eProceedings of

PROCEEDINGS OF 4th INTERNATIONAL CONFERENCE ON AGRICULTURAL AND FOOD ENGINEERING 2018

'Adapting to Challenges' (CAFE*i* 2018)

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FOREWORD BY THE VICE CHANCELLOR

PROFESSOR DATIN PADUKA DATO' DR. AINI IDERIS
Vice Chancellor of Universiti Putra Malaysia

Assalamualaikum W.B.T and greetings. First of all, I would like to welcome all participants to the 4th International Conference on Agricultural and Food Engineering 2018 (CAFE*i*2018) organized by the Department of Process and Food Engineering and the Department of Biological and Agricultural Engineering, Universiti Putra Malaysia.

With this conference being the 4th to be held, I am happy that the organizers have continued to organize this biennial event. I believe this reflects the passion of the academics within the field of food and agriculture engineering in Universiti Putra Malaysia to gather people all across the world to be here in UPM promoting global intellectual interactions.

It is crucial for us to adapt to the dynamically evolving global scenarios, particularly involving the field of food and agriculture engineering and new challenges. I believe that the organizers have realized these new current challenges must be identified, studied and solutions must be sought after. The theme of this current conference is aptly chosen to be 'Adapting to Challenges'. As we all know, the field of engineering is to offer practical solutions to problems. The engineers in the field of food and agriculture engineering must use their knowledge to adapt to new challenges so that they can offer practicable new solutions. This is to ensure that Malaysia, and globally can find solutions to end hunger and any forms of malnutrition. UPM, being an established university with a solid agricultural background in Malaysia continues to give birth to new theories and offer practical approaches to address these new challenges in the area of food and agriculture. In Malaysia, UPM has a long and reputable history in addressing not only Malaysia's need in the field of food and agriculture, but globally as well. This has been well recognized internationally, where UPM has progressed upwards in the global university rankings such as 202nd position in the QS World University Rankings 2018.

Finally, congratulations to the organizers who have made this conference a success. I hope this conference will be able to bring forth the challenges and issues in the field of food and agriculture engineering and interactively discuss and provide beneficial and practical solutions to them. I wish you all a great and successful conference. Thank you and best wishes.

'With Knowledge We Serve'
PROFESSOR DATIN PADUKA DATO' DR. AINI IDERIS, *FASc.*

FOREWORD BY THE DEAN

PROFESSOR DR. NOR KAMARIAH NOORDIN
Dean, Faculty of Engineering, Universiti Putra Malaysia

On behalf of the Organizing Committee, I am delighted to welcome you to the 4th International Conference of Agricultural and Food Engineering 2018 (CAFE*i*2018). I welcome scientists, engineers, researchers, government authorities, academicians and all experts from all over the world to be here for this three-day conference, CAFE*i*2018. I am very pleased that this conference will be a venue where participants from local and abroad can get together to present and discuss innovation in agricultural and food engineering. As an advisor to CAFE*i*2018, I am confident that the main organizers, Departments of Process and Food and Biological and Agricultural Engineering as well as the co-organizers have created an excellent conference program to address the theme of this conference, 'Adapting to challenges'.

The topic of agriculture and food has inherently been embedded in the faculty of engineering. This is reflected in the active research involvement of academics from various other engineering departments in the faculty of engineering UPM in the area of food and agriculture engineering. I believe that a strong interdisciplinary work and collaboration will be key to support research growth and its adaptability to new challenges faced in this important field. Being the pioneer in providing education in the field of agricultural and food engineering in Malaysia, I am motivated that both departments have taken initiatives to promote the interdisciplinary interactions amongst academicians and experts that can contribute to the development of this field by continuing to organize this biennial conference which is the 4th event since its inception in 2012. From the topic of agricultural mechanization and automation to the topic of food security and safety, this conference covered the necessary aspects of today's challenges in the food and agriculture engineering. Platforms to encourage linkages between academia and industry are available and I hope that this conference can be one of those platforms encouraging academia-industry collaborative works in addressing engineering challenges in the food and agriculture industries. Finally, I would like to thank all delegates and exhibitors for your sharing and contributions. Also, a special gratitude should be given to all the organizers and co-organizers for their willingness to support this conference. May CAFE*i*2018 be a success!

'With Knowledge We Serve'
PROFESSOR DR. NOR KAMARIAH NOORDIN

FOREWORD BY CAFE*i*2018 CHAIRPERSON

ASSOC. PROF. DR.-ING MOHD NORIZNAN MOKHTAR
Chairperson, CAFEi2018

On behalf of the organizing secretariat, I would like to welcome all speakers, delegates, guests, and participants to this 4th International Conference on Agricultural and Food Engineering, CAFE*i*2018. This biennial conference was firstly organized in 2012, with the theme 'Bringing Engineering to Life', followed by in 2014 themed 'New Trends Forward', and previously in 2016 with the theme given as 'Sustaining Agriculture, Preserving Live'. For this current conference that is starting today, the theme is 'Adapting to Challenges'. We have chosen this theme as to highlight what we are facing a lot today: challenges. We need to adapt to the challenges to avoid being left behind in today's challenging environment particularly in the area of food and agriculture. The main objective of CAFE*i*2018 is to provide a forum for discussions, finding solutions and promoting recent innovations to adapt to the current challenges in the broad area of food and agriculture engineering. This is to aid agricultural and food development, modernization of agriculture and food processes, establishment of sustainable farming for food security and poverty alleviation and water quality management for agriculture and environment. These are global issues, and we welcome participants from all over the world that have come to join us today in this conference, including those from Indonesia, Thailand, Philippine, Japan, Taiwan, Nigeria, Saudi Arabia and other countries to CAFE*i*2018. Thank you for coming. Also, with us today, we are joined by distinguished speakers from the academia as well as the industry. We have also received more than 200 registered participants with more than 180 submitted works. After the reviewing process, we managed to compile more than 60 good quality papers to be published in UPM's very own Pertanika Journal, Food Research journal, and also in e-proceedings. I encourage delegates to participate actively in the today's and tomorrow's discussions and achieve successful and fruitful outcomes from this conference. I would also like to take the opportunity to express my gratitude to the other members of the conference organizing committee for their hard work and effort in planning and coordinating this event. I would also like to acknowledge the financial support of many organizations and individuals who have contributed to this conference. To the keynote speakers, I am grateful that you have come and share your valuable experience and ideas in this conference. Last but not least, I wish all the participants a safe and enjoyable moment during CAFE*i*2018. Please take this opportunity to expand your networking and enjoy your stay in Malaysia. Thank you all for your participation and contribution.

'With Knowledge We Serve'
ASSOC. PROF. DR.-ING MOHD NORIZNAN MOKHTAR

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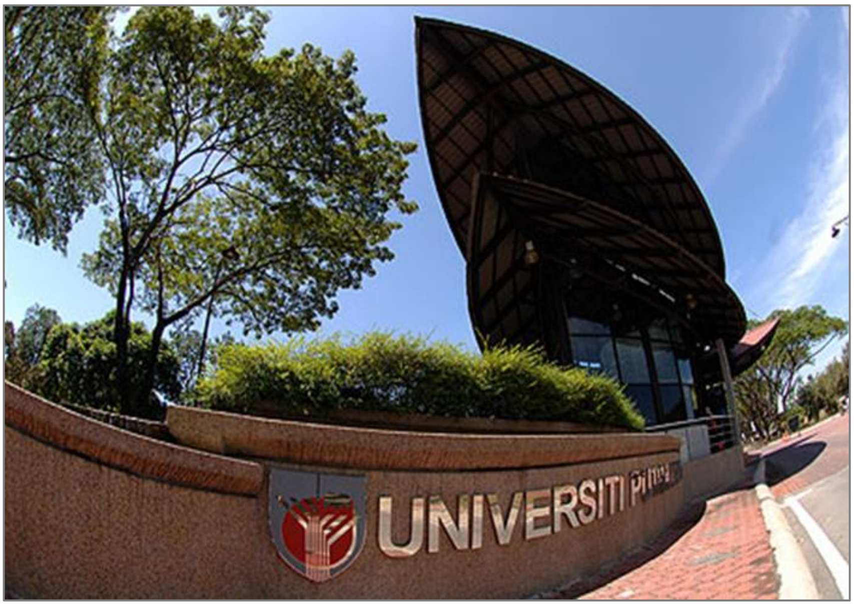
ABOUT UNIVERITI PUTRA MALAYSIA



Universiti Putra Malaysia (UPM) is a leading research university in Malaysia and is first established as the School of Agriculture in 1931. The school was located on a 22-acre piece of land in Serdang and offered two programs – a three-year diploma program and a one-year certificate course in Agriculture. In 1947, the school was declared as the College of Agriculture Malaya by Sir Edward Gent, the then Governor of the Malayan Union. The establishment of Universiti Pertanian Malaysia came about when the College of Agriculture in Serdang merged with the Faculty of Agriculture, University of Malaya. Dr. Mohd. Rashdan bin Haji Baba, the then principal of the College of Agriculture Malaya, was appointed as the first Vice-Chancellor by virtue of the provisions of Section 18 of the Universities and University Colleges Act, 1971. With the first intake of 1,559 students, Universiti Pertanian Malaysia had its first academic session in July 1973 in three central faculties and one basic division: the Faculty of Veterinary Medicine and Animal Sciences, the Faculty of Forestry, the Faculty of Agriculture and the Division of Foundation Studies. In the early 80s, UPM extended its area of studies to include the field of Science and Technology (S&T). In 1997, the name Universiti Pertanian Malaysia was changed to Universiti Putra Malaysia by former Prime Minister, Tun Dr. Mahathir Mohammad, as a strategic gesture to portray the status of UPM as a center of higher education capable of providing education in various fields of studies, especially in science and information technology that has spearheaded national development in the new millennium.

ABOUT FACULTY OF ENGINEERING, UPM

LEADING THE WAY IN EDUCATION EXCELLENCE

The Faculty of Engineering, UPM focuses strongly on teaching and learning, research and innovation, as well as professional services. Named as one of the best engineering schools in Malaysia by independent government assessments for its impressive modern facilities and dynamic approach to teaching and research, it constantly benchmarks the quality of its programs against those of world-renowned universities, winning numerous awards and accolades in the process and placed among the highest rated faculties in the region. To equip students with the skills and knowledge required to meet emerging workplace and career challenges, its curricula are subject to a regular 5-yearly curriculum review to ensure that they meet current market demands. As a testament to its successful commitment to quality education, the Faculty has attracted high-achieving students from around the world. Out of 800 postgraduate students, almost 50% are international students, coming from more than 50 countries. The Faculty has been awarded the MS ISO 9001:2000 certification continuously since the year 2001.

GROWING FROM STRENGTH TO STRENGTH

The Faculty of Engineering was established in 1975 as the Faculty of Agricultural Engineering. Starting with only four departments, it has now grown to eight departments, focusing on some of the most advanced technological fields. Today, the Faculty is one of the largest faculties at UPM with a student population of over 3000. Its location in the heart of the Multimedia Super Corridor (MSC) of Malaysia provides the faculty with access to arrays of IT and multimedia facilities available in the Corridor.

The eight departments of the Faculty are the Departments of Aerospace Engineering, Civil Engineering, Biological and Agricultural Engineering, Electrical and Electronic Engineering, Chemical and Environmental Engineering, Computer and Communication Systems Engineering, Mechanical and Manufacturing Engineering, and Process and Food Engineering. A total of eight Bachelor and 34 postgraduate programs are offered. In line with UPM's inspirational motto, 'With Knowledge We

Serve', the Engineering Faculty is fully committed towards helping students develop holistically, developing cutting-edge technology and contributing to the creation of wealth and nation building.

GLOBAL RECOGNITION THROUGH QUALITY RESEARCH

The Faculty is also known as one of the country's leading R&D centers for its work in various Research Centers focusing on engineering and related fields. The quality of these research findings is tested through publications in reputable international journals, patents and publication awards. Each year, the Faculty produces over 1,000 publications, including 250 journal articles. One of the objectives of such prodigious research activities is to elevate the Faculty's international status in order to receive its due recognition.

HOLISTIC DEVELOPMENT FOR GLOBAL VISION

The Faculty provides a study environment conducive to students. Surrounded by nature, the faculty is equipped with all the amenities a top university, allowing students to enjoy social, recreational and sporting activities. Students are also encouraged to pursue broader interests through on-campus activities, from student politics, to arts, to sports. The diversity in UPM provides an unparalleled cultural learning experience. With a diverse student population coming from over 50 countries, students are exposed to a variety of cultures and languages. This environment helps students develop a globalized world-view so that they have the much-needed international edge to equip them for the competitive job market.

PROGRAM OFFERED

BACHELOR PROGRAM

All bachelor programs offered in the Faculty of Engineering are accredited by the Engineering Accreditation Council Malaysia. They are:

1. Bachelor of Aerospace Engineering
2. Bachelor of Agricultural and Biosystems Engineering
3. Bachelor of Chemical Engineering
4. Bachelor of Civil Engineering
5. Bachelor of Computer and Communication Systems Engineering
6. Bachelor of Electrical and Electronic Engineering
7. Bachelor of Mechanical Engineering
8. Bachelor of Process and Food Engineering

Contact person:
Assoc. Prof. Dr. Wan Zuha Wan Hasan
Deputy Dean (Undergraduate Studies)
Email: eng.tda@upm.edu.my

ABOUT DEPARTMENT OF PROCESS AND FOOD ENGINEERING

The Department of Process and Food Engineering was established in 1996. Since its establishment, the Department had graduated many batches of students in various areas of process and food engineering. In line with the Prime Minister's emphasis on the importance of Agriculture and Biotechnology sectors, the Department of Process and Food Engineering in UPM plays a significant role in nurturing and producing graduates who are able to realize this mission. Currently, the department comprises of 34 family members, whereby 27 are academic staffs and 7 support staffs. At present, there are 25 staffs with PhD qualifications with 4 of the staffs having professional engineer status.

For the first degree, the Department offers the Bachelor of Process and Food Engineering with three specialized options in areas namely Food Engineering, Bio-Material Process Engineering, and Processing Machine Design Engineering. The option is taken in the third and fourth year of the curriculum. The Bio-Material Process Engineering Option emphasizes on the application of process engineering principles and concepts for processing of major agricultural commodities and for processing to develop new bio-based products for use as food materials and raw materials for manufacturing industries. The Food Engineering Option emphasizes on the application of the process engineering principles and concepts for food processing industries. The Processing Machine Design Engineering Option focuses on the processing machinery elements design and processing machinery dynamics, in addition to the processing machinery system and automation.

The Department of Process and Food Engineering has always been in step with the fast paced development of the nation. As one of the program providers in this new field of engineering in Malaysia, the department believes that it has a huge responsibility in developing the field further.

MASTERS WITH THESIS & PHD

The Masters (1½ - 3 years) and the Ph.D. (2 – 4 years) programs are offered in the following 4 fields of studies;

1. Food Engineering
2. Packaging Engineering
3. Biochemical Engineering
4. Agricultural Process Engineering

A thesis is required for graduation.

Contact person:
Assoc. Prof. Dr.-Ing. Mohd. Noriznan Mokhtar
Head
Department of Process and Food Engineering
Email: noriznan@upm.edu.my

ABOUT DEPARTMENT OF BIOLOGICAL AND AGRICULTURAL ENGINEERING

Agricultural engineering education in Malaysia started as far back as 1961. A full bachelor degree program in agricultural engineering was introduced at the Faculty of Agricultural Engineering, Universiti Pertanian Malaysia in 1975. The first batch of agricultural engineers graduated in 1979. In 1980, the diploma level program in agricultural engineering was introduced. Since then, agricultural engineering professionals (i.e., agricultural engineers and agricultural engineering technical assistants) have significantly contributed to the development of agriculture in the country. To date there are about 1000 agricultural engineers and agricultural engineering technical assistants in Malaysia serving in both agricultural and non-agricultural fields. The department has evolved tremendously and become a leader in providing engineering solutions to agricultural problems in Malaysia.

Currently, the department comprises of 42 family members of 28 academic staffs including 4 tutors, and 14 support staffs. The department is offering a four years study of Bachelor of Agricultural and Biosystems Engineering, with four specialization options namely Mechanization and Automation, Postharvest and Environment, Soil and Water Resources, and Agricultural Informatics. The program offered is fully accredited by the Engineering Accreditation Council Malaysia and Malaysian Qualifications Agency. The program is also recognized by the Washington Accord Signatories.

We also provides research-based learning opportunities through the postgraduate degrees in Masters and PhD levels to continue extend the frontier knowledge in the area of agricultural and biosystems engineering. Join our internationally-renowned postgraduate studies focus on fundamental and applied research in thrust areas namely Agricultural Mechanization and Automation, Agricultural Robotics Engineering, Agricultural Informatics, Precision Farming, Post-Harvest Engineering, Agricultural Process Engineering, Soil and Water Resources, Irrigation and Drainage Engineering, and Safety, Health and Environment.

We are certified by ISO 9001: 2008 for all operations including matters pertaining to teaching and learning processes. Outcome Based Education (OBE) has been adopted as the main approach of teaching and learning at the department towards good quality and world-class education. We welcome you to work with us whether to further your education, to do collaborative research, to utilize our expertise as consultants or in any other manner that will benefit the quality of life.

Contact person:
Assoc. Prof. Dr. Siti Khairunniza Bejo
Head
Department of Biological and Agricultural Engineering
Email: skbejo@upm.edu.my

POSTGRADUATE PROGRAMS AT
DEPARTMENT OF BIOLOGICAL AND AGRICULTURAL ENGINEERING

MASTERS WITHOUT THESIS

A non-thesis program is offered in Emergency Response and Planning. Students enrolling in this program must fulfill a minimum of 40 credits of coursework with a study period of 1½ - 2 years.

Contact person:
Dr. Hazreen Haizi Harith
Coordinator of Masters of Emergency Response and Planning
E-mail: hazreen@upm.edu.my

MASTERS WITH THESIS & PHD

The Masters (1½ - 3 years) and the Ph.D. (2 - 4 years) programs are offered in the following fields of studies encompassing all of the thrust areas:

1. Agricultural Mechanization and Automation
2. Agricultural Process Engineering
3. Agricultural Waste Engineering
4. Soil and Water Engineering
5. Farm structures

A thesis is required for graduation.

Contact person:
Assoc. Prof Dr. Hasfalina Che Man
Coordinator of Postgraduate Studies
Email: hasfalina@upm.edu.my

ABOUT MALAYSIAN SOCIETY OF AGRICULTURAL ENGINEERS (MSAE)

The Malaysian Society of Agricultural Engineers or MSAE is a learned society established in 1982. It is a professional and technical organization with members who are interested in engineering knowledge and technology for food, agriculture, associated industries and related resources. The founding members are mainly lecturers in the Department of Biological and Agricultural Engineering or DBAE, University Putra Malaysia or UPM who have obtained their highest degrees from US universities. Hence, they are very familiar with the American Society of Agricultural and Biological Engineers or ASABE, which is an active professional engineering organization internationally with more than 8000 members worldwide.

To date there are about 1500 Agricultural Engineers and Agricultural Engineering Technical Assistants in Malaysia involving in both agricultural and non-agricultural fields. MSAE members are employed mainly by government departments and agencies, universities and colleges, palm oil mills and plantations, agricultural machinery companies, irrigation companies and agricultural and food processing plants. In the government departments and agencies, they are either in the research fields such as in the Malaysian Agricultural Research and Development Institute (MARDI), Malaysian Palm Oil Board (MPOB), Malaysian Rubber Board (LGM), Malaysian Cocoa Board (LKM), Malaysian Pineapple Industry Board (MPIB), and (Forest Research Institute Malaysia (FRIM) or in the service fields such as in the Department of Agriculture (DOA), Department of Environment (DOE), and Farmers' Organization Authority (LPP).

The main activities of MSAE include organizing short courses, seminars, workshops and conferences; publications; social, sports and recreational activities and technical visits especially for members of the MSAE-Student Chapter. A national conference entitled 'Engineering SMART Farming' was organized by MSAE and DBAE-UPM in March 1999 to commemorate 25 years of teaching, research, consultancy and extension in agricultural engineering in Malaysia. The national founding landmark of AE curriculum and the national founding landmark of MSAE were officially launched at UPM in 2016 to commemorate the 41 years of teaching, research, consultancy and extension in agricultural engineering in Malaysia and the 34 years establishment of the professional engineering association in Malaysia.

Contact person:
Assoc. Prof. Dr. Rosnah Shamsuddin
President Malaysian Society of Agricultural Engineers 2017/2019
Email: eng.msae@upm.edu.my

ABOUT HALAL PRODUCTS RESEARCH INSTITUTE (IPPH)

The Halal Products Research Institute (IPPH), Universiti Putra Malaysia (UPM) was established in July, 1st 2006 as a pioneer Institute of Halal Food to undertake research and development (R&D) in the halal industry in Malaysia. The establishment of IPPH serves as a one-stop center through a multifaceted approach on various aspects of halal products in both national and international levels. Our vision is to upholding the sanctity of halal through research and services. Our mission is to have total commitment towards halal globalization and enterprise.

Amongst the research program offered include Halal Products Traceability, Authenticity & Quality, Halal Products Innovation, Business and Management Halal, and Shariah and Halal Laws. IPPH also offers postgraduate program for MS and PhD studies that consists of four main areas Halal Products Science, Halal Products Development, Halal Products Management, and Shariah and Halal Laws.

IPPH also do offers analysis services on halal food and selected non-food products, halal training and halal consultation. Halal training includes a Professional Certification in Halal Executive Course whereby the institute has been recognized as one of the training providers appointed by Department of Islamic Development Malaysia (JAKIM). Our stakeholders include government agencies, industry players and public.

Contact information:
Halal Products Research Institute
Universiti Putra Malaysia
43400 Serdang
Selangor, Malaysia
Email: halal@upm.edu.my

CAFE*i*2018 PROGRAM OVERVIEW

7th NOVEMBER 2018 (WEDNESDAY) VENUE: THE EVERLY HOTEL, PUTRAJAYA	
0800 – 0900 hrs	Pre-registration for Technical Visit at Lobby, Ground Floor
0900 – 1700 hrs	Technical Visit
1700 – 1900 hrs	Pre-registration for Conference, First Floor

8th NOVEMBER 2018 (THURSDAY) VENUE: THE EVERLY HOTEL, PUTRAJAYA	
0800 - 0845 hrs	Registration for conference outside of Mesmera Ballroom, First Floor
0845 - 1000 hrs	Venue: Mesmera Ballroom 1 & 2, First Floor **OPENING CEREMONY** • Recitation of Doa • Welcoming Remarks by Chairman of International Conference on Agricultural and Food Engineering **ASSOC. PROF. DR.-ING MOHD. NORIZNAN MOKHTAR** • Opening Remarks by Vice Chancellor of UPM **PROF. DATIN PADUKA DATO' DR. AINI IDERIS**
1000 - 1020 hrs	**TEA BREAK & REFRESHMENT**
1020 - 1050 hrs	Venue: Mesmera Ballroom 1 & 2, First Floor ***KEYNOTE I: PRECISION AGRICULTURE, ADAPTING TO TECHNOLOGY AND OPERATIONAL CHALLENGES*** PROFESSOR DR. IAN YULE *Director and Professor of Precision Agriculture, Massey Agritech Partnership Research Centre, Massey University, New Zealand* Chairperson : Prof. Ir. Dr. Chin Nyuk Ling
1050 - 1120 hrs	Venue: Mesmera Ballroom 1 & 2, First Floor ***KEYNOTE II: ON THE USE OF ADVANCED FOOD PROCESSING TECHNOLOGIES TO PRODUCE DYSPHAGIA DIETS: A BRIEF REVIEW*** PROFESSOR DR. SAKAMON DEVAHASTIN *Professor, Department of Food Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, Thailand* Chairperson : Prof. Ir. Dr. Chin Nyuk Ling
1120 - 1150 hrs	Venue: Mesmera Ballroom 1 & 2, First Floor ***KEYNOTE III: OVERVIEW ON AGRICULTURE POTENTIAL IN MALAYSIA*** MR. OTHMAN YUSOFF *Head of Halal Affairs, Nestlé Malaysia Bhd.* Chairperson : Prof. Ir. Dr. Chin Nyuk Ling
1200 – 1300 hrs	Venues: Mesmera Ballroom 1 & 2 / Irama 5 / Irama 6 & 7 **PARALLEL TECHNICAL SESSION 1**
1300 - 1415 hrs	Venue: Outside of Mesmera Ballroom **LUNCH BREAK**
1415 - 1630 hrs	Venues: Mesmera Ballroom 1 & 2 / Irama 5 / Irama 6 & 7 **PARALLEL TECHNICAL SESSION 2**
	WELCOMING HIGH-TEA
1730 - 1830 hrs	Venue: Fuze Restaurant, Ground Floor • Recitation of Doa • Conference High-Tea

9th NOVEMBER 2018 (FRIDAY) VENUE: THE EVERLY HOTEL, PUTRAJAYA	
0830 - 0900 hrs	Venue: Mesmera Ballroom 1 & 2, First Floor ***KEYNOTE IV: TOWARDS THE NEXT WAVE OF MODERN AGRICULTURE - SMART AGRICULTURE*** PROFESSOR DR. TA-TE LIN *Distinguished Professor, Department of Bio-Industrial Mechatronics Engineering and Executive Vice President for University Affairs of National Taiwan University* Chairperson : Prof. Dr. Abdul Rashid Mohamed Shariff
0900 - 0930 hrs	Venue: Mesmera Ballroom 1 & 2, First Floor ***KEYNOTE V: ENGINEERING THE PRODUCTION OF RICE FOR FOOD SECURITY IN MALAYSIA*** PROFESSOR IR. DR. AZMI DATO' YAHYA *Professor, Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia* Chairperson : Prof. Dr. Abdul Rashid Mohamed Shariff
0945 - 1030 hrs	Venues: Mesmera Ballroom 1 & 2 / Irama 5 / Irama 6 & 7 **PARALLEL TECHNICAL SESSION 3**
1030 - 1045 hrs	**TEA BREAK AND REFRESHMENT**
1045 - 1230 hrs	Venues: Mesmera Ballroom 1 & 2 / Irama 5 / Irama 6 & 7 **PARALLEL TECHNICAL SESSION 4**
1230 - 1400 hrs	Venue: Outside of Mesmera Ballroom **LUNCH BREAK**
1430 - 1630 hrs	Venues: Mesmera Ballroom 1 & 2 / Irama 5 / Irama 6 & 7 **PARALLEL TECHNICAL SESSION 5**
1630 - 1645 hrs	**TEA BREAK & REFRESHMENT**
	CLOSING CEREMONY AND AWARD GIVING
1700 hrs	Venue: Mesmera Ballroom 1 & 2, First Floor CLOSING CEREMONY AND AWARD GIVING • Recitation of Doa • Closing Remarks by Co-Chairman of International Conference on Agricultural and Food Engineering, Assoc. Prof. Dr. Siti Khairunniza Bejo • Awards Ceremony

** Refer to floor layout of conference venue for locations of Parallel Technical Sessions*

KEYNOTE SPEAKERS

Keynote Speaker I

PROFESSOR DR. IAN YULE

Director and Professor of Precision Agriculture, Massey Agritech Partnership Research Centre, Massey University, New Zealand

President-Elect (2018-2020) for the International Society of Precision Agriculture

Prof. Dr. Ian Yule started his career as a lecturer in Agricultural Engineering at Durham Agricultural College in the UK before moving to the University of Newcastle upon Tyne where he initiated research on precision agriculture. He came to Massey University as a Senior Lecturer in 1997. In 2000 he became the Director of the New Zealand Centre for Precision Agriculture and was made Professor in Precision Agriculture in 2011. Prof. Dr. Ian Yule holds a PhD in Agricultural Engineering and has a passion for remote and hyperspectral sensing, as well as finding practical, usable solutions to problems within the agriculture space. His work is concentrated on contract research projects, research outputs and postgraduate supervision. He is the main supervisor to 6 full time PhD students and carries a $10M portfolio of contracted research activity. He has spent the last 10 years concentrating his research efforts on developing remote sensing and imaging. His work is at the forefront of developing practical applications for remote sensing and imaging that has worked towards NZ’s largest jointly funded (by Ravensdown and MPI) remote sensing project – Pioneering to Precision, PGP Project. He has extensive knowledge on theory of spectroscopy and the ways of its implementations to improve management of agricultural crops, hill county farms and dairy farms. He has published extensively and actively promotes the work of the centre through presentations to conferences, workshops and professional bodies.

ABSTRACT

Precision Agriculture, Adapting to Technology and Operational Challenges

The world is constantly changing and precision agriculture is no exception. From starting off in the cropping sector of the USA in the 1980’s it has developed and adapted to new operational challenges in new fields of use. After forty years it includes much more than cropping, with livestock now being considered as well as different agricultural and horticultural crops, including trees crops. It came about because of our ability to recognize spatial variation and map those differences. We now realize that temporal variation is also extremely significant. What this means at the operational level is that we must respond to each new situation as best we can. In order to do that we must have good information that is accessible to the user. Technology is improving through means such as wireless communication, IoT, remote and proximal sensing. Our ability to capture data used to describe our environment has never been better. We now need to provide integration of captured data and transform it into usable management information.

We are now dealing with multi-scale, multi temporal data within complex agricultural environments and value chains where product provenance is required. Dealing with real world situations is challenging for scientists who have used traditional experimental methods to isolate factors affecting change or differences. New methods of data analysis and data mining offer further opportunities to explain our environment. All of these things illustrate the constantly changing world, and the technology and operational challenges that are created. Precision Agriculture is not the same as it was

forty years ago and it will continue to adapt and change. This paper examines some of the current and future challenges.

Keynote Speaker II

PROFESSOR DR. SAKAMON DEVAHASTIN

Professor, Advanced Food Processing Research Laboratory, Department of Food Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, Thailand

Prof. Dr. Sakamon Devahastin is currently with the Department of Food Engineering, King Mongkut's University of Technology Thonburi (KMUTT) in Bangkok, Thailand. His main research interests are in both thermal and non-thermal processing of foods and biomaterials, in particular the development and study of novel drying technologies for heat- and oxygen-sensitive materials, and also in material property and structural characterization as well as computational fluid dynamics and heat/mass transfer. He has so far published more than 160 papers in referred international journals and given some 100 presentations at various international conferences. He is an author/co-author of 16 book chapters, author/editor of four books and co-inventor of 4 patents. He has served as Senior Associate Editor of an archival journal *Drying Technology* and been on the editorial boards of various other journals in food and thermal engineering. Among the many awards bestowed upon him, Prof. Dr. Sakamon Devahastin was awarded the Young Technologist Award by the Foundation for the Promotion of Science and Technology under the Patronage of H.M. the King of Thailand in 2004; the TRF-CHE-Scopus® Researcher Award in Engineering and Multidisciplinary Category by the Thailand Research Fund (TRF), Commission on Higher Education (CHE) and Scopus® as well as the Taylor & Francis Award for Sustained Exemplary Service to *Drying Technology* and Excellence in Drying Research Contributions by Taylor & Francis, both in 2009. He is the recipient of the 2012 National Outstanding Researcher Award (Engineering and Industrial Research Category) from the National Research Council of Thailand, the 2014 Award for Excellence in Drying from the Association Française pour le Séchage dans l'Industrie et l'Agriculture (French Drying Association for Industry and Agriculture) and the 2018 Ajinomoto Award for Outstanding Food Science and Technology Researcher from the Ajinomoto Foundation and the Food Science and Technology Association of Thailand. He has been elected Associate Fellow of the Academy of Science of the Royal Society of Thailand since 2016. Prof. Dr. Sakamon Devahastin received his Ph.D. in Chemical Engineering from McGill University, Montreal, Canada in 2001.

ABSTRACT

On the Use of Advanced Food Processing Technologies to Produce Dysphagia Diets: A Brief Review

As many countries are rapidly approaching a state of being an aging society, a pressing need to serve more patients suffering dysphagia, which is a symptom involving the difficulty moving food, liquid, saliva and oral medication from the mouth to the stomach, is soon to be expected. Dysphagia diets need to be prepared to allow both swallowing safety and efficiency; in other words, these diets must be safely swallowable and provide adequate nutrition for the patients. An ability to prepare novel dysphagia diets is highly desirable as these diets can serve not only the aforementioned requirements but may also be able to provide adequate sensory satisfaction to the patients. In this presentation, some advanced food processing technologies that may be used to prepare *dys*phagia diets will be reviewed. These range from such simple processes as pureeing, foam-mat drying to more advanced processes like 3D printing, among others. Microstructural and textural modifications that need to be achieved for effective preparation of dysphagia diets will be mentioned.

Keynote Speaker III

MR. OTHMAN MD YUSOFF

Head of Halal Affairs, Nestlé Malaysia Bhd

Mr. Othman Md Yusoff received his Bachelor of Science in Food Science and Technology from Universiti Putra Malaysia. He is currently the Head of Halal Affairs at Nestlé Malaysia Bhd and has been working with the company about 30 years. Mr. Othman Md Yusoff has industry-wide experience in manufacturing, Halal affairs as well as research and development. Additionally, his extensive experience also includes his involvement with Nestlé companies all over the world.

ABSTRACT

Overview on Agriculture Potential in Malaysia

The keynote provides an overview on agri-food field such as the strength in products like palm oil, rice and chili as well as their sustainability supply, routine monitoring of contamination for agriculture based materials, grading of agricultural products such as eggs, rice and fruits to a standardized quality and certification of agricultural best practice by Ministry of Agriculture, exemplarily, Malaysian Good Agricultural Practice (myGAP). Other areas of the keynote include the scientific and marketing supports from agricultural agencies such as Malaysian Palm Oil Board (MPOB), Malaysian Palm Oil Council (MPOC), Padiberas Nasional Bhd (BERNAS), Malaysian Agricultural Research and Development Institute (MARDI), Department of Veterinary Services (DVS), and Federal Agricultural Marketing Authority (FAMA), natural and 'green' agriculture practices, post-harvest innovations and halal certification, dependency on imported processed agriculture based products such as dehydrated vegetables, spices, chicken products, and improving competency of Small and Medium Enterprises (SMEs) to meet international standards. The keynote further delivers understanding on the upstream of agriculture based materials, advanced technology for exporting frozen fruits (e.g. *durian*), high export demand for tropical fruits (e.g., mangosteen, banana, and pineapple) and bird nest, free-range chicken – Healthy Hens, micro-scale vegetable production and miscellaneous crops as well as business development for halal products.

Keynote Speaker IV

PROFESSOR DR. TA-TE LIN

Distinguished Professor, Department of Bio-Industrial Mechatronics Engineering, and Executive Vice President for University Affairs of National Taiwan University

Prof. Dr. Ta-Te Lin received the B.S. degree in Agricultural Engineering from National Taiwan University, Taiwan, R.O.C. in 1981, and the MS and Ph.D. degree from Cornell University in 1985 and 1989, respectively. He has been on the faculty of National Taiwan University since 1989, and he is currently Distinguished Professor of the Department of Bio-Industrial Mechatronics Engineering and the Executive Vice President for University Affairs of the National Taiwan University. His research interests include agricultural automation, digital image processing and machine vision, mathematical modelling of biological systems, biorobotics, and mechatronics. He is a member of several international societies including the ASABE, the IEEE Computer Society, Japanese Society for Agricultural Informatics, and the Society for Cryobiology. Domestically, he serves as the board members of the Taiwan Institute of Biomechatronics, Chinese Institute of Agricultural Machinery, and Taiwan Agricultural Information Technology Association. Prof. Dr. Ta-Te Lin has received numerous recognitions in teaching and research. He received twice the distinguished teaching award from National Taiwan University in 1999 and 2007. He was awarded the academic achievement award for the Chinese Institute of Agricultural Machinery (CIAM) in 2005. He received the best annual paper awards from CIAM in 2000, 2003, and 2005, respectively, best poster paper awards from TIBM in 2006, 2007, and 2009, and best annual paper awards from Taiwan Entomological Society in 2007. He was elected as one of the Ten Outstanding Agriculturist by the Kiwanis Internationals, Taiwan District in 2013. He has authored and co-authored more than 300 journals and conference papers, and granted more than 20 patents.

ABSTRACT

Towards the Next Wave of Modern Agriculture - Smart Agriculture

Agricultural mechanization lays the foundation of improving production efficiency as well as quality of farm produce. Labor intensive operations are replaced with powered machinery. Agricultural automation forms the additional layer of technology evolution in agriculture production utilizing digital computers, control devices and algorithms, and sensors. Integrated and automated systems deliver further enhancement of agricultural operations from production, postharvest processing, and logistics. With the advent of innovative technologies in the past decades, the traditional agriculture and food industry is undergoing rapid transformation. Smart agriculture becomes the next wave of modern agriculture that will effectively solve agricultural problems and support the sustainability of our planet. In this presentation, the evolution of engineering technologies that facilitate the agricultural development will be elucidated. Key technologies that play crucial roles of making the transformation are introduced and discussed, and the synergistic effect are made clear with examples of recent novel applications in agriculture research as well as industry. Modern agricultural operations or business will work differently because of fast-moving advancement of technologies such as devices, sensors, machines, communication and information technologies. Among many advanced technologies, Internet of Things (IoT), wireless sensor networks (WSN), mobile computing, data analytics, artificial intelligence (AI), robotics, drone technology, just to name a few, are permeating in various agricultural applications from field to fork. That is, the chain from crop, livestock, and aquaculture production, to food processing, logistics and distribution, and finally to consumers are linked with smart options to ensure food security as well as food quality. Information and data analytics play even vital role in farm management and agri-business. New business models emerge as

a result of new technologies made available in a faster and faster pace in recent years. The synergistic mechanism of these advanced technologies to deliver a promising future agricultural world can be envisioned with a cyber-physical cycle. Application examples context-aware sensing approach using AI and image sensor network will be given to demonstrate the concept and importance of the cyber-physical cycle in the development of smart agriculture in the presentation.

Keynote Speaker V

PROFESSOR IR. DR. AZMI DATO' YAHYA

Professor, Department of Biological and Agricultural Engineering, Universiti Putra Malaysia

Prof. Ir. Dr. Azmi Dato' Yahya holds Bachelor Engineering (Agricultural) degree from Universiti Putra Malaysia in 1982. He received his MS in Agricultural Engineering from Iowa State University of Science and Technology, USA in 1985 and then his doctorate majoring in Agricultural Engineering and minoring in Engineering Science and Mechanics from the same university in 1988. He is a registered professional engineer with the Board of Engineers, Malaysia (BEM); Corporate Member of Institution of Engineers, Malaysia (IEM); Fellow Member of Malaysian Society of Agricultural Engineers (MSAE); Member of the Incorporated Society of Planters (ISP); Life Member of the Asian Association of Agricultural Engineering (AAAE); Member of American Society of Agricultural and Biological Engineers (ASABE); and Member of International Society of Precision Agriculture (ISPA). He had served as the Head for the Department of Biological and Agricultural Engineering in the Faculty of Engineering, Deputy Dean (Research) for the Faculty of Engineering, and in the previous appointment as the Dean for the Faculty of Engineering at UPM. Prof. Ir. Dr. Azmi Dato' Yahya field of expertise is in the area of Agricultural Machinery Engineering. He has contributed throughout his career in developing the agricultural engineering curriculum and teaching facilities at UPM and at the same time has been enthusiastically involved in the design and development of field machineries for the oil palm mechanization and automation program in Malaysia. He had managed to secure as a principal researcher a total of more than RM6 million external research grants to UPM. He was the recipient for UPM's Excellent Service Award in 1992, 1998, 2002, 2007, 2010 and 2013 and was conferred the Star of Order DARJAH SERI MAHKOTA TERENGGANU (SMT) by the Highness Sultan of Terengganu in 2002.

ABSTRACT

Engineering the Production of Rice for Food Security in Malaysia

Rice is the staple food for the populace and a source of income to the rural dwellers in Malaysia. With the current average rice yield of 3.8 tons per ha under a total cultivated area of 673,745 ha of land, the local production can only fulfilled 73% of the country's consumption. The average yield is regarded too low as compared to other rice producing countries in Asia while the yield variabilities are very high between the rice granaries areas in the country. Furthermore, very low work qualities exist in the various rice field cultivation operations due to improper selections and operations of the field machineries in the farms. The current mechanization index of 0.59 and cost benefit ratio of 1.28 are considered to be too low for a country that regards rice as an important security crop. Attempt to increase the country's rice production should not only focus on opening new cultivated area or breeding new high yield rice varieties since both efforts take time and involve big investments. However, immediate engagement should be on increasing the country's average rice yield or total rice production by reducing the production variabilities that currently exist between and within the existing rice granaries areas in the country. Such an effort can be made through precise use of input energies (i.e seed, fuel, fertiliser, chemical, human and machine) under the implementation of Good Agricultural Practices (GAP), proper selection and use of appropriate field machineries, and lastly engaging on R&D with prime objectives on solving real ground problems. Consequently, the present cost benefit ratio of rice could be increased with the increased in crop yield and the reduction of cost inputs through efficient management of the crops, fields and machineries. With the population of 28,401,000 and per capita rice consumption of 110 kg per year, it is possible for the country to achieve 100% self-sufficiency from the present 73% sufficiency by increasing the current average rice yield of 3.8 tons per ha to 4.8 tons per ha while maintaining the same total cultivated acreage.

LIST OF e-PROCEEDING PAPERS

Development of Soil Moisture Monitoring Device for Irrigation Water Scheduling

[1]Shitu, A. and [1]Daniel, P.
[1]Department of Agricultural and Environmental Engineering, Faculty of Engineering, Bayero University, Kano-Nigeria

E-mail address:
ashitu.age@buk.edu.ng (Shitu, A.)

Abstract

Farmers need to rely on some methods of determining the water needs of their crops to avoid production and quality losses. In this work, a soil moisture monitoring device has been developed. It is capable of monitoring soil moisture level at the root zone of the crops and can also send short message service (SMS) to the farmer on his mobile phone when the threshold value is reached, either when irrigating or depletion of the soil moisture. The device comprises of three major units; input unit made up of YL-69 soil moisture sensor, control unit made up of PIC16F877A microcontroller and the output unit; which comprises of GSM module SIM9000A and 16x2 LCD screen. Device's performance carried out/determined at 0-60% output range setting. From the experimental result on the developed soil moisture device, first-day reading obtained at 0-60% output range was 56%. Also, readings from soil moisture meter and gravimetric method on the same day were found to be 55% and 52.5%, respectively. The result indicates the effectiveness of the device. Furthermore, from the result obtained by calibrating the device at 0-60% output range with the gravimetric output gives the coefficient of determination (R^2) values of 0.9808. These values indicate a strong linear correlation relationship.

Keywords: Soil moisture sensor, Irrigation scheduling, Monitoring device, Gravimetric method.

Introduction

Crops require water to grow and produce good yields. When the crop is water stressed they close their stomata and cannot photosynthesis effectively (Bernie, 2000). Best growth can be achieved only if plants have a suitable balance of water and air in their root zones. Some stages in the growth of a crop are particularly sensitive to moisture stress. Water shortage sufficient to hinder crop growth can occur without producing obvious wilting of foliage, while waterlogging can cause large yield reductions. The farmer must therefore, rely on some other method of determining the water needs of the crops to avoid production or quality losses.

This requires an understanding of the movement and storage of water in the root zone of the crop and the rate of water use by the crop (Bernie, 2000).

Measurement of soil water is essential for proper scheduling of irrigation and estimating the amount of water needed for irrigation. Since soil water is dynamic, knowledge on the change in soil water content from time to time is important for proper monitoring of water management practice both in irrigated and rain fed farming. Several methods have been developed for measurement of soil water (Majumdar, 2010).

The decision of when to irrigate is usually based on; past experiences, weather-based information (crop evapotranspiration data), or soil-based measurements. Past experiences may not be correct and are often not adjusted for annual changes in weather. Scheduling irrigations based on crop evapotranspiration can be difficult because it is hard to obtain accurate data for some locations and, even when data are available, the task of keeping track of evapotranspiration data for individual fields can be time consuming. Due to the difficulties and shortcomings of these methods, soil based irrigation scheduling may be the preferred technique (Heiniger, 2013).

Therefore, the objective of this work is to develop simple and affordable moisture monitoring device for irrigation water scheduling.

Materials and Methods

This developed device has three major units; input unit, control unit and the output unit. The input unit comprises of soil moisture sensor for sensing the moisture content of the soil and two potentiometers for setting the threshold by the user. YL-69 soil moisture sensor (a resistance type sensor) was used in this work. The control unit was achieved using PIC16F877A microcontroller. GSM module SIM900A and 16x2 LCD (liquid crystal display) screen are used in the output unit. The GSM module sends SMS message to the user at the upper and lower threshold set by the user himself while the LCD screen displays the soil moisture content. Micron C compiler software was used to develop the program. The block diagram for hardware connections is shown in Figure 1.

Power supply unit

The power supply unit uses a battery of 12 V to supply dc voltage to the circuit and regulated to 5V by LM7805 regulator as required by the device as shown in Table 1.

Soil moisture sensor

This unit consists of soil moisture sensor for monitoring conductivity and resistivity of the soil; variable resistor for the moisture probe. Copper rod has been used to measure the resistance of the soil between the two probes.

Table 1. Total Current Estimation to the Circuit

Components List	Quantity	Current(mA)	Total current (mA)
PIC16F877A	1	25	25
GSM module	1	100	100
LCD	1	30	30
Moisture sensor	1	35	35

Total = 190mA. The battery voltage=12V The current = 2A

If the soil is wet to saturation the resistance between the two probe will be $R_{moisture}$= 0Ω and if the soil is completely dry the resistance between the two probe will be R_{dry}=8.6kΩ. The soil moisture detecting circuit is shown in Figure 1. The R_{v1} (variable resistor) obtained by equation (1) was used to control the output signal from the sensor which was connected to port AO of microcontroller, thus the output range of the device can be adjusted.

The resistance of soil moisture is 8.6kΩ. Then R_{v1} is calculated below by choosing the followings (Theraja 2011).

$$V_{out} = \frac{Vcc \times Rv1}{Rv1 + R(dry)} \tag{1}$$

Where, V_{out} = voltage output from the sensor, V_{cc} = voltage input to the sensor, and R_{dry}= resistance between the two probe in dry condition.

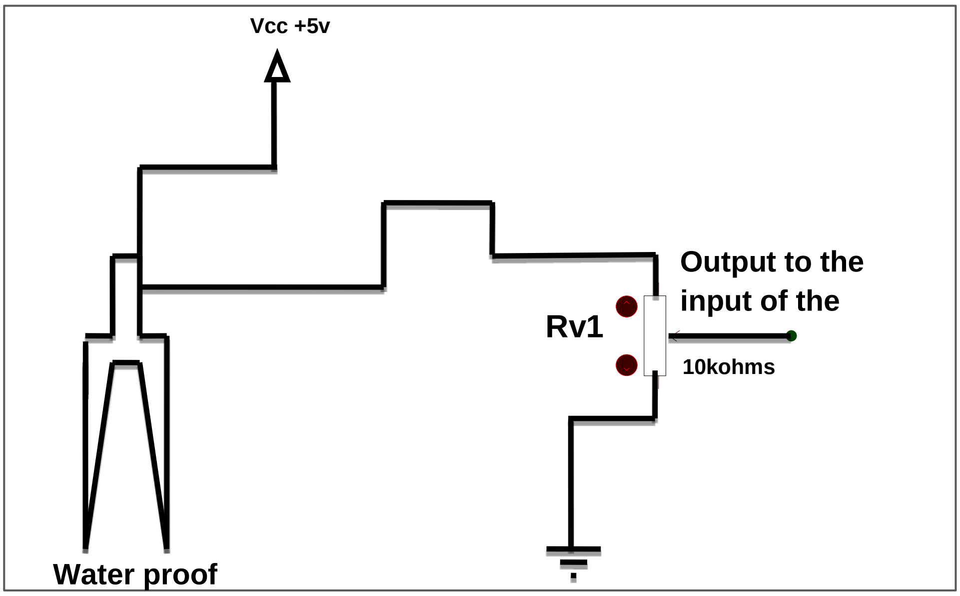


Figure 1. Soil Moisture Detecting Circuit (Theraja 2011)

Control unit

A Microcontroller is a small computer on a signal integrated circuit containing a processor core, memory and programmable input/output peripherals (Amanullah, 2013). This unit controls the entire output unit like, LCD and the GSM module while monitoring the input signals from the soil moisture sensor and the set threshold. The PIC16F877A was used in this unit due to it is very easy to program (Huthaifa e*t al., 2016*).

Liquid crystal display (LCD) Interface PIC16F877A

16x2 LCD screen was used to display the moisture content because it can be easily programmed. It has no limitation of displaying special and even custom characters, animations and so on.

SMS reporting unit

This unit is responsible for sending SMS to the user mobile when moisture is low or high as set by the user. For sending message GSM Module SIM900A was used in this work. GSM Module SIM900A with SIM-card holder, RS232 interfaces. The GSM Module is interface with microcontroller directly through port C of the microcontroller. GSM Module works with AT COMMANDS. Attention (AT) commands was used to control MODEMS Figure 2. Shows the interface between PIC16F877A microcontroller and GSM Module SIM900A.

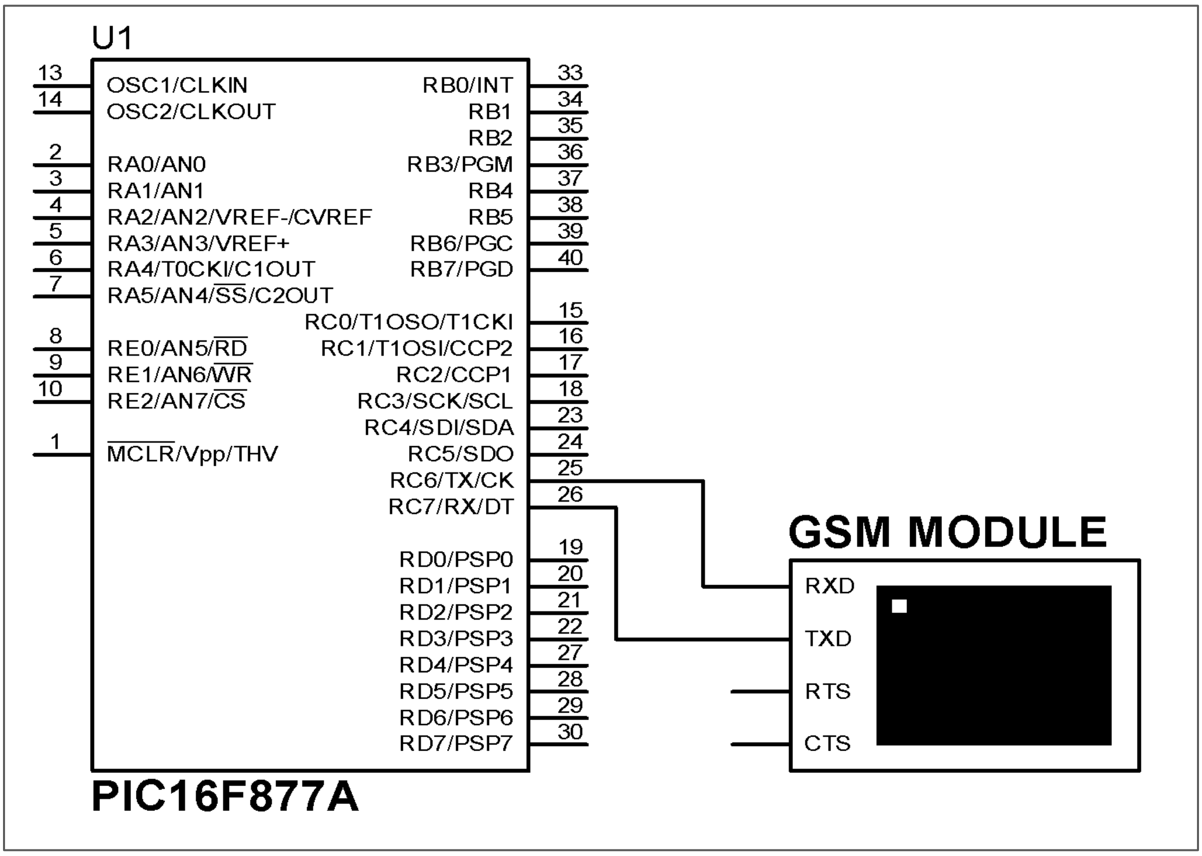


Figure 2. GSM Module PIC16F877A Interface

The software design

Program flowchart was developed as shown in Figure 3. First the device initializes and the user input the maximum and minimum threshold of the moisture content that is required for the device to send message. If the moisture content reach any of the threshold value set by the user, short message service is send to the user notifying him of the statues of the moisture content as program. The program was developed using mikro C pro for PIC.

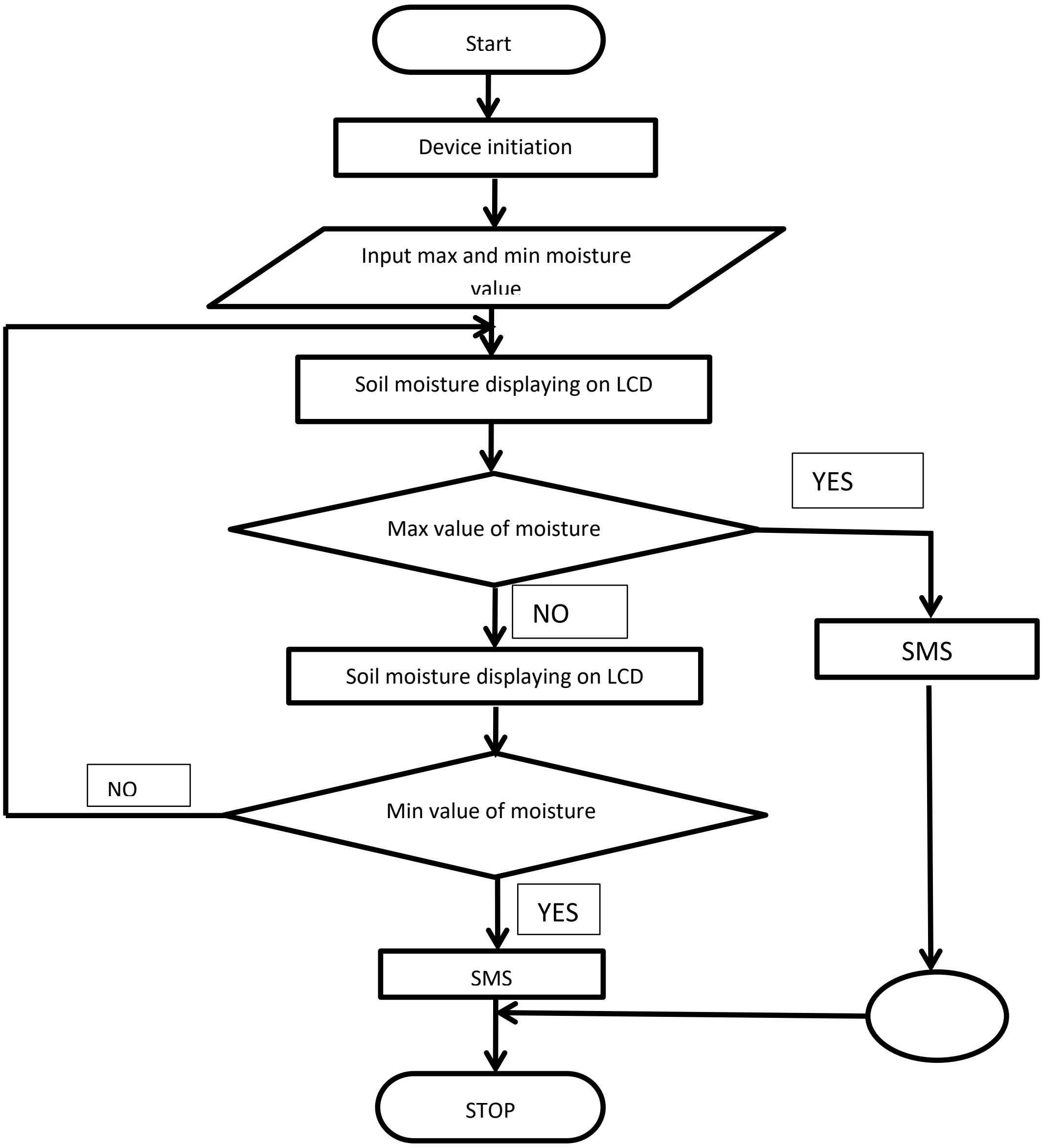


Figure 3. System Flow Chart

Simulation Diagram

The simulation diagram developed using proteus software, while mikronC pro for PIC software used to develop the program as shown in Figure 4. The simulation gave the desired result into the microcontroller.

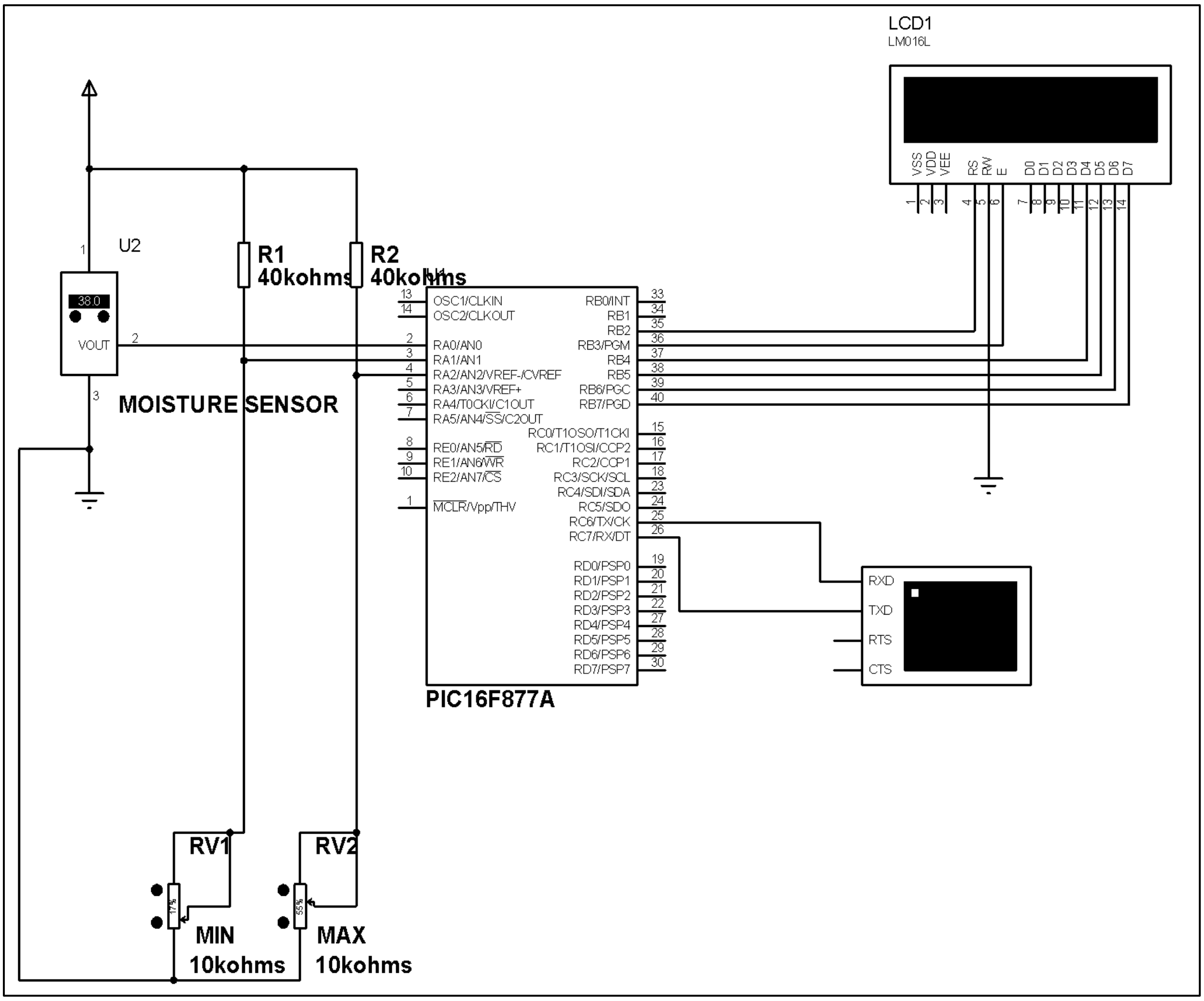


Figure 4. Simulation Diagram

Circuit design

Circuit is a continuous conducting path where electric current can flow. It comprises of various electrical element. The complete circuit design for the device is shown in Figure 5. This encompasses all the subunits that were described.

Device testing

After construction, tests were carried out on the device to ensure that the device is functioning according to the design specifications. The test conducted on the device is to verify the level of conformity of the output of the device. Soil sample was collected from the field and placed inside the perforated plastic container. The soil then undergoes continued wetting every day for a week in order to give the soil some level of compaction inside the container. Then water was added to the soil inside the container until it reaches saturation point and the water was drained gravitationally through the perforation. The Soil sensor was then placed at a depth of 5 cm in the soil and the output readings were taken at 0-60% output range setting of the device

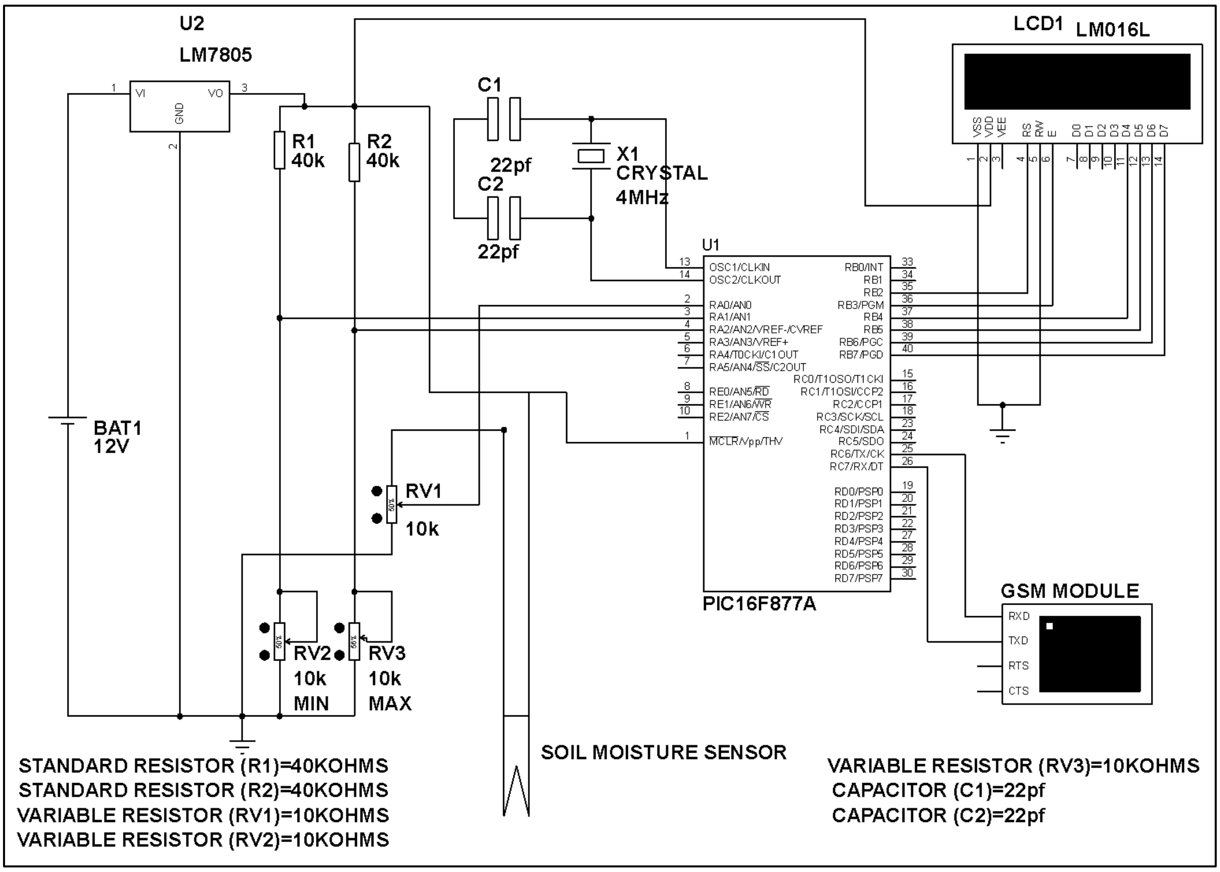


Figure 5. Circuit Design

On other hand, soil moisture levels were also determine using conventional soil moisture meter and gravimetric method for comparison.

Results and Discussion

Figure 6 shows the complete device setup for soil water monitoring. The result was obtained at 0-60% output range setting when the test was conducted. As can be seen from Figure 7. The soil moisture levels reading from the developed device, conventional moisture meter and gravimetric method shows similar trend having little differences. This indicated the effectiveness of the developed device. However, further performance evaluation will be conducted on the field irrigated crops. It is important here to note that the output range of the device can be varied by the user through a potentiometer (variable resistor) inside the device. Whenever standardization is require to be made with any other moisture monitoring device.

Device calibration

The device calibration graph at 0-60% is shown in Figure 8. Gravimetric output is on vertical axis against developed device output on horizontal -axis. The coefficient of determination (R^2) value was 0.9809.

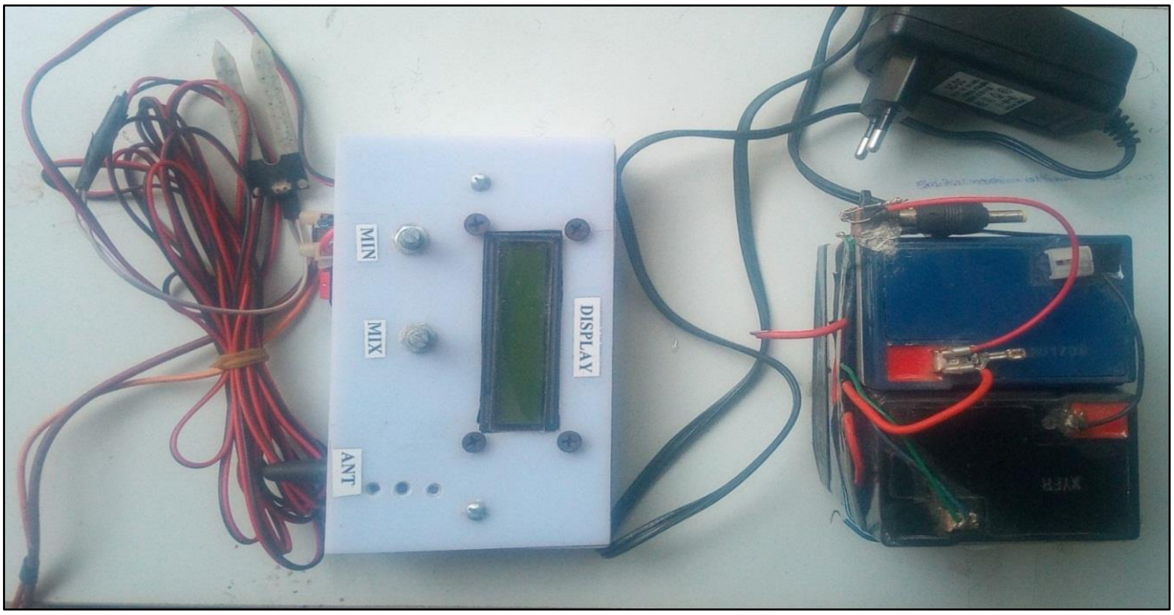


Figure 6. Device Setup

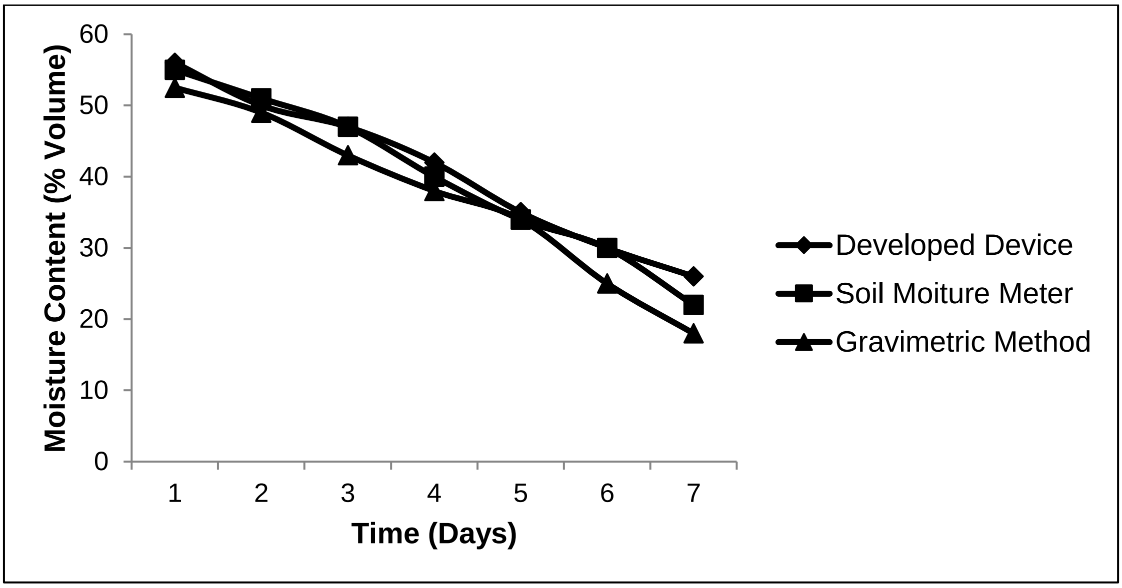


Figure 7. Soil moisture readings from the developed device, soil moisture meter and gravimetric Method

This linear regression equations can be used to determine the actual gravimetric moisture content by using the value of the output from the device as unknown value in the equation and the coefficient of linear regression values indicate a strong linear relationship, between the device and gravimetric moisture content.

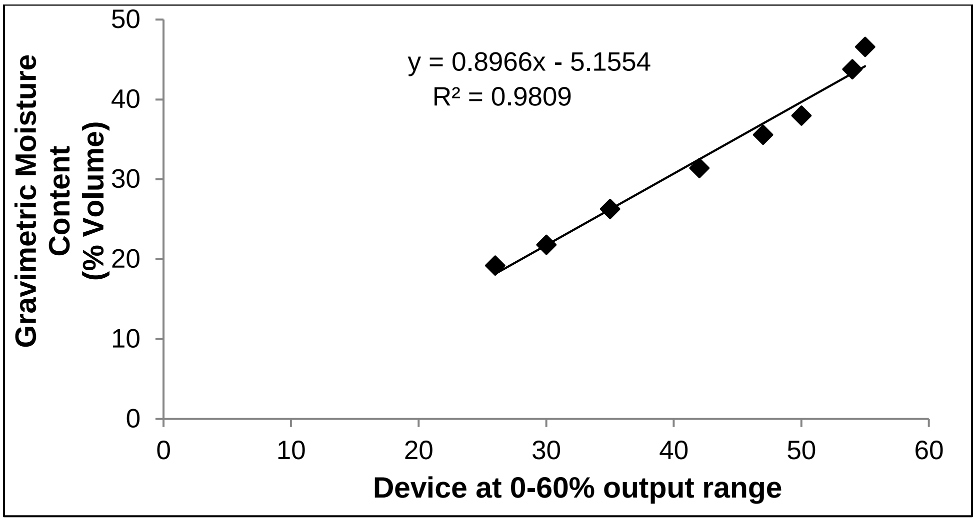


Figure 8. Device Calibration at 0-60% Output Range

Conclusion

In this work, soil moisture monitoring device was successively assembled, calibrated and tested. The test conducted on the device was found to operate based on the developed program. Moisture content can be monitor on the device and it is also capable of sending short message service. The device will provide an alternative choice for automatic irrigation system. Furthermore, from the result obtained by calibrating the device at 0-60% moisture content output range with the gravimetric output gives coefficient of determination (R^2) values as 0.9809. These values indicate a strong linear relationship, between the device and gravimetric moisture content.

Acknowledgement

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Influence of Crop Planting Ratio on the Yield and Quality of Combined Forage of Corn-Bambara Nut Grown Under The Tropical Humid Climate

[1]Beleland, M.D. and [2]Halim,R.A.
[1]Department of Horticultural Technology, Federal Polytechnic, Mubi, Nigeria.
[2]Department of Crop Science, University Putra Malaysia

E-mail address:
mustaphabelel@gmail.com (Belel, M.D.)

Abstract

The forage corn has been used as a feed resource for ruminant but it is low in crude protein content such that animals have to be supplemented with protein sources. An experiment was set up using corn intercropped with bambara nut landrace, Bambwus in a randomized complete block design to in order to investigate the contribution of different combination ratios (C4:B0, C4:B0+N, C3:B1, C2:B2, C1:B3, C0:B4) of corn with bambara on the quality of combined forage. Results from the study showed that crop growth rate, leaf chlorophyll and total leaf area were significantly higher among the intercrops compared to monocrop. Total dry matter yield was similar in all combinations. Sole corn had 73% neutral detergent fiber (NDF) which was higher than in the intercrops except C1:B3. Corn-bambara nut combinations ratios also differed significantly in NDF and acid detergent fiber (ADF). Protein in sole bambara nut was 14.8%. Among the combinations, crude protein was highest in C1:B3 (17.3%). Crude protein in sole corn was 8.52%. Lignin was highest in combinations with more bambara nut with sole bambara nut having 4.92% lignin. For improvement of overall forage quality, it is recommended that bambara nut be planted as an intercrop with corn at the ratio of 1 corn to 3 bambara nut.

Keywords: Bambara nut, Corn, Forage, Humid climate, Planting ratio, Quality, Yield

Introduction

The purpose of expanding crop production is to increase and stabilize yield of crop plants in order to meet the various needs of man; first to ensure that food supply meet the demand of an increasing human population so as to reduce or eradicate hunger and next is to produce feed for livestock. The essential features of intercropping systems are that they exhibit intensification in space and time and competition between the system components for light, water and nutrients. The right crop combination is very important in intercropping systems due to the fact that plant competition could be manipulated by spatial arrangement and by combining those crops best able to exploit soil nutrients (Fisher, 1977).

In the legume mixtures with cereals, it is essential to know the rates of the legume and cereal species for a high forage yield and quality. Several scientists have earlier reported on forage production using different intercropping ratios such as in studies involving: corn/vegetables (Mbah and Ogbodo, 2013), sorghum/soybean (Egbe, 2010), sorghum/cowpea (Tajudeen, 2010) and sesame/legumes (Bhatti *et al*., 2006). There is hardly any research involving bambara nut in different intercropping ratio with corn for a better forage mixture. Karikari (2000) and Alhassan and Egbe (2014) worked on intercropping sorghum/bambara nut and corn/bambara nut and both were aiming at the grain yield with no attention to the forage aspect, respectively.

It is glaring that there is the challenge of identifying the optimal combination ratios of crops capable of sustaining potential yield when grown in specific row arrangements. Different intercropping ratios and crop composition need to be optimized to obtain the best yield and forage quality in a corn-legume intercrop.

This paper therefore aim to determine the growth and yield characteristics of corn and bambara in different crop ratios as well as assess the quality and yield of forage that will result from the different crop ratios.

Materials and Methods

The field experiment was conducted at Field 2 of Universiti Putra Malaysia (UPM) Serdang, latitude 3º 2'N and longitude 101º 42' E; elevation 31 m. The experiment covered the period from October 2014 to January, 2015. The experiment was arranged in a randomized complete block design with three replications. Land was ploughed and made into ridges of 4 m long with each of the 18 plots containing eight ridges. Treatments comprised of different ratios of intercropping in the corn/bambara mixture (C4:B0 =Pure stands of corn without nitrogen; C4:B0+N =Pure stands of corn with nitrogen; C3:B1 =Six rows of corn with two rows of bambara nut; C2:B2 =Four rows of corn with four rows of bambara nut; C1:B3 = Two rows of corn with six rows of bambara nut and C0:B4 =Pure stands of bambara nut).

Nitrogen fertilizer in the form of urea (46% N) was applied only to sole corn with N plots at the rate of 200 kg/ha (Dahmadeh, 2013; Amjad *et al*., 2014) in two split doses while phosphorus (TSP-21% P) and potassium (MOP- 50% K) fertilizers were applied to all treatments during land preparation at 65 kg/ha and 200 kg/ha, respectively**.** Weed control was achieved by use of plastic mulch spread over the entire field. Specific spots where the seeds were planted were cut open using scissors. The shiny black plastic mulch was held to the ground using 1.5 mm (diameter) galvanized iron wires, 150 mm long and clipped down the edges of the mulch sheet against the wind from blowing it off.

Destructive sampling of plants was done to determine crop growth rate at 6 and 12 weeks after sowing using the procedure of Kumar and Kumar, 2008 and Hunt *et al*., 2002 as given below:

$$CGR = \frac{W1 - W0}{t1 - t0} \quad (1)$$

Where; W_1 and W_2 are dry matter (g) produced at time t_1 and t_0

Leaf area index (LAI) was taken at 4 weeks after sowing (4WAS) using the plant canopy analyzer (LI-COR 2200) which consisted of a probe connected to a meter. The probe was held at four locations around the plant from which each a measurement is taken, the LAI value is then generated by the LAI meter. Photosynthesis, stomata conductance and transpiration were measured at noon on a cloud clear day at 6 weeks after sowing using LI-COR (LI-6400 portable photosynthesis system). Sampled plants were harvested using one quadrat (0.25 m^2) from each plot for both pod yield and above-ground biomass yield. The plants were harvested at 10WAS by cutting at 2 cm above ground level and the fresh weight was taken immediately using a digital scale (30 kg capacity scale Model CAMRY ACS-30-JC21G). Dry matter yield of forage material was obtained after oven drying at 70^o C for 72 hours (Achim, 2005). The dried material was weighed using digital weighing scale (1 kg capacity digital balance model APEX A5000-I).

Nutritive values such as neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), crude protein (CP) and dry matter (DM) were analyzed using the near infrared reflectance spectroscopy (NIRS) technology. Plant materials were pre dried overnight in an oven set at temperature of 50^o C and placed in a desiccator before NIRS analysis. NIRS FOSS DS2500 connected to a computer was switched on and allowed to run both the hardware and performance test before samples were scanned. Laboratory result of chemical analysis of previous study was used to calibrate the machine for measurement of nutritive quality. The analysis of mineral concentration of forage was done following the digestion of forage samples. During mineral analysis, solutions were transferred into small test tubes to fit in the auto-analyzer. Nitrogen and phosphorus were analyzed using an auto analyzer (Lachat Instrument 8000 series). After auto analysis, the nitrogen value was converted by multiplying with a constant value of 6.25 to obtain the crude protein percent (AOAC, 2007). Potassium, calcium, magnesium, copper and iron were analyzed by Atomic Absorption Spectrophotometer Model 3110, Perkin Elmer, USA.

Data that was generated from this experiment was subjected to analysis of variance using SAS version 9.2. Mean values were compared using least significance difference at the 5 % level of probability (Gomez and Gomez, 1984).

Results and Discussion

There was no significant difference in the plant height of corn among the treatments at 2 weeks after sowing. However, at 4WAS there was a significant effect of N-fertilizers as well as intercropping on plant height of corn. At 8WAS, the sole corn without fertilizer significantly reduced corn height compared with the nitrogen-fertilized sole corn (Figure 1). Corn intercropped with bambara nut at all ratios showed similar growth as sole corn fertilized with N. This indicated that bambara nut could give the same effect to corn growth as with the use of nitrogen fertilizer.

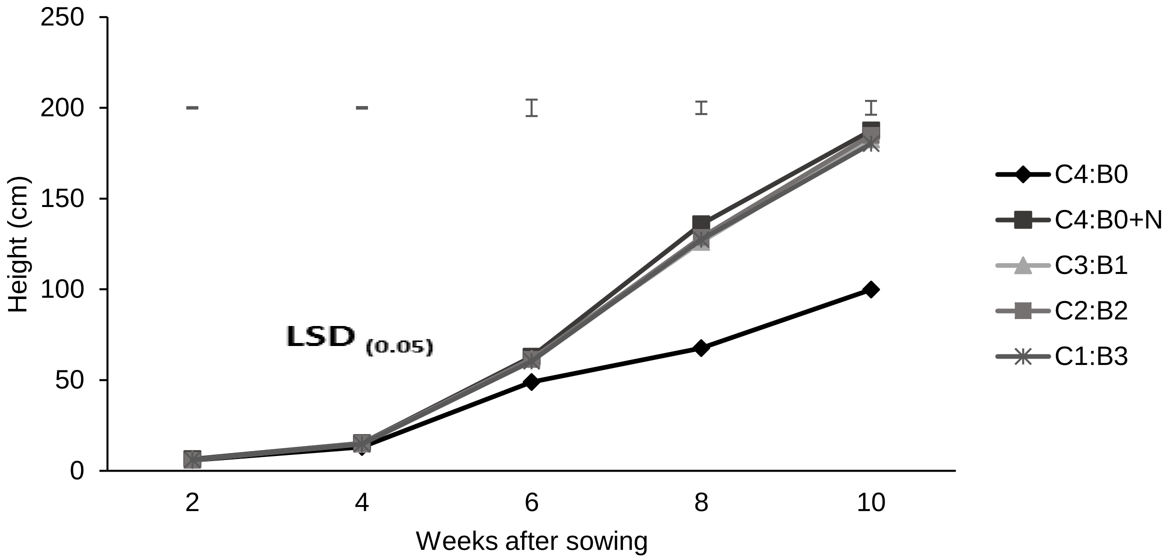

Figure 1. Effect of different intercropping ratios on the height of corn. Bars indicate least significant difference (LSD) for plant height on two weeks interval, C= Corn, B= Bambara nut, N= Nitrogen, 0, 1, 2, 3, 4= Intercrop combination ratios.

The height of bambara nut was significantly ($P<0.01$) reduced with increased corn ratio to bambara nut in C3:B1. However, bambara nut height was not affected by corn when the ratio of corn was less or equal to C2:B2 (Figure 2).

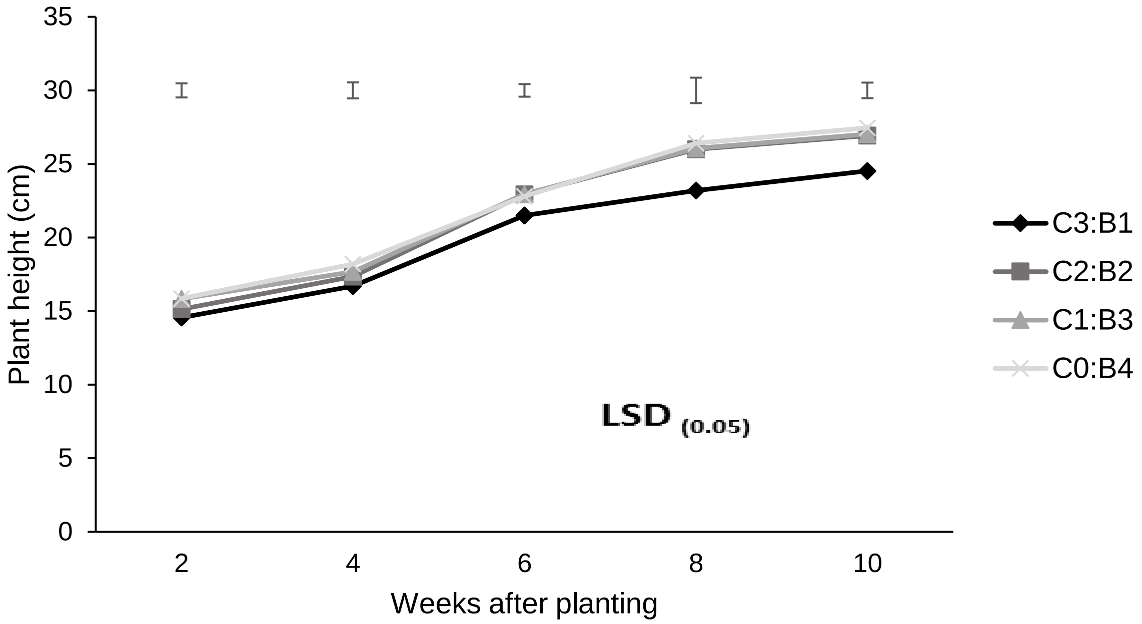

Figure 2: Effect of different intercropping ratios on the height of Bambara nut. Bars indicate least significant difference (LSD) for plant height on two weeks interval, C= Corn, B= Bambara nut, N= Nitrogen, 0, 1, 2, 3, 4= Intercrop combination ratios.

Significant difference ($P<0.01$) in the canopy width of bambara nut indicated that with decrease in the ratio of corn in the mixture, the canopy width of bambara nut increased at 6 and 8 weeks. C0:B4 had the largest canopy of 60.03 cm and the narrowest canopy was in C3:B1 (43.10 cm) at 10 weeks (Figure 3).

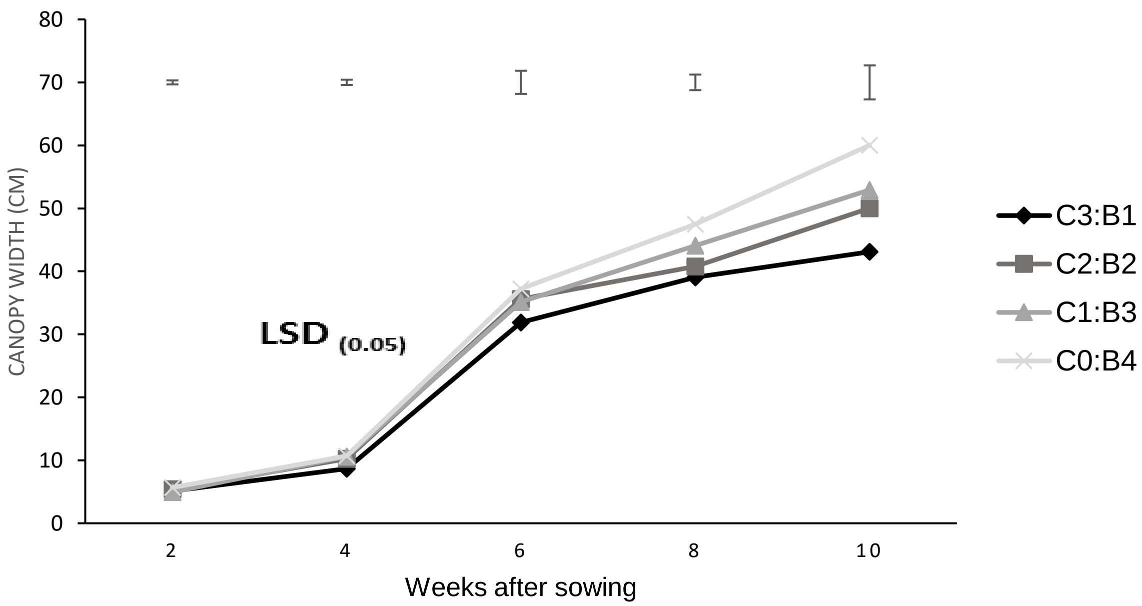

Figure 3. Effect of different intercropping ratios on canopy width of bambara nut. Bars indicate least significant difference (LSD) for canopy width on two weeks interval, C= Corn, B= Bambara nut, N= Nitrogen, 0, 1, 2, 3, 4= Intercrop combination ratios.

The crop growth rate (CGR) of bambara nut was significantly ($P<0.01$) reduced (by 19.3 %) when the ratio of corn to bambara nut reaches 3:1 but was not significantly ($P>0.05$) different when the ratios of corn to bambara nut were lower (C1:B3) or equal (C2:B2) (Table 1). The sole bambara nut recorded a CGR of 45.97 g m^{-2} d^{-1}. The application of N-fertilizer to corn significantly ($P<0.01$) increased the CGR by 45% from 123.43 to 178.91 g m^{-2} d^{-1}. The presence of bambara nut at C2:B2 and C1:B3 gave the same CGR to corn as with the application of nitrogen to corn. The total leaf area (TLA) of bambara nut was reduced when the ratio of corn was C2:B2 and above. For corn, application of nitrogen significantly increased the TLA form 1445.4 to 4231.6 cm^2. Intercropping with bambara nut even at C3:B1 gave the same effect as nitrogen in increasing the total leaf area of corn (Table 1).

Table 1. Effect of different intercropping ratios on growth characters of corn and bambara nut

Intercropping ratios	**Crop growth rate ($g\ m^{-2}\ d^{-1}$)**		**Total leaf area (cm^2)**	
	Corn	**Bambara nut**	**Corn**	**Bambara nut**
C4:B0	123.43c	-	1445.4b	-
C4: B0+N	178.91a	-	4231.6a	-
C3:B1	158.80b	38.53b	3557.5a	142.59c
C2:B2	168.83ab	43.82a	4131.7a	156.11b
C1:B3	170.03ab	43.00a	3632.8a	158.33ab
C0:B4	-	45.96a	-	164.14a
$LSD_{(0.05)}$	14.26	3.29	958.39	7.64
CV (%)	4.73	3.85	14.97	2.46
SE	3.747	2.645	614.66	6.336
P>F	0.0002	0.0079	0.0009	0.0024

Note: Means within columns with similar letters are not significantly different using LSD (P>0.05), C= Corn, B= Bambara nut, N= Nitrogen, 0, 1, 2, 3, 4= Intercrop combination ratio

Application of N-fertilizer to corn significantly (P<0.01) increased its leaf relative chlorophyll content (Table 2). Intercropping with bambara nut even at C3:B1 gave the same effect in increasing the relative chlorophyll content of corn as with the application of N-fertilizer. Relative leaf chlorophyll of bambara nut was highest in sole crop and the intercropping with corn reduced bambara nuts relative chlorophyll content.

The application of N-fertilizer to corn significantly (P<0.01) increased the leaf area index (LAI) by 44.8% from 1.79 to 3.24. Intercropping with bambara nut significantly increased the LAI of corn but not to the same extent as the application of nitrogen fertilizer (Table 2). Bambara nut did not show any significant (P>0.05) difference in LAI among treatments. The LAI for bambara nut treatments ranged from 2.13 to 2.53.

Table 2. Effect of different intercropping ratios on physiology of corn and bambara nut

	Relative leaf chlorophyll		**Leaf area index**	
Treatments	**Corn**	**Bambara nut**	**Corn**	**Bambara nut**
C4:B0	31.02b	-	1.79c	-
C4: B0+N	47.54a	-	3.24a	-
C3:B1	41.86a	44.16b	2.54b	2.13
C2:B2	43.55a	45.73ab	3.00ab	2.28
C1:B3	45.65a	44.50b	2.55b	2.19
C0:B4	-	48.53a	-	2.53
LSD $_{(0.05)}$	6.05	2.81	0.484	-
CV (%)	7.66	3.07	9.78	12.99
SE	2.855	1.328	0.182	0.240
P>F	0.0018	0.031	0.0011	0.4267

Note: Means within columns with similar letters are not significantly different using LSD (P>0.05), C= Corn, B= Bambara nut, N= Nitrogen, 0, 1, 2, 3, 4= Intercrop combination ratios.

Table 3 shows the effect of intercropping ratios on dry matter yield and forage yield per hectare of corn and bambara nut. The application of N-fertilizer to corn significantly (P<0.01) increased the dry matter yield by 150% from 2,733 to 6,852 kg/ha. Intercropping did not have any significant (P>0.05) effect on the dry matter yields of corn. In the bambara nut component, when the ratio of corn was higher than that of bambara nut in the mixture (C3:B1), the dry matter yield of bambara nut was significantly (P<0.01) lowered from 1,746 to 940 kg/ha (Table 3). Similarly when the ratio of corn to bambara nut is equal (C2:B2) or corn is lower than bambara nut (C1:B3), the dry matter yield of bambara nut was significantly (P<0.01) reduced by 70 and 53 % respectively.

Intercropping did not have any significant (P>0.05) effect on the fresh forage yield of corn but the application of N-fertilizer to corn significantly (P<0.01) increased the fresh forage yield from 14,083 to 33,292 kg/ha (Table 3). In the bambara nut component, the fresh forage yield was significantly (P<0.01) lowered by 157.7 % when the ratio of corn to bambara nut is high (C3:B1), by 85 % when the ratio of corn to bambara nut were equal (C2:B2), and by 79 % when the ratio of corn to bambara nut was low (C1:B3).

Table 3. Effect of different intercropping ratios on yield of corn and bambara nut

	Dry matter yield (kg/ha)		Fresh forage yield (kg/ha)	
Treatments	**Corn**	**Bambara nut**	**Corn**	**Bambara nut**
C4:B0	2733.8b	-	14083b	-
C4: B0+N	6852.9a	-	33292a	-
C3:B1	3138.7b	940.42c	14927b	2445.2c
C2:B2	3332.5b	1027.95bc	15110b	3384.5b
C1:B3	2395.6b	1140.64b	10417b	3519.1b
C0:B4	-	1746.27a	-	6301.5a
LSD $_{(0.05)}$	1663.7	139.2	6262	534.26
CV (%)	23.94	5.73	18.93	6.83
SE	879.75	37.13	4357.46	246.95
P>F	0.0016	< .0001	0.0002	< .0001

Note: Means within columns with similar letters are not significantly different using bars, C= Corn, B= Bambara nut, N= Nitrogen, 0, 1, 2, 3, 4= Intercrop combination ratios.

The total dry matter yield (corn + bambara nut) of the different planting patterns is shown in Figure 4. Intercropping significantly (P<0.01) increased the total dry matter yield in C3:B1 and C2:B2 from 1,746 to 4,079 kg/ha and 4,360 kg/ha respectively. Intercropping did not significantly (P>0.05) affect the total DMY of treatments when compared to C4:B0. The application of nitrogen fertilizer significantly (P<0.01) increased the total dry matter yield of C4: B0+N by 150.6% compared to C4:B0 and by 292.4 % when compared to C0:B4.

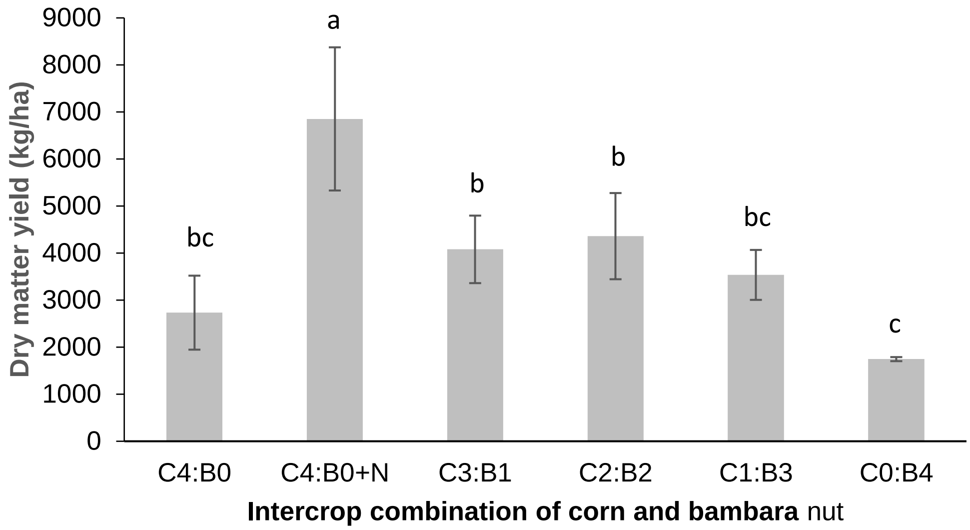

Figure 4. Total dry matter yield of different combination ratios of corn and bambara nut

Note: Means within columns with similar letters are not significantly different using bars, C= Corn, B= Bambara nut, N= Nitrogen, 0, 1, 2, 3, 4= Intercrop combination ratios.

Table 4 shows the effect of intercropping ratios on forage nutritive values such as acid detergent fiber (ADF), neutral detergent fiber (NDF), dry matter (DM), crude protein (CP) and acid detergent Lignin (ADL).

Corn has lower ADF than bambara nut (Table 4). Application of nitrogen to corn increased the ADF content. As sole bambara nut has the highest ADF content, intercropping corn with bambara nut increased the ADF of total forage with higher ratios of bambara nut.

Table 4 Effect of different intercropping ratios on nutritive value of forage

Treatments	Acid detergent fiber (%)	Neutral detergent fiber (%)	Dry matter (%)	Acid detergent lignin (%)
C4:B0	18.83d	73.00a	85.44a	2.33e
C4: B0+N	24.15bc	68.41ab	83.79bc	2.76d
C3:B1	22.64cd	68.17ab	84.45bc	2.05f
C2:B2	27.50b	67.72b	83.73bc	3.40c
C1:B3	26.05bc	59.05c	84.04ab	4.11b
C0:B4	36.23a	56.21c	83.24c	4.92a
$LSD_{(0.05)}$	4.31	4.97	1.04	0.178
CV (%)	9.14	4.17	0.679	3.00
SE	1.136	1.025	0.255	0.049
P>F	< .0001	0.0002	0.012	< .0001

Note: Means within columns with similar letters are not significantly different using LSD (P>0.05), C= Corn, B= Bambara nut, N= Nitrogen, 0, 1, 2, 3, 4= Intercrop combination ratios.

Sole corn has higher NDF content than bambara nut. Application of N-fertilizer did not affect the NDF content of corn forage. Bambara nut reduced the NDF content of total forage because it has lower NDF than corn. Sole bambara nut has lower dry matter than sole corn. Intercropping significantly (P<0.01) reduced the dry matter content of forage with increased bambara nut ratio (C1:B3) from 83 to 84%. Also the application of N-fertilizer to corn significantly increased the DM from 85 to 84%. Sole bambara nut has higher ADL than sole corn and the ADL content in forage increased with increased bambara nut ratios. The application of N-fertilizer to corn significantly (P<0.01) increased the acid detergent lignin content in corn from 2.33 to 2.76%. The crude protein content of feed should meet a minimum requirement for livestock. The result in Figure 5-6 showed that sole bambara nut has higher CP than sole corn and the 8.52% crude protein in sole corn cannot meet the minimum crude protein requirement of livestock. Most of the crude protein found in treatment combination were greater in CP than the benchmark value recommended for mature beef cattle for optimum rumen function (7%) but deficient of the requirement for high producing dairy cows (19%). Intercropping significantly (P<0.01) increased the crude protein content of C1:B3 by 16.5 % from 14.86 to 17.31% but reduced that of C3:B1 by 18.8 % from 14.86 to 12.51%. Similarly, the addition of nitrogen fertilizer to corn significantly (P<0.01) raised the crude protein content of forage by 64 % from 8.52 to 14.02% but this increase cannot match the incorporation of bambara nut to raise the CP in forage when compared to combination C1:B3.

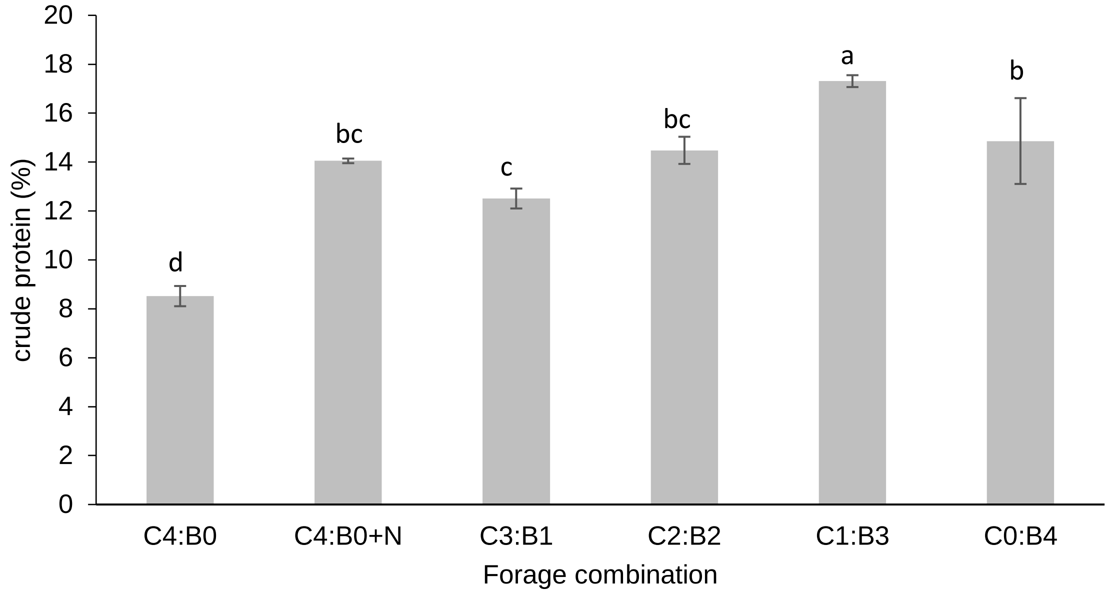

Figure 5. Percentage crude protein content of different corn/ bambara combination ratios Note: Means within columns with similar letters are not significantly different using bars: C= Corn, B= Bambara nut, N= Nitrogen, 0, 1, 2, 3, 4= Intercrop combination ratios.

Table 5 presents the effect of intercropping ratios on the mineral content of forage from corn and bambara nut mixtures.

The mean phosphorus content was not significantly (P>0.05) different among treatment combinations. It ranged from 0.496 to 0.803% (Table 5). Similarly, the mean potassium content ranged from 2.06 to 2.58% and was not significantly (P>0.05) different among treatment combinations. There was equally no significant (P>0.05) difference for magnesium among all the treatment combination mixtures.

Table 5. Effect of different intercropping ratios on mineral contents of forage for corn/bambara nut mixtures

Treatments	Phosphorus (%)	Potassium (%)	Magnesium (%)	Calcium (%)	Zinc (ppm)	Iron (ppm)	Copper (ppm)	Manganese (ppm)
C0:B4	0.610	2.30	0.24	0.716a	0.203	0.666	0.026	0.100
C1:B3	0.690	2.38	0.23	0.710a	0.216	0.653	0.030	0.096
C2:B2	0.770	2.58	0.29	0.560ab	0.256	0.900	0.026	0.106
C3:B1	0.533	2.46	0.23	0.526b	0.210	0.703	0.033	0.086
C4:B0	0.803	2.06	0.26	0.276c	0.216	0.600	0.023	0.083
C4: B0+N	0.496	2.42	0.15	0.343c	0.173	0.633	0.026	0.090
$LSD_{(0.05)}$	-	-	-	0.176	-	-	-	-
CV (%)	22.17	9.29	20.53	18.56	16.06	19.01	30.59	28.02
SE	0.062	0.091	0.019	0.046	0.019	0.059	0.005	0.015
P>F	0.1283	0.1758	0.076	0.0009	0.1902	0.1666	0.7753	0.8802

Note: Means within columns with similar letters are not significantly different using LSD (P > 0.05), C= Corn, B= Bambara nut, N= Nitrogen, 0, 1, 2, 3, 4= Intercrop combination ratios.

Sole bambara nut has higher calcium content than sole corn. Intercropping significantly (P<0.01) reduced the calcium concentration of forage with higher corn ratios (C3:B1) from 0.716 to 0.526% (Table 5). The application of N-fertilizer did not have any significant (P>0.05) effect on the calcium concentration of corn There was no significant (P>0.05) difference in the zinc content of the different forage combination mixture. The mean zinc content ranged from 0.173 to 0.256 ppm (Table 5). There was no significant (P>0.05) difference for in the iron contents of forage mixtures. The mean iron content ranged from 0.600 to 0.900 ppm (Table 5). There was no significant (P>0.05) difference in the copper content of different forage mixtures. The mean copper content ranged from 0.023 to 0.033 ppm (Table 5). There was no significant (P>0.05) difference in the manganese content of the forage mixture. The mean zinc content ranged from 0.083 to 0.106 ppm (Table 5).

Discussion

Total dry matter yield (corn + bambara nut) of different corn-bambara nut mixtures in intercrop were similar and this suggests that dry matter yield is independent of increase or decrease in the proportion of component crops in mixture. The C4:B0+N which showed a highest total dry matter was due to the inorganic nitrogen fertilizer applied to corn. The contribution of legumes to the total dry matter yield as well as the effect of cereal in dominating the legume in the mixture tended to strike a balance which probably made all the various combination ratios not to have any significant difference. However, the higher (C3:B1) or equal (C2:B2) corn proportion to bambara nut had higher total dry matter yield probably due to the aggressiveness of corn and its ability to convert environmental resources better being a C4 crop than the legume (C3) crop. The taller maize component shaded the low canopy legume reducing light availability for optimum photosynthetic activity and subsequently culminating in lower yields of bambara nut component. Such observations were common in legume/cereal intercropping (Molatudi and Mariga, 2012; Alhassan *et al*., 2012). The decline in yields with a decrease in ratio of bambara nut suggested that increased yields from increased cropping ratio was possible. Ibrahim *et al.*, (2012) found increased ratio of wheat in vetch/wheat mixture resulted in increased dry matter yield per unit area. Tajudeen (2010) also reported a highest yield of sorghum with the high sorghum ratio in the 2S:1C (sorghum-cowpea) planting arrangement.

Hauggaard-Nielsen *et al*., (2006) reported that each of the components in mixture may use ecological resources more efficiently than sole crops The results of this study was confirmed by the findings that regardless of mixing proportion the high or equal ratio was preferred for high dry matter yield. Similarly, Karikari (2000a) found a higher dry matter yield in intercropped sorghum-bambara nut with increasing ratio of bambara nut to sorghum.

Protein was increased with increased bambara nut ratio to corn as witnessed in C1:B3 combination. An increase in the CP of intercropped corn was reported by Geren *et al*., (2008). Nitrogen is known to form an integral building block of proteins. Foster and Malhi (2013) found protein content in forage decreased as dry matter yield increased. Emine *et al*., (2010) found that crude protein content of forage corn decreased with increased corn density which appeared true for C3:B1 combination. This result concur with the findings of Sanchez *et al*., (2010) who reported CP increases with corn-legume intercrop. Bambara nut is also known to be a nitrogen fixer for the benefit of the companion corn crop. The combination C1:B3 demonstrated potentials for providing higher CP in the corn-bambara nut mixtures. The nutritive value of forage in the mixed proportion was significantly better than in monocrop. It is the quantity of dry matter made available to be consumed by livestock (Shi *et al*., 2012). Lignification of cells may have caused higher NDF and ADF in the C4:B0+N and in C3:B1 or C2:B2 probably due to rapid cell development and ageing as a result of improved nourishment from fixed legumes nitrogen or available nitrogen from fertilizer. When corn was present in higher or equal proportions to bambara nut the dry matter yield increased. Also when bambara nut is present in higher or equal proportion to corn the lignin content become higher. Bambara nut was more lignified than corn hence in the mixed proportions, C1:B3 or C2:B2 indicated a higher lignin content probably due to its structural component. An increase in the bambara nut ratio had influenced the NDF and ADF of mixtures in the C1:B3 combination and this agreed with the findings of Aesen *et al.,* (2004) that increasing the legume proportion resulted in decreased ADF and NDF concentrations for the legume-grass mixtures. Carr *et al*., (2004) found that pea, barley, oat, pea-barley and pea-oat mixtures of ADF values 38.2%, 38.5%, 34.4% and 36.5%, respectively. Strydhorst *et al*., (2008) reported that barley and pea-barley mixtures of NDF values were 55.2% and 41.8%, respectively. Van Soest (1996) indicated that under similar growth conditions, legumes have low NDF values, whereas cereals have high values which are in agreement with the present study**.** Higher calcium content in higher (C3:B1) or equal (C2:B2) corn proportions was possibly due to improvement in absorption from the soil as a result of an important inter-specific root interaction that contributed to the nutrition of legumes by the corn component (Hongchun *et al*., (2013). Iron nutrition of legumes was enhanced by the root exudates from corn plants. The high iron content in bambara nut crops or combinations with higher ratios of bambara nut to corn may have been explained by the report of Hongchun *et al*., (2013) that in groundnut/maize intercropping, the secretion of phytosiderophore from maize in the intercrop arrangement may have contributed to the improvement of iron (Fe) nutrition of the groundnut. This was further supported by the fact that intercropping greatly augments Fe and Zinc (Zn) concentration in seeds of groundnut (Hongchun *et al.,* 2013). The higher ratios of corn to bambara nut have shown a better absorption of the mineral from the soil ensuring a satisfactory minerals in forages from corn-bambara nut mixture which suggest that virtually all the minerals fell within the optimum levels that will meet animals requirement.

Conclusion and Recommendations

Intercropping is an important practice in the tropical agro-ecology and is considered part of the subsistence farming designed to meet increasing domestic food requirements. Corn and bambara nut were grown in mixtures at various planting patterns to increase total production and provide a better high quality forage. The total dry matter yield in the different corn-bambara nut mixture was not significantly different but applying N-fertilizer to corn gave more dry matter than any of the combinations. The combination C1:B3 gave a higher crude protein than other combinations and the addition of N-fertilizer to corn did not contribute as much protein to the forage as did the combination C1:B3. Intercropping increased the yield through the cropping ratios over sole cropping, and C1:B3 is the best in increasing forage proteins.

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Data Based Modelling and Feature Generation as a Tool for Plant Disease Forecasting

[1] Outti, Mäyrä, [1]Mika Ruusunen and [1]Kauko Leiviskä
[1]Control Engineering research group, Faculty of Technology, University of Oulu (P.O.Box 8000 FI-90014 University of Oulu), Finland

E-mail address:
outi.mayra@oulu.fi (Outi, M.)

Abstract

This work describes the novel data-based method for the plant disease forecasting. The existing information about the weather conditions and the plant disease observations are utilized without the time-consuming measurement campaigns. This work combines the collected information and fuses it for a new purpose. There, information content of the data is enriched by the advanced data-analysis and therefore the feature generation methods and the data based modelling are in the key role. This work is focusing on generating the quantitative forecasting application for the plant disease occurrence, more than studying the plant infection phenomena itself. The general overview of the method is described step by step with results of forecasting one barley disease, the net blotch. The accurate plant disease forecasting is important for the modern agriculture. The reliable estimation helps the farmers to optimize the amount and timing of chemical spraying in the crop farming and thus saving money and environment.

Keywords: Plant disease forecasting, Advanced data-analysis, Feature generation, Data-based modelling

Introduction

The modern agriculture and the related innovations are in the focus of the worldwide research. The higher efficiency of farming and crop production (for food, fibre or energy purposes) is required to fulfil the demands for growing population. The yield per arable area should be increased to make the expanding of the food production possible. In crop farming, the challenges include the pests and the plant diseases besides the global warming and the natural disasters. In addition, there is variation in the yield and the quality of the crop depending on the weather conditions during the growing season.

In agricultural cases, the modelling has been found a valuable tool for decision-making and preparing for the variation of the crop. Attention has been paid to, how the weather is affecting the crop yield and the quality. Gobin (2018) has discussed the weather related risks in Belgium based on the weather measurements and the crop data during the period 1947-2012. He has compared the agrometeorological indicators between the low and the high yield of some cultivated plants. He has also summarized the average chances in the weather measurements and the growing season during the studied timeframe and discussed about the effects on the yield. More about the risk management, climate change and the crop yield estimation is found for example from Antón et al. (2013), Barlow et al. (2015), Ceglar et al. (2016), Mathieu and Aires (2018) and Urruty et al. (2017).

In addition to the crop yield, the forecasting of the pests and different plant diseases is in the centre of the discussion. The different models for estimating the occurence of the pests or some plant diseases have been published and discussed with details. Donatelli et al. (2017) have reviewed the state of the art and the challenges in coupling the pest or the plant disease modelling to the crop modelling. Jones et al. (2017 A) have published the review of the agricultural systems modelling and discussed briefly its history. In Jones et al. (2017 B), the current state of agricultural systems science, especially the capabilities and limitations of agricultural systems models has discussed thoroughly.

Besides the model input interactions, the challenges in modelling the occurrence of the pests or the plant diseases are in the amount and the quality of the data. The measurement campaigns are typically time consuming and often expensive. Then, again, the weather data with many variables are stored all over the World. Also, the agricultural statistics and the observations of different plant diseases during last decades already exist. This research utilizes solely the already collected information. As a result, the novel method for plant disease forecasting is presented in this paper. The open weather measurement database is used and the focus here was to identify the combinations of variables, which indicates the plant infection. The infection phenomena are not under the consideration in this case. The modelling scheme is demonstrated with one example, where the appearance of the barley net blotch is estimated with the generated algorithm.

Materials and Methods

The aim of the research is to generate the simple plant disease forecasting algorithm, which is adaptable to new diseases and fields by using the existing information and upgrading the information content of the data. This paper describes the framework of the data-based plant disease forecasting with a novel perspective.

The weather data is combined with the plant disease observations and the information content of the selected datasets is upgraded with data mining methods. The principle of this study is demonstrated in the Figure 1.

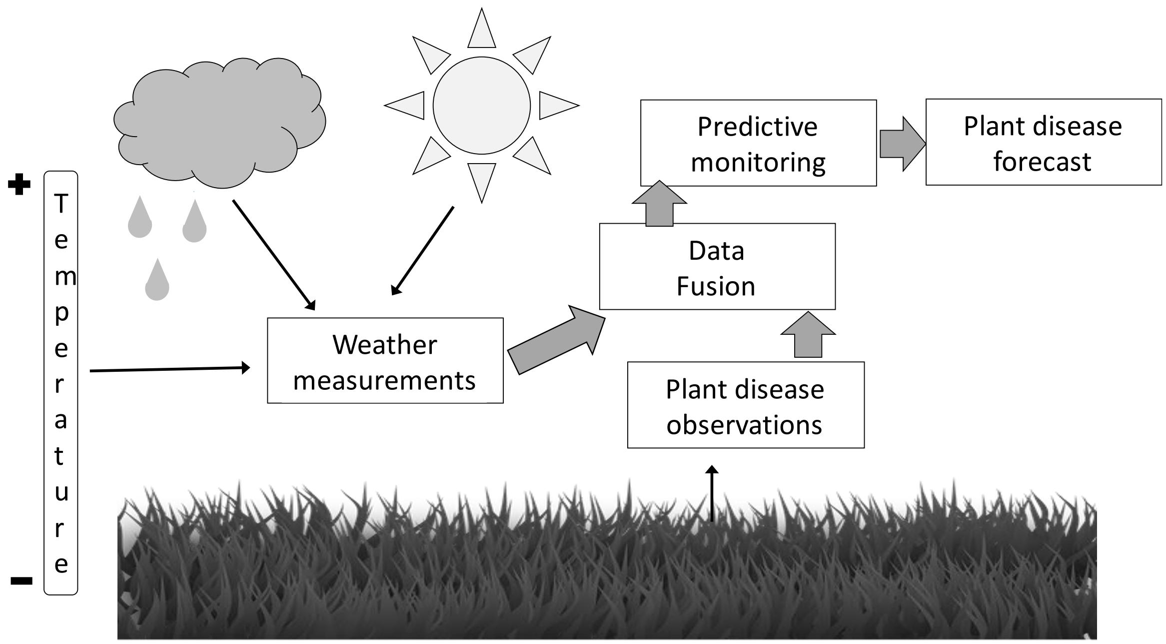

Figure 1. The framework for the development of the plant disease forecasting system.

The weather measurements are gathered from the open weather database of Finnish Meteorological Institute and the plant disease observations are from the database of Natural Resources Institute Finland (Luke). The period of the observations was 1991 – 2015 and the observation fields are situated all over Finland. It is noticeable, that the used weather measurement stations are not necessary next to the observation fields, but the location of the weather stations and the observation fields are the same during the period.

The data was arranged to the datasets, where one set included the yearly weather observations and the barley net blotch index. In the Figure 2, the mean and the standard deviation of two variables, daily rainfall [mm] and daily average temperature [°C], are presented. It is obvious, that the statistical characteristics are similar between the datasets and the correlation between the characteristics and the net blotch index does not exist.

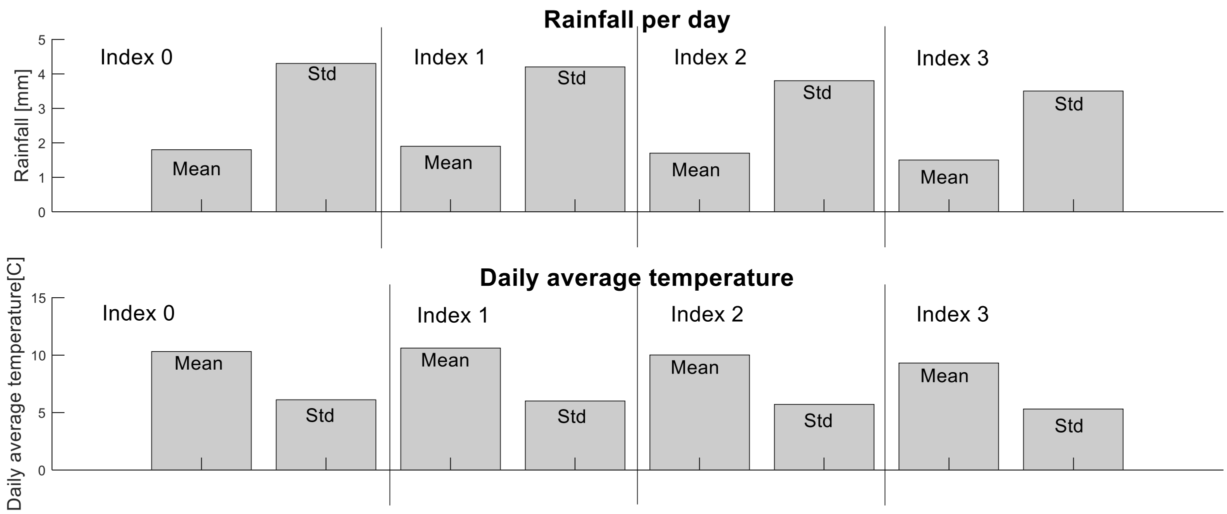

Figure 2. The statistical characteristics of two selected variables, presented according to the net blotch index. See the definition of the index in Table 1.

The variables of the weather data, which were tested in this study, are listed in Table 1. In addition, the barley net blotch indexes are presented with the short description. The observation period in this study started from the beginning of the growing season and the data after the growing season was excluded from the analysis.

Table 1. The content of the original datasets.

Weather observations	**The index and category reflecting the amount of selected plant disease**
place	0 = No observations
date	1 = Few observations
rain fall per day [mm]	2 = Observations
average temperature per day [°C]	3 = Many observations
daily minimum temperature [°C]	4 = A lot of observations
daily maximum temperature [°C]	

The above listed variables were fused together with the feature generation technique. Briefly, the selected variables were combined using mathematical operations e.g. summation, subtraction, multiplication, division, involution, logarithm, square root and the different combinations of those. This results in variables, features. More about the feature generation technique can be found for example from Blum and Langley (1997) and Garcia-Torres et al. (2016). The technique, which is utilized in this study, is presented in Ruusunen (2013, p. 50) with details and the tested features in Ruusunen (2013, appendix 1). The features were used to separate the data sets according to the net blotch index in the early stage of the growing season. Basically the cumulative sum of the generated feature value was used here as the modelling method, because the appearance of the net blotch was assumed to be a kind of dynamic phenomena. The generated features were evaluated according to the ability to separate the datasets with net blotch index 0 from the others. The most suitable feature was selected graphical interpretation of the results.

Results and Discussion

The case study of the barley net blotch forecasting for one observation field is presented in this chapter. The observation field locates in the western part of Finland.

Seven datasets (seven years weather observations and the plant disease indexes of those years) were analysed and classified with the feature generation. The dataset included four years with the net blotch index 0 and three years with the index 1. After the above described data-analysis and modelling steps, the best suitable feature in this case was the natural logarithm of the daily minimum temperature. As a result, the information content of each dataset was compressed to the cumulative sum of the selected feature. Those results are presented in Figure 3. The datasets with the net blotch index 0 are plotted with solid line and the datasets with the plant disease are plotted with dash lines.

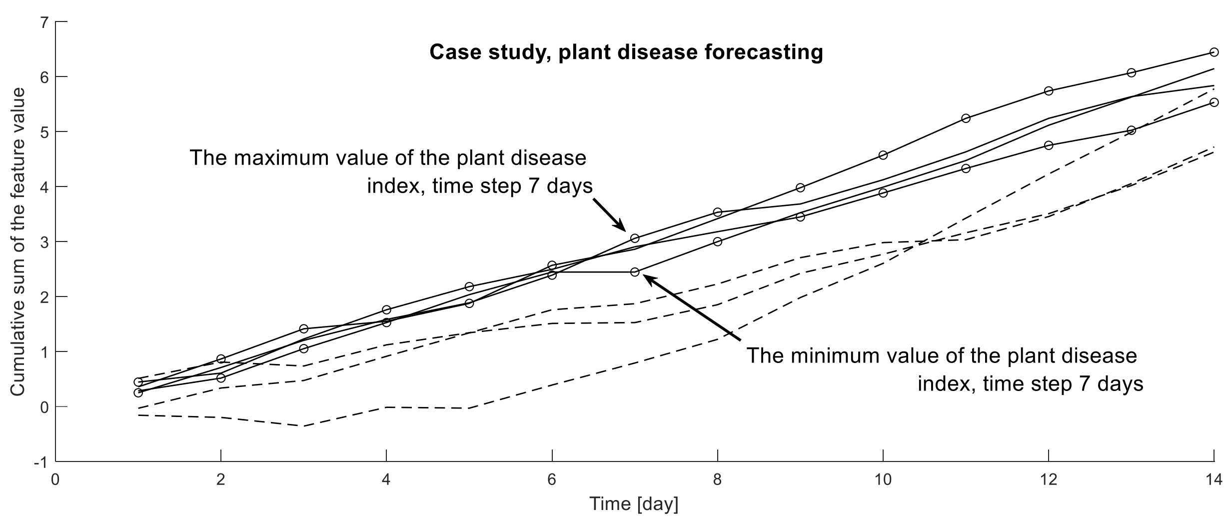

Figure 3. The case study results. The datasets without the net blotch are plotted with the solid line.

It can be seen that the datasets with and without net blotch are separated at the early stage of the growing season by using the generated feature. In Figure 3, the minimum and the maximum values of the "no net blotch" years are marked with **o**. Those are a kind of limit values of the features. The generated method forecasts net blotch, if the feature value is somewhere outside these limit values. It is noticeable, that the best suiting feature differed between the observation fields and the natural logarithm was used in that particular case. The structure of the generated forecasting method is simple and therefore easily adaptable even though the best suiting feature has to be selected separately for each of the observed areas.

The generated forecasting algorithm can be implemented for example to the expert systems. The reliable estimation of the different plant diseases appearance helps farmers to optimize the timing of the field spraying and that way decrease the use of the pesticides.

Conclusion

The novel data-based method for plant disease forecasting with the fresh perspective is presented in this paper. The method based on the feature generation and the cumulative sum is discussed and the modelling steps are described with the case study. It is noticeable that the feature selection and the best suiting feature depends on the data of the examined observation field. Still, the forecasting method can be generalized and adapted to the new observed areas while the best suiting features have to be recognised. The results of this research can be utilized for example by implementing the generated forecasting method into the agricultural expert system, which helps farmers to optimize the field spraying. By decreasing the use of the pesticides, the farmers can save both money and environment.

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Reclamation of Irrigated Sodic Soil Using Millet Chaff as an Amendment

[1]Nasidi N. M; [1]W. Aimrun; [2]K. M. Sani; [2]N. J. Shanono; and [2]M. D. Zakari
[1]Department of Biological and Agricultural Engineering, Universiti Putra Malaysia, 43400, UPM Serdang, Selangor, Malaysia.
[2]Department of Agricultural and Environmental Engineering, Bayero University, Kano Faculty of Engineering, PMB 3011 Kano, Kano – Nigeria

E-mail address:
nmnasidi.age@buk.edu.ng (Nasidi, N.M.)

Abstract

The productivity of agricultural lands is known to gradually reduce when the salt continue to accumulate. Such salt accumulation is resulted from both underground intrusion and the excessive application of chemical fertilizer by the farmers. Following a preliminary study in the Thomas Irrigation Scheme, Kano, a larger proportion of the soil found to be sodic. Although, reclaiming such soil using chemical amendment found to be promising and economically viable in many places, but in some places it is not. An effort towards employing organic materials that are abundant and economically viable as amendments can help reclaim sodic soil thereby informing local farmers. Herein, we reported the outcomes of using Millet chaff as an organic amendment for reclaiming sodic soils. The experiment carried out in twelve plots out of which nine were treated with three different quantities of millet chaff (M_1 = 680, M_2 = 1,080 and M_3 = 1,440 g/m^2), whereas the remaining three were left as control (C) . A significant improvement in soil quality indicators were observed at the end of the experiment. Sodium adsorption ratios found to drastically reduce for M_1 (0.66), M_2 (0.76), M_3 (0.42) as compared to C (8.10). The exchangeable sodium percentage are M_1 (23.92%), M_2 (28.46%), M3 (12.56%) as compared to C (76.82%). The least significant difference value (26.45) showed difference between M1 and M2 (32.955 mean difference) and M_2 and M_3 (34.778 mean difference) respectively. This showed that the M_2 (1,080 g/m^2) is statistically the best quantity. Results also showed that the application of amendment would be more effective when applied at least one month before planting to attain maximum decomposition of millet chaff. This process of soil organic reclamation is considered the most effective and efficient as the amendment is readily available, none hazardous, and it requires no high technical skills.

Keywords: Organic amendments; Irrigated sodic soils; Millet chaff; Soil reclamation,

Introduction

Soil salinity is an issue of global concern which causes many socio-economic problems. It is considered as a serious threat to world food security by lowering the productivity of soils. Salt-affected soils cover at least 20% of the world's cultivated lands (Nasidi et al., 2017; and Ghassemi et al., 1995). Incidentally, many countries of South-Eastern Asia, Africa and South America lying in arid and semi-arid climates are affected by this challenge. On global basis around one-third of the total world's irrigated land and 7% of the world's total land areas are considered salt-affected (Munns and Tester, 2008). According to another estimate, about 30% world's rice-growing lands are affected by the problem of soil salinity (Ahmad and Prasad, 2011). This resulted in the global economy to lose hundreds of millions of dollars (US$ 12.6 billion) per year to agriculture (Ghassemi *et al*., 1995). The estimates of every year (0.25 – 0.50 million hectares) of irrigated lands are becoming out of production in the world due to salts build up in the soil (Martinez and Manzur, 2005). Rice production lands are more often affected by the salinity those are within arid and semi-arid climates of the world simply because of high evaporation with less amount of precipitation (Ashraf *et al*., 2008).

Based on the source of salts, soil salinity can broadly be categorized as either primary salinity (natural intrusion from underground water) or secondary salinity (human-induced) (David, 2007). The main source of salts in the soil is the weathering of primary minerals in the exposed layer of the earth 's crust as well as seawater (contains around 500 mole/m^3 of NaCl) (Wheinhold and Trooies, 1995). Moreover, cyclones or exceptionally high tides for example Tsunami that occurred in Indonesia and Thailand in 2004 deposited a huge amount of salts in soils of coastal lands (Rengasamy, 2006). In another hand, human-induced salinity is manifesting in areas where there are uncontrolled practices and mismanagement of resources. In particular, over irrigation, over and irregular fertilizer application, inadequate drainage facilities, and high water table zones caused severe problems soils such as soil pollution, waterlogging, and Salinization. Sodicity occurs when sodium is the dominant element in the soil (David, 2007). This form of salinity is more challenging to handle because it could not be leached just with the application of good quality water unless with the addition of Amendment. Presence of sodicity in the soil causes poor soil structure, low permeability, high of pH, and a decrease in micronutrients.

A preliminary survey revealed that there is an existence of considerable salinity and sodicity issues in Thomas irrigation scheme and it is growing at an alarming rate. Several measures have been adopted to minimize the salt effects on crops which include chemical application and cultural approach. It was discovered that the use of chemicals have some negative consequences and sometimes unaffordable to many farmers. Eventually, the farmers abandon their plots, especially during dry season farming activities. However, some farmers use millet chaff to reduce the level of salinity and produce crops successfully. Meanwhile, the farmers are applying the millet chaff without knowing the exact dose required and at what level salinity problem. There is need to scientifically study the effect of millet chaff on the soil as an amendment to manage saline soil at Thomas Irrigation Scheme. The use of chemicals such as gypsum has been adopted by farmers to remedy salinity and sodicity for a long time and this, in turn, it is becoming too expensive for many farmers. Also, the excessive chemical application adds to the persistent soil salts situation. Lead to pollution of the soil environment. It is therefore essential to find another amendment preferably organic like millet chaff to tackle the problem of salinity and sodicity from soils. Therefore, this work aims at verifying whether there is an improvement in soil quality parameters upon application of this organic amendment. Also, a required amount will be evaluated to know how much dose is sufficient.

Materials and Methods

Study area

The study was conducted at Thomas Irrigation Scheme, Dambatta, Kano-Nigeria and located at a plot (12° 25’ 59” N; 8° 30’ 55” E). Kano state is located in Northern part of Nigeria and it borders Katsina state to the north-west, Jigawa state to the north-east, Bauchi state to the south-east and Kaduna state to the south-west (Figure 1). The irrigation Scheme covered an area of 732 km^2. The region is being characterized by an average temperature of 36^oC and rainfall amount of 780 mm per annum. Most common crops grown there are rice, sugar cane, maize, millet, tomatoes, pepper, onions, barley, groundnut, and sorghum among others.

Figure 1. A Map of Kano Sate - Nigeria where the research was conducted

Field survey

Field study was conducted within the area that most affected by salts as identified during preliminary study. Close observation for details is made in such a way that, all information required for this research are accessible. The information comprised of the nature of the soil, response of crops in the affected area, size of the affected land, irrigation practice, nature of the canals and also the quality of irrigation water. The sodicity was so pronounced that some plots could no longer support crop production in Thomas irrigation Scheme (Figure. 2).

Figure 2. A Typical Soil Suffering from Salinity at Thomas Irrigation Scheme

Sample collection

The soil and water samplings were conducted according to Nasidi et al., (2015). The technique ensured a good representative site was selected and samples were taken at random within the experimental unit. This was achieved by sub-dividing the area into units and sampling from a number of the sub-areas according to a pre-determined random distribution. This was used to know the level of sodicity in the area. Twelve samples each of soil and irrigation water were collected. Also, three doses of millet chaff were sampled for this experiment. These are; $M_{1,}$ M_2 and M_3 levels of 680 g/m^2 1080 g/m^2, and 1440 g/m^2 respectively. Also, $C_{1,}$ C_2, C_3 are left as controls. The amount of millet chaff used for this experiment was based on the local farmers approach because no existing work conducted to estimate the optimum quantity required for reclamation purpose. So, this work provides useful information regarding the use of millet chaff as a soil amendment and may be used as a bench mark for future studies.

Experimental set-up

The experiment consisted of three levels of millet chaff applied to an equal sized plot of 2 x 2 m^2 (M_1, M_2, M_3) and replicated three times. The chaff was mixed thoroughly with the soil by the use of manual tools such hoe and shovel and then left for three months. This was to enable a complete mixture and decomposing of organic constituents of the millet chaff to be attained. This will also improve the soil structure and allow for maximum infiltration with consequences of improving leaching of soluble salts (Figure 3). However, the control (no treatment) was left, and readings were taken for every dose of the amendment to have a clear representation of the field. The soil temperature was monitored and recorded at a strategic location within the experimental site. Also, the agronomic procedures were conducted as per the local farmer's practice.

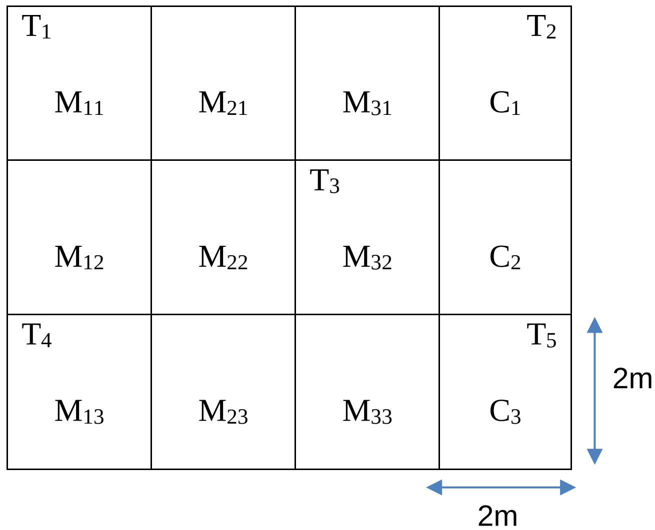

Figure 3. Experimental plots layout. Plots are M_1 = 680 g/m^2, M_2 = 1,080 g/m^2, M_3 = 1,440 g/m^2, C_1, C_2, C_3 are controls; and T_1, T_2, …, T_5 are temperature recording stations

Laboratory analysis

Irrigation water was analyzed using standard method (APHA, 1975) and the parameters determined were; the potential of hydrogen (pH), electrical conductivity (EC), temperature, carbonate, bicarbonate, metallic ions (calcium, magnesium, sodium, potassium), boron, chloride, and nitrate. Also, soil quality determinates analyzed in the laboratory were; pH, EC, temperature, carbonate, bicarbonate, metallic ions, cation exchange capacity and exchangeable bases. More so, millet chaff was analyzed for pH, EC, metallic ions, and nitrate.

A digital pH meter of model 3520 JENWAY was first calibrated using a buffer of pH 4 and pH 7. Soil and water samples were analyzed as in the procedure of reported (APHA, 1975). For both soil and millet chaff, 10g of each sample was weighed using a weighing balance of model PA2012 OHAUS Pioneer. Samples were made into a saturation paste with 25ml of distilled water. The samples were then stirred with glass rod dipping the probe into the paste and readings were recorded (AWWA, 1995 and Shanono et al., 2012).

Electrical conductivity

A digital conductivity meter of model DDS-307 was used for the determination of electrical conductivity. 25ml of distilled water was added to the samples and then stirred for 30 minutes at an interval of 5 minutes after which the samples were allowed to settle for 30 minutes undisturbed. Conductivity probe was then dipped into the samples and the EC values were obtained (AWWA, 1975).

Calcium and magnesium concentration

Atomic Absorption Spectrophotometer (AAS) was used for the determination of calcium and magnesium in water, soil and millet chaff samples by digestion method. For water samples, beakers were rinsed with distilled water and 100ml of water samples were poured in the beakers. 5ml of concentrated nitric acid (HNO_3) was added to the sample each and evaporated on a hot plate to 20ml mark. The samples were then filtered in a sample bottle and added distilled water to 50ml mark. Portion of the samples were inserted into AAS and the readings were obtained (APHA, 1980).

For both soil and millet chaff samples, 0.5 grams of the samples were weighed and transferred into a beaker. 30 ml of aquaregia (mixture of nitric and hydrochloric acid) was added to each sample and evaporated on a hot plate till the yellow coloration disappeared. The samples were then filtered in a sample bottle and added distilled water to 50 ml mark. Portion of the samples were inserted into AAS and the readings were obtained.

Sodium and potassium concentration

Flame photometer was used for the determination of sodium and potassium in water, soil and millet chaff samples by digestion method. 0.5 grams of the millet chaff was put into a beaker. 30 ml of aquaregia (mixture of nitric and hydrochloric acid) was added sample and evaporated on a hot plate till the yellow coloration disappeared before taking the readings. Carbonate, bi-carbonate, Chloride, Nitrate Exchangeable bases were determined based on appropriate laboratory procedures (APHA, 1980; AWWA, 1975).

Statistical analysis

Analysis of variance (ANOVA) was used to statistically evaluate the quality of soil treated with various quantities of millet chaff. The qualitative variable is the soil and the quantitative variable is the millet chaff. Also, Least Significant Difference (LSD) was used (equation 1) after conducting the ANOVA analysis to identify the millet dose that gives the best results for the soil reclamation of Thomas Irrigation soil.

The Least Significant Difference (LSD) was used to make a rational choice of optimum Millet chaff quantity to be applied. It was determined using the formula;

$$\text{LSD} = t\sqrt{MSW\ \left(\frac{1}{n1} + \frac{1}{n2}\right)} \qquad (1)$$

Where: LSD is Least Significant Difference, t is critical mean square value for n_1 and n_2 sample sizes, MSW is Mean Square within group derived from ANOVA.

Results and Discussion

Irrigation water

The result of soil, irrigation water, and millet chaff analysis was presented and compared with FAO standard. Average pH and EC are within the acceptable ranges 7.06, and 0.157 dS/m respectively.Ca, Mg, Na, values are safe for irrigation water and not cause soil pollution (Figure 4). Irrigation water assessment shows that the quality of irrigation is adequate and does not contain a reasonable amount of salt that can cause salinity and sodicity problems. Therefore, the salt is expected to come from groundwater intrusion or/and excessive use of chemical fertilizer.

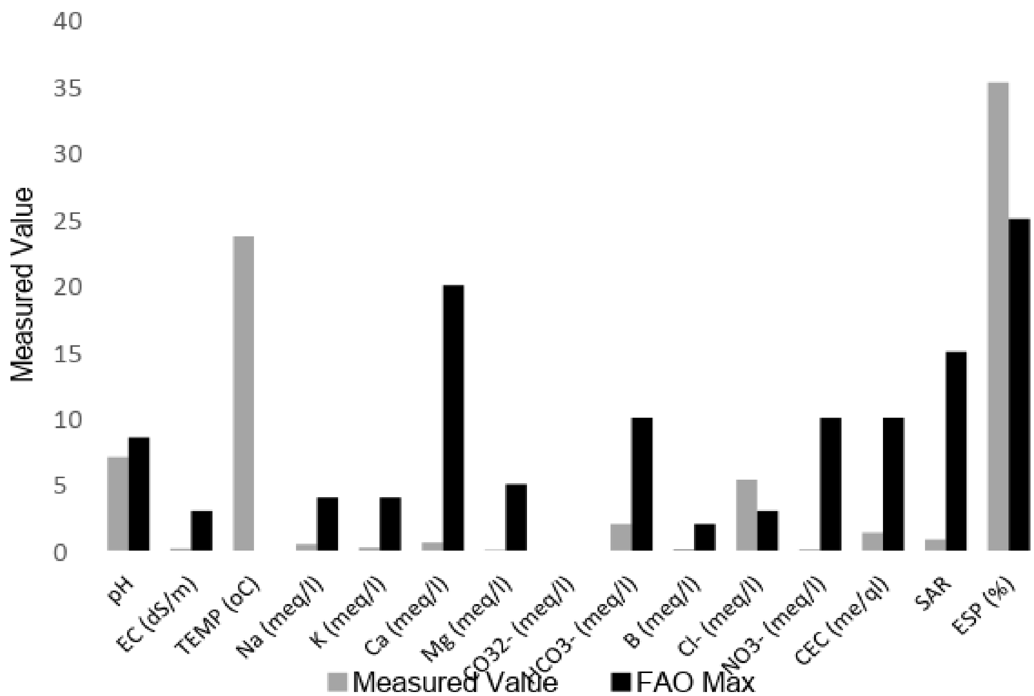

Figure 4. Quality of irrigation water at Thomas Irrigation Scheme

Millet chaff amendment

The chemical constituent of millet chaff was presented in Figure 5 below. It could be observe that the chaff is slightly acidic with pH of 6.36 and EC of 0.26 dS/m. also the chaff was found to contain high amount of K (27.22 mg/g) compared to Na, N, Ca and Mg. However, the used of this type of amendment was possible to reclaim a salt affect soils because it contain small amount of sodium but high potassium content.

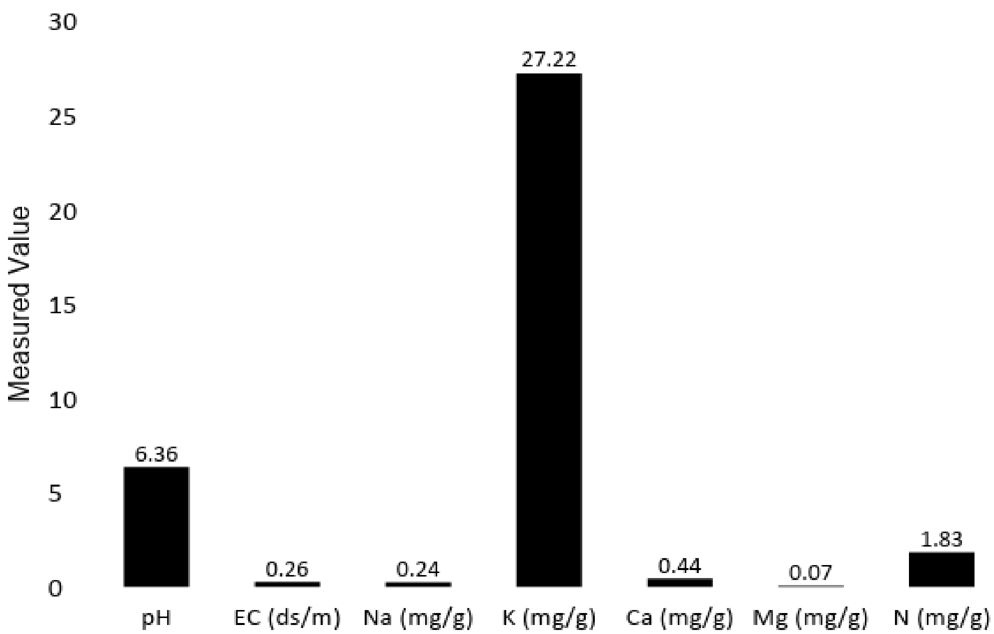

Figure 5. Chemical Properties of millet chaff

Soil samples

The results of soil analysis after the experiment were conducted and the impacts of millet chaff as an amendment were revealed. It was observed that, there were differences of soil quality determinants between soil samples in control and treated plots. Ca, Mg, and K which are good attributes for productive soils were found to be relatively high in treated plots compared to those in controls. Similarly, highest pH (9.88) was observed in control plots, likewise the EC (2.2 dS/m) was much larger than all the treated soils. Furthermore, important quality parameters SAR and ESP were evaluated, the control plots gave highest ESP (76.82 %) which is by far more than both treated soils and FAO standard (FAO, 2009). Similarly, SAR was higher at control plots whereas for all these parameters tested, M_3 (1044 g/m^2) was having least values (Figure 6). This shows that, the high application of the amendment the more good result is obtained. Economically, the plot treated with m2 (1,080 gm2) was found to be statistically the best dose.

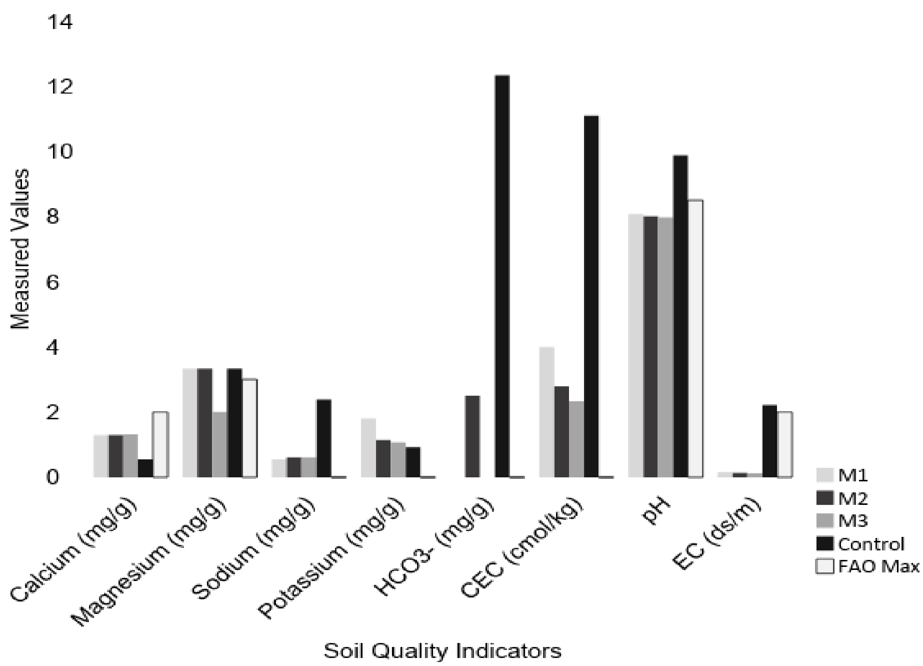

Figure 6. Soil Quality after Treatment with Various Levels of Millet Chaff

The statistical analysis showed that null hypothesis should be rejected since there is significant differences between treated and untreated soils at ($P<0.05$). However, there is a significant difference between the various quantities of millet chaff applied on the field for the reclamation of sodic soil at Thomas Irrigation Scheme (Table 1 and 2). The drop in soil salts concentration is a clear indication that certain level of reclamation is achieved. This could be confirmed by the ability of farmers to cultivate their lands after treatment application. In addition, LSD test shows that M_2 (1080 g/m^2) is statistically the best dose and more economical to be used. From economic point of view, famers should apply 1080 g/m^2 as it gives adequate reclamation level even though 1044 g/m^2 gave less SAR and ESP values.

Table 1: Analysis of Variance for Salinity Values under Different Millet Chaff Treatments

Source of Variation	**df**	**SS**	**MS**	**F**	**P-value**	**F critical**
Treatments (M)	2	3065.177	1532.589	5.601188	0.026289	3.006452**
Interactions	9	2462.566	273.6185			
Total	11	5527.743				

**Highly Significant

Table 2. Grouping of Salinity Concentration under Different Treatment using LSD Test.

Treatment combination		Mean Differences	Null hypothesis
M_1	M_2	32.955**	Reject
	M_3	1.8235^{ns}	Do not reject
M_2	M_1	32.955**	Reject
	M_3	34.778**	Reject
M_3	M_1	1.8235^{ns}	Do not reject
	M_2	34.778**	Reject

**Highly Significant; ns - Not Significance

Conclusion

The soil reclamation was successfully conducted at Thomas Irrigation Scheme, Kano using millet chaff as an amendment for sodic soil and tested statistically. The experiment confirms a reasonable improvement in soil quality parameters after been treated with millet chaff. This confirms statistically that, Statistical analysis revealed that millet chaff has the potentials for reclaiming sodic soils, and hence can be used in place of chemical amendments.

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Effect of Spray Drying Temperature and Maltodextrin Concentration towards Physical Properties and Antioxidant Activity in Josephine Pineapple Powder and Peels

[1] Ibrahim, U.K., [1]Hashib, S.A. and [1]Suzihaque, M.U.H

[1]Faculty of Chemical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

E-mail address:

syafiza0358@salam.uitm.edu.my (Hashib, S. A.)

Abstract

Antioxidants are compounds in foods that neutralize chemicals also known as free radicals. These chemicals linked to heart, liver disease and cancer. Antioxidant such as Vitamin C had lack of ability to be produced by body. The objectives that this research is to study the effect of spray dryer temperature and concentration of maltodextrin on antioxidant activity, phenolic content, and ascorbic acid in Josephine pineapple and peels powder. Sample was prepared to get pure juice before spray dried for powder formation. The spray drying temperature and percentage of maltodextrin was set at 140°C to 160° and 17 % to 27% respectively. The analysis conducted was antioxidant activity, pH, pulp content, moisture content, absorbance, titratable acidity and total soluble solid (TSS). For the pH analysis, the result shows that the flesh samples had higher pH in acidity compared to the peels with the highest value is 4.08 for the sample with parameters 140°C and 27% maltodextrin. For antioxidant analysis, the DPPH test shows that the flesh sample had highest value at 35.21% in sample 140°C and 27% maltodextrin. From the results, the ascorbic acid compound exist in pineapple powder and this prove that both flesh and peels had benefit to human health either in powder or fresh drinks.

Keywords: Maltodextrin, Moisture content, pH, TSS, TA, Pulp content

Introduction

Spray Drying is a method that can turn liquid food into a powder form. This method are using spray dryer to convert liquid product into powder by fast drying with hot gas that are widely used for commercial production of fruit, milk and vegetables(Suzihaque, Hashib, & Ibrahim, 2015). Other than rapid drying, this equipment also can convert a solution into powder in a single step,that can useful for maximizing the profit and minimize the process (Phisut, 2012). Usually, it is applied in the pharmaceutical and food manufacturing process. Spray drying the fruit juice has a great potential in economical because when the juice is dried, the volume of product produced is lower and the shelf life also increase. However, this method can cause the product to become sticky because fruit juice powders are easy to absorb moisture from the surrounding air. Spray drying only use low temperature and short time for production. However, when the different temperature are applied on the food sample, the physical and antioxidant activity will have changes. Other than the different of spray dry temperature, the concentration of maltodextrin also give different effect on each sample. In this research, the range of spray dry temperature that are used is 140°C to 160°C. While, the range for concentration of maltodextrin is 17% to 27%.

Pineapple contains many useful ingredients that are useful for human body. One of it is antioxidants which are function as medium to protect body from oxidation that cause by smoking habit, alcohol and depression. Antioxidant can be defined as “any substance that, when present in low concentration compared to that of an oxidisable delays, substrate or inhibit the oxidation of the substrate” (Sivanandham, 2014). In order to reduce oxidation, human needs to consume fruit that are rich in antioxidant by eating raw or as supplements. Pineapple need to be extracted to get the chemical compound such as ascorbic acid. Ascorbic acid is an example of antioxidant that are important for human body. This ascorbic acid is one of the important water soluble vitamins and required for carnitione, collagen and neurotransmitters biosynthesis (Naidu, 2003). By consuming ascorbic acid or known as vitamin c, some disease that can give harm to body can be prevented.There are many industries that show interest to get natural antioxidants since the already existing sythethic food antioxidants is not too favored. Antioxidants are widely used in pharmaceutical, cosmetics and plastics to prevent deterioration. Example of antioxidants is vitamin C that can be found in fruits and vegetables. This antioxidants can help in protecting against oxidative damage in living system. Other than vitamin C, antioxidants such as vitamin E and carotenoids can act as dietary constituents. Fruit is the best option as the antioxidants supplier because fruit like berries contain strong antioxidants compounds. Another example are citrus, cherries, prunes and kiwi that are also tasty when eaten raw.

Nowadays, there are many technique to improve food sample. Pineapple is one of the fruit that contain high antioxidants and when undergoes spry dry and addition of maltodextrin, there might changes to the antioxidants activity and other physical properties. Thus, many experiment are done to provide suitable temperature and concentration of maltodextrin in order to retain the best condition of the food sample.

Materials and Methods

Sample preparation

The first step in preparing the sample was cutting the pineapple into small size. The pineapple was separated by flesh and peels. The flesh is then grinded by using electric blender. However, for the peels, it was boiled first with hot water before grinding. This is because of the texture of peels that are hard to be blended.

The liquid that are produce after grinding will be mixed with different concentration of maltodextrin which are ranging from 17% to 27%. Then, the pineapple-maltodextrin solution was put in spray dryer that are operated at different temperature which are 140°C to 160°C at 3 rpm.

Antioxidant analysis

The first step was preparing the DPPH solution. 10ml DPPH was mixed with 100 ml of 80% methanol. Then, the control is prepared with mixing 1 ml of DPPH with 4 ml 80% methanol. To prepare for the analysis, 10 g of sample was mixed with 100 ml of 5% methanol and 100 ml distilled water. The solution is then kept on the hot plate for 45 minutes at 65°C. After 45 minutes, 1ml of the sample was mixed 4 ml of 80% methanol and DPPH solution. The mixture was shake and kept in dark place for 30 minutes. Then, by using spectrophotometer, the absorbance was read at 517 nm.

Physical properties analysis

pH – A10 ml of sample was taken out and the pH was determined by using pH meter (Hajar et al., 2012).

Pulp Content - To determine the pulp content, 5ml of sample was taken out and undergoes centrifugation for 10 minutes. The pulp content that are formed was then weight(Hajar et al., 2012).

Moisture Content - 3 gram of sample was place on the moisture analyzer at the 130°C for 10 minutes. The result was then read.

Total soluble solid – A 3ml of sample was taken out and squinted on the prism of refractometer. After the reading are shown, the result was tabulated (Hajar et al., 2012).

Absorbance – A 10 ml of water was used as the blank. 10ml of sample was taken out and measured by *using* refractometer that was set at 600nm of wavelength. The reading shown was then taken as the result in abs (Hajar et al., 2012).

Titratable acidity - For this analysis, 0.1N sodium hydroxide which are strong bases was used because the sample are rich in organic acid. Firstly, 10ml of sample was taken out and weighted using weighting balance. Then the sample was put into 500ml conical flask. The sample was diluted with 250 ml deionised water. Phenolphthalein indicator was used in order to determine the end point of titration. 1ml of phenolphthalein indicator was added to the sample. Then, the titration was started until the mixture form faded pink color. The step was repeated around three times. Below expression was used to calculate the percentage of citric acid (Hajar et al., 2012).

%Acid (as anhydrous citric acid) = volume of NaOH (ml) x 0.64/10 (1)

Results and Discussion

pH

From the result tabulated, it is shown that for the flesh sample, the most acidic sample is at temperature 140°C and 27% maltodextrin with value of 4.08. While, the least acidic sample is at temperature 140°C and 17% maltodextrin with value of 4.55. This is because, when the temperature of spry dry is set at low value, the pH of sample is high thus showing that the sample are acidic. For the peels sample, the most acidic is sample at temperature 160°C and 27% maltodextrin with value of 4.41. While, the least acidic sample is at 140°C and 17% maltodextrin with value 4.99. This is prove that the above theory also applied for the peels samples where the higher the temperature apply in spray dry, the lower the value of pH.

Pulp content

From the result tabulated, it is shown that for the flesh sample, the highest pulp content is at temperature 140°C and 17% maltodextrin with value of 11.53g. While, the least pulp content sample is at temperature 160°C and 27% maltodextrin with value of 9.60g. For the peels sample, the highest pulp content is sample at temperature 140°C and 17% maltodextrin with value of 14.24g. While, the lowest pulp content is at 160°C and 27% maltodextrin with value 10.25g. This is prove that high temperature and low concentration of maltodextrin can gives low pulp content value to the sample.

Moisture content

For flesh samples, the moisture content are lowest at temperature 160 °C and 27% maltodextrin with value of 3.63%M. While, the highest value of moisture content are recorded at temperature 140°C and 17% maltodextrin with value of 7.96%M. For the peels samples, the highest value of moisture content are recorded at temperature 140°C and 27% maltodextrin with value 8.30%M. While, the lowest moisture content is at temperature 160°C and 27% maltodextrin with 5.36%M. All these result for these two type sample are following the theory where the increasing of air drying temperature leads to decreasing of moisture content (Jittanit, Niti-Att, & Techanuntachaikul, 2010). This is because the heat and rates of moisture transfer are enhance when the temperature is raised.

Total soluble solid (TSS)

For flesh samples, the total soluble solid are lowest at temperature 140 °C and 27% maltodextrin with value of 1.35125 n.D. While, the highest value of total soluble solid are recorded at temperature 160°C and 27% maltodextrin with value of 1.35186 n.D. For the peels samples, the highest value of total soluble solid are recorded at temperature 160°C and 27% maltodextrin with value 1.35642 n.D. While, the lowest total soluble solid is at temperature 140°C and 17% maltodextrin with 1.35162 n.D. These result are follow the expected result where the concentration of maltodextrin give effect to the sample as the maltodextrin is high, the total soluble solid also give high value. However, for the temperature, there is no constant trend of decreasing and increasing total soluble solid when the temperature is increase, thus the total soluble solid does not depend on the temperature value.

Absorbance

From the table, it is shown that the highest value of absorbance for flesh samples are at temperature 160°C and 27% maltodextrin with value 1.233%. While, the lowest value are recorded at temperature 140°C and 17% maltodextrin with value of 0.226%. For the peels samples, the highest value of absorbance are recorded at temperature 140°C and 27% maltodextrin with value 0.053%. While, the lowest absorbance is at temperature 160°C and 27% maltodextrin with 0.013%. These result are following the theory as the absorbance are recorded high when the temperature is high.

Titratable acidity

From the table, it is shown that the highest value of titratable acidity for flesh samples are at temperature 140°C and 27% maltodextrin with value 0.1920%. While, the lowest value are recorded at temperature 140°C and 17% maltodextrin with value of 0.0533%. For the peels samples, the highest value of titratable acidity are recorded at temperature 140°C and 17% maltodextrin with value 0.1621%. While, the lowest titratable acidity is at temperature 140°C and 27% maltodextrin with 0.0640%. All these result for these two type sample are following the theory where the high value of maltodextrin and temperature leads to the lowest titratable acidity.

Antioxidants analysis

The highest value of antioxidant activity for flesh samples are at temperature 140°C and 27% maltodextrin with value 35.21%. While, the lowest value are recorded at temperature 160°C and 27% maltodextrin with value of 13.17%. For the peels samples, the highest value of antioxidant activity are recorded at temperature 140°C and 27% maltodextrin with value 34.47%. While, the lowest antioxidant activity is at temperature 160°C and 77% maltodextrin with 22.08%. All these result for these two type sample are following the theory where the high temperature can reduce the antioxidant activity in the sample.

Table 1. Physical Properties analysis on maltodextrin (MD) concentration, pH, Pulp Content (PC), Moisture Content (MC), absorbance (ABS) and Titratable acidity (TA)

IT (ºC)	MD (%)	pH	PC	MC(%)	TSS	ABS	TA
140	17	4.55	11.53	7.96	1.35130	0.226	0.0533
160	17	4.16	10.96	6.52	1.35178	0.320	0.1792
140	27	4.08	9.98	7.76	1.35125	0.794	0.1920
160	27	4.09	9.60	3.63	1.35186	1.233	0.1237
140	17	4.99	14.24	7.99	1.35162	0.042	0.1621
160	17	4.63	12.75	6.82	1.35194	0.023	0.0896
140	27	4.59	12.47	8.30	1.35165	0.053	0.0640
160	27	4.41	10.25	5.36	1.35642	0.013	0.0853

Conclusion

The effect of spray dry temperature and concentration of maltodextrin are important factors on physical properties and antioxidant activity of pineapple powders. From the result obtained, it is shown that when the temperature of spry dry is increasing, the moisture content, titratable acidity, absorbance and antioxidant activity are decreasing. While, high concentration of maltodextrin leads to high pH level, total soluble solids and pulp contents. It is shown that flesh samples are having more absorbance, titratable acidity and acidic level (pH) compared to the peels.

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Effect of Inlet Temperature, Maltodextrin Additions and Pump Speed towards Physical Properties Of Pineapple Powder

[1] Syafiza Abd Hashib, [1]Nurul Asyikin Md Zaki, [1]Norazah Abd Rahman and [2]Mohd Azizi Che Yunus

[1] Faculty of Chemical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

[2] Centre of Lipid Engineering and Applied Research (CLEAR), Universiti Teknologi Malaysia, 81310 UTM Johor, Malaysia.

E-mail address:
syafiza0358@salam.uitm.edu.my (Hashib, S.A.)

Abstract

Spray drying is the common method of dehydration in food related materials which involved rapid removal of vapor or moisture from a liquid slurry contacted with hot gas. This paper aims to study the effect of various parameters like inlet spray dryer temperature, feed flow rate and maltodextrin (MD) concentrations in pineapple spray drying. The pineapple slurry was added with 15% to 25% maltodextrin (MD) concentrations, varied inlet spray dryer temperature from 130°C to 150°C and pump speed ranged from 3 to 5 using Lab Plant SD-Basic Spray Dryer. The pineapple powder then analyzed for its yield, moisture content, colour, particle size, titratable acidity (TA) and total soluble solid (TSS). The highest yield of powder produced in the range from 0.45 L/hr to 0.60 L/hr feed flow rate with 25 % MD concentration and temperature 150 °C. The results showed that lower pump speed and increased of MD concentration decreased the moisture content of pineapple powder.

Keywords: Inlet temperature, Maltodextrin, Pineapple, Pump speed, Spray dry

Introduction

Pineapple or its scientific name known as *Ananas Comosus L.* belongs to the *Bromeliaceae* family. According to the Malaysian Industrial Pineapple Board, Malaysia is in the 9th position globally in the aspect of production and 10th position among the countries of fresh and canned pineapple exporters. There are three types of pineapple that are mostly planted in Malaysia known as Sarawak, N 36, Josephine and Morris. Pineapple is commonly consumed as fresh or as processed products such as pineapple juice, which is a popular product due to its pleasant aroma and flavor (Wong *et al.,* 2015). Morris pineapple is chosen because there is lack of study that using this type of pineapple and it has high sugar content that will have high total soluble solid (TSS) (Silva *et al.,* 2008). Due to shorter shelf life and with the help of technology, incentive should been taken to change the fresh pineapple in the form of powder. Spray dry is one of the method best in converting liquid slurry into solid particles (Suzihaque *et al.,* 2015; Caliskan *et al.,* 2013). The main objective of spray drying is to reduce the amount of moisture content that will help to slow down microbial and enzymatic activities which is the most important part in determining the quality of product (Henry Sabarez, 2016). Fruit juice powder have its own advantages such as reduced volume or weight, reduced in packaging, easy handling as well as for better shelf life time (Fazaeli, M. *et al.,* 2012).

There are few parameters need to be considered during spray drying process which are inlet temperature, feed flow rate, concentration of maltodextrin and volume of feed slurry. Feed flow rate plays important role between the contact time of the feed and drying hot air. The high feed flow rate will cause shorter contact time and make the heat transfer less efficient which caused lower water evaporation and affect the moisture content of powder (Phisut, N. 2012) Fruit juices powder may present problem in their properties such as stickiness, hygroscopic and low solubility (Hashib *et al.,* 2015). Addition of maltodextrin can help to overcome the thermoplasticity and hgroscopicity. Total acidity and total soluble solid plays important criteria of the fruit powder in order to evaluate the products behavior. This paper aims to study the effect of various parameters like inlet spray dryer temperature, feed flow rate and maltodextrin (MD) concentrations in pineapple spray drying.

Materials and Methods

Morris pineapple type was used and obtained from pineapple farm in Klang, Selangor. The pineapple was peeled off and cut into a small piece. After that, it was crushed into juice by using a blender to produce pineapple slurry. The slurry was filtrated to avoid more pineapple fibrous clogging into the atomizer during spray drying process. The pineapple slurry was measured for its pH value, colour and soluble contents using pH meter, chromameter and refractometer respectively.

The pineapple slurry was added with 15 w/w %, 20 w/w% and 25 w/w% maltodextrin and stirred to get the maltodextrin fully dissolved with the pineapple slurry. To analyze the solubility, colour and pH measurement, the powder was added into the distilled water with the ratio 18.5 g of powder: 50 ml of water. This ratio was based on the average production yield to powder ration in the previous work by Hashib *et al.,* (2015). The beaker was placed on a Fisher (Model 210T) magnetic stirrer and set at speed 1100 rpm. For moisture content determination, the powder was analyzed using Sartorius (MA35) moisture analyzer. A five (5) grams of pineapple powder was weighed and put into the moisture analyzer at 105 ^{o}C for 10 minutes.

Total soluble solids (TSS) measurement.

The measurement of TSS was conducted using an analog refractometer. First the refractrometer was blanked using distilled water. Then two drops of pineapple juice were placed onto a reading cell. The total soluble solids value was expressed as ^{o}Brix value.

Particle size analysis

The particle size of pineapple powder was measured by using Malvern Zeta Sizer particle size analyzer , 25 ^{o}C following method by Legako and Dunford (2010).

Colour characteristics

The color of pineapple powders were measured by using chromameter (CR-400, Konica Minolta). The pineapple powders were poured into petri dishes, slightly shaken to form a thin layer and covered with transparent film, following steps by Saran *et al.,* (2012); Caparino *et al*., (2012) & Ng *et al.,* (2012). The International Commission on Illumination (CIE) parameters *L, a** and *b** were obtained by placing the lens of chromameter on the powder covered with transparent film. Three Hunter parameters, namely *L* value (lightness of colour from 0 (black) to 100 (white), *a** value (degree of redness (0-60) / degree of greenness (0-60)) and *b** value (yellowness (0-60) / blueness (0-60)) were measured and colour changes were calculated by using equation 1 :

$$\Delta L = L - L_o \qquad (1)$$

$$\Delta a = a - a_o$$

$$\Delta b = b - b_o$$

Where;

L = lightness of dried sample

a = redness/greenness of dried sample

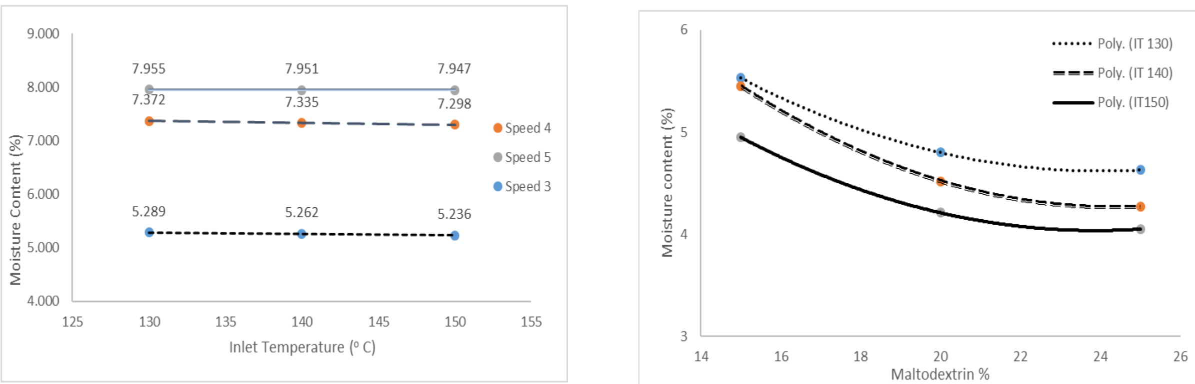
b = yellowness/blueness of dried sample

L_o, a_o and b_o are initial values of the lightness, redness and yellowness of the sample prior to drying respectively.

Results and Discussion

Effect of pump speed maltodextrin concentrations towards moisture content

The study on pineapple powder moisture content was conducted by spray drying at pump speed level 3, 4 and 5 using Lab Plant SD-Basic Spray Dryer. The results showed as in Figure 1 (a), where the lower speed pump resulted in lower moisture content of pineapple powder. The average pineapple powder moisture content is 5.3%, 7.3% and 7.9% for pump speed level 3, 4 and 5 respectively. Lower speed pump level allows longer heat transfer of hot air onto the sprayed liquid therefore increase the drying efficiencies.



(a) (b)

Figure 1. (a) Effect of pump speed on powder moisture content (MC), (b) Effect of maltodextrin concentrations and inlet temperature on moisture content.

In Figure 1(b), it was observed that an increase of maltodextrin concentrations and slurry temperature reduced moisture content of the powder. Increase of slurry temperature from 130°C to 150°C, resulted in significant decrease of pineapple powder moisture content from average 4.9% to 4.4%. This could be due to an increased rate of heat transfer into the particles at higher temperature, and thus producing a greater driving force for moisture evaporation to speed up water removal (Caparino *et al.,* 2012). The similar trend was observed in a study by Acosta *et al.,* (2015) on the effect of increasing level of maltodextrin from 10 w/v % to 15 w/v % in reducing moisture content from pineapple juice powder. Increased level of maltodextrin increased the level of feed solids and consequently reduced the level of total moisture for evaporation (Candia-Muñoz *et al.,* 2015). The present findings were also in agreement with study on spray dried tomato powder (Ramos *et al.,* 2016), orange juice powder (Santiago *et al.,* 2016), cactus pear juice powder (Rodriguez-Hernandez *et al.,*2005), black carrot powder (Dellacassa *et al.,* 2017) and gac juice powder (Vladić *et al.,* 2016).

Yield of pineapple powder

Figure 2, shows the effect of maltodextrin concentrations and inlet temperature (IT) on the pineapple powder yield. Following this figure, pineapple slurry with 25 w/w % maltodextrin (MD) produced highest product yield at average 79.5 gram. It can be seen that the difference in the inlet temperature did not affected powder yield as IT 130 ^{o}C produced 79.85 gram, IT 140 ^{o}C produced 79.27 gram and IT 150 ^{o}C produced 80.42 gram. This results is in agreement with findings by Suzihaque *et al.,* (2015) & Hashib *et al.,* (2015) whereas the maltodextrin concentration increases, the yield of the pineapple powder formed also increases.

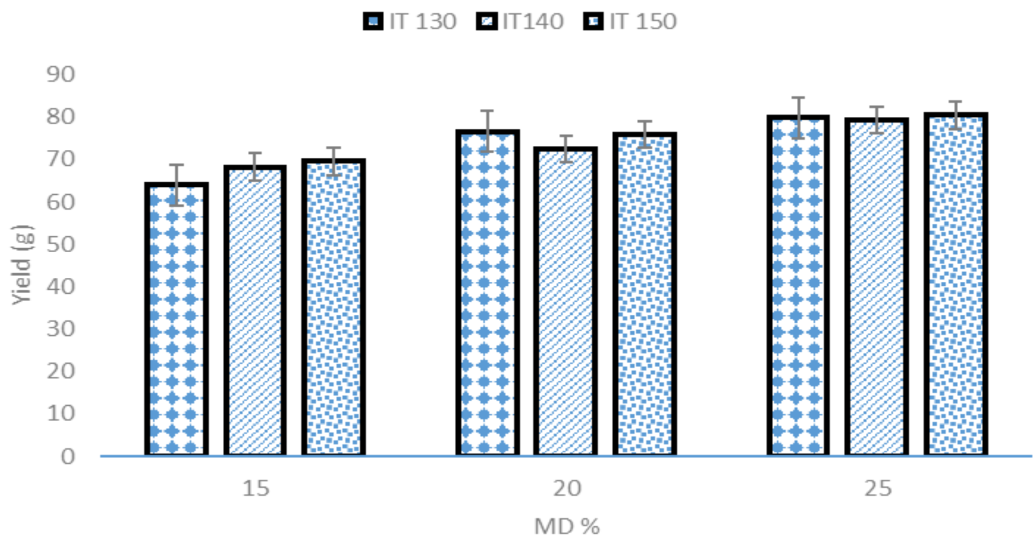


Figure 2. Effect of inlet temperature (IT) and maltodextrin (MD) towards powder yield.

Figure 2 also shows that the amount of pineapple powder is increased with an increase of spray drying inlet temperature. Hence, it gives another relationship that process yield is also depending on the inlet temperatures of a spray dryer, consequently related to the efficiency of heat and mass transfer during spray drying process. The higher inlet air temperatures were set, the greater efficiency of heat and mass transfer processes rate. However, sometimes an increase in inlet air temperature has reduced the yield due to melting of the powder and cohesion wall, for a case of inlet temperature more than 200 ^{o}C. Therefore, the amount of powder production would also reduce (Chegini & Gobadian, 2007).

The effect of maltodextrin concentrations on total acidity (TA)

Figure 3 shows the effect of maltodextrin concentrations on total acidity, expressed in percentage (%) citric acid. It can be observed that the highest citric acid contain in pineapple powder is 2.24 % TA with 15 w/w % maltodextrin concentration and the lowest with higher maltodextrin concentration in 25 w/w % resulted in 1.79 % TA. The percentage of titratable acidity decrease as the concentration of maltodextrin increase. This is because maltodextrin is a carbohydrate which is product of starch thus reduces the acidity. Total acidity reflecting fruit quality and indicates the sourness (Nadya Hajar *et al.,*2012)

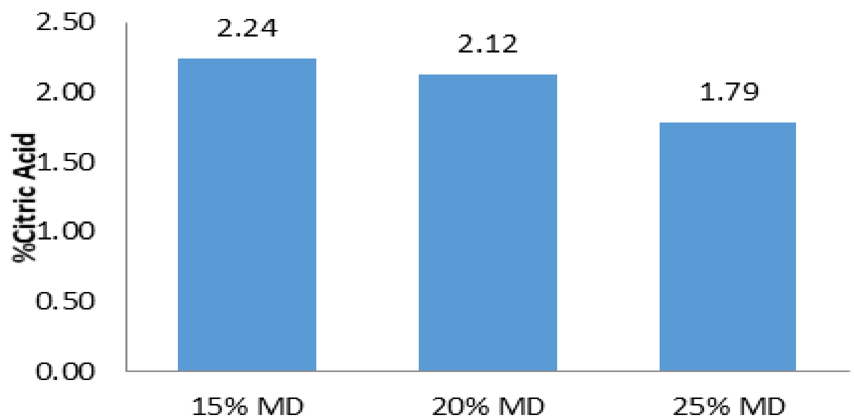


Figure 3. Effect of maltodextrin (MD) concentrations towards total acidity.

The effect of maltodextrin concentrations also can be seen through particle size where smaller particle size is related to higher maltodextrin concentrations as can bee seen in Figure 4.

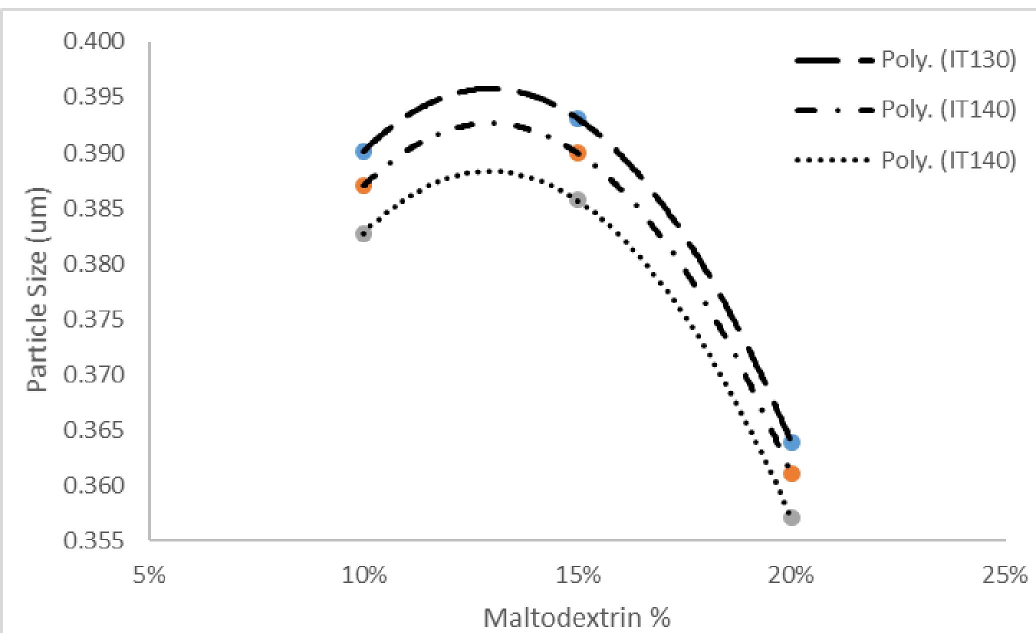


Figure 4. Effect of maltodextrin (MD) concentrations towards particle size.

The effect of maltodextrin (MD) concentrations on colour total soluble solids (TSS)

Table 1 showing the color appearance, the lightness *(L),* redness/greenness *(a*)* and yellowness/blueness *(b*)* of the pineapple powder. It can be seen that there are an increase in average lightness, reduced in redness and increased in yellowness between the pineapple juice and pineapple powder juice. This is because the sample was exposed to heat during the spray drying process and non-enzymatic browning reaction occurring during the spray drying. The soluble solid content in the pineapple is higher than the fresh pineapple juice. The soluble solid content is increase as the addition of the maltodextrin in the sample (Phisut, N., 2012). However, TSS was not so much affected by an inlet temperature increased which in agreement with Jittanit *et al*.,(2009) where solid soluble content of the pineapple powder does not depend on the inlet temperature as there does not have a constant trend of increasing or decreasing solid soluble content as the inlet temperature

Table 1. The effect of maltodextrin concentrations and inlet temperature on colour and total soluble solids of pineapple powder.

Inlet temp. (°C)	**MD conc. (%)**	**Fresh pineapple juice**				**Pineapple powder juice**			
		Total soluble solids (°Brix)	**Colour**			**Total soluble solids (°Brix)**	**Colour**		
			L*	**a***	**b***		**L***	**a***	**b***
130	15	1.34115	26.31	-2.30	5.52	1.37238	31.99	-1.46	13.29
	20	1.34144	25.94	-2.17	5.28	1.37310	28.83	-1.62	6.53
	25	1.34177	25.68	-2.20	5.68	1.37287	27.53	-1.85	7.44
140	15	1.34126	26.47	-2.40	5.73	1.37293	27.52	-2.01	6.83
	20	1.34265	25.36	-2.91	6.47	1.37558	28.16	-2.17	8.93
	25	1.34706	24.80	-2.70	6.23	1.376281	26.98	-1.38	8.09
150	15	1.34372	28.50	-2.87	7.65	1.375410	29.86	-2.69	11.77
	20	1.34613	28.15	-3.36	9.89	1.37579	34.27	-2.87	18.12
	25	1.34339	24.80	-2.70	6.23	1.37700	26.98	-1.38	8.09

Conclusion

This study showed practicability of producing pineapple powder using spray dryer. Obviously the pump speed and addition of maltodextrin significantly affect the product quality. Increasing the concentration of maltodextrin and reducing the pump speed will increase the product yield. The spray drying is a cost effective process and also able to prolong the shelf life of the fruit while maintain its quality. Maltodextrin is a carbohydrate which is product of starch helps to improve the spray drying process by reducing the moisture content thus produces a less sticky powder. The feed flow rate is also important parameter. Low feed flow rate is will increase the contact time of solution with the drying air thus increase the product yield. The physicochemical powder of the pineapple powder shows high total soluble solid and less citric acid. It shows a good quality powder of pineapple fruit which contain high value of sucrose, fructose and glucose.

Acknowledgment

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Geospatial Multi-Criteria Assessment and Distribution Analysis for Farming Management in Western Desert, Egypt

[1] Khaled M. Darwish, [2]R. R. Ali, and [2]F. Awad

[1] Land & Water Technologies Dept., Arid Land Cultivation Research Institute, City of Scientific Research and Technological Applications (SRTA), Borg El-Arab, Alexandria, Egypt

[2] Soils & Water Use Department, National Research Centre, Dokki, Giza, Egypt

E-mail address:

kdarwish9@gmail.com (Khaled M. Darwish)

Abstract

Basically, land use decisions be compatible with management principles and sustainable use of natural resources. Recently, statistical and geostatistical modeling has been developed for spatial analysis of environmental attributes. Differentiating the geospatial variability of soil characteristics and crop factor parameters by inventorying them is required to assess the effectiveness of land management. This study addresses an approach for examining a spatial multi-criteria evaluation model and determining the profitability for farming development in some plots in Farafra oasis, Western desert, Egypt. The study aimed to discuss the spatial distribution of specific land attributes and their relevance with the actual properties to carry out an itemized suitability assessment for agro-land utilization types. Relief elements, meteorological data, soil properties as well as specified crop criteria were integrated using geographic information GIS raster coverage's to obtain thematic criteria maps and used to set up the Multi-Criteria Assessment algorithm. Crop water requirements were calculated in variable rate according to the actual plant demands based on the aid of FAO Aquacrop model. Utilize a model of suitability built in ALES-arid system, the most suitable crops for the study area were clover, groundnut, sesame, wheat, alfalfa, barley, soybean, sunflower and watermelon. Implementing an improve soil properties program would enhance and manage the land capability status. The analysis spatial data distribution proved to be advisable technique to accomplish the prerequisite large precision farm computational requirements.

Keywords: Geospatial analysis, criteria assessment, Land use planning, Crop water requirements, Western desert of Egypt.

Introduction

Especially, spatial decision tooling analysis is beneficial for the construction, development and assessment of agro-ecology potential methods that prevent land vulnerability to degradation processes by focusing on the native land resource variability, land utilize system and agro-socio-economic conditions (De la Rosa et al., 2009). In this study, there are multi-aspects for spatial decision tools regarding land resources potentiality, their inherent strengths, its classification based on describing their properties, approaches and fundamental characteristics for agricultural development in the study area. Therefore, the Egyptian government is destined more attention towards exploring the natural resources through series of projects in the western desert natural depressions. One of the promising area is Farafra depression. In this region, Natural resources management studies are considered of vital importance for future development. The agricultural utilization demands precise input to secure decision-action process for expansion and investments in the target area. Identifying the geo-spatial variability of soil properties and crop parameters by inventorying them is prerequisite to assess the effective management system for sustainability and environmental quality.

Formerly, investigations on management and land use planning for agricultural purposes have been carried out in Farafra oasis using microLEIS-DSS (Darwish et al., 2006; Wahba et al., 2007; Abdel Kawy & Abou El-Magd, 2012). Their studies stated that most of the *Typic Haplogypsids* soil classification units exhibited high suitability for wheat, potato and sunflower crop cultivation, while the lower land suitability was attributed to soil salinity, sodium saturation and soil texture limitations. This sequence reflects the priority of agro-land utilization. Discover by using spatial DSS in this region are worthwhile because this evaluation could improve agricultural land.

The main purpose of this research was to focus on the potentiality of land resources for agricultural use planning on a provincial level at Farafra oasis as an arid environment. One of the objective was to examine the geospatial distribution of certain soil variables. The study aimed to combine validated land assessment methodology and high advisory spatial decision support methods for exploiting knowledge on environmental sustain planning. On the meanwhile, it is essential to maximize yield and biomass production through crop watering strategy. This can be achieved through the implementation of FAO-AquaCrop model as a notarized water productivity system.

Materials and Methods

Description of land characteristics

The areas under investigation are called "Sahl Baraka" and Bir Karawin. It lies 35 km east of Farafra oasis's capital city, along Farafra-Asyut main road. Its total area of about 10000 acres (106 km^2), with coordinates 27°01′40″ N and 28°15′ 32″ E. It belongs to the New-Valley Governorate, Western Desert (Figure 1).

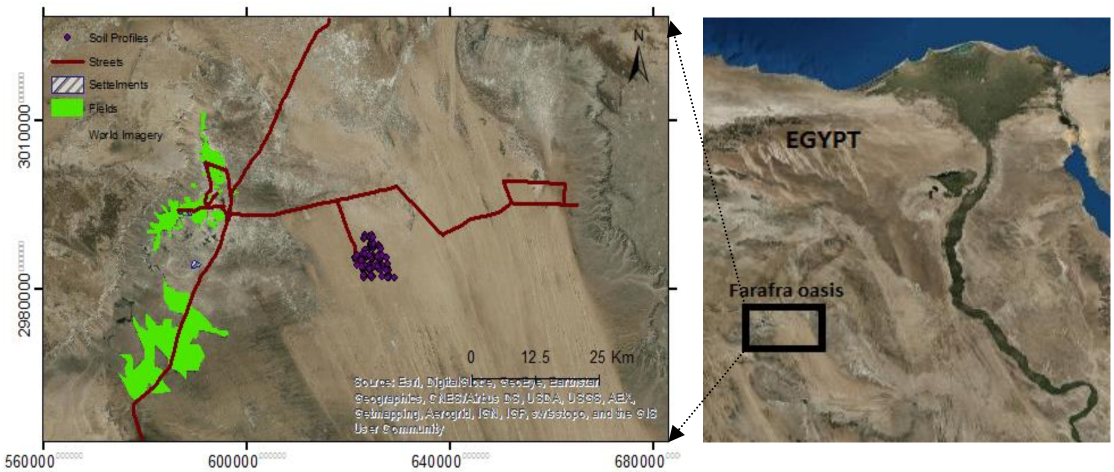


Figure 1. Location of study area in Farafra oasis, New-Valley, Western Desert

The study area is characterized by hot dry climate. The average monthly temperature is 23.3°C, with mean value 30.8°C in summer and 14.2°C in winter. All over the year, the annual rainfall is low about 0.75 mm/month, while evapo-transpiration rate ranged from 3.8 to 13.2 mm/day (Climatologically Normal for Egypt, 2016). Basically, Farafra oasis belongs to Pleistocene sediments with elevated plateau, foothill slopes and the lowered depression as geomorphologic features. In principle, water resources are originated from the huge Nubian sandstone deep aquifer (Hassan et al., 2002). Recently, machinery pumping is necessary as a result of over pumping, besides the resultant formation of regional cones of depression. Nevertheless, irrigation of new cultivation areas has developed widespread salt accumulation spots and waterlogging patches that are obviously visible in the field as well as detectable on satellite images.

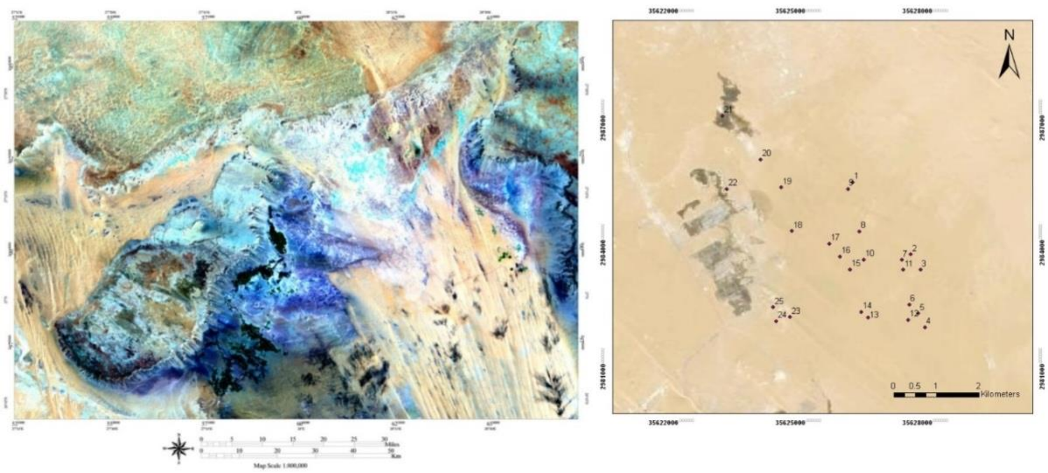


Figure 2. Satellite image and sample locations of the studied area

Digital image processing

Landsat 8 satellite image of Farafra oasis, acquired in Aug., 2016, was processed to identify the available landforms and land cover futures (ITT 2009) in regard to the Digital Elevation Model (DEM) which generated from the Shuttle Radar Mission SRTM data (NCSA 2005) (Dobos et al., 2002). (Figure 2).

Soil sampling Geomorphology features and mapping

Twenty-five soil profiles and number of mini-pits were digged to examine the soil properties and accuracy of boundary mapping (Fig. 2). The laboratory routine analysis was conducted in refer to USDA, 2004. Generation of soil map was done based on ground truth profile description, soil map of Egypt (ASRT, 1989) and the Keys to Soil Taxonomy (USDA, 2014).

Spatial data analysis and geostatistical mapping

The obtained measured results were used to generate interpolation maps of (soil EC, pH, $CaCO_3$%, O.M.%, Gypsum & CEC meq/100g soil) to demonstrate the geospatial distribution and relationship between different soil attributes (Akdemir et al., 2005). Data analyses were carried out in three main stages: (1) normal distribution verification test; (2) statistic distribution analysis; (3) geostatistical interpolation calculated for each variable by kriging analysis technique was performed to conduct semi-variogram analysis and spatial structure for the investigated soil variables (Robertson 2008). Correlation and regression analyses were proceeded to measure the relationships between the interpolated mapped values of soil attributes.

Land suitability assessment

In this research, Agriculture Land Evaluation model for arid and semi-arid regions (ALESarid-GIS) was applied (Ismail et al., 2005). Suitability classes, indices and limitations for thirteen crops were computed based on matching various soil parameter levels with the crop requirements (Ismail et al., 2001). The main selected impartially traditional crops were alfalaf, barley, clover, dry beans, green beans, groundnut, maize, sesame, sorghum, soybean, sunflower, watermelon and wheat.

Corp water requirement

The model of FAO AquaCrop was used to calculate the actual crop water requirements. The program segregates the ETa into crop transpiration Tr and non-beneficial soil evaporation Ea. It determines ETo using Penman–Monteith method (Steduto et al., 2009). In AquaCrop model system, the data inputs were saved in climate, crop, soil, management (irrigation schedule) and initial files of soil water condition (Raes et al., 2009).

Results and Discussion

Geomorphology and Physiographic mapping

The geomorphic features were delineated by analysing major landscape phenomena acquired from field survey, satellite image with the aid of elevation data and topographic maps. The major landscape units in the study area are as follow: (a) Plateau; (b) Peneplain including foot-slopes and rock outcrop; and (c) depression floor with five prime landform units, i.e., mudflats, playas, gravely outwash plains, sabkhas, sand sheet, sand dunes and wetland (Figure 3).

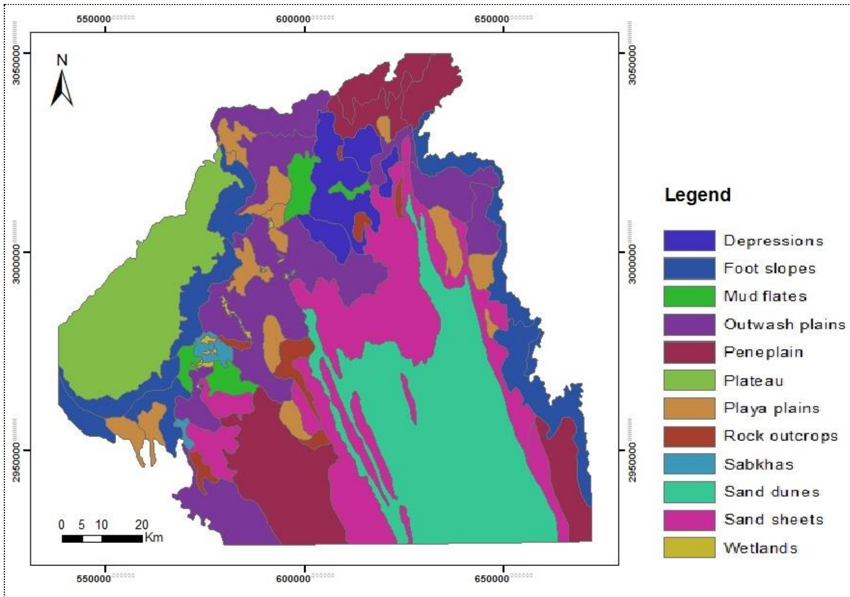


Figure 3. Geomorphology map expressed the main landforms

The ground observations and image analysis showed that the recent reclamation project farms have developed large-scale waterlogging areas and ponds in low elevation plots that are entailed by seepage areas heading to the old agriculture fields. Generally, the cultivated fields are existing on depression flower, footslopes, mudflats, outwash plains and playa landforms. Commonly, soils are shallow in depth (<0.5m deep), with *Lithic Torrifluvents*, *Torriorthents* and *Torripsamments* soil classification. Nevertheless, the deep soils (1.5 to 1.7m) are presented as *Vertic Torrifluvents* and *Typic Torrifluvents* unit types and occupied the old agricultural area. Specifically, in *Typic Haplocalcids* soils, calcium carbonate content is very high, that implies development of calcic eipedon horizon to develop a subsurface hardpan that encroaches waterlogging hazards to some extent. Saline soils expressed by *Typic Haplosalids* are distributed widespread in various farming fields (Figure 4).

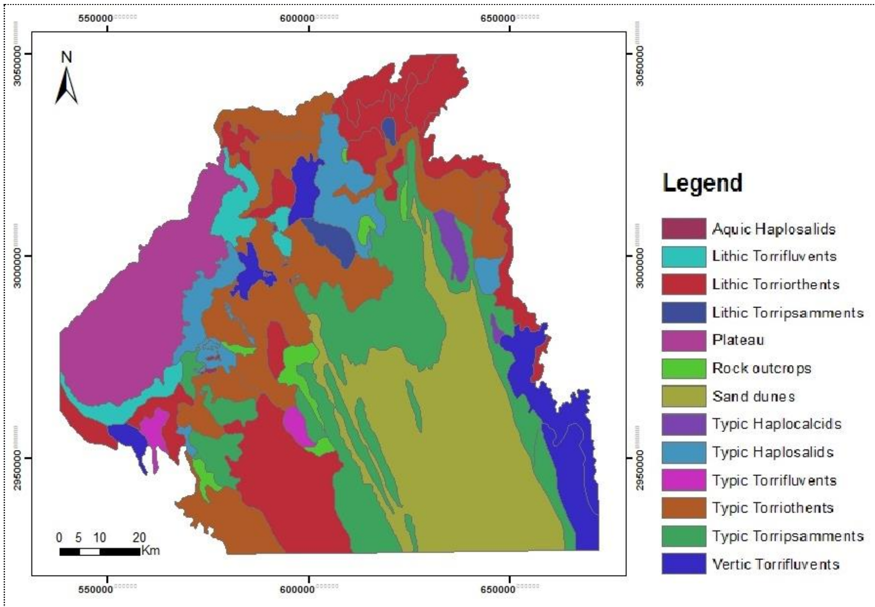


Figure 4. Soil map and their associated soil classification units

Statistical analysis

Table 1 presents summary of the statistical descriptive of selected soil parameters in the study area. The probability distributions of soil attributes were analyzed using skewness and kurtosis indicators, and those not normally distributed were subjected to log-normal transformation process to improve estimation (Duffera et al. 2007). Data set normality was examined using the Kolmogorov–Smirnov test, which in turn signalized that all variables were not significantly normal distributed except (pH number). The natural logarithmic Ln transformation was exercised to the data set for EC, $CaCO_3$, CEC and clay%. After transformation of those soil variables, the indicators of skewness and kurtosis were highly reduced, providing inclination to normally distributed data.

Table 1. The statistical analysis of soil properties in sampling sites [n = 99 (1)]

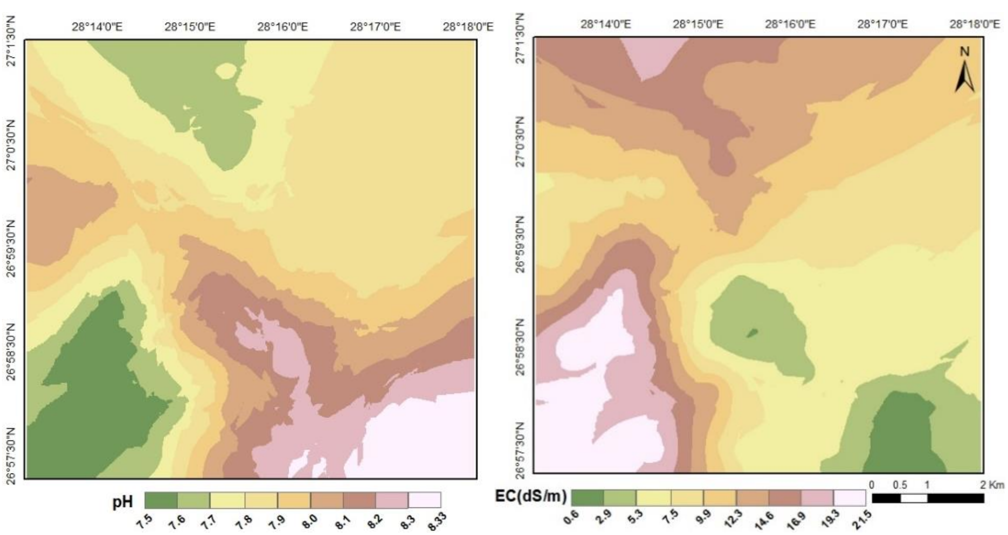
Soil property	Min.	Max.	Mean	SD*	Sample variance	Skewness	Kurtosis
pH	7.30	8.37	7.85	0.29	0.08	0.19	-1.13
EC (dS/m)	0.37	32.04	5.70	6.89	47.55	1.98	3.87
CaCO3 (%)	2.17	73.8	22.79	16.89	285.53	1.21	0.74
CEC meq/100 g soil	0.05	7.48	2.94	1.52	2.32	1.60	1.47
Clay (%)	0.25	47.5	7.65	13.37	178.9	2.01	2.27

*SD standard deviation

Spatial distribution of soil variables

In this study, experimental isotropic semivariances analysis of soil attributes were modeled using GS + gamma software with respect restricted to half the maximum lag distance (Journel and Huijbregts 1978). The investigated soil attributes exhibited spatial auto-correlative structure, pointing out them respond to process that occur throughout the area. Consequently, with implementing the best fit theoretical geostatistic models and the corresponding semi-variogram analysis, geospatial distribution maps of soil attribute were generated using kriging interpolation algorithm. Kriging algorithm provides a means of interpolating values for points not physically sampled using knowledge about the underlying spatial relationships in a data set to do so (Journel and Huijbregts 1978). In this study, ordinary kriging was performed. Ordinary kriging assumes a constant but unknown mean that may fluctuate among local neighborhoods within a study area. In it the sum of kriging weights equals to one. Figure 5 shows interpolated maps of soil attributes generated from them most fitted semi-variograms.

In Figure 5, maps of soil attributes illustrated various patterns of low, middle and high concentrations. Eventually, in the study area, soil pH ranged between 7.30 and 8.37, which reflected quite natural to almost base pH soil type with a mean of 7.85 (Table 1). Soil pH widely varied in the most middle southeast and southwest side of the area under investigation.



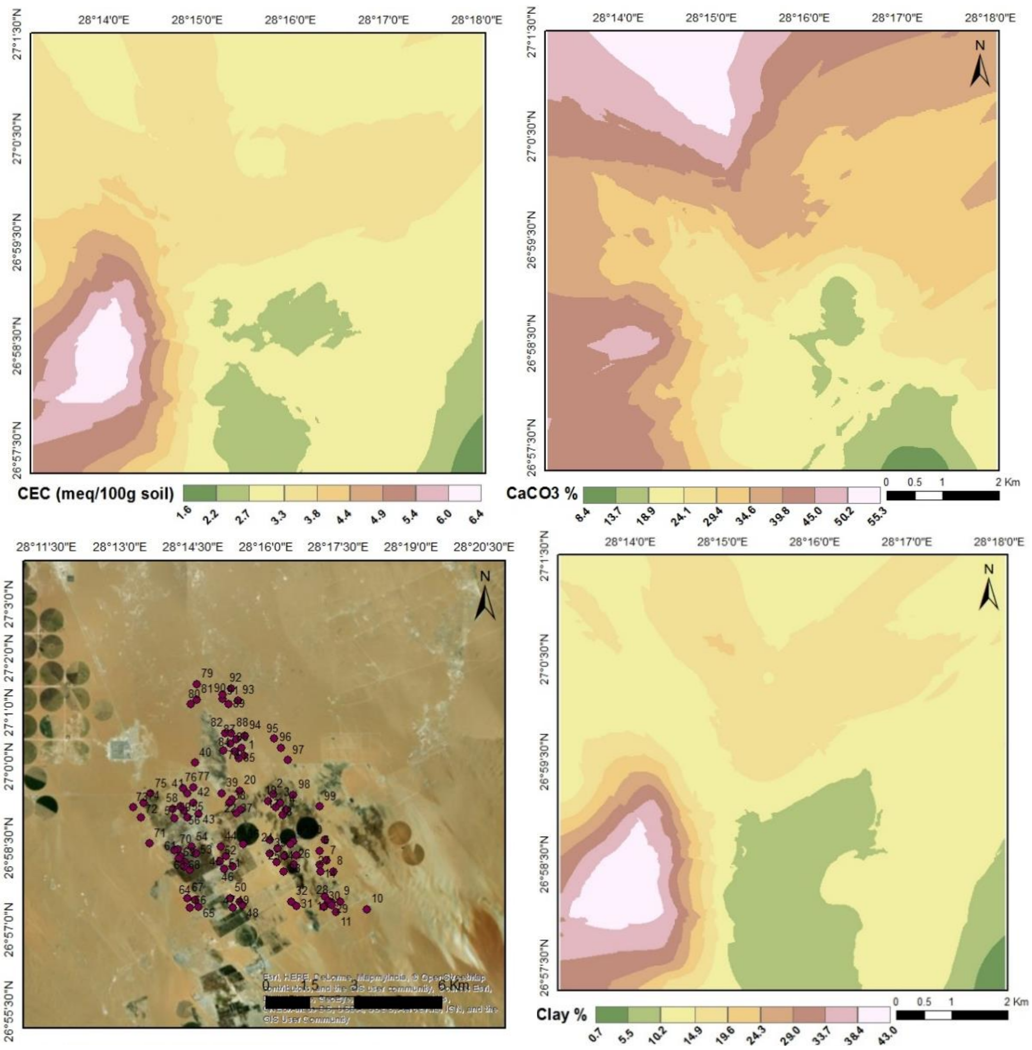


Figure 5. Spatial distribution maps of soil attributes

On the other hand, soil Electrical Conductivity EC values were high spot spatially distributed in the middle northwestern part because this portion have number of pivots agro-irrigation system that may cause high groundwater level in some areas. A similar trend was observed for CEC and clay content that correspond to the highly significant positive correlation distribution between clay minerals and the Caution Exchange Capacity. Calcium carbonate showed high geospatial content in the northwest and southwest parts of the study area. With increasing capillary movement in the soil and plants evapotranspiration, salts rise to the surface. Application of low-quality groundwater would result in increase in EC and $CaCO_3$ values.

Actual and potential agro-land suitability

The obtained results illustrated that the proposed land use types of dry beans, green beans, maize and sorghum plantations are conditionally (S4) to potentially (NS1) suitable, where the most limiting factors of these crops are the clay content, Exchangeable Sodium Percentage ESP and soil hydraulic conductivity. The actual suitability of alfalfa, barley, soybean, sunflower and watermelon are marginally (S3) to conditionally suitable (S4) in most of the studied soil profiles. In the study area, the most suitable crops to cultivate were clover, groundnut, sesame and wheat. With moderate to high input, the potential suitability of these soils can be moderate (S2) for the selected land utilization types (Table 2) in regard to figure 2.

Table 2. Agricultural land suitability for some crops using ALESarid system

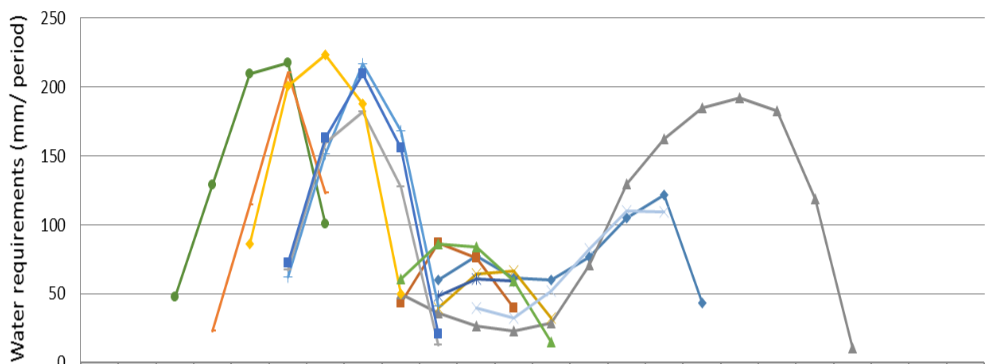
Profile No.	Alfalfa	Barley	Clover	Dry Beans	Green Beans	Groundnut	Maize	Sesame	Sorghum	Soybean	Sunflower	Watermelon	Wheat
1	S4	S3	S2	NS1	NS1	S3	S4	S4	S4	S4	S4	S4	S2
2	S4	S3	S2	S4	S4	S3	NS1	S4	S4	S4	S4	S3	S2
3	S4	S3	S3	S4	S4	S3	NS1	S2	S4	S4	S3	S4	S3
4	S4	S3	S3	NS1	NS1	S4	S4	S2	S4	S4	S4	S4	S3
5	S4	S3	S3	S4	S4	S4	S4	S3	S4	S4	S4	S4	S4
6	S4	S3	S3	S4	S4	S4	S4	S3	S4	S4	S4	S4	S4
7	S4	S4	S2	S4	S4	S4	NS1	S4	S4	S4	S4	S4	S4
8	S4	S4	S2	NS1	NS1	S4	NS1	S4	S4	S4	S4	S4	S2
9	S4	S4	S2	NS1	NS1	S4	S4	S4	S4	S4	S4	S4	S2
10	S4	S3	S2	S4	S4	S4	S4	S2	S4	S4	S4	S4	S3
11	S4	S3	S3	S4	S4	S4	NS1	S2	S4	S4	S4	S4	S3
12	S4	S3	S3	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3
13	S4	S3	S3	NS1	NS1	S4	S4	S4	S3	S3	S3	S3	S3
14	S4	S3	S4	NS1	NS1	S3	S4	S4	S3	S3	S3	S3	S3
15	S4	S3	S4	NS1	NS1	S3	S4	S4	NS1	S4	S4	S4	S3
16	S4	S3	S2	S4	S4	S3	S4	S4	NS1	S4	S4	S4	S3
17	S4	S3	S2	S4	S4	S4	NS1	S4	NS1	S4	S4	S4	S3
18	S4	S3	S2	S4	S4	S4	NS1	S4	NS1	S4	S4	S4	S3
19	S4	S3	S2	S4	S4	S4	NS1	S4	NS1	S4	S4	S4	S3
20	S4	S4	S2	NS1	NS1	S4	S4	S4	S3	S3	S3	S3	S3
21	S4	S3	S3	S4	S4	S2	NS1	S3	S4	S4	S4	S4	S3
22	S4	S3	S3	S4	S4	S2	S4	S3	S4	S4	S4	S4	S2
23	S4	S3	S3	NS1	NS1	S4	S4	S3	S4	S4	S4	S4	S2
24	S4	S4	S3	S4	S4	S4	S4	S4	S3	S4	S4	S4	S3
25	S4	S3	S3	NS1	NS1	S4	NS1	S4	S4	S4	S4	S4	S3

S1	S2	S3	S4	NS1	NS2
Highly Suitable	**Moderately Suitable**	**Marginally Suitable**	**Conditionally Suitable**	**Potentially Suitable**	**Actually unsuitable**

The needed land improvements include controlled fertilization system, modern irrigation method, controlling gravels and establishing wind breaks. Soil salinity considers as the major constrain expansion of crop cultivation. Salt effected soils and water irrigation salinity are significant limiting parameters for sesame cultivation and the opposite is true for wheat plantation (Abd El-Kawy et al. 2010).

Crop water requirements

The standard reference evapo-transpiration ET_O from January to December were 23, 35, 45, 49, 62, 65, 64, 54, 42, 32, 23, 17(mm/10days) respectively. The crop water requirements were calculated for the selective crops using AquaCrop FAO model. The ET crop consumption use values were: alfalfa=605.8mm, barley= 245.5mm, clover=1217.5mm, dry beans= 204.2mm, green beans= 168.5mm, groundnut= 703.5mm, maize= 640.3mm, sesame= 470.3mm, sorghum= 549.2mm, soybean= 747.5mm, sunflower= 621.5mm, watermelon= 305.6mm, wheat= 426.6mm, respectively (Figure 6).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ALFALFA										60	77.7	61.4	60	76.8	105	121	43.2							
BARLEY									43.5	86.6	75.9	39.5												
CLOVER									50.2	36.4	26.4	23.2	28.9	70.6	130	162	185	192	183	119	10.6			
DRY BEANS										40	64.7	66.8	32.7											
GREEN BEANS										48.1	61.1	59.4												
GROUNDNUT			47.4	129	209	217	101																	
MAIZE						62.4	152	217	168	41.3														
SESAME				22.9	114	210	123																	
SORGHUM						67.6	159	182	128	12.6														
SOYBEAN					86.3	201	223	188	49.6															
SUNFLOWER						72.5	163	209	156	21														
WATERMELON									60.7	86	84.2	59.6	15.1											
WHEAT											39.7	32.7	52	82.4	110	109								

Figure 6. Crop water requirements under the climatic conditions of Farafra oasis

Conclusion

The study investigates reclaimed areas in Farafra depression, specifically in "Sahl Baraka" and Bir Karawin plots, with the target of introducing optimum land use by performing spatial multi-criteria assessment (SMCE) model. The produced agricultural land use could support to improve land use quality, taken right decisions and clear guide to what management strategy and crops that mostly suitable for planation in the area. Especial attention is given in cases where there are limited water resources and imperfect agricultural knowledge regarding land properties of the study area.

Basically, geospatial distribution analysis of soil properties would be performed to develop thematic indicator maps of the study area according to them land management and restoration requirements. Spatially, soil attributes are not necessary homogeneous in distribution because of the effect of origin lithology, topography and variation of management and land use practices. Most of the investigated soil attributes exhibited high spatial dependency. This is would lead to shallow soil depth, salinity effect, drainage and ground water level. Modern techniques of irrigation systems should be preferred for optimizing water productivity.

Sand sheet map unit showed more suitability for most evaluated crops. The most suitable farm crops to plant in the target area are clover, groundnut, sesame and wheat. The alfalfa, barley, soybean, sunflower and watermelon cultivations showed marginally (S3) to conditionally (S4) suitability in most of the observed soil profiles. In the study area, the three major limiting factors that affect yield production are clay texture content, Exchangeable Sodium Percentage ESP and soil hydraulic conductivity.

However, soil salinity induced by human activities is the active issue throughout the investigated area. The applied irrigation system, water quality, soil depth, drainage condition and land surface topography are the major specified responsible factors that impede salinity leaching and require designed appropriate land management programs.

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Performance evaluation of automated vacuum planter

[1,2]Abdulkadir, T.D., [1]Ismail, W.I.W., [1]Mohd Kassim, M.S., and [1]Bejo, S. K.

[1]Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor.

[2]Department of Agricultural and Bio-Environmental Engineering Technology, Samaru College of Agriculture, Ahmadu Bello University Zaria, 1058 Zaria, Nigeria.

Email address:

dantukuro@gmail.com (Abdulkadir, T.D.)

Abstract

In this study the mechanical seed metering system of a vacuum seed planter was replaced with an electronic seed metering system due to its poor performance in seeding of capsulated paddy seed for the system of rice intensification (SRI). The modified seeder was evaluated both at the laboratory and in the field. The laboratory evaluation was carried out with the aid of a grease belt using two seed plate designs, one with zero seed-hole entry angle and the other with 120^o seed-hole entry angle. The plate with zero entry angle was found to have better performance indices than the plate with 120^o entry angle, and was used for the field evaluation of the electronic metering system. The performances of the electronic and conventional seed spacing and metering systems were evaluated at the field simultaneously. The result of the performance indices for six treatments (each a combination of vacuum and speed of operation) was then compared statistically using SPSS software. The developed electronic seed metering and spacing system with 32.9 cm average seed spacing, 3.7 % miss index, 0 % multiple index, and 96.3 % quality of feed index, obtained at 10 mbar and 0.51 m s^{-1} operating pressure and speed respectively, was found to be better than the conventional seed spacing and metering system at all the treatments considered.

Keywords: Electronic seed metering, Mechanical seed metering, Performance evaluation, Vacuum planter.

Introduction

Vacuum seed planters are usually employed where precise placement of agricultural seeds to the soil is required. Preliminary test have shown that vacuum planter could not ordinarily be used to achieve paddy singulation due to its irregular shape. Gaspardo SP540 was tested for singulation of capsulated (coated) paddy seeds using 16 hole seed plate. At the point of dropping, majority of the coated seeds end up being sucked back by a nearest succeeding seed hole under vacuum pressure, upon released from a seed hole under atmospheric pressure. An eight holes seed plate with the seed holes widely spaced was developed to address this problem. For efficient use of the new seed plates a simple electronic metering system was used to replace the conventional seed metering system.

Many researches that involve modification of vacuum seed planter for different purposes were carried out. Parish and Bracy (2003) attempted to improve the planting uniformity of a Gaspardo planter through the introduction of a slide and enclosed tube for seed guiding. Karayel (2009) modified a vacuum planter for no-till application using serrated disc and double disk openers. Increased precision of no–tillage sowing of soya beans and maize was achieved using the double disc furrow opener on the basis of percentage emergence, and uniformity of seed distribution along the path of planting and planting depth.

The use of grease belt is the most common process of laboratory evaluation of vacuum planter. Yazgi and Degirmencioglu (2007) used grease belt to evaluate the seed spacing uniformity of a vacuum seed planter. The diameter of seed holes, vacuum pressure, and peripheral speeds were replicated and used as the evaluation variables. Miller et al., (2012) evaluated the performance of three vacuum planters in response to speed, where four treatments were randomized: 4.8 km h^{-1}, 8 km h^{-1}, 11.3 km h^{-1} and 14.5 km h^{-1}. For all the four brands tested, it was found that reducing speed below 8 km h^{-1} does not improve the planter spacing uniformity. Yazgi and Degirmencioglu (2014) conducted a research to evaluate the performance of vacuum seeder based on number of seed cells as a variable using the performance indices of miss index, multiple index, and quality of feed index. Three operational speeds of 1.0, 1.5, and 2.0 m s^{-1} were used for five different number of seed holes: 20, 26, 36, 52, and 72 seed holes, and were tested at 6.3 kPa. The performance was found to be better at lower operational speed.

Electronic appliances were employed for planter evaluation. Lan et al., (1999) developed and used a photo electronic sensor for the evaluation of seed spacing uniformity of pneumatic planter. Navid et al., (2011) carry out performance evaluation of planter vertical rotor seed metering system using Nikon D70 digital camera for image acquisition, and Matlab program for image processing. The performance of these instruments was not significantly different from that of the grease belt system. The grease belt method for vacuum planter evaluation was adopted for the laboratory evaluation process in this study, due to its ease, simplicity of usage, and availability at the environment of this research. Field evaluation was carried out using both mechanical and electronic metering systems simultaneously. Analysis of variance (ANOVA) has been used as a tool for investigation of interaction among variables, and choice of optimum values combination (Din et al., 2013); (Berger et al., 2015).

It is a practice in the agricultural industry to evaluate seed planters that were newly acquired, developed, or modified. This study aimed at evaluating the performance of electronic seed metering system for a pneumatic seed planter using a coated paddy seed.

Materials and Methods

Gaspardo SP540 vacuum planter was used in this study. The relevant physical properties of a capsulated paddy seed were studied. Two seed plates, one without entry angle (0^o) and the other with 120^o entry angle were fabricated based on the relevant physical properties of the capsulated paddy seed. The electronic seed metering system was evaluated both in the laboratory and field. However, this study does not involve the design aspect of the electronic seed spacing and metering system. Rather it only deals with the evaluation of the system.

Physical properties of coated seeds

The physical properties studied in this paper were used in estimating the theoretical vacuum suction for pneumatic picking of the coated paddy seed and the development of the seed plate suitable for electronic seed metering system.

Dimensions

The principal dimensions: Length (L), Width (W), and Thickness (T) of twenty capsules sampled at random from a box containing 1000 capsules were measured using vernier caliper with an accuracy of 0.05 mm.

Geometric and arithmetic mean diameter

The geometric mean diameter (D_g) and arithmetic mean diameter (D_a) of the capsules were calculated using equations 3.1 and 3.2 given by Gharibzahedi et al., (2012); Vishwakarma et al., (2011):

$$D_g = (LWT)^{1/3} \qquad 3.1$$

$$D_a = \frac{(L+W+T)}{3} \qquad 3.2$$

Where,

L, T, and W are the length, thickness and width of the capsules in mm respectively.

Sphericity and surface area

The surface area S and sphericity φ of the capsule were computed as a function of geometric mean diameter D_g using Equations 3.3 and 3.4 respectively (Gharibzahedi et al., 2012)

$$S = \pi {D_g}^2 \qquad 3.3$$

$$\varphi = \frac{D_g}{L} \qquad 3.4$$

Where, S, φ, and D_g have units of mm^2, dimensionless, and mm respectively.

Projected area

The projected area (A_p) was estimated using Equation 3.5 by Gupta et al., (2007a)

$$A_p = \left(\frac{\pi}{4}\right) L_1 L_2 \qquad 3.5$$

Where L_1 and L_2 are largest two dimensions of the capsule. L_1 and L_2 were found to be 21.8 and 6.6 mm respectively

One thousand capsulated seed mass (M_{1000})

To determine the one thousand kernel mass M_{1000} , an electric digital weighing balance TX423L with an accuracy of 0.0001 g was used. The mass measured here is that of the paddy seeds + coating material (capsule). The mass of the three treatments: dry untreated paddy, primed paddy, and pre germinated paddy was measured separately and recorded.

Bulk density

For the purpose of bulk density measurement (ρ_b), the bulk volume of coated paddy seed (V_b) was measured using standard procedure by Koocheki et al., (2007) where capsulated seeds were dropped in to a measuring cylinder of known volume and mass at a height of 15 cm, and the excess amount was removed by strike-off stick without further compaction. The measured capsulated seeds were then weighed on electric weighing balance and the average mass M was recorded. Bulk density was then computed using equation 3.6.

$$\rho_b = \frac{M}{V_b} \qquad 3.6$$

Real volume and true density of capsulated seed

In the standard procedure, water was used to fill the empty spaces left unoccupied in the cylinder during bulk density measurement, the amount of water consumed by the pore spaces is then drained and measured. The real volume (V_r) is what is left from subtracting the water volume from the bulk volume. In this study, the seed was coated with capsule which is soluble in water. Therefore, vegetable oil was used in place of water and it served the purpose without dissolving the coating material. The true density was measured using equation 3.7.

$$\rho_t = \frac{M}{V_r} \qquad 3.7$$

Theoretical operating vacuum

For this study, four models developed by Karayel et al., (2004) were used to estimate the vacuum pressure needed for planting capsulated paddy seeds. The first model is a function of 1000 kernel mass M_{1000}, the second is a function of seed projected area A_p, the third is a function of sphericity, and the fourth is a function of true kernel density.

Based on 1000 kernel mass M_{1000}

$$P = 1.18(M_{1000})^{0.20} \qquad 3.8$$

Where,

P = predicted pressure kPa, M_{1000} = one thousand kernel mass g.

The estimated pressure P for the coated paddy is

P = $1.18(100)^{0.2}$ =2.96 kPa

Based on projected area A_p

$$P = 1.96\,(A_P)^{0.11} \qquad 3.9$$

Where, A_p is the projected area

Therefore

P=$1.96(1.13 \times 10^2)^{0.11}$ = 3.3 kPa

Base on sphericity

$$P = 0.04(\varphi) + 0.43 \qquad 3.10$$

Where, φ is the sphericity, %

$P = 0.04(45) + 0.43 = 2.23$ kPa

Based on true kernel density

$$P = 0.002(\rho_t) + 1.02, \qquad 3.11$$

Where ρ_t is the true kernel density, kg m^{-3}

ρ_t =172.78 kg m^{-3}

Therefore,

$$P = 0.002(172.78) + 1.02$$

= 1.37 kPa

Laboratory evaluation of modified vacuum planter

At the laboratory, the electronic seed metering system was evaluated using the two seed plate designs. A grease belt shown in Fig. 1 was used for laboratory evaluation of the modified vacuum seeder. The grease belt consist of a fiber belt of 7 m long, 1.5 mm thickness and 20 cm width, powered by a one phase DC electric motor at one end, and supported by a roller at the other end. Grease was smeared onto the belt surface to about 0.5 m thickness, to prevent seed from rolling and bouncing after dropping. The modified vacuum planter was attached to the tractor three point hitches, and raised to a height of 90 cm, just above the grease belt. The implement drive wheel was synchronized to the belt speed. As the belt translates, the implement drive wheel mounted on the belt drive rotates, resulting in dropping seeds from the seed plates. The machine was evaluated using 9 treatments (each a combination of vacuum pressure and speed) using each of the two seed plates, one at a time. Performance indices were computed for each plate design. The indices were compared using SPSS software to get the best performing plate and use it for field evaluation.

Figure 1. Laboratory Evaluation of Vacuum Planter

Field evaluation of the modified vacuum planter

The field evaluation was conducted at *Ladang 10* experimental farm at Universiti Putra Malaysia. The land was first prepared. Two seed metering units were used for the field evaluation, with one unit having the mechanical (conventional) seed metering system, while the second unit has the electronic metering system. The evaluation was carried out in three replicates using six treatments each made of vacuum pressure and operational speed. A 3.3 m length of planting was used for each of the six treatments for the evaluation process. The number of seeds at each planting point was counted manually, the spacing between the seeds planted was measured and the performance indices of seed spacing, miss index, multiple index, and quality of feed index computed for both the electronic and mechanical system, using equations 3.12, 3.13, and 3.14. Analysis of variance (ANOVA) was used to determine the best treatment in both mechanical and electronic seed metering system. The best of each (mechanical and electronic system) were then compared using T test with the aid of SPSS software.

Miss index

Miss index MI is the percentage of seed spacing that are greater than 1.5 times the theoretical planting distance $T_{s.}$

$$\mathrm{MI} = \frac{n_1}{N} \qquad 3.12$$

Where, n_1 is the number of seed spacing > 1.5 times T_s, N is the total number of seed spacing measured.

Multiple index

Multiple index MTI is the percentage of seed spacing less than or equal to 0.5 times the theoretical spacing T_s.

$$\mathrm{MTI} = \frac{n_2}{N} \qquad 3.13$$

Where, n_2 is the number of seed spacing ≤ 0.5 T_s

Quality of feed index

The quality of feed index (QFI) is the percentage of seed spacing greater than 0.5 of theoretical spacing and less than 1.5 of theoretical spacing. Is another way of expressing miss and multiple index.

$$\mathrm{QFI} = 100 - (\mathrm{MI} + \mathrm{MTI}) \qquad 3.14$$

Seed plate

The seed plate used in this evaluation process is shown in Fig. 3. The seed plate has 8 seed hole which is unusual of the conventional seed plates. The widely spaced seed hole should enable an efficient seed picking and placement.

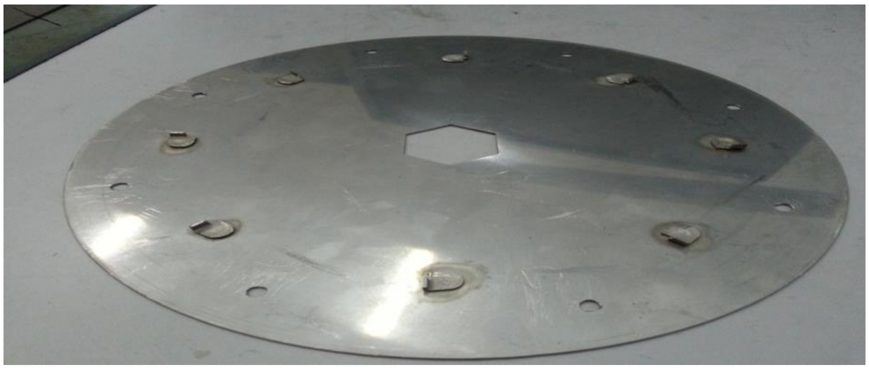

Figure 2. Eight holes seed plate

Results and Discussion

Physical properties

The results of the physical properties study is shown in Table 1. Analysis of variance (ANOVA) for the physical properties of the capsulated seed was carried out to check level of significance of the effect of different seed treatments on the physical properties of the seed. From the ANOVA test result shown in Table 2. The effect of different seed treatments on M_{1000}, Bulk density and true density was found to be significant at 1% significant level ($P < 0.01$).

Physical properties of capsulated paddy seed

Table 1. Physical properties of coated paddy seed

Physical Property of Coated Seed	**Unit**	**Untreated Seed**	**Primed Seed**	**Pre-germinated Seed**
Length	mm	21.04	21.04	21.04
Width	mm	6.35	6.35	6.35
Thickness	mm	6.35	6.35	6.35
Arithmetic mean Diameter	mm	11.25	11.25	11.25
Geometric mean Diameter	mm	9.46	9.46	9.46
Projected area	mm^2	113.00	113.00	113.00
Surface Area	mm^2	281.15	281.15	281.15
Moisture Content	% d.b	9.70	13.7	22.4
1000 Kernel Mass	kg	0.10	0.104	0.11
Sphericity	decimal	0.45	0.45	0.45
Bulk Density	kg/m^3	95.24	98.7	104.76
True Density	kg/m^3	166.7	172.78	183.73

Table 2. ANOVA of the effect of seed treatments on physical properties of coated paddy

Source of variation	**df**	**M_{1000}**		**TD**		**BD**	
		F value	**P value**	**F. value**	**SV**	**F. value**	**SV**
Seed treatment	2	691	0.000*	691.772	0.000*	693.845	0.000*

Where: M_{1000} is 1000 kernel mass, BD is Bulk density, TD is true density, *: significant at 1% significance level.

Effect of seed plate design on seeder performance

The result of the performance evaluation of seed plate with the zero entry angle is shown in Table 3. Based on the 25 cm seed spacing target, treatment one (10 mbar and 1 m/s) with average seed spacing, miss index, multiple index, and quality of feed index of 25.4, 0, 0%, and 100% respectively from has the best result.

Table 3. Laboratory performance indices for zero entry angle seed plate

Perfor-mance indices	10 mbar and 1 m/s	10 mbar and 1.5 m/s	10 mbar and 2 m/s	20 mbar and 1 m/s	20 mbar and 1.5 m/s	20 mbar and 2 m/s	30 mbar and 1 m/s	30 mbar and 1.5 m/s	30 mbar and 2 m/s
Average spacing (cm).	25.4	28.42	26.45	28.3	25.89	26.2	30.72	25.67	25.94
Miss index (%).	0	2.56	0	2.56	0	6.06	9.7	6.06	2.78
Multiple index (%).	0	0	0	0	0	0	0	2.57	0
Quality of feed index (%).	100	97.44	100	97.44	100	93.94	90.3	91.37	97.22

The results of performance evaluation of seed plate with 120^o seed hole entry angle is shown in Table 4. Based on the 25 cm seed spacing target, and the values of performance indices obtained, treatment 5 with average seed spacing, miss index, multiple index, and quality of feed index, of 24.62 cm, 0%, 0%, and 100% respectively was found to be the best treatment in seed plate with 120^o entry angle.

Table 4. Laboratory performance indices for 120o entry angle seed plate

Perfor-mance indices	10 mbar and 1 m/s	10 mbar and 1.5 m/s	10 mbar and 2 m/s	20 mbar and 1 m/s	20 mbar and 1.5 m/s	20 mbar and 2 m/s	30 mbar and 1 m/s	30 mbar and 1.5 m/s	30 mbar and 2 m/s
Average spacing (cm)	27.48	29.03	28.26	27.63	24.62	25.55	29.83	31	28.17
Miss index (%)	3.03	6.67	11.87	6.67	0	6.67	9.04	10	3.33
Multiple index (%)	0	0	0	0	0	0	0	0	0
Quality of feed index (%)	96.97	93.33	88.13	93.33	100	93.33	90.96	90	96.67

T test of 120^o and 0^o degree entry angles seed plates

T test between the best treatments from each of the two plate design was conducted using average seed spacing only as there was no variation between the replicates on other performance indices. The result (Table 5) shows no significance difference (P > 0.05) between the two plates design in terms of average seed spacing. However, plate with zero entry angle was found to perform best at lower vacuum pressure (10 mbar) than that with 120^{o} entry angle (20 mbar). Hence, zero entry angle seed plate was recommended for the field evaluation.

Table 5. T test of two seed plates

Source of variation	**Df**	**Average seed spacing**	
		F value	**P value**
Entry angle	0	2.241	0.326[a]

[a]:not significant at 5% significant level.

Field Evaluation of the electronic seed metering system

The result of the field performance evaluation of the electronic seed metering system is shown in Table 6. From among the treatments considered, and based on the 25 cm target seed spacing, the best result (32.9 cm seed spacing) with 3.7% miss index, 0% multiple index and 96.3 quality of feed index was obtained at 10 mbar operational pressure and 0.51 m/s operational speed. It was observed that the seed spacing increases with increase in operational speed and vacuum pressure.

Table 6. Field performance indices of electronic seed metering system

Performance indices	**10mbar and 0.51m/s**	**15mbar and 0.62m/s**	**20mbar and 0.67m/s**	**25mbar and 0.89m/s**	**30mbar and 0.93m/s**	**35mbar and 0.97m/s**
Average Spacing (cm)	32.90	39.60	40.57	68.00	69.75	91.67
Miss Index (%)	3.70	51.19	86.31	100.00	100.00	100.00
Multiple Index (%)	0.00	0.00	4.17	0.00	0.00	0.00
Quality of feed Index (%)	96.30	48.81	9.52	0.00	0.00	0.00

Results of the Analysis of variance (ANOVA) of the planter performance indices using six different treatments (a combination of vacuum pressure and operational speed) for the electronic seed metering system (Table 7) shows a significant different (P < 0.05) between the six treatments for seed spacing, multiple index and quality of feed index. No significant difference was observed between the treatments in terms of miss index. The minimum and maximum seed spacing of

32.89 cm and 91.67 cm respectively were observed at the first treatment (10 mbar and 0.51 m s^{-1}) and sixth treatment (35 mbar and 0.97 m s^{-1}) respectively.

Table 7. ANOVA of result of field evaluation of the electronic seed metering system

Source of variation	**df**	**Average seed spacing**		**Miss index**		**Multiple index**		**Quality of feed index**	
		F. Value	P value	F. Value	P value	F. Value	P value	F. Value	P value
Electronic	3	69.933	0.000*	22.550	0.000*	1.000	0.458[a]	21.715	0.000*
CV		38.450		52.520		424.200		151.330	

*: significant at 1% significant level

[a]: not significant at 5% significant level

The seed spacing increases with increase in operational speed. Significant variation was observed between treatments. This is due to the limitation in servo motor speed. It could therefore be concluded that as the operation pressure increases, by increase in speed of operation, seed spacing increases. Hence, the best operation parameters with regards to seed spacing are 10 mbar and 0.51 m s^{-1}. Although the seed spacing obtained is not exactly 25 cm, but it can still be used base on spacing greater than 25 cm reported to have better yield by some researchers (Miyazato et al., 2010). In fact 25 cm spacing can be achieved with further decrease in operation speed with the aid of equation 3.15.

A linear relationship was observed between speed of operation and seed spacing using the electro mechanical seed metering system. Equation 3.15 represents the relationship between speed of operation and seed spacing.

$$Y = 115.67x - 31.409 \quad (3.15)$$

$$R^2 = 0.9124$$

Field evaluation of the mechanical seed metering system

The result of the field performance evaluation of the mechanical seed metering system using seed plate with eight seed holes is shown in Table 8. A number of missed hills were observed here as evident by the high miss index value. The lower seed spacing observed here was due to the high number of missed hills, as the missed hills were considered in computing the average seed spacing.

Table 8. Field performance indices of mechanical seed metering system

Performance indices	**10mbar and 0.51m/s**	**15mbar And 0.62m/s**	**20mbar and 0.67m/s**	**30mbar and 0.93m/s**	**35mbar And 0.97m/s**
Average Spacing (cm)	28.25	38.78	26.34	21.53	23.01
Miss Index (%)	25.76	52.73	18.84	7.22	7.72
Multiple Index (%)	3.03	8.33	17.47	16.59	20.79
Quality of Feed Index (%)	71.21	38.94	63.69	76.19	71.49

Result of the analysis of variance (ANOVA) for the conventional (mechanical) seed metering shows a significant difference ($P < 0.1$) for average seed spacing and miss index. No significant difference was observed in terms of multiple index and quality of feed index QFI. The best treatment at (30 mbar and 0.93 m/s) from the mechanical seed metering system has QFI of 76.19%.

Table 9. ANOVA result for field evaluation of mechanical seed metering system

Source	**df**	**Average seed spacing**		**Miss index**		**Multiple index**		**Quality of feed index**	
		F. Value	P value	F. Value	P value	F. Value	P value	F. Value	P value
Electronic	3	15.200	0.000*	15.204	0.006*	3.100	0.005[a]	2.450	0.095[a]
CV		27		101.59		77.25		27.63	

*: significant at 1% significant level

[a]: not significant at 5% significant level

To determine the best result between the modified (electronic) seed metering system and the conventional (mechanical) seed metering system. Two best treatments, one each from the modified and the mechanical system were selected and subjected to T test.

T test between the best of mechanical and electronic seed metering system

The result of T test (Table 6.) conducted between treatment 1 (10 mbar and 0.51 m s^{-1}) of electronic seed metering system and treatment 5 (30 mbar and 0.93 m s^{-1}) of the mechanical (conventional) seed metering system shows a significant difference ($P < 0.01$) between the electronic and conventional system at 1% significance level in terms of average seed spacing. Significant difference ($P < 0.05$) was observed in multiple index and quality of feed index between the two systems considered at 5% significance level. In the other hand no significant difference was observed with miss index. With the above results, it could be suggested that the electronic metering system with lower multiple index of 0% and higher quality of feed index of 96.3% is better than the mechanical metering system statistically with 76.19% quality of feed index.

Table 10 T test result for mechanical and electronic seed metering systems

Source	**df**	**Average seed spacing**		**Miss index**		**Multiple index**		**Quality of feed index**	
		F. Value	P value	F. Value	P value	F. Value	P value	F. Value	P value
Metering system	4	1.058	0.004*	0.030	0.548[a]	14.679	0.016**	0.335	0.031**

*: significant at 1% significant level

**: significant at 5% significant level

[a]: not significant at 5% significant level

Conclusion

Two seed plate designs were developed, based on the relevant physical properties of the capsulated seed. The performance of electro mechanical seed spacing and metering system was evaluated at the laboratory and field. At laboratory level, seed plate with zero entry angles was found to have better performance, and it was recommended for the field evaluation. For all the speed and pressure tested in the field, consistency in seed spacing was achieved with the developed electromechanical system. The seed spacing increases with increase in operation speed and pressure. This is due to speed limitation of the servo motor as well as additional load due to shock and vibration during field operations. From the field evaluation, the best operational parameters for the electronic seed spacing and metering system are 0.51 m s^{-1} and 10 mbar. The developed electronic seed spacing and metering system achieved the highest quality of feed index (96.3%) and is better than the mechanical seed spacing and metering system with the best QFI of 76.19% at the field test.

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Physical and mechanical analysis of chitosan film incorporated with *Garcinia atroviridis*

[1]Zaman, N. K., [1]Nyam, K. L., and [1]Pui, L. P.
[1]Department of Food Science, Faculty of Applied Sciences, UCSI University, 56000 Cheras, Kuala Lumpur, Malaysia.

E-mail address:
puilp.ucsiuniversity.edu.my (Pui, L.P.)

Abstract

Addition of *Garcinia atroviridis* extract into films reduces microbial growth, yet may affect its physical and mechanical strength. The aim of this study was to investigate the physical and mechanical properties of chitosan film incorporated with *Garcinia atroviridis* extract. The 1.5% chitosan film were added with different concentrations of *Garcinia atroviridis* extract (1%, 2%, 3%, 4%, 5%) and were evaluated based on its water solubility, color, thickness, tensile strength and Young's modulus. As *Garcinia atroviridis* extract incorporated increases, water solubility of the films increases (from 21.17 to 53.61%). Increase of *Garcinia atroviridis* incorporated into chitosan film increase the total color difference. All the films were generally yellow-brownish in color with the addition of *Garcinia atroviridis* extract, and the film's opacity increased with the increase of the extract. Film with higher concentration of *Garcinia atroviridis* extract produced thicker film compared to the film without extract (from 0.048 to 0.143 mm). The film with 5% *Garcinia atroviridis* extract possessed low tensile strength (3.28 MPa) and elongation break (13.90%). Young's modulus decreased in value (from 0.72 to 0.24 MPa) as the higher concentration of *Garcinia atroviridis* extract was added, implicating that the addition of *Garcinia atroviridis* decrease the mechanical properties of the chitosan film.

Keywords: *Garcinia atroviridis*, Chitosan, Edible film, Physical, Mechanical.

Introduction

Food packaging enables food to be safely distributed over long distance but maintain its nutritional values and taste prior to consumption (Trinetta 2016). It functions to protect food from microbial growth as well as retard the growth of yeasts and molds (Coles *et al*. 2009). Edible packaging is one of the packaging types in food industry. There are variety of films and coating such as proteins, lipids, resins, polysaccharides with or without the addition of other components (e.g. plasticizers, and surfactants) (Cerqueira *et al*. 2011). Polysaccharides for films and coating are derived from starch, starch derivatives, cellulose derivatives, alginates, carrageenan, various plant, microbial gums, chitosan and pectinates (Lin and Zhao 2007).

Chitosan has several advantages that makes it suitable to be used as edible packaging such as biocompatibility, biodegradability, no toxicity and presenting functional properties as bacteriostatic and fungistatic (Hosseini *et al*. 2013). Besides that, the addition of different herbs and spices into the edible packaging such as green tea, oregano and thyme found to enhance the properties of the edible films (Siripatrawan and Harte 2010, Seydim *et al*. 2006).

*Garcinia atrovi*ridis, also known as 'asam keping', is commonly used in preparing dishes to season the curries, sour relish and for fish dressing as well (Mackeen *et al*. 2000). Extracts of *Garcinia atroviridis* possessed strong antibacterial activity against *Bacillus subtilis* B28 (mutant), B. subtilis B29 (wild type), methicillin-resistant *S. aureus*, E. coli. *Garcinia atroviridis* root extract had showed strongest inhibition against *Pseudomonas aeruginosa* by disc diffusion method. Besides that, *Garcinia atroviridis* has antioxidant and antitumor-promoting activities (Negi *et al*. 2008, Mackeen et al. 2000).

Thus far, there is no study reported on edible film incorporated with *Garcinia atroviridis*. Hence, the development of chitosan film incorporated with *Garcinia atroviridis* was done to investigate the potential application of *Garcinia atroviridis* in packaging film. However, addition of *Garcinia atroviridis* may affect the strength of chitosan film, leading to the need in conducting the investigation on its physical and mechanical properties of the film.

Materials and Methods

Preparation and extraction of Garcinia atroviridis

Medium sized *Garcinia atroviridis* (loose pack) was purchased from the local market at Sungai Besi, Malaysia. It was cut and dried overnight at 60 ºC before grinded (Sharp grinder, EM-11, Malaysia).

Extraction of *Garcinia atroviridis* was performed in accordance to Mackeen *et al*. (2000) with slight modification. Firstly, grinded *Garcinia atroviridis* (80 g) was added into 800 mL ethanol (extraction solvent), and stirred overnight before filtration process. The filtrate was then subjected to rotary evaporator (Buchi, Rotavapor R II, Switzerland) at 60 ºC, medium speed for 1 hour.

Preparation and production of film

Film casting was carried out according to Ojagh *et al*. (2010) with modifications. Chitosan solution (1.5%) was prepared and acetic acid (1%) to reduce the water vapor permeability, was added into the solution and stirred for 24 hours before filtration. Different concentration of *Garcinia atroviridis* extract (1%, 2%, 3% 4%, 5%) was added into the chitosan filtrate with 0.5% glycerol and 0.01% Tween-80 (Thermo Fisher Scientific, US), and homogenized at 9,000 rpm for 4 minutes. The solution (25 mL) was poured into the petri dish

(90 mm × 15 mm) for film casting for 24 hours at 40 ºC. Dried films were peeled manually using forceps.

Determination of water solubility

The water solubility test was conducted according to Mehdizadeh *et al*. (2012) with slight modification. The film was cut into 2 cm × 2 cm and dried for 24 hours at 60 ºC. Dried film was then placed into the boiling tube (Pyrex, US) with 20 mL distilled water, and covered for 3 hours before filtration. After drying process, the film was collected and weighed. The water solubility of the film was calculated using the formula in Equation (1).

Water solubility %= (Initial dry weight-Final dry weight)/(Initial dry weight)×100 (1)

Determination of colour

Colour test for film was carried out according to Indrawati *et al*. (2015) with slight modification by using calorimeter (ColorFlex Ez, Hunter lab US). Color of the film was expressed as L* (lightness-darkness), a* (red-green) and b* (yellow-blue) values. Total color differences (ΔE) for the films were calculated according to the Equation (2).

$$\Delta E = \sqrt{(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})} \quad (2)$$

Determination of thickness

The thickness of film was measured using a manual micrometer (JY, China) according to method of Akhtar *et al*. (2009).

Determination of tensile strength and Young's modulus

Mechanical properties measurement is essential, where tensile strength and Young's determines the strength and stiffness or elasticity of the films, respectively (Karki *et al*. (2016). Tensile strength at break, elongation break and Young's modulus were determined according to Dick *et al*. (2015) with slight modifications, in terms of separation grip. Texture analyser (Lloyd Instrument, UK) was pre-set for speed, gauge length, thickness, width, units (for tensile strength and elongation break) before putting sample at the grip. The speed was set to 20 mm/min. The film was cut into 20 × 70 mm rectangular strip and held parallel by the grip with a separation of 30 mm. Tensile strength (mPa) and elongation break (%) results were obtained from the texture analyser indicated by peak load (N) and peak extension (%) respectively. On the other hand, Young's modulus was determined in Equation (3).

$$\text{Young' s modulus mPa} = \text{Stress/Strain} \quad (3)$$

Where the stress is force applied (F)/ cross sectional area (A) and strain is length of extension of film (e)/ original length of film (lo).

Statistical analysis

Data collected were analysed by using Minitab 17 software. Data were represented as a mean value ± standard deviation (n=3) and analysed using analysis of variance (one-way ANOVA) with Tukey's test at a significance level of $p<0.05$.

Results and Discussion

*Effects on w*ater solubility

Film solubility in water was defined as the content of dry matter solubilized after 24 hours of immersion (Belibi *et al*. 2014). It determines the resistance of film sample towards water. Higher water solubility would result in high water activity, therefore increase the probability of contamination (Rostamzad *et al*. 2006). Table 1 shows the water solubility of film incorporated with different concentration of *Garcinia atroviridis* extracts.

Based on Table 1, the water solubility ranged from 21.17% to 53.61%. Chitosan film shows 21.17% water solubility and the water solubility increased to 25.12% when 1% of *Garcinia atroviridis* extract was added into chitosan film. The water solubility was increasing as the *Garcinia atroviridis* extract incorporated into chitosan films. Low water solubility is required to control the contamination occurred during storage Mehdizadeh *et al*. (2012). Hence, for the purpose of edible film to be applied on food product, it is preferable to have lower water solubility.

Table 12. Water solubility (%) on different concentration of *Garcinia atroviridis* extracts incorporated into chitosan film

Concentration of *Garcinia atroviridis* extract, %	**Water solubility, %**
0	21.17 ± 3.309^{a}
1	25.12 ± 2.789^{ab}
2	35.82 ± 6.468^{b}
3	48.21 ± 2.004^{c}
4	48.56 ± 6.666^{c}
5	53.61 ± 4.354^{c}

Values were expressed as triplicate in mean ± standard deviation. a-c different superscripts within the same column indicate significant differences between formulations ($p<0.05$)

Effects on colour

Colour is one of the sensory attributes that determine consumer acceptance. It influence the quality perception and acceptability (Macfie 2012). Color test was done on the chitosan film incorporated with *Garcinia atroviridis* extract, where the L* (lightness/ darkness), a* (redness/greenness) and b* (yellowness/blueness) and total color change (ΔE) were determined (Table 2).

Table 2. The parameter of color in different concentration of *Garcinia atroviridis* extract incorporated into chitosan films

Concentration of *Garcinia atroviridis* extract, %	**L***	**a***	**b***	**ΔE**
0	29.62 ± 0.01[f]	-1.18 ± 0.03[a]	4.88 ± 0.02[a]	0.00
1	29.07 ± 0.07[e]	2.75 ± 0.03[b]	6.38 ± 0.02[b]	4.24
2	26.74 ± 0.01[d]	2.81 ± 0.00[b]	6.83 ± 0.01[c]	5.29
3	24.01 ± 0.01[c]	3.02 ± 0.03[c]	8.13 ± 0.07[d]	7.72
4	21.89 ± 0.02[b]	4.33 ± 0.01[d]	9.63 ± 0.06[e]	10.61
5	18.22 ± 0.01[a]	7.29 ± 0.02[e]	11.07 ± 0.02[f]	15.49

Values were expressed as triplicate in mean ± standard deviation. a-f different superscripts within the same column indicate significant differences between formulations ($p<0.05$).

Garcinia atroviridis extract is dark and brownish in color. When incorporated into chitosan film, it is found that for Lightness (L*), addition of 1% *Garcinia atroviridis* showed the lighter color of film (highest L* value), as lesser *Garcinia atroviridis*, was incorporated. With the increase of *Garcinia atroviridis* extract, the L* value decreases, indicating a darker shade at higher concentration of *Garcinia atroviridis*.

These finding in agreement with study by Mehdizadeh *et al*. (2012), where the incorporation of thyme essential oil into starch-chitosan films showed decreasing in L* value, indicated that film without essential oil is lighter. Chana-Thaworn *et al*. (2011) also reported that extract of Kiam wood added affected the L* value reduce with increase of concentration. It was observed that all chitosan films incorporated with *Garcinia atroviridis* extract were in yellow-brownish color. Chitosan film appeared to be clear transparent film with slight yellowish color. Color appeared in chitosan film with *Garcinia atroviridis* extract attributed to the pigments in *Garcinia atroviridis* called xanthonoids (Mackeen *et al*. 2000).

With the increase of *Garcinia atroviridis* extract in chitosan film, the film exhibits increase of redness (a* value), form -1.18 with no extract, to 7.29 at film with 5% extract, and increase of yellowness (b* value), from 4.88 (0% extract) to 11.07 (5% extract). The increase was due to *Garcinia atroviridis* extract, which is yellowish brown in color. *Garcinia atroviridis* extract imparts yellow tint, thus increasing the b* value while brown color impart redness. Based on the result in Table 2, with the increase of *Garcinia atroviridis* extract, the total different color (ΔE) increases, to 15.49 at 5% of *Garcinia atroviridis* incorporation. This is due to increase in the content of *Garcinia atroviridis*.

Effects on thickness

Thickness of the films was measured manually using micrometer and the results were reported as shown in Table 3. Based on the result in Table 3, chitosan film showed 0.048 mm thickness and it increased to 0.068 mm as 1% of the *Garcinia atroviridis* extract incorporated into the chitosan film. The film thickness increased as higher concentration of *Garcinia atroviridis* extract added. Thicker film indicated that *Garcinia atroviridis* extracts filled the chitosan matrix causing film to thicken. Similar result obtained for the increasing chitosan concentration incorporated.

The thickness and weight of LLDPE films with clove essential oil was found to be greater compare to the film without the essential oil (Mulla *et al*. 2017). Different in thickness in films also caused by the molecular weight of the film solution even though amount of the solution before the film casting is constant for every film. Different concentration of extract contributes different weight therefore increasing the thickness of films (Siripatrawan and Harte 2010).

Table 3. The thickness and mechanical properties on different concentration of *Garcinia atroviridis* extract incorporated into chitosan film

Concentration of *Garcinia atroviridis* extract, %	**Thickness, mm**	**Tensile strength, MPa**	**Elongation break, %**	**Young's Modulus, MPa**
0	0.048 ± 0.003^{a}	13.37 ± 1.22^{c}	18.47 ± 1.24^{b}	0.72 ± 0.02^{c}
1	0.068 ± 0.007^{b}	7.76 ± 0.79^{b}	17.32 ± 1.80^{ab}	0.45 ± 0.02^{b}
2	0.081 ± 0.004^{c}	6.64 ± 0.87^{b}	17.05 ± 1.52^{ab}	0.40 ± 0.09^{b}
3	0.091 ± 0.003^{c}	3.92 ± 0.47^{a}	15.52 ± 1.41^{ab}	0.25 ± 0.01^{ab}
4	0.096 ± 0.003^{c}	3.45 ± 0.53^{a}	13.00 ± 3.32^{a}	0.28 ± 0.12^{ab}
5	0.143 ± 0.012^{d}	3.28 ± 0.75^{a}	13.90 ± 2.62^{ab}	0.24 ± 0.05^{a}

Values were expressed as triplicate in mean ± standard deviation. a-d different superscripts within the same column indicate significant differences between formulations ($p<0.05$).

Effects on tensile strength, elongation break and Young's modulus

Mechanical properties of film could be evaluated by tensile strength test. Tensile strength is the capacity of material to withstand loads without fracture against the cross-sectional area of the material (Siripatrawan and Harte 2010, Mulla *et al*. 2017). Based on the result in Table 3, the tensile strength for chitosan film (0% extract) was 13.37 MPa and it reduced to 7.76 MPa when 1% of *Garcinia atroviridis* extracts was added into chitosan film. The tensile strength further decreased as the concentration of *Garcinia atroviridis* increased. This showed that higher concentration of *Garcinia atroviridis* could cause the film to be easily break.

Elongation is important as it measures the extend bending and shaping as material can withstand without breaking It is usually expressed as a percentage of the original gage length (Kaufman *et al*. 1997). Based on the Table 3, the elongation break ranged from 13.00%

to 18.47%. Chitosan film (0% extract) showed the highest elongation break percentage (18.47%) and the value reduced to 17.32% as 1% of *Garcinia atroviridis* extract reinforced into chitosan film. The elongation break percentage reduce as higher concentration of *Garcinia atroviridis* incorporated, to 13.90% (5% extract).

Lower elongation break indicates the brittle materials and do not plastically deform. Zailuddin and Husseinsyah (2016) reported decrease in elongation break of regenerated cellulose biocomposite films at 2%, attributed to OPEFB which strain the slippage movement of regenerated cellulose chain during the deformation . This indicates that the film formed was rigid than other percentage.

Young's modulus is a measurement on the ability of material to withstand changes in length when under lengthwise tension or compression. Based on the Table 3, chitosan film showed the highest Young's modulus among the films with 0.72 MPa and the value reduce to 0.45 MPa as 1% of *Garcinia atroviridis* extract incorporated into chitosan film, and to 0.24 MPa at 5% extract incorporated into the film. Therefore, it was concluded that addition of *Garcinia atroviridis* extract showed the low value of Young's modulus indicated high stiffness in film. This situation explained low value in elongation break percentage of film. This may be due to the discontinuous film and uneven matrix with the addition of substance into the film (Shahbazi, 2017).

Conclusion

In the development of chitosan film incorporated with *Garcinia atroviridis*, different concentration of *Garcinia atroviridis* (1%, 2%, 3%, 4%, 5%) was applied into 1.5% chitosan film, with evaluation of physical and mechanical properties of the film. Higher concentration of *Garcinia atroviridis* extract incorporated into chitosan film resulted in high water solubility in film. With increase of *Garcinia atroviridis*, decrease in tensile strength, elongation break and Young's modulus were observed. Although addition of *Garcinia atroviridis* did not improve the solubility and mechanical properties, edible film incorporated with *Garcinia atroviridis* has benefits in terms of its antimicrobial and antioxidant properties. Further investigation is needed from other aspect such as chemical and antimicrobial properties to determine the optimum concentration of *Garcinia atroviridis* to be incorporated into chitosan edible film.

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Relationship between soil apparent electrical conductivity with nitrogen and cec in oil palm plantation

[1, 2]Ezrin, M.H., Aimrun, W., [2]Bejo, S.K., [2]Abdullah, A.F. [2]
[1]Smart Farming Technology Research Center, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[2]Department of Biological and Agriculture Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

E-mail address:
ezrin@upm.edu.my (Ezrin, M.H.)

Abstract

Soil electrical conductivity (ECa) sensor had been widely used in precision farming in identify the soil variability such of its nutrient requirement and soil productivity. In oil palm industry, nitrogen fertilizer and other nutrients are usually broadcast uniformly throughout a field. Site-specific management can be developed through understanding the relationship between sensor measurement and soil properties. This study was conduct in order to determine the relationship between soil ECa with Nitrogen (N) and Cation Exchange Capacity (CEC) in oil palm plantation at Jawa Series. The soil samples were collected at three different depths; 0-15cm, 15-30cm and 30-45 cm respectively. The study showed that both nitrogen and CEC had significant negative correlation with shallow ECa at all three different depths. From the results, the soil variability map has been produced as a reference for oil palm plantation management.

Keywords: Apparent electrical conductivity, Oil palm, Nitrogen, Cation exchange capacity

Introduction

Oil palm is an ideal plant as a perennial crop for Malaysia and Indonesia. Oil palm fertilisers requirements vary from one environment to another depend on many interrelated factors (Foster, 2003). The fertiliser element such nitrogen which mostly enters the plant is a building block for tissue growth. Without nitrogen there is no growth and no yield (Jacquemard, J.C., 1998). Hew and Ng (1968) had reported that soil physical and chemical properties have been used to group the soil nutrient supply to oil palm. Meanwhile, Goh et al. (2005) stated that the easiest way to determine fertiliser requirement for oil palm was through leaf analysis, soil analysis and nutrient balanced or the combination. Collecting soil samples in the large scale plantation area using traditional methods are very crucial and time consuming. Besides that, all those method was difficult, take time to analyse and costly. Thus, a rapid system to identify soil nutrient is required to manage the plantation systematically. The emerging soil sensor such apparent electrical conductivity (ECa) sensor was successfully proven to assist farmer on managing their farm. This sensor is a promising tool to assist in data acquisition in order to study the soil properties. Soil ECa map can be the reference in describe the soil condition and variability. Soil condition in terms of its nutrient requirement and fertility can be defined through soil variability. The soil properties considered highly influential on crop-yield potential which resulted in having similar spatial pattern with ECa data (Sun et al., 2012). Soil Aimrun et al., (2009) stated that soil ECa sensor can produce a very useful soil zoning map as the data were collected at every one meter and delineated rapidly with higher contras. Besides that, many researchers had report that soil ECa and soil properties were correlated with yield either with positive or negative correlation (Sudduth et al., 2005; Jung et al., 2005; Sudduth et al., 2001) as it can assist as a soil quality indicator.Therefore, soil ECa sensor is very practical device in mapping soil variability as it can be measured rapidly at the precise position.

Materials and methods

Site description

Oil palm at the age of 3 years was selected in this study. It was selected due to the stem in not well developed where the respond of FFB to soil can be observed. In this study area which located in Perak, majority the soil type was Jawa series with brown colour B horizon and had poor drainage system.

Soil ECa measurement

Veris 3100 was used in this study to measured soil ECa. It has three pairs of coulter electrodes depends on the coulter spacing. The centre pair integrates conductivity between depths of 0 to 30 cm (Shallow ECa) while the outside pair integrates between depths 0 to 90 cm (Deep ECa). Soil ECa measurement was taken using Trimble AgGPS132.

Soil sampling

Trimble AgGPS132 was used to locate the position of the soil sampling by using soil auger. Soil samples were taken at three different depths which are 0-15cm, 15-30cm and 30-45cm and were sent to the laboratory for chemical soil analysis. The utmost number of roots was found at 20-60cm depths.

Data analyses

The collected data (soil ECa, nitrogen and CEC) were analysed by using statistical software for their description, correlation and regression. The coefficient of determination (R^2) measured how well the regression line approximates the real data points. The strength and direction between soil ECa, nitrogen and CEC was performed using Pearson correlation. Interpolation method in ArcMAP 10.1 was conduct in producing soil variability map by using geometric interval classification.

Result and Discussion

Soil ECa measurement

The descriptive statistic of soil ECa is shown in Table 1 below. For 0-15cm depth, the values of shallow ECa were found to be 13.30 mS/m, 23.39 mS/m and 18.43 mS/m for minimum, maximum and mean value respectively. The value of deep ECa was slightly lower compared to shallow ECa values. It was found to be 6.21 mS/m, 10.49 mS/m and 7.84 mS/m for minimum, maximum and mean value respectively. For 15-30cm, shallow ECa range from 13.17 mS/m to 23.30 mS/m with the mean value of 18.45 mS/m. The deep ECa values ranged from 6.13 mS/m to 10.57 mS/m with an average of 7.85 mS/m. The similar trend can also be observed for the depth of 30-45 cm where shallow ECa showed higher reading with the values of 13.40 mS/m, 22.51 mS/m and 18.44 mS/m compared to deep ECa with 5.34 mS/m, 10.52 mS/m and 7.83 mS/m for minimum, maximum and mean values respectively. The coefficients of variation (CV) for shallow ECa are 12.79%, 12.76% and 12.54 % while for deep ECa, the values are slightly lower with 10.74%, 10.84% and 11.02 % for all three corresponding depths. It can be concluded that shallow ECa has more variability than deep ECa. The variability difference could be affected by the difference of bulk density and soil textures.

Table 13: Descriptive statistics of shallow ECa and deep ECa

	Shallow ECa			**Deep ECa**		
Depth (cm)	0-15	15-30	30-45	0-15	15-30	30-45
Min	13.30	13.17	13.40	6.21	6.13	5.34
Max	23.39	23.30	22.51	10.49	10.57	10.52
Mean	18.43	18.45	18.44	7.84	7.85	7.83
Range	10.10	10.12	10.10	4.28	4.44	5.17
Std. Deviation	2.36	2.35	2.32	0.84	0.85	0.86
Variance	5.56	5.54	5.39	0.71	0.72	0.74
Coef. Of variation	12.79	12.76	12.59	10.74	10.84	11.02

Soil nitrogen and cec value

Malaysian soils are mostly highly weathered and have low inherent fertility example low in CEC and high soil acidity which cause low crop productivity (Bakar et al., 2011). Table

2 shown descriptive statistics of nitrogen and CEC. At depth of 0-15cm, nitrogen range from 0.02 to 1.00 with the mean of 0.3. Meanwhile for depth of 15-30cm, the minimum, maximum and mean are 0.13, 0.97 and 0.31 respectively. These values are insignificantly different at 30-45cm where the reading ranged from 0.02 to 0.97 with mean of 0.25. Meanwhile for CEC, the values range from 17.55 to 21.01 with the mean of 19.16 at 0-15cm. For 15-30cm depth, the minimum, maximum and mean values are 13.63, 23.54 and 18.83 respectively. The CEC value ranged from 14.42 to 23.08 with mean of 19.76 at depth of 30-45cm.

Table 2: Descriptive statistics of nitrogen and CEC

Depth (cm)	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**
	CEC			**NITROGEN**		
Minimum	17.55	13.63	14.42	0.02	0.13	0.02
Maximum	21.01	23.54	23.08	1.00	0.97	0.97
Mean	19.16	18.83	19.76	0.30	0.31	0.25
Std. Deviation	0.73	1.69	1.47	0.23	0.24	0.21
Variance	0.53	2.85	2.16	0.05	0.06	0.04
Coef. Of variation	3.79	8.97	7.44	77.38	77.16	83.05

Correlation and regression analysis

Table 3 showed correlation between Nitrogen and CEC with both shallow ECa and deep ECa. It showed that nitrogen had significantly negative correlation at 0.01 levels with deep ECa at all three different depths. Meanwhile for CEC, it had significant negatives correlation with shallow ECa at all three different depths but it only had a correlation with deep ECa at the depth of 0 – 15 cm. It can be concluded that shallow ECa had significantly negative correlation with CEC meanwhile for nitrogen it had significantly correlation with deep ECa at all three different depths.

Table 3: Correlation of total Nitrogen and CEC to the soil apparent electrical conductivity (ECa)

Depth	**PARAMETERS**	**DEEP ECa**	**SHALLOW ECa**
0 cm – 15 cm	CEC	-0.382**	-0.689**
	Total N	-0.296**	0.074
15 cm – 30 cm	CEC	-0.067	-0.247*
	Total N	-0.260**	0.244*
30 cm – 45 cm	CEC	-0.058	-0.216*
	Total N	-0.348**	-0.089

**Correlation is significant at the 0.01 level (2-tailed).

Curve estimation technique was used to find the best model that relate between soil ECa with nitrogen and CEC where shallow ECa as independent variable for CEC while deep

ECa as independent variable for nitrogen. Figure 1 below represents the relationship between ECa with CEC and nitrogen at depth at 0-15cm. The graph indicated that both nitrogen and CEC had a negative relationship to soil ECa with R^2 of 0.11 and 0.38 respectively. Meanwhile in figure 2 it indicated the relationship of soil ECa and nitrogen and CEC at 15-30 cm. Nitrogen had R^2 = 0.64 meanwhile CEC had R^2 = 0.94 with both soil had negative relationship. Figure 3 also indicated negative relationship between soil ECa with nitrogen and CEC where it had R^2 of 0.053 and 0.15 respectively. The best model to predict nitrogen and CEC using soil ECa for this study area was shown in Table 4 for nitrogen and Table 5 for CEC. RMSE for both nutrients was calculated with both nitrogen and CEC had an average of 0.166 and 1.164 respectively.

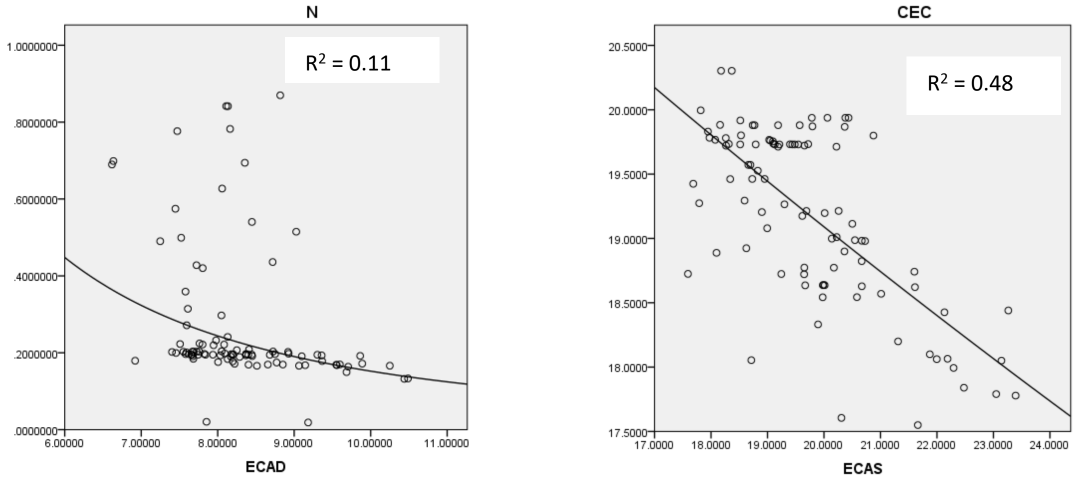


Figure 1: Regression relationship of soil ECa with (a) nitrogen and (b) CEC at 0-15 cm.

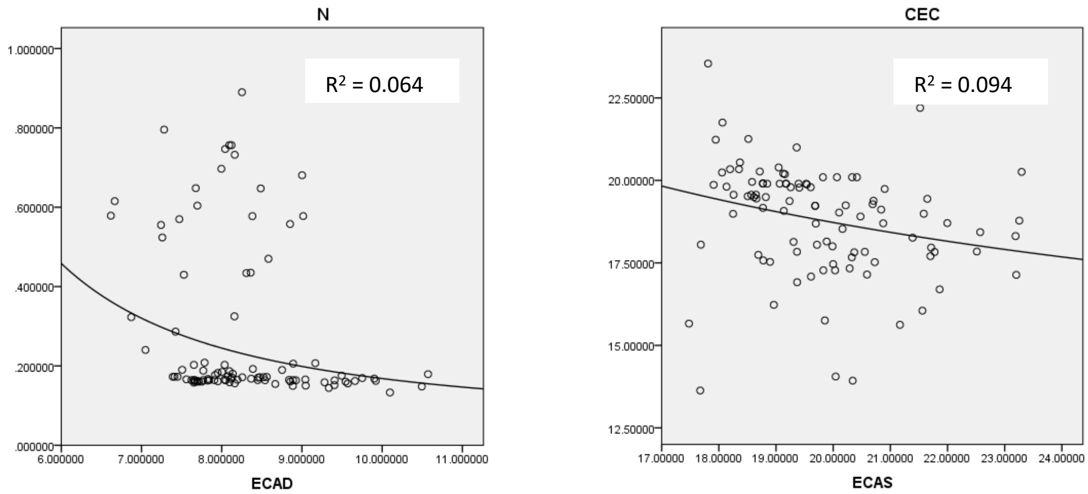
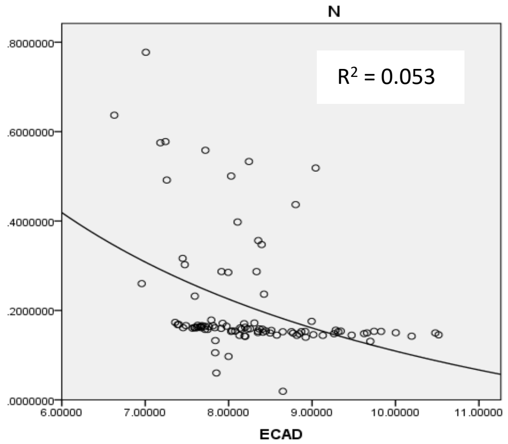


Figure 2: Regression relationship of soil ECa with (a) nitrogen and (b) CEC at 15-30 cm.



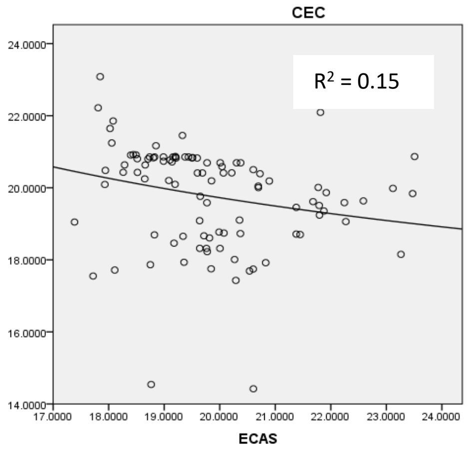


Figure 3: Regression relationship of soil ECa with (a) nitrogen and (b) CEC at 30-45 cm.

Table 34: Model to predict nitrogen with Deep ECa

Depth (cm)	**Model of Nitrogen**	**R^2**	**RMSE**
0 – 15	$N = 19.746*ecad^{(-2.113)}$	0.11	0.180
15 – 30	$N=e^{(-3.286+15.033/ECad)}$	0.064	0.197
30 – 45	N= -0.356 + (4.647/ECad)	0.053	0.122

Table 4: Model to predict CEC with Shallow ECa

Depth (cm)	**CEC**	**R^2**	**RMSE**
0 – 15	$CEC=27.572*e^{(-0.018*ECas)}$	0.48	0.513
15 – 30	CEC = 12.466 + (125.158/ECas)	0.094	1.603
30 – 45	CEC = 14.874 +(96.992/ECas)	0.15	1.375

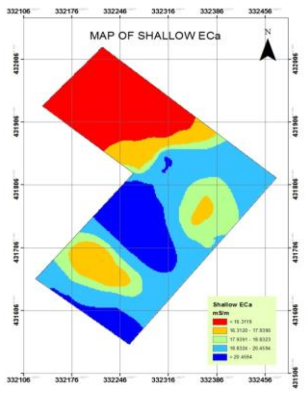
Spatial distribution maps

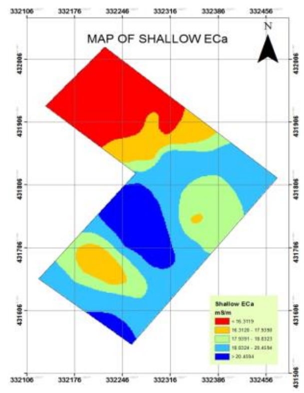
Geometric interval was selected in the interpolation technique with five zones to visualise the variability of soil ECa, nitrogen and CEC distribution as it could be manageable and also easy to compare. As shown in Figure 4, the variability of shallow ECa and nitrogen at three depths are almost the similar. However, the interpolation pattern was different at depth of 0-15cm for CEC map. Besides, shallow ECa had occupied half of the study area with high ECa value. However, low nitrogen (green color) can be seen at the south east of the study area where it occupied half of the study area at all three depths. High CEC can be seen at the north study area and the area of high CEC decrease with increase of the depth.

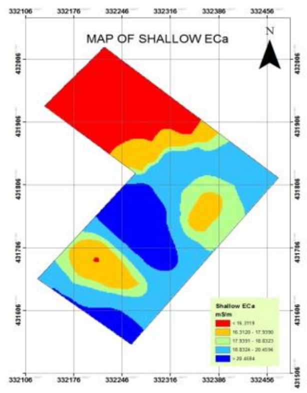
For predicted map in Figure 5, the area with high nitrogen content was increasing with the increase of the depth where higher nitrogen occupied half of the study area at depth of 30-45cm. Nevertheless, the patterns of the CEC maps were almost similar for each depth.

0 -15cm	15 – 30cm	30 – 45cm

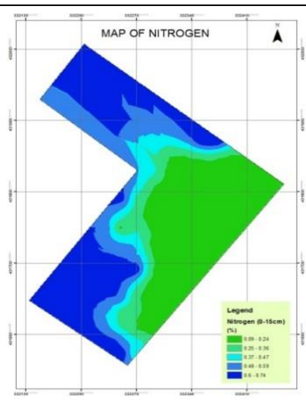
Shallow ECa

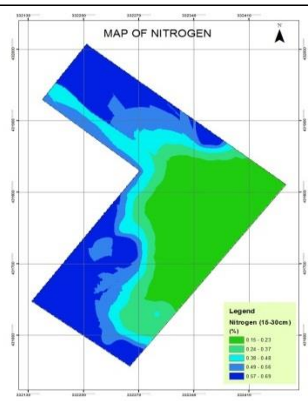


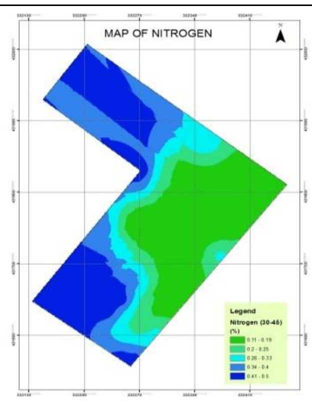




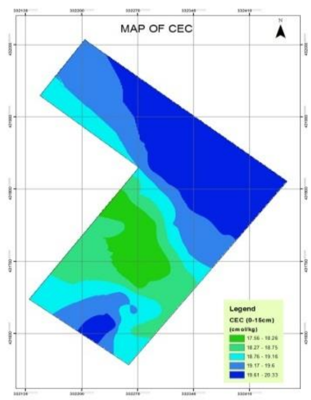
Nitrogen

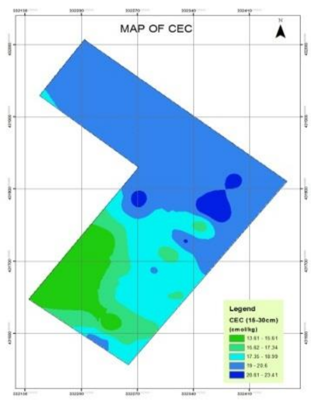






Cation Exchange Capacity (CEC)





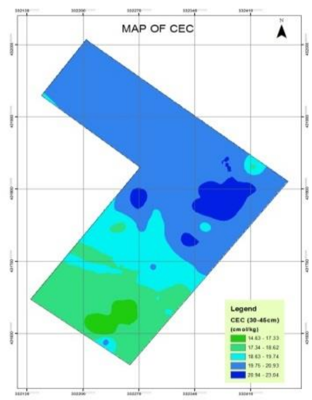


Figure 4: Distribution map of Nitrogen and CEC at three different depths.

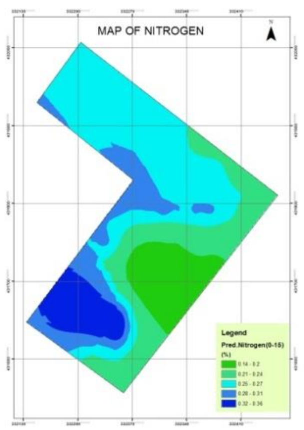
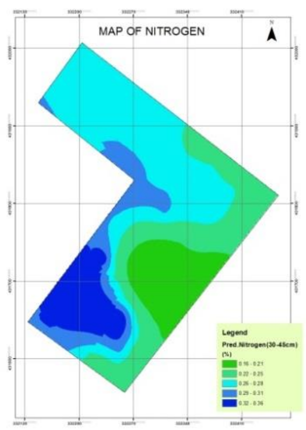
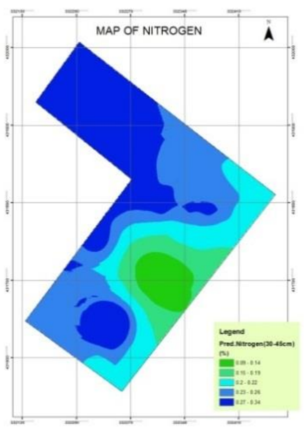
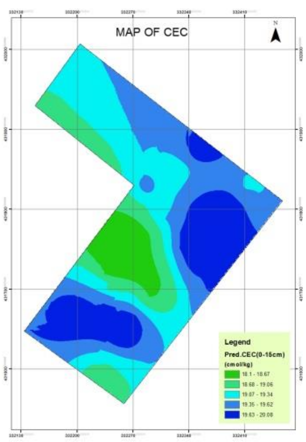
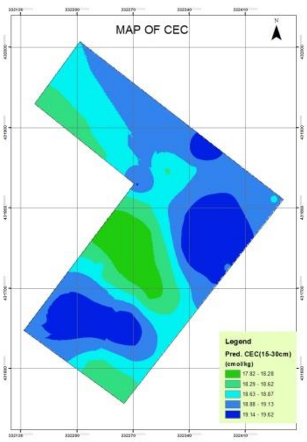
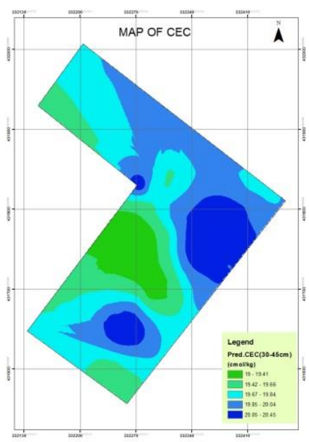
0 -15cm	15 – 30cm	30 – 45cm
Nitrogen		
		
Cation Exchange Capacity (CEC)		
		

Figure 5: Distribution map of Predicted Nitrogen and CEC

Conclusion

As a conclusion, soil ECa can be used as a parameter to determine CEC and nitrogen content in the soil. Shallow ECa had highly significant with CEC meanwhile deep ECa had significant with nitrogen at all three different depth 0-15cm, 15-30cm and 30-45cm respectively. The soil variability map has been produced as a reference for oil palm plantation management.

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Converting agro industrial wastes into feed ingredient for growing rabbits (*Oryctolagus cunniculus*) in Northern Nigeria

[1]Makinde, O.J., [1]Maidala, A., [2]Sikiru, A.B., and [3] Ajibade, A.J.

[1]Department of Animal Science, Federal University, Gashua, PMB 1005, Nigeria

[2]Department of Animal Production, Federal University of Technology, Minna, Nigeria

[3]Department of Animal Production Technology, Federal College of Wildlife Management, New Bussa, Nigeria

E-mail address:
johyinmak@yahoo.com

Abstract

The quest for meeting animal protein demand in the tropics using unconventional feed resources without compromising the quality led to this study. An 8-week study was conducted to assess the growth response of growing rabbits fed diets containing different agro industrial by-products. Four experimental diets were formulated such that Diet 1 – control diet contained 20% rice offal (RO) as its main fibre source. Diets 2, 3 and 4 contained 20% each of brewers waste (BW), cassava peel meal (CPM) and maize offal (MO) respectively as their main fibre source. There were three replicates per treatment. Each replicate contained 4 rabbits in a completely randomized design. Results showed that average weight gain and feed conversion ratio were influenced ($P<0.05$) by the dietary treatments. Rabbits fed 20% BW gained weight faster ($P<0.05$) than those fed other diets. Average feed intake was not affected ($P>0.05$) by the dietary treatments. This study has revealed that 20% BW can be included in the diet of grower rabbits without compromising the performance of rabbits.

Keywords: rabbits, brewer waste, maize offal, rice offal, growth performance, haematology

Introduction

Rabbit (*Oryctolagus cunniculus*) is a non-ruminant herbivore which utilizes much undigested, unabsorbed feed materials, primarily cellulose, as a source of nutrients for maintenance and production. They are known to have the ability to thrive on non-conventional feedstuffs and forages which man cannot consume. Such forages are abundant, cheap and available all the year round in many parts of Nigeria (Odeyinka and Ijiyemi, 1997; Shiawoya and Musa, 2006). Arijeniwa *et al.,* (2000) reported that rabbits can survive on all forage diets, however, optimum performance can only be obtained in a mixed feeding regime involving forage and formulated feeds. Feed constitutes about 65 - 75 % of the total cost of animal production particularly for monogastric. Also, over 90 % of feed industry in Nigeria depend solely on various feed ingredients (Esonu *et al.*, 2004). Hence, there is obvious relationship between feed ingredient and output of animal production in Nigeria. Esonu *et al*., (2004) reported that there is scarcity of conventional protein and energy feed ingredients for non-ruminants including rabbits and this is due to competition between humans and animals for these feed ingredients. This trend has necessitated the use of agro industrial by-products such as wheat offal, rice offal, yam peel meal, sweet potato peel meal, maize offal, cassava peel meal, groundnut shell, brewers dried grains, palm kernel meal etc. in compounding feed for the livestock. Hence, this study seeks to evaluate the use of different agro industrial by-products in the diets for growing rabbits.

Materials and methods

Experimental site

The experiment was conducted in a rabbitary experimental farm around the Federal College of Wildlife Management, New Bussa, Niger State, Nigeria. The climatic condition of the area is tropical with mean annual relative humidity of 60% and monthly average temperature of 34°C.

Procurement of experimental materials

The test samples used in this research were cassava peel meal, rice offal, maize offal and brewer waste. They were all purchased around neighbouring market within New Bussa and its catchment areas.

Experimental design and management of rabbits

A total of forty eight (48) weaner rabbits of composite breeds and mixed sexes, aged between 5 and 6 weeks were purchased from the local rabbitry farmers in Mokwa, Niger state, Nigeria. The rabbits were reared in hutches at the Teaching and Research farm of the College. They were housed based on individual treatment. All the hutches were fitted with drinkers and feeders. The rabbits were acclamatized for 3 days, during which Ivermectin injection was given as dewormer against parasitic infestation. Feed and clean water were supplied *ad libitum* during the 8 weeks of the research. At the beginning of the research, the rabbits with the initial average weight of 805 $\pm$ 1.5g were randomly alloted to four dietary treatments of twelve (12) rabbits per treatment, each treatment was replicated thrice with four rabbits per replicate in a completely randomized design (CRD).

Experimental diets

Four experimental diets were formulated such that Diet 1 – control diet contained 20% rice offal (RO) as its main fibre source. Diets 2, 3 and 4 contained 20% each of brewers waste (BW), cassava peel meal (CPM) and maize offal (MO) respectively as their main fibre source. The gross composition of the experimental diets and proximate composition of the different agro industrial by-products are presented in Table 1 and 2 respectively.

Table 1: Gross composition of Experimental diets

Ingredients, %	20% RO	20% BW	20% CPM	20% MO
Maize	50.00	50.00	50.00	50.00
Groundnut cake	15.00	15.00	15.00	15.00
Soyabean	12.00	12.00	12.00	12.00
Fish meal	1.00	1.00	1.00	1.00
Rice offal	20.00	-	-	-
Brewer waste	-	20.00	-	-
Cassava peel meal	-	-	20.00	-
Maize offal	-	-	-	20.00
Salt	0.40	0.40	0.40	0.40
Bone meal	1.00	1.00	1.00	1.00
*Premix	0.30	0.30	0.30	0.30
Lysine	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20
Total	**100.00**	**100.00**	**100.00**	**100.00**
Calculated Nutrients, %				
M.E (Kcal/kgME)	2502.08	2670.46	2571.65	2580.09
Crude fibre	10.39	10.47	10.87	10.65
Crude protein	16.93	17.06	15.98	15.67
Ether extract	5.73	5.88	5.76	5.80

ME=Metabolizable energy. RO=Rice offal, CPM=Cassava peel meal, BW=Brewer waste, MO=Maize offal.*Premix in diets provided per kg: Vit. E 13000 IU, Vit. A 10000 IU, Vit. K 1500mg, Vit. B 2000 IU, Riboflavin 5000mg, Vit. B12 10mg, Panthothenic acid 8000mg, Thiamine 1300mg, Pyridoxine 1300mg, Folic acid 500mg, Nicotinic acid 28000mg, Biotin 40mg, Iron 58000mg, Selenium 120mg, Manganese 48000mg, Zinc 58000mg, Copper 7000mg, Choline 27500mg, Iodine 60mg, Cobalt 300mg

Table 2: Nutrient composition of the test samples

Nutrients, %	Rice offal	Brewer waste	Cassava peel meal	Maize offal
Dry Matter	92.63	93.54	90.56	93.89
Ether Extract	6.69	4.50	5.19	6.77
Crude protein	17.08	24.07	18.98	17.02
Ash	6.21	5.00	6.64	6.81
Crude fibre	6.04	8.20	8.05	4.91
Nitrogen free extract	56.61	51.77	51.7	58.38

Data collection

Data on live weight, body weight gain, average feed intake, feed conversion ratio were collected.

Two (2) rabbits from each diet group were randomly selected and slaughtered by severing the jugular vein. Five (5) ml blood sample was collected into sample bottles containing an anticoagulant of ethylene diamine tetra-acetate. Blood samples meant for determining biochemical indices (total protein, albumin, globulin, and glucose) were collected into the bottles without EDTA. The blood samples were taken at once to the College Research Laboratory and blood analysis were determined using the standard clinical chemistry procedure described by Peters *et al.* (1982). Nutrient composition of the test samples used for the study were analysed using the methods of AOAC (2006).

Statistical analysis

All the data generated were subjected to one-way analysis of variance (SAS, 2008) while difference between means were separated using Duncan's multiple range test at 5% level of probability.

Results

Figure 1 shows the results of the growth response of rabbits fed diets containing different agro industrial by-products. Significant ($P<0.05$) differences were observed in the daily weight gain and feed conversion ratio. Rabbits fed 20% BW gained weight ($P<0.05$) faster compared with those fed other diets. The lowest daily weight gain was observed among rabbits fed 20% MO diets. The feed conversion ratio of rabbits fed 20% BW was significantly better ($P<0.05$) compare to those fed other diets. The daily feed intake of rabbits was not influenced ($P>0.05$) by the different dietary treatments. Figures 2 and 3 show the results of the blood parameters of growing rabbits fed diets containing different agro industrial by-products. The dietary treatments had effect ($P<0.05$) on the parameters measured except on haemoglobin. Only glucose was significantly different ($P<0.05$) among the serum parameters measured across the treatment groups.

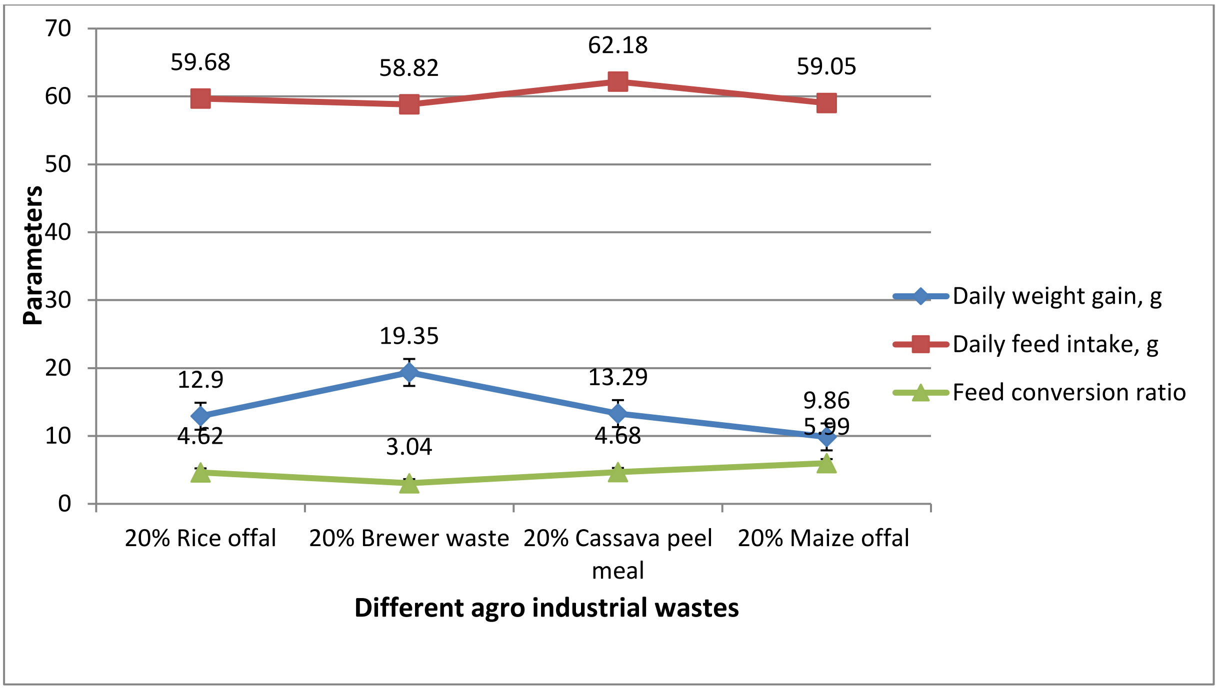

Figure 1: Response of growing rabbits fed diets containing different agro industrial wastes

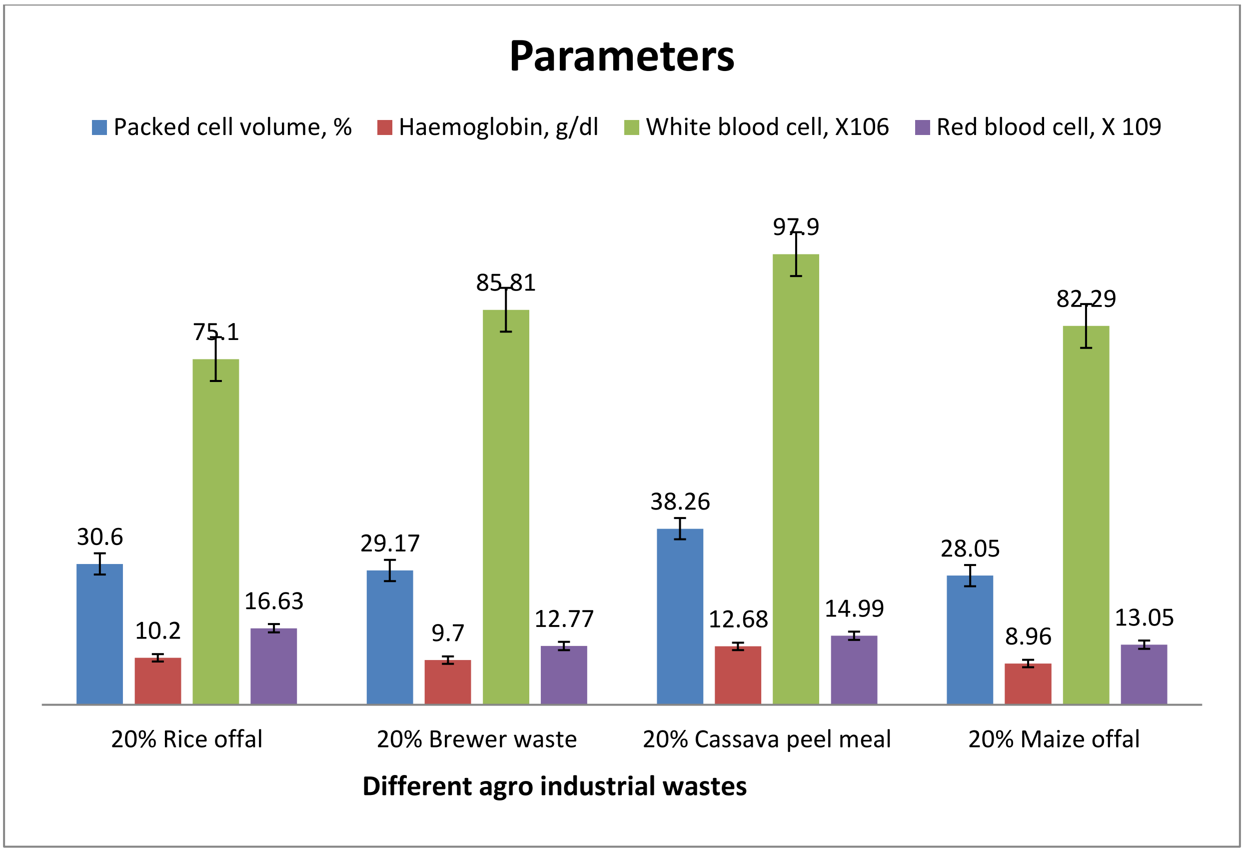

Figure 2: Haematological response of growing rabbits fed diets containing different agro industrial wastes

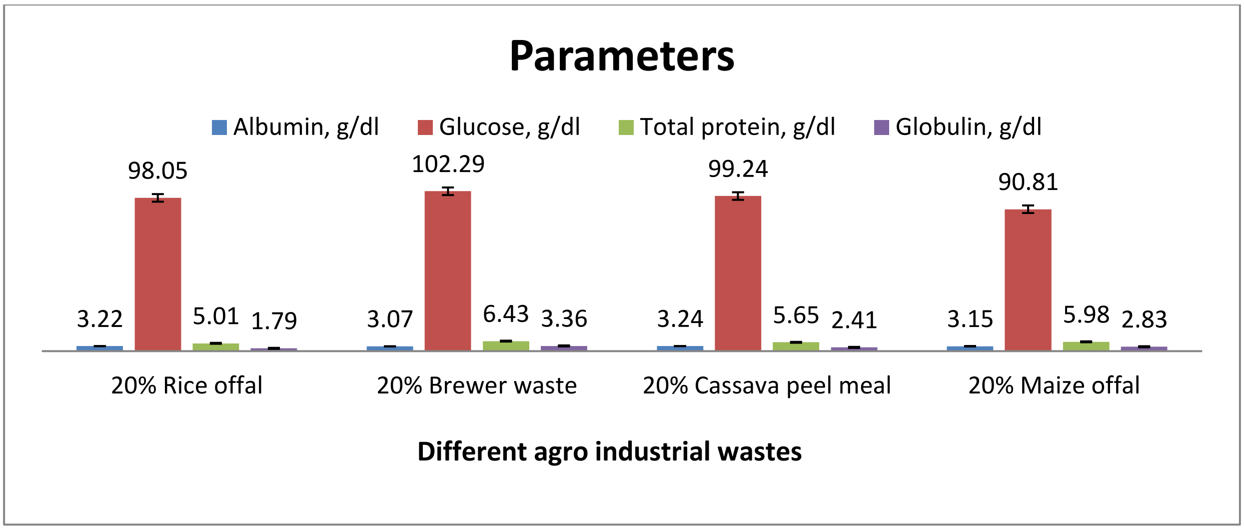

Figure 3: Serum indices of growing rabbits fed diets containing different agro industrial wastes

Discussion

Wide variations have been observed in responses of rabbits when they were fed agro industrial by-products in the diets. These observations may be due to differences in varieties, quality, climatic conditions, storage periods among others. Several authors have reported positive response as regards the inclusion of agro by-products in rabbit diets in Nigeria (Orunmuyi *et al.*, 2006; Adeyemi *et al*., 2014; Makinde, 2016). The results of this research shows that average daily weight gain and feed conversion ratio of rabbits fed 20% BW diet were compared with those fed other diets. The crude protein content of BW (24.07%) in comparison with other test ingredients might have contributed to the superior performance of rabbits fed BW diet. Abdulmalik (1997) reported that up to 15 and 20% sorghum spent residue can be included in the diets of breeding and weanling does respectively without adversely affecting the performance.

Tegbe *et al.* (1995) reported that there were no significant differences in the performance of adult pigs fed diets 0, 12.5, 25 and 37.5% brewer waste. The significant decrease in body weight gain of rabbits fed 20% RO, 20% MO and 20% CPM diets as observed in this study may be due to the anti-nutritional factors such as trypsin inhibitors and tannins which might have negatively influenced the absorption of nutrients in the ingesta resulting in poor weight gain observed among rabbits that were fed the diets (Ensminger *et al.*, 1996). Abeke *et al.*, (2008) had earlier reported that anti-nutrients are known for interfering with utilization of nutrient in animals. They form complexes with the substrate at the digestion site. Also, it was observed from this study that the nutrients supplied by 20% RO, 20% MO and 20% CPM diets were not enough to produce significant increase in weight similar to the rabbits fed 20% BW based diet. Researchers have earlier reported that rice offal contained high level of fibre, low protein and energy. High dietary fibre is known to decrease daily weight gain and increase feed to gain ratio, it also depresses apparent digestibility of dry matter and nitrogen, (Longe and Adekoya, 1988; Kocher, 2001).

The data on blood parameters recorded in this study were all within the normal range reported by Mitruka and Rawnsley (1977). Adenkola and Durotoye (2004) opined that haematological parameters are good measures of the physiological status of animals while Yadav *et al.,* (2002) reported that variations in blood parameters are of value in measuring the sensitivity of animals to various physiological and disease conditions. Togun *et al.* (2007) stated that when the haematological values fall within the normal range, it means that the diets did not show any adverse effects on haematological parameters during the study period, but when the values fall below the normal range, it indicates anaemia (Mitruka and Rawnsley, 1977; Ameen *et al.,*2007).

Conclusion

The result of this research has shown that up to 20% brewer waste can be included in the diet of growing rabbits without adversely affecting the growth response of rabbits.

Further researches should be carried out to determine different methods of reducing anti-nutritional factors present in various agro industrial wastes.

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The Value of Tiv Indigenous Knowledge in Climate Change Mitigation and Adaption Streategy in Nigeria

Abaji Akumave

Department of Agricultural Education College of Education Katsina-Ala, Benue State

E-mail address:
abajisundaya@gmail.com

Abstract
The initial skepticism surrounding the possibility that the global climate may change have been laid to rest with the publication of the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report in early 2007 which confirmed that global climate is already changing.The report indicates that communities whose livelihood are highly dependent on natural resources are among those highly vulnerable to climate change. The climate change not only changes biodiversity of local resources and subsistence environment of the Tiv people in Nigeria, but also affects local knowledge, and traditions of subsistence. This paper analyzes some of the Tiv people mitigation and adaptation strategies to climate change in term of how they alleviate the degree of local climate change and how they adjust subsistence traditions to adapt to the climate change. The paper recommends the need to incorporate Tiv indigenous knowledge into climate change polices that can lead to the development of effective mitigation and adaptation strategies that are cost effective, participatory and sustainable.

Keywords: Adaptation, Climate Change, Indigenous Knowledge, Mitigation, Tiv.

Introduction

The survey of the Tiv rural communities in Nigeria suggests the value of blending their indigenous knowledge and scientific knowledge as strategies for adaption and mitigation ofclimate change and variability.

After the December, 2004 tsunami off the coast of Indonesia, many called for the installation of early warning systems using cutting-edge satellite and ocean buoy technologies to prevent similar disastrous occurrences. Meanwhile just before the Indian Ocean tsunami struck in 2004, numerous people were attracted to the shoreline by unusual spectacle of fish flopping on the sea floor exposed by the seas withdrawal. But all of theMoken and UrokLawai people of Thailand’s coasts and islands, the Ong of India’s Andaman Islands and the Simeulue community of Indonesia, all knew through their indigenous knowledge of the danger ahead and rapidly headed inland to avoid the destructive force of the sea. Moken and Ongvillages were completely destroyed, but the inhabitants escaped unharmed. More surprising was the displacement of more than 80,000 Simeule people beyond the reach of the tsunami, with only seven dead people. Nyong and Adesina, 2007). This efficient response is in contrast with the frightening losses suffered elsewhere in Indonesia and was acknowledge by the granting of a United Nations Sasakawa Award for disaster reduction to the Simeule people. This recognition by the United Nation shows the importance of indigenous knowledge in disaster management and reduction.

The Inter-Governmental Panel on Climate Change (IPCC) assessment reports in 2007 noted that indigenous knowledge is an invaluable basis for developing adaptation and natural resources management strategies in response to environmental and other forms of change. This was reaffirmed at the 32nd session of the IPCC in 2010: which states that indigenous or traditional knowledge may prove useful for understanding the potential of certain adaptation strategies that are cost effective, participatory and sustainable. IPCC have been working to organize a series of workshops to ensure that the experience of indigenous and traditional people to climate change impact and their adaptation and mitigation strategies are fully integrated in the IPCC Assessment Report which will be widely available to the global community.

Incorporating indigenous knowledge into climate change policy can lead to the development of effective cost effective, participatory and sustainable. (Robinson and Herbert 2001). It is important to note the most vulnerable people are the rural poor with limited access to information, financial and technical supports in order to adapt to the best of their abilities.

It is essential to facilitate participation at the local level in the development of adaptive strategies in order to have a more effective response. However, incorporating indigenous knowledge into climate change concerns should not be done at the expense of modern scientific knowledge. It should complement, rather than compete with the global knowledge system. Climate change is threatening not only the sustainable development of socio-economic activities of nations but also to the totality of human existence. Presently, all Nigerians and indeed the world over have begun to feel the effects and challenges of climate change as the frequency and intensity of extreme events like floods, rainfall and droughts have increased. The challenges of climate change in Nigeria have brought about the destruction of many economic institutions including rural houses and economic trees worth millions of naira by wind storm and floods.

Heat and water related diseases are becoming more common in Nigeria. Malaria incidence has increased, as people are exposed to mosquitoes by sleeping in the open or with their windows open because of unusually high night temperature during prolonged rainfall shortages, water sources become scarce, stagnant and contaminated raising the incidence of diarrhea and bilharzias, skin diseases, some of which were previously rare, have also become common during periods of high temperature.

The local Tiv person may not understand the concept of global warming or climate change, but they observe and feel the effect of decreasing rainfall, increasing air temperature, increasing sunshine intensity and seasonal changes in rainfall patterns, flooding, more rapid growth of weeds and greater resistance of weeds to weeding and herbicide application, greater risk of crops failures. Invasion by exotic grass species, increased growing seasonal length, unpredictability of weather and climate making planning of farm operation difficult. Their observation are supported by the changes that are associated with climate change worldwide (Nyoni; Adesnia; 2007). The reduced rainfall, compounded by deforestation and forest degradation has reduced water discharge in Tiv land such that some streams completely dried up leading to water scarcity. Some of the wells dug by communities to ensure availability of water all year round also dried up, indicating a possible reduction in ground water. Water availability is decreasing at a time when the community's water demand is increasing because of population growth. Increasing temperature and intense sunshine, coupled with flooding in some part of Tiv land destroy crops where some vegetable and rice growers described their plants withering as a result of flooding. Pepper and Tomatoes grower claimed that high temperature were causing their vegetable to ripen prematurely thereby decreasing the sale value of these produce, when crops fail, money spent on land preparation and planting, as well as income from sale of farm produce is lost and house hold saving are spent to replant.

The Tiv people have confronted the extremes of climate change for generation and have developed a large arsenal of practices to survive and adapt to an increasingly dangerous climate. They observe climate change and react to it positively by making use of their indigenous knowledge and ancestor's rich experience, they use diversified mitigation and adaptive strategies to survive and ensure food security.

This paper explores some of the ways in which the Tiv people in Benue State, Nigeria have integrated climate change mitigation and adaptation into their livelihood strategies to reduce vulnerability to climate change and its attendant consequences. This knowledge represents a dynamic information base that has supported the Tiv population by adapting to constantly changing and varying climate.

Indigenous knowledge

Indigenous knowledge is an institutionalized local knowledge that has been built upon and passed on from one generation to the other by word of mouth, this knowledge which they accrued over many years is critical and a substantial part of the culture and technology of any society. This sum of knowledge and experience of a given ethnic groups forms the basis for decision making in the face of familiar problems and challenges, and is always unique to given culture and society. (Osunade 1994; Warren 1992).

Mitigation and Adaptation

Two lines of actions according to Nyong, Adesina and Elasha (2007) are articulated for dealing with adverse conditions that are expected to attend to ultimate change. These are mitigation and adaptation actions. Mitigation strategies to them are procedures or activities that help prevent or minimize the process or climate change.

According to Swart; Robinson; Cohen (2003), mitigation strategies can be grouped into two categories, some represent mainly technologies solution, others involve changes in economic structures, societal organization, or individual behavior, In Tiv land, mitigation activities are traditionally employed as natural resources conservation measures, and they generally serve the dual purposes of reducing the emission of green house gases and enhancing carbon ”sink” Strategies aimed at reducing GHG emission emphasize cutbacks in the burning fossil fuel through improved energy efficiency, use of clean energy sources. Carbon sink enhancement generally involves forestry programmers that protect the forest and encourage afforestation in marginal areas including range lands.

Adaptation methods are those strategies that enable the individual or the community to cope with or adjust to the impact of the climate in the local areas. Such strategies include the planting of early maturing crops, adoption of hardy varieties of crops and selective keeping of livestock in areas where rainfall declined. They also include the use of cover crops, mix cropping, weed control, weather forecasting, (Ajani 2013). Obviously, adaptation strategies are expected to be many, and their combination in various ways will be required in any given location.

Tiv indigenous knowledge in climate change mitigation and adaptation.

Indigenous, according to Osunade (1994); Warren (1992) is institutionalized local knowledge that has been built upon passed on from generation to the other by word mouth. Tiv indigenous knowledge is the knowledge that has been developed over time in the community mainly through accumulation of experiences and intimate understanding the environment in which they live. This indigenous knowledge has value not only for the Tiv people that practice it, but also for scientists and people striving to improve conditions in rural localities. Indigenous knowledge set is influenced by the previous generation's observation and experiments and provides an inherent connection to ones environment and surrounding. Therefore indigenous knowledge connects people directly to their environment and changes that occur within it, including climate change.

The climate change mitigation and adaptation strategies of the Tiv people are generally simple and have minimal negative impact on the total environment. Owing to their simplicity and the fact that they are usually individually small scale, this indigenous knowledge have often been disregarded or even despised as primitive by other people, this attitude has been reinforced by the fact that the Tiv technology and culture are poorly understood and alien to other culture within which scientific thinking developed.

The Tiv people who are mainly farmers have been known to conserve soil fertility and moisture through the use of mulching, planting of cover crops. Before the advent of chemical fertilizer the Tiv people depend on organic fertilizer like the use of goat, cattle and poultry dung as manure.

The Tiv Indigenous knowledge and practice on climate change and weather

The Tiv indigenous knowledge which is the wisdom, knowledge and practices of the Tiv people gained over time through experience and orally passed on from generation to generation has over the years played a significant part in solving problems including problems related to climate change and variability. Tiv people that live close to natural resources often observe the activities around them and are first to identify and adapt to any changes. The appearance of certain birds and insect, mating of certain animals (dogs) and insect (cotton stainer) crying of cricket, flowering of certain plants are all important signal of changes in time and seasons that are well understood in Tiv indigenous knowledge system.

The Tiv people have a close inter-relationship and knowledge of the weather and the landscape of the place they inhabit, acknowledge the weather as result of their view of the world and organize their daily activities according to it. This daily coexistence with the climate and the weather (meteorological phenomena) has helped them to developed different responses and adaptabilities to climate variability, particularly those related to agriculture. The Tiv people have their own ways of knowing when there will be rain and when there will be none even if the clouds form on the sky, for example if there are a lots of stars in the night then the next day is expected to be sunny and if the rain clouds form in the east (Wankwase Hungwa Dyeregh) then the rain will be heavy and the appearance of rainbow in the sky signifies that there will be no rain or shallow rain.

The Tiv Indigenous knowledge and practice on afforestation and forest conservation

Tiv people practice the shifting cultivation and then fallow system of cultivation which encourages the development of forest and also plant oranges and mangoes in every household hence there are the largest producers of oranges, mango pawpaw in the whole world.

The use of agro forestry which is the planting system find some balance in the raising of food crops and forest tree as can be seen the planting of pepper, banana, oranges and yam. Staking the yam to position its leaves for adequate absorption of sun light for photosynthesis is the Tiv Indigenous knowledge and practice.

The Tiv people identified deforestation as a major factor for increasing soil erosion, and they adopt practices to remedy the situation. The practices include tiring a cloth around the trunks of big trees frightening the young ones that these big tress habor spirit and if they are cut down the spirit will be angry and dry up the water or stop rain from falling. These trees are preserved and managed to provide timber and medicine resources to the Tiv community, they also serve as carbon sink. The Tiv people now plants an economic tree like mango, cashew and orange beside a timber tree as a way of preventing it from been cut down.This prevent the tree from been cut down because the timber tree cannot be cut without destroying the mango, cashew and orange planted beside it. Tiv people protect the forest trees by raising bees in the forest. This prevent the forest trees from been cut down even in the absence of elders or forest guard.

The Tiv Indigenous knowledge and practice on pest and disease control

The Tiv people have practiced various indigenous methods ofpest and disease control even before the advent of modern synthetic pesticide, most of the indigenous insect pest control methods were to deny the pest of their most prefer food to control their population below economic damage level, like in the case melon beetle where they usually have a skip cultivation. Tiv farmers do not cultivate melon the year that follow it harvesting. This is to prevent buildup of beetle that eats the melon.

Fire wood ashes mix with melon leaf juice are commonly used by the Tiv people to treat yam cutting or sets to prevent infestation of pest and diseases, sanitation practices like burning of crop residues, volunteer crops and ratoons, reduce pest population. The Tiv farmers are good in keeping their farm field weed free.

Tiv Indigenous Knowledge and Practice on soil fertility.

Mixed cropping is one of the frequently used Tiv indigenous methods of maintaining soil fertility. Mixed cropping is the growing of two or more crops simultaneously on the same piece of land with or without distinct row arrangement. Mix crop systems create a favorable condition for the soil, water, nutrients and provide excellent environmental conservation and sustainability. This practice has been part of Tiv cropping system for a very long time, like planting of yam, beans and cassava on heaps where yam which is always the main crop fail to germinate.

Another practice of maintaining soil fertility by the Tiv people is to raise shade tolerant crops such as yam and cassava in essentially permanent forest setting like pears, this practice help to cope with the higher population density in Tiv and Nigeria now, it also lead to an increase in the amount of organic matter in the soil thereby improving agricultural productivity and reducing deforestation.

Tiv Indigenous Knowledge and Practice on Water Harvesting, Treatment and Purification.

The Tiv people realized that water shortage occasioned by climate change is a major threat to their survival and have developed several strategies to adapt to these phenomena. Tiv people have actively used their indigenous knowledge in harvesting rain water, a traditional way of collecting water and storing in pots and basin placed under the roofs of houses is an aged long practice.

It is a taboo in Tiv land to go to the river or stream in the night so that the stream spirit or god could have a rest and that touch light should not be used in fetching water in the night, are all aim at providing a means of protecting the water bodies and ensuring that everybody have access to available water during the day.

The collection of water from house roof and storing in clay pots are Tiv indigenous knowledge on water management acquired over years of practice which help the communities to cope well with water shortage and drought.

The Tiv people used juice squeeze from moringa seeds to purify water which is not normally clean as a result of flooding and drought.

Tiv Indigenous Knowledge and Practice on prevention of crop failure

The Tiv indigenous knowledge in agriculture acquired over the years of practice, previously help the communities to cope well with crop loses and damage,but traditional approaches have become difficult to apply in recent years because of changing rainfall patterns. Tiv farmers are adapting to this constraint by planting different crops. Crops that thrive well under the current prevailing conditions are increasingly being planted in areas previously did not support their cultivation. An example is the cultivation of onion in Tiv land and the shift from yam cultivation to drought resistant crop such as cassava in Tiv land, the digging of bigger heaps for planting of yam and the strict use of stake for every yam. Vegetable growers are also gradually moving into the stream plains where their crops can have more water. Banana, kola, pears and oil palm that were thought to be crops that only survive in the south are been planted in Tiv land in large quantities.

In coping with risk due to excessive or low rainfall, drought and crop failure, the Tiv people grow many crops and varieties with different susceptibility to drought and floods and supplement these with hunting, fishing and gathering wild food plant. The diversity of crops and food resources is often matched by a similar diversity in location of field, as a safety measure to ensure that in the face of extreme weather, some field will survive to produce harvestable crops.

The planting of yam was normally done during the dry of season (December to February) but they have changed for a reason that planting in the dry season always affect the seed because of lack of moisture. The people now plant with the arrival of rain and also cover the heap to prevent excess heat occasioned by high sun light.

Tiv Indigenous Knowledge and Practice on weeds control.

Majority of small holders farms in Tiv land still practice cultural methods such as pull and burn, mulching, shifting cultivation, fallowing, slash and burn, intercropping, cover cropping and shallow cultivation. Weed spices like commelina are buried to prevent their exposed parts from regenerating. The sowing of finger millet which is striga resistance and guinea corn in the same hole is a Tiv indigenous practice to reduce the effect of striga on the corn.

Tiv Indigenous Knowledge and Practice on harvesting and storage of produce

Many Tiv people have been primarily dependent on the perishable staples for centuries or millennia and have devised many highly indigenous storage and processing technique for these staples. Some of the people practice a greater or lesser degree of storage avoidance. Harvesting only for immediate or short term requirement throughout much of or even the whole year like sweet potatoes, only the tubers meant for immediate use are harvested while others are covered with dry leaves. Groundnut are harvested, tie and kept upright with the seed facing up for easy drying and to prevent them from germinating as result of heavy rain occasioned by climate change.

Conclusion

There is much to learn from Tiv indigenous knowledge, tradition and community-based approaches to natural disasters preparedness. Tiv people have been confronted with changing environments for millennia and have developed a wide range of strategies. Their traditional knowledge and practices provide an important basis for facing the even greater challenges of climate changes. Although these strategies may not succeed completely, they are effective to some extent and that is why the people continue to use them while the Tiv communities undoubtedly need much support to adapt to climate change, they do also have expertise to offer on adaptation and mitigation through traditional time tested mechanisms which are cheap enough to be avoidable, simple enough to be applicable under particular circumstances, cost effective and sustainable.

Suggestions

The following recommendations have been derived from the conclusion since the Tiv indigenous knowledge is important to climate change mitigation and adaptation.

I recommend that a proper recording and documentation of Tiv indigenous knowledge should be done by ministries of agriculture and the ministry of culture and tourism. However when recording, it is important to find who knows what in order to tap the right source, otherwise data will not truly reflect the Tiv indigenous knowledge. The Tiv indigenous knowledge should be further studied, developed, expanded and mainstream into global adaptation and mitigation strategies.There should be awareness programme about the value of Tiv indigenous knowledge in order for the communities to conserve their indigenous knowledge.

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Sensory Evaluation of Instant Noodles Produced from Blends of Sweet Potato, Soybean and Maize Flour

[1]Olorunsogo, S.T., [1]Adebayo, S.E., [1]Orhevba, B.A., and Awoyinka, T.B.

[1] Department of Agricultural and Bioresources Engineering, School of Infrastructure, Process Engineering and Technology, Federal University of Technology, Minna, Niger State, Nigeria.

E-mail address:

olorunsogosam@yahoo.com (Olorunsogo, S.T.)

Abstract

Wheat flour is unique for noodles production, but due to high cost, its continuous use in a developing economy is no longer encouraged. This study was aimed at determining the effects of substitution of non-wheat flour on the sensory properties of noodles. D-optimal mixture-process experimental design of the response surface methodology (RSM) was employed. Thirty-nine (39) samples of noodles were formulated with each blend of sweet potato, soybean and corn flour. The design constraints for the formulations are sweet potato flour ($10\%<x1<61\%$), soybean flour ($5\%\le x2\le 20\%$), corn flour ($5\%\le x2\le 30\%$), and water ($25\%\le x4\le 37\%$).Other components of the formulation are salt (2.5%), sodium carbonate (0.5%), guar gum (0.5%), and Soy lecithin (0.5%). The processing parameters cosidered are mixing duration ($2min\le z_1$,10min), frying duration ($1min\le z_2\le 3min$) and frying temperature ($140°C\le z_3\le 160°C$). The formulated instant noodles were subjected to sensory evaluation by a panel of semi-trained panelists who had eaten noodles for a long time, and the best formulations were determined in accordance with a preference test. Optimization analysis on the data obtained from the sensory session showed that blend of sweet potato flour (23.305%), soya bean flour (28.529%), corn flour (18.021%), water (26.145%), 2.749 minutes mixing time, 1.35minutes frying time, and 140°C frying temperature, with the highest desirability index of 0.723, produced the best composite instant noodles in terms of taste, texture, flavour, appearance, and overall acceptability. The proximate compositions, cooking, physical and sensory properties of this optimal formulation were: moisture content (13.17%), ash content (6.616%), crude protein (22.862%), energy value (37.707%), crude fat (16.001%) and, crude fibre (4.643%), cooking time (5.415 minutes), cooking weight (26.449 g), water absorption index (164.49), bulk density (0.77), taste (6.406), texture (8.253), flavour (7.659), appearance (6.224), and overall acceptability (5.333). The mixture-process design (D-optimal) was used to establish the effect of changes in mixture compositions and the three processing factors on the main proximate, cooking and physical qualities of instant noodles. The effects were evaluated through analysis of variance at 5% level of significance. The quadratic x mean

model for taste, the reduced special cubic x cubic model for texture, the reduced special cubic x cubic model flavour, the quadratic x mean model for appearance, and the quadratic x mean model for overall acceptability were all found to be statistically significant ($p<0.05$).

Keywords: Noodles, Formulation, D-optimal, Sensory evaluation, Optimization

Introduction

In Nigeria, ready-to-eat baked products (snacks) consumption is continually growing and there has been increasing reliance on imported wheat (Akpapunam and Darbe, 1999; Olaoye et al., 2006). Wheat cannot perform well under tropical climate, Nigeria had over the years depended on wheat imports mostly from the United States. This has detrimental effects on the economy involving huge expenditure of foreign exchange. The economy of the country will surely improve if other staple food crops that are grown locally are exploited. In Staple crops grown locally that can be exploited for baking include cassava, yam, sweet potatoes and cereals can be used (Shittu et al., 2009; Baljeet et al 2014; Oluwamukomi et al., 2011).

Efforts have been made to partially replace wheat flour with non-wheat flours as a possibility for increasing the utilization of indigenous crops cultivated in Nigeria as well as contribute to lowering cost of bakery products (Ayo and Gaffa, 2002). Horsfall Mepba et al. (2007) stated that many researchers have studied the physical and baking properties of composite biscuits from starchy staples (Sanni et al., 2007; Shittu et al., 2009; Ogunsua and Hudson, 1976; Nout, 1977; Orunkoyi, 2009; Taneya et al 2014).

The main objective of this research was to optimise the formulation and some process parameters of noodles production from blends of sweet potatoes, maize and soybean flour, employing the statistical D-optimal mixture-process design methodology.

Materials and Methods

Materials

Yellow maize, sweet potato, soybean, and salt were obtained from the local market at Mile 12 in Lagos, Nigeria. Other ingredients were purchased from a food chemical market in Lagos. The chemicals used were of analytical grade. The apparatus and equipments used in the study include steaming machine, grater, milling machine, noodles maker, mixer, dryer, deep fryer, manual kneader, soxhlet apparatus, kjeidal apparatus, makahmps apparatus, condenser, chopping board, petri dishes, electronic weighing balance, desiccators, crucibles, bunsen-burner, fume cupboard, thimbles, filter paper, beaker, oven, spatula, thimble, complete digestion block set, burette, pipette, pipette filler, and cornical flask.

Preparation of Soybean flour

The preparation of the soybean flour was according to the methods of Oluwamukomi et al., (2005). Soybeans were cleaned and sorted, washed and boiled in water at 100°C for 30 mins. The pre-treated soybean were manually dehulled, oven dried at 70°C for 15 h and milled in a disc attrition mill to obtain the flour followed by sieving using a muslin cloth. The fine flour obtained was stored at room temperature in air tight polyethylene bags.

Preparation of Sweet potato flour

Sweet potato tubers were peeled, washed, cut into thin slices, spread in a tray and oven dried at 60°C for 10 hours after which they was milled into fine flour. The flours were screened through an 80 mesh sieve, and then stored in polyethylene bags.

Preparation of corn flour

Corn samples were dehusked, shelled, dried, cleaned and milled. The milled sample was then passed through a sieve to obtain fine sample of corn flour.

Experimental design

The experiment was designed using Design-Expert software (version 11, Stat-Ease Inc.). A constrained D-optimal mixture-process experimental design, totalling 39 randomized experimental runs, was employed to generate the experimental data. The design matrix for the D-Optimal mixture – process design is presented in Table 1. Response surface methodology was used to evaluate the effect of changes in mixture compositions and the three processing factors on dependent variables. Statistical optimization of the blends formulation was also carried out. Both process and mixture components were optimized by this method. Four major variable components, four constant components, with three processing parameters were investigated. The sensory qualities of the instant noodles selected as the dependent (response) variables were texture, taste, appearance, flavour, and overall acceptability.

Experimental results

The mean sensory scores, based on nine-point hedonic scale, for the thirty-nine formulated instant noodle samples from composite flour blends are presented in Table 2.

Table 1. D-Optimal mixture – process design matrix

Run	x_1 (%)	x_2 (%)	x_3 (%)	x_4 (%)	z_1 (%)	z_2 (%)	z_3 (%)	c_1 (%)	c_2 (%)	c_3 (%)	c_4 (%)
1	46	20	5	25	10	3	140	0.5	0.5	0.5	0.5
2	21	20	30	25	10	1	160	0.5	0.5	0.5	0.5
3	22	20	17	37	10	1	160	0.5	0.5	0.5	0.5
4	49	5	5	37	10	1	140	0.5	0.5	0.5	0.5
5	36.5	5	17.5	37	2	1	140	0.5	0.5	0.5	0.5
6	41.5	12.5	30	37	2	3	160	0.5	0.5	0.5	0.5
7	33.5	20	30	25	10	3	160	0.5	0.5	0.5	0.5
8	10	19	13.3	37	2	2	150	0.5	0.5	0.5	0.5
9	21	20	5	25	10	3	140	0.5	0.5	0.5	0.5
10	42.7	15	30	25	6	2	150	0.5	0.5	0.5	0.5
11	61	5	5	25	2	1	160	0.5	0.5	0.5	0.5
12	36	5	30	25	10	3	140	0.5	0.5	0.5	0.5
13	49	5	5	37	10	1	140	0.5	0.5	0.5	0.5
14	21	20	30	25	2	1	160	0.5	0.5	0.5	0.5
15	61	5	5	25	10	3	140	0.5	0.5	0.5	0.5
16	28.5	12.5	30	25	2	3	160	0.5	0.5	0.5	0.5
17	55	5	5	31	2	3	140	0.5	0.5	0.5	0.5
18	15.5	20	30	30.5	2	3	160	0.5	0.5	0.5	0.5
19	46	20	5	25	2	3	140	0.5	0.5	0.5	0.5
20	53.5	12.5	5	25	2	1	140	0.5	0.5	0.5	0.5
21	21	20	30	25	2	3	140	0.5	0.5	0.5	0.5
22	46	20	5	25	10	1	140	0.5	0.5	0.5	0.5
23	25.4	13.8	19.8	37	10	3	140	0.5	0.5	0.5	0.5
24	10	19	30	37	10	3	160	0.5	0.5	0.5	0.5
25	10	19	30	37	6	3	150	0.5	0.5	0.5	0.5
26	2.3	9.7	30	33	2	1	140	0.5	0.5	0.5	0.5
27	48.5	5	17.5	25	2	1	140	0.5	0.5	0.5	0.5
28	24	5	30	37	10	3	160	0.5	0.5	0.5	0.5
29	34	20	5	37	2	1	140	0.5	0.5	0.5	0.5
30	34	20	5	37	10	3	160	0.5	0.5	0.5	0.5
31	22	20	17	37	2	3	140	0.5	0.5	0.5	0.5
32	21	20	30	25	2	1	140	0.5	0.5	0.5	0.5
33	36	5	30	25	2	3	140	0.5	0.5	0.5	0.5
34	10	19	30	37	2	1	140	0.5	0.5	0.5	0.5
35	21	20	30	25	10	1	140	0.5	0.5	0.5	0.5
36	10	19	30	37	6	1	150	0.5	0.5	0.5	0.5
37	10	19	30	37	10	2	150	0.5	0.5	0.5	0.5
38	33.5	20	17.5	25	2	2	160	0.5	0.5	0.5	0.5
39	42.5	5	17.5	31	10	3	160	0.5	0.5	0.5	0.5

X_1= Sweet potato Flour, X_2= Corn Flour, X_3= Soy bean flour, X_4= Water, C_1= Salt, C_2= Sodium carbonate, C_3= Guar gum, C_4= Soy Lecithin, Z_1= Mixing time, Z_2= Frying time, Z_3= Frying Temperature.

Statistical analysis of experimental results

Appropriate Scheffe canonical models were fitted to the mean sensory data of each sensory response (texture, taste, appearance, flavour, and overall acceptability). The missing terms in the models were found aliased. The statistical significance of the terms in the Scheffe canonical models were examined by ANOVA for each response, and the adequacy of the models were evaluated by coefficient of determination. r^2, F-value and model p-value at the 0.05 level of significance. The models were subjected to lack-of-fit and adequacy tests and only the model terms that were found to be statistically significant were retained in the final fitted Scheffe canonical models. The fitted models for all the attributes were used to generate three-dimensional response surfaces as well as their contour plots using the DESIGN EXPERT 11.0 statistical software.

Table 2. Mean of sensory scores for the formulated composite instant noodles

Run	Texture	Taste	Appearance	Flavour	Overall acceptability
1	7	6	6	5	6
2	2	3	4	2	1
3	7	7	7	7	7
4	3	2	3	4	1
5	4	5	6	5	4
6	1	1	1	1	1
7	7	7	6	6	5
8	8	7	7	6	6
9	7	7	6	7	6
10	5	5	7	5	5
11	7	6	7	7	7
12	6	7	6	7	6
13	4	5	7	5	5
14	7	7	7	6	6
15	7	8	7	6	7
16	7	7	6	7	6
17	6	5	3	3	2
18	6	5	5	6	4
19	6	5	4	4	4
20	6	6	5	6	6
21	6	6	6	6	6
22	7	7	7	7	7
23	8	6	5	5	5
24	8	8	8	8	8
25	9	8	6	6	7
26	9	9	9	9	9
27	7	7	7	7	7
28	9	8	8	8	8
29	1	1	1	1	1
30	1	1	1	1	1
31	2	2	2	2	2
32	8	8	9	2	7
33	7	7	6	7	7
34	9	9	9	7	9
35	8	8	9	9	8
36	9	8	8	8	8
37	9	8	7	8	8
38	3	3	5	3	1
39	7	8	6	7	7

The model regression coefficients in terms of coded factors for the sensory responses (texture, taste, appearance, flavour, and overall acceptability) are presented in Tables 3 - 7. The summary of the analysis of variance (ANOVA) for the responses are presented in Tables 8 and 9.

The final fitted Scheffe canonical models for the sensory responses (texture, taste, appearance, flavour, and overall acceptability) are presented as Equations 1-5. The 3-D surface mix-process plots and their contour mix-process plots for the sensory responses are presented in Figures 1and 2.

Table 3. Taste model regression coefficients in terms of coded factors

Model Terms	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
x_1	7.17	1	0.8374	5.46	8.88	3.34
x_2	5.90	1	23.40	-41.95	53.75	498.23
x_3	9.22	1	5.48	-1.99	20.42	66.97
x_4	-17.35	1	46.63	-112.72	78.03	950.51
x_{12}	-6.24	1	32.67	-73.07	60.58	140.00
x_{13}	-3.95	1	9.66	-23.71	15.82	16.59
x_{14}	9.24	1	60.36	-114.21	132.68	266.41
x_{23}	-4.93	1	36.33	-79.23	69.36	172.99
x_{24}	0.0243	1	71.58	-146.38	146.43	113.78
x_{34}	6.39	1	61.11	-68.60	181.37	200.71

Taste Model:

$$\begin{aligned} y_{taste} &= 7.16951x_1 + 5.89824x_2 + 9.21853x_3 - 17.3493x_4 - 6.24466x_{12} \\ &- 3.94872x_{13} + 9.23689x_{14} - 4.93225x_{23} + 0.024317x_{24} + 56.3858x_{34} \end{aligned} \quad (1)$$

Texture Model:

$$\begin{aligned} y_{texture} &= 7.02346x_1 + 24.1123x_2 + 13.4045x_3 - 48.999x_4 - 35.9195x_{12} - 14.0816x_{13} \\ &+ 58.2605x_{14} - 0.73912x_1z_1 + 0.748581x_1z_2 + 0.060819x_1z_3 - 59.9743x_{23} - 25.1284x_{24} \\ &+ 3.64647x_2z_1 - 2.47439x_2z_2 - 6.84451x_2z_3 + 77.2376x_{34} - 2.41795x_3z_1 + 0.643297x_3z_2 \\ &+ 1.43859x_3z_3 + 4.68261x_4z_1 - 3.31731x_4z_2 + 6.52836x_4z_3 + 102.507x_{123} + 73.2715_{124} \\ &+ 7.97434x_{134} + 240.121x_{234} + 35.2783x_{123}z_1z_2 - 13.9188x_{123}z_1z_3 + 15.7502x_{123}z_2z_3 \\ &- 0.80361x_{12}z_1z_2z_3 - 4.40357x_{13}z_1z_2z_3 - 3.86346x_{23}z_1z_2z_3 + 58.6539x_{123}z_1z_2z_3 \end{aligned} \quad (2)$$

Table 4. Texture model regression coefficients in terms of coded factors

Model Terms	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
x_1	7.02	1	0.5087	5.78	8.27	5.12
x_2	24.11	1	18.94	-22.22	70.44	1354.83
x_3	13.40	1	5.62	-0.3413	27.15	292.28
x_4	-49.00	1	30.30	-123.15	25.15	1666.35
x_{12}	-35.92	1	26.83	-101.58	29.74	392.08
x_{13}	-14.08	1	10.06	-38.70	10.54	74.68
x_{14}	58.26	1	39.46	-38.30	154.82	472.82
x_1z_1	-0.7391	1	0.3555	-1.61	0.1308	2.40
x_1z_2	0.7486	1	0.4022	-0.2355	1.73	3.08
x_1z_3	0.0608	1	0.4127	-0.9491	1.07	3.24
x_{23}	-59.97	1	38.60	-154.41	34.47	810.78
x_{24}	-25.13	1	108.70	-291.10	240.84	1089.16
x_2z_1	3.65	1	1.06	1.04	6.25	3.87
x_2z_2	-2.47	1	1.41	-5.92	0.9671	6.76
x_2z_3	-6.84	1	1.59	-10.73	-2.96	7.88
x_{34}	77.24	1	51.46	-48.68	203.15	590.84
x_3z_1	-2.42	1	0.6917	-4.11	-0.7253	3.97
x_3z_2	0.6433	1	0.8401	-1.41	2.70	5.85
x_3z_3	1.44	1	0.9279	-0.8319	3.71	6.35
x_4z_1	4.68	1	1.37	1.32	8.042	3.02
x_4z_2	-3.32	1	1.41	-6.7740	0.1395	3.20
x_4z_3	6.53	1	1.78	2.16	10.89	4.43
x_{123}	102.51	1	45.86	-9.70	214.72	41.19
x_{124}	73.27	1	159.06	-315.94	462.48	158.77
x_{134}	7.97	1	51.41	-117.83	133.78	17.37
x_{234}	240.12	1	166.21	-166.57	646.81	368.18
$x_{123}z_1z_2$	35.28	1	8.10	15.45	55.10	1.23
$x_{123}z_1z_3$	-13.92	1	8.20	-33.98	6.15	1.26
$x_{123}z_2z_3$	15.75	1	9.04	-6.36	37.86	1.53
$x_{12}z_1z_2z_3$	-0.8036	1	1.91	-5.49	3.88	1.88
$x_{13}z_1z_2z_3$	-4.40	1	2.20	-9.78	0.9697	3.46
$x_{23}z_1z_2z_3$	-3.86	1	4.19	-14.11	6.39	7.09
$x_{123}z_1z_2z_3$	58.65	1	22.53	3.53	113.78	9.53

Table 5. Flavour model regression coefficients in terms of coded factors

Model Terms	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
x_1	6.49	1	0.7389	4.68	8.30	5.12
x_2	-0.0142	1	27.50	-67.31	67.28	1354.83
x_3	13.99	1	8.16	-5.98	33.95	292.28
x_4	-38.69	1	44.01	-146.39	69.00	1666.35
x_{12}	-2.60	1	38.97	-97.97	92.77	392.08
x_{13}	-12.00	1	14.61	- 47.76	23.76	74.68
x_{14}	44.39	1	57.32	-95.86	184.64	472.82
x_1z_1	0.1227	1	0.5163	-1.14	1.39	2.40
x_1z_2	-0.5906	1	0.5841	-2.02	0.8387	3.08
x_1z_3	0.2438	1	0.5995	-1.22	1.71	3.23
x_{23}	-22.53	1	56.06	-159.70	114.63	810.78
x_{24}	17.61	1	157.87	-368.69	403.92	1089.16
x_2z_1	2.13	1	1.55	- 1.66	5.91	3.87
x_2z_2	-1.13	1	2.04	-6.13	3.86	6.76
x_2z_3	-4.83	1	2.31	-10.47	0.8062	7.88
x_{34}	40.21	1	74.74	-142.67	223.09	590.84
x_3z_1	-1.41	1	1.00	-3.87	1.04	3.97
x_3z_2	0.9366	1	1.22	-2.05	3.92	5.85
x_3z_3	0.2035	1	1.35	-3.09	3.50	6.35
x_4z_1	3.33	1	1.99	-1.55	8.21	3.02
x_4z_2	-4.86	1	2.05	-9.88	0.1625	3.20
x_4z_3	6.88	1	2.59	0.5514	13.23	4.43
x_{123}	70.08	1	66.60	-92.89	233.05	41.19
x_{124}	41.37	1	231.02	-523.92	606.67	158.77
x_{134}	62.68	1	74.67	-120.04	245.40	17.37
x_{234}	215.50	1	241.40	-375.19	806.19	368.18
$x_{123}z_1z_2$	22.06	1	11.77	-6.73	50.86	1.23
$x_{123}z_1z_3$	-16.64	1	11.91	-45.78	12.50	1.26
$x_{123}z_2z_3$	17.85	1	13.12	-14.26	49.97	1.53
$x_{12}z_1z_2z_3$	0.5416	1	2.78	-6.26	7.34	1.88
$x_{13}z_1z_2z_3$	-2.74	1	3.19	-10.54	5.07	3.46
$x_{23}z_1z_2z_3$	-3.24	1	6.08	-18.13	11.64	7.09
$x_{123}z_1z_2z_3$	45.25	1	32.72	-34.82	125.31	9.53

Table 6. Appearance model regression coefficients in terms of coded factors

Model Terms	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
x_1	6.77	1	0.8638	5.00	8.54	3.34
x_2	9.86	1	24.13	-39.50	59.22	498.23
x_3	5.07	1	5.65	-6.49	16.63	66.97
x_4	51.48	1	48.10	-46.91	149.86	950.51
x_{12}	-10.96	1	33.70	-79.89	57.97	140.00
x_{13}	1.50	1	9.97	-18.88	21.89	16.59
x_{14}	-73.29	1	62.26	-200.63	54.05	266.41
x_{23}	2.80	1	37.47	-73.84	79.43	172.99
x_{24}	-110.88	1	73.84	-261.91	40.14	113.78
x_{34}	-26.18	1	63.04	-155.10	102.75	200.71

Table 7. Overall acceptability model regression coefficients in terms of coded factors

Model Terms	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
x_1	6.88	1	1.03	4.78	8.98	3.34
x_2	-1.95	1	28.68	-60.60	56.71	498.23
x_3	12.42	1	6.72	-1.32	26.15	66.97
x_4	25.22	1	57.16	-91.69	142.12	950.51
x_{12}	3.94	1	40.05	-77.97	85.85	140.00
x_{13}	-10.17	1	11.85	-34.40	14.06	16.59
x_{14}	-49.23	1	73.98	-200.55	102.08	266.41
x_{23}	-6.37	1	44.53	-97.44	84.69	172.992
x_{24}	-35.92	1	87.74	-215.38	143.54	113.78
x_{34}	-4.92	1	74.91	-158.13	148.28	200.71

Flavour Model:

$$\begin{aligned} y_{flavour} &= 6.48867x_1 - 0.0141693x_2 + 13.9884x_3 - 38.6938x_4 - 2.60169x_{12} - 12.0013x_{13} \\ &+ 44.3917x_{14} + 0.122667x_1z_1 - 0.59059x_1z_2 + 0.243758x_1z_3 - 22.5319x_{23} + 17.6134x_{24} \\ &+ 2.12578x_2z_1 - 1.13364x_2z_2 - 4.83436x_2z_3 + 40.2138x_{34} - 1.41338x_3z_1 + 0.936572x_3z_2 \\ &+ 0.203473x_3z_3 + 3.33129x_4z_1 - 4.85815x_4z_2 + 6.8899x_4z_3 + 70.0804x_{123} + 41.3743x_{124} \\ &+ 62.6767x_{134} + 215.499x_{234} + 22.0638x_{123}z_1z_2 - 16.6402x_{123}z_1z_3 + 17.8549x_{123}z_2z_3 \\ &+ 0.541558x_{12}z_1z_2z_3 - 2.73658x_{13}z_1z_2z_3 - 3.24329x_{23}z_1z_2z_3 + 45.2462x_{123}z_1z_2z_3 \end{aligned} \quad (3)$$

Appearance Model:

$$y_{appearance} = 6.77129x_1 + 9.86222x_2 + 5.07002x_3 + 51.4756x_4 - 10.9585x_{12} + 1.50439x_{13} - 73.2924x_{14} + 2.79549x_{23} - 110.885x_{24} - 26.175x_{34} \quad (4)$$

Overall Acceptability Model:

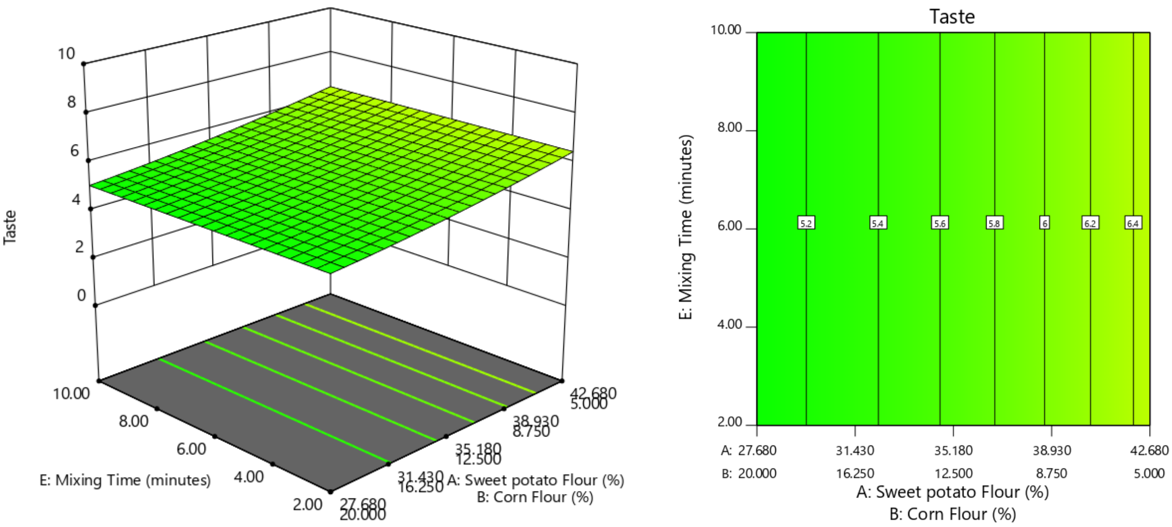
$$y_{acceptability} = 6.8763 - 1.94925 + 12.4167 + 25.2166 + 3.93907 - 10.169 - 49.2342 - 6.37425 - 35.9175 - 4.92447 \quad (5)$$

Table 8. Summary of the analysis of variance for the responses

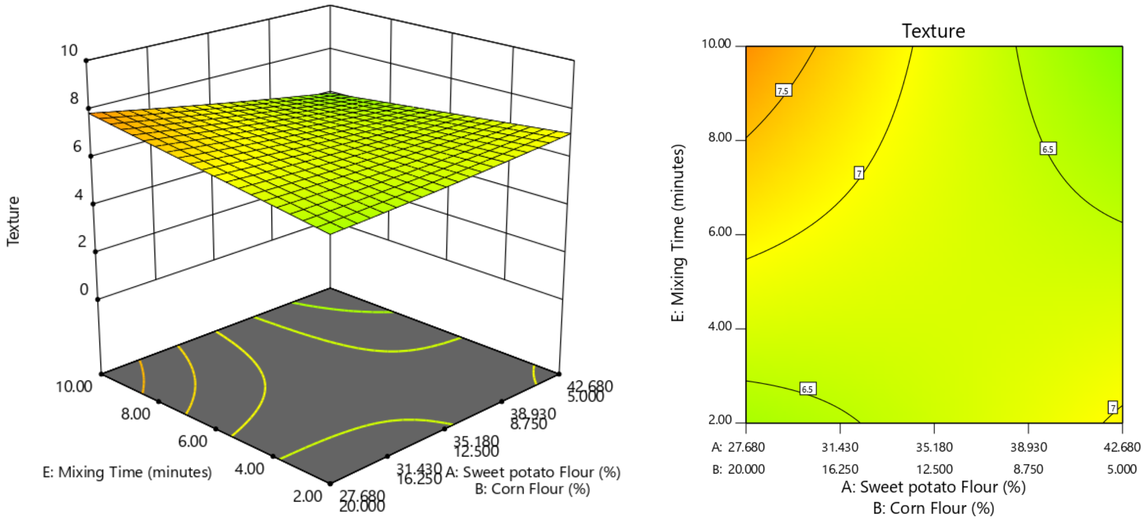
Response	Source	Sum of Square	df	Mean Square	F-value	Prob>F
Taste	Model	131.96	9	14.66	6.75	<0.0001 significant
y_{taste}	Linear Mixture	75.16	3	25.05	11.53	<0.0001
	Residual	63.01	29	2.17		
	Lack of Fit	58.51	28	2.09	0.4644	0.8466
	Pure Error	4.5	1	4.5		
	Cor Total	194.97	38			
	Std. Dev.	1.47	R^2	0.6768	Adeq Precision	10.4325
	Mean	5.97		Adjusted R^2	0.5765	
	C.V. %	24.67		Predicted R^2	0.4313	
Texture	Model	207.63	32	6.49	12.40	0.0023
$y_{testure}$	Linear Mixture	66.24	3	22.08	42.19	0.0002
	Residual	3.14	6	0.5234		
	Lack of Fit	2.64	5	0.5280	1.06	0.6248^*
	Pure Error	0.5	1	0.5		
	Cor Total	210.77	38			
	Std. Dev.	0.7234	R^2	0.9851	Adeq Precision	13.1327
	Mean	6.08		Adjusted R^2	0.9056	
	C.V. %	11.90		Predicted R^2	-5.366	
Flavour	Model	172.04	32	5.38	4.87	0.0274 significant
$y_{flavour}$	Linear Mixture	72.82	3	24.27	21.98	0.0012
	Residual	6.62	6	1.10		
	Lack of Fit	6.12	5	1.22	2.45	0.4490^*
	Pure Error	0.5	1	0.5		
	Cor Total	178.36	38			
	Std. Dev.	1.05	R^2	0.9629	Adeq Precision	8.2192
	Mean	5.67		Adjusted R^2	0.7652	5.67
	C.V. %	18.54		Predicted R^2	-5.9869	18.54

Table 9. Summary of the Analysis of Variance for the Responses (Continues)

Response	Source	Sum of Square	df	Mean Square	F-value	Prob>F
Appearance	Model	111.31	9	12.37	5.35	0.0003 significant
$y_{appearance}$	Linear Mixture	62.59	3	20.86	9.02	0.0015
	Residual	67.05	29	2.31		
	Lack of Fit	59.05	28	2.11	0.2636	0.9384
	Pure Error	8.00	1	8.00		
	Cor Total	178.36	38			
	Std. Dev.	1.52	R^2	0.6241	Adeq Precision	10.4325
	Mean	5.87		Adjusted R^2	0.5074	
	C.V. %	25.90		Predicted R^2	0.3195	
Overall Acceptability	Model	136.76	9	15.20	4.65	significant
$y_{overall\ acceptability}$	Linear Mixture	65.35	3	21.78	6.67	0.0015
	Residual	94.68	29	94.68		
	Lack of Fit	2.64	5	0.5280	1.06	0.6248*
	Pure Error	0.5	1	0.5		
	Cor Total	231.44	38			
	Std. Dev.	1.81	R^2	0.5909	Adeq Precision	8.2926
	Mean	5.41		Adjusted R^2	0.4640	
	C.V. %	33.40		Predicted R^2	0.2878	

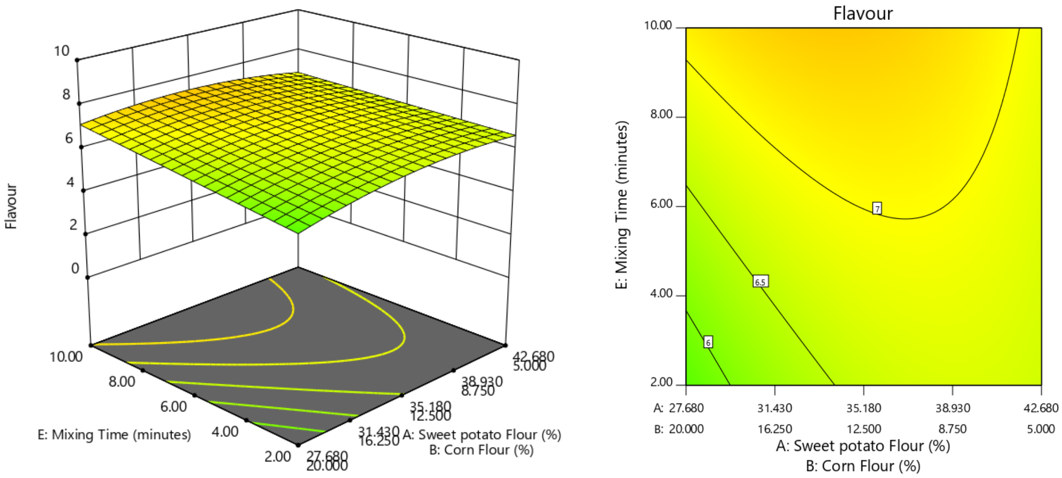


(a) Response surface and contour plots showing the effects on taste

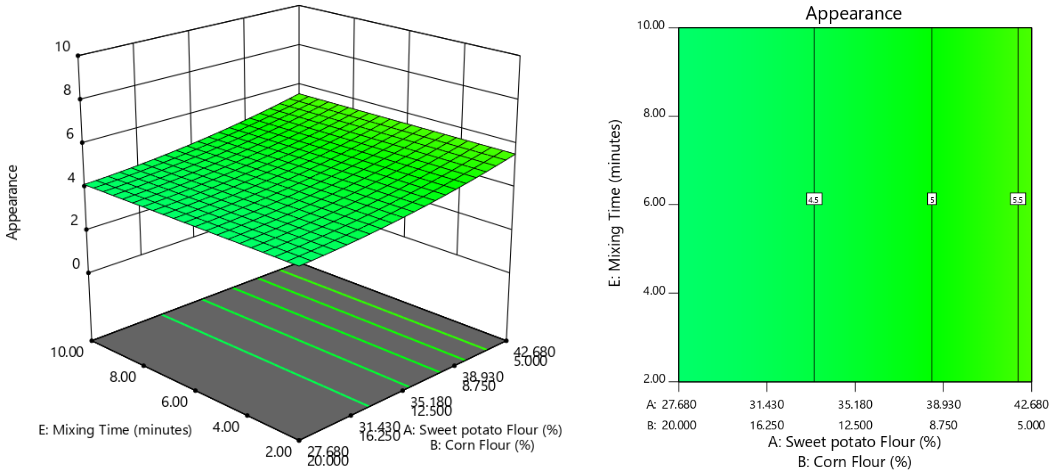


(b) Response surface and contour plots showing the effects on texture

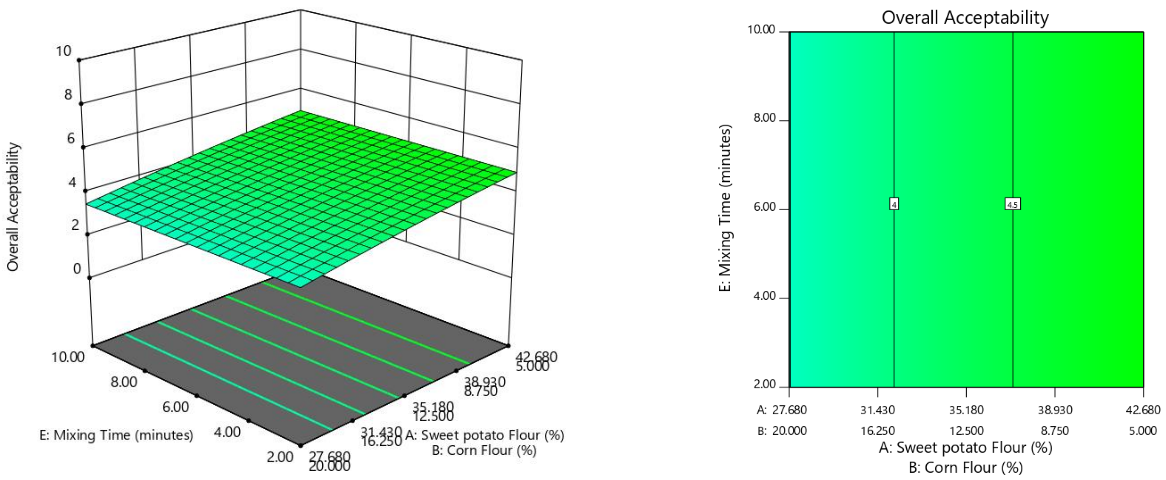
Figure 1. The ten 3-D Surface mix-process graphs and their contour mix-process plots.



(a) Response surface and contour plots showing the effects on flavour



(b) Response surface and contour plots showing the effects on appearance



(c) Response surface and contour plots showing the effects on overall acceptability

Figure 2. The ten 3-D Surface mix-process graphs and their contour mix-process plots.

Results and Discussion

The quadratic x mean taste model, the reduced special cubic x cubic texture model, the reduced special cubic x cubic flavour model, the quadratic x mean appearance model, and the quadratic x mean overall acceptability model were all found to be statistically significant at 5% level of significance ($p<0.05$). The analyses of variances (ANOVA) also show that all the model terms were statistically significant.

Conclusion

In this research, instant noodles from composite blends of sweet potato, corn, soybean flours, and water were developed and optimized using D-optimal mixture-process experimental design. Five sensory attributes (texture, taste, appearance, flavour, and overall acceptability) were evaluated. The fitted models for all the sensory attributes were used to generate three-dimensional response surfaces as well as contour plots using the Design-Expert software.

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LIST OF POSTERS

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