of water loss during transportation varies according to the method of package and conditions of the environment.

Table 1. Quality changes of leek at the end of transportation

Parameters	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	Initial value
WL (%)	1.96^{bc}	1.24^{c}	2.64^{b}	1.73^{bc}	1.34^{c}	6.00^{a}	-
WR	4.33^{bc}	3.00^{c}	5.66^{ab}	4.33^{bc}	3.00^{bc}	6.33^{a}	1
PD	2.67^{ab}	1.67^{b}	3.33^{a}	1.67^{b}	1.67^{b}	3.67^{a}	1
VQR	6.33^{a}	7.00^{a}	5.67^{a}	7.00^{a}	6.33^{a}	3.00^{b}	9

WL: weight loss, WR: wilting rating, PD: physical damage, VQR: visual quality ratung. Figures with same superscripts in same raw are not significantly different (α=0.05) along the same row

T_1-75cm x 45cm x25cm with filling height 20cm , T_2- 75cm x 45cm x30cm with filling height 25cm, T_3-75cm x 45cm x 25cm with filling height 20cm, T_4- 75cm x 45cm x 30cm with filling height 25cm and T_5-80cm x 45cm 30cm cover with plastic coated wire on four sides with filling height 25cm. T_6-poly-sack

Physical damages during transportation are shown in (Table 1). The lowest damages (1.67) were observed in T_2 and T_5. Results revealed that the highest level of physical damages (3.67) was recorded in T_6 (control). The higher level of physical damages identified as compression bruising due to inappropriateness of present packaging system and its effect during transportation. Compression of the product after it has been packed into the container is a major cause of bruising. Overfilling is the most obvious problem because of the containers at the bottom layer absorbs much of the stacking force on it. Therefore, it is economically feasible to design a package to withstand the additional weight beyond their designed limit.

According to the adopted scale for ranking the higher rank belongs to the lower deteriorated vegetables. During transportation, there is no highly change VQR except leeks transported by using poly-sack T_6 (Table 1).

Variation of in package temperature and relative humidity from farmer field to economic center at Dambulla, are given respectively in figure 1a and 1b. According to results lowest in-package temperature was recorded in treatment T_2 and T_5 during transportation (22.33^0C). Highest in-package temperature was shown in control (25.67^0C) may be due to tightly packed leek in poly-sack. Results revealed that highest relative humidity was recorded in T_2 during transportation (85.00%). Previous studies revealed that when transporting perishables the RH and temperature surrounding the product must be maintained 80%-90% and 15^0C- 25^0C respectively (Sonkar and Ladaniya 1999).

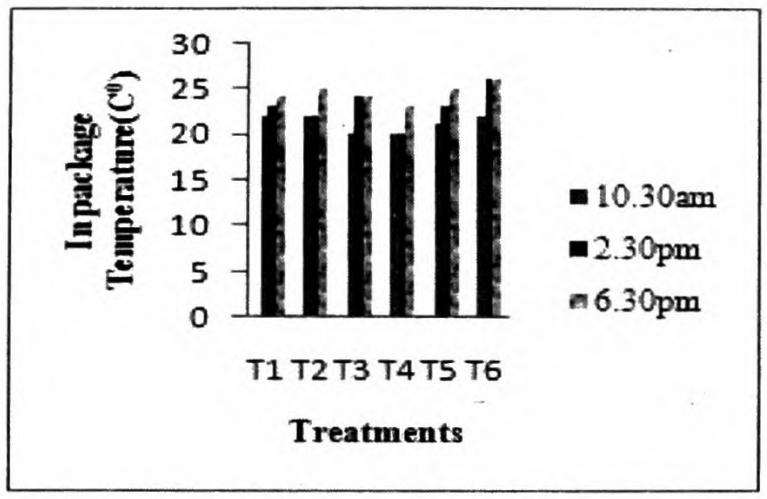


Figure 1a

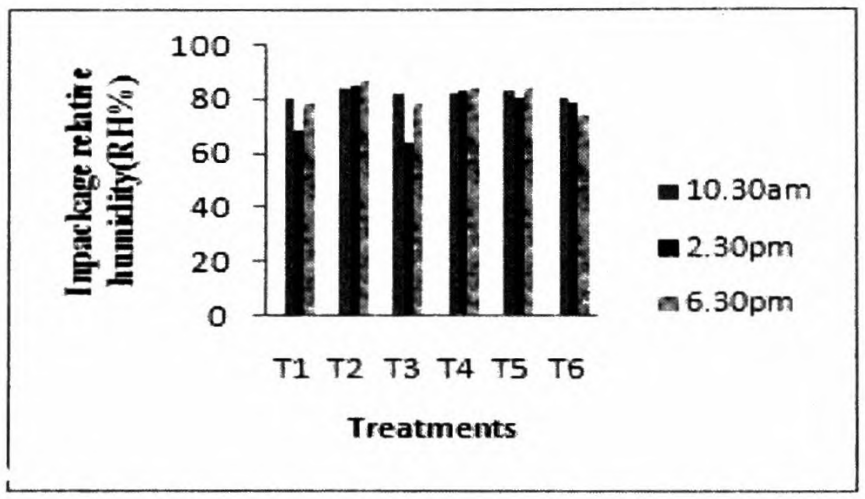


Figure 1b

Fig. 1. Change in inpackage temperature (a) and relative humidity (b) during transpotation

Variation of respiration rate and ethylene production from farmer field to economic center at dambulla was measured during and at the end of transpotation. The lowest CO_2 production was shown by T_2 during transportation and at the end of the transportation respectively (0.41 ml/kg/hr,0.11 ml/kg/hr) compaierd to control. The results revealed that the ethyleen concentration inside not given any significant difference between the treatments and control. Kader (1992) reported that generally ethylene and CO_2 production increase with maturity of harvest, physical injuries, disease incidence, high temperatures and water stress. The results observed that, higher physical damages was recorded in control and it may be cause to increase emission of higher higher level of CO_2 .

CONCLUSION

Among the packaging methods tested, T_2- 75cm x 45cm x30cm with filling height 25cm showed better performances by reducing wilting %, physical damage and weight loss (%) by retaining higher rating in visual quality. Therefore the tested package will be the most suitable alternative for transportation of leek without removing majority of the leaf portion and reducing losses during transportation due to use of appropriate height and the length for stacking.

REFERENCES

Sonker RK and Ladaniya MS (1999) Individual film wrapping of mandarin with heat stretching film for refrigerated storage. Journal science and technology. 36: 273-276.

Department of Census and statistics (2010) Socio Economic and Planing Center, Department of agriculture, Peradeniya. Sri Lanka.

Ekanayake NT, Soysa M and Ekanayake LL (2009) Vegetable Marketing in Sri Lanka, Proceeding of 2nd National Symposium 2009, University of Ruhuna, Sri Lanka.

Kader AA (1992) Postharvest Technology of Horticultural crops, 2nd ed. Publication 3311, Oakland: Division of Agriculture and Natural Resource, University of California.

Assessment of postharvest losses and quality deteriorations of banana fruits during supply chain activities in Sri Lanka

WMCB Wasala*, CR Gunawardhane, WAH Champa, RMNA Wijewardhane, RMRNK Rathnayake, UG Chandrajith and BMKS Thilakarathne
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka
*Corresponding auther:wasala73@yahoo.com

ABSTRACT

Banana is the most cultivated and consumed fruit crop in Sri Lanka. Due to its perishability and improper post harvest handling practices, post harvest losses of banana during the supply chain activities is very high. Therefore, the research was conducted to assess the post harvest losses of banana at different handling stages and to identify the causes for these losses. This will immensely benefit the post harvest industry in minimizing the post harvest loss as well as preserving the fruit quality.

The study was conducted from Embilipitiya to Colombo which is the main banana supply chain in Sri Lanka. Quantitative losses and quality deterioration of banana fruits at farmer, transporter/whole seller, retailer and consumer stages were studied. The total mechanical damages of banana were 21.82%. Physiological weight loss during the post production time was 9.34 %. Overall visual quality from farmer to consumer changed from excellent to poor which limits the usability. Fruit firmness significantly declined by 61.88 N in the supply chain. Use of improper packaging techniques was identified as the main cause of post harvest loss of banana.

INTRODUCTION

Banana is the most important fruit crop in Sri Lanka in terms of hectarage, production and consumption (Kudagamage *et al.* 2002). Over 50,000 ha of land area are under banana cultivation with an annual production of 45,000 tones. Because of its high economic gain, it has become an attractive fruit crop among Sri Lankan farmers. (Hirimburegama *et al.* 2004). Banana is a climacteric perishable fruit and therefore, its post harvest losses are relatively high due to mechanical damages occur during post harvest handling and transportation. Although bananas are harvested at the mature green stage, the external appearance of the ripened bananas at the retail shops is extremely poor as a result of excessive mechanical damages caused by improper handling during the supply chain (Sarananada, 2000). However, the loss is due to multiple factors and poor packaging is one of the main contributors to the total loss. In the traditional distribution, bananas are bulk packed in trucks without any cushioning or lining materials. Trucks are over-filled and bunches are stacked into number of layers. The wholesaler generally attempt to transport maximum amount of produce per truck load to minimize transport cost. The loss is further aggravated due to careless handling during unloading at the turning points and the final destinations. Furthermore, some transport trucks are exposed to the direct sun and rain which accelerate the deterioration of the fruit quality. Mechanical damage not only leads to postharvest losses

but also creates various stresses to fruits. Such stresses lead to physiological and morphological changes of the fruit (Shewfelt 1987).

Hence, the Institute of Postharvest Technology (IPHT) as well as several other organizations such as Food Research Unit of the Department of Agriculture, Industrial Technology Institute of the Ministry of Science and Technology and some of the universities have estimated after harvest losses for several selected crops to some extent during late nineties to early 2000. However, those studies are not sufficient to make strategies for postharvest loss management as those are not entirely covered up the whole perishable supply chain that is being practiced currently in the Island. On the other hand, being the key institute on postharvest technology in Sri Lanka, the IPHT has to have latest information and statistics regarding the entire supply chains functioning all over the Island. Therefore, a study was carried out to assess the post harvest losses of banana through the supply chain being practiced in the country in order to enhance the efficiency and to meet the future improvement needs of the system.

MATERIALS AND METHODS

The banana supply chain from Embilipitiya to Colombo was selected for this transport study. Farmers' banana samples in Embilipitiya were analyzed for the initial quality parameters such as: fruit firmness, peel colour, mechanical damages, physical damage index, total soluble solids and visual quality before the journey. Medium size open truck with leaf steel suspensions was used for this study. Fresh banana leaves were placed between bunches in the conventional packaging method as it is the usual practice. Loaded banana bunches were transported to Colombo during the night time. After transporting to Colombo, 27 bunches were selected as test samples to represent front, centre and rear locations of the truck and the top, middle and bottom layers (Figure1) .

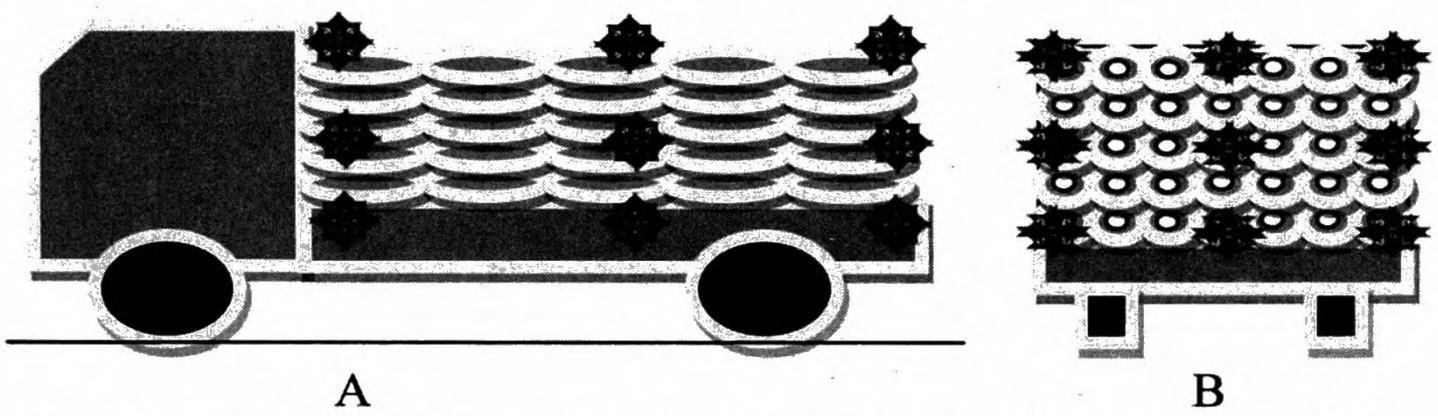


Fig.1. Sampling points of the truck on side view (A) and rear view (B)

Temperature and relative humidity of atmosphere, in-pack and in-fruit were measured at the starting point of journey, during transport, at the end of journey, at the retailer and consumer levels. Mechanical damages, fruit firmness, physiological weight loss, total soluble solids, ripening index (RI) and overall visual quality (VQR) of fruits were measured after the transportation. VQR and RI of banana fruits were determined as mentioned by Karder and Cantwell (2007). All these data were recorded at the retailer and consumer levels as well to get a comprehensive idea about the transport damages.

RESULTS AND DISCUSSIONS

Mechanical damage is the main cause of postharvest losses of banana during transportation which can also lead to secondary postharvest decay by microbial infections (Mashau *et al.* 2012). Table 1 shows the percentage quantitative losses at farmer, transporter, retailer and consumer levels of the distribution chain.

Table 1. Postharvest losses and visual quality changes in supply chain

	Handling stage				
	Farmer	**Transporter**	**Retailer**	**Consumer**	**Total**
MD (%)	3.02	6.51	8.55	3.75	21.82
PLW (%)	-	2.52	3.79	3.03	9.34
VQR	9	7	5	3	-

MD: mechanical damage, PLW: physiological loss in weight, VQR: visual quality ratings: 9- Excellent (Essentially no symptoms of deterioration), 7- Good (minor symptoms of deterioration, not objectionable), 5- Fair (deterioration evident, but not serious, limit of salability), 3- Poor (serious deterioration, limit of usability), 1- Extremely poor (Not usable)

The total postharvest losses due to mechanical damages during handling were 21.92% under conventional distribution and highest proportion was observed at retailer stage. Murthy *et al.* (2007) has previously reported that 28.5% of losses in India through wholesale channel. Abrasion and impact injuries on fruit surfaces were observed mainly as mechanical damages. Injuries due to compression effect were not found at detectable level. As mentioned by Maia *et al* (2011) compression damage caused no harmful effect on banana during transportation. Ilayas *et al.* (2007) also reported that mechanical damage of banana were higher in wholesale and retail marketing than harvesting and consumption within producer to consumer supply chain.

Results indicated that the physiological loss in weight (PLW) of banana fruits increased from harvesting to consumption. Jandal *et al.* (2005) reported that increase in weight loss of fruits was mainly due to continuous loss of moisture from fruits as a result of transpiration and respiration. Total PLW was 9.34% which was closer to the discarding level of the produce (10%). Gast and Flores (1991) reported that when PLW of fruits and vegetables is more than 10%, the produce should be discarded because with the loss of moisture it looses its freshness significantly.

The visual quality of fresh fruits and vegetables is one of the best quality determinants made by the buyer. At harvesting, visual quality rating (VQR) of banana was at an excellent level (Essencially no symptoms of detrioration). However, after transportation, visual quality of banana felt in to good level (minor symptoms). At the consumer stage, VQR of banana fruits was observed as poor. Previous researches have also stated that michanical damage of fruits could effect quality appriciation of the consumer and exposure of injury area to the atmosphere may lead to discoulourations (Zhau *et al.* 2007).
The Total soluble solids (TSS) and firmness of banana fruits at each postharvest handling stages are shown in table 02. Measurement of TSS is usually given in "Brix degrees".

Table 2. Changing of TSS of fruit pulp and fruit firmness during handling

Properties	Handling stages			
	Farmer	Transporter	Retailer	Consumer
TSS (brix)	9.12	11.46	15.72	17.56
Fruit firmness (N)	86.11	76.17	51.79	24.23

From harvesting to consumption, TSS increased and reached to a peak at the consumption point. A previous study by Liew and Lau (2012) reported that TSS value of banana increased from 4.7 (harvesting) to 19.9% (consumption). Sultani *et al.* (2010) reported that changing of brix and ripening from harvesting to consumption showed a positive correlation and also indicated that there was a linear correlation between TSS and stage of banana ripening.

In addition to colour and aroma, fruit firmness is rated by consumers as one of the most important quality attributes when selecting fruits. A large decline in fruit firmness occurred from harvesting to consumption in fruits. Degradation of cell wall polysaccharides in fruits were accompanied by loss of firmness and transport vibration induced changes in the activity in hydrolysis, which decomposed supporting materials of cell wall (Zhou *et al.* 2007). Results further showed that the fruit firmness changed along the supply chain although fruits remained unripe at harvesting and transporting stages.

Variation of Ripeness Index (RI) of banana fruits at different handling stages in supply chain is shown in Figure 2.

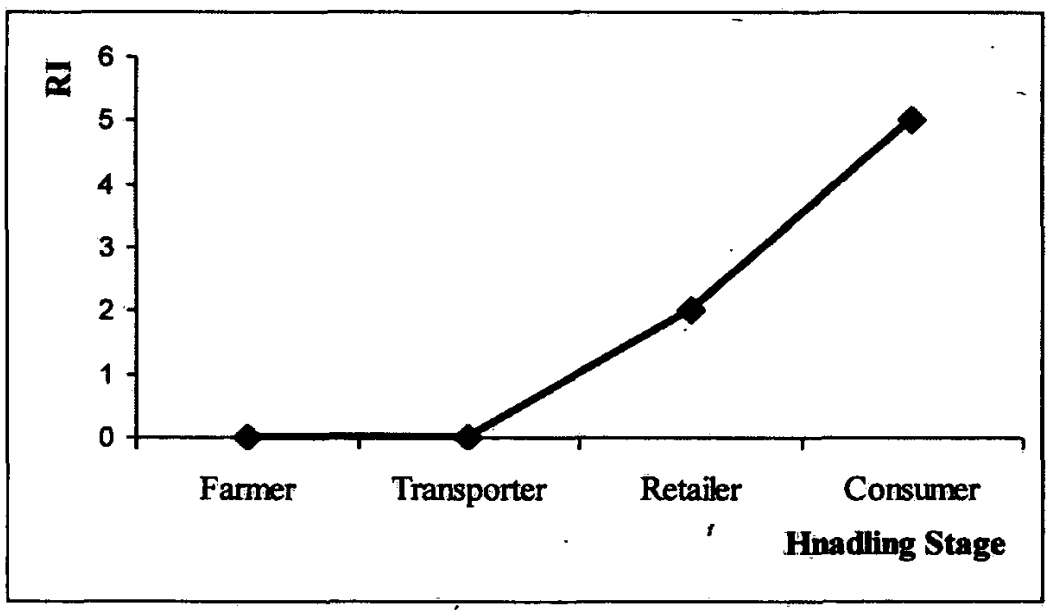


Fig. 2. Changing of ripeness index (RI)

Ripening Index (RI) of banana is important factor because during ripening process, physical, mechanical and chemical properties of fruir change. At farmer and transporter stages, all sampled banana bunches remained unripen (all green) and RI changed to light green colour. Banana fruits turned in to yellow colur at consumer step. Wasala *et al.* (2013) reported that ripening of banana at retail level can be controlled when bananas were transported as whole bunches.

CONCLUSION

The total losses of banana due to mechanical damages were 21.82% in convention banana supply chain. Physiological weight loss during the post production time was 9.34 %. Overall visual quality from farmer to consumer changed from excellent to poor level. Fruit firmness significantly declined by 61.88N in the supply chain. Use of improper packaging techniques for handling and transportation was identified as the main cause of post harvest loss of banana.

REFERENCES

Al-Hosni AS, Al-Busaid IK, Al-Farsi M, Al-Jabri M and Al-Azri H (2010). Postharvest characteristics and qualities of selected banana (Musa spp.) cultivars in Oman. Proc. Int. Conf. Banana and Plantain in Africa, Acta Hort. 879: 407- 411.

Gast KLB and Flores R (1991) Post harvest management of commercial horticulture crops, The Journal of the Agric. Research, 7(2):12-18.

Hirimburegama WK, Dias WKG and Hirimburegama K (2004) Banana improvement through gamma irradiation and testing for banana bract mosaic virus in Sri Lanka. FAO corporate document repository, Available at http://www.fao.org/docrep/007/ae216e/ ae216e09.htm#TopOfPage

Ilyas MB, Ghazanfar MU, Khan MA, Khan CA and Bhatti MAR (2007). Post harvest losses in apple and banana during transport and storage, Pak.J.Agri. Sci., 44(3):534-539.

Karder AA and Cantwell M (2007). Produce quality rating scales and colour charts, Post harvest technology research and information center, UC Davis University, CA, USA.

Kudagamage C, Chandrasiri GWJ and Razmy AMZ (2002). Analysis of long-term trends in banana sector of Sri Lanka, Annals of the Sri Lanka Department of Agriculture, 4: 21-32.

Liew CY and Lau CY (2012). Determination of quality parameters in Cavendish banana during ripening by NIR spectroscopy, International food research journal, 19(2):751-758.

Maia VM, Salomao LCC, Siqueria DL, Puschman R, Filho VJGM and Cecon PR (2011). Physical and metabolic alterations in ' Prata Ana' banana induced by mechanical damge at room temparature, Sci. Agric, 68(1):31-36.

Mashau ME, Moyane JN and Jideani A (2012). Assessment of postharvest losses of fruits at Tshakhuma fruit market in Limpopo province, South Africa, African journal of agricultural research, 7(29) : 4145-4150.

Murthy DS, Gajanana TM, Sudha M and Dakshinamoorthy V (2007). Marketing losses and their impact on marketing margins: A case study of banana in Karnataka, Agricultural economics research review, 20: 47-60.

Sarananda KH (2000). Country paper - Sri Lanka. Report of the APO seminar on appropriate postharvest technologies for horticultural crops in Asia.5-9 July, 1999, Bankgok, Thailand: 230-236.

Shewfelt RL, Meyers SC and Resurreccion AVA (1987). Effect of physiological maturity at harvest on peach quality during low temperature storage. J. Food Qual. 10(1): 9-20.

Wasala WMCB, Dissanayake CAK, Dharmasena DAN, Gunawardane CR, Dissanayake, T.M.R. and Thilakarathne, B.M.K.S. (2013). Postharvest losses, current issues and demand for postharvest technologies for loss management in the main banana supply chains in Sri Lanka. J.Postharvest Technology, 02 (01).

Zhou R, Su S, Yan Q, and Li YF (2007). Effect of transport vibration levels on mechanical damage and physiological responses of Huanghua pears (*Pyrus pyrifolia Nakai, cv. Huanghua*), Postharvest Biology and Technology, 46 (1): 20-28.

Evaluation of big onion bulbs size grading machine

DMCC Gunathilake* and KB Palipane
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka
*corresponding author:champathi@hotmail.com

ABSTRACT

Improvement of quality and value addition in agricultural produce has gained higher concern in Sri Lanka in recent times due to creation of new opportunities for sale of agricultural commodities in open market at competitive prices. Grading in equal sizes in agricultural product as value adding techniques is also become even more important in the future, the price of many agricultural produce varies significantly according to uniformity in size. Uniformity in size not only makes the produce more attractive to consumers but also improve its processing qualities. At present, size grading of most crops are carried out manually by collectors, whole sellers and retailers, farmers market their product without grading. In Sri Lanka, persons engaged in post harvest handling of crops have less chance to use high cost grading. To overcome these problems, institute of post harvest technology attempted to develop low cost grading machine for size grading of big onion bulbs. Hence, this research was focused to optimize and evaluate size grading machine for its size grading performance. Developed big onion size grading machine was tested for grading quality/efficiency of bulbs and results have been shown that maximum grading quality of small, medium and large size were 84.47%, 93.46% and 90.14 respectively. Optimized machine adjustments were obtained for maximum grading quality, i.e. incline angle of 3° and rotating speed 15 rpm of grading cylinder. The capacity of the grading machine under the optimum operating condition was 630 kg/hour. Hence size grading machine is suitable for grading big onion bulbs at medium and large scale.

Keywords: Size grading, big onion, machine, evaluation

INTRODUCTION

Apart from quantitative losses, quality deterioration and hence a reduction in the market value due to use of improper post harvest techniques are common in agricultural commodities in Sri Lanka. Improvement of quality and value addition of agricultural produce has gained importance in Sri Lanka in recent times due to creation of new opportunities for sale of agricultural commodities in the open market at competitive prices. This situation has resulted in a growing awareness and increased demand for better market quality among consumers. Improvement of product quality such as grading in equal size will become even more important in the future in Sri Lanka, like most of the other countries, entering into international as well as regional trade agreements and thereby opening its market to the outside world. The price of many agricultural produce varies significantly according their uniformity in size. Uniformity in size not only makes the produce more attractive to consumers but also improve its processing qualities. Therefore, size grading of

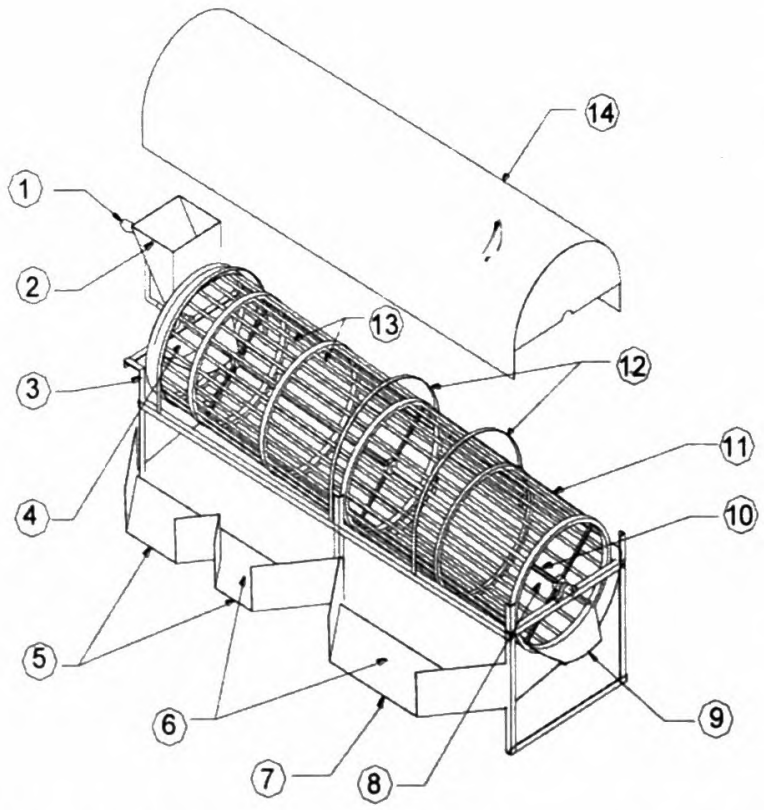
agricultural commodities to achieve uniformity in size is an important value adding technique to increase their market value.

Big onion (*Allium cepa*) is one of the major spice/vegetable cash crops, which is grown in Sri Lanka. The level of big onion production and prices shows an immense potential for increasing incomes of local farmers. Profit from big onion is greater than other major crops such as chilli and potato (Ratnayake, 1991). Generally, it can be observed, that there is an appreciable difference in the market price of big onion according to the size of bulbs. Graded big onions bulbs according to its size can be obtained higher price than the un-graded onions (Bhattarai,1993). Local farmers sell their produce to the market without grading. Hence, farmers are getting lower value for their produce. However, manual size grading of most crops are practiced by collectors, whole sellers and retailers and thereby, they make higher profit than farmers. In Sri Lanka, persons engaged in post harvest handling of crops have less chance to use high cost size separation techniques. Hence, Institute of Post Harvest Technology, Anuradhapura attempted to develop size grading machine for big onion bulbs to an affordable price. Hence this research was conducted to optimize and evaluate the developed size grading machine for its performance. Hence, objectives of this study were to evaluate the big onion bulbs size grading machine for its efficiency, performance and to determine the grading capacity.

MATERIALS AND METHODS

Big onion bulbs size grading machine, designing and fabrication works were carried out at research workshop, R & D Centre, Institute of Post Harvest Technology, Anuradhapura. Figure 1 shows three dimensional view with its component of the big onion bulbs size grading machine. Size grader was designed for grading onion bulbs into three difference sizes *i.e.* small (diameter < 4 cm), medium (diameter between 4- 6 cm) and large diameter > 6 cm).

Procedure for optimization and evaluation of the machine: Size grading machine was optimized by altering its adjustable parameters such as incline angle and rpm of grading cylinder. Incline angle and rpm of the grading cylinder were considered in the range of 2 to 4 and 10 to 20 respectively during optimization of the machine. Mixture of the different sizes of big onion bulbs were used for testing and evaluation. During optimization and evaluation, Machine was operated by electric gear motor. Three variable rotational speeds *i.e.* 10, 15 & 20 and three variable incline angles *i.e.* 2°, 3° and 4° were selected as machine adjustments. Weights of the final graded (three different size) onions were measured by electric balance.



1. Manual rotating lever
2. Hopper
3. Frame for grading cylinder.
4. Section for grading of small onion bulbs
5. Out let for small size big onion
6. Net and cushioning material
7. Out let for medium size big onion
8. Section for grading of medium onion bulbs
9. Out let for large size big onion
10. Main axel
11. Rotating cylinder
12. Supporter for outer cover
13. PVC tube
14. Outer cover

Fig. 1. Three dimensional line diagram and component of the big onion size grader

Measuring of grading quality/efficiency: Grading quality of above mentioned graded sizes such as small size, medium size and large sizes were calculated by following equations respectively.

$$\frac{W_1 - P_1}{W_1} * 100 \qquad \frac{W_2 - P_2}{W_2} * 100 \qquad \frac{W_3 - P_3}{W_3} * 100$$

Where:
P_1 – Weight of the bulbs other than small size grade
W_1 – Total weight of the onion bulbs collect in small size collector bin
P_2 – Weight of the bulbs other than medium size grade
W_2 – Total weight of the big onion collect in medium size collector bin
P_3 – Weight of the bulbs other than large size grade
W_3 – Total weight of the big onion collect in large size collector bin

Determination of capacity of the size grader: Capacity of the big onion size grader under optimum operating conditions (optimum rpm and incline angle) was determined. Capacity of size grader was calculated according to the weight of the big onion bulbs graded at a unit time.

Statistical analysis: Optimization of the machine was done by Design Expert® (version 7). Operational parameters *i.e.* incline angle and rpm were optimized by surface response methodology.

RESULTS AND DISCUSSION

Variation in grading qualities of three grades with incline angles of grading cylinder under 10 rpm: Figure 2 shows the variation in grading quality with three different incline angles under the 10rpm of rotating cylinder. It was clear that the highest grading quality was observed in 3° incline angle of grading cylinder. Incline angles of 2^0 and 4° reported comparatively low grading quality for all three grads

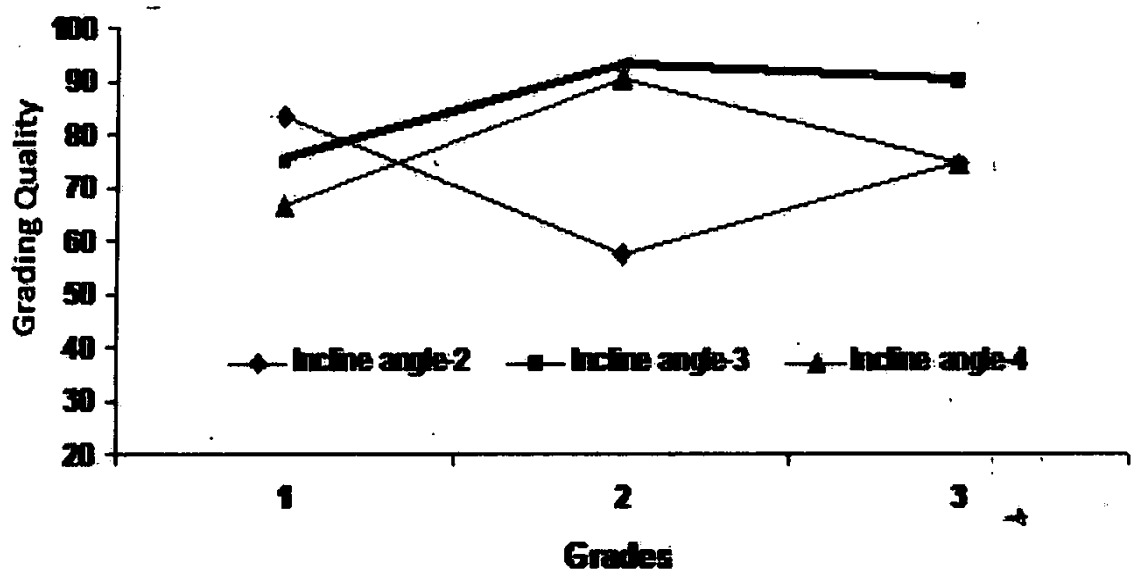


Fig. 2. Variation in grading qualities of big onion grades with 3 different incline angle of grading cylinder under 10 rpm

Variation in grading qualities of three grades with incline angle of grading cylinder under 15 rpm: Figure 3 shows the variation of grading quality with three different incline angles under the 15 rpm of rotating cylinder. The results indicated that incline angle 3° was reported the highest grading efficiency in comparison to incline angles of 2° and 4°. However, incline angle 4° also reported higher grading efficiency than incline angle 2°.

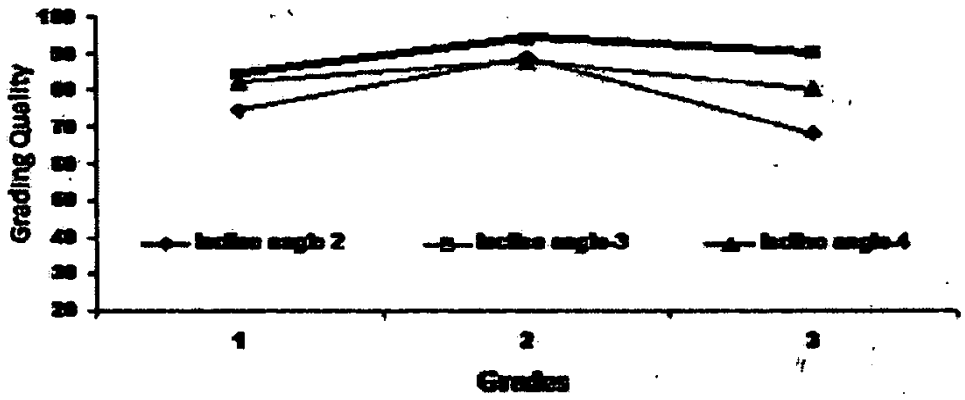


Fig. 3. Variation in grading qualities of big onion grades with 3 different incline angles of grading cylinder under 15 rpm

Variation in grading qualities of three grades with incline angle of grading cylinder under 20 rpm: Figure 4 shows that the variation of grading quality with three different incline angles under the 20 rpm of rotating cylinder. Results clearly indicated that grading efficiency was decreased with increase in rpm more than 15. The highest grading efficiency was observed in incline angle 3° under the 20 rpm also.

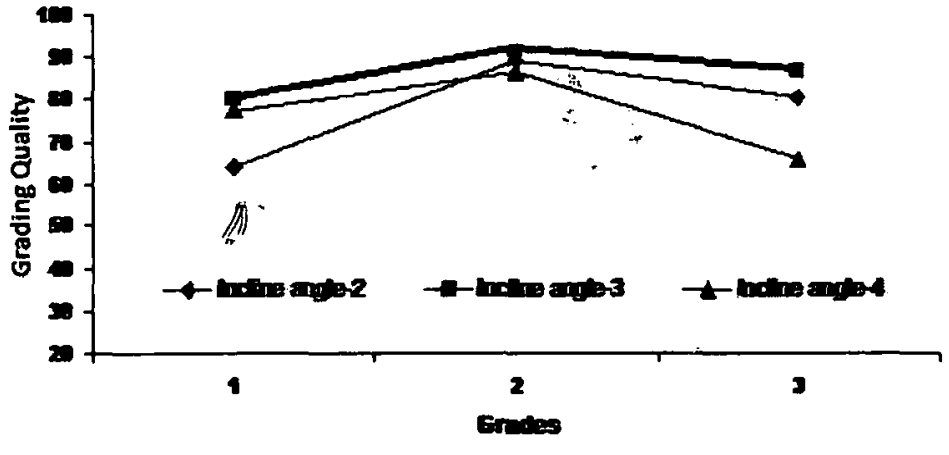


Fig. 4. Variation in grading qualities of big onion grades with 3 different incline angle of grading cylinder under 20 rpm

Selection of optimum rpm and incline angle for maximum grading quality: Graphical surface response optimization technique was adopted to determine the workable optimum operational combination in above mentioned range of rpm and incline angle combinations of the grading machine. Figure 5 shows the desirability contour plot for overall grading quality. The results indicated clearly that maximum grading qualities of 3 grades were positioned close to 15rpm and 3° incline angle of the grading cylinder adjustments. It can be predicted that (Table 1) maximum grading qualities of three grades can be obtained under 14.45rpm and 2.99 incline angle of grading cylinder.

Table 1. Statement for optimization and the selected operational parameters

Predicted optimized adjustments						
Process parameters	*Target*	*Experiment range*		*Importance*	*Optimization*	
					Optimum conditions	*Desirability*
rpm	*is in range*	*10*	*20*	*3*	*14.45*	
Incline angle	*is in range*	*02*	*04*	*3*	*2.99*	
Response					***Predicted values***	*0.991*
Grading Quality						
Small	*Maximum*	*63.65*	*84.47*	*3*	*84.06*	
Medium	*Maximum*	*57.18*	*93.46*	*3*	*94.71*	
Large grade	*Maximum*	*65.41*	*90.14*	*3*	*89.97*	

Selected optimized adjustments				
Treatment	*Grading quality of small size*	*Grading quality of medium size*	*Grading quality of large size*	*Desirability*
15 rpm and incline angle 3°	*84.47*	*93.46*	*90.14*	*0.990*

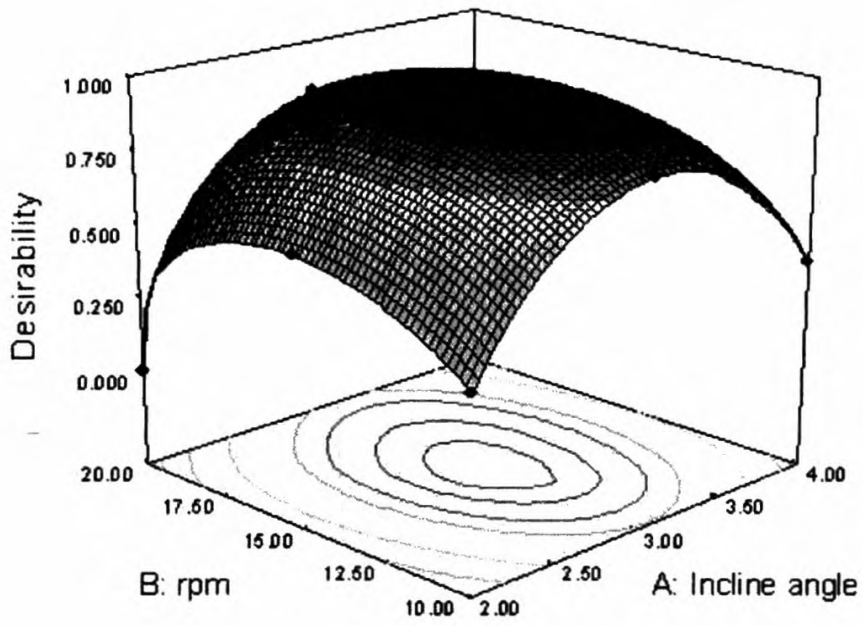


Fig.5. Desirability contour plots for overall grading efficiency

The results were revealed that 3° incline angle adjustment of the grading cylinder and 15 rpm operation were optimum operational and adjustment to obtain maximum grading quality/efficiency. Hence, under these operational conditions grading capacity observed was 630 Kg/h.

CONCLUSIONS

Finally, it can be concluded that the combination of 15 rpm and 3° incline angle of grading cylinder reported optimum adjustment of grader to work out at the highest performance of size grading of big onion bulbs. The capacity of the grader under optimum operation conditions was 630 Kg/hr and grading qualities of small, medium and large grades were 84.47%, 93.46% and 90.14 respectively.

REFERENCES

Bhattarai SP (1993). Report on post harvest research of bulb onion (*Allium cepa*) crop at Lumle 1991/92. Working Paper No. 93/36, Lumle Agricultural Research Center, Lumle, Nepal

Rathnayake W (1991). Production of Big Onion, Agriculture Department Press, Peradeniya, Sri Lanka.

Development of an appropriate methodology for extending shelf life of cassava (*Manihot esculenta* Crantz)

WAH Champa, RMRNK Ratnayake and BMKS Thilakarathne
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka.
Corresponding author: harindra74@gmail.com

ABSTRACT

Fresh cassava (*Manihot esculenta* Crantz) roots are highly perishable under ambient conditions, becoming unmarketable in 3 days or less. It is believed that cassava roots when stored at high relative humidity of around 80-90% and at temperature of 35 °C can be kept fresh. Therefore, this study was conducted with the objective of development of an appropriate methodology for extending shelf life of fresh cassava and to evaluate the impact of storage condition on extending postharvest life.

Ten months old cassava plants were de-topped at 10-20 cm above ground, 08 days prior to harvest. Then, the roots were harvested and brushed by a soft brush. Harvested fresh roots were transported the laboratory of Institute of Postharvest Technology (IPHT) and medium sized roots which are free from any visible damage were selected for the study. The selected roots were stored in a box made out of plywood sheets (L x W x H: 75 x 60 x 60 cm) lined with aluminium coated foil while covering the roots alternatively by layers (15 cm thick) of sun dried guinea grass (*Panicum maximum*). Wet and dry bulb temperatures within the box were measured three times a day (at 8, 12 and 16 h) using a digital thermometer. Roots stored in plastic crates (560mmx295mmx395mm) at room temperature (32^{0}C and RH 71-77%) were used as the control. Ambient temperature and relative humidity was also measured. The stored produce was analyzed for cyanogen content, colour, firmness, weight loss, moisture & dry matter contents and for brix at regular intervals. A sensory evaluation was also conducted.

It was revealed that, fresh cassava roots free from any visible damage, soil and other foreign materials and without surface moisture can be stored successfully in a box made out of plywood sheets (L x W x H: 75 x 60 x 60 cm) lined with aluminium coated foil while covering the roots alternatively by layers (15 cm thick) of properly dried guinea grass (*Panicum maximum*) for up to 21 days (temperature 35°C and RH 96-98%). In contrast, the same fresh cassava roots can only be kept less than 5 days when they are under ambient conditions (temperature 32^{0}C and RH 71-77%).

Keywords: Cassava, curing, low cost technologies

INTRODUCTION

Fresh cassava (*Manihot esculenta* Crantz) roots are highly perishable under ambient conditions, which become unmarketable in 3 days or less. The fresh market quality is characterized by firm, turgid, fairly straight roots which are free from mechanical injuries, decay and vascular streaking. It has been reported that cassava roots when stored at high relative humidity of around 80-90% show a typical wound healing response with periderm formation occurring in 7-9 days at 35°C and 10-14 days at 25°C (Rickard 1985). Booth (1976) however, demonstrated that periderm formation in cassava roots occurred around small V shaped cuts within 4-7 days at 35°C indicating that magnitude of the wound sustained can affect the time required for periderm formation. In cassava the formation of a wound periderm (curing) has been found to suppress the development of physiological deterioration.

Cassava roots have been successfully stored in field clamps covered by straw (Aliou 1998). He has observed cured roots with visible evidence of wound healing after one month. Furthermore, the losses that occured during clamp storage were observed rarely to be due to primary deterioration but rather are caused by pathogenic rot. It has proved that curing and wound healing process prevent the onset of primary deterioration. However, during prolonged hot and dry periods and during periods of heavy rainfall higher losses resulted. Therefore, this study was conducted to develop an in-store curing methodology for extending shelf life of fresh cassava roots and to evaluate the impact of storage conditions on quality of roots.

MATERIALS AND METHODS

A farmer field where the crop was at harvesting stage (nearly 10 month old) was selected and de-topping was done 10-20 cm above ground, 08 days prior to harvest. Roots were harvested carefully in order to minimize mechanical damages and brushing was done, using a soft brush, to remove sand, soil and dust. Harvested fresh roots were transported to the laboratory immediately and medium sized undamaged roots were selected for the study. The storage structure used was a box made out of ply wood sheets (L x W x H: 75 x 60 x 60 cm) lined with aluminium coated foil (Mc-foil). The selected roots were packed as layers alternatively by covering the roots with sun dried guinea grass (*Panicum maximum*) at a thickness of 15 cm. Thermocouples (type K), connected to digital thermometers, were placed among different layers of the stacked roots for recording the temperature. Relative humidity within the box was recorded by installing a wet and dry bulb thermometer and was resorded three times a day (8, 12 and 16 h). Roots stored in a plastic crates (560mmx295mmx395mm) kept at ambient conditions (temperature 32^{0}C and RH 71-77%) were used as the control. Ambient temperature and relative humidity was also recorded during the study. The stored produce was analyzed for physicochemical parameters such as cyanogens (HCN) content (AOAC 1995), dry matter content (oven dry method at 60 °C, 24 h wet basis), weight loss (%), firmness (N), peel & pulp colour, total soluble solids content (%, by hand refractometer) and sensory evaluation (5-point hedonic test, 30 semi trained panelists) at 0, 5 and 21 days after storage (DAS).

The experiment was carried out as complete randomized design with three replicates. Each replicate was consisted of 50 roots. The data was subjected to variance analysis using the SAS package. Treatment means were compared at $p<0.05$ according to the LSD procedure.

RESULTS AND DISCUSSION

Temperature and relative humidity: Variations of temperature and relative humidity (RH) within the boxes and in ambient condition are shown in Figure 1 during 10 days storage period.

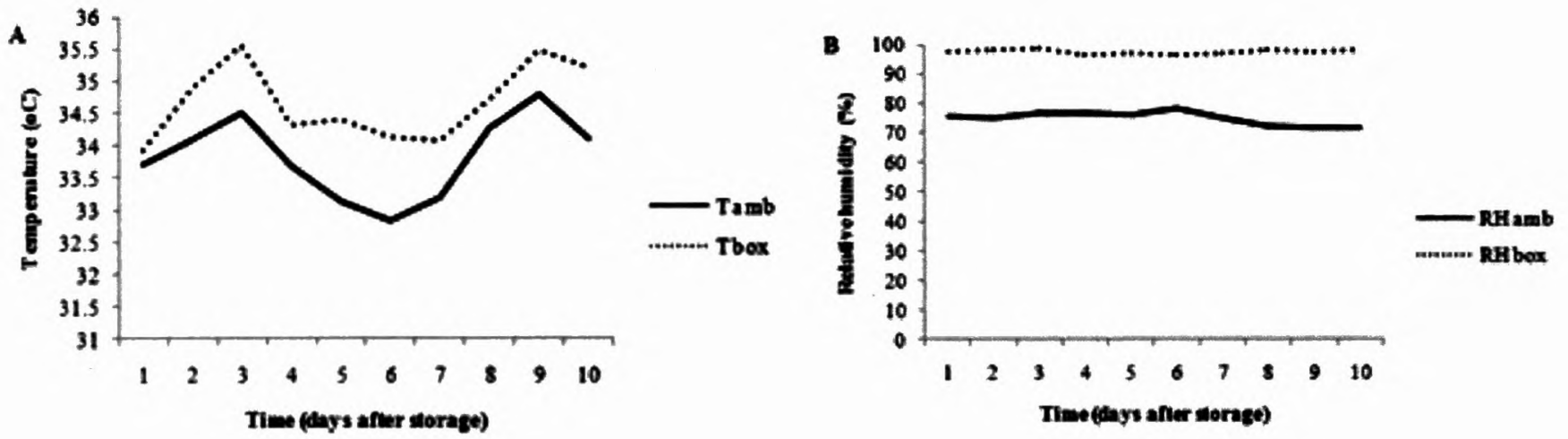


Fig. 1. Variation of temperature (panel A) and relative humidity (panel B) during 10 days of study period. (T: temperature, amb: ambient)

The temperature and RH within the box which stored cassava were always higher (by ≈ 1 °C temperature and by ≈23% RH) than that of the ambient temperature and RH. Rickard, (1985) reported that cassava roots when stored at high relative humidity of around 80-90% show a typical wound healing response with periderm formation occurring in 7-9 days at 35°C. In this study, it was possible to achieve those conditions with the applied treatments.

Quality analysis

Chemical and physical properties: Contents of cyanogens (HCN), total soluble solids (TSS) moisture, dry matter and firmness of cassava roots stored under different conditions are given in the table 1. No significant differences were observed between cassava roots stored under the developed method and in between cassava stored under ambient conditions in terms of cyanogens and firmness while there was a significant difference between TSS, moisture and dry matter content on 5 days after storage (DAS). Cassava roots kept under ambient conditions could not be kept more than 5 days. They showed fibrous (tough) texture at the end of 5 DAS in contrast cassava stored under the developed method, where they stayed fresh up to 21 days.

Table 1. Cyanogens (HCN), total soluble solids (TSS) moisture, dry matter and firmness of cassava roots stored under different conditions.

Parameter	Treatment			Control		
	Days after storage			Days after storage		
	0	5	21	0	5	21
HCN (ppm wb)	25.2[a]	14.40[a]	ND	25.2[a]	14.96[a]	NA
HCN (ppm db)	66.4[a]	38.8[a]	ND	66.4[a]	40.0[a]	NA
TSS (%)	8.5[a]	9.7[a]	11.0	8.2[b]	9.5[b]	NA
Moisture (% wb)	62.7[a]	60.8[a]	58.5	62.7[a]	60.1[b]	NA
Dry matter (% wb)	37.2[a]	39.2[b]	41.5	37.2[a]	39.9[a]	NA
Firmness (N)	132.44[a]	145.28[a]	170.93	135.12[a]	148.53[a]	NA

Means in a row with the same letter are not significantly different (at $P \leq 0.05$) according to LSD. Each value represent mean of 3 replicates (n = 10), wb: wet basis, db: dry basis, ND: not detected, NA: samples not available

Peel and flesh colour: Peel and flesh colour of the treated and control roots are shown in the table 2. There was no significant difference observed peel and flesh colour of cassava roots stored under the in-store curing structure and under ambient conditions.

Sensory evaluation: Results of the 05 point hedonic scale test are given in the table 3. It is clear that cassava stored under the developed method superior in quality compared to the control. Because, presence of high RH (>95%) and temperature (around 35 °C) under the developed method; reduction in moisture and dry matter contents were lower and maintained higher TSS content than that of the control which might have contributed to gain higher acceptability in the sensory test.

Table 2. Peel and flesh colour of cassava stored under the developed method vs under ambient condition

Treatment	Days after storage					
	0		5		21	
	Peel colour	Pulp colour	Peel colour	Pulp colour	Peel colour	Pulp colour
L	30.57[a]	76.97[a]	36.15[a]	79.18[a]	36.0	81.48
a	4.19[a]	-2.14[a]	5.83[a]	-3.75[a]	4.61	-2.73
b	8.12[a]	18.53[a]	10.0[a]	15.88[a]	8.99	17.63
Control						
L	30.21[a]	80.93[a]	30.84[a]	75.26[a]	NA	NA
a	7.05[a]	-3.22[a]	7.33[a]	-3.79[a]	NA	NA
b	9.55[a]	22.67[a]	9.42[a]	16.60[a]	NA	NA

Means in a column with the same letter are not significantly different (at $P \leq 0.05$) according to LSD. Each value represent mean of 3 replicates (n = 6), NA: samples not available

Table 3. Sensory evaluation of cassava stored under the developed method vs under ambient condition (5 DAS)

Parameter	Treatment	Control
Colour	4.25	3.25
Odour	4.00	3.50
Taste	4.00	3.00
Texture	4.00	3.00
Overall acceptability	4.00	3.00

Rank median of the 30 untrained panellists analysed by Friedman test, 5 point hedonic scale *(i.e.: 5= like extremely, 1=dislike extremely)*

CONCLUSION

Fresh cassava which are free from mechanical damage, soil and other dirty materials and without external free moisture can be stored successfully in a box made of ply wood sheets (L x W x H: 75 x 60 x 60 cm) lined with Mc-foil while covering the roots alternatively by layers (15 cm thick) of properly dried Guinea grass (*Panicum maximum*) for up to 21 days (temperature 35°C and RH 96-98%) in contrast the same fresh cassava roots can only be kept less than 5 days when they are under ambient conditions (temperature 32^0C and RH 71-77%).

REFERENCES

Aliou DIP (1998). Storage and processing of roots and tubers in the tropics. In: Food and Agriculture of the United Nations, Agro-industry and postharvest management service, Agriculture support systems division. FAO, Rome.

AOAC (1995) Official Method of Analysis of AOAC International. Suite 500 481, North Frederick Avenue, Gaithersburg, Maryland 20877-2417. USA.

Booth RH, de Bucle TS, Cardenas OS, Gomez G and Hervas E. (1976). Changes in quality of cassava roots during storage. J. Food Technol. 11:245-264.

Rickard JE (1985). Physiological disorders of cassava roots. J of the Science of Food and Agric. 36(3):167-176.

Postharvest keeping quality and some nutritional aspects of *Trianthema portulacastrum* L. - an under-utilized leafy vegetable in Sri Lanka

EGCK Priyadarshika[1], WAM Daundasekera[*1], P. Malathy[2]
[1]Department of Botany, Faculty of Science, University of Peradeniya, Sri Lanka.
[2]Horticultural Crops Research and Development Institute, Gannoruwa, Peradeniya, Sri Lanka.
*Corresponding author: malkanthid@pdn.ac.lk

ABSTRACT

Trianthema portulacastrum L. ('Sãrana') is considered as an under-utilized vegetable crop and the market is limited due to its short postharvest life. Postharvest keeping quality of two varieties; 'Red' and 'White' was compared under five different storage conditions. T1 (Control) - cut ends dipped in water container and stored in room temperature (RT) and relative humidity (RH) (26±2 °C and 60 %, respectively); T2- packaged in Low Density Polyethylene (LDPE) film and stored under RT and RH; T3- Packaged in perforated LDPE film and stored in RT and RH; T4- packaged in LDPE bags and stored under 10 °C and 90% RH; T5- packaged in perforated LDPE film and stored in 10 °C and 90% RH. Shelf life was determined as time (days) taken to exhibit 10% wilting (in control samples) and 5% yellowing (in poly-film packaged samples). Levels of crude protein, Phosphorus (P), Calcium (Ca), Magnesium (Mg) and iron (Fe) were quantified. Both varieties behaved more or less in the same manner under five different storage conditions. Packaging with LDPE film combined with cold storage was the most effective in prolonging the shelf life of harvested 'Sãrana' where it exhibited four-fold extension of the shelf life against the control. Variety 'Red' was superior to 'White' in terms of crude protein, P, Ca, Mg and Fe levels.

Keywords: *Trianthema portulacastrum*, postharvest, crude protein, packaging

INTRODUCTION

Trianthema portulacastrum L. is considered as a weedy plant in cultivated areas thus it is not popular as a leafy vegetable in many countries. It is known as 'Sãrana' in Sinhala. 'Sãrana' is an annual or perennial herb that can grow fast under frequent water. There are two main varieties of *T. portulacastrum* grown in Sri Lanka; variety 'Red' has solitary axial flowers with light pink colour perianths while 'White' possesses white colour perianths. In Sri Lanka, Sãrana is considered as an under-utilized crop and there are no published records available on nutritional or postharvest aspects of local varieties. Higher perishability and

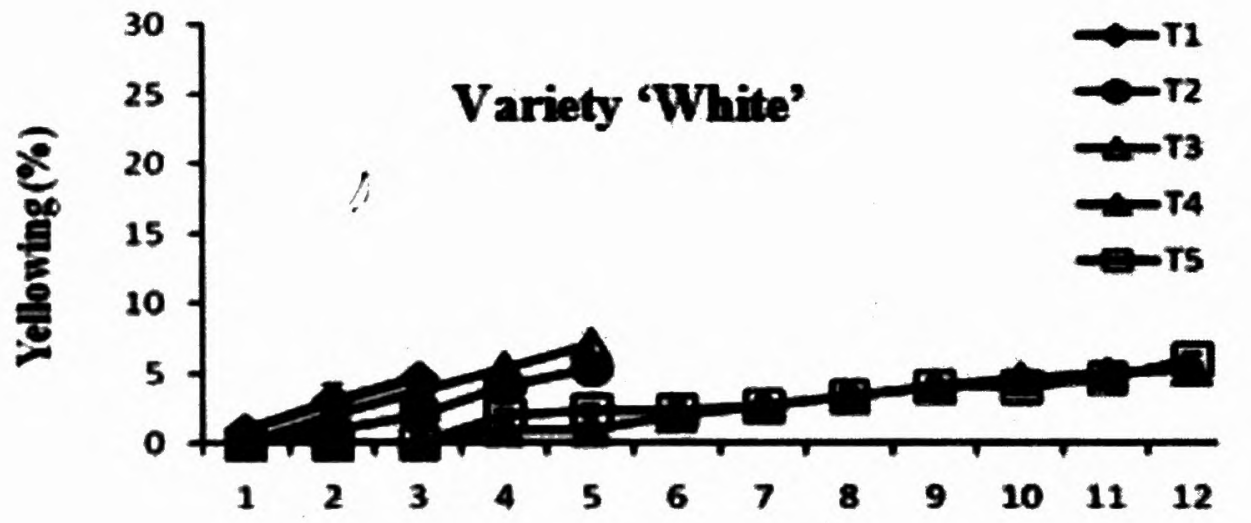
shorter shelf life are two key factors which restrict the distribution and utilization of Sãrana. Quality of leafy vegetables is mainly based on the appearance including freshness, right colour and other human senses such as firmness, tenderness and taste (Acedo, 2010). This study was conducted as a part of a variety-wise evaluation of the varieties 'Red' and 'White' of *T. portulacastrum* by the Horticultural Crop Research and Development Institute (HORDI), Gannoruwa, Sri Lanka. Objectives of study reported in this paper were to compare some nutritional aspects and postharvest keeping quality of the above two varieties.

MATERIALS AND METHODS

T. portulacastrum was cultivated at the HORDI according to the Department of Agriculture recommendations. The crop was harvested 25 days after sowing and transported to the Postharvest Technology Laboratory of the Department of Botany, University of Peradeniya. Plants free from damages and visible signs of disease were selected. Their roots were trimmed and bundles of 250 g were prepared. Each bundle served as a replicate. Storage conditions used were: T1(control) - stored under ambient conditions (26±2 °C and 60 %, RH) with cut stem ends dipped in tap water; T2 - sealed in Low Density Polyethylene (LDPE -150 µm gauge) bags (30×45 cm^2) and stored under ambient conditions as given in T1; T3- Packaged in perforated LDPE bags and stored under ambient conditions; T4 - sealed in LDPE bags and stored in 10 °C and 90% RH; T5 - packaged in perforated LDPE bags (12 perforations per 30×45 cm^2 area, diameter of the perforation-5 mm) and stored in 10 °C and 90% RH. In control samples, cut ends were dipped in tap water as it is practiced by many sellers in the local market. Samples were daily assessed for % fresh weight loss. The visual quality of samples was ranked using self-prepared scale based on leaf wilting, yellowing and rotting. Shelf life was determined as time (in days) taken to reach 10 % wilting (for control set without packaging) and 5 % yellowing (for other treatments) of the samples. Crude protein levels were quantified by Kjeldhal method (AOAC, 1998), Phosphorus (P) levels by UV spectrophotometry and Ca, Mg and Fe levels by atomic absorption spectroscopy method (Anderson and Ingrum, 1993). The experiment was laid out according to Complete Randomized Design with six replicates per treatment. Data were analyzed by MINITAB software.

RESULTS AND DISCUSSION

In this study, shelf life of Sãrana was determined using visual quality parameters including wilting, yellowing, browning, rotting and loss of glossiness. The shelf life-determining parameter of samples without polyfilm packaging was wilting whereas the shelf life of the samples with packaging depended on yellowing (Figure 1) as they did not show signs of wilting (data not shown).



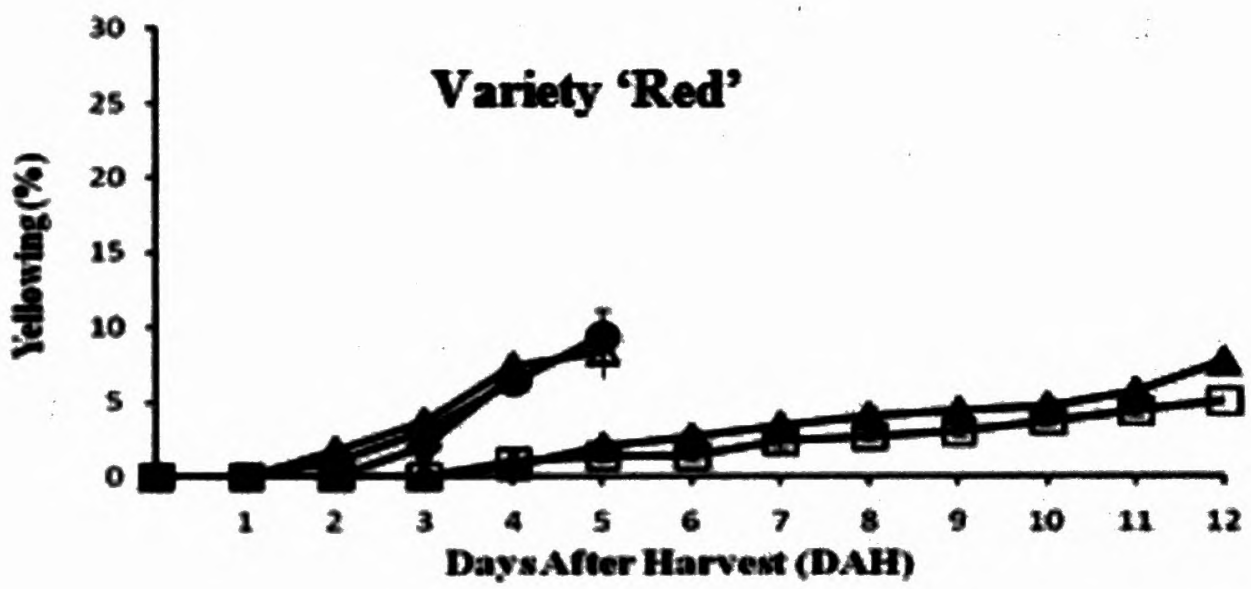


Fig. 1. Percentage yellowing of the varieties 'White' and 'Red' of *T. Portulacastrum* under five different storage conditions; T1(control) - cut stem ends dipped in tap water and stored under ambient conditions (26±2 °C and 60 %, RH); T2 - sealed in LDPE bags and stored under ambient conditions; T3- packaged in perforated LDPE bags and stored under ambient conditions; T4 - sealed in LDPE bags and stored in 10 °C and 90% RH; T5 - packaged in perforated LDPE bags and stored in 10 °C and 90% RH.

There was no significant difference ($p<0.05$) in shelf life between two *T. portulacastrum* varieties (Table 1). LDPE packaging coupled with low temperature storage extended the shelf life by 4-fold compared to storage under ambient conditions without packaging. The degree of % weight loss significantly varied on storage temperatures but not between varieties. Samples packed in LDPE package showed significant reduction of weight loss and they did not show signs of wilting even upon senescence. The two varieties behaved more or less in similar manner under different storage conditions.

Table 1. Weight loss and shelf life of two varieties of *Trianthema portulacastrum* under different storage conditions

Treatment	Shelf life (days after harvest)		% Weight loss at the end of shelf life	
	'Red'	'White'	'Red'	'White'
T1	3 B d	3 B d	18.28 A a	18.48 A a
T2	4 B e	5 B e	4.78 A b	4.09 A b
T3	5 B e	6 B e	5.29 A b	5.11 A b
T4	11 B f	12 B f	1.12 A c	1.18 A c
T5	12 B f	12 B f	1.28 A c	1.20 A c

Mean values indicated in different letters are significantly different at $p < 0.05$ level. Uppercase letters indicate the variety while the lowercase letters indicate the difference among the treatments. T1 (control) - cut stem ends dipped in tap water and stored under ambient conditions (26±2 °C and 60 %, RH); T2 - sealed in Low Density Polyethylene bags and stored under ambient conditions; T3- Packaged in perforated LDPE bags and stored under ambient conditions; T4 - sealed in LDPE bags and stored in 10 °C and 90% RH; T5 - packaged in perforated LDPE bags and stored in 10 °C and 90% RH.

When compare the crude protein, P, Mg, Ca and Fe levels, the variety 'Red' had a higher amounts than variety 'White' (Table 2).

Table 2. Crude protein, calcium, magnesium, iron and phosphorus levels of two different varieties of *Trianthema portulacastrum*

Variety	% crude protein /g db	Calcium (mg/ 100 g db)	Magnesium (mg/ 100 g db)	Iron(mg/ 100 g db)	Phosphorus (mg/ 100 g db)
'Red'	20.99 a	97.73 a	234.3 a	38.6 a	38.21 a
'White'	19.98 b	72.08 b	207.3 b	14.1 b	27.76 b

Mean values in each column followed by the same letter are not significantly different at $p < 0.05$ level, db:dry basis

Storage under low temperature coupled with polyfilm packaging has extended the shelf life of *T. portulacastrum* by four-fold compared to the control samples, possibly through reduction of water loss. Reduction of quantity and degradation of nutrients is often associated with water loss leading to the reduction of quality (Kanlayanarat 2007). Low temperature storage has advantages on extending shelf life and protecting qualities such as texture, nutrition, aroma and flavor and also reduction of microbial activities (Watada *et al.* 1996).

Protein levels and studied dietary mineral contents were significantly different between the two varieties of *T. portulacastrum*. Ash content of variety 'Red' was higher (~22 %) than that of variety 'White' (~19 %; data not presented). As the amount of ash is a good indicator of amount of mineral nutrients in the sample, variety 'Red' appears to contain higher amount of mineral elements than variety 'White'. According to literature, crude protein levels in the two *T. portulacastrum* varieties were comparable to that in *Centella*

asiatica ('Gotu Kola') and *Bassella alba* ('Nivithi') but less when compared to *Sesbania grandiflora* and *Alternanthera sessilis*. Phosphorous contents detected in *T. portulacastrum* are higher when compared with that of *Bassella alba* (21 mg/100 g). Calcium contents detected in *T. portulacastrum* are comparatively lower than that of *Amaranthus tricolor* (800 mg/100 g), *Centella asiatica* (224 mg/100 g) and *Ipomoea aquatica* (110 mg/100 g). Iron level of *T. portulacastrum* was higher than that in *Bassella alba* (10.9 mg/ 100 g) and *Ipomoea aquatica* (3.9 mg/100 g; Wahundeniya and Kurukalaarachchi 2010).

CONCLUSIONS

T. portulacastrum varieties 'Red' and 'White' exhibited the same shelf life under different storage conditions tested. Storage under 10 °C and 90 % RH combined with LDPE-film packaging can be recommended for *T. portulacastrum* leaves as it exhibits 4-fold extension of shelf life compared to storage under ambient conditions. Variety 'Red' was superior to variety 'White' in terms of the levels of crude protein, calcium, magnesium, phosphorus and iron.

REFERENCES

Acedo AL (2010). Postharvest technology for leafy vegetables. AVRDC-ADB Postharvest Projects RETA 6208/6376. AVRDC Publication No. 10-733.

Anderson JM and Ingram JSI (1993).Tropical Soil Biology and Fertility: A Handbook of Methods. Second Edition. CAB International, London. Pp. 70 – 89.

AOAC (1990). Official Method of Analysis, 16 th edn. Washington, DC: Association of Official Analytical Chemists, 4th Rivision (2)

Kanlayanarat S (2007). Postharvest technologies for fresh leafy vegetables in Thailand; Paper presented during the RETA 6376 Workshop on Best Practices in Postharvest Management of Leafy Vegetables in GMS Countries.

Wahundeniya KB and Kurukalaarachchi N (2010). 'Kola elawalu wagawa' Department of Agriculture publication, Sri Lanka. pp. 7-14.

Postharvest losses of the potato marketing channel: a case of food waste foot printing

HKN Darshika*, SNM Wickramarathna and DAM De Silva
Department of Agribusiness Management, Faculty of Agricultural Sciences, Sabaragamuwa University, P.O. Box 02, Belihuloya, Sri Lanka.
*Corresponding author:darshi.nayoma@gmail.com

ABSTRACT

Potato is the most important food crop in the world after wheat, rice and maize which have significant contribution to the Sri Lankan economy. Potato cultivation plays an important role in rural economy of the central highlands. Returns of the potato industry were fluctuating sharply and unpredictable income attached to several reasons. Postharvest loses in potato marketing channel is critical issue. In this context, this study examined the post-harvest losses of different stages in potato marketing channel and food waste foot print. Rapid market chain analysis was used to collect the primary data and experienced field investigators were involved in the process. The sample consisted of 10 potato farmers, 10 traders, 10 wholesalers, 10 retailers and 10 consumers who were selected in each districts by using purposive sampling technique. The study revealed the various reasons for post harvest losses and measured the level of food waste. Method of harvesting, tools, time of harvesting, variety, type of soil, type of labour were effected on Post harvest losses at harvesting stage. Curing, sorting and grading, washing and transportation from farm to farm house were key post harvest loss points in farm field. Third stage losses were reported from storage in farm (duration, season, method, variety) and transportation from farm gate to market (mode of transport, handling). Post-harvest losses at market composed of method of storage, duration, season and the location. Losses reported at a retail point include transportation from market places to retailers, in the retail storage, distance from market and method of display. Final post-harvest losses were recorded at consumers, both individual and institutional consumers. Method of losses were depends on consumer storage, preparation methods as well as consumption habits. Study identified relationship of post-harvest losses and its relationship to the food waste foot printing.

Keywords: Potato, post-harvest losses, food waste foot print, marketing channel

INTRODUCTION

The potato (*Solanum tuberosum* L.) is one of the most commonly grown tuber crops in all over the world which originated in Andes highlands in Peru. It is the most important food crop in the world after wheat, rice and maize (Kibar, 2012). Recently, developing countries have increased their contribution. This situation has evolved rapidly indicating that a sustained trend will result in most of the world production of tubers coming from Asia, Africa and Latin America (Meyhuay 2001).

Potato has been introduced into Sri Lanka in 1850's and at present it is extensively cultivated in two major seasons, *Yala* and *Maha*. Potato is considered as the most popular food crop of the upcountry farmers due to its high net returns. It can be grown in Up

Country Wet, Intermediate, and Dry Zones at temperatures between 24 ^{0}C and 32 ^{0}C and rainfall is >2,500mm, as well as in Puttalum and Jaffna districts during Maha. The optimum day temperature for potato is 20 - 25 ^{0}C and temperature difference between day and night should be 10 ^{0}C. In Sri Lanka Hillstar, Desiree, Sante, Raja, Granola, Kondor, Isna, and Golden star are major varieties recommend by the Department of Agriculture.

Food losses in developed countries occur primarily at the consumer level and losses in developing countries, in contrast, occur mostly during the field-to-market stages, with the smallest share of losses occurring at the consumer level. Premature harvesting, poor storage facilities, lack of infrastructure, lack of processing facilities, and inadequate market facilities cause high food losses in developing countries (Aulakh *et al.* 2013).

Potato harvest is distributed from farm to end consumer via long marketing channel which exposes potato tubers for significant amount of post-harvest losses. The qualitative losses greatly reduce the market price of potatoes. Therefore, farmers are away from receiving the expected net returns and the returns are fluctuating sharply within the seasons.

In general, potato growers utilize considerable amount of resources at production where labour and agro chemicals claim the largest portion of the production cost. Post harvest losses occurred along the supply chain lead to minimize the returns to the farmers in one hand. On the other hand supply fluctuations directly hit the market. Post harvest losses vary from 30-35% of harvest and which directly links with the food waste as well as adversely affect the environment.

MATERIALS AND METHODS

Rapid market chain approach was the principal tool used to collect the data and experienced field researchers were involved in the data collection process. Each and every node of the potato value chain was investigated comprehensively to identify the post harvest losses which were measured in qualitative means. Potato value chain actors considered for the study were farmers, traders, wholesalers, retailers and consumers and 10 members from the each node and each district were purposively selected for the study. 89Potato farmers in Nuwara-Eliya and Badulla districts were considered for the starting point of the study. Total potato land extent in Nuwara-Eliya district is 851 ha and total potato land extent in Badulla district is 3,966ha (Department of Census and Statistics 2013). Potato farmer's databases and secondary data were gathered from the agriculture research station Seetha Eliya and Department of Agriculture, Badulla.

Data were collected by using both primary and secondary data collection methods. Primary data were collected by using pre-tested interviewer administrated structured questionnaire. Close ended, multiple-choice questions and few open-ended questions were used in the questionnaire and through focus group discussions.

RESULTS AND DISCUSSION

Potato, a single most important tuber crop and its contribution to rural as well as national economy received utmost important. High cost of production, sharp fluctuations of market prices as well as demand, quality deterioration, government policy on pricing and imports and availability of quality seed potato were major visible burning issues that farmers facing today. Unfortunately very high post harvest losses, and its impact on returns to the investment were still invisible. Very limited research attention has been paid to identify the impact of invisible post harvest loss of potato farming and its impact on value chain.

Present study has identified invisible post harvest losses along the potato value chain and points where significant losses were recorded. Potato post harvest losses directly result to food waste in one hand. On the other hand post harvest losses and waste of produced food create environmental problems

Numerous post-harvest losses were identified in the of potato value chain and Post harvest losses of harvesting stage depends on method of harvesting, tools, time of harvesting, variety, type of soil, type of labor. Curing, sorting and grading, washing and transportation from farm to farm house were key post harvest loss points in farm field. Third stage losses were reported from storage in farm (duration, season, method, variety) and transportation from farm gate to market (mode of transport, handling). Market place post harvest losses composed of method of storage, duration, season and the location. Losses reported from retail point include transportation from market places to retailers, in the retail storage, distance from market and method of display. Final post harvest loses were recorded from consumers, both individual and institutional consumers. Method of losses were depends on consumer storage, preparation methods as well as consumption habits. Study has identified relationship of post harvest losses and its relationship to the food waste foot printing.

The study revealed that at the harvesting stage, due to improper identification of maturity level, rough handling of tubers during harvesting, inappropriate tools, careless handling of tools and equipment, incorrect practice of harvesting methods, harvesting under wet weather, less experience of farmer causes significant level of mechanical, physiological and pathological post-harvest damages during harvesting stage of potato.

After harvesting, potatoes undergo a special process called curing. Before curing, potatoes should be properly dried to enhance the keeping quality. According to the observations, due to insufficient drying of the harvested tubers, storing the tubers immediately if they are exposed to rain after harvest and inadequate curing are the causes of post-harvest losses at this stage.

At the sorting, grading and washing stages mainly due to mechanical damages during handling abrasion and bruising were commonly observed. Potatoes should be kept at very low temperatures in order to obtain its maximum quality. Temperature is the single most important factor in the keeping quality of stored potatoes. Respiration, sprouting, water loss, relative humidity, chemical composition and the development of storage diseases are all influenced by temperature. Through this study observed quality loss due to improper

management of temperature. Conferring to the observations at transporting from farm to farm house due to careless handling and at the storage, due to less use of appropriate storage conditions, potatoes undergo considerable level of post-harvest damages.

Stored potatoes were again transported to wholesalers and retailers subsequently. According to our study the most prominent post-harvest damage was bruising of potatoes caused by vibrations at transportation. In addition post-harvest damages which were leading to the reduction of post-harvest life were identified at the end of the market channel at wholesale, retail and consumer storages.

CONCLUSION

The study revealed that mechanical, physiological and pathological damages cause post-harvest damages in potato in different stages of marketing channel and it leads to reduce the keeping quality. Both quantity and quality losses directly linked with the returns to the value chain members as well as food waste. Post harvest losses of the potato industry were invisible and unrecorded along the value chain. High level of post harvest losses create the big gap in market demand and supply where value chain members made extra pressure on environment to fill the gap. This food wastage represents a missed opportunity to improve food security, but also to mitigate environmental impacts and resources use from food chains.

REFERENCES

Department of Agriculture, (2006), Available at: http://www.agridept.gov.lk/index.php, [Accessed on 02.12.2013].

Kibar H (2012). Design and management of postharvest potato (*Solanum tuberosum* l.) storage structures, Ordu Univ. J. Sci. Tech.,Vol: 2, no:1, pp.23-48.

Meyhuay M (2001). Potato: post-harvest operations, Instituto de Desarrollo Agroindustrial Available online at: http://www.lamolina.edu.pe,[Accessed on 02.12.2013].

FSC (1996). Potato post-harvest, Available online at: http://www.fsc.org, [Accessed on 02.12.2013].

Aulakh J, Regmi A, Fulton JR and Alexander C (2013). Estimating Post-Harvest Food Losses: Developing a Consistent Global Estimation Framework, Agricultural & Applied Economics Association's, Washington.

Department of Census and Statistics (2013). available at: http://www.statistics.gov.lk/agriculture/seasonalcrops/PotatoNationalandsubNational.html,[Accessed on 02.12.2013].

Preharvest foliar sprays of salicylic acid enhance berry quality of table grapes (*Vitis vinifera* L.) cv. Flame Seedless

WAH Champa*[1], MIS. Gill [1], BVC Mahajan [2], NK Arora [1] and Seema Bedi[3]

[1]Department of Fruit Science, Punjab Agricultural University, Ludhiana, 141 004, Punjab, India.

[2] Punjab Horticultural Post Harvest Technology Centre, Punjab Agricultural University, Ludhiana, Punjab, 141 004, India.

[3] Department of Botany, Punjab Agricultural University, Ludhiana, 141 004, Punjab, India.

*Corresponding author:harindra74@gmail.com

ABSTRACT

The purpose of the present study was to examine the significance of preharvest application of salicylic acid (SA) to improve physicochemical properties of clusters and berries of grape cv. Flame Seedless. The study was conducted in two consecutive seasons of 2012 and 2013 on 12-year old own rooted, Flame Seedless vines planted at 3m x 3m spacing (440 plants acre^{-1}) trained on overhead system. Vines were treated with four concentrations of SA (0.0, 1.0, 1.5 and 2.0 mM) when the berries were at pea stage (2 weeks after fruit set) and again at veraison (colour break). Clusters were harvested at commercial maturity and analysed for bunch and berry weight, length, breadth, peel colour, firmness, TSS, TA, anthocyanins and total phenols. The results revealed that spraying of SA at the dose of 1.5 mM reduced cluster compactness, increased berry size, decreased berry lightness (L*) while increasing total anthocyanin content and berry firmness significantly.

Keywords: Flame Seedless, salicylic acid, table grapes

INTRODUCTION

Grapes (*Vitis vinifera* L.), owing to their high functional properties, play an important role in ensuring a healthy life. They are rich in polyphenolic phytochemical compounds such as resveratrol, anthocyanins and other phenolics which are powerful anti-oxidants, thus found to play a protective role against cancers of colon and prostate, coronary heart disease, degenerative nerve disease and viral/ fungal infections. The quality of grape berries is the prime consideration in both domestic and export markets. Grape berry develop as clusters with each berry attached to the bunch stem (rachis and branches) via a pedicel which contains vascular bundles. Therefore, the important quality characteristics composed of both bunch as well as berry properties. These include uniform bunch colour, bunch size, shape and weight, stem quality, berry colour, size and shape, firmness, total soluble solids (TSS), titratable acidity (TA), antioxidents (anthocyanins, phenols), flavour which determines by sugar acid blend and free from harmful chemical residues.

Salicylic acid (SA) or ortho-hydroxyl benzoic acid is an endogenous plant growth regulator of phenolic nature and classified as a growth promoter. It has been found to play a key role in the regulation of plant growth, development and enhance plant vigour under biotic and

abiotic stresses (Hayat *et al.* 2010). Recent research reports evidenced that SA can hasten maturity, enhance physicochemical properties and postharvest longevity of fruits (Marzouk and Kassem 2011, Ranjbaran et al. 2011). Therefore, the present study was conducted to investigate the effect of preharvest treatments of SA on physicochemical properties of table grapes cv. Flame Seedless.

MATERIALS AND METHODS

The experiment was performed on 12-year old own rooted grapevine (*Vitis vinifera* L.) cv. Flame Seedless planted at 3 m x 3 m spacing (440 plants acre^{-1}) trained on bower (overhead) system in the vineyard of the New Orchard, Department of Fruit Science, Punjab Agricultural University, Ludhiana, Punjab, India during 2012 and 2013 seasons. Twenty vines (5 vines per treatment) having a girth diameter of 7.22±1.02 cm which bear 60-80 canes (4 buds cane^{-1}) were chosen and uniform cultural practises were adopted each season as per the recommendations (Anon 2010), Aqueous solutions of SA (0.0 – control, 1.0, 1.5 and 2.0 mM - Sigma Aldrich Co., USA) were prepared by dissolving them in a small amount of ethanol and bringing to the final volume of 25 L with water. The surfactant Tween 20® at the rate of 0.1% was added to obtain better retention and penetration of sprayed chemicals. The prepared solutions were applied directly to the clusters of vines (5 L vine^{-1}) at pea stage (4-5 mm diameter berry size, two weeks after fruit set) and at veraision (approximately 10% of the berries of 50% of the clusters become soft and at colour break) by a sprayer machine until runoff in the morning on a sunny day. The corresponding control vines were treated in the same way excluding SA.

After harvesting cluster weight, length and breadth were measured from 10 randomly selected clusters from each vine (replicate). The observation on berry characters were recorded on the basis of 50 berries taken from 10 bunches (5 berries from each bunch *i.e.* two from shoulders, two from middle and one from tip). The 50 berries were first weighed to obtain mean berry weight and then placed in a trough so that their ends or equators are gently touched to measure mean berry length and diameter, respectively. Peel colour of berries was measured by using Hunter lab colour difference meter (ColorFlex® EZ, USA) as CIE L*, a*, b* values. Berry firmness was measured by a Texture Analyzer (TA+HDi® Stable Micro Systems, Godalming, Surrey, UK).

For analysis of chemical parameters, 50 berries from each replicate squeezed by a squeezer and the juice obtained filtered through a cheese cloth. Percent TSS content was measured by a temperature compensated digital refractometer (Atago PAL-1, model 3810, Japan). TA was determined as per AOAC (2000) and expressed as grams of tartaric acid equivalents per 100 ml of juice. Total anthocyanin content of berries was determined as described by Ranganna (1986) and total phenols were determined by Folin-Ciocalteu method, based on colourimetric oxidation/reduction reaction of phenols (Slinkard and Singleton 1977).

The experiment was performed according to randomized complete block design with five blocks. Data were analyzed for variance by using SAS (V 9.3, SAS Institute Inc., USA).

When interactions between treatments were significant ($P \leq 0.05$), the effect of each treatment was determined separating means by Least Significant Difference (LSD).

RESULTS AND DISCUSSION

Significant increase in cluster weight, length and breadth as well as berry weight, length and breadth were observed when vines were sprayed with 1.5 or 2 mM SA, compared to control and 1 mM SA (Table 1). Grapes treated with either 1.5 or 2.0 mM SA produced less compact bunches (higher cluster length and breadth) alongside larger berries compared to control and our results are in agreement with Marzouk and Kassem (2011).

Table 1. Physical properties of Flame Seedless clusters and berries as affected by various concentrations of SA

Concentration (mM)	Cluster			Berry		
	Weight (g)	Length (cm)	Breadth (cm)	Weight (g)	Length (cm)	Breadth (cm)
0.0	500.0^{d}	23.2^{c}	13.13^{b}	2.38^{c}	1.71^{b}	1.59^{c}
1.0	620.7^{b}	29.0^{b}	13.33^{b}	2.97^{b}	1.87^{a}	1.65^{b}
1.5	662.3^{a}	32.8^{a}	19.83^{a}	3.33^{a}	1.93^{a}	1.77^{a}
2.0	643.6^{c}	33.0^{a}	20.33^{a}	3.00^{b}	1.98^{a}	1.76^{a}
LSD ($P < 0.05$)	21.6	2.03	0.87	0.18	0.13	0.05

Means in a column with the same letter are not significantly different (at $P \leq 0.05$) according to LSD. Each value represent mean of 3 replicates (n=10 for cluster weight, length and breadth; n = 50 for berry weight, length and breadth).

Peel colour, firmness, TSS, TA, total anthocyanin (TAC) and total phenol content (TPC) of Flame Seedless grape berries treated with different concentrations of SA are given in the table 2. SA treatment decreased lightness of the berries, but this was significant only with the highest concentration of SA tested (2 mM). Highest berry firmness was shown by the clusters received 1.5 mM SA. Maintenance of higher fruit firmness when treated with SA has been reported in grapes (Marzouk and Kassem 2011, Ranjbaran *et al.* 2011), kiwifruit (Fattahi *et al.* 2010), strawberry (Shafiee *et al.* 2010) in Chinese jujube (Kaseem *et al.* 2011) and in peach (Tareen *et al.* 2012).

All SA treatments displayed a lower TSS content and TA compared to control at harvest (Table 2). Decreased TSS of fruits when treated with SA has been reported in strawberry (Lolaei *et al.* 2012) pineapple (Lu *et al.* 2010) and kiwi (Fattahi *et al.* 2010).

Anthocyanins and phenolic compounds are important constituents in human health and there is rising awareness among consumers about their functional properties. Table grapes are a good source of health promoting compounds and being a coloured variety, the *cv.* Flame Seedless is also rich in these important antioxidants. All three concentrations of SA significantly increased anthocyanin content on concentration dependent manner at harvest (Table 2). The results comply with Peppi et al. (2006) who reported that lightness (L*) has a highly significant inverse relationship with anthocyanins. As skin anthocyanins rises lightness decreases and the fruit appears darker. Preharvest treatment of SA significantly

affected TPC of berries compared to the control. SA treated berries had higher TPC at harvest. The results are in line with Sarikhani et al. (2010) who observed that postharvest treatment of SA induced much higher TPC than those of control. Similar results were reported by Jamali *et al.* (2013).

Table 2. Peel colour, firmness, TSS, TA, total anthocyanin (TAC) and total phenol contents (TPC) of Flame Seedless grape berries treated with different concentrations of SA

Concentration (mM)	Peel colour (L*)	Firmness (g force)	TSS (%)	TA (g/100 ml)	TAC (mg/100g FW)	TPC (mg GAE/100 g FW)
0.0	21.99^{ab}	103.2d	18.6a	0.75^{a}	27.9^{b}	52.90^{b}
1.0	22.85^{a}	123.3a	16.8c	0.67^{b}	26.8^{b}	65.77^{a}
1.5	20.95^{bc}	156.6a	17.3b	0.68^{b}	27.5^{b}	56.78^{b}
2.0	19.99^{c}	136.9a	17.5b	0.63^{b}	38.1^{a}	52.71^{b}
LSD ($P < 0.05$)	1.89	1.80	0.38	0.06	2.69	5.17

Means in a column with the same letter are not significantly different (at $P \leq 0.05$) according to LSD. Each value represent mean of 3 replicates (n=30 for peel colour; n = 10 for berry firmness).

CONCLUSIONS

Salicylic acid (SA) reduced cluster compactness, increased berry size and firmness of Flame Seedless grapes significantly. It also enhanced anthocyanins of the berry while, decreasing berry lightness (L*). Therefore, use of 1.5 mM of SA twice *i.e.* at 2 weeks after fruit set (pea stage) and at veraison, does improve the physicochemical qualities of Flame Seedless grapes.

REFERENCES

Anonymous (2010) Package of practices for cultivation of fruits. Punjab Agricultural University, Ludhiana, Punjab, India. pp. 63-74.

AOAC (2000) Official Method of Analysis of AOAC International (Vol. II). Suite 500 481, North Frederick Avenue, Gaithersburg, Maryland 20877-2417. USA.

Fattahi J, Fifall R and Babri M (2010). Postharvest quality of kiwifruit (*Actinidia deliciosa* cv. Hayward) affected by prestorage application of salicylic acid. South west J Hortic Biol Environ. 1(2)175-186.

Hayat Q, Hayat S, Irfan M and Ahmad A (2010) Effect of exogenous Salicylic acid under changing environment: A review. *Environ Exp Bot* **68**:14-25.

Jamali B, Eshghi S and Taffazoli E (2013) Vegetative growth, yield, fruit quality and fruit and leaf composition of strawberry cv. 'Pajaro' as influenced by salicylic acid and nickel sprays, J Plant Nutr, **36**:1043-55.

Kaseem H A, Al-Obeed R S, Ahmed M A and Omar A K H (2011) Productivity, fruit quality and profitability of jujube trees improvement by preharvest application of agrochemicals. *Middle-East J Sc Res.* **9**:628-37.

Lolaei A, Kaviani B, Ali Rezaei M, Khorrami Raad M and Mohammadipour R (2012) Effect of Pre- and Postharvest Treatment of Salicylic Acid on Ripening of Fruit and

Overall Quality of Strawberry (*Fragaria ananasa* Duch cv. Camarosa) Fruit. *Ann Biol Res* **3**:4680-84.

Lu X, Sun D, Li Y, Shi W and Sun G (2011) Pre- and post-harvest salicylic acid treatments alleviate internal browning and maintain quality of winter pineapple fruit. *Sci Hortic* **130**:97–101.

Marzouk HA and Kassem HA (2011) Improving yield, quality and shelf life of Thompson Seedless grapevine by preharvest foliar applications. Sci Hortic 130: 425-430.

Peppi M C, Fidelibus M W and Dokoozlian N (2006) Abscisic acid application timing and concentration affect firmness, pigmentation and colour of Flame Seedless grapes. *Hortscience.* **41**:1440-45.

Ranganna S (1986) Anthocyanin. In: Handbook of analysis and quality control of fruit and vegetable products. Tata McGrow Hill Publishing Co.Ltd, 7 west Patel Nagar, New Delhi 110 008. pp 94-99.

Ranjbaran E, Sarikhani H, Bakshi D and Pouya EM (2011) Investigation of salicylic acid application to reduce postharvest losses in stored Bidaneh Ghermez table grapes. Int J Fruit Sci, 11: 430–439.

Sarikhani H, Sasani-Homa R and Bakshi D (2010) Effect of salicylic acid and SO_2 generator pad on storage life and phenolic contents of grape (Vitis vinifera L. Bidaneh Sefid and Bidaneh Ghermez). *Acta Hort* **877**:1623-30.

Shafiee M, Taghave TS and Babalar M (2010) Application of SA to nutrient solution combined with postharvest treatments (hot water, SA and Ca dipping) improved postharvest fruit quality of strawberry. Sci Hortic. 124: 40-45.

Slinkard K and Singleton V L (1977) Total phenol analysis: automation and comparison with manual methods. Am J Enol Viticult 28(1): 49-53.

Tareen MJ, Abbasi NA and Hafiz IA (2012) Postharvest application of salicylic acid enhanced antioxidant enzyme activity and maintained quality of peach cv. 'Flordaking' fruit during storage. Sci Hortic 142: 221-228.

Effect of sodium bicarbonate and ammonium bicarbonate on anthracnose fruit rot of tomato caused by *Colletotrichum cocodes*

RMRNK Rathnayake*, WMCB Wasala, CAK Dissanayake, CR Gunawardhane, UG Chandrajith and BMKS Thilakarathne
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka
*Corresponding author : rratnayake@hotmail.com

ABSTRACT

The effect of two Generally Recommended As Safe (GRAS) compounds, namely, sodium bicarbonate and ammonium bicarbonate in different concentrations were evaluated on conidial germination and mycelial growth of *Colletotrichum cocodes,* a major postharvest pathogen on tomato fruits.Disease development was observed on tomato fruits, surface inoculated or un-inoculated with the pathogen before or after the treatment withsodium bicarbonate in 40 g l^{-1}concentration.Un-treated, un-inoculated fruits were used as controls. Physico- chemical parameters and organoleptic properties of sodium bicarbonate treated fruits were compared with commercially available non treated fruits.Sodium bicarbonate either completely inhibited or significantly reduced the *in vitro* mycelial growth and conidial germination of the pathogen, whereas, inhibitory effect of ammonium bicarbonatewas not significant.Fruits that were first inoculated and then treated with 40 g l^{-1}sodium bicarbonate, or the reverse, gave 64.6% and 98.1% disease reduction, respectively. Non-treated control fruits were diseased completely after4 daysand fruits treated with sodium bicarbonate without inoculation (naturally infected fruits)were free from the disease up to 14 days at 27 ± 2°C and 65–70% RH. Physico-chemical parameters and sensory attributes were not significantly different.

Keywords: Ammonium bicarbonate, *Colletotrichum cocodes,* sodium bicarbonate

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.; family Solanaceae.), is a nutrient rich vegetable crop which has a high consumer demand worldwide.It is rich in Lycopene, a powerful antioxidant and also an excellent source of vitamin A and C. However, postharvest diseases, especially anthracnose caused by *Colletotrichum cocodes* greatly limit its economic value emphasizing the need for effective control measures.

Application of commercial fungicides may play a vital role in controlling such diseases. However, drawbacks associated with application of fungicides emphasize the need to find effective and eco-friendly disease control methods for postharvest industry.Today, a greater awareness is being focused on chemicals that are 'Generally Recommended As Safe'

(GRAS) to control post harvest diseases, throughout the world since they are inexpensive, easily accepted by consumers, nontoxic, with minor environmental impact at the effective concentrations , and usually used in the food industry (Nigro et al, 2006).

Several GRAS compounds have been identified as active antimicrobial agents against a range of phytopathogenic fungi. In particular, postharvest treatments with bicarbonate salts have been proposed as safe and effective alternative means to control postharvest rots of many fruits and vegetables including melon, papaya , citrus, banana and bell pepper.Bicarbonates are common food additives for leavening, pH-control, taste, texture modification, and spoilage control. In 1997, the US Environmental Protection Agency declared that bicarbonates were exempt from residue tolerances on all agricultural commodities, and many bicarbonates were classified as approved ingredients on products labeled "organic(Smilanick et al, 1998). In this context, this study was conducted with the objective of determining an effective method of controlling the disease using GRAS chemicals that are freely available and recommended as safe for usage and also determining effective storage methods to extend the postharvest life of tomatoes.

MATERIALS AND METHODS

The pathogen *Colletotrichum cocodes* was isolated from infected tomato fruits (*Lycopersicon esculentum* L.) and pure cultures were maintained on Potato Dextrose Agar (PDA).The effect of Sodium bicarbonate (SBC), and ammonium bicarbonate (ABC)in fivedifferent concentrations, 10, 20, 30, 40 and 50 gl^{-1} was evaluated on the radial mycelial growth and spore germination of *Colletotrichum cocodes*. Efficacy of the GRAS compounds to control the pathogen *in vitro* was expressed as percentage growth inhibition (Vincent, 1947) and inhibition of conidial germination respectively. The most effective compound was selected and its efficacy was evaluated on healthy, ripe tomato fruits in uniform size (125±25 g) after surface disinfection with 90% ethanol. Three treatments were used; 1). Middle of the fruit surface, 3 cm below the stem scar were inoculated with 10µL of a conidial suspension (10^4 conidia/ml), allowed to incubate for 24 h at 27 ± 2 °C and treated (10µL were added to the pathogen inoculated spot) with Sodium bicarbonate at the concentration of 40 gl^{-1}, 2). Fruits were treated with SBC and then inoculated with the pathogen as above, 3). Fruits treated with SBC without inoculation. Un-treated, un-inoculated fruits and fruits treated with distilled water with and without inoculation were used as controls. Then they were placed on plastic basins at over 80% RH and 27±2°C and the disease development was recorded at 2 day intervals. Physico- chemical parameters and organoleptic properties of sodium bicarbonate treated fruits were compared with commercially available,un- treated,healthy, ripe fruitsfor 14 days.During the storage, sensory analysis was done using five point hedonic scalewith 30 untrained panelists. The experimental structure of all the experiments was complete randomized design and data

gathered were analyzed using Analysis of Variance (ANOVA) by Statistical Analysis System. Percentage data were transformed to arc sinvalues prior to analysis. Differences between treatment means were obtained by Duncan's multiple range test at 5% significance level ($p<0.05$) and the subjective measurements were analyzed by Friedman test using the MINITAB statistical package.

RESULTS AND DISCUSSION

Effect of bicarbonates on radial mycelial growth of *Colletotrichum cocodes:* Colony diameter *Colletotrichum cocodes* on control plates (PDA without GRAS compounds) at 27±2 °C exceeded 7 cm within seven days whereas both GRAS compounds reduce the growth of the pathogen compared to the control. Effect of sodium bicarbonate on mycelia growth was highly significant ($p<0.001$) and a complete growth inhibition was obtained at the concentration of 40 g/L. The increasing concentration of ammonium bicarbonate caused a marked reduction of the fungal growth however it was less significant to sodium bicarbonate.(Table 1).

Table 1. Effect of bicarbonates on radial mycelia growth of *Colletotrichum cocodes*

GRAS compound	Inhibition of mycelia growth * Concentration of GRAS compounds (g/L)				
	10	20	30	40	50
Ammonium bicarbonate	14.56 [b]	21.32 [b]	25.46 [b]	32.32 [b]	33.50 [b]
Sodium bicarbonate	19.20 [a]	42.36 [a]	84.52 [a]	100.0 [a]	100.0 [a]
Control	0.0 [c]	0.0 [c]	0.0 [c]	0.0 [c]	0.0 [c]

* Data based on observation on the seventh day after inoculation, any two means in the same column followed by different letters differ significantly according to Duncan's multiple range test ($P<0.05$).

Effect of bicarbonates on inhibition of conidial germination of *Colletotrichum cocodes:* The spore germination test indicated that Sodium bicarbonate completely inhibited the germination of *Colletotrichum cocodes* conidia at 40 g/L level. However, effect of ammonium bicarbonate was not significant. Results obtained from the above experiments revealed that the efficacy of SBC on both the radial mycelia growth and inhibition of spore germination was higher than ammonium bicarbonate thus, SBC was selected for the next experiments.

Effect of sodium bicarbonate to control the pathogen on tomato fruits: Un-treated, un-inoculated fruits were diseased after four days of incubation where distilled water treated fruits diseased within three days. Fruits treated with SBC without inoculations were free of disease up to 14 days. The inhibition of anthracnose development in fruits treated with SBC followed by inoculation (84.2.1%) was highly significant ($p<0.0001$) to the inoculation

followed by SBC treatment (64.6%). However all the fruits got diseased after fourteen days (Table 1).

Quality evaluation of sodium bicarbonate treated fruits

Total soluble solids (TSS), titratable acidity (TA) and pH: Total soluble solids and pH of SBC treated fruits increased veryslowly during the storage period while titratable acidity decreased with the corresponding increase of pH . However at 11 days of storage there was no significant difference between the SBC treated and control fruits (Table 2).

Sensory evaluation: According to the sensory evaluation (Table 2) , no off-flavors or odors were detected in the SBC treated fruit up to 14 days as compared to the fresh fruits (P=0.564) at the ambient condition (27 $\pm 2\ ^0$C) .

Table 2 Changes of total soluble solids (TSS), Titratable acidity (TA) andpH of sodium bicarbonate treated tomato fruits after a storage period of 14 days of at 27 $\pm 2\ ^0$C

Treatment	Physicochemical analysis			Sensory evaluation (estimated median value for sensory attributes)			
	TSS (°Brix)	TA (% citric acid)	pH	Colour	Odour	Taste	Overall acceptability
SBC treated	4.80	0.42	4.48	4.5	4.5	4.5	4.5
Control	4.78	0.44	4.50	5.0	4.5	4.5	4.5
P (α=0.05)	0.3695	0.2308	0.8182	0.317	1.0	0.248	0.564

This study reveals the efficacy of sodium bicarbonate to control can inhibit the growth of *Colletotrichum cocodes* in vitro and reduce disease development of the pathogen on tomato fruits. Further, results have shown that the preventive effect (treatment followed by inoculation) of SBC is more pronounced than the curative (inoculation followed by the treatment) effect. The principal mode of action of the bicarbonate ion is through its buffering capacity, where by an alkaline environment is sustained (Mills *et al.* 2004). This may explain why sodium bicarbonate as a disease control agent is possibly more effective as a preventive than a curative treatment. Scientists believe that p^H to be a factor in bicarbonate effectiveness and it seems to damage cell wall membrane in fungal spores. Furthermore, Smilanick et al, (1998) suggest that sodium may apparently have some role in the control of the disease because the sodium salts were superior to the ammonium and potassium bicarbonate solutions. The superior performance of the sodium salts was not anticipated. In this study TSS, TA and pH of the treated fruits did not differ significantly from control and sensory panel did not observe any difference in organoleptic properties thus the findings

emphasize the potential of SBC as a control agent of anthracnose fruit rot caused by *Colletotrichum cocodes.*

CONCLUSION

Hence, from the results of the study, it can be concluded that 40 g/l sodium bicarbonate inhibit in vitro mycilial growth, spore germination and also it can be used to control *Anthracnose* fruit rot on tomato caused by *Colletotrichum cocodes..*

REFERENCES

Aharoni Y, Fallik E, Copel A, Gil M and Grinberg S (1997). Sodium bicarbonate reduces postharvest decay development on melons. *Postharvest Biology & Technology*, 10, 201-206.

Mills AAS, Platt HW, Hurta RAR (2004). Effect of salt compounds on mycelial growth, sporulation and spore germination of various potato pathogens. *Postharvest Biology and Technology*34, 341-350.

Nigro F, Schena L, Ligorio A, Pentimone I, Ippolito A, Salerno MG (2006). Control of table grape storage rots by pre-harvest application of salts. *Postharvest Biology and Technology,* 42, 142-149.

Smilanick JL, Margosan DA, Mlicota F, Usall J and Michael IF(1999). Control of Citrus Green Mold by Carbonate and Bicarbonate Saltsand the Influence of Commercial Postharvest Practices on Their Efficacy.*Plant Disease*83, 139-145.

Vincent JM (1947). Distortion of fungal hyphae in the presence of certain inhibitors. *Nature* (Lond.). 159.

Food Process Engineering

The role of pre-gelatinization on quality improvement of rice flour

DMSP Bandara*, CR Gunawardane, TMR Dissanayake, BMKS Thilakaratne and HMAP Rathnayake.
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka
*Corresponding author: srimapriyangika@yahoo.com

ABSTRACT

Pre-gelatinized rice flour has been widely used for many foods. Popular rice oriental foods, such as baby foods and instant rice milk, are also made from pre-gelatinized rice flour. In Sri Lanka, pre-gelatinized properties has not been previously evaluated. Therefore, the aim of this study was to develop a process for producing pre-gelatinized rice flour and observe their physicochemical properties.

The popular Sri Lankan paddy variety BG 94/1 was selected for the study. Paddy was treated varying soaking time, steaming temperature and steaming time called hydrothermal treatment. Lab scale apparatus, soaking bins, water bath, and oven were used for preparation of pre-gelatinized paddy. Steamed paddy was immediately dried in an oven up to the moisture content of 12%. Then paddy samples were de- husked using lab scale rubber roll sheller and whitened with the polisher to the bran removal percentage of 60%. For making into flour, disk mill was used. The degree of gelatinization (SG) of starch was measured by using Barbender method. Treatment which was prepared paddy under rinsed and steaming 20 minutes time at 80^0C was given the satisfactory change in visco-Amylograph. It is predicted that hydrothermal treatments could be affected to the change of physicochemical properties of rice flour. This study proved that pasting and nutritional values are markedly dependent on hydrothermally treatments.

Keywords: Pre-gelatinization, rice flour

INTRODUCTION

In recent years, rice flour has been increasingly used for production of novel foods like noodles, gluten free bread, cakes, soup cubes, rice ice cream and crackers, because of its unique functional properties such as being hypoallergenic, colorless, and bland. As rice is staple food and main crop, adopting rice based foods among the public is not difficult task in Sri Lanka. Therefore, Institute of Post harvest Technology has conducted preliminary tests to evaluate the different types of rice flour milling machinery for their performance for producing quality rice flour in a previous study. In that study, different machinery combination for producing different quality rice flour has been identified and of some of the combinations could be recommended for specific food items.

However, clients are constantly questioning on rice flour based products that are found to become hard, and they decline in texture and taste overtime. It is exactly found to be a

phenomenon generally called "retrogradation" that can be improved by modification (Juliano 1985). Pre-gelatinized rice flour has been widely used for many foods as major ingredients (His Mei Lai 2000). Plenty of studies on pre-gelatinized properties of rice flour have been conducted by many foreign universities and institution on their rice verities. They have proved that many property improvements could be obtained using pre-gelatinization. Some studies were also revealed that gluten can be substituted by gelatinized rice.

Even though, other countries have been experimented for this, no previous work has been done to evaluate the physicochemical properties of pre-gelatinization and no previous data on applications of pre-gelatinization flour using local rice varieties in Sri Lanka. In this study, the different hydrothermal treatments of varying soaking time, at different temperatures of steaming and time durations of steaming were carried out. It is hoped, that the results may give a deeper insight into evaluation of physico-chemical properties in Sri Lankan long grain rice (BG 94/1) variety under process of pre-gelatinization and milling. The degree of gelatinization (SG) of starch was measured by using Barbender method. A plot of paste vis-cosity in arbitrary BU units versus time was used to determine peak visc-osity (PV), temperature at PV (Ptemp), final viscosity (FV), breakdown viscosity (BKD), and total setback viscosity (TSB).

MATERIALS AND METHODS

The necessary steps for treatments were identified. According to pretreatment steps, the main equipment was identified as steaming unit. Here, low temperature steam must be used. It is expected that the temperature of steam should be below the boiling point. A water bath with temperature controller was used. The capacity of 2 kg per batch steaming container was used. According to the Steam table the pressure was maintain to get relevant temperature. Secondly, it was necessary to use the dryer with 40 °C and 70% RH cabin. Lab scale oven was used without a fan. Then the soaked paddy was milled and polished to obtain polished rice. To perform this, lab scale SATAKE rubber roll Sheller and polisher was used. Under this, there are different types of mills were identified as flour grinders, from that the best grinding mill was selected as the disk mill in the previous studies.The popular Sri Lankan paddy varieties, BG 94/1 was selected for this study.

RESULTS AND DISCUSSION

The moisture content of rinsed paddy was 23.8± 0.5% for every sample. The soaked paddy was saturated after different soaking time and there were no significant differences in the moisture contents within the same variety, which were soaked either for 1 or 4 h. Therefore, all the analysis was done just rinse off and undergone for heat-moisture treatment.

Table 1. Treatment combinations

Treatment	Steaming Temperature (°C)	Steaming time (min)
T1	70	20
T2	70	40
T3	70	60
T4	80	20
T5	80	40
T6	80	60
T7	90	20
T8	90	40
T9	90	60
T10	Raw rice	-

First three samples were undergone for 70 °C low temperature steaming and those were only deviated from steaming time that is predicted in the Figure 1. While, the treated samples could lower the PV, except Treatment 1, other two treated samples keeps the BKD constant and FV goes down in every treated sample than raw rice.

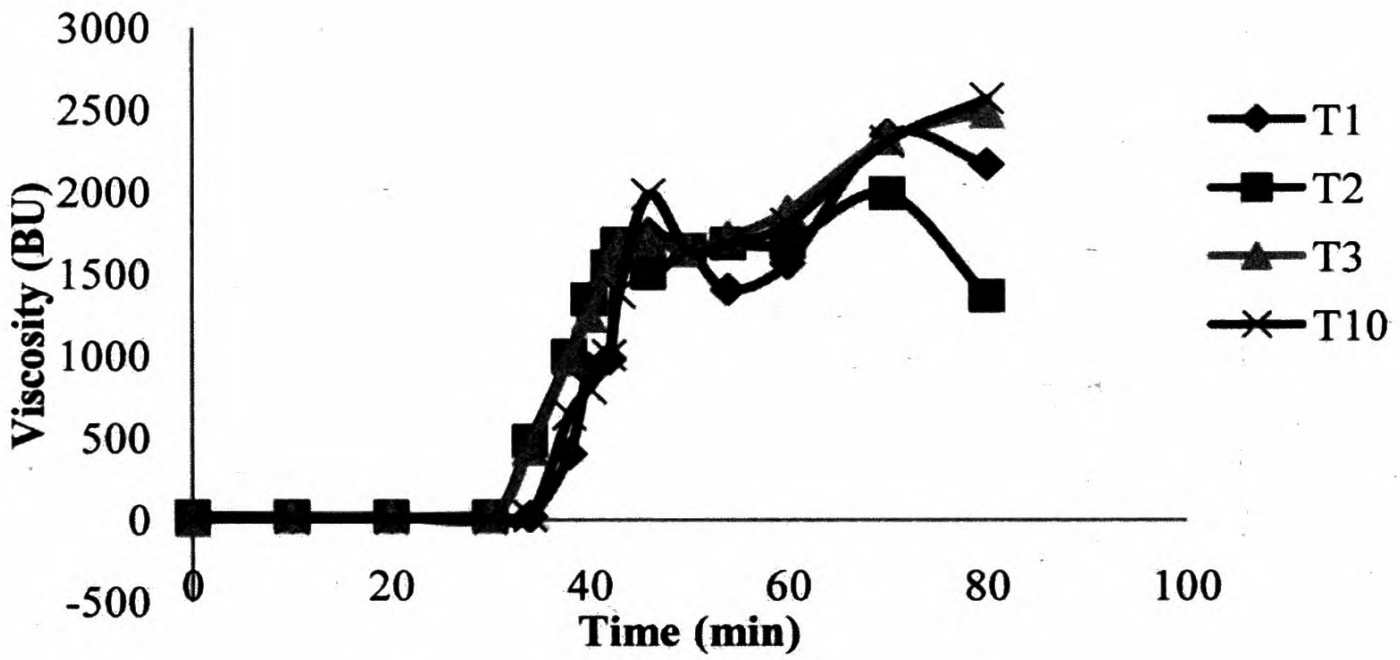


Fig. 1. Visco-graph of hydrothermally treated paddy prepared at 70 °C steaming temperature under different steaming time. Raw rice was also analyzed for comparison.

At the second set of treatments from T4 to T6, the steaming temperature was 80 °C and varied the steaming time from 20 to 60 min. The Figure 2 shows the significant impact from heat-moisture treatment, only treatment 4 shows significant stability in the amylo-graph. Treatment 4 (T4 lowered the PV, increase the BKV while decreasing the FV.

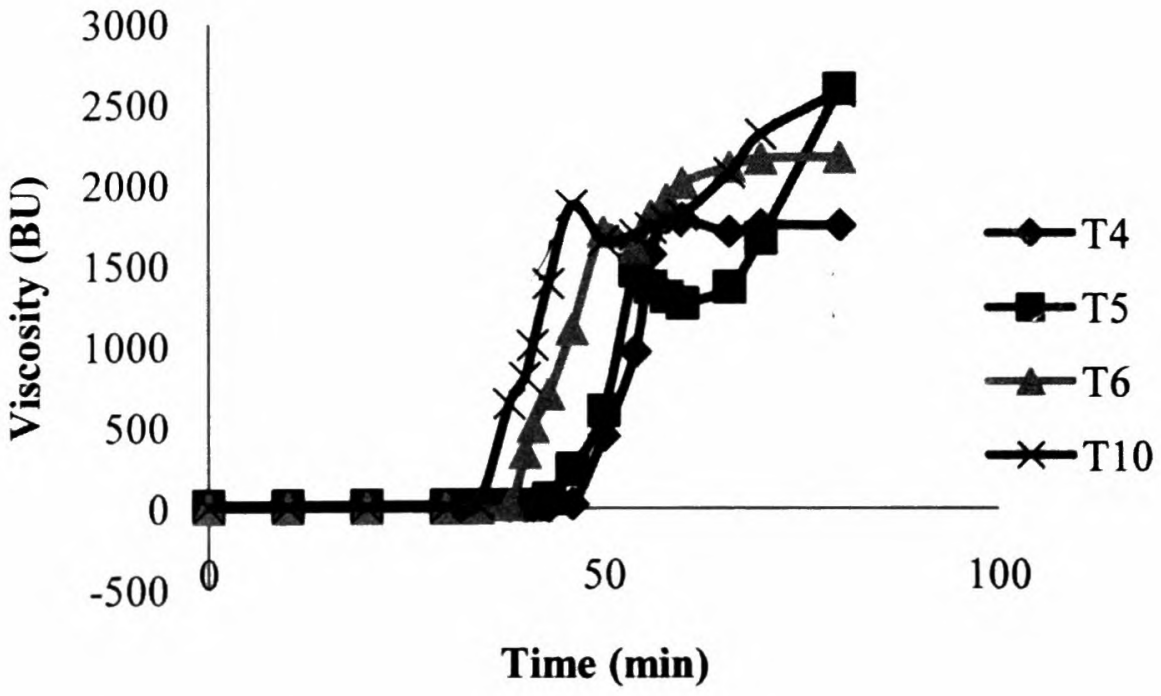


Fig.2. Visco-graph of hydrothermally treated paddy prepared at 80 °C steaming temperature under different steaming time. Raw rice was also analyzed for comparison.

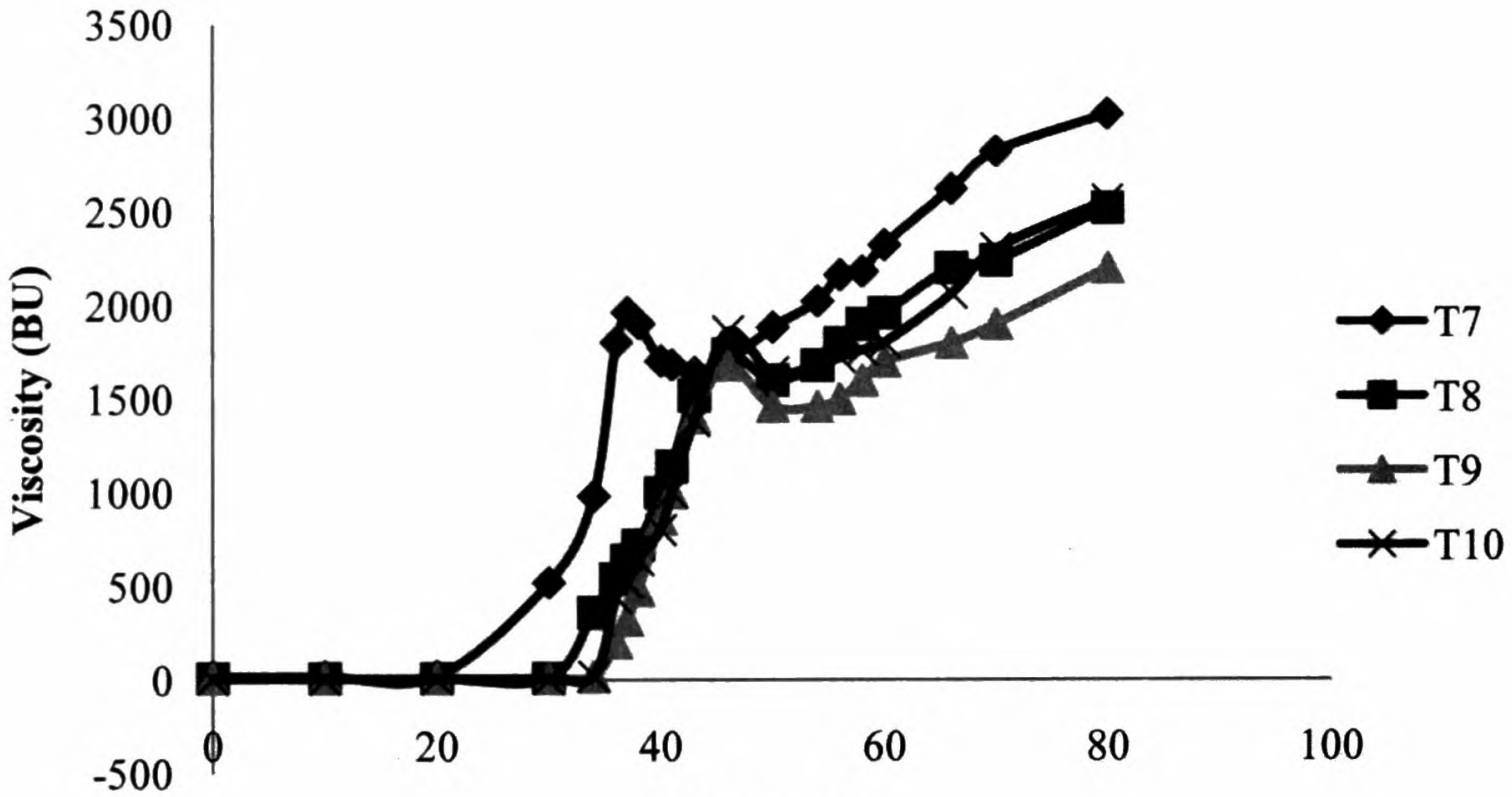


Fig. 3. Visco-graph of hydrothermally treated paddy prepared at 90 °C steaming temperature under different steaming time. Raw rice was also analyzed for comparison.

In the third set of treatments, the temperature of steam was increased and the steaming duration was differentiated in each samples. Figure 3 shows that PV increases (T7) while others are not under significant change rather compared to the raw sample. After the cooling effect the viscosity was continuously increased without stabling.

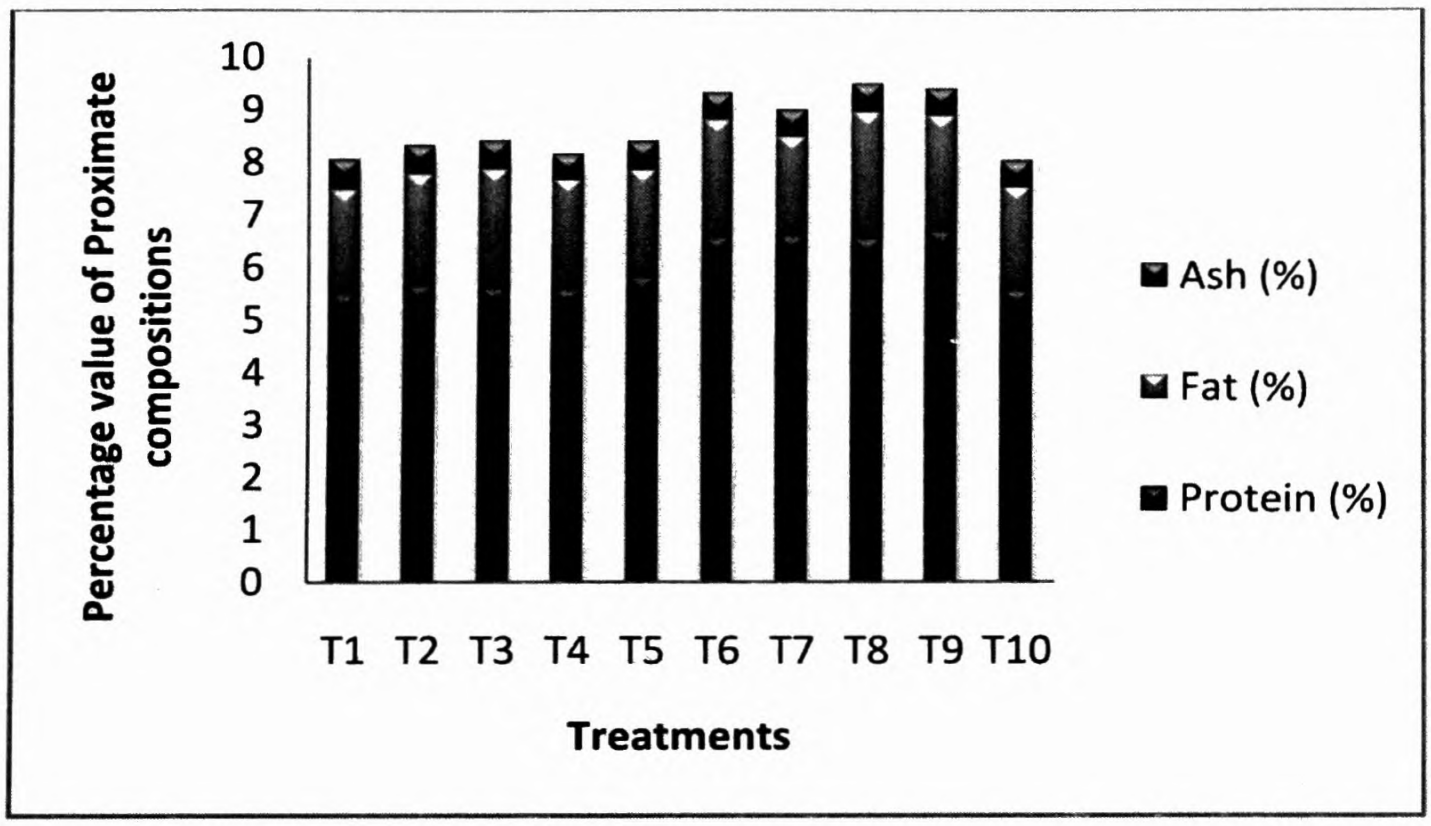


Fig.4. Proximate composition of treated rice flour

The proximate compositions of flour samples are shown in Figure 4. It shows that there is no significant difference in ash but in protein and fat content has change in relevance to the heat treatments. The protein content is high in T6, T7, T8 and T9 compared to the raw rice an;d other treatments.

CONCLUSION

A popular Sri Lankan paddy variety, BG 94/1 was subjected to different heat treatments. The study proved that pasting and nutritional values are markedly dependent on hydrothermal treatments. The treatment which was prepared paddy under rinsed and steaming at 80 °C for 20 min gave the satisfactory change in visco-amylograph. It is predicted that hydrothermal treatments could be affected to the change of physicochemical properties of rice flour.

REFERANCES

Hsi-Mei Lai and Hsiao-Hsien Cheng (2004). Properties of pregelatinized rice flour made by hot air or gum puffing, International Journal of Food Science and Technology 39:201–212.

Hsi-Mei Lai (2001). Effects of hydrothermal treatment on the physicochemical properties of pregelatinized rice flour, Food Chemistry 72:455-463.

Juliano BO (1985). Rice chemistry and technology, 2nd ed. The American Association of Cereal Chemist Inc.,USA. 60:539-553.

Kuprits YaN (1965). Technology of grain processing and provender milling, 1st ed. Israel programme for scientific translation, Jerusalem. p199.

Prediction of suitable isotherm model to treat paddy soaking wastewater using paddy husk charcoal

SMWTPK Ariyarathna* and R Shanthini
Department of Chemical & Process Engineering, Faculty of Engineering, University of Peradeniya, Peradeniya, Sri Lanka
*Corresponding author:thusharia@pdn.ac.lk

ABSTRACT

In the design of an adsorption system for the adsorption of Chemical Oxygen Demand (COD) in Paddy soaking Wastewater (PSW) with Paddy Husk Charcoal (PHC), it is important to establish the most appropriate correlation for the equilibrium system. Various isotherm equations have been used to describe the equilibrium nature of adsorption. Under this study, four different non-linear isotherms with two parameters, namely langmuir, fruendlich, tempkin and dubbinin radushkevich were considered at room temperature. Suitability of linear and non linear relationships was compared with the experimental data collected. Due to the inherent bias resulting from linearization, non-linear isotherm parameter sets were determined by non linear regression. Non –linear optimization provides a more complex and mathematically rigorous method for determining isotherm parameters. So, four non-linear error functions; sum of squares errors (SSE), average relative error (ARE), absolute error (EABS) and Marquard's percent standard deviation (MPSD) were examined. The applicability of these isotherm models were compared by judging the minimum normalized error of each function. It confirmed that both the Langmuir and Fruendlich isotherm models fits the system equilibrium well and least normalized error values of SSE function determined the Langmuir model as the best.

Keywords: Adsorption, equilibrium, isotherms, optimization

INTRODUCTION

PSW is a liquid waste generates only in parboiled rice processing industry. Though it is not identified as a toxic waste, it has high Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), COD and low pH (Ariyarathna *et al.* 2004). PHC is available at the same venue where PSW is generated and it was found as a good adsorbent in wastewater treatment (Sethi Beena and Sharma 2012, Pushpa Jha 2011). So, this work is to study the adsorption treatment process governing in reducing of COD in PSW with PHC.

In order to determine the adsorption capacity of COD into PHC and to find out the performance of the system, the equilibrium relationship between the liquid and the solid

phase is to be considered. The literature revealed that there are so many equilibrium relations (isotherms) for any selected system (Kumar and Sivanasan 2005, Kumar *et al.* 2007, Foo and Hameed 2009). Two parameter models: Langmuir, Fruendlich, Temkin and Dubinin- Radushkevich were considered out of the several correlations found in the literature review. It was found that the method of linear regression was the most frequently used method for determining the best fitted isotherm. Nevertheless, it was showed that depending on the way of linearization of the equilibrium equation, the error distribution changes the size of the error. There is a probability to have better fit or a worse fit. So, linear and non-linear regression methods were applied and the most related isotherm was established for the system by considering the correlation coefficient (R^2) for each model.

The study revealed that the non – linear regression method is the most sutable way to predict the best fit model. The Langmuir isotherm was established as the best model for the system by using four non-linear error functions; SSE, ARE, EABS and MPSD.

MATERIALS AND METHODS

The study was conducted with industrial wastewater samples. A particular rice mill was selected in Kalawewa situated in Mahaweli H Zone, Sri Lanka. The wastewater discharge in the paddy soaking ponds in the mill was used and COD and BOD_5 of PSW were measured by the test procedure given by Eaten *et al.* 1995.

PHC used in this experiment was also industrial sample and randomly collected from a paddy husk boiler in the same mill mentioned above. Moisture content, ash content and CTC activity of PHC were measured using standard test procedures following in ASTM D 2867, ASTM D 2868 and ASTM D 3467 respectively.

Equilibrium experiments were carried out by contacting 250 ml of wastewater of eight different initial COD concentrations with 20 gram of PHC at atmospheric temperature. All the test samples were shaken by a mechanical shaker to maintain proper mixing and the adsorption studies were continued until equilibrium was reached. The amount of COD adsorbed into the solid phase at equilibrium (q_e) was calculated by:

$$q_e = (C_o - C_e)\frac{V}{W}$$

Where, Co and Ce are the initial and equilibrium liquid phase concentration of COD, respectively. Volume of the solution is V and W is the weight of the PHC used. The experiment was repeated and average values were considered for final calculations.
As shown in Table 1, Langmuir, Fruendlich, Temkin and Dubinin- Radushkevich were compared for the prediction of best fitted isotherm.

Table 1. Isotherms and their linear forms

Isotherm	Non-linear equation	Linear equation
Fruendlich	$q_e = k_f c_e^n$	$\log(q_e) = \log(k_F) + \frac{1}{n}\log(c_e)$
Langmuir -1	$q_e = \frac{q_m k_{L1} c_e}{1 + k_{L1} c_e}$	$\frac{c_e}{q_e} = \frac{1}{q_m} c_e + \frac{1}{k_{L1} q_m}$
Langmuir -2		$\frac{1}{q_e} = \left(\frac{1}{k_{L2} q_m}\right)\frac{1}{c_e} + \frac{1}{q_m}$
Langmuir -3		$q_e = q_m - \left(\frac{1}{k_{L3}}\right)\frac{q_e}{c_e}$
Temkin	$q_e = \frac{RT}{b}\ln A c_e$	$q_e = \left(\frac{RT}{b}\right)\ln A + \left(\frac{RT}{b}\right)\ln c_e$
Dubinin-Radushkevich	$q_e = Q_m \exp(-k_D \varepsilon^2)$	$\ln q_e = \ln Q_m - k_D \varepsilon^2$
	$\varepsilon = RT \ln(1 + c_e^{-1})$	

Four non-linear error functions; SSE, ARE, EABS, MPSD shown below were used and in each case the isotherm parameters were determined by minimizing the respective error function. The parameters of non-linear relationships were calculated using the *Solver* add-in with Microsoft's spreadsheet Excel. The applicability of these isotherm models were compared by judging the minimum normalized error of each functions.

$$\text{SSE} = \sum_{i=1}^{n} \left(q_{e,calc} - q_{e,meas}\right)_i^2$$

$$\text{ARE} = \frac{100}{n}\sum_{i=1}^{n}\left|\frac{q_{e,meas} - q_{e,calc}}{q_{e,meas}}\right|_i$$

$$\text{EABS} = \sum_{i=1}^{n} ABS\left(q_{e,meas} - q_{e,calc}\right)$$

$$\text{MPSD}) = 100\sqrt{\frac{1}{n-p}\sum_{i=1}^{n}\left(\frac{q_{e,meas} - q_{e,calc}}{q_{e,meas}}\right)_i^2}$$ (Demirbas et al., 2007)

Where, $qe._{meas}$ and $qe._{calc}$ are experimentally measured and model calculated qe values respectively. Number of data points is n and the p is number of parameters in the system.

RESULTS AND DISCUSSION

According to Table 1, Langmuir isotherm can be transformed into three different linear forms. Calculated R^2 values are 0.88, 0.79 and 0.43 for Langmuir-1, Langmuir-2 and Lanmuir-3 respectively. By looking at the R^2 values, it can be determined that the way of linearization affects the error distribution of the models. So, the way of transformation can gain the best or the worse plot of the isotherm. Therefore it was determined that non-linear regression is more suitable in predicting a best isotherm model for the system.

Then, all the four non-linear models were compared with the use of four different non-linear error functions mentioned above. Table 2 shows the model parameters obtained for each error function with R^2 values. As shown in table, R^2 values for various isotherm models used for the system shows that these values are closed to unity for all the models. Therefore it was able to determine that all the models are fit quite well to the system. According to the R^2 values shown below, Langmuir and Fruendlich models were identified as the best out of the four models.

Table 2. Comparison of Error functions for non-linear isotherm models

Isotherm model	SSE	ARE	EABS	MPSD	R^2
Fruendlich					
k_f/((mg/g)(L/g)^1/n_f	0.6549	0.4816	0.6534	0.2477	
1/n_f	0.5728	0.6015	0.5660	0.6909	0.99
normalized error	3.1958	3.4029	3.6392	3.2487	
Langmuir					
q_o/(g/g solid)	147.3843	134.1035	129.1582	88.0871	
k_L/(g/L)	3448.5247	2498.8243	2499.5688	1293.7932	0.99
R_L	0.7835	0.8332	0.8331	0.9061	
normalized error	1.7707	3.6644	2.3393	3.7156	
Tempkin					
β/(mg/g)	16.2150	16.2150	16.2150	16.2150	
A/(L/g)	0.0220	0.0310	0.0310	0.0310	0.93
b	155.3585	155.3586	155.3586	155.3586	
normalized error	2.4191	3.6262	3.6262	2.6520	
Dubbinin Radushhkevich					
K/(mol^2/kJ^2)	0.3105	0.3037	0.3037	0.3034	0.98
Q_m/(mg/g)	95.6598	95.6598	95.6598	95.0364	
normalized error	3.9973	3.9886	3.9849	4.0000	

Fruendlich constants, k_f and $1/n_f$ indicate the adsorption capacity and adsorption intensity respectively. Higher the value of $1/n_f$, means the higher the attraction between the adsorbate and the adsorbent and the heterogeneity of adsorption sites. And also, the value of $1/n_f$ indicates the relative distribution of energy sites. In this study, $1/n_f$ is 0.57 and it refers to the fact that 57% of the active adsorption sites have equal energy level on the adsorbent (Kumar *et al.* 2007). Since, $1/n_f$ value is less than one it reflects that the COD adsorption is favourable into PHC (Rivas *et al.* 2005).

When, normalized error values were considered, SSE function value was observed as the least value representing function. So, out of the four, Langmuir isotherm gives the least values for the error function selected in this study. This means the theoretical and experimental results matches with the non linear Langmuir model and this was selected as the best fit model for the system. So, the essential characteristic of the Langmuir isotherm is dimensionless constant separation factor or equilibrium parameter, R_L and it was found out following the relation (Weber and Chakravoti 1974):

$$R_L = \frac{1}{1 + \frac{C_o}{K_L}}$$

The value of the R_L indicates the shape of the isotherm to be either unfavourable ($R_L > 1$), linear ($R_L=1$), favourable ($0<R_L<1$) or irreversible ($R_L=0$) (Hadi et al., 2011). As shown in table above, R_L value lies between one and zero and therefore, it was determined that the adsorption is favourable (Foo and Hameed 2010). Since the Langmuir model explains the system well, it reveals the monolayer adsorption of COD into PHC. And also, q_o is the monolayer saturation at equilibrium and it was calculated as 147.38 g/g solid.

CONCLUSIONS

With the above observations, it was concluded that it is not appropriate to use the linear correlations in determining the isotherm parameters. This is mainly because transforming a non-linear model to a linearized function, it alters the error distribution and deforms the parameters of the models. Therefore non-linear method is the better way to fit the best isotherms for a selected system. When using linear method, size of the error function is also not a deciding factor to select optimum isotherm. But, in non-linear method it can be used to determine the optimum.

Finally the Langmuir isotherm model was selected as the best model for the adsorption of COD constituents in PSW to PHC. And also, it was determined that the adsorption treatment can be applied for the treatment of the PSW and there is a mono layer adsorption with the system.

REFERENCES

Ariyarathna SMWTPK, De Silva WPM, Wimalasena BDSN and Shanthini R (2004). Investigating the possibility of the use of paddy husk charcoal for the treatment of rice mil wastewater in Sri Lanka, Procedings of the University Research Session, University of Peradeniya, Sri Lanka.

Demirbas E, Kobya M and Konukman AES (2007). Error analyziz of Equilibroum studies for the almond shell activated carbon adsorption of Cr(VI) from aqueous solutions, Journal of Hazardous Materials 154: 787-794

Foo KY and Hameed BH (2010). Insights into the modeling of adsorption isotherm systems, Chemical Engineering Journal 156: 2-10

Pushpa Jha (2011). Rice-husk as an adsorbent for phenol removal. International journal of science and nature, 2(3): 593 – 596.

Rivas FJ, Beltran FJ, Gimino O, Frades J and Carvalho F (2005). Adsorption of landfill leachates onto activated carbon Equilibrium and kinetics. Journal of Hazardous Material.

Sethi Beena and Sharma Jyoti (2012). Kinetic study of steam activated pigmented rice husk carbon as an adsorbent to remove amaranth dye from aqueous solution. Novel Science International Journal of Pharmaceutical Science, 1(2): 83-86.

Vasanth Kumar K, Porkodi K and Rocha F (2007). Comparison of various erroe functions in predicting the optimum isotherm by linear and non-linear regression analysis for the sorption of basic red 9 by activated carbon, Journal of Hazardous Materials 150:158-165.

Vasanth Kumar K and Sivanesan S (2005). Prediction of optimum sorption isotherm: Comparision of linear and non-linear method, Journal of Hazardous Materials, B126:198-201.

Weber Jr TW and Chakravorti RK (1974). Pore and solid diffusion models for fixed bed adsorbers. Journal of American Institute of Chemistry.20:228–238.

The performance analysis of far infrared emission on rice flour gelatinization

G Abhiram* and KSP Amaratunga
Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka.
*Corresponding author:gabhiram004@gmail.com

ABSTRACT

This study investigated the effects of various processing parameters which measure the degree of gelatinization on rice flour that exposed to far infrared radiation (FIR) heating under different combination of FIR intensity and exposure time. Viscosity changes with roasting and Iodometric value are the parameters were measured to quantify the degree of gelatinization. Results show that the Iodomatric value and viscosity changes increases with the combination of FIR intensity and exposure time. Under high FIR intensity the gelatinization process took place extremely quick. The best combination of FIR intensity and FIR exposure time to achieve more than 80% of gelatinization was exposing the rice flour at 17125.1 W/m^2 for 9 seconds.

Keywords: Far infrared radiation, gelatinization, iodometric value, viscosity

INTRODUCTION

Drying is probably the oldest method of food preservation and it is one of the most common processes used to improve food stability, since it decreases the water activity of the product, reduces microbiological activity and minimizes physical and chemical changes during storage. Infrared drying is an effective method of dehydration. FIR drying energy transfer mechanism is very unique. During far infrared radiation, the energy in the form of electromagnetic wave is absorbed directly by the product without loss to the environment, leading to considerable energy savings (Afzal 2003). Therefor the application of FIR has received much attention in food processing technology. There were no findings reported in application of FIR on rice flour roasting. The present conventional techniques use for rice flour roasting in Sri Lanka, such as manual roasting and electric oven roasting are out dated. FIR has wide scope of industrial applications due to its deep penetration into the biomolecules increase the rate of heating and direct absorbability by the material. Gelatinization and viscosity changes are the major physical parameters, which should be given more attention in the roasting process since they are directly affect the quality of the final product. Starch polymers (amylose and amylopectin) are tightly packed in granules which are insoluble in cold water. The transformation takes place, when the starch granules exposed to heat in the presence of water, it undergoes an irreversible swelling and destruction of the internal crystalline structure is termed as gelatinization (Ahamed *et al.*

2010). The objective of this study is to assess the performance of the FIR on rice flour roasting.

MATERIALS AND METHODS

The experiment was carried out in postharvest laboratory of the department of Agricultural Engineering, Faculty of Agriculture,University of Peradeniya. The polished rice (*Oriza zativa* indica) was grinded and sieved with 150µm sieve. The initial moisture content of rice flour was measured. Rice flour was roasted by using three ceramic coated FIR elements each having 650W by changing the combination of FIR intensity (17125.1, 14123.5 and 11254.3 W/m^2) and FIR exposure time (1, 2, 3, 4, 6, 8, 9 and 10 seconds).

A pyranometer was developed locally to measure the FIR intensity. To get different FIR intensities the gap between the FIR elements and the rice flour sample was changed and above mentioned three different FIR intensities were attained. Pyranometer was placed at different points at the same height level under the FIR emitter and the analog signals produce by the temperature transducer (LM 35, National semiconductors, USA) in the pyranometer were logged in to a computer using a data acquisition module. From the recorded data the FIR intensities with respective height were calculated.

The guide lines from Wootton and Kensington (1989) were followed to determine the Iodomatric value to measure the degree of gelatinization of gelatinized rice flour. The formula (a) used to calculate the gelatinization percentage.

$$\textbf{Gelatinization \%} = \frac{\textbf{(Spectrometer reading of roast sample)}}{\textbf{(Spectrometer reading of optimum gelatinize sample)}} \times 100\% \qquad \text{(a)}$$

Viscometer (Tokimac-model BL, Japan) was used to study pasting properties of gelatinized starch water suspension. Room temperature (28°-30°C) was maintained throughout all the viscosity measurements with the help of water bath. Three replicates of 55% of rice starch solution were prepared. The No 2 spindle was employed for each treatment, while shear rate was set up at 60 rpm throughout the experiment. The dial readings of three replicates were taken and the average reading was converted to Torque (M) by multiply by the factor. The formula (b) used to calculate the viscosity changes during roasting of rice flour.

$$\textbf{Torque} = \textbf{(Dial reading/100)} \times \textbf{Factor} \qquad \text{(b)}$$

RESULTS AND DISCUSSION

The 80% level of gelatinization was optimized as the set level, since the above level of gelatinization cause charring of rice flour because of excess heat exposure. Since the charred rice flour is poor in quality, above 80% of gelatinization was rejected. The figure 1

shows the gelatinization percentage increases with the FIR exposure time for all three different FIR intensities and higher the intensity higher the gelatinization percentage. The maximum gelatinization was gained at the IR intensity of 17125.1 W/m^2. The maximum gelatinization of rice flour was gained by reducing the gap between thin layer of rice flour and the FIR emitter, which reduced the time taken for roasting as few seconds.

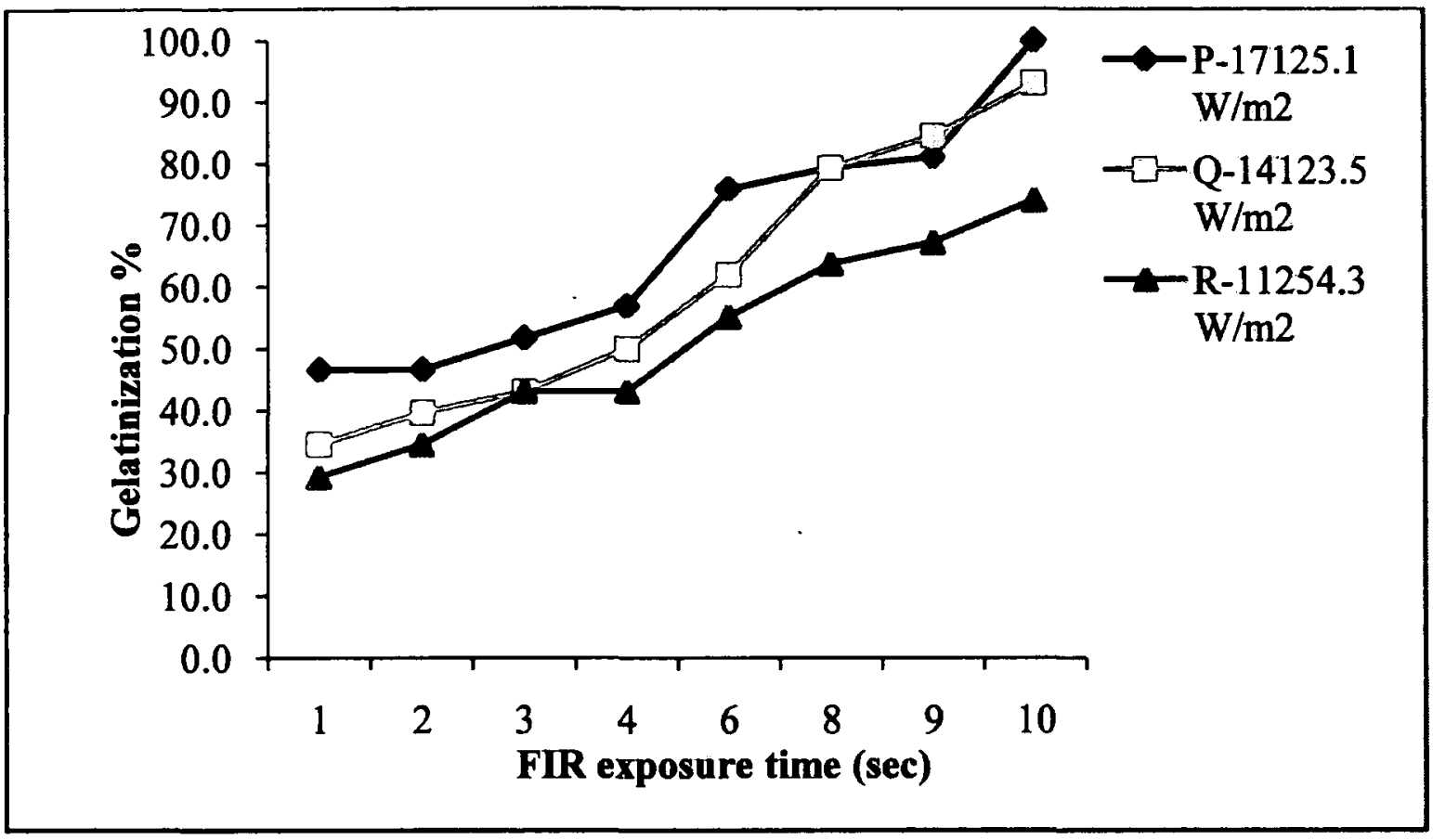


Fig. 1. Gelatinization percentage changes with FIR exposure time.

When the FIR intensity and FIR exposure time increase, the energy absorb by the rice flour granules will increase. Therefore free water molecules bound to the surface of the rice starch granules penetrate into the granules and it starts to swell within few seconds cause for the gelatinization.

The Figure 2 shows the viscosity increases with the FIR exposure time and higher the FIR intensity higher the viscosity. The rice flour was roasted to the maximum level within few seconds by increasing the FIR intensity to 17125.1 W/m^2. The viscosity value directly depends on crystallinity of the starch granule and the level of swelling due to gelatinization. There are three phases of gelatinization were identified. Those are initial phase, swelling phase and melting phase (Alexander and Zobel 1993).Viscosity increases when the crystallinity losses in starch granule's swelling phase. With the time, moisture absorb by the starch granule increases cause for the increasement of viscosity. But it is true up to a certain point.

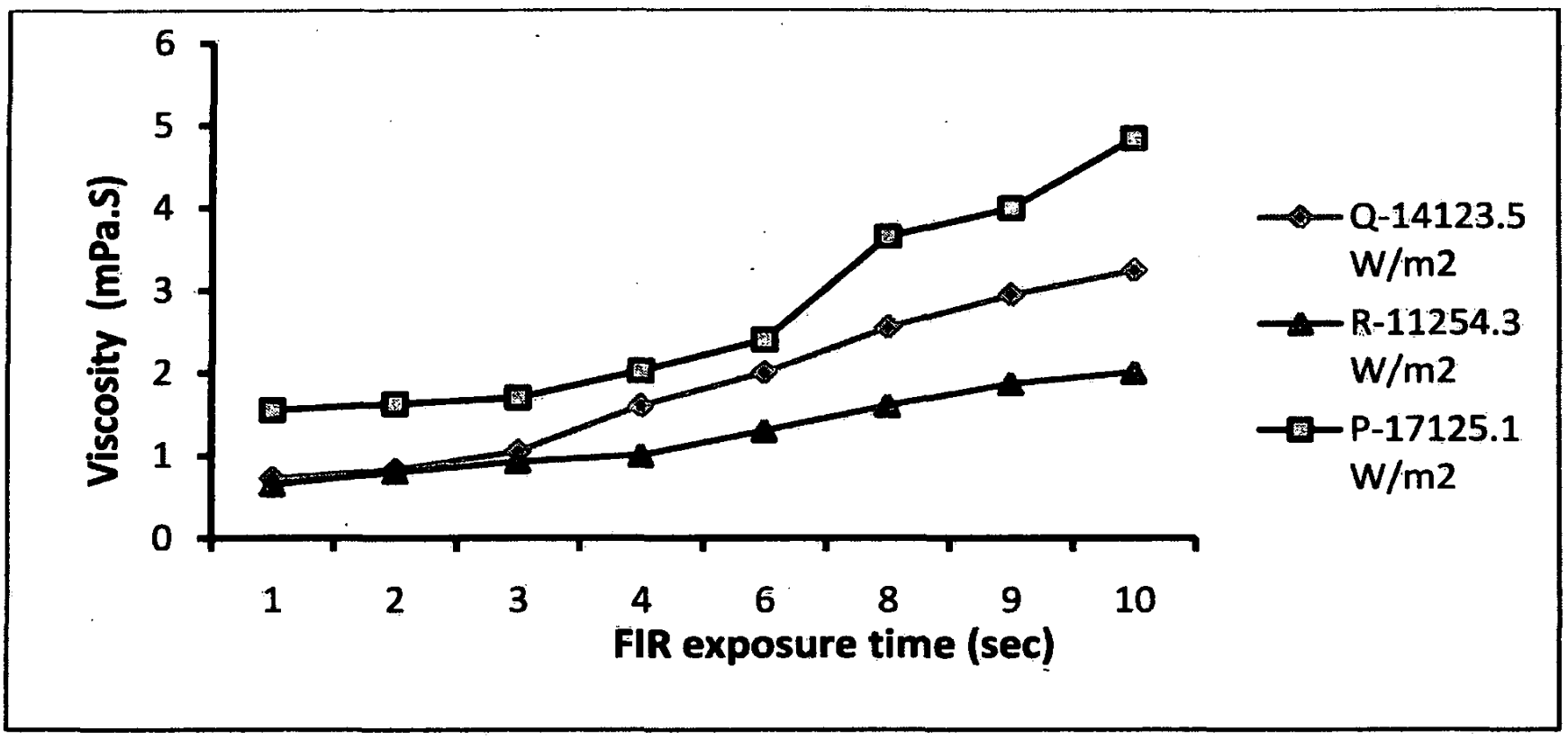


Fig. 2. The viscosity changes with FIR exposure time.

At a stage when FIR exposure time increases, the viscosity suddenly starts to drop due to the melting phase. In this phase the starch granule collapse and lose its rigidity, result for viscosity reduction. In our experiment the rice flour starch granule still in swelling phase, not reach the melting phase because of continuous viscosity increasement.

CONCLUSION

More than 80% gelatinization and optimum viscosity change was obtained under the combination of FIR intensity at 17125.1 W/m^2 and exposure time at 9 seconds. When the FIR intensity increased more than that, the rice flour starts to char. Therefore the maximum FIR intensity can be used for the rice flour roasting is 17125.1 W/m^2 when it is exposing for radiation for one second. FIR radiation fairly reduces the time taken for roasting compare to the conventional methods of heating. Therefore FIR radiation has high potential as a heating source for rice flour roasting.

REFERENCES

Afzal MT (2003). Intermittent far infrared radiate on drying. The society for engineering in agricultural, food, and biological systems. ASAE 036201.

Ahamed J, Ramaswamy H S, Kasapis S and Boye JI (2010). Novel Food Processing. CRC press, London.

Alexander R J and Zobel HF (1993). Development in carbohydrate chemistry. AACC, Minnesota, USA.

Das I and Bal S (2009). Drying kinetics of high moisture paddy undergoing vibrated-assisted infrared drying. Journal of Food Engineering. 95:166-171.

Wootton M and Kensington HP (1989). Alkali gelatinization of Wheat starch. Transaction of the Starch 41(7): 261–265.

Model for internal porosity development of different shaped foods

Wijitha Senadeera*
School of Chemistry Physics and Mechanical Engineering,Queensland University of Technology, 4001, George Street, Brisbane, Australia
*Corresponding author: w3.senadeera@qut.edu.au

ABSTRACT

Three particular geometrical shapes of foods were prepared from food materials. Cuboidal (aspect ratio = 1:1, 2:1, 3:1), cylindrical (length: diameter = 1:1, 2:1, 3:1) and spheres were selected from potato, beans and peas respectively. Internal porosity was determined from solid density (theoretical) and particle density (experimental)during fluidised bed drying at different moisture contents. Solid density was calculated using formulae (conservation of mass and volume) already published in the literature by previous researchers. Determined porosity values were correlated with moisture ratio for different geometrical shapes.

Keywords: Porosity, shapes, solid density, particle density, model

INTRODUCTION

Drying of foods is a major operation in the industry consuming larger amounts of energy. Drying operation is used as a primary operation for preservation of food materials or as secondary process in some manufacturing operations. This is a complex process involving mass and heat transfer accompanied by physical and structural changes (Senadeera 2009). The quality of food materials that undergo drying depends on their initial quality and changes during drying. Shape and size changes occur influencing their physical properties which will change their internal porosity, final texture and transport properties (Senadeera *et al.* 1998).

Porosity is the amount of air space or void in the material. The measure of porosity can be calculated from values of theoretical and practical data of particle density. As shrinkage affects porosity of food, Lewicki *et al.* (2004) proved that temperature and airflow from drying change the degree of damage of the internal plant tissue structure. This results in alteration of physical and mechanical properties of the food that leads to changing the amount of porosity.

It can be argued that chemical composition of food also has an effect to the overall porosity (Karathanos *et al.* 1998). Chemical composition of food can be used in calculating solid density from its constituents with a correction for drying temperature, experiments can be

used for determining particle density. These two densities are then use to calculate the porosity inside the food.

The objective of this research is to understand the relationship between the development of internal porosity and the shape of the food particulates during fluidised bed drying. Also, a generalised model was derived for the porosity development with changes in moisture content during drying. This model equation was capable of describing the relationship between porosity and moisture ratio of all shapes under consideration.

MATERIALS AND METHODS

*Raw Materials and material preparation:*Three vegetables was selected and different food shapes were prepared–they were potato, peas and green beans with cuboidal, spherical and cylindrical shapes respectively as shown in Figure 1. The objective of this experiment is to investigate porosity changes of these three different shaped foods during fluidised drying at three different temperatures, 30, 40 and 50 °C.

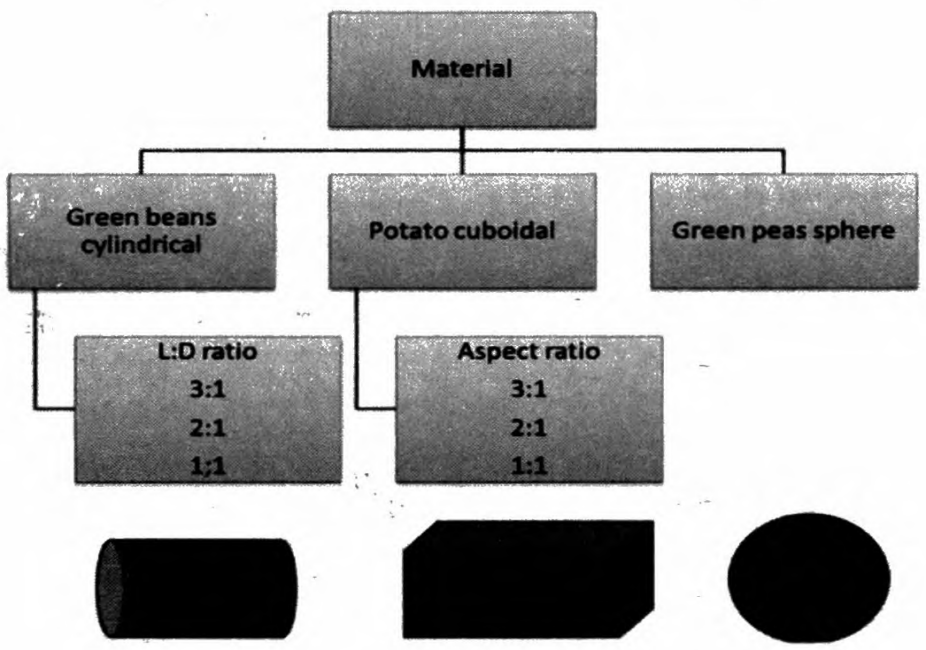


Fig. 1. Materials and shapes

Experimental design for drying experimentation: Three batches were prepared at once and used for three drying temperatures. Two replicate batches were prepared for cut beans (3 L:D ratios) and diced potato (3 aspect ratios). Three replicate batches were prepared for peas.

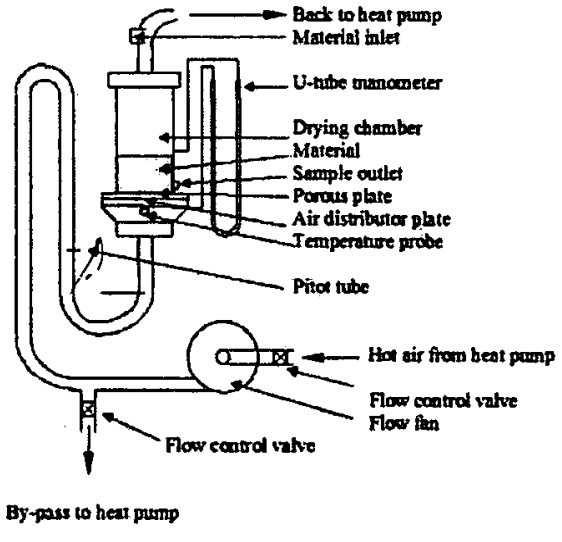


Fig. 2. Schematic of the drying loop

Analysis of experimental data and modeling: Solid particle density was calculated for different moisture contents similar to experimental moisture contents using Equation 1. Porosity was calculated using equation 2 and temperature effets were introduced to solid density at different drying temperatures.

$$\rho_a = a + B\,MR + c\exp(-d\,MR) \quad (1)$$

where,

ρa – particle density, MR- moisture ratio

For calculation of solid density food materials was considered as multi-phase systems. When the mixing process conserves mass and volume principle, then density of the multiphase system can be written as in equation 2. Solid particle density based on each composition is calculated by this equation:

$$\frac{1}{\rho_S}\sum_{i=1}^{n}\frac{w_i}{\rho_i} \quad (2)$$

Where,

ρ_s – solid density, w_i – percentage by weight and ρ_i – composition solid density.

Main compositions considered for the materials under consideration are water, protein, carbohydrates, fat and ash. Their raw (initial) compositions are given in the Table 1.

Table 1 Initial composition of the materials

Material	Water (%)	Protein (%)	Fat (%)	Carbohydrate (%)	Ash (%)
Potato	81.7	1.7	0.3	16.1	0.2
Beans	90.7	1.9	0.5	3.2	3.7
Peas	74.6	6.9	1.5	11.3	5.7

Source: Food Properties Hand Book (2007), Rahman M S (Ed)

Through curve fitting and optimisation, a generalised governing equation was created. Coeffcientof determination was used to find the suitability of the models.

RESULTS AND DISCUSSION

Particle density (apparent): Experimental values of particle density were fitted to a non-linear model similar to Lozano *et al.* (1994) as these finding was published earlier (Senadeera 2009) was not shown here. But individual apparent particle density values were used for porosity determination. (Figure 3 for beans)

Porosity determination and model formulation: Internal porosity was calculated by using solid density (theoretical) and particle density (experimental)

$$\varepsilon = 1 - \frac{\rho_a}{\rho_s} \qquad (3)$$

where,

ε – porosity, ρ_s – soiddensity and ρ_a – apparent particledensity

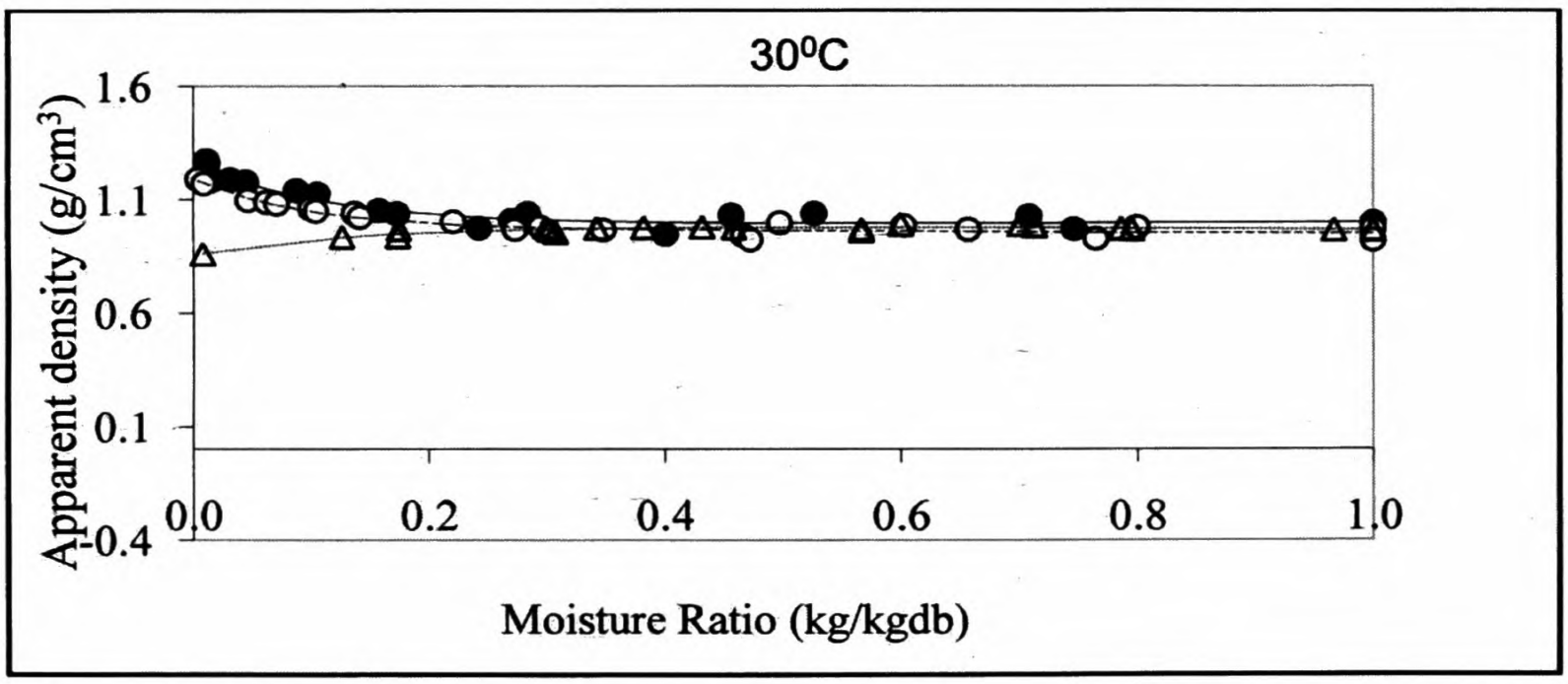


Fig. 3. Particle density variations of beans during fluidised bed drying

(• experimental L:D =1:1 - model L:D =1:1); (o experimental L:D=2:1 -- model L:D=2:1); (Δ experimental L:D =3:1 … model L:D =3:1)

A three parameter exponential decay curve added to a linear term with a fractional exponent was chosen.A generalised governing equation was created (equation 4).

$$\varepsilon = a \cdot e^{-b \cdot (MR)^n} + c \cdot (MR)^m \qquad (4)$$

where,

ε = porosity, MR = moisture ratio and a, b, n, c and m are model parameters.

Figure 5 shows potato (cuboidal) porosity variation for aspect ratios of 3:1, 2:1 and 1:1 at 50 °C drying temperature and model graphs. Similar charts was for other materials and not shown. The model parameters of, equation 4 is shown in the Table 2 below.

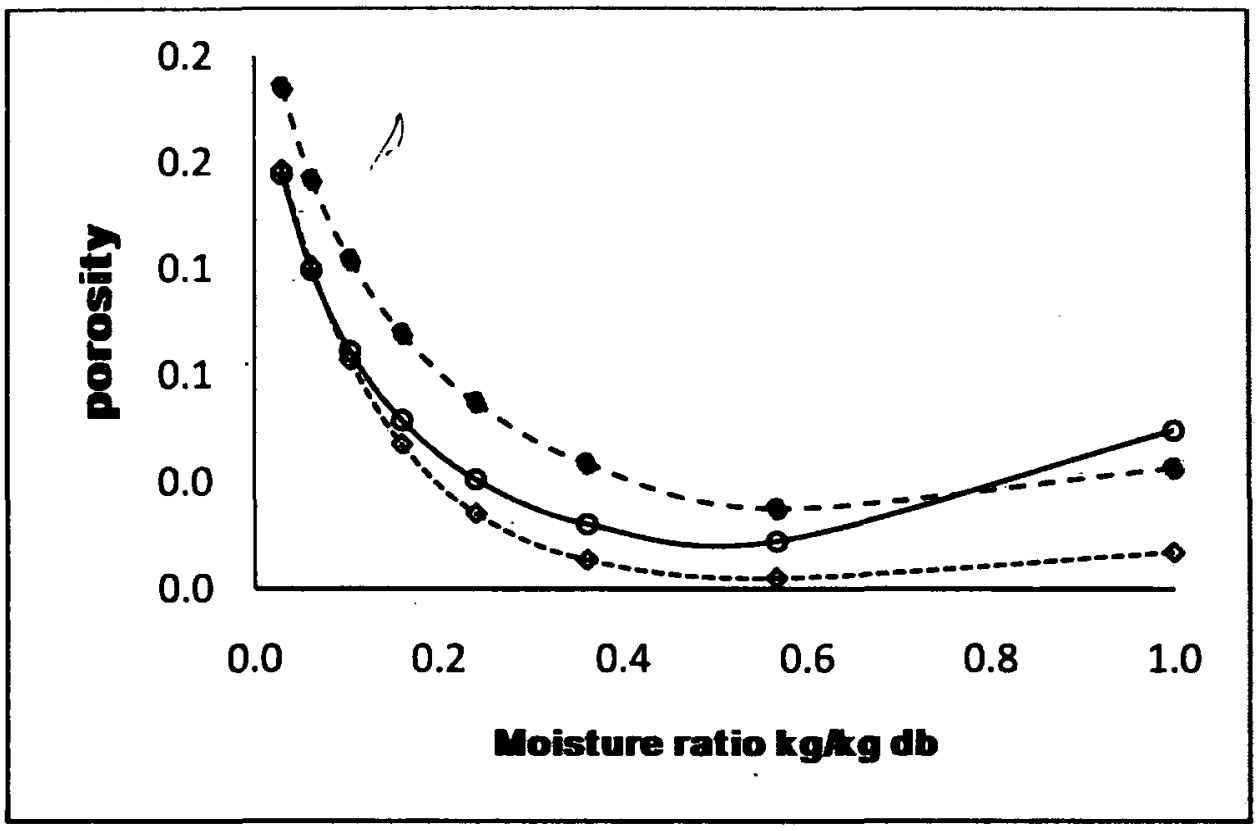


Fig. 5. Potato porosity variations at 50° C

Aspect ratio ◊ 1:1 ○ 2:1 ● 3

Table2. Porosity model parameters

Material	Temp	size	a	b	n	c	m	R^2
		1	0.2034	6.4767	0.9574	0.0244	3.3	0.9997
	30	2	0.3231	5.4856	0.8182	0.0259	3.3	0.9999
		3	0.3135	4.8124	0.6744	0.0151	3.3	0.9990
		1	0.2157	7.8815	0.8864	0.0444	3.3	0.9984
Potato	40	2	0.2356	4.6205	0.9010	0.000	3.3	0.9999
		3	0.2678	5.5097	0.7957	0.0042	3.3	0.9981
		1	0.2002	8.2192	1.0024	0.0137	3.3	0.9991
	50	2	0.2278	4.8689	0.7264	0.0578	3.3	0.9985
		3	0.2586	3.4713	0.6812	0.0373	3.3	0.9982
		1	0.1715	1.4905	0.4895	0.0000	1.7	0.9638
	30	2	0.6904	2.1267	0.1346	0.0000	1.7	0.9978
		3	0.5312	3.1946	0.6125	0.0426	1.7	0.9997
		1	0.1418	12.9664	3.6451	0.0326	1.7	0.8345
Beans	40	2	0.1858	6.5309	7.5219	0.0939	1.7	0.9844
		3	0.9104	3.0917	0.4126	0.0157	1.7	0.9989
		1	0.5048	2.7382	0.4391	0.0437	1.7	0.9996
	50	2	0.3103	2.0628	0.6765	0.0508	1.7	0.9993
		3	1.9951	4.0616	0.2406	0.0785	1.7	0.9988
	30		0.1289	4.9600	1.2617	0.0748	1.2	0.9998
Peas	40		0.1228	4.3131	1.6155	0.0762	1.2	0.9895
	50		0.2380	2.6751	0.8247	0.0607	1.2	0.9998

CONCLUSIONS

Internal porosity development behavior of the different food particulates change as the drying proceeded. It is important to understand the changes in porosity, so that predictions can be made related to food structure. Further experiments are necessary to investigate the relation between this approach and actual porosity development.

Nomenclature

a, b, c, d constants
D diameter (m)
L sample length (m)
m moisture content (kg/kg)
MR moisture ratio
m, n model exponents
T temperature (K0
ε internal porosity
ρ particle density (g/cm^3)

Subscripts
i integer
a apparent
s solid

REFERENCES

Karathanos VT, Krokida MK and Maroulis ZB (1998). Effect of Freeze-drying Conditions on Shrinkage and Porosity of Dehydrated Agricultural Products. Journal of Food Engineering, 35: 369 – 380.

Lewicki PP and Jakubczyk E (2004) . Effect of hot air temperature on mechanical properties of dried apples. Journal of Food Engineering, 34 (3): 307–314.

Lozano JE, Rotstein E and Urbician MJ (1994).Shrinkage, porosity and bulk density of food stuffs at changing moisture contents. *Journal of Food Science,* 48:1497-1502.

Rahman MS (Ed) (2007). Food Properties Hand Book

Senadeera W (2009). Minimum fludization velocity of food materials: effect of moisture and shape. Chemical product and Process Modeling, 4 (4): article 11.

Senadeera W (2009). Density variation of different shaped food particulates in fluid bed drying: Empirical Models, Agricultural and marine Sciences, 14: 27-34. Sultan Qaboos University, Oman.

Senadeera W, Bhandari BH, Young G and Wijesinghe B (2003). Influence of shapes of selected vegetable materials on drying kinetics during fluidized bed drying. Journal of Food Engineering, 58:277-283.

Senadeera W, Bhandari BH, Young G and Wijesinghe B (1998). Change of physical properties of green beans during drying and its influence of fluidization. In '*Drying 98*', Volume B-Proceedings of the 11th International Drying Symposium, Halkidiki, Greece, Eds. C. B. Akitidis, D. Marinos-Kuoris and G. D. Saravokos, Ziti Editions, Thessaloniki, Greece:1139-1146.

Far-infrared drying of stored coriander (*Coriandrum sativum* L.) up to grinding moisture content

AJ Fernando[1]*, KSP Amaratunga[2] and LBMDL Priyadarshana[2]
[1]Department of Agricultural Engineering and Soil Science, Faculty of Agriculture, Rajarata University of Sri Lanka
[2]Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Peradeniya
Corresponding author: jayaruwanifernando@yahoo.com

ABSTRACT

Coriander (*Coriandrum sativum* L.) is presently drying using solar power up to 11% moisture content. In this study, the possibility of using Far Infrared (FIR) radiation heating for drying coriander up to required standard grinding moisture content was investigated. The moisture content of coriander seeds at 3240, 3920, 5260 and 7188 W/m^2 FIR radiation intensities with different exposure time were measured. The moisture content of coriander was reduced up to 9% (db) less than 60 s at all radiation intensities. Thus it matches with commercially coriander powder making process as it is a faster drying with continuous operation.

Keywords: Coriander, drying, far-infrared, heating

INTRODUCTION

Coriander (*Coriandrum sativum* L.) is a culinary and medicinal plant from the Umbelliferae family (Pruthi 1980). It is a widely cultivated mainly for its seed. Drying removes water from products to avoid microbial spoilage. It facilitates easier handling and transportation characteristics of herbs and spices. The FIR wavelength lies in the wavelength range between 4−1000 μm (Von and Staack 2008). FIR radiation is advantageous for food processing because most food components absorb radiative energy in the FIR region (Sandu 1986).

Grinding is one of the very important unit operations in the post-harvest processing of spices. The reasons for reducing size of a material are to: create appropriate particle size for subsequent processing or end use, create a free-flowing material, improve material blending and prevent segregation by making products different size ranges and increase the material's surface area to improve a material's reactiveness and drying efficiency (Wennerstrum *et al.* 2002).

The coriander procured from market has a moisture content of 11% (db). It should be reduced to 9% moisture content (db) to achieve the required standards (Bureau of Indian Standards) and direct it to grinding process. The available drying methods can be practiced to reduce the coriander moisture content up to 9%. But commercially coriander powder making process requires a faster drying mechanism to match the speed of the grinding

process with continuous operation. Heat transfer in radiation heating is faster than conduction and convection heating (Yang *et al.* 2010). Therefore the objective of the research was to study the possibility of applying FIR radiation for drying coriander to achieve the standard moisture content before the grinding process.

MATERIALS AND METHODS

The coriander seeds (diameter 4 mm, spherical shape) were obtained from bulk coriander stored at a factory in Kundasale, Sri Lanka. The samples were temporary stored in polythene pouches (gauge 300) in the laboratory for the experiments. Moisture content of the samples was 11% (db).

The schematic diagram of the FIR coriander drying setup is shown in Figure 1. FIR was produced using 15 cm x 5 cm ceramic electric IR module with 660 W power mounted at the top of the apparatus. An aluminum reflective waveguide surrounding the FIR emitter, guides the IR waves on to the sample, fairly a uniform distribution of IR across the cross section. A single layer of coriander (12.41±1.06 g) was exposed to FIR radiation by placing the sample under the FIR emitter, on 5 mm thick wooden sample tray, at predetermined distances for 240 s. The required IR intensity was achieved by adjusting distance between the sample and the FIR emitter. The distance to achieve the required FIR intensities, 7188, 5260, 3920 and 3240 W/m^2 were determined at 10, 15, 20, 25 cm respectively. These intensities were selected as they were the practically important intensities nearly at 1000 W/m^2 intervals.

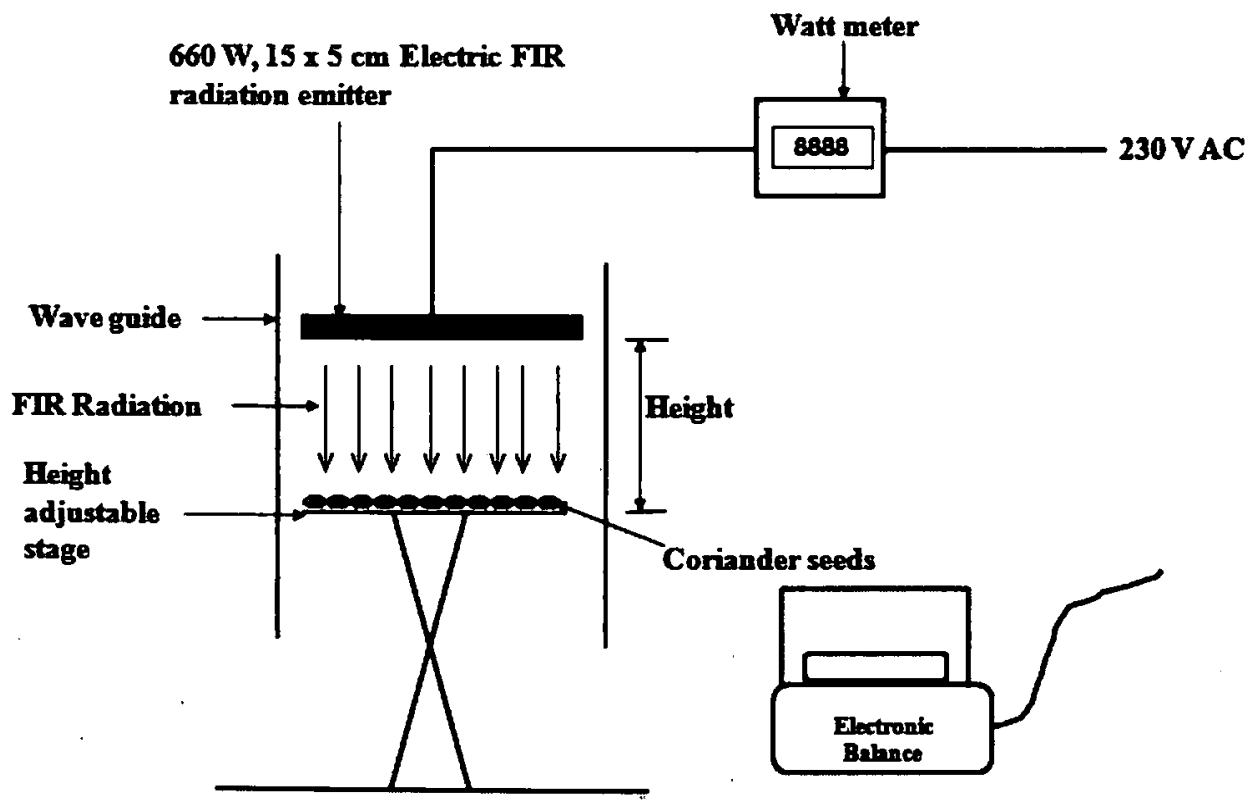


Fig. 1. Schematic diagram of the FIR coriander drying setup.

The FIR heating device turned on for 5 minutes to reach the working temperature before place the samples. The intensity of FIR radiation was measured using OPHIR FL205A Thermal Excimer Absorber Head (Ophir Optronics Inc., Wilmington, Mass., U.S.A.) and the height adjustable stage set to the required height depending on the radiation intensity.

Coriander seeds were kept as a single layer on a wooden plate to avoid FIR reflection during the experiment. At the time of FIR exposure the moisture content was measured. The weight loss of roasting sample under different FIR radiation intensities (3240, 3920, 5260 and 7188 W/m^2) was measured using an electronic balance (CTG 602B-600, CITIZEN SCALE Inc. USA) at predetermined time intervals (0, 60, 120, 180 seconds). Coriander seeds (12.41±1.06 g) were spreaded on a wooden plate and kept on the height adjustable stage for FIR radiation exposure.

RESULTS AND DISCUSSION

Table 1 shows the variation of moisture content during FIR drying of coriander at different radiation intensities. The coriander moisture removal during FIR heating showed a linear relationship (Figure 2) with time contrast to convectional drying shows logarithmic drying characteristics. Rate of drying increased with increasing radiation intensity.

Table 1. Moisture content and rate of drying with different radiation intensities.

Time (t), s	3240 W/m^2		3920 W/m^2		5260 W/m^2		7188 W/m^2	
	MC	dM C/dt	MC	dM C/dt	MC	dM C/dt	MC	dM C/dt
0	11.00 ±0.00	0.00	11.00 ±0.00	0.00	10.99 ±0.00	0.00	11.00 ±0.00	0.00
60	8.33 ±0.01	2.66	7.75 ±0.02	3.24	8.30 ±0.01	2.69	8.00 ±0.02	3.00
120	6.11 ±0.02	2.22	5.32 ±0.01	2.43	5.60 ±0.02	2.69	4.50 ±0.01	3.50
180	4.34 ±0.01	1.77	3.70 ±0.01	1.62	3.80 ±0.01	1.79	3.00 ±0.02	1.50

MC (Moisture content %, dry basis), dMC/dt (Moisture removal rate)

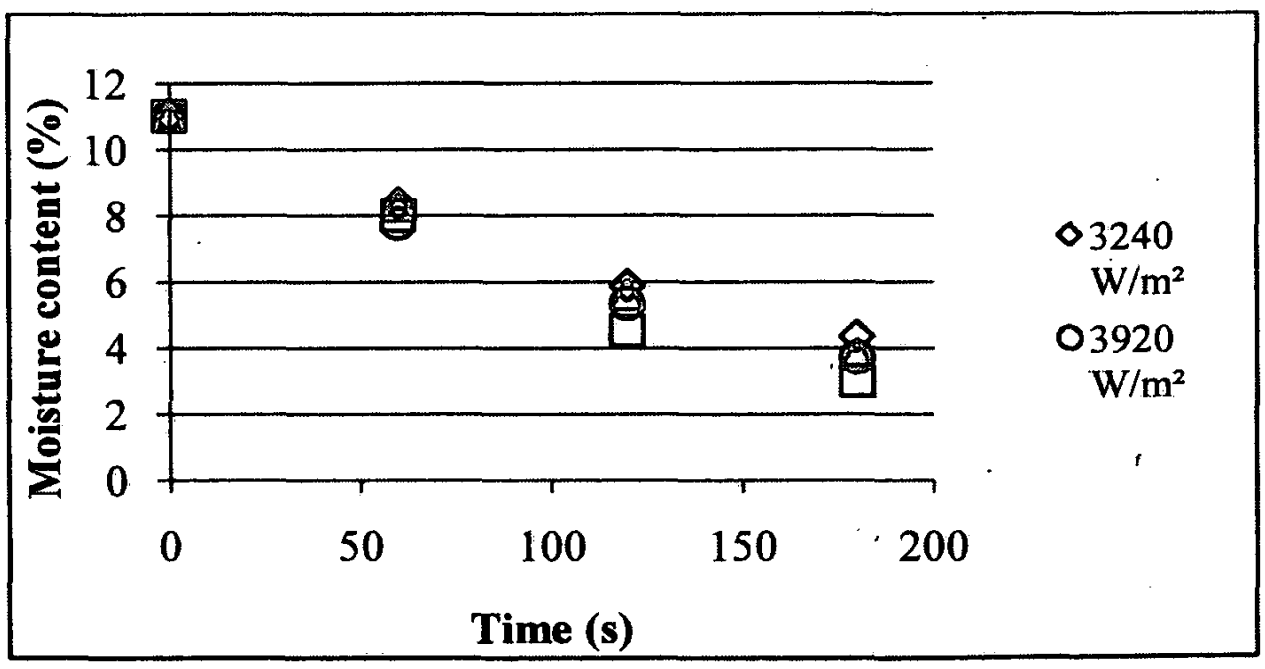


Fig. 2. Relationship between average coriander moisture content and FIR heating time under different radiation intensities.

The graph explains the behaviour of moisture in coriander samples when they exposed to different FIR radiation intensities. The moisture content of each sample decreased with time in all radiation intensities. Because when the temperature increased the moisture in the sample was removed.

When the radiation intensity increased then the moisture content of the sample reduced. Because when the radiation intensity increased, the heat energy gained by the samples was increased and moisture removed rapidly. When consider the 180 seconds time period, the lowest moisture content gained by 7188 W/m^2 radiation intensity and the highest moisture level obtained by 3240 W/m^2 radiation intensity.

Except 7188 W/m^2 radiation intensity in other radiation intensities the moisture content reduced with increasing radiation intensity. Because it can remove more moisture from the product when supply high amount of heat energy. In 7188 W/m^2 radiation intensity although the coriander sample achieved low moisture content within 60 seconds it had highest moisture content. It was because although it had high energy to change the colour of the sample, the holding period of the energy was low.

When consider 3240 W/m^2 radiation intensity although it had high holding period it also had considerable amount of moisture content compared to other samples. It may because the energy gained was not sufficient to remove enough moisture from the sample.

CONCLUSION

The obtained results indicated that FIR radiation can be effectively used in drying corinder. The highest FIR intensity used in this trial was 7188 W/m^2 and increasing intensity further restricted by the space limitation between FIR emitter and the sample. At 3240, 3920, 5260 W/m^2 radiation intensities the coriander was achieved the 9% (db) moisture content in 60 s. Therefore it could be concluded that FIR radiation could be effectively used in drying coriander up to required moisture contnet for grinding. Further studies are required for dried coriander quality with FIR radiation before applying the technology at industrial scale.

REFERENCES

Pruthi JS (1980). Spices and Condiments: Chemistry, Microbiology, Technology. Advances in Food Research, Vol. 4, Supplement. New York: Academic Press.

Sandu, C. (1986). Infrared radiative drying in food engineering: a process analysis. Biotechnol Prog 2(3):109–119.

Von V and Staack N (2008). Potential of infrared heating as a method for decontaminating food powder. Process development and impact on product quality. [on line]. [Accessed on 07.05.2013]. Available at opus.kobv.de/tuberlin/volltexte/2008/1860/pdf/staack_norman.pdf

Wennerstrum S, Tomaka TJ and Cain J (2002). Size reduction solutions for hard-to reduce materials. Powder and Bulk Engineering 1–5.

Yang J, Bingol G, Pan Z, Brandl MT, Mchugh TH and Wang H (2010). Infrared heating for dry-roasting and pasteurization of almonds, Journal of Food Engineering, 101:273-28.

A novel approach for numerical simulation of plant tissue shrinkage during drying

H.C.P. Karunasena,[1,2] W. Senadeera,*[1] R.J. Brown[1] and Y.T. Gu[1]

[1] School of Chemistry, Physics and Mechanical Engineering, Faculty of Science and Engineering, Queensland University of Technology, 2-George Street, Brisbane,QLD 4001, Australia.

[2] Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, University of Ruhuna, Hapugala, Galle, Sri Lanka.

*Corresponding author: w3.senadeera@qut.edu.au

ABSTRACT

Drying is a key processing techniques used in food engineering which demands continual developments on advanced analysis techniques in order to optimize the product and the process. In this regard, plant based materials are a frequent subject of interest where microstructural studies can provide a clearer understanding on the fundamental physical mechanisms involved. In this context, considering numerous challenges of using conventional numerical grid-based modelling techniques, a meshfree particle based model was developed to simulate extreme deformations of plant microstructure during drying. The proposed technique is based on a particle based meshfree method: Smoothed Particle Hydrodynamics (SPH) and a Discrete Element Method (DEM). A tissue model was developed by aggrading individual cells modelled with SPH-DEM coupled approach by initializing the cells as hexagons and aggregating them to form a tissue. The model also involves a middle lamella resembling real tissues. Using the model, different dried tissue states were simulated with different moisture content, the turgor pressure, and cell wall contraction effects. Compared to the state of the art grid-based microscale plant tissue drying models, the proposed model is capable of simulating plant tissues at lower moisture contents which results in excessive shrinkage and cell wall wrinkling. Model predictions were compared with experimental findings and a fairly good agreement was observed both qualitatively and quantitatively.

Keywords: Food drying, plant cells, SPH, moisture content, shrinkage

INTRODUCTION

Dehydration or drying is one of the most popular food preservation techniques used in the food industry. In drying process, the food materials subject to excessive moisture reductions which result in excessive structural deformations of the food material. In the literature, there is a comprehensive collection of the conventional empirical and theoretical models that relate different physical properties of the food materials during drying. But, based on the practical challenges and limitations of popular grid-based modelling techniques such as Finite Element Methods (FEM) and Finite Different Methods (FDM), numerical modelling has not been well explored on food materials under drying conditions. In this background, we have developed a meshfree based numerical modelling approach for microscale modelling of plant cells during drying (Karunasena, Senadeera *et al.* 2014b)The

fundamental difference between grid based methods and meshfree methods is the discretisation.

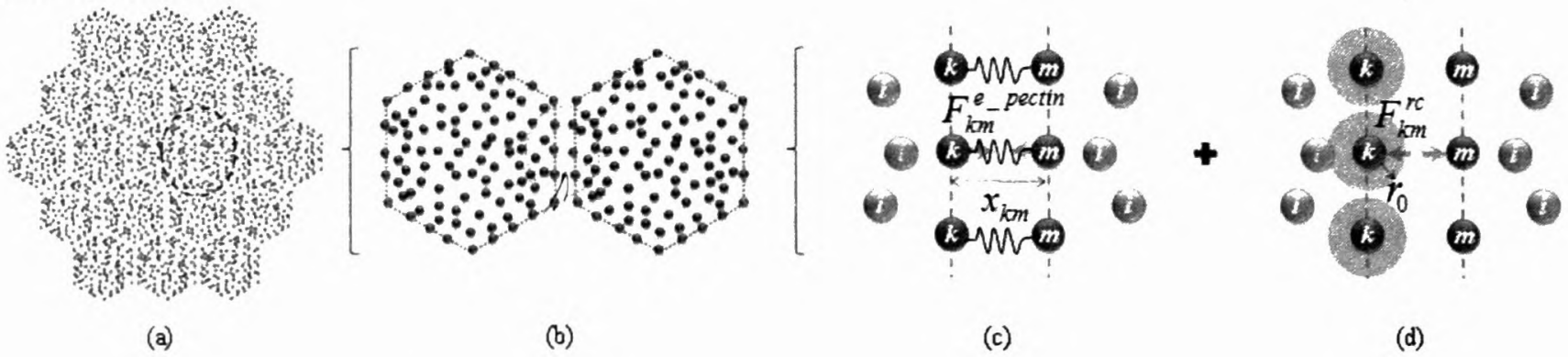


Fig. 1 Tissue model and cell-cell force interactions: (a) hexagonal shaped cells are used for tissue initialization with positive pectin layer gap. (b) Interacting wall particle pairs of adjacent cells. (c) Pectin layer stiff forces. (d) Cell-cell repulsion forces. (*i*: fluid particles; *k* & *m*: wall particles)

technique used. In meshfree methods, interconnected meshes or grids are not involved as in the case of FEM or DEM. The discretisation is achieved by representing the problem domain using non-connected particles that can time-evolve to produce new states. Due to the fundamental benefit of grid-free nature of these meshfree methods, they are more capable of handling problems that characterise excessive geometric deformations and multi phase systems. Our model is based on one of the most popular meshfree techniques: Smoothed Particle Hydrodynamics (SPH) (Gingold and Monaghan 1977, Liu and Liu 2003) and is coupled with a Discrete Element Method (DEM) to model plant cells. SPH is used to model cell protoplasm (cell fluid) and DEM is used to model the cell wall. In our previous works (Karunasena, Senadeera *et al.* 2012a; Karunasena, Senadeera *et al.* 2012b; Karunasena, Senadeera *et al.* 2014b), we have presented how a single cell can be modelled with this technique to study moisture content and turgor pressure driven structural deformations under drying conditions. In this work, we demonstrate how a tissue model can be developed using such a single cell drying model by incorporating several new improvements. Sections below describe how the model was developed and how the model predictions were compared with experimental findings on apple parenchyma cell drying (Mayor, Silva *et al.* 2005; Karunasena, Hesami *et al.* 2014a).

MATERIALS AND METHODS

Firstly the individual cells were modelled in two-dimension (2-D) according to the procedure introduced in our previous work (Karunasena, Senadeera *et al.* 2014b). Such individual cells were initiated as hexagons as shown in Fig. 1 and were bonded together by two fundamental force interactions: Pectin layer stiffness and Lenard Jones (LJ) type repulsion forces between them. Using this method, a sample tissue model of 37 cells was generated and drying conditions were established by varying the moisture content and turgor pressure. For this purpose we used a moisture-content-domain based approach which was introduced in our previous works (Karunasena, Senadeera *et al.* 2012b; Karunasena, Senadeera *et al.* 2014b). Further, based on the experimental evidence of moisture content dependent positive turgor pressure existence in cells when they are subjected moisture

deficiencies (Barker, Sullivan *et al.* 1993; Neumann 1995; Hills and Remigereau 1997; Marshall and Dumbroff 1999; Blum 2011), we simply assumed that the turgor pressure will remain positive during drying that would linearly reduce with the reduction of the cell fluid mass. Therefore, when 200 kPa is used as the fresh cell turgor pressure, the dried tissues of: $X/X_0 = 0.8$, $X/X_0 = 0.6$, $X/X_0 = 0.4$ and $X/X_0 = 0.3$ were simulated by initially setting the turgor pressures to: 160 kPa, 120 kPa, 80 kPa and 60 kPa in each cells. At the end of each tissue time evolution, the dry basis moisture content X = (kg water / kg dry material) was computed and related with steady state cell deformations which were quantified using a set of cellular geometrical parameters: cell area (*A*), ferret diameter1 (*D*), perimeter (*P*), roundness2 (*R*), elongation3 (*EL*) and compactness4 (*C*). Further, in order to facilitate analysis and comparison of the model performances, normalized parameters (X/X_0, A/A_0, D/D_0, P/P_0, R/R_0, EL/EL_0 and C/C_0) were involved used. For model validation, these results were compared with experimental data for apple cell drying obtained from our experiments (Karunasena, Hesami et al. 2014a) (see Fig. 2) and literature (Mayor, Silva et al. 2005).

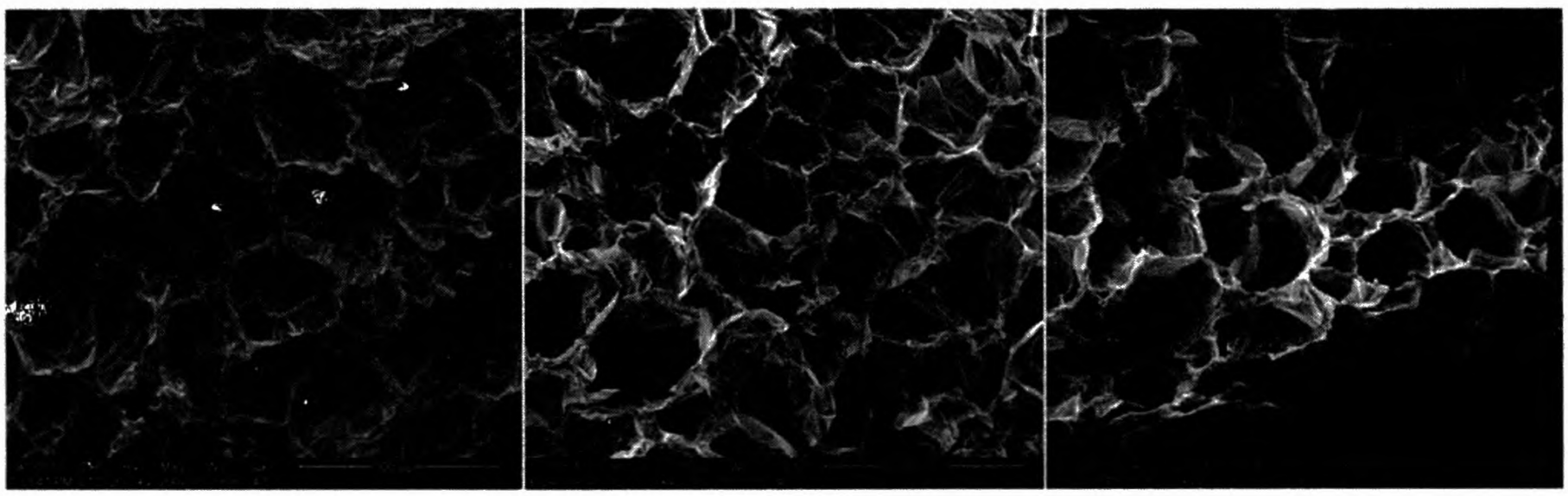


Fig. 2 SEM images of apple cells at different states of dryness: (a) x/x_0= 1.0. (b) x/x_0 = 0.5. (c) x/x_0 = 0.2.

RESULTS AND DISCUSSION

When considering the 37-cell tissue as seen from Fig. 3 and Fig. 4 extensive shrinkage patterns can be observed with cell wall local wrinkling or warping. This is in close agreement with the wrinkled cell walls of realistic dried tissues (see Fig. 2(b) and (c)). To elaborate these trends quantitatively, the geometric parameters introduced were studied and as seen from Fig. 5, predictions are fairly in a good agreement with the experimental findings. Model predictions show a slightly rapid shrinkage during the latter part of drying (X/X_0 < 0.6) which replicates what is observed from the experimental curves. All these observations highlight the capability of the proposed tissue model to replicate realistic tissue deformations during drying.

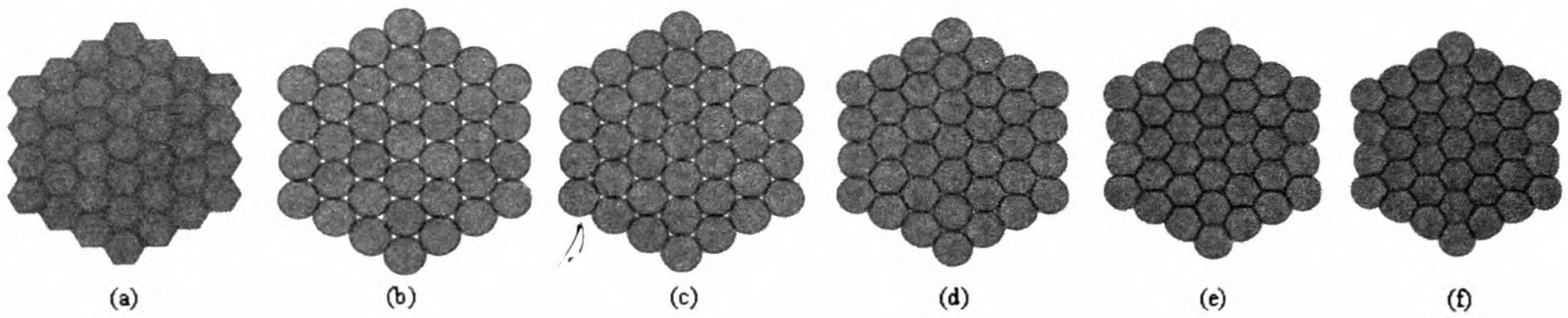


Fig. 3 37-cell tissue model: (*a*) Initial condition before simulations. (*b*) Turgid condition: X/X_0 = 1.0 & P_T = 200 kPa. Dried conditions: (*c*) X/X_0 = 0.8 & P_T = 160 kPa. (*d*) X/X_0 = 0.6 & P_T = 120 kPa. (*e*) X/X_0 = 0.4 & P_T = 80 kPa. (*f*) X/X_0 = 0.3 & P_T = 60 kPa.

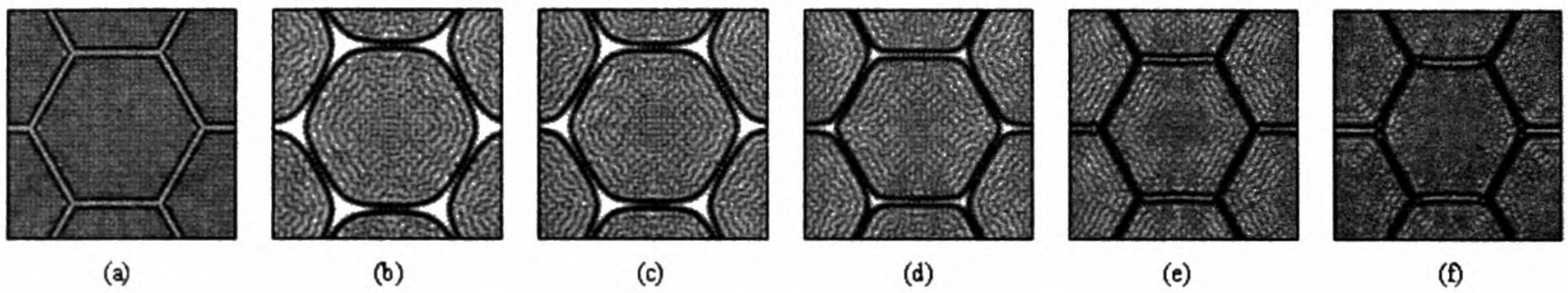


Fig. 4 37-cell tissue model (enlarged view): (*a*) Initial condition before simulations. (*b*) Turgid condition: X/X_0 = 1.0 & P_T = 200 kPa. Dried conditions: (*c*) X/X_0 = 0.8 & P_T = 160 kPa. (*d*) X/X_0 = 0.6 & P_T = 120 kPa. (*e*) X/X_0 = 0.4 & P_T = 80 kPa. (*f*) X/X_0 = 0.3 & P_T = 60 kPa.

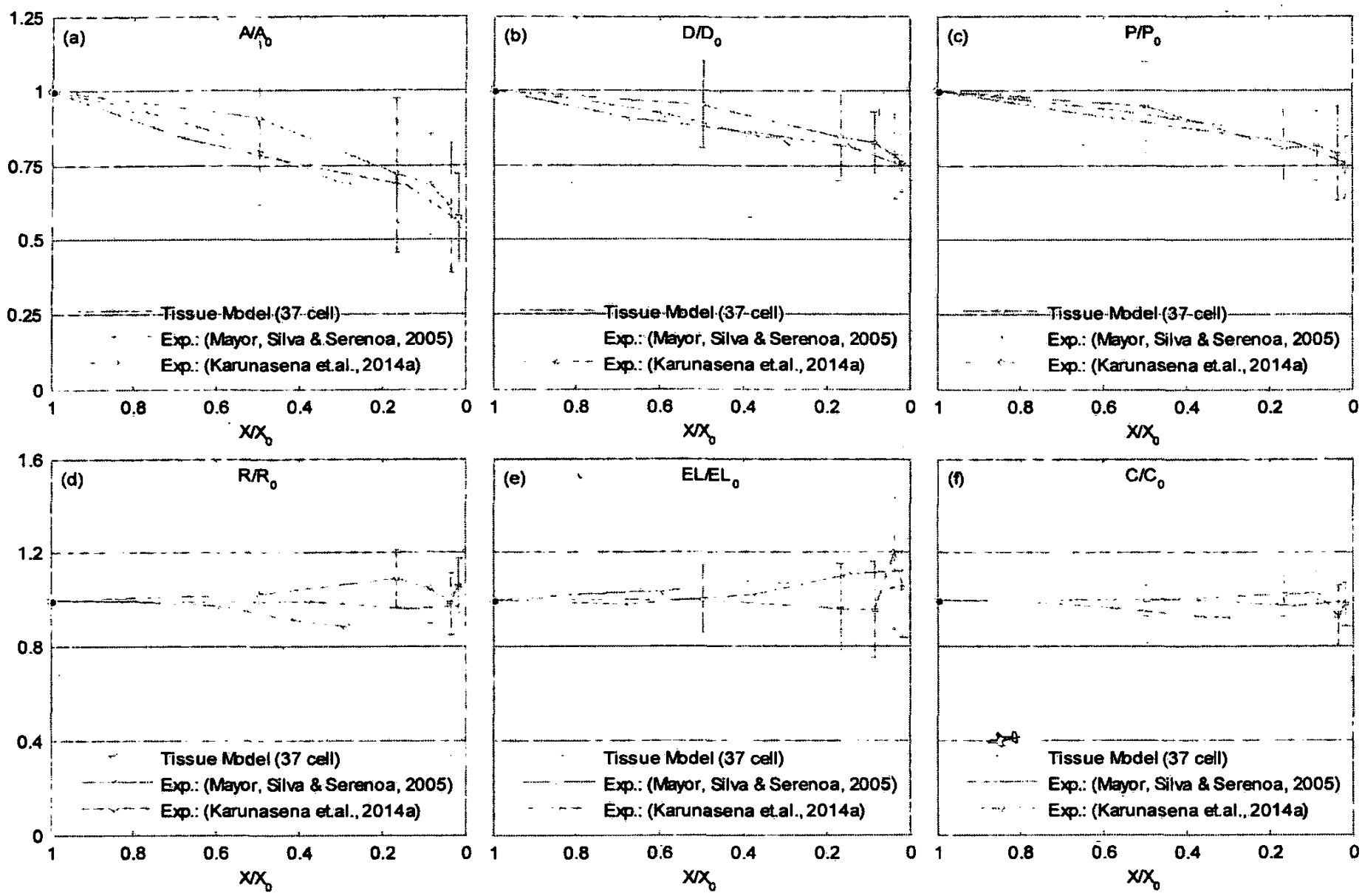


Fig. 5 Influence of moisture content reduction for cellular geometric property variations of tissues: (*a*) A/A_0. (*b*) D/D_0. (*c*) P/P_0. (*d*) R/R_0. (*e*) EL/EL_0. (*f*) C/C_0. (Error bars indicate one standard deviation).

REFERENCES

Barker DJ, CY Sullivan et al. (1993). Water Deficit Effects on Osmotic Potential, Cell Wall Elasticity, and Proline in Five Forage Grasses Agronomy Journal **85**(2): 270-275.

Blum A (2011). Plant Water Relations, Plant Stress and Plant Production. Plant Breeding for Water-Limited Environments, Springer New York: 26.

Gingold R A and JJ Monaghan (1977). Smoothed particle hydrodynamics - Theory and application to non-spherical stars. Monthly Notices of the Royal Astronomical Society **181**: 375-389.

Hills BP and B Remigereau (1997). NMR studies of changes in subcellular water compartmentation in parenchyma apple tissue during drying and freezing. International Journal of Food Science & Technology **32**(1): 51-61.

Karunasena H C P, P Hesami et al. (2014a). Scanning Electron Microscopic Study of Microstructure of Gala Apples During Hot Air Drying. Drying Technology **32**(4): 455-468.

Karunasena HCP, W Senadeera et al. (2012a). A particle based micromechanics model to simulate drying behaviors of vegetable cells. 4th International Conference on Computational Methods (ICCM 2012), Gold Coast, Australia.

Karunasena HCP, W Senadeera et al. (2012b). A Coupled SPH-DEM Model for Fluid and Solid Mechanics of Apple Parenchyma Cells During Drying. 18th Australian Fluid Mechanics Conference, Launceston - Australia, Australasian Fluid Mechanics Society.

Karunasena HCP, W Senadeera et al. (2014b). A Coupled SPH-DEM Model for Micro-scale Structural Deformations of Plant Cells during Drying. Applied Mathematical Modelling.

Liu G R and MB Liu (2003). Smoothed Particle Hydrodynamics : A Meshfree Particle Method. Singapore, World Scientific Publishing Co.

Marshall J G and E B Dumbroff (1999). Turgor regulation via cell wall adjustment in white spruce. Plant Physiology. **119**: 313-319.

Mayor L, MA Silva et al. (2005). Microstructural Changes during Drying of Apple Slices. Drying Technology. **23**(9-11): 2261-2276.

Neumann P M (1995). The Role of Cell Wall Adjustments in Plant Resistance to Water Deficits.Crop Science. **35**(5): 1258-1266.

Design of Postharvest Machnery

Development of continuous type paddy cooker

TMR Dissanayake*, DMSP Bandara, HMAP Rathnayake and DP Senanayake
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka
*Corresponding author: mrdissanayake@yahoo.com

ABSTRACT

A continuous type paddy cooker was developed to steam soaked paddy in parboiling process taking into consideration the flow characteristics of high- moisture paddy through a screw conveyor. The machine consists of a hopper to feed soaked paddy , bottom perforated "U" trough and screw with hollow shaft as a steaming section, variable speed drive and steam union. Regulation of paddy exposure to steam was achieved by using variable speed drive. Paddy soaked in normal water for 30 h and equilibrated overnight was steamed using the cooker. It was found to give optimum quality of parboiled rice with average total milling yield, average head rice yield, average white belly and average discolored grain at 70.86, 64.53, 1.55 and 1.99 respectively. The exposure time for steam is 108s. The steam supplied at a rate of 480 kg/h and pressure of 60 psi. Under these conditions, the capacity of the cooker was 729 kg/h of soaked paddy. These results indicate potential applications for reducing the cost of parboiling equipment by precluding the need for large boilers and steaming tanks with elaborate steam distribution systems, in addition to improvements in the quality of the parboiled rice.

Keywords: Cooker, parboiling, soaked paddy steaming,

INTRODUCTION

Rice has been used as a staple food since ancient times. Rice processing industry is the largest agro-based industry in the Sri Lanka turning more value of product than any other industry. The parboiling process finds extensive application in the North Central; Eastern, North Western, Central and North provinces of the country. Parboiling of paddy is practiced both at village level as well as on large scale at commercial mills. It is estimated that one fifth of the world's rice is parboiled (Gariboldi 1974).

The rice obtained from milling pretreated paddy is known as parboiled rice; whereas rice obtained from milling untreated paddy is known as raw rice. Parboiling of paddy is a hydrothermal process that may be defined as the gelatinization of starch within the rice grain. During the process, an irreversible swelling and fusion of starch granules occurs that changes the starch from a crystalline form to an amorphous one. Parboiling of paddy requires three steps: soaking, steaming and drying. The essential steps in the parboiling

process are soaking of rough rice, steam heating and drying to pretreatment levels using different heat treatment methods (Pillaiyar *et al.* 1996). Among these steps, steaming is the most important treatment since this is necessary for the complete gelatinization of starch. The steaming process depends on: the condition of the steam, which could either be saturated as in an open system, or superheated as in a closed system; the pressure of the steam; the steaming time (Gariboldi 1974, Bhattacharya and Rao 1966). During the steaming, soaked paddy is exposed to steam heat for a given duration and the starch present in the rice kernel is gelatinized. Subsequently, the paddy is dried to 14-16% moisture content, which imparts the hardness that. The duration of steaming is dependent on the amount of rough rice to be steamed and the process of steam application, which may be carried out in either a batch or continuous operation (Adhikaritanayake and Noomhorm 1998).

MATERIALS AND METHODS

Sample Preparation: Short grain paddy of BG variety from regional stores at Anuradhapura of Paddy Marketing Board of Sri Lanka was used for this study. Raw paddy will be cleaned first and then soaked in cold water for 30hours. After soaking is complete, the water is drained out completely prior to steaming. The water was changed every 12 h period to curb development of spores of fungi and other microbiological in the paddy. This causes off flavor (odour) in final rice.

Experimental Procedure: After preliminary tests using the continuous type steamer, three rpm will be selected. The hopper is filled initially with a small quantity of soaked paddy and steam will be then supplied to the steaming section at a pressure of 0.35 MPa to heat the steam jacket. When steam from the steaming section appeared through the paddy, the paddy is allowed to flow through the steaming section by operating the screw conveyer. The retention time or duration of exposure of paddy to steam is measured starting from the appearance of the colored grains at the outlet of the steamer. The paddy will be discharged after the colored grains is collected and then dried. . The steam supply outlet immersed in a container with a known quantity of water and then the steam supply rate was calculated.

After steaming using the three different methods, paddy will be removed immediately, spread in thin layers on a PVC wire net and dried in the shade for 2 days until the moisture content reached 14% wb. The dried paddy will be kept in sealed polyethylene bags for milling analysis. A standard test milling procedure with a rubber roll huller will be followed and the total milled rice will be hand graded into whole grains and broken grains (Gariboldi 1973). The whole grains will be further graded manually into translucent, discolored and grains with white bellies.

RESULTS AND DISCUSSION

A continuous steaming operation was possible with the developed continuous type paddy cooker and the overall performance was very satisfactory in terms of ease of operation, energy and labor consumption and the quality of parboiled rice obtained.

Table 1: Relationship between the steam exposure time and cooker performance

VSDF	ET (S)	Capacity kg/h	TMY (%)	HRY (%)	White Belly (%)	Discolored Grains (%)
60	24	2184	70.76	62.88	2.90	1.61
30	108	729	70.86	64.53	1.55	1.99
15	227	479	70.75	64.07	1.34	2.08

VSDF: VSD Frequency, ET: exposure time, TMY: total milling yield, HRY: head rice yield.

Milling quality: There was no significant difference in the total milling yield for all three steam exposure times. The highest total milling yield has shown in steam exposure time 108s compared to other two. As total milling yield, there was no more significant difference in the head rice yield too. However, there is some significant difference between steam exposure time 24s and 108s and no any significant difference between steam exposure time 108 s and 227s. The highest head rice yield is from steam exposure time 108s.

White bellies and discolored grains: When comparing average values of white belly percentage of three different exposure times for steam, the highest white belly percentage was shown in lowest steam exposure time. The lowest value has shown in highest steam exposure time of 227s. This trend indicated insufficient exposure of soaked paddy to the steam or insufficient steam pressure. Moreover, the amount of discolored grains increased as the steam exposure time increased. No significant difference in the quantity of discolored grains was observed among three different steam exposure time.

Optimum combination of operating parameters for the continuous steamer: The standard for quality of parboiled rice stipulates that no under-parboiled grain or white bellies should be present in the milled parboiled rice. In this study, less white belly percentage was shown in highest steam exposure time. No significant differences were found for the total milling yield, head rice yield, white bellies and discolored grains for these combinations. However, the total milling yield and head rice yield is higher in the steam exposure time 108s. Therefore, the combination of a 108s steam exposure time was considered to be optimum for the developed paddy cooker to obtain the best quality of parboiled rice.

Capacity and energy requirement of the steamer: At the optimum combination or steam exposure time of 108s, the capacity of developed paddy cooker is 729 kg of soaked paddy

per h. The steam supplied to the steamer was 480 kg/h, determined by passing steam at a pressure of 60 psi. At this rate, 36.23 kg of steam would be required to steam 1 ton of soaked paddy in the developed cooker. In addition to the potential improvements in parboiled rice quality, the development of a continuous type cooker which process small quantities of paddy at a time requiring lower steam capacity imply potential advantages for reducing the cost of parboiling equipment since investing on large holding and steaming tanks, elaborate steam distribution systems and large boilers can be avoided. The developed cooker would be suitable for small scale to large scale applications for parboiling paddy to meet the local demand. However, several units of the model may be used in parallel for large-scale parboiling operations without sacrificing the advantage of better output quality and a lower cost per unit.

CONCLUSIONS

The continuous type paddy cooker developed in this study yielded an optimum quality of parboiled rice with steam supplied at 60 psi pressure at a rate of 729 kg/h and an exposure time for the paddy of approximately 108 s (obtained by setting the VSD frequency at 30). The cooker used only 36.23 kg of the steam to steam 1 ton of soaked paddy. The developed continuous type cooker has potential applications in the development of less-expensive parboiling systems, since investing in big plant structures, large boilers and steaming vessels as well as in steam distribution systems can be avoided, while still producing an output with improved quality.

REFERENCES

Adhikaritanayake TB and Noomhorm A (1998). Effect of continuous steaming on parboiled rice quality, Journal of Food Engineering, 36: 135-143.

Gariholdi F (1974). Rice parboiling. FAO Agricultural Development Paper No. 07. Food and Agriculture Organization of the United Nations, Rome, Italy.

Pillaiyar P, Sabarathinam PL, Subramaniyan V and Sulochana S (1996). Parboiling of paddy using thermic fluid. Journal sf Food Engineering, 27: 267-278.

Garibaldi F (1973). Rice testing methods and equipment. Agricultural Services Bulletin -1X. Food and Agricultural Industry Service, Agricultural Services Division. Agriculture Department, Food and Agriculture Organization of the United Nations, Rome, Italy.

Bhattacharya KR and Rao PVS (1966). Effect of processing conditions on quality of parboiled rice. Journal o f Agricultural and Food Chemistry, 14: 476-479.

Design and development of an energy efficient vibrated flour sifter for the rice flour industry

HMAP Rathnayake*, TMR. Dissanayake, DMSP Bandara, DP Senanayake and BMKS Thilakarathna
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka.
*corresponding author: aprathnayake@hotmail.com

ABSTRACT

This project aims to develop and introduce efficient flour sifter for medium scale flour processors to enhance their production capacity. Sifter was designed by considering draw backs of presently available horizontal flour sifter. The machine was designed by using vibration motor in order to improving the sieving action. For separating coarse particles from fine particles 100 BSS mesh was used. The capacity and Fine flour percentage in course flour after sifting of the developed machine were 140.18 kg per h and 3.82% respectively. Power consumption of the machine under working condition was 0.61kW. The electricity cost for processing 01 kg of rice flour was 0.06 LKR.

Keywords: Flour sifter, sieving, vibration motors

INTRODUCTION

Processing rice flour is becoming vitally important in Sri Lanka, because of continuous increase in usage and demand for rice based products. The rice flour is used to produce many traditional food items such as hoppers, string-hoppers, pittu, noodles, snacks and sweets. Rice is the first cereal recommended for infants and also commonly known for its non-allergenic properties. The people, who live in urban areas, prefer to consume rice based food items at least for one or two meals per day.

The one of the main important characteristics of rice flour that influences in preparing food items is the particle size distribution. Harlic and Kelly (1959) noted that particle size greatly influence the pasting characteristics of rice flour. Nishitha and Bean (1982) noted that water absorption is greater for fine flour compared to coarse flour. Hence, screening of rice flour is very important unit operation in rice flour process line. In the course of flour grinding, a mixture of coarse and fine particles are obtained as final product. Therefore, it is necessary to separate these particles according to size according to requirement of the product. Hence, flour sifter is used for screening of flour. Rotary, cylindrical, conical and horizontal (reciprocal action) flour sifters are commonly used in Sri Lanka, but low screening efficiency, frequent maintenance requirement or breakdown reduce the efficiency and profit margin of the industry.

More than three thousand medium scale rice flour processors in this industry face difficulties due to these medium level inefficient flour sifters. Because of the low separation

capacity in one pass (40-60%), to separate fine particles, it is necessary to do several passes which is time consuming. This also causes high energy loss and low production capacity leading to high cost of production. As a result, the product cannot be marketed at competitive prices. This situation badly guides to give up the rice flour industry.

Therefore, in our study, a vibration (vibro) - motor was used to develop the machine. The motor was fixed under the horizontal flour sifter with necessary structural modifications for proper vibration. The vibro-motor and the flour sieving bed were designed under the adjustable manner so as to increase the flour separation efficiency. Currently available horizontal flour sifter has eccentrically positioned rod and rotational plate to create horizontal reciprocal action, thus there is no proper vibration occurred in several directions without adjustable mean. This is the reason for lower screening efficiency of it.This project aims to develop and introduce an efficient flour sifter with low energy consumption for medium scale flour processors to enhance their production capacity.

MATERIALS AND METHODS

The vibro flour sifter was developed in the workshop of Institute of Post Harvest Technology, Anuradapura. The machine was evaluated for screening efficiency and energy consumption. Also it was compared with the available horizontal flour sifter.

Design: Design was done by considering available material and requirement of the flour industry. Flour sifting area was selected considering available horizontal flour sifter. The vibration frame of the sifter was selected as 25 *x* 25 *x* 5mm angle iron and base structure fabricated using 50 *x* 50mm box bar. BSS 100 mesh (150 μ) was use as the requirement of the flour industry. Feed hoper and covering plate was produced using 1.5mm BI sheet. Sifter was mounted in base frame using rubber mounts which absorb the yibration. Vibration motor which has power of 0.75 kW was used to create required vibration on sifter. Feed hopper which was fixed above the sifter controls the feeding rate of flour.

Evaluation of the sifter: Ten kg of rice flour was ground in a plate mill and used for evaluation. Sieving time, amperage, amount of flour that passes through the sifter screen were measured. Performance was evaluated considering capacity, power requirement and screening efficiency.

First the machine was optimized by optimizing vibration of the mortar by increasing the angle between the eccentric mass of the motors step by step. Suitable angle was selected as 90^{o} and screening time was selected as 8 min by considering the preliminary results. The performance of machine was evaluated using following equations.

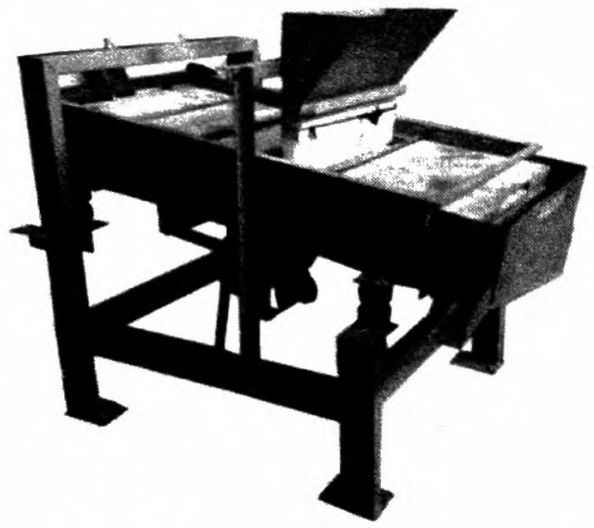


Fig.1. Vibro-Rice flour sifter

Capacity(C) = weight of feeding flour /Time for fine flour separation ----------(1)

Power (P)= $\sqrt{3}\ vicos\emptyset$ ----------(2)

Fine flour % in course flour after sifting = $\left(\frac{w2}{w1}\right)x100$----------(3)

W_1-Sample weight of coarse flour after sieving in sifter

W_2- weight of separated fine flour from coarse flour in sieve analysis

Sieve analysis: A set of standard Tylar sieves was used for sieve analysis of rice flour. The selected sieves were 150, 106, 75, 53 μ net and the pan. The set of screens were arranged serially in stack and vibration sieve shaker was used for uniform vibration of the screen set. Each treatment with 200g of rice flour was treated in sieve shaker at 15 min. Amount of coarse flour retained on 150 μ was measured and then fine flour that passes through the net was calculated. Then using the equation (3), separation efficiency of the machine was calculated.

Cost benefit: Cost benefit or processing cost per hour was calculated by considering the cost of electrical unit and power requirement. The cost of electrical unit was taken as 13.50 LKR.

Electrical cost per h= Cost of electrical unit × power requirement---------- (4)

Electrical cost per kg = Electrical cost per h/ capacity per h---------- (5)

Labor cost per kg = cost of labor per h/capacity per h of the flour sifter--------- (6)

The most commonly used horizontal flour sifter was also evaluated and the results were compared with the developed vibro flour sifter. Screening efficiency of this machine was checked at 8 min and sieving was continued until separation of all fine particles to find the capacity.

RESULTS AND DISCUSSION

Average data on machine performance parameters of the developed vibro sifter and existing horizontal flour sifter are shown in the Table 1. Following assumptions were made during calculations.

Assumptions:

Cost of electrical unit - Rs. 13.50
Labour cost per day - Rs. 700.00

Table 1. Comparison performance results of the developed vibro- sifter and existing horizontal sifter

Performance Parameters	Developed Vibro sifter	Horizontal flour sifter
Capacity (kg/h)	140.18	66.35
Electrical power consumption (kW)	0.61	1.78
Processing cost (LKR./kg)	0.06	0.36
Fine flour % in course flour after sifting	3.82	5.05
Loss during sifting (%)	1.69	1.95

Capacity of the machine: Average capacity of the developed machine was 140.18 kg/h. This capacity is well suited for present medium scale rice flour processors. When comparing with the capacity of existing horizontal flour sifter (66.35 kg/h), the capacity of vibro- sifter is more than double (Table 1). Therefore, capacity of the developed machine is in satisfactory level.

Power consumption: Power consumption of the developed machine is 0.61 kW. This result is significantly lower than that of the existing horizontal flour sifter. Due to the facilitation of vertical and horizontal movement of the developed machine, the separation capacity of the machine has been increased.

Processing cost: The processing cost in terms of electricity in vibro sifter is only 0.06 LKR per kg of rice flour. However, it is 0.36 LKR in the existing horizontal flour sifter. On the contrary to vibro flour sifter, power consumption of the horizontal flour sifter is significantly high. Labor cost of vibro flour sifter is 0.62 per kg, but due to low capacity of horizontal flour sifter, cost of labour for 01 kg is 1.32 LKR. Therefore, cost of processing of the vibro flour sifter is comparatively lower than the horizontal flour sifter.

Fine flour percntage in course flour after sifting: Efficiency of the flour sifter depends on the amount of fine flour retained with coarse flour after sieving. If the retained fine flour with coarse flour is less, the efficiency of the machine is high. According to the Table 1, the percentage of fine flour remaining with coarse flour of the vibro flour sifter is 3.82%. It is reasonably good when value compared to the horizontal flour sifter value that of 5.05%.

Also at this stage, the loss percentage of the vibro sifter was 1.69% whereas, in horizontal flour sifter it was 1.95%.

CONCLUSION

A Vibro-floor sifter was designed, developed and evaluated at the workshop of Institute of Post-Harvest Technology, Anuradhapura. The viro-flour sifter exhibited higher capacity and higher screening efficiency in contrast to the existing flour sifter. The developed machine also demonstrated low power consumption and low processing cost compared to the existing horizontal flour sifter. The developed vibro flour sifter also showed high performance than the commonly available horizontal flour sifter.

REFERENCES

Bean MM, CA Esser and KD Nishita (1984). Some physicochemical and food application characteristics of California waxy rice varieties. Cereal Chem. 61(6): 475-479

Chen JJ, S Lu and CY Lii (1999). Effect of milling on the physicochemical characteristics of waxy rice in Taiwan. Cereal chem. 76 (5): 796-749.

Halick JV and VJ Kelli (1959). Gelatinization and pasting characteristics of rice varieties as related to cooking behaviour. Cereal Chem. 36: 91-99.

Nishitha KD and MM Bean (1982). Grinding methods their impact on rice flour. Cereal Chem. 59 (1): 46-49.

Sahay KM and KK Singh (2001). Unit Operations of Agricultural Processing. Vikas Publi., New Delhi.

Design and development of a low cost grain flour blending equipment

BDMPB Dissanayake*, HS Jayawardena and BMKS Thilakarathne
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka.
*Corresponding author: bandaraipht@yahoo.com

ABSTRACT

To reduce the consumption of wheat flour in the country, one of the major solution is to introduce flour mixtures prepared with rice flour and other locally produced grains flour to the market and flour based food processors, since it has a great demand even now. Blending equipments are essential to produce flour mixture with uniformly distributed particles. Flour blending machines are available in the international market. But they are very expensive and those are not in an affordable price to purchase for even medium scale flour producers. Therefore a low cost grains flour blending equipment was designed and developed under this project to introduce for flour producers. Developed grain flour blending equipment was tested with blending rice flour and wheat flour with the ratio of 3:7 which is generally used as a mixture for preparing bread. It was found that the minimum blending time required for giving an uniform mixture was 3 minutes when equipment was operated at 51 rpm. Capacity of the equipement was 50 kg per batch and it was operated by a 3 Hp electric motor.

Keywords: Blending machine, grains, mixtures, processors, rice flour

INTRODUCTION

Increasing the availability of rice flour and other locally produced grain flour by developing flour processing industry in the country and popularizing the foods prepared with theses flour among the people, it could be able to reduce the consumption of wheat flour in the country within few years. To reduce the consumption of wheat flour further, one of the major solution is to introduce flour mixtures prepared with rice flour and other locally produced grains flour to the market and flour based food processors, since it has a great demand even now. According to the research findings, any food item that is prepared with wheat flour can be prepared adding 20% rice flour by following the same manufacturing methods. So it can be introduced rice flour to the bakery and other flour based food industries and also rice flour blended wheat flour can be introduced instead of wheat flour for wheat flour consuming peoples in upcountry for their favorite food item called rotti. Some bakery owners are now started to prepare bakery products such as breads, biscuits, cake with rice flour or wheat flour blended rice flour. In this regards the problem has been faced by the bakery owners and other flour based food manufactures is finding suitable flour mixtures for their products, since it is difficult to find flour mixtures in the market. How ever, a few flour processors in the country have introduced blended flour (eg: rice flour + wheat flour, rice flour + finger millet flour etc.) to market and there is good demand for their products. The blending of flours is basically done by these processors by manually with the help of spoons and plastic vessels. This method besides being time consuming, laborious

and inefficient, the final product is not in uniform. Flour blending machines are available in the international market. But they are very expensive and those are not in a range that possible to purchase for even medium scale flour producers. Therefore a low cost grains flour blending equipment was designed and developed under this project to introduce for flour producers. Performance of the developed equipment was evaluated.

MATERIALS AND METHODS

Design description: Considering maximum space required for a batch size of grain flour under design condition, dimension of casing and hopper were selected. Size of the blades were selected according to the inside dimension of the cylindrical mixing drum. Materials were selected for a hygiene design. Various components of the equipment were designed with the help of the standard relations in a textbook of machine design (Khurmi and Gupta 1993). Power requirement was calculated by using the relevant formula(Kazembe 2005). Considering nearest available values of the material and also the available facilities for fabrication the dimension of the components were selected.

Design: The volumetric capacity of the equipment is 178 L. Figure 1 shows the grain flour blending equipment. It consists of a hopper, closing door, cylindrical mixing drum, mixing blades assembly, power transmission assembly, discharging plate and frame. A cylindrical drum with diameter 600 mm and 600 mm length was fabricated using 18 BWG (1.5mm) SS-304 sheets and use as the flour mixing chamber. A hopper with a cross sectional dimension of 225 *x* 600 mm and 25 mm height is fitted to cylindrical drum. The hopper was fabricated using 18 BWG (1.5 mm) SS-304 sheets. A rectangular door having cross sectional area of 275 *x* 600 mm, fabricated using 18 BWG (1.5 mm) SS-304 sheets was hinged to the hopper and it was used as the closing door. Three pieces os SS-304 pipes having 12.5 mm diameter and 100 mm length were welded to the other side of the closing door and door can be locked by fastning a 6 mm SS rod through three pieces of pipes welded to the closing door.

A hollow shaft was fixed at the centre axis of the cylindrical drum and three SS-304 flat blades having cross sectional area 50 *x* 5 mm and 575 mm length were bolted to the arms welded to the hollow shaft. Blades have been fixed with 120° angular distance to each. The location of the blades can be changed. Another three blades having same dimension as described above were bolted to the arms welded to the inner periphery of the cylindrical drum. Each blades were bolted to three arms. The cylindrical mixing drum containing blades, hopper, clossing door was fixed to rigid frame by using a 25 mm diameter mild steel shaft running through the hollow centre axis shaft and two pillow block bearing fixed at the ends of the shaft. Two 6 mm diameter SS rods were attached to the closing door as the controller for the door opening. Closing door can be kept at the a place by fixing the rods by a locking mechanism fixed to the cylindrical drum. Discharging plate was fabricated using 18 BWG (1.5 mm) SS-304 sheet and fixed at the bottom of the cylindrical drum. Discharging plate has a 40° angle to the horizontal direction. The equipment is mounted on the rigid frame is made of mild steel angles. The rigid frame was fabricated by using 37.5 *x* 37.5 mm angles having 5.5 mm thickness. Frame has the overall dimensions of 600 *x* 725 *x* 1100 mm. Power required to rotate the mixer was given by a 3Hp, three phase electrical

motor fixed to the frame. Rotational speed of the motor is 1440 rpm. A rotational speed of 51 rpm was given to the cylindrical mixing drum by reducing the motor speed with two belt drive systems having speed reduction ratios of 3:14 and 3:18 as shown in the figure. A cast iron pulley having 75mm diameter was fixed to the motor shaft and power was transfered to 350mm diameter cast iron pulley fixed in a intermediate shaft. Intermediate shaft was made up of mild steel and having 25 mm diameter was fixed to the frame at place where 250 mm above the motor. Power from the intermediate shaft to the cylindrical drum mixer shaft was transmitted by a V belt using a 75 mm diameter cast iron pulley fixed to intermediate shaft and 450 mm diameter cast iron pulley fixed to the mixer drum shaft. The machine was fixed on the ground by using bolts to provide the stability when machine is in operation.

In operation, mixing drum was held in a up position and flour were put to the machine. Then the door was closed and locked. Power supply was switched on and mixing was done for a few minutes time. Then power was switched off. The speed of the machine was gradualy reduced and come to stationary. Mixing drum turn to a position that the hopper come to the bottom and then the door was unlocked and opened slowly and fixed in a position with the help of door controlling devices. Then flour mixture was discharged from the machine.

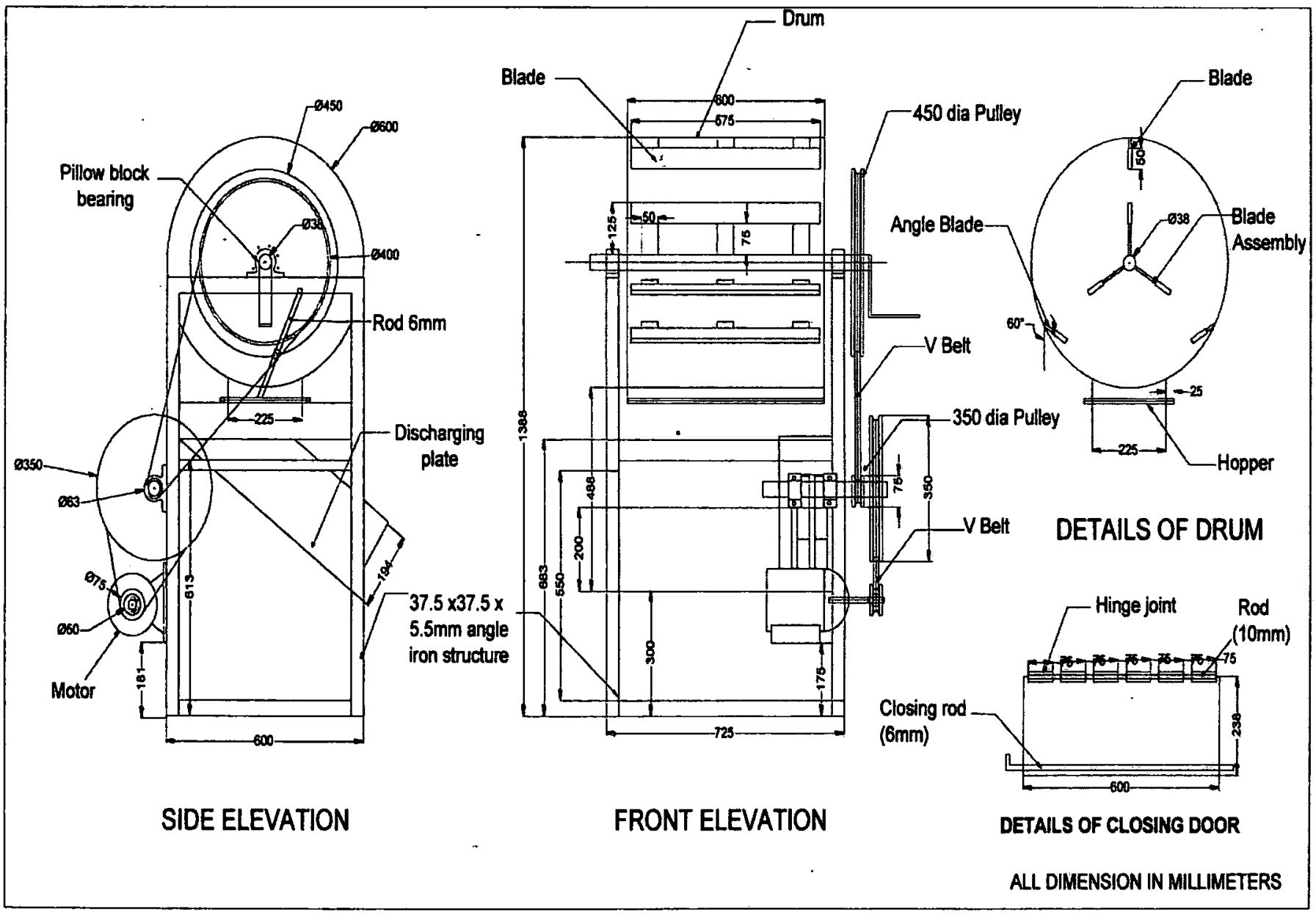


Fig. 1. Diagram of grain flour blending equipment

Experimental procedure: Grain flour blending equipment was tested with blending rice flour and wheat flour with the ratio of 3:7 which is generally used as a mixture for preparing

bread. The capacity of the blending equipment was 50 kg per batch and rotational speed of the blender was 51 rpm. 35 kg of wheat flour and 15 kg of rice flour were put to the blending equipment and blending was done with different time periods (1, 2, 3 and 4 min) and three replicates with each batch. The performance of the blending equipment was evaluated with regards to the time required for blending to give an uniform mixture. The uniformity of the blended mixture was evaluated with gluten content and particle size distributions. Four samples were taken from four different places in the blender to find the uniformity in each trails. Determination of Gluten (SLS 144, 2003) was done by following SLS method. Particle size distributions were measured by using the impact laboratory test sieve shaker (modle: YGM15418). 150, 125,106, 90 and 75 μm sieves were fixed to the sieve shaker. A sample of 200 g was put to the sieve shaker and it was operated for 20 min. Particle size distributions were calculated by measuring weight of the materilas retained in each sieves.

RESULTS AND DISCUSSION

Table 1 shows the gluten content at different places of flour mixture with mixing time. Data were statistically analized and it was shown that gluten content was not significantly different when mixing time was 3 min and more. Table 2 shows the percentage particle size distribution at different places of flour mixture with mixing time. Data were statistically analyzed and it was shown that percentage particle size distribution was not significantly different when mixing time was 3 minutes and more. According to the results, it can be concluded that the minimum mixing time require to give a uniform flour mixture is 3 min.

Table 1. Gluten content at different places of flour mixtures with mixing time

Mixing time (Min.)	Gluten % (dry basis) at different places			
	A	B	C	D
1	9.41[b]	10.31[a]	9.41[b]	8.82c
2	9.54[b]	9.45[b]	8.1[c]	9.9[a]
3	9.41[a]	9.38[a]	9.42[a]	9.39[a]
4	9.45[a]	9.45[a]	9.44[a]	9.36[a]

Values followed by different letter within row for each mixing time are significantly different at $p < 0.05$, according to LSD.

Table 2. Percentage particle size distribution at different places of flour mixtures with mixing time.

Mixing time (Min.)	Place	Particle size distribution (%)					
		>150µm	150-25µm	125-06µm	106-0µm	90-5µm	75µm <
1	A	30.68□	56.97^{b}	9.98^{a}	2.12^{a}	0.02^{c}	0.23^{b}
	B	26.87^{d}	69.45^{a}	3.38^{b}	0.23^{b}	0.03^{b}	0.04^{c}
	C	43.19^{b}	52.98^{c}	3.03^{c}	0.27^{b}	0.03^{b}	0.5^{a}
	D	46.94^{a}	50.06^{c}	2.69^{d}	0.16^{c}	0.04^{a}	0.11^{b}
2	A	28.85^{b}	60.39^{d}	7.4^{a}	2.45^{a}	0.5^{b}	0.41^{b}
	B	26.67^{d}	64.26^{b}	6.34^{b}	1.8^{b}	0.47^{b}	0.46^{a}
	C	27.92^{c}	62.34^{c}	6.38^{c}	2.43^{a}	0.57^{a}	0.36^{d}
	D	30.01^{a}	65.63^{a}	2.33^{c}	1.36^{c}	0.28^{c}	0.39^{c}
3	A	27.45^{a}	65.31^{a}	5.07^{a}	1.13^{a}	0.54^{a}	0.5^{a}
	B	27.41^{a}	65.32^{a}	5.08^{a}	1.15^{a}	0.53^{a}	0.51^{a}
	C	27.4^{a}	65.35^{a}	5.06^{a}	1.16^{a}	0.52^{a}	0.51^{a}
	D	27.42^{a}	65.3^{a}	5.1^{a}	1.17^{a}	0.51^{a}	0.5^{a}
4	A	27.46^{a}	65.32^{a}	5.09^{a}	1.14^{a}	0.5^{a}	0.49^{a}
	B	27.4^{a}	65.33^{a}	5.1^{a}	1.15^{a}	0.54^{a}	0.48^{a}
	C	27.43^{a}	65.35^{a}	5.02^{a}	1.18^{a}	0.52^{a}	0.5^{a}
	D	27.45^{a}	65.29^{a}	5.04^{a}	1.13^{a}	0.57^{a}	0.52^{a}

Values followed by different letter within column for each mixing time are significantly different at $p< 0.05$, according to LSD.

REFERENCES

Kazembe HW (2005). Approaches to Successful Development of Low-Cost Fruit Juice Extraction Technologies: A Case Study to Improved Rural Livelihood in Malawi. Tropentag, Stuttgart-Hohenheim, pp 3.

Khurmi RS and Gupta JK (1993). A Text Book of Machine Design, 2nd ed., Eurasia Publishing, New Delhi, 614-625.

SLS 144 (2003). Determination of Gluten. Sri Lanka Standard Specification for wheat flour, 1st revision, pp10.

Development and testing of pedal-cum-motor operated paddy cleaner

DP Senanayaka*, HMAP Rathnayake, BDMP Bandara and TMR Dissanayake
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka.
*Corresponding author: dumindra28@yahoo.com

ABSTRACT

Paddy parboiling at rural level of small scale capacity is practiced at villages in major paddy producing areas of Sri Lanka. They are using either the small scale method introduced by IPHT or *Goviya* method for parboiling. The daily capacity of these small scale processors is around 150-300 kg per day. Grain should be cleaned and graded before parboiling and processing. At present paddy is cleaned at paddy field either combine harvester large scale farmers or manually by the natural wind by small scale farmers. The objectives of this project are to develop a low cost and small capacity cleaner for cleaning paddy of small scale farmers and processors and to determine the machine operating parameters for effective separation of paddy grains. The work has been done india by Kachru and Sahay in 1990 for other grain such as wheat, soy been and chikpea. The capacity of their cleaner 350-600 kg/h for pedal operated cleaner.he purity of the seperated grain was in between 99.6-99.9%. Screen effectiveness of 71.3% to 99.6% for different raw materials. However they have not tested the machine for paddy. We have found that the machine is capable of cleaning 250-500 kg of paddy per hr, the purity of separated grain95%, and screen effectiveness is 55-72% for paddy.

Keywords: Paddy cleaner, cleaning of paddy

INTRODUCTION

The harvested paddy should be cleaned before parboiling or milling in order to obtain high price for their product. The harvested paddy normally consists of impurities such as, stones, weed seeds, eggs of insects and mud particles. If the paddy harvest could be cleaned and de-stoned, a longer storage life can be expected. Small scale processors do not have cleaners for this purpose. They de-stoned by hand sieves. If there is a cleaner suitable for farmers or small scale processors they can clean the paddy and obtain high quality product for both parboiling and processing. Cleaning and grading would results in reduced bulk of the material, high value products, safe and longer storage, increased the life time of the machinery, more out turn of better quality milled product, and pure by-products.

The objectives of this project are to development of a low cost and small capacity cleaner for cleaning paddy for small scale farmers and processors and to determine machine and operating parameters for effective separation of paddy grains.

ureDesign proceed

The Torque transmitted by the driven pulley shaft

$$T_e = \frac{P_e \times 60}{2\pi N} = \frac{(30 \times 1000 \times 60)}{2 \times \pi \times 700} = 409\ Nm \quad \text{----------(1)}$$

The equais used for t 1tion he measurem ent of tensiletestof the eccentric drive and equivelent ben dingmoments were calculated using the following formula.

Equivalent twisting moment:

$$T_e = \sqrt{T^2} + M^2 = \sqrt{134464^2} + 40.92^2$$

=134.646 Nmm.

$$= \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times \tau \times d^3 =$$

$=8.25d^3$, d=25.36mm

the diamerer of the eccentric play disc was 106.16 mm was selcted.

Fatigue stress concentration factor for reversed bending

$$K_{fb} = 1 + q(K_{tb} - 1) = 1 + 0.9(1.44 - 1) = 1.396$$

Since the correction factor for reversal bending load is 1 (i.e. $K_b = 1$)

Therefore the endurance limit for reversed bending load

$$\sigma_{eb} K_b = \sigma_e = 300 \frac{N}{mm^2}$$

The equivalent normal stress due to bending

$$\sigma_{neb} = \sigma_m + \frac{\sigma_v \times \sigma_y \times K_{Fb}}{\sigma_{eb} \times K_{sur} \times K_{st}} = \frac{30550}{d^3} + \frac{152750 \times 330 \times 1.396}{d^3 \times 300 \times 0.9 \times 0.85} = \frac{337168}{d^3}$$

Total equivalent normal stress

$$\sigma_{ne} = \sigma_{neb} + \sigma_{nea} = \frac{337168}{d^3} + \frac{1428}{d^2}$$

That equivalent normal stress

$$\sigma_{ne} = \frac{\sigma_y}{F.S.} = \frac{330}{2} = 165 \frac{N}{mm^2}$$

$$\frac{337168}{d^3} + \frac{1428}{d^2} = 165 \frac{N}{mm^2} = \quad \text{d=12.9mm} \quad \text{Safety factor was used as 2.}$$

Main shaft diameter was selected as 25.4 mm

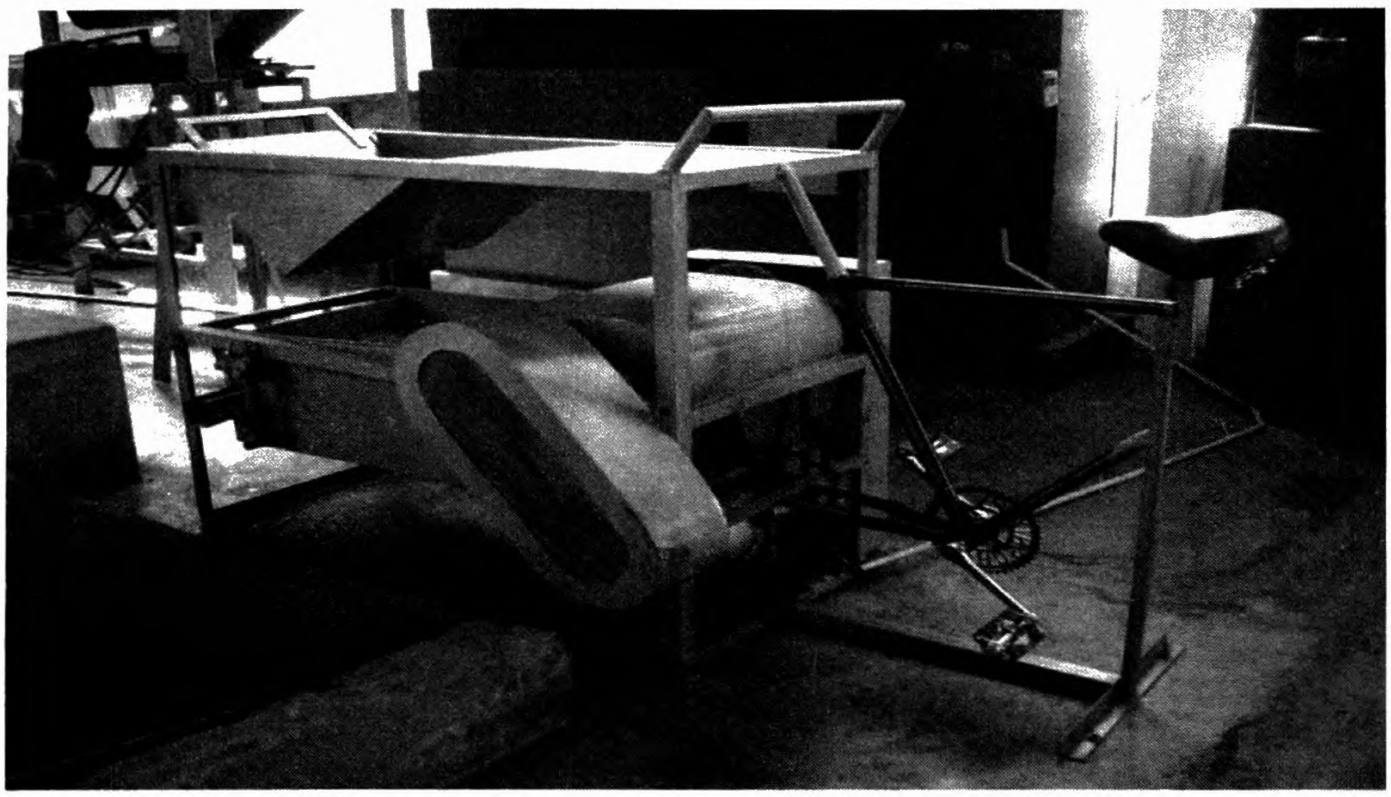


Fig.1. Developed pedal –cum-motor operated paddy cleaner

MATERIALS AND METHODS

The cleaner was fabricated at the workshop of Institute of Post Harvest Technology. Components of the cleaner are: Grain hopper; Feeding Hopper; Separating sieve box; Blower unit; Eccentric unit for driving; Motor drive unit and Pedal operated bicycle unit. Angle Iron of size 38.1*x*38.1*x*3.175 mm was used for the main frame of the cleaner; 25.4 mm diameter iron tube was used for the bicycle frame. 0.75 kW single phase motor was used to drive the main shaft of the cleaner. The main shaft is 25.4 mm diameter round bar. Bicycle sprocket wheels were used as the driving mechanism in pedal operated mode. Gauge 16 sheets were used for fabrication blower vanes. Gauge 18 sheets were used for fabrication of blower casing. Gauge 16 sheet was used for sieve box. 25.4*x*25.4*x*3.175 mm angle iron was used for brazing of blower unit and main frame. Gauge 18 sheets were used to cover the cleaner. Mesh number 6 and 10 wire meshes were used as sieves inside the sieve box. Eccentric unit was fabricated by 12.7 mm thick mild steel sheet.

Testing methodology was as follows. Physical properties of the paddy were determined. Testing of the cleaner by feeding paddy, will be carried out and following results are to be find out, Cleaning capacity (kg/h), Purity of the cleaned grain (%), Screen effectiveness (%), Sieve size, machine and operating parameters, screen dimensions, screen pitch, hopper capacity, length of the stroke of sieve box, rpm of the eccentric unit, rpm of the blower unit, air capacity at blower outlet and winnowing section.

One ton of paddy from each was procured from different farmers. The samples were analyzed by AAOC standard methods, for identification percentage of each foreign matter present in the sample and for the determination of physical properties viz size (length, width, diameter), thickness, specific gravity.moisture content and 1000 grain weight.

RESULTS AND DISCUSSION

Samples drawn from three paddy varieties were analyzed in the laboratory and their physical Properties were shown in the Table 1.

Table 1. Physical properties

Sample	Length (mm)	Breath(mm)	Width(mm)	Bulk density (g/mm^2)
Short	5.9	2.04	2.86	234.2
Medium	7.75.	2.07	2.89	248.13
Long	9.33	2.08	2.75	234.74

The condition of initial samples were given in the table 2. Good Cleaner should be able to remove impurities completly , the varital admixture and the chaff.

Table 2. Quality parameters of paddy

Sample	Moisture content (%)	Impurities (%)	Type admixture (%)	Discolored Grain (%)	Chaff by volume
Short	13.73	0.14	0.86	1.39	12.00
Medium	13.76	0.27	2.52	2.15	16.00
Long	12.67	1.36	2.56	1.98	15.00

Table 3. Cleaning capacity (kg/h)

Sample	Cleaning capacity (kg/h) (motor operated)			Screen effectiveness (%)
Short	514.8	435.6	350	53.31
medium	286	253.2	273	72.29
lomg	303	200.0	305	57.42

As shown in the Table 4 the machine was incorporated a sprocket and chain drive in order to facilitate to continue the machine operation.

Table 4. Machine specifcation of the cleaner

Opertating mode	Overll dimensions (mm)	Total weight (kg)	Type of drive	Power requirment
Pedal operated	1600*x*500*x*1000	100	Sproket and chain	Manual (pedal)
Motor operated	1600*x*500*x*1000	110	v belt and pulley	1.0HP,1450 rpm elecrtic motor

CONCLUSION

The developed paddy cleaner is suitable for small scale paddy processorers in rural areas in Sri Lanka.Capacity of the the cleaner is around 350 kg per hour. The cost of the machine is 85000 LKR with the single phase motor.While in the pedal driving mode, the capacity is around 200-500 kg/h. One person can operate the cleaner, also it can be operated with 15 A current supply are an additional advntages.

REFERENCES

Kachru RP and Sahay KM (1990). Development and testing of pedal cum power operated air screen grain cleaner, Agricultural Mechanization in Asia,Africa and Latin America,Vol 21,No.4

Khurmi RS and Gupta JK (2005). Textbook of machine design, Eurasia Publishing House (pvt) LTD. Ram Nagar,New Delhi 110 055.

Evaluation of medium scale IPHT maize thresher

HMAP Rathnayake, DP Senanayake BDMPB Dissanayake, DMSP Bandara, KB Palipane and BMKS Thilakaratne
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka.
*Corresponding author: dumindra28yahoo.com

ABSTRACT

This study aims to evaluate a power driven maize thresher developed by Institute of Post Harvest Technology to optimize the threshing efficiency while reducing the cost of processing and time consumption for threshing. At optimum machinery settings (*i.e.* speed of 550 rpm), the machine capacity was 456.71 kg/h giving maximum threshing efficiency of 99% under 12% average moisture content of cobs. The optimum cleaning efficiency was 75% and power consumption for processing one kg of maize cobs was 0.48 kW/h. After threshing, percent broken grains, cracked grains and bruised grains were 3.06, 6.26 and 4.62 respectively

Keywords: Maize, maize thresher

INTRODUCTION

Maize is a food preferred by almost all groups of people including children, youths and adults. It is botanically know as *Zea maize* and can be grown in many parts of Sri Lanka. Maize is a popular cultivation among Sri Lankan *Chena* farmers since ancient times. At present, the demand for maize has begun to increase and the farmers are also keen on cultivation of it in their paddy fields during *Yala* season. Since maize is grown as a commercial crop, the land extent under maize cultivation is increasing resulting in increased production, thus the framers' revenue. Maize contributes the nutritional requirement of the nation. It is used in preparation of weaning foods like *Thriposha* as an ingredient in animal feed and in certain other food items. More than 75% of the harvest is sold at the field itself while the rest is stored for consumption later.

After drying, seeds have to be separated from the cobs for utilizing in different purposes and this process is known as threshing. Various methods are being used by farmers for performing this task. Small scale farmers tend to dry maize pods under sunlight followed by separation of seeds either by hand, bashing with stick or beating the pods enclosed in a gunny bag which consume a lot of time and labour. Moreover, this practice results in heavy damages to the seeds, incorporate a significant amount of impurities leading to poor quality of the produce which ultimately affect lower demand for locally produce seeds. It is quite evident that, medium and large-scale farmers can use two wheel tractors for separation of seeds. This also results in seed damages and addition of impurities. Damaged maize seeds are more prone to attack by fungus like *Aspergillus sp.* which produce carcinogenic compound called aflotoxin.

MATERIALS AND METHODS

Medium scale maize threshing machine was developed by the Institute of Post Harvest Technology as per the requirement of the processors and it is shown in Figure 1.

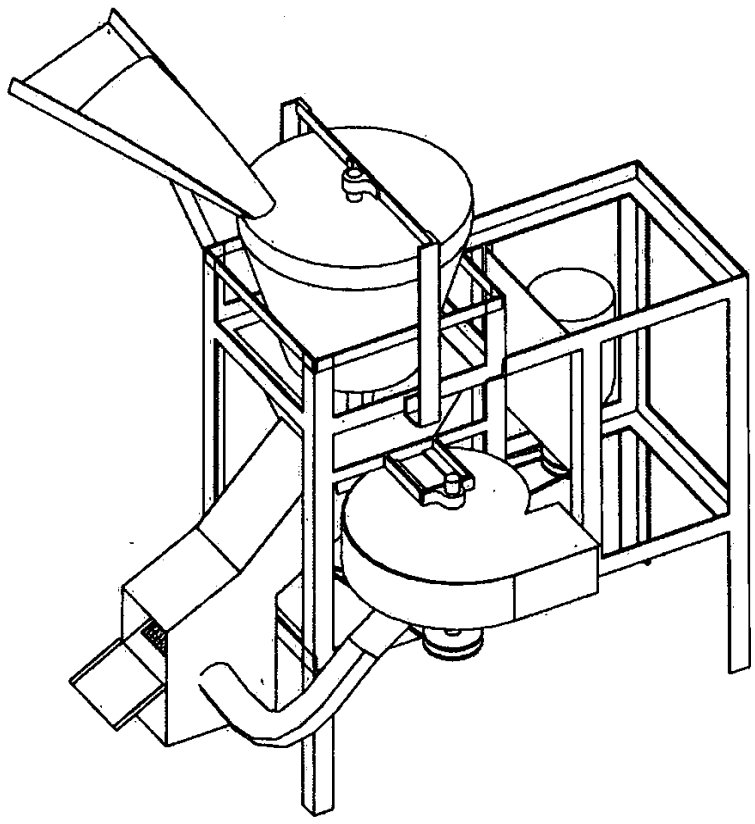


Fig. 1. IPHT Maize threshing machine

The machine consists of conical shape rotating inner drum and stationary outer drum which are in vertical direction. Inner drum consists of small wire loops and resistance bars.The gap between the drums were slightly reduced from top to bottom. Wire loops facilitate applying forces on the seeds when rotating and resisting bars.

Lower part consists of wire mesh to separate the seeds and cobs. Blower was fixed at lower part to separate light impurities from the seeds. Selected size of pulley and belt were used to maintain the power transmission. Feed hopper was fixed on the top part of the machine to facilitate feeding. Mounting structure was formed in 500 mm angle iron bars.

The machine was fixed on the ground to provide stability for driving operation. Three-horse power motor was used to supply required power for the machine. Dried maize was fed into the processing chamber through feed hopper one by one. Seeds were removed from the cobs in processing chamber with high efficiency. Then, the lower mesh separated the seeds from the remnants. Remaining light impurities were blown off by the blower at the lower part.

The performances of the thresher in terms of capacity, grain separation efficiency, cleaning efficiency and percent broken grains were evaluated against different drum speeds of the developed thresher. The data were statistically analysed using SAS statistical package.
The capacity of the maize thresher (cobs/h and kg/h) was calculated by using equation (01).

$$Capacity(kg/h) = \frac{Weight\ of\ input\ cobs(kg)}{Time\ (Sec)} X\ 3600 \quad [01]$$

The power consumption was calculated by:

$$P = V\ I\ Cos\phi \quad [02]$$

The cleaning efficiency was calculated by:

$$Cleaning\ efficiency = \frac{weight\ of\ cleaned - weight\ of\ manual\ cleaned}{Weight\ of\ without\ cleaned - Weight\ of\ manual\ cleaned}\ x\ 100 \quad [03]$$

The separation efficiency was calculated by:

$$Separationefficiency = \frac{Total\ shelled\ seeds}{Total\ shelled\ seeds + Unshelled\ seeds} x100 \quad [04]$$

The percent damaged grains was recorded as broken, cracked and bruised grains and calculated by equations 5, 6 and 7 respectively.

$$Percentage\ of\ Brokens = \frac{Weight\ of\ broken\ grains\ in\ sample}{Total\ weight\ of\ sample} X100 \quad [05]$$

$$Percentage\ of\ Cracks = \frac{Weight\ of\ cracked\ grains\ in\ sample}{Total\ seight\ of\ sample} X100 \quad [06]$$

$$Percentage\ of\ Bruised = \frac{Weight\ of\ bruised\ grains\ in\ sample}{Total\ weight\ of\ sample} X100 \quad [07]$$

RESULTS AND DISCUSSION

Table 1. Performance parameters of the IPHT maize thresher at different drum speeds.

Drum Speed	Capacity (kg/h)	Power consumption (kW)	Cleaning efficiency (%)	Separation efficiency (%)	BG (%)	CG (%)	BR (%)
450	404.89[b]	0.4462[a]	72[a]	98.94[a]	2.68[b]	6.81[b]	1.72[b]
500	456.71[ab]	0.4621[a]	73[a]	99.36[a]	2.31[b]	6.16[b]	4.28[ab]
550	467.03[a]	0.4780[a]	75[a]	99.37[a]	3.06[ab]	6.26[b]	4.62[a]
600	475.45[a]	0.4940[a]	77[a]	99.39[a]	4.28[a]	8.78[a]	4.78[ab]

BG: broken grains, CG: cracked grains, BR: bruised grains

According to Table 1 and Figure 2, it is evident that, when the drum speed is increased, the percent brokens, cracked and bruised grains are also increased. However, at 600 rpm, the cracked grain as well as brokens percentages was significantly higher than the other speeds.

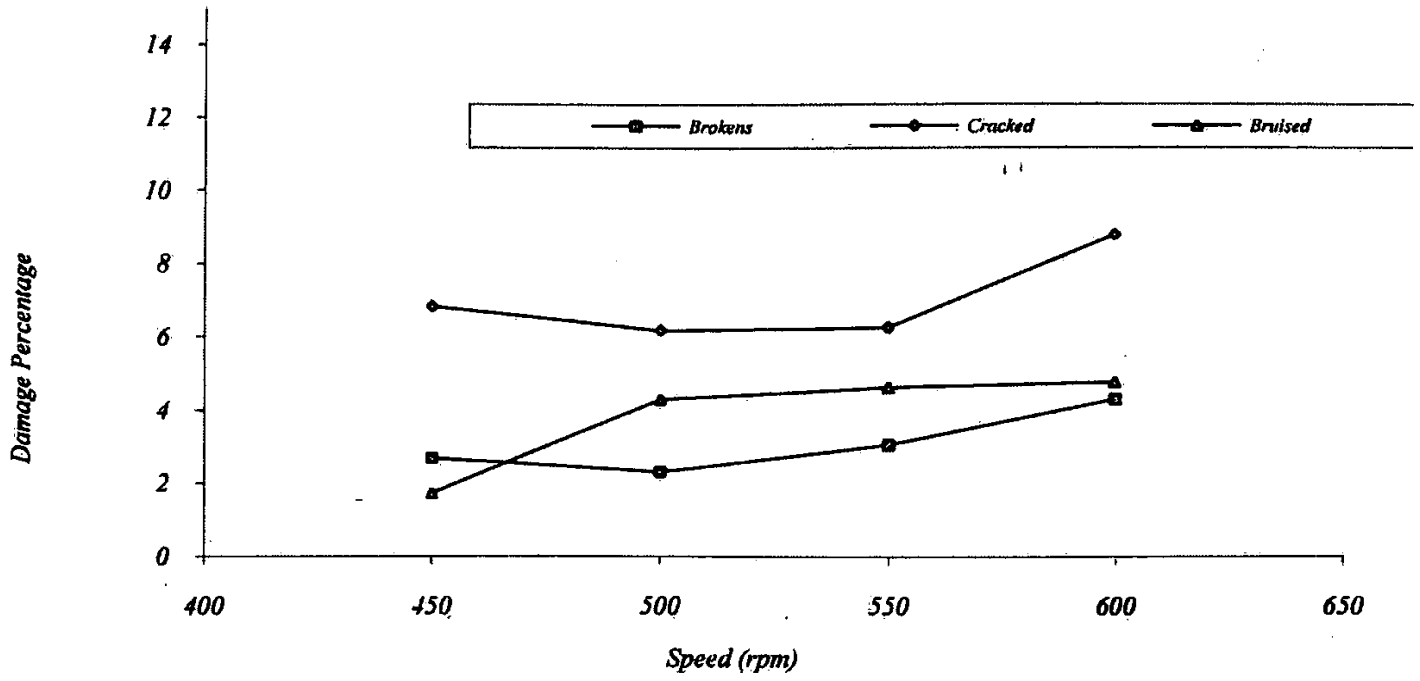


Fig. 2. Percent damaged grains at different drum speeds

Power consumption, cleaning efficiency and separation efficiency were not significantly different from each other. Obviously, the quality depletion started at 600 rpm. Considering the other three speeds, capacity at 500 and 550 rpm were not significantly different from each other. Not only the capacity but also other parameters (*i.e.* power consumption, cleaning efficiency, separation efficiency, broken grain,cracked grain and bruised grain) at these two speeds were not significantly different from each other. Therefore, 550 rpm, which gave a capacity of 467.03 kg/h was identified as the optimum position of the machine.

CONCLUSION

The machine performance at the drum speed of 550 rpm which gave the capacity of 467 kg/h is well enough for the medium scale processors and can be recommended to use in the industry.

REFERENCES

Nwakairea JN, Ugwuishiwub BO and Ohagwuc CJ (2011). Design, construction and performance analysis of a maize thresher for rural dweller. Nigerian Journal of Technology, 30(2): 49-54.

Watson A, Stanly Ramastd E and Paul (1987). Corn: chemistry and technology. American assosiation of cerial chemiststry. Inc. St.Paul, Minnesota USA

Macken CN, Erickson GE and. Klopfenstein TJ (2006). The cost of corn processing for finishing cattle 1. Journal of Professional Animal Scientist 22: 23–32.

Owens FN, Secrist DS, Hill WJ, Gill DR (1997). The effect of grain source and grain processing on performance a review. Journal of Animal Science. 75(3): 868-879.

http://www.journal.au.edu/au_techno/2009/jan09/12(3)8MaizeThreshing.pdf

Evaluation of rasp bar mill for size reduction of maize

DP Senanayaka*, HMAP Rathnayake, BMKSThilakarathne, BDMP Bandara and TMR Dissanayake
Research and Development Center, Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura 50000, Sri Lanka.
*Corresponding author: dumindra28@yahoo.com

ABSTRACT

Maize (*Zea mays*) is an important coarse grain cereal crop grown and maize milling is one of the arising agro-based industry in Sri Lanka at present. After shelling, maize gritting is the first step of dry milling which, leads to separation of bran and germ from the endosperm and passing through the screen. The aim of this project is to design and development of rasp mill for size reduction ofmaize seeds.for differerent pourposes The fabricated rasp bar mil is capable of feeding maize around 180 kg/h, delevering percentage of grits 90%, seive effectivness 90 100% at a power requirment of 800 1400 w, for different seive perforation size. (*i.e.* 5,6,7,8 mm).The good result shows at 6 mm perforations of sieve at maize moisture content of 8%

Keywords: Size reduction, rasp bar mill, maize gritting -----

INTRODUCTION

Maize (*Zea mays*) is the most important coarse grain cereal crop in the Lowland cropping systems, such as Badulla, Moneragala, Ampara, Anuradhapura and Batticalo where in dry zone of the country as well as in the Uplands like Matale , which around 30,000 ha of land area devoted annually, the second highest extent of land next to rice in Sri Lanka (DOA 2006). Total Maize production of the country was 202.3 million metric tons in 2012 (Central Bank of Sri Lanka 2012). Maize is utilizing mainly for local consumption, Thriposha production, livestock feed formulation and other industries. In addition to that we import maize products such as corn flakes, corn oil, corn starch and corn flour for different uses. Virtually maize is utilized for production of over 500 different products and bi-products worldwide (DOA 2006).For the rural farmers to maximize profit from their maize, appropriate technology that suites their needs must be used. The processing of agricultural products like maize into quality forms not only prolongs the useful life of these products, but increases the net profit farmers make from mechanization technologies such products. One of the most important processing operations done to bring out the quality of maize is milling. There are two methods of milling, *i.e.* dry milling and wet milling. Gritting or size reduction is one of the operations in dry milling. There is no machine in Sri Lanka for this purpose. The objective of this project is to fabricate and evaluate an affordable gritting machine for size reduction of maize.

MATERIALS AND METHODS

Construction of machine: Maize rasp bar milling or the corn gritting is a kind of dry milling, which can be simply defined as process of impacting corn grains, that leads to grain size reduction and passing through the screen. Electrically operated small scale rasp bar mill has been developed and tested for maize. The mill consists with 5 major components including feeding funnel, grinding chamber, power supplying unit, blower unit and collecting outlet. Grinding chamber cover, the feeding funnel, the cyclone and path to cyclone, safety guards and the blower blades are made of mild steel gauge 18 sheets. Rotor axis, rotor blades and perforated sieves are fabricated by using stainless steel material. Rotor axis is 50 mm round stainless steel bar. Rotor blades are made out of flat stainless steel bar (25 mm *x* 3 mm).Other 1inch diameter axis bars are mild steel material. The underneath stage is made out of 3 mm mild steel sheet and 50 mm angle Iron bars. Canvas rubber belts were used for power transmission.

Grinding chamber consists of 4 sets of rectanguler blades attached to a rotor shaft that leads to size reduction of grains and a sieve, that has round perforations, enclosed the blades to prevent leaving grits from the grinding chamber until they are at least as small as the sieve openings. There are 4 sieves having 5, 6, 7 and 8 mm perforations that can use separately according to the preference. Screen pitch is 10 mm which having 5 and 6 mm perforation size. Also screen pich is 15 mm for screen having 7 and 8 mm perforation sizes. Three horse power (3 Hp) motor supplies power.

Maize grains flowed under gravity to the gritting chamber where impact of revolving gritting occures. Rotor with 4 sets of rasp bars gritted the grain. Pneumatic cleaning is the process of using air to lift light, chaffy and dusty materials out of the grain while heavier materials move downward. Air is generated by mechanical fan. Light materials get collected in to cyclone,of which input is fixed into the grain falling path. The speed of the rasp bar rotor and speed of the fan were kept at 1440 rpm and 2880 rpm respectively in all experiments.

Testing methodology: A study was conducted to develop a gritting unit for size reduction of maize. The performance was evaluated in terms of output capacity, gritting efficiency, power requirement against different moisture levels. Maize grains flowed under gravity to the gritting chamber where impact of revolving gritting occures. Rotor with 4 sets of rasp bars gritted the grain. Pneumatic cleaning is the process of using air to lift light, chaffy and dusty materials out of the grain while heavier materials move downward. Air is generated by mechanical fan. Light materials get collected in to cyclone,of which input is fixed into the grain falling path. The same experiments were carried out at different moisture levels (wb). (8, 9, 10 and 11%).

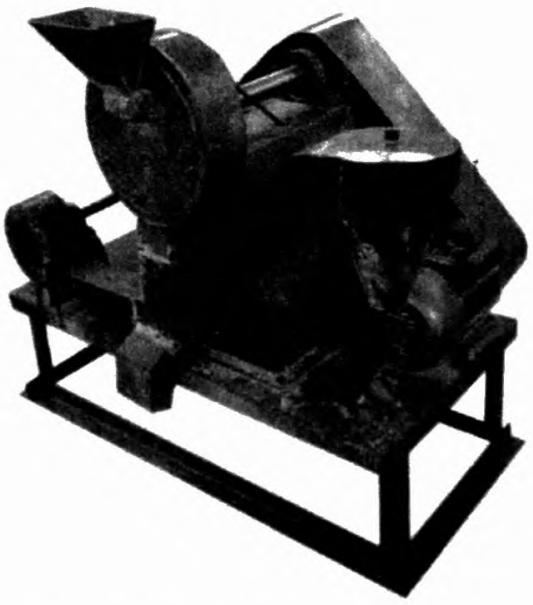


Fig.1. Raspbar mill

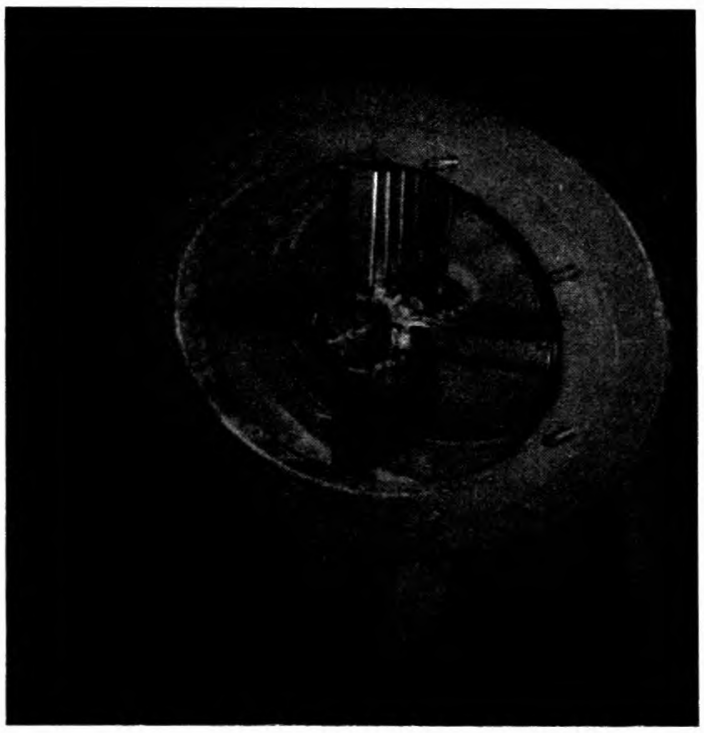


Fig. 2. Inside view of the gritting chamber

RESULTS AND DISCUSSION

Machine was tested at the workshop of Institute of post Harvest Technology.The perpormacnce paramerers shown in figuers given below.

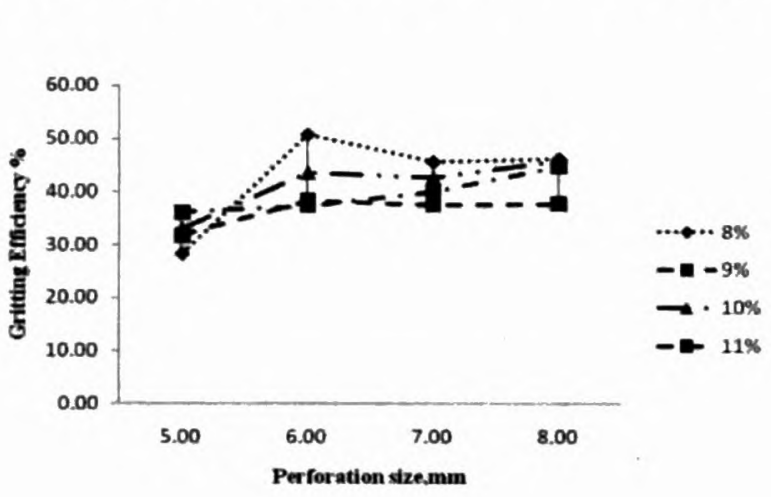


Fig. 3. Gritting capacity *vs* perforations size

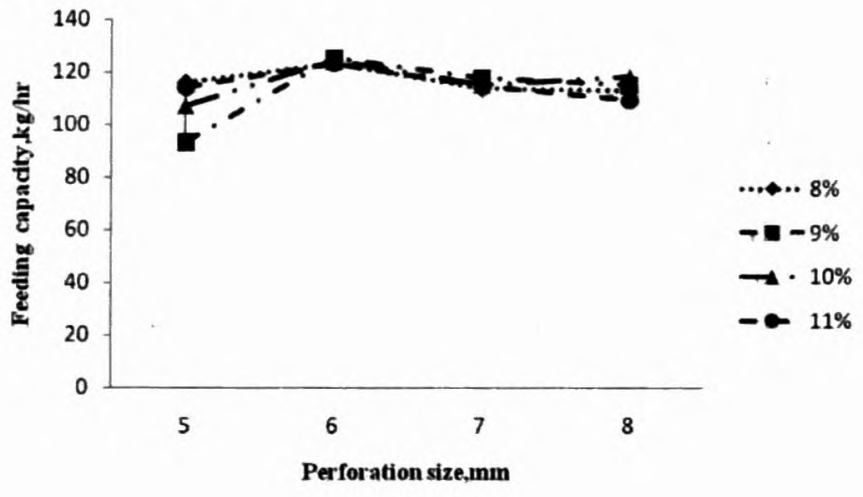
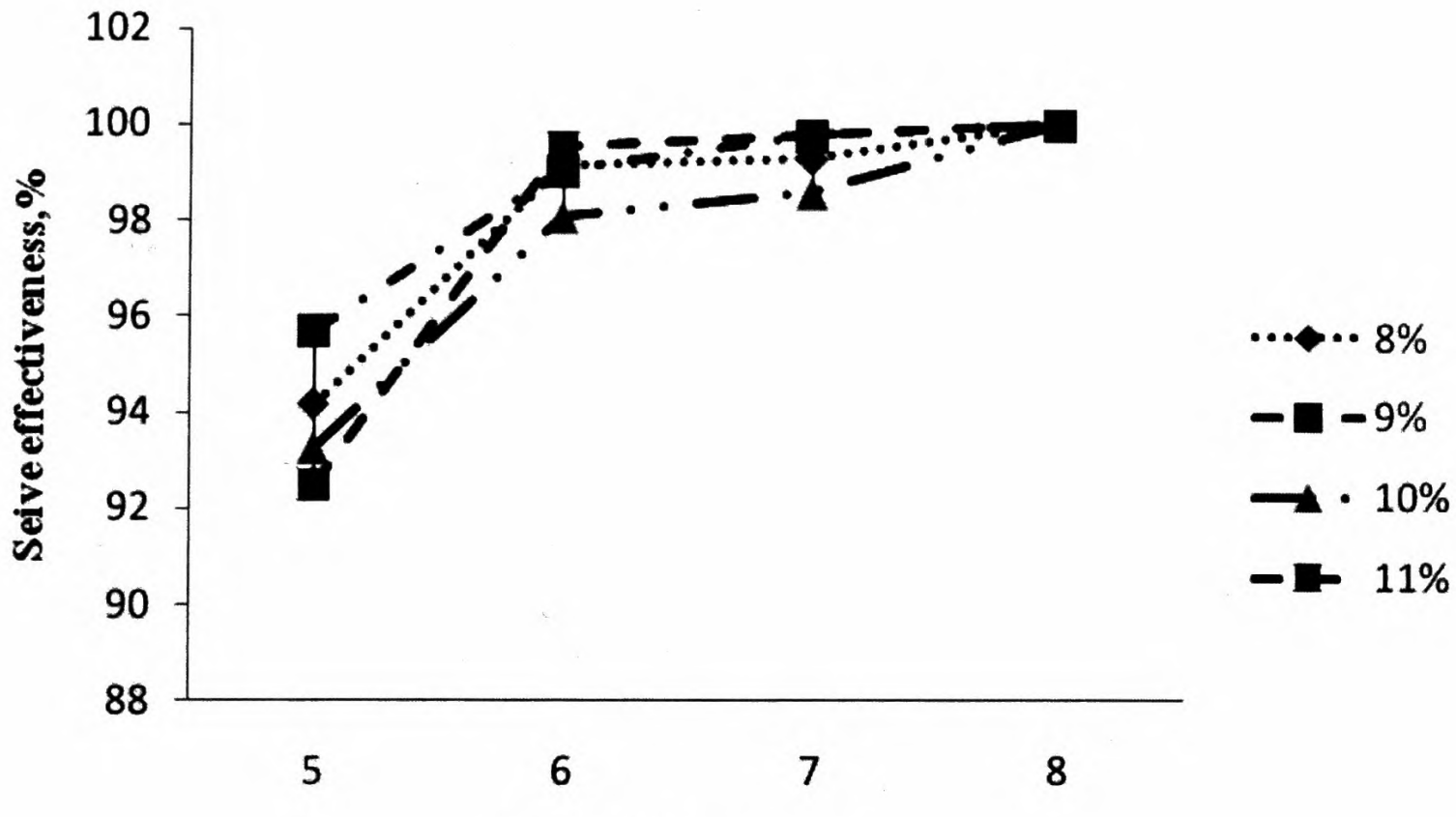


Fig.4. Feeding capacity *vs* perforations size

According to Figure 3, the gritting efficiency of the machine is higer in the 6mm perforation sieve than the other sieve. Low sieve effectiveness is observed in perfortion size 5 mm at all moisture levels. High gritting efficiency was shown at the moisture content of 6% with compering of other moisture content. Feeding capacity of the machine is 180kg/h. According to the results low feeding capacity is shown in 5 mm perforation size. In 6mm perforation shows high sieve effectiveness (98%) according to the Figure 5. That is also high than the 5 mm perforation sieve but near to the effectiveness of other sieves. Power requrement of the machine also considerably low at 6mm perforation sieve when compare with 5 mm perforation sieve. Same result shows at every test at all for moisture content.



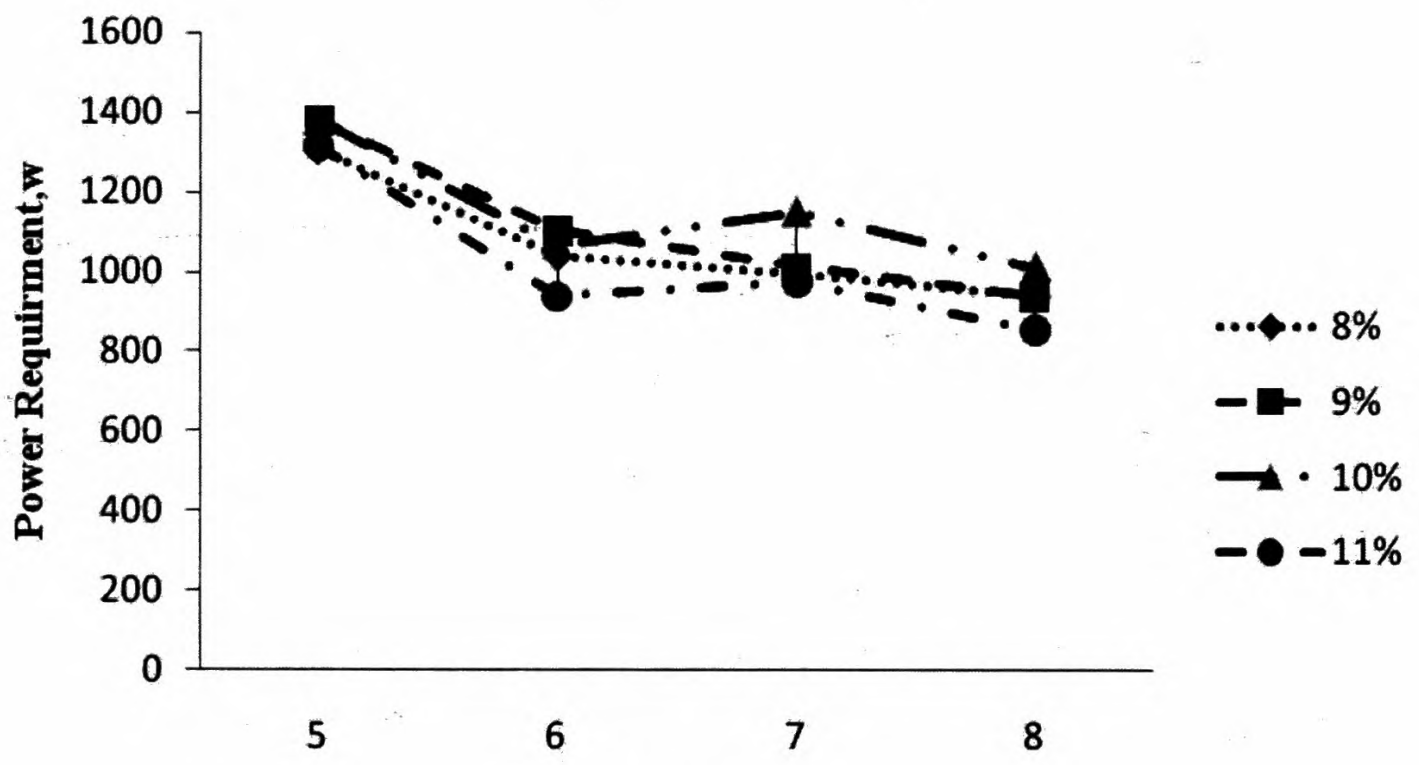


Fig.5. Seive effectiveness *vs* perforations size Fig.6. Power requirment *vs* perforations size

CONCLUSIONS

The study revealed that the fabricated maize gritting machine is capable of gritting maize at different moisture levels of maize and different seive perforation sizes. *i.e.* 5 , 6, 7 and 8 mm in diameter.however good performance shows at the perforation size of sieve in 6 mm and the moisture content of 8%.

REFERENCES

Watson AS, Ramastd E, Paul (1987). Corn: Chemistry and technology. American assosiation of cerial chemiststry. Inc. St.Paul, Minnesota USA

Khurmi RS and Gupta JK (2005). A textbook of machine design, Eurasia Publishing House,New Delhi, India.

Dong A and Edberg RJ (2013). Hammer mill grain thresher. Original version 8/1994. Retrieved 24 October 2013 from of feedlot cattle:

Owens FN, Secrist DS, Hill WJ and Gill DR (1997). The effect of grain source and grain processing on performance a review. Journal Animal Science. 75 (3): 868-879.

Macken CN, Erickson GE, and. Klopfenstein TJ (2006). The cost of corn processing for finishing cattle 1. Journal of Professional Animal Scientist 22 :23–32.

http://lorien.ncl.ac.uk/ming/particle/cpe124p3.html

http://www.fourleafmilling.com.au/products.php?id=14

Organizing Committees

Symposium organizing committee

Director
Dr (Mrs). B.M.K.S. Tilakaratne

Coordinators
Mr. D. P. C. Swarnasiri
Eng. (Mrs.) D. P. Senanayake

Secretary
Dr (Mrs.) W.A H. Champa

Committee Members
Eng. H.M.A.P. Ratnayake
Dr. D.M.C.C.Gunathilake
Dr. (Mrs.) R.M.N.A. Wijewardane
Mr. W.M.C.B. Wasala
Mr. C.R. Gunawardane
Mrs. H.S. Jayawardane
Eng. B.D.M.P. Bandara
Eng. T.M.R. Dissanayake
Eng. (Mrs.) D.M.S. P. Bandara
Mrs. C.A.K. Dissanayake
Mr. P.G.L. Wasantha
Mr. Mahinda Herath
Mr. U.G. Chandrajith
Mr. N. Sonakanthan

Exhibition organizing committee
Mrs. C.A.K. Dissanayake (Chairman)
Mr. C.R. Gunawardane
Eng. H.M.A.P. Ratnayake
Mr. W.M.C.B. Wasala
Eng. (Mrs.) D.M.S. P. Bandara
Eng. T.M.R. Dissanayake
Mr.M.M. Herath

Fund raising committee
Eng. H.M.A.P. Ratnayake (Chairman)
Dr. D.M.C.C.Gunathilake
Mr. W.M.C.B. Wasala
Eng. T.M.R. Dissanayake
Eng. B.D.M.P. Bandara

Publication committee
Dr (Mrs.) W.A H. Champa (Chairman)
Mr. D. P. C. Swarnasiri
Eng. (Mrs.) D. P. Senanayake
Mrs. C.A.K. Dissanayake
Mr. C.R. Gunawardane
Eng. (Mrs.) D.M.S. P. Bandara
Dr. D.M.C.C.Gunathilake
Dr. (Mrs.) R.M.N.A. Wijewardane

Logistics & hospitality services committee
Eng. (Mrs.) D.M.S. P. Bandara(Chairman)
Mrs. C.A.K. Dissanayake
Mr. C.R. Gunawardane
Mr. U.G. Chandrajith
Mrs. H.S. Jayawardane

Food & catering committee
Dr. (Mrs.) R.M.N.A. Wijewardane (Chairman)
Eng. T.M.R. Dissanayake
Mr. Mahinda Herath
Mr.R.M.D.Rathnayake
Mr.I.M.N.P. N.Illangasinghe
Mr. A. K. Dasanayake
Mr.Janaka Subasinghe
Mr.P.Pathirana

Audiovisual services
Mr. C.R. Gunawardane (Chairman)
Mr.Ranjith Palipane
Mr.Janaka Subasinghe
Mr. C.P.Kumara
Mr.N.W.Hemantha

Decorations (Interior)
Dr. (Mrs.) R.M.N.A. Wijewardane (Chairman)
Mrs. C.A.K. Dissanayake
Mrs.R.M.R.N.K.Ratnayake
Mr. U.G. Chandrajith

Decorations (outdoor)
Mr. C.R. Gunawardane (Chairman)
Mr.Ranjith Palipane
Mr.J.K.Paranavithana
Mr. C.P.Kumara
Mr. A. K. Dasanayake
Mr.N.W.Hemantha
Mr.Sarath Munasighe

Preparation of souvenir
Eng. B.D.M.P. Bandara (Chairman)
Eng. (Mrs.) D. P. Senanayake
Mr. W.M.C.B. Wasala
Mr. C.R. Gunawardane

Maintenance committee
Mr.R.K.A.P.Ramanayake (Chairman)
Eng. T.M.R. Dissanayake
Eng. B.D.M.P. Bandara
Eng. (Mrs.) D.M.S. P. Bandara
Mr.I.M.N.P. N.Illangasinghe
Mr.Ranjith Palipane
Mr.Janaka Subasinghe
Mr.N.H.Hemantha

Preparation of exhibition stalls
Mr. C.R. Gunawardane (Chairman)
Mr.Ranjith Palipane
Mr.Janaka Subasinghe
Mr.J.K.Paranawithana
Mr. C.P.Kumara
Mr.N.W.Hemantha

IPRS 2014

RESEARCH AND DEVELOPMENT CENTRE
INSTITUTE OF POST HARVEST TECHNOLOGY
JAYANTHI MAWATHA
ANURADHAPURA

MINISTRY OF AGRICULTURE

9 772362 094003

National Digitization Project

National Science Foundation

Institute : National Science Foundation

1. Place of Scanning : Sanje (Private) Ltd, Hokandara
2. Date Scanned : 02/06/2017
3. Name of Digitizing Company : Sanje (Private) Ltd, No 435/16, Kottawa Rd, Hokandara North, Arangala, Hokandara
4. Scanning Officer

Name : Angelo Melvin Luwis

Signature : A. M. Luwis

Certification of Scanning

I hereby certify that the scanning of this document was carried out under my supervision, according to the norms and standards of digital scanning accurately, also keeping with the originality of the original document to be accepted in a court of law.

Certifying Officer

Designation : Information Officer

Name : Renuka Sugathadasa

Signature : R. P. Sugathadasa

Date : 02/06/2017

"This document/publication was digitized under National Digitization Project of the National Science Foundation, Sri Lanka"