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Aim & Scope

The CMU Journal of Science is a peer-reviewed multidisciplinary journal published annually by Central Mindanao University, Musuan, Maramag, Bukidnon, Philippines. This official scientific journal of the University is accredited by the Philippine Commission on Higher Education (CHED) as category B. It publishes quality research articles, perspectives, review articles, and technical notes of researchers in the fields of natural science, engineering, social science, and mathematics from local, national, and international contributors.

Editorial Policy

CMU Journal of Science

The CMU Journal of Science (CMUJS) is a multidisciplinary peer-reviewed scientific journal published annually by Central Mindanao University, University Town, Musuan, Bukidnon, Philippines.

All submitted manuscripts are reviewed and evaluated by the Editorial Board to determine whether these manuscripts are publishable or not. To be accepted, articles must satisfy all of the following criteria.

1. The manuscript has not been published by any journal;
2. The manuscript is recommended for publication by a minimum of two peer-reviewers;
3. The manuscript has passed the plagiarism detection test with a score of at least 85% for originality not more than 15% similarity index); and,
4. The manuscript has passed the grammar checker software.

The CMUJS adopts a double-blind peer-review process before the papers are published to ensure the quality of the publication and to avoid plagiarism.

The Editor-in-Chief, upon consultation with the Editorial Board, assigns a manuscript to at least two reviewers.

A letter of request, together with the abstract and the Response Form, is sent to the reviewers who have the expertise on the topic. If they agree to review

the manuscript, the full paper will be sent to them.

After the review process, each reviewer will return the reviewed manuscript and the Assessment Form indicating his/her recommendation. A manuscript recommended for deferment of publication will be considered if the comments by reviewers are complied. Otherwise, it will be rejected.

Manuscript that passed the review process will then be subjected to plagiarism and grammar tests before the final decision is made. The final manuscript to be published in the following issue of the journal will be presented to the Editorial Board for approval. The Editor-in-Chief then notifies the corresponding author if his/her manuscript is accepted or rejected.

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The manuscript should be written in good English (American or British usage is accepted, but not a mixture of these). A soft copy of the paper must be submitted in one file only. This would be emailed to journalofscience@cmu.edu.ph. Paper size is A4 (8.25 x 11.69), with an inch margin on all sides. Font style is Times New Roman, Font size is 12. The paper should be double-spaced; with about 4,000-6,000 words in single column format, inclusive of tables and figures. Manuscripts should be encoded in Microsoft Word (at least Word 2007) and Excel (for graphs and tables). Articles encoded using other softwares (Corel, LaTeX, Photoshop, etc.) may be accepted after consultation with the publication staff. Photos, maps, graphs, charts, and other illustrations shall be labeled as Figures, tables and matrices, as Tables. These should be appropriately numbered and labeled based on their order or presentation. Figure titles shall be written below the figure whereas, table titles shall be on top of the table matrix.

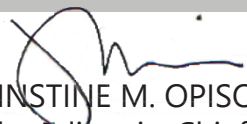
Introduction To The Issue

CMU Journal of Science on its 23rd Volume continues to publish quality research outputs in the field of natural and social sciences from local, national, and international contributors. This year, on behalf of CMU Journal of Science Publication and Editorial Board, it is my profound pleasure to introduce Natural Sciences Issue (2) of 2019. I want to take this opportunity to express my sincere gratitude to the authors, section editors, publication board members, invited peer reviewers from various academe, and administrators who contributed their time and expertise for the success of CMUJS Natural Science publication.

The articles presented in this second issue of Volume 23 focuses on Natural Science with a perspective article about Food Security amid the COVID-19 pandemic. Specifically, it covers topics on Physico-Chemical Properties of the Fish Pond Water in CMU, Bukidnon, Philippines; Fish Abundance and Physico-chemical Properties of Matingao River and Marbel River, Mount Apo Natural Park, Mindanao, Philippines; Growth and Profitability of Broilers with Vermimeal on Ration Under Two Management; Saluyot (*Corchorus olitorius* L.) Leaves as Acoustic Gel for Ultrasound Imaging; Computational Modeling and Simulation of Linear Accelerator Performance for General Radiotherapy and; Eggshells as Alternative Shielding Material Against Diagnostic X-rays.

CMU Journal of Science aims to annually publish quality research outputs across all disciplines regardless of its perceived impact. We hope these peer-reviewed articles will provide notable development and practical usefulness to every researcher and readers.

CMUJS will continue to help researchers, teachers, students, and other individuals through the dissemination and publication of scholarly articles. We are looking forward and more than grateful for receiving research articles and respond to the needs of the contributors.



EINSTINE M. OPISO
The Editor-in-Chief



Food Security amid the COVID-19 Pandemic: Research and Development Priorities for Higher Education Institutions in the Philippines and Southeast Asia

Glenn B. Gregorio^{1,2,3} and Rico C. Ancog^{1,4}

¹Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), Laguna, Philippines

²Institute of Crop Science, College of Agriculture and Food Science, University of the Philippines Los Baños, Philippines

³National Academy of Science and Technology (NAST) Philippines

⁴School of Environmental Science and Management, University of the Philippines Los Baños, Philippines

Food security has long been a major development priority of all countries and will remain to be in the future. This has become all the more important in this time of COVID19 pandemic. It is achieved when there is the availability of and adequate access to sufficient, safe, and nutritious food at all times for individuals to maintain a healthy and active life. The United Nations has identified four pillars of food security: food availability, food access, food utilization, and food stability. Through the years, all our efforts are expected to contribute to the pillars of food security, and a country's ability to consolidate its resources towards defining and achieving their aspired food security targets across relevant scales has become a major hallmark of development success.

Just as conceptual definitions of what food security is may vary from culture to culture, so do the mechanisms and the strategies to achieve it. What is easy to understand however is the opposite of being food secure---people and communities being hungry and malnourished, or a situation of severe climatic events resulting in significant production and income losses, or a situation of market and government failures resulting in production constraints as well as volatile political institutions affecting access. Surely, food security is a complex development goal requiring equally far more complex solutions to define and achieve.

Where we are in our food security targets has been brought to the fore by our recent experience with CoViD-19 pandemic. The pandemic has created supply and demand shocks resulting in 3.11 percent or 17.03 million tons reduction in the aggregate volume of agriculture production in Southeast Asia due to decline in agricultural farm labor affecting 100.77 million individuals (Gregorio and Ancog, 2020). This crisis was estimated to translate to a 1.4 percent decrease in the GDP of the Southeast Asian region equivalent to USD 3.76 billion thereby limiting the region's capacity to achieve its Sustainable Development Goals (SDGs). Achieving food security has been a continuing challenge, and it remains an elusive goal in many areas in the Philippines and Southeast Asia. Clearly, the on-set of COVID-19 pandemic reminded us once again that food security is simply not just a ratio between supply and demand of food. Timing matters-- food must always be available to all. And, the universal standard of living is already clear: being hungry and malnourished is unacceptable, with or without pandemic.

Agriculture has long been our ally, but much more must be done for us to maximize what it can offer to achieve food security targets. On the production side, we need to produce more with less---more in terms of yield, income and social inclusivity; and less in terms of unnecessary inputs, energy consumption, and environmental impacts. On the supply side, we need massive behavioral adjustments in terms of responsible consumption both at the individual and collective levels. With CoViD-19, we are compelled to see connections between the supply chains and our consumption patterns, and the urgent need to redefine agricultural systems as food systems. A systemic view on the agricultural food systems is a prerequisite for the needed transformation.

The needed transformative change in the agricultural food systems would stem right at the hallowed halls of the universities and colleges. Through the years, the higher education institutions (HEIs) have been in a strategic position to pursue projects and initiatives related to food security. Even prior to COVID-19 pandemic, the research agenda of the HEIs must clearly be towards public good generation especially in food security. In fact, the agility of the HEIs in designing their curricular and extension programs to produce professionals who can actively engage in achieving food security goals has been very instrumental. This important role of the HEIs have been once again made more evident by COVID-19 crisis, as we need more individuals who imbibe the transformative mindset and are adept in understanding the growing complex social concerns and in affecting actions both in the present and even more in the future.

Considering the COVID-19 pandemic, the following overarching questions are for the HEIs as an organization and the researchers/faculty members as individual to reflect upon:

1. What are the major priority areas for research in agriculture and allied fields to accelerate transformation towards sustainable agricultural food systems?

Corresponding author:

Glenn B. Gregorio

Email Address: Gbgregorio@up.edu.ph

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- How can the human capital of the HEIs, particularly through its research and academic initiatives, be strategically wielded so it can be fully maximized towards contributing to the solving of pressing societal concern, particularly COVID-19?
- As research funding and other resources will be limited, what innovative solutions could be put forward for HEIs to continue to enhance its capability in knowledge generation?

Priority areas for research in agriculture and allied fields to accelerate transformation towards sustainable agriculture food systems

For most of the countries in Southeast Asia, agriculture remains a major engine of economic development. Hence, agricultural universities and colleges are expected to pursue academic and research programs that must accelerate the science and art of agriculture towards economic development. The architecture of agricultural research themes and modalities have been in place, but its reorientation as seen from business perspective is crucial to afford systemic change of the agriculture sector.

Figure 1 shows the proposed key priority areas for research in agriculture and allied fields to accelerate transformation of the agriculture sector and strengthen its contribution to socio-economic development particularly towards resilience against pandemic.

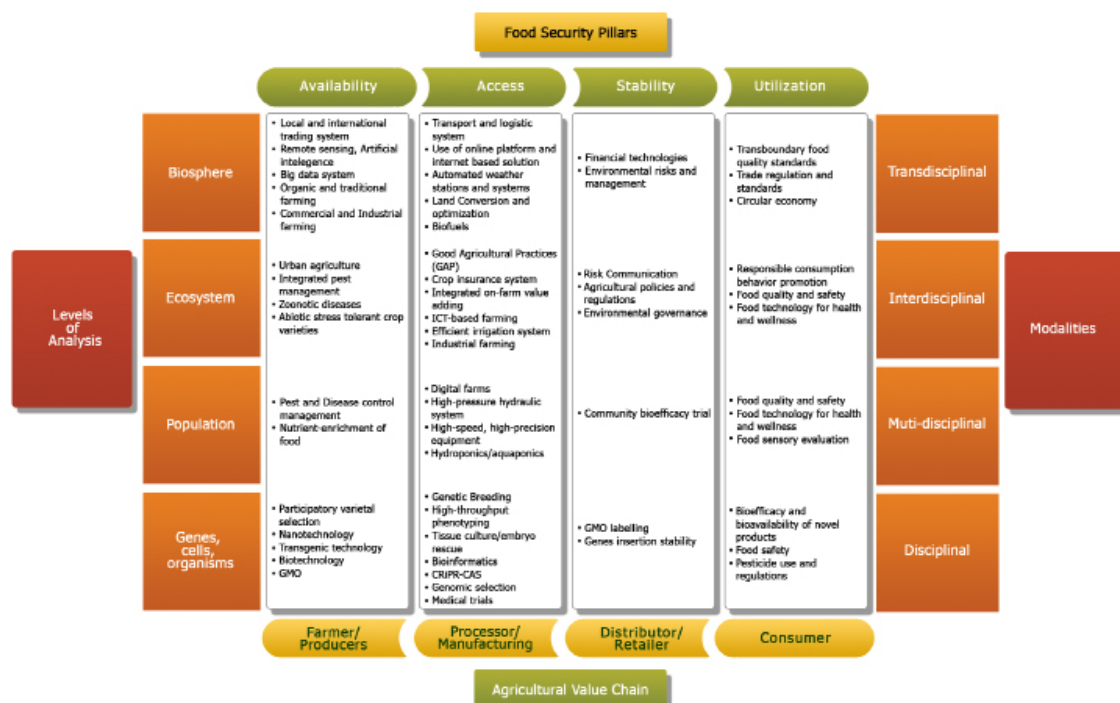


Figure 1. Examples of Proposed Key Priority Areas for Research in Agriculture and Allied Fields for HEIs in the Philippines and Southeast Asia

Maximizing the human capital of the Higher Education Institutions (HEIs) in areas of research and extension initiatives

The HEIs enjoy high concentration of knowledge capital that must be handy and put to good use. For years,

the individual researcher has been trained to pursue specific research questions and conduct research work that yield on specific answers. While this is important, a re-orientation towards strengthening multi- and interdisciplinary studies must be given more emphasis. Equally critical is the ability of an individual researcher to place its specific research efforts in the context of the larger societal problems. Also, there is a need for more researchers who are not just good in doing basic science but also navigating the development dimension of his or her work. A country like the Philippines needs an adequate cadre of researchers who appreciate the need to shorten the gap between research productivity and its translation to economic development.

The following are the major priorities towards this front:

- Providing the enabling environment for faculty members and researchers to be encouraged in mutual-learning and co-learning through the establishment of multi-and interdisciplinary research laboratories, centers, and institutes.
- Incentivize scientific productivity that do not favor just publication articles generation but also other Ps namely, People, Partnerships, Patents, Product, and Profit.
- Retooling faculty members and researchers to be more conversant and engaged in applications for intellectual property rights, patents, technology transfer system, technology-based incubation, and entrepreneurship.

- Provision of more faculty and researchers grants and extension awards that enable them to engage with the industry, private companies, community beneficiaries, and other stakeholders across the agricultural supply chain.

5. Clear rearticulating in terms of its direct and indirect value in response to a country's COVID-19 response efforts for on-going projects already under implementation even prior to COVID-19.
6. Creative crafting of research proposals related to COVID-19 by faculty members and researchers.

Innovations in the Fiscal and Research Implementation

Any government's allocation of its financial resources on HEIs is a good investment but whether it has been fully maximized for public value creating is another matter. As CoViD-19 pushed governments to revisit its fiscal allocation, universities and colleges would benefit from exploring complementary alternative sources of income that are likewise instrumental to its academic and extension activities. The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) in its 11th Five Year Plan (2020-2025) has touted for more universities and colleges actively engaging in Academe-Industry-Government (AIG) interconnectivity models as a framework for research collaboration and financial resources co-sharing, while ensuring a shortened gap between research and utilization. This modality would also ensure the proper contextualization of research projects to the larger value chains.

The following are the suggested major initiatives that the universities and colleges could pursue under the AIG interconnectivity model:

1. Strengthened collaboration for research priority identification and implementation embarked through design thinking approach,
2. Resource sharing both in terms of human and financial capital to facilitate strengthened linkage between basic and applied researches with the industry needs,
3. Designing and implementing digital agriculture infrastructure and open-systems innovation systems across the agricultural supply chains,
4. Knowledge generation co-sharing through joint publications, patenting, and technology transfer systems, and business incubation,
5. Support for publications of research products including new crop varieties and livestock breeds,
6. Encouraging and supporting researchers to be innovative whenever possible in their research implementation and data generation, and must always be directed towards public value contribution,
7. Continued encouragement to and support for faculty members and researchers in active journal publication. One support that can be maximized by young researchers in the Philippines is the scientific journal training provided by the National Academy of Science and Technology (NAST) Philippines. It must be emphasized that a research work is not

complete unless results are published (Publication), as well as Patents and income (Profits). At the individual level, researchers need to be reminded that there is no such thing as a good writer, but only a good rewriter. Scientists ability to tell the individual stories learned from their researches are invaluable for the general public to appreciate the value of science-based decision making, and

8. For universities and research organizations managing scientific journals, investment towards real-time online publications or advanced online publication is a must to be relevant in this time where researchers need to publish their research results as early as possible and make it readily accessible to all.

Overall, higher education institutions in the Philippines and Southeast Asia are expected to up the ante in knowledge generation and scientific productivity. However, the need to ensure that research efforts would have significant societal impacts is a philosophy that must be widely upheld. With our experience with CoViD-19, a revisiting of the priority areas for research in agriculture and allied fields is necessary and must be done given the urgent need of transforming agricultural systems to sustainable food systems. Challenges in terms of research funding due to CoViD-19 is already imminent but innovations in fiscal and research implementation abound. At the current scenario, various modalities of Academe-Industry-Government interconnectivity models need to be explored so it can be customized to their specific needs. Higher education institutions are key players in the society's overall ability to achieve the aspired food security and economic development. But HEIs can do aspire to contribute beyond---toward an economic development that is sustainable, inclusive, environment-friendly, and most importantly resilient to current and future pandemics.

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Physico-Chemical Properties of the Fish Pond Water in CMU, Bukidnon, Philippines

Gloria Jesusa D. Baltazar

Department of Chemistry, College of Arts and Sciences, Central Mindanao University
Musuan, Maramag, Bukidnon, 8710 Philippines

ABSTRACT

Good water quality is a key component of sustainable aquaculture production. The present study reports the water physico-chemical properties of selected fish ponds in Central Mindanao University, Bukidnon, Philippines. The values of the parameters ranged from pH 8.36-8.64, 26.73-27.61 °C temperature, 203-211 $\mu\text{S}/\text{cm}$ electrical conductivity, 98-128 NTU turbidity, 13.04-13.78 mg/L dissolved oxygen, 0.095-0.104 g/L total dissolved solids, 73.2-81.9 mg CaCO_3/L total alkalinity, 91.0-101.9 mg CaCO_3/L total hardness, 11.18-27.86 mg/L sulfate, 0.44-1.08 mg/L chloride, 24.61-50.52 mg/L phosphate, <0.001 mg/L cadmium, <0.01 mg/L lead, and <0.001 mg/L mercury. These findings conformed to the water quality guidelines for aquaculture production except for turbidity and phosphate content. Chloride concentrations were also remarkably low. It is recommended to conduct regular monitoring of the physico-chemical parameters of the pond water, and undertake corrective measures to reduce turbidity and phosphate to an acceptable level and increase the chloride to a level specifically suitable for catfish production.

Keywords: fish pond, physico-chemical parameters, CMU

INTRODUCTION

The global aquaculture industry has grown in the past decades, with food fish supply increasing at an average annual rate of 3.2 % (Food and Agriculture Organization of the United Nations [FAO], 2014). According to Subasinghe (2015), fish production would double by 2030 to meet the world's growing demand and needs. The aquafarming in the Philippines includes catfish and tilapia production. Statistics show that from 2011 to 2015, there was a volume production increase of 16.2 % for catfish, from 3,100 to 3,600 MT, and 1.48 % for tilapia, from 257,400 to 261,200 MT (Philippine Statistics Authority, 2016). The promising productivity of catfish and tilapia farming has prompted Central Mindanao University (CMU), an agricultural university in Bukidnon, Philippines, to venture into aquaculture. In less than a year of active operation, the tilapia-catfish project has proven to be a potential big income earner.

An indispensable consideration for optimum and sustainable production of catfish and tilapia is good water quality. In recent years, however, inland waters have been altered ecologically partly due to anthropogenic activities. The continued degradation of water resources resulting from chemical contaminations of water bodies poses a threat to freshwater aquaculture (Patil et al., 2012; Njoku et al., 2015). Poor water quality can result in poor fish quality, low profit, and potential human health risks (South Africa Department of Water Affairs and Forestry [DWAF], 1996).

The CMU tilapia-catfish fishpond area is located along the National Highway and adjacent to the PhilRice and University rice fields. The water sources of the fishpond are the National Irrigation Administration Canal and the Kibalagon Creek, which channel agricultural runoffs and wastewater discharge from nearby households and market stalls. These environs, as well as water supply, pose

potential sources of contamination of the pond water. Thus, this study was conducted to determine and assess the physico-chemical properties of the fish pond water in Central Mindanao University, Bukidnon, Philippines.

METHODOLOGY

Duration and Location of the Study

The study was conducted from February to June 2017. Sampling was done at the tilapia-catfish fish pond of Central Mindanao University, Bukidnon, Philippines, with geographical coordinates of 7°50'57.8" North latitude and 125°02'54.8" East longitude. In the study, only the three big fish ponds with areas ranging from ~1,800-2,500 square meters and water depth of one meter were selected as sampling sites. Specifically, Pond 1 is adjacent to the University rice fields with the aqua-duckery facility on one side of the pond (*Figure 1*). Pond 2 is along the national highway (*Figure 2*). Pond 3 is near the PhilRice at CMU facility and its rice fields, and with the aqua-duckery facility on one side of the pond (*Figure 3*).

Collection of Samples

Water samples from the three selected fish ponds were collected on the morning of March 14, 2017. Sampling was done in a zigzag manner giving five subsites: the center and the four corners (2 meters away from the edge of the pond). In each subsite, a water sample was collected approximately 0.5 m below the pond water surface. The water samples were stored in an ice-cold styrofoam container.

Corresponding author:

Gloria Jesusa D. Baltazar

Email Address: gebaltaza@yahoo.com

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Figure 1. Pond 1 has its one side adjacent to the rice fields and has an aqua-duckery facility



Figure 3. Pond 3 is adjacent to the PhilRice at CMU facility and its rice fields



Figure 2. Pond 2 is along the national highway

Physico-chemical Analysis

Table 1 shows the list of methods used to analyze the water samples from the different ponds for physico-chemical characteristics. The pH, temperature, electrical conductivity, turbidity, dissolved oxygen, and total dissolved solids were determined *in situ*. Analysis of the other parameters was done at the Chemistry Laboratory, CMU for alkalinity and hardness, at the Soil and Plant Analysis Laboratory (SPAL), CMU for phosphates, and at

the F.A.S.T. Laboratories at Cagayan de Oro City for sulfates and chlorides. Water samples for metal determination were digested according to the APHA-AWWA 3030E method using nitric acid (American Public Health Association [APHA], 1998). The digested water samples and reagent blank were submitted for analysis to the F.A.S.T. Laboratories, an ISO/IEC 17025:2005 accredited testing laboratory for physico-chemical analysis of water samples.

Table 1

Methods of Water Analysis

Parameter	Method of Analysis
pH	Horiba U-52G kit
Temperature, °C	Horiba U-52G kit
Turbidity, NTU	Horiba U-52G kit
Total dissolved solids, g/L	Horiba U-52G kit
Electrical conductivity, $\mu\text{S}/\text{cm}$	Horiba U-52G kit
Dissolved oxygen, mg/L	Horiba U-52G kit
Alkalinity, mg CaCO_3/L	Titration with sulfuric acid using phenolphthalein (phenolphthalein alkalinity) and methyl orange (total alkalinity) indicators
Total Hardness, mg CaCO_3/L	EDTA titrating using Eriochrome Black T indicator
Chloride, mg/L	Argentometric titration using potassium chromate indicator
Sulfate, mg/L	Turbidimetry
Phosphate, mg/L	Colorimetry
Metals (Cd and Pb), mg/L	Flame Atomic Absorption Spectrometry
Mercury, mg/L	Cold Vapor Atomic Absorption Spectrometry

Statistical Analysis

The data were subjected to one-way analysis of variance. Significant differences among means were evaluated using Tukey's Test at 5 % probability level.

RESULTS AND DISCUSSION

Good water quality is an indispensable feature of a viable aquaculture operation. Poor water quality can result in low productivity and potential human health risk. Table 2 and 3 summarize the results of the physico-chemical analysis of the water samples from the selected fish ponds of Central Mindanao University, Bukidnon, Philippines. Except for dissolved oxygen and heavy metals (Cd, Pb, and Hg), significant differences ($p < 0.05$) in the water physico-chemical parameters were observed among the fish ponds studied. The discrepancies in the results might be due to the differences in the collection time, the existence of the aqua-duckery facility, and the environs of the ponds. Nonetheless, the results of the physico-chemical analysis of the water samples from the fish ponds studied were relatively similar to conformance to the water quality guidelines for aquaculture production.

pH

The pH of water refers to its hydrogen ion (H^+) activity. It serves as an index of the intensity of the acidic or basic character of water. In the study, the pH values of the pond water were found to vary from 8.36 to 8.64. These values indicate slight alkalinity of the pond water which can be attributed to the presence of bicarbonates. It has been known that pH is interdependent with other water quality parameters, such as alkalinity and hardness. For most freshwater species, the desirable pH range is between 6.5 and 9.0 (DWAF, 1996; Stone et al., 2013; Department of Environment and Natural Resources [DENR], 2016). The present results are within this required range for fish production and similar to those reported by Njoku et al. (2015) and Sayeswara et al. (2010). In contrast, Sandoval

et al. (2017) have reported relatively higher pH values ranging from 8.70 to 9.57 for fishpond water in Pampanga, Philippines.

Temperature

Temperature is one of the most crucial physical variables for the aquatic ecosystem as it affects the metabolism, physiology and reproduction of fish as well as the physico-chemical parameters of water (Snyder, 2018). In the study, the temperature of the pond water ranged from 26.73 to 27.61°C. The temperature readings of the pond water samples are within the optimum water temperature range of 25-31°C (DENR, 2016) for the growth and reproduction of freshwater fish. The present results are relatively lower than those reported by Sandoval et al. (2017).

Electrical conductivity

Electrical conductivity is an index of mineralization and salinity as it estimates the total ionic content of water. The electrical conductivity values of the pond water ranged between 203 and 211 $\mu S/cm$. The acceptable limit for electrical conductivity in pond water fishery is 60-2,000 $\mu S/cm$ (Stone et al., 2013). Thus, the parameter condition is favorable for aquaculture production.

Turbidity

Turbidity is the reduction of transparency due to the presence of suspended or dissolved particles in water that scatter light making the water appear cloudy or murky (Minnesota Pollution Control Agency [MPCA], 2008). The turbidity of the pond water samples ranged from 98 to 128 NTU. The present findings exceed the maximum permissible turbidity of 25 NTU (MPCA, 2008) and 80 NTU (Queensland Department of Environment and Heritage Protection, 2009) for water fishery. High turbidity can be attributed to particulate matters including suspended soil particles, planktonic organisms, fish wastes, uneaten fish

Table 2

Mean pH, temperature, electrical conductivity, turbidity, dissolved oxygen, total dissolved solids, total alkalinity, and total and calcium hardness of the fish pond water of Central Mindanao University, Bukidnon, Philippines compared with regulatory standards

Parameter	Pond			Regulatory Standard
	1	2	3	
pH	8.36 $\pm$ 0.21 ^b	8.63 $\pm$ 0.18 ^a	8.64 $\pm$ 0.08 ^a	6.5-9.0 ^{1,2,3}
Temperature, °C	27.30 $\pm$ 0.08 ^b	27.61 $\pm$ 0.16 ^a	26.73 $\pm$ 0.09 ^c	25-31 ¹
Electrical Conductivity, $\mu S/cm$	209 $\pm$ 11 ^{a,b}	211 $\pm$ 4 ^a	203 $\pm$ 7 ^b	60-2,000 ³
Turbidity, NTU	128 $\pm$ 48 ^a	116 $\pm$ 17 ^{a,b}	98 $\pm$ 22 ^b	$\leq$ 25 ⁴
Dissolved Oxygen, mg/L	13.17 $\pm$ 0.84 ^a	13.04 $\pm$ 0.78 ^a	13.78 $\pm$ 1.03 ^a	$\geq$ 5.0 ^{1,5}
Total Dissolved Solids, g/L	0.104 $\pm$ 0.00 ^a	0.095 $\pm$ 0.00 ^b	0.104 $\pm$ 0.00 ^a	< 16
Total alkalinity, mg CaCO ₃ /L	81.9 $\pm$ 5.2 ^a	73.2 $\pm$ 8.7 ^b	78.2 $\pm$ 4.5 ^{a,b}	50-150 ³
Total hardness, mg CaCO ₃ /L	91.0 $\pm$ 6.9 ^b	94.0 $\pm$ 9.5 ^{a,b}	101.9 $\pm$ 10.4 ^a	50-150 ³

Values are means $\pm$ standard deviation for fifteen replicates.

^{a,b,c} Means with the same letter superscript within a row are not significantly different at 0.05 level of significance using Tukey's Test.

¹DENR (2016); ²DWAF (1996); ³ Stone et al. (2013); ⁴MPCA (2013); ⁵ANZECC & ARMCA (2000); ⁶Scannell & Jacob (2001)

feeds, and other humic substances produced through the decomposition of organic matter (Baotong et al., 1983; Swann, 1997; MPCA, 2008). Furthermore, mechanical activities associated with the bottom feeding fish, such as the catfish, stir up the bottom mud (Swann, 1997). Although catfish prefers turbid waters, excessive turbidity can irritate fish and precipitate disease (Buttner, 1993). High turbidity can affect the feeding ability, growth, and reproduction of fish (Bash & Berman, 2001). According to Bhatnagar and Devi (2013), muddy water is not good for fish culture because soil particles clog gills, which can result in death. Moreover, high turbidity lowers the water dissolved oxygen level by restricting light penetration resulting in the reduction of photosynthetic activity and absorbing heat from sunlight, thus, increasing the water temperature (PHILMINAQ, 2008).

Dissolved oxygen

The level of dissolved oxygen (DO) in water is commonly used as an indicator of water quality. Maintaining adequate concentrations of DO is vitally important for supporting fish, invertebrates, and other aquatic life. In the study, the dissolved oxygen level of the pond water ranged from 13.04 to 13.78 mg/L. The results conform to the water quality guideline of > 5.0 mg/L dissolved oxygen for fish production (Australian and New Zealand Environment and Conservation Council [ANZECC] & Agriculture and Resource Management Council of Australia [ARMCA], 2000; Ekubo & Abowei, 2011; Department of Environment and Natural Resources [DENR], 2016). The present findings are relatively higher than those reported for fish pond water in Pampanga, Philippines, with DO ranging from 5.20-7.57 mg/L (Sandoval et al., 2017). According to Wellborn (1988), less than 4 mg/L dissolved oxygen in water retards the growth of catfish, and one mg/L oxygen concentration is fatal. At zero salinity, one mmHg atmospheric pressure, and 26.73-27.61 °C, the saturation level of dissolved oxygen in water is around 8 mg/L (Maine Volunteer Lake Monitoring Program, 2014). In the tropical fish pond supplied with high nutrients and with the temperature around 30°C or above, the oxygen concentration would go high, having a daily maximum in the oxygen of 2-3 times

the saturation level owing to the high oxygen production by the phytoplankton (FAO, n.d.).

Total Dissolved Solids

Total Dissolved Solids (TDS) include the mineral and dissolved organic matter. The TDS in the pond water samples ranged from 0.095 to 0.104 g/L, which is below the maximum allowable level of < 1 g/L TDS in water (Scannell & Jacobs, 2001). These findings suggest that the pond water is suitable for aquaculture farming concerning to total dissolved solids.

Alkalinity

Alkalinity is a chemical measurement of the buffering capacity of water or its ability to neutralize acids, thus, protecting the aquatic organisms from major fluctuations in pH (Swann, 1997). In the study, all the pond water samples recorded zero phenolphthalein alkalinity, while the total alkalinity ranged from 73.2 to 81.9 mg CaCO₃/L. These findings indicate a bicarbonate type of alkalinity (India Central Pollution Control Board [ICPCB], 2011), which supports the slightly basic character of the pond water samples having pH values of 8.36-8.64. It has been known that bicarbonates represent the major form of alkalinity in natural water. Bicarbonate alkalinity occurs as a result of the uptake of CO₂ and the weathering of carbonate minerals in rocks and soil (White, 2011). The present results fall within the water quality criterion for good pond productivity and protection of aquatic species (DWAF, 1996; Swan, 1997; ANZECC & ARMCA, 2000; Santhosh & Singh, 2007; Stone et al., 2013).

Hardness

Hardness is a measure of alkaline earth elements such as calcium and magnesium in pond water. The total hardness of the pond water samples ranged from 91.0-101.9 mg CaCO₃/L, indicative of moderately hard water (ICPCB, 2011). The results conform to the water quality standards for fish culture (DWAF, 1996; ANZECC & ARMCA, 2000; Santhosh & Singh, 2007; Stone et al., 2013). In the study, the obtained total hardness is greater than the total

Table 3

Mean sulfate, chlorides, phosphate, cadmium, lead, and mercury of the fish pond water of Central Mindanao University, Bukidnon, Philippines compared with the Philippine Department of Environment and Natural Resources (DENR, 2016) water quality guidelines for fishery freshwater Class C

Parameter	Pond			DENR Standard
	1	2	3	
Sulfate, mg/L	14.62±1.18 _b	27.86±5.23 _a	11.18±2.83 _b	< 275
Chloride, mg/L	1.08±0.24 _a	0.44±0.14 _b	0.52±0.11 _b	< 350
Phosphate, mg/L	27.53±2.34 _b	50.52±2.60 _a	24.61±1.62 _b	< 0.5
Cadmium, mg/L	<0.001	<0.001	<0.001	<0.005
Lead, mg/L	<0.01	<0.01	<0.01	<0.05
Mercury, mg/L	<0.001	<0.001	<0.001	<0.002

Values are means±standard deviation for five replicates.

a,b,c Means with the same letter superscript within a row are not significantly different at 0.05 level of significance using Tukey's Test.

alkalinity; both expressed as CaCO₃. Accordingly, the water hardness is both carbonate (temporary) and non-carbonate (permanent) in nature (ICPCB, 2011). The amount of hardness equivalent to alkalinity constitutes the carbonate hardness, while the amount of hardness over total alkalinity gives the non-carbonate hardness. The present findings suggest that the pond water hardness is mainly temporary in nature and caused by the bicarbonates. Contributory to non-carbonate hardness might be the association of the hardness-causing cation with sulfate, chloride, or nitrate (ICPCB, 2011).

Sulfate

Sulfate is a naturally occurring anion in freshwater. The concentrations of sulfate in the pond water ranged from 11.18 to 27.86 mg/L. These findings are below the maximum permissible limit of 275 mg/L for sulfate in aquaculture (DENR, 2016). Thus, the parameter condition is suitable for fish production.

Chloride

Chloride is a common component of most waters and is beneficial to fish in maintaining their osmotic balance (Stone et al., 2013). The chloride concentrations in the pond water ranged from 0.44 to 1.08 mg/L. Although the present results are below the maximum permissible chloride level of 350 mg/L for freshwater fish culture (DENR, 2016), the remarkably low chloride content is worth noting as it poses a concern, especially for catfish production. According to Stone et al. (2013), the desirable minimum level of chloride for commercial catfish ponds is 100 mg/L because these species are susceptible to "brown blood" disease. Chloride concentrations can easily be increased by adding "mixing" salt to the water.

Phosphate

Inorganic phosphorus is soluble in water and readily utilized by aquatic primary producers. The phosphorus in water usually occurs in the form of phosphate (Stone et al., 2013). The phosphate in the pond water samples ranged from 24.61 to 50.52 mg/L. These values exceed the maximum permissible limit of 0.5 mg/L for freshwater aquaculture (DENR, 2016), although ANZECC and ARMCA (2000) has imposed a stricter water quality guideline of <0.1 mg/L phosphate for the protection of aquaculture species. It is worth noting that the main water sources of the ponds are the Kibalagon Creek and the irrigation canal. Phosphate might have been introduced into the pond through agricultural runoffs carrying phosphorus from fertilizers and insecticides, commercial and domestic waste and sewage from the use of detergents, as well as the fish feeds and duck manure droppings (Baotong et al., 1983; Stone et al., 2013; Njoku et al., 2015). According to MPCA (2008), phosphorus from various sources can cause algae growth resulting in increased turbidities. Excessive phytoplankton turbidity can lead to depletion of dissolved oxygen levels due to increased rates of respiration during the night (Swann, 1997).

Heavy Metals

The heavy metals such as cadmium, lead and

mercury in all the pond water samples were non-detectable, i.e., below the method detection limit of 0.001 mg/L for cadmium, 0.01 mg/L for lead, and 0.001 mg/L for mercury. The results conform to the quality standard of <0.005 mg/L cadmium, <0.05 mg/L lead, and <0.002 mg/L mercury for fishery freshwater (DENR, 2016).

CONCLUSIONS

The present study provides valuable data on the physico-chemical properties of the fish pond water of Central Mindanao University, Bukidnon, Philippines. Parameters such as pH, temperature, electrical conductivity, dissolved oxygen, total dissolved solids, total alkalinity, total hardness, sulfate, chloride, cadmium, lead, and mercury were within the acceptable levels to sustain aquaculture production. However, turbidity and phosphate content of the pond water exceeded quality guidelines for aquaculture production. Although the chloride concentration did not exceed the maximum permissible chloride level for freshwater fish culture but the remarkably low chloride content is a concern, especially for catfish production. Except for dissolved oxygen, cadmium, lead, and mercury, there are significant differences in the physico-chemical properties among the fish ponds studied.

RECOMMENDATIONS

It is recommended to undertake corrective measures to reduce turbidity and phosphate to acceptable levels and increase the chloride content specifically suitable for catfish production. In this way, a healthy aquatic ecosystem, humans, and the environment can be guaranteed. Moreover, it is recommended to conduct regular monthly monitoring of the physico-chemical parameters for a period of one year (EMB-DENR, 2008) to account for seasonal differences and among other sources of variations.

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Fish Abundance and Physico-chemical Properties of Matingao River and Marbel River, Mount Apo Natural Park, Mindanao, Philippines

Victoria T. Quimpang¹, Maricris G. Cudal¹, Einstine M. Opiso^{1,3}, Romeo M. Tubongbanua, Jr.¹, Mary Cor S. Salolog¹, Emmanuel P. Leaño^{1,2}, and Victor B. Amoroso^{1,2}

¹Center for Biodiversity Research and Extension in Mindanao, Central Mindanao University, Musuan, Bukidnon, 8710 Philippines

²Department of Biology, College of Arts and Sciences, Central Mindanao University, Musuan, Bukidnon, 8710 Philippines

³Department of Civil Engineering, College of Engineering, Central Mindanao University, Musuan, Bukidnon, 8710 Philippines

ABSTRACT

Mount Apo Natural Park (MANP) is an important forest reserve in most part of Region XI and XII because of its watershed importance. However, the MANP may also be threatened by habitat modification that may alter most of its water resource. Thus, this study was conducted to assess the abundance of freshwater fish and analyze the physico-chemical properties like water temperature, pH, turbidity, dissolved oxygen (DO), total dissolved solids (TDS), electric conductivity (EC), oxidation-reduction potential (ORP) of the two major rivers of MANP. A total of six freshwater fishes consisting of four native and two introduced species were collected and identified in the two sampling stations. The native *Barbodes binotatus* (Valenciennes 1842) was found to be the most abundant in all the years the survey was conducted. The data on physico-chemical properties showed fluctuations in all year (2012-13 and 2015). High turbidity rate in Marbel River and high water temperature recorded in upper station of Matingao River could have influenced the collection and abundance of freshwater fishes. Shannon diversity index in Marbel River and Matingao River are very low with values of 0.69 (2012-2013); 0.68 (2015) and 0.70 (2012-2013); 0.70 (2015) for the two rivers, respectively. This could be attributed to anthropogenic activities, characteristics and physico-chemical properties of the river.

Keywords: freshwater fish, introduced, native, turbidity, water quality

INTRODUCTION

Mount Apo Natural Park (MANP) is the highest mountain peak in the Philippines with an elevation of approximately 3,143 meters above sea level (masl). It is located at the southern part of Mindanao and declared as a natural park by virtue of Presidential Proclamation No. 882 last September 26, 1997, with a base cover of about 71,796 hectares which extends to two regions of Mindanao: Region XI (Davao City, Bansalan, Digos, and Sta. Cruz, Davao del Sur) and Region XII (Makilala, Magpet and Kidapawan, North Cotabato). The Mount Apo Natural Park is one of the Long-Term Ecological Research (LTER) sites in Mindanao and known to be the remaining frontiers in the Philippines which serves as the habitat of 629 species of flora, 227 species of fauna, 118 species of odonata and 272 species of avifauna (UNESCO, 2009). Due to its richness in biodiversity, it became a protected area through Republic Act 9237 in 2003.

The MANP has 19 major rivers and 21 creeks that drain its eight major watersheds. This includes the Kabacan-Pulangi River and the Marbel-Matingao River which were reported to have direct input flow to the geothermal plant located within the MANP (PASALIST, 1992). Meanwhile, the Marbel-Matingao River is found to be directly draining to the Kabacan River. Additionally, these river ecosystems provide less economic and commercial value due to its low biological productivity and species diversity as reported by

SEA-BMB, consultants for the Mount Apo Geothermal Project Environment Impact Assessment in 1991.

The river may play a function in the dispersal of discharge from the industrial, municipal and agricultural land run-offs to the surrounding areas within the watershed (Sigua & Tweedley, 2003). Significantly, the MANP benefited the irrigation facilities, industries, commercial, household and water utilities that operate in the administrative areas of Kidapawan City, Bansalan, Digos and Davao City (DENR-PAWCZMS, 2013). However, habitat modification, through water quality detriment and changes in flow regime may alter most of a river's water resource (López-López & Sedeño-Díaz, 2015). This makes freshwater ecosystems the most endangered and threatened ecosystem worldwide (Dudgeon et al., 2006). The water quality of a river, is, therefore, characterized by a high level of changes in time and space due to cover-land characterization (Al-Badai et al., 2013). Anthropogenic pollutants could be related to land use that may result in drastic deterioration of aquatic systems in watersheds (Massoud et al., 2006).

The utilization of resources in Mt. Apo through

Corresponding author:

Maricris G. Cudal

Email Address: mcrisGcudal@gmail.com

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various types of anthropogenic activities within and surrounding its riverine system is one major source of ecological stressors; thus, the need to conduct inventory and monitoring studies is very crucial.

Monitoring on water quality provides basis as to how and for what water can be used and the support it gives to the aquatic organisms and its ecosystem (Perez-Martinico et al., 2016). Thus, the focus of this study is to monitor the water quality and assess the freshwater fish composition and diversity of the Marbel River and the Matingao River of the Mount Apo Natural Park.

MATERIALS AND METHODS

Duration and area of the study

The study was carried out last October 2012, February, May and October 2013 and January, April and September 2015 in the Marbel River and Matingao River (Figure 1). The study sites are among the 19 major rivers of Mount Apo Natural Park (MANP) and tributaries of the Kabacan River. These rivers were reported to be physically draining to the Mount Apo Geothermal Project within the MANP. The two rivers are characterized by narrow channels and clear waters at highly elevated areas, with rapid water flows and rock boulder-rich river banks and beds. The Marbel River and the Matingao River are strategically located at the foot of the Mount Apo Natural Park in the province of North Cotabato with elevations of 1,476 and 1,355 masl, respectively.

The Matingao River has coordinates of 125°13'22.89" E to 125°11'21.46" E; 07°1'9.03" N to 07°1'55.69" N. The upstream of Matingao River begins in the geothermal project site situated in MANP, whereas, the midstream portion is being partly used in the small-scale industrial work such as hollow block making. The midstream area of Matingao River is a residential with proximity of approximately 10 households with no toilet. Additionally, the hot water from the Lake Agco also directly flows in the upstream portion of the Matingao River.

The Marbel River with coordinates of 125°13'28.54" E to 125°14'45.19" E; 07°1'29.47" N to 07°0'11.39" N- is

narrower and rapid than the Matingao River. This river is being used primarily for river bank trekking of mountaineers mounting to the peak of Mount Apo.

Site selection and sampling scheme

Marbel River and Matingao River were divided into four sampling stations designated as: **S1**, upstream; **S2**, upper midstream; **S3**, lower midstream; and, **S4**, downstream. The location and elevation of the sampling stations were determined using a Global Positioning System (GPS) device. Surrounding land uses were also noted during survey.

Data Analysis

The Shannon-Weiner Diversity Index (H') was used to analyze the diversity index of collected fish species. Species richness and abundance of the fish were also determined in this study.

Fish collection and identification

The collection of fish was done along the 3 sampling stations within the river gradient using a low voltage (10V) improvised backpack electrofishing gear accompanied with gill net with approximately 1.2mm x 1.2mm mesh size employed in the down part of the river's gradient. The electric fishing method was intentionally used to catch specific fish species of interest where seine netting is not applicable (Paller et al., 2011).

The stunned fish caught by this method were immediately put in a bucket, documented and initially identified in the field. Description of the live fish was done by noting their color, number of fins, and barbels if present, shape of the tail and head, body structure and mouth. Voucher specimens for each species were preserved in a 10% formalin solution, and other stunned fish were returned to the water after their recovery from the current shock. Samples were identified and assessed in their current systematic status using the FishBase website (Froese & Pauly, 2018). Consultation with experts was also done for the verification of species.

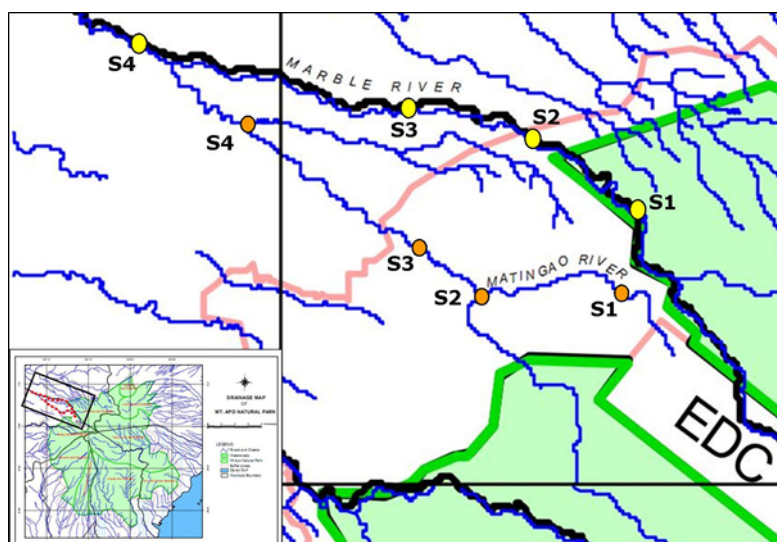


Figure 1. Modified study area and sampling stations map along the Marbel River and Matingao River, Mount Apo Natural Park.

Physico-chemical analysis

Parameters like water temperature, pH, oxidation reduction potential (ORP), electrical conductivity (EC), turbidity, dissolved oxygen (DO) and total dissolved solids (TDS) were measured in-situ using HORIBA U-52G multiparameter probe during wet and dry season. In every sampling stations of the river, nine (9) sampling points were randomly selected close to the right and left river banks and in the middle of the river with triplicates.

RESULTS AND DISCUSSION

Physico-chemical analysis

Table 1 shows the summary of the mean average values of physico-chemical parameters of Marbel River and Matingao River. Water temperatures in both river sites were high in year 2012-2013 (*Figure 2*). Minimal fluctuations for the pH (7.98-8.15) in Marbel River and Matingao River (8.39-7.66) for year 2012-2013 and 2015, respectively were observed. Whereas, a very low values of EC and TDS were noted in the two rivers in all year. The DO level varies between 9.3 (2012-2013) and 9.17 (2015) in Marbel River and 9.1 (2012-2013) and 8.94 (2015) in Matingao River. The water turbidity in Matingao River has low value of about 18.21 NTU in the year 2012-2013 and increases to 46.49 NTU in year 2015.

The study showed a fluctuation trend of physico-chemical parameters from 2012-2013 to 2015 across the two rivers of MANP (*Figure 2*) which may be due to elevation gradient and surrounding land use. The mean water temperature of both rivers was low which ranges between 18.9°C and 22.08°C. This is closely comparable to Layawan River (21.2°C-22.5°C) in Misamis Occidental (Cuivillas et al., 2016). A high temperature (22°C- 22.7°C) was observed in Station 1 and Station 2 in Matingao River which may be attributed to its proximity in the geothermal site of MANP and the sulfuric Lake Agco.

During the years of monitoring, a decrease trend of electric conductivity, total dissolved solids and turbidity in both rivers were observed (*Figure 2*). The high temperature of water recorded (22.7°C) in station 2 of Matingao River may be attributed to the total dissolved solid with value of 0.34 mg/L. Martinez et al. (2011) reported that increase in suspended and dissolved solids can increase

the temperature primarily because they absorb heat from sunlight. The high rate of TDS of about 0.74 was recorded in the midstream station of Matingao River in the year 2015 which may be linked to the on-going road construction near the sampling site.

High turbidity rate (142 NTU) was observed in year 2012-2013 in upstream (S1) in Marbel River which gradually decreased in year 2015 (30.7 NTU). The high turbidity indicates the presence of colloidal particles arising from clay and silt during rainfall or from discharges of sewage and industrial waste or the presence of a large number of microorganisms (Olatayo, 2013). Hence, the geothermal plant in the upstream station may contribute to the turbidity in the Marbel River.

A decreasing trend of DO level from the upstream to downstream gradient of Marbel River in year 2012-2013 was evident (*Figure 2*). Inverse relationship was observed that when the concentration of DO decreases, water temperature increases. This corroborates the report of George *et al.* (2003) which states that higher temperatures reveal low DO concentrations. The highest DO level was recorded in year 2012-13 is 20.1mg/L and 19.2mg/L in Matingao River and Matingao River, respectively. It was observed that there was an increasing trend of pH value (7-8.8) from downstream to upstream gradient of the Matingao River in the year 2012-2013.

The water conductivity of the two rivers was high in S2 with the similar value of 0.54 in all years. The oxidation reduction potential (ORP) which is an essential indicator of natural and wastewater (Goncharuk et al., 2010) and classifies condition of a river has values ranging from 76 mV to 344.6 mV observed in all years. George et al. (2013) reported the inverse relationship of temperature and ORP, as the temperature increases, the ORP value decreases.

In the case of Matingao River in year 2012-2013, low ORP value (76 mV) was observed in S2 with high water temperature recorded at 22.66°C. However, it was noted in Marbel River in all years that station with high water temperature (21.97°C-21.76°C) has the high recorded rate of ORP value (154.9 mV-286.29 mV).

In general, Marbel River and Matingao River are naturally slightly alkaline with high pH values noted in Station 2 (8.84) and Station 4 (8.3) in Matingao River.

Table 1

Mean Parameter Values of Marbel River and Matingao River (2012-2013 and 2015)

Parameter	2012-2013		2015	
	Marbel River	Matingao River	Marbel River	Matingao River
Temp (C)	20.83	22.09	19.83	20.95
pH	7.98	8.39	8.15	7.66
ORP	141.69	82.91	269.38	312.02
EC (mS/cm)	0.39	0.26	0.45	0.19
Turbidity	50.73	18.21	53.56	46.49
DO (mg/L)	9.3	9.1	9.17	8.94
TDS (mg/L)	0.25	0.16	0.35	0.26

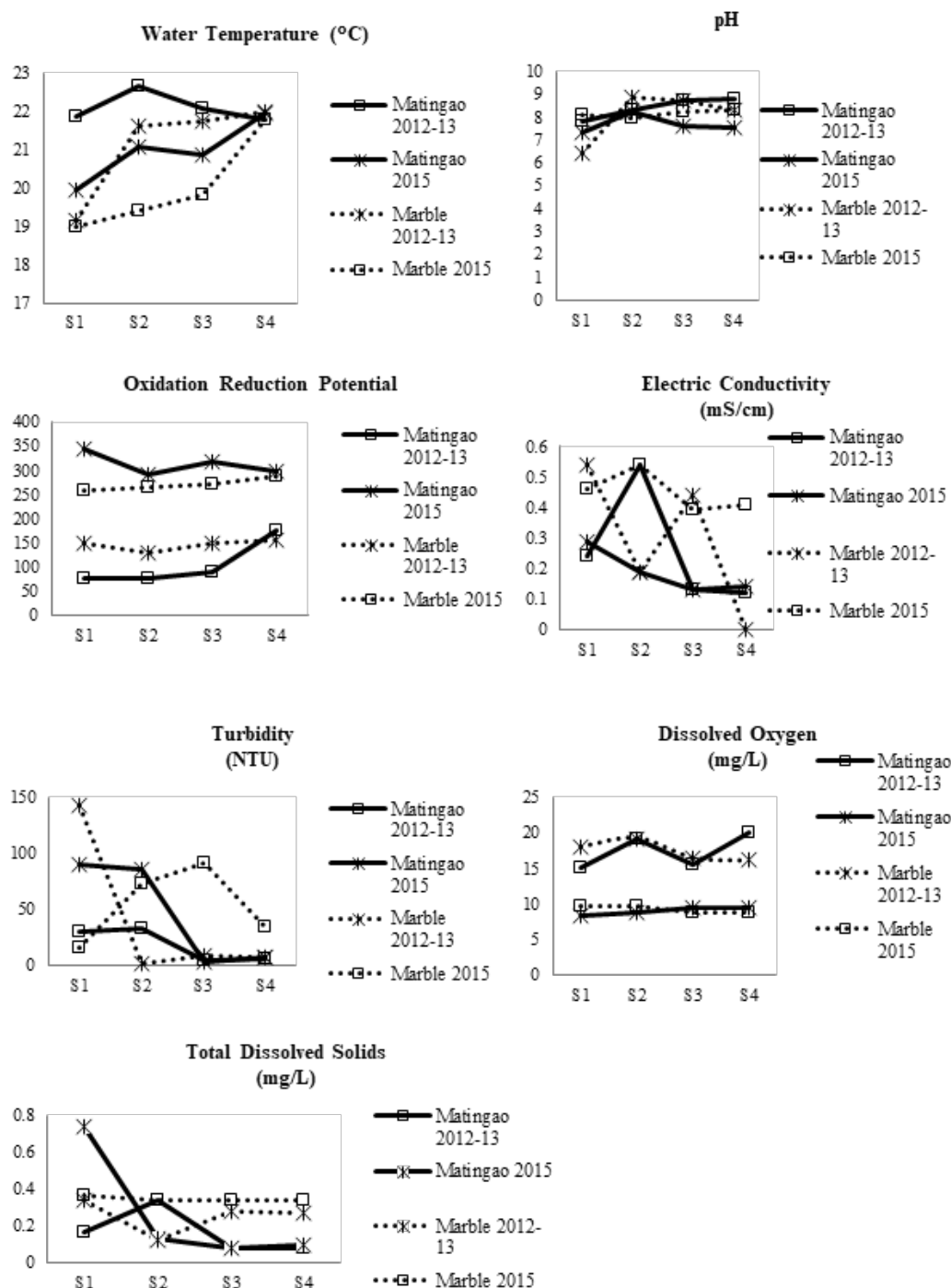


Figure 2. Distribution Mean Values of Physico-chemical Properties of Marbel River and Matingao River from 2012-2013 to 2015

High pH noted in Marbel River in year 2012-2013 was in Station 2 (8.84) and Station 4 (8.3) in year the monitoring year (2015). In the case of Matingao River, high pH was observed in Station 4 (8.8) in 2012-13 and Station 2 (8.2) in 2015. Whereas, low pH (6.39) was recorded in year 2012-2013 in Station 1 of Marbel River.

Reading of pH and other parameters that were done after rainfall could be the possible reason for the low reading of pH in Station 1. This corroborates the statement of Davie (2008), that rainfall naturally lowers the pH between ranges of 5 to 6. The pH finding in this study was closely comparable to the findings of Cuivillas et al. (2016) in Layawan River, Misamis Occidental that ranges between 7.62 and 8.30. As cited by Cuivillas et al. (2016), the water's pH in a river is primarily affected by its age and

the chemicals discharged by communities and industries. In the case of Matingao River, high pH noted in Station 2 and 4 could be attributed to its proximity to residential houses where frequent bathing, and laundry were observed. Theoretically, pure water has pH of 7.0 (ASCC, 2003), such water with a little high pH refers to increase concentration of bicarbonates (Lutz and Francois, 2007).

Fish species diversity and composition

Table 2 shows comparative data for abundance of freshwater fishes collected in Marbel River and Matingao River for the year 2012-2013 and 2015. A total of six species (Figure 3) belonging to four families were collected in the Marbel River and the Matingao River. The native *Barbodes binotatus* (Valenciennes 1842) was found to be the most

abundant species in all years with values of 22.7% (2012-2013) and 13.40% (2015) in Marbel River and 16.9% (2012-2013) and 19.1% (2015) in Matingao River. Two species of introduced species belonging to family Poeciliidae were also recorded in the two rivers, namely: *Xiphophorus hellerii* Heckel 1848, and *Poecilia reticulata* Peters 1859.

Shannon diversity index was found to be low in both study areas with values of 0.69 (2012-2013) and 0.68 (2015) for Marbel River and 0.70 in Matingao River, respectively in all years (Table 3). This shows that there were no variations of fish collected in all years among the two river sites.

During this study, no additional species have been collected in the monitoring year (2015). The most collected fish species is the native *B. binotatus* which is commonly found in most riverine ecosystem of Mindanao (Ismail, 2011) as cited by Cudal et al. (2019). Further, the native *Rhinogobius* sp. and *S. lagocephalus* of the family Gobiidae were collected during the whole period of the study. In terms of species individual counts per station, it was found out that the maximum numbers were recorded from low altitude areas particularly in midstream and downstream. This supports the study of Shaikh et al. (2011), which freshwater fish diversity in low and middle land areas was found to be higher.

CONCLUSIONS

The Marbel River and Matingao River supports low diversity of fish fauna comprising of four native (*B. binotatus*,

Rhinogobius sp., *S. lagocephalus* and *A. marmorata*) and two introduced species (*X. hellerii*, and *P. reticulata*). The fishes of the Marbel River and Matingao River were mostly dominated by the native *B. binotatus*. Hence, the presence of introduced freshwater fishes indicates the disturbed state of the area. Further, the high turbidity rate was recorded in the Marbel River may be attributed to the presence of geothermal plant in the upstream portion of the river.

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Table 2

Freshwater Fish Species Recorded in Marbel River and Matingao River (2012-2013 and 2015)

Species	Year	Marbel River				Matingao River			
		Relative Abundance (%)				Relative Abundance (%)			
		S1	S2	S3	S4	S1	S2	S3	S4
Cyprinidae									
<i>Barbodes binotatus</i> *	2012-2013	17.10	25.50	6.20	22.70	10.5	8.2	12.3	16.9
	2015	14.95	13.76	16.25	13.40	8.5	7.7	7.8	19.1
Gobiidae									
<i>Rhinogobius</i> sp.*	2012-2013	10.1	8.8	11.0	13.1	10.8	8.5	12.0	7.6
	2015	9.8	8.0	14.4	7.2	11.9	8.1	7.9	6.7
<i>Sicyopterus lagocephalus</i> *	2012-2013	9.4	7.4	11.2	10.2	11.9	7.8	7.6	7.5
	2015	7.8	7.4	8.9	5.4	9.2	9.0	13.3	6.9
Poeciliidae									
<i>Poecilia reticulata</i> **	2012-2013	8.0	7.0	8.2	7.2	5.0	9.4	13.2	10.2
	2015	5.5	6.0	7.1	5.7	8.9	11.6	8.3	10.1
<i>Xiphophorus hellerii</i> **	2012-2013	10.0	8.4	8.9	10.0	11.4	9.0	9.1	6.8
	2015	6.9	7.8	7.6	4.6	10.7	11.5	8.2	7.9
Anguillidae									
<i>Anguilla marmorata</i> *	2012-13	1 ^a	-	1 ^a	3 ^a	-	-	1 ^a	2 ^a
	2015	1 ^a	-	-	-	-	1 ^a	2 ^a	1 ^a

Note: ^a individual count only

* native species

** introduced species

Table 3

Diversity Index of Marbel and Matingao River (2012-2013 and 2015)

Diversity Indices	2012-2013		2015	
	Marbel River	Matingao River	Marbel River	Matingao River
Shannon-Weiner (H')	0.69	0.70	0.68	0.70
Species Richness	6	6	6	6



Figure 3. Freshwater fish collected in Marbel River and Matingao River, MANP. (A) *Barbodes binotatus* (Valenciennes 1842); (B) *Anguilla marmorata* Quoy and Gaimard 1824; (C) *Sicyopterus lagocephalus* (Pallas 1770); (D) *Rhinogobius* sp.; (E) male and female *Xiphophorus hellerii* Heckel 1848; (F) *Poecilia reticulata* Peters 1859.

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Growth and Profitability of Broilers with Vermimeal on Ration Under Two Management

Marcos Bollido

Agriculture Department and other Related Programs, Northwest Samar State University
Gomez Ext, Calbayog City, Samar, Philippines

ABSTRACT

The study was conducted to evaluate the growth and profitability of broilers in the different levels of vermi (*Eisenia fetida*) meal ration under two management systems. 120 day old chicks were tested in Randomized Complete Block Design with 4 treatments: commercial feeds, 2% vermi meal (vm)+local ingredients(li), 3% vm+li, 5% vm+li in three replications. Result revealed that total confinement (TC) had higher body weight (bw) and weight gain (wg) with a difference of 35.60 grams and 36.90 grams respectively compared to that of free-range (FR) that had lesser feed consumption (fc) with a difference of 81.10 grams and high in net income and ROI. Infeed ration, fc increased when given a higher percentage of vm, and it was significantly different from the commercial feeds (cf). In 3 different levels of vm, though they did not have a significant difference to each other, the 2% level of vm was comparable to cf and showed a difference in terms of bw 296.70 grams in TC; 326.00 grams in FR. In wg 296.67 grams in TC and 370.97 grams in FR in both management systems. Consequently, 2% level vm had an optimum result in final body weight, wg, and high in feed conversion.

Keywords: vermi, free- range, total confinement, profitability

INTRODUCTION

Broiler chickens (*Gallus gallus domesticus*), or broilers, are gallinaceous domesticated fowls, bred and raised specifically for meat production. They are a hybrid of the egg-laying chickens, both being subspecies of the red jungle fowls (*Gallus gallus*). Typical broilers have white feathers and yellowish skin.

Broiler production is one of the most progressive enterprises in the Philippines today. The poultry industry began as a backyard enterprise but has shifted to the formation of large integrated contract farming operations. (Kruchten, 2002).

The industry is mostly dependent on protein feedstuffs which are imported at a high cost. However, backyard raisers, farmers resort to feeding their broilers with commercial feeds but not appropriate to the ages of their birds due to limited capital to purchase the feeds needed. (Ravindran & Blair, 1993).

Broiler production is raised in confinement due to its inherent characteristics of being very susceptible to the harsh environment. They tend to be adapted if they are gradually exposed to the prevailing conditions, feeding, and other management systems.

The trend of today is to produce broiler with little alteration of their usual habitat such as from confining the broilers to a free-range system. This is done to minimize the housing cost usually incurred in production. Another way is to alter the feeding management by using indigenous but nutritious feed ingredients rather than feeding them with costly commercial feeds, (Ravindran & Blair, 1993). The

nutritional value of vermi meal was emphasized on the study of (Istiqomah, L. et al., 2016) that the composition of vermi meal was: Moisture 9.03, Crude Protein 63.06, Ether Extract 18.5, Crude Fiber 0.19, Nitrogen Free Extract 12.41, Organic Matter 94.16 and Ash 5.81. Bahadori et al. (2014) used of 2%, 3%, 4%, and 6% vermi meal on broilers showed that heart weight was not affected in none of the vermi meal percentages while the breast weight was only affected by 2% and 3% of the treatments.

Studies of raising broilers partly in the free-range system and feeding them with indigenous materials such as vermi meals are considered highly nutritious. Vermo utilization is very limited in Samar province, and even in the Philippines as a whole; hence, this study is proposed.

Generally, this study aimed to determine the growth performance and profitability of broilers raised under two management systems with vermi meal in their diet. Specifically, this study aimed to: identify the growth performance of broilers with vermi meal supplementation in their diet raised under free- range and in total confinement system in terms of: body weight, weight gain, feed consumption, feed conversion ratio (FCR), water consumption, and dressing percentage; calculate the production, profitability and the return of investment of broilers raised under two management systems and with vermi meal; measure the level of vermi meal incorporation in the feed for broiler growth and profitability performances; and compare the interaction

Corresponding author:

Marcos Bollido

Email Address: markbollido@yahoo.com

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of the levels of vermi meals in the diet of the broilers with the two management systems of raising.

Time and Place of the Study

The study was conducted at the Northwest Samar State University- San Jorge Campus, barangay Erenas, San Jorge, Samar, from March 2018 to April 2018.

METHODOLOGY

Housing of the Experimental Birds

Brooding cages both for free-range and total confinement were separately made. Growing cages for confinement and areas for a free-range group of broilers were prepared following the caging and space density requirements. Required brooding and rearing management were employed for the protection and safety of the experimental birds. Free-Range requires 2.4 sq. meter per bird, five birds per treatment requires 12 sq. meter area (2mx6m cage), a total of 144 sq. meter for 60 birds. Total Confinement requires 1.0 sq. foot per bird, five birds per treatment needs five sq. feet area (2 ft. x 2.5 ft. cage), a total of 60 sq. feet for 60 birds.

Preparation of the Experimental Diets

An agrivet supplier produced commercial feeds. Chick booster contains 22% CP, chick starter with 16% CP, and broiler finisher with 14% CP. The formulated feeds were composed of ground yellow corn, rice bran (D1), Soybean meal, copra meal, and vermi meal. The diets were formulated based on the broiler nutritional requirements propose. The experimental broilers were fed 50 grams per bird per day with chick booster in 14 days and 75 grams

with chick starter in 14 days and 110 grams with broiler finisher also in 7 days. Birds received feeds and water in ad libitum throughout the experimental period. The 120 heads broilers and the different experimental feeds were weighed to determine the growth performance and profitability with vermi meal supplementation in their diet raised under free range and in total confinement system in terms of body weight, feed consumption, Feed Conversion Ratio (FCR), water consumption, dressing percentage. The researcher determined the minimum level of vermi meal for broiler growth performance, the profitability of broilers in the minimum level of vermi meal, and compared the minimum level of vermi meal for broiler growth performance and profitability. Then, the researcher also determined the production, profitability, and the Return on Investment (ROI) of broilers based on current market price.

Experimental Birds, Design, and Treatments

A total of 120 broiler chicks were used and randomly divided into two groups of management systems and four feeding treatments. The study involved eight (8) treatment combinations in a 2x4 factorial experiment and distributed using Randomized Complete Block Design (RCBD). At the brooding stage, the chicks were distributed to two study areas corresponding to two (2) management systems; the total confinement and free-range systems. Each management system has 60 chicks distributed to four (4) treatments and three (3) replications. Thus, each treatment replicates allotted five (5) heads of broiler chicks.

Factor A: Management System

A1- Total confinement (TC)

A2- Free range (FR)

Table 1

The Composition of Experimental Diets with a Different Level of Vermi Meal (VM) as Feed during the Brooding and Growing Stage (kg)

Feed Ingredients	Chick Booster			Chick Starter			Broiler Finisher		
	2% VM	3% VM	5% VM	2% VM	3% VM	5% VM	2% VM	3% VM	5% VM
Rice bran D1	21.14	21.14	21.14	33.14	33.14	33.14	35.34	35.34	35.34
Ground yellow corn	42.28	42.28	42.28	46.39	46.39	46.39	49.47	49.47	49.47
Copra meal	10.03	9.50	8.23	4.12	3.37	3.28	2.47	3.02	1.22
Soybean meal	19.20	18.73	18.00	9.00	8.75	6.84	5.37	3.82	3.62
Vermi meal	2.00	3.00	5.00	2.00	3.00	5.00	2.00	3.00	5.00
Molasses	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Oil	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL-Methionine	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Vitamin Premix	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Dicaphos	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Lysine	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Total	100	100	100	100	100	100	100	100	100

Factor B: Levels of Vermi Meal in the Diet

B₀- Commercial feeds (control)

B₁= 2% vermi meal & 98% other ingredients

B₂= 3% vermi meal & 97% other ingredients

B₃= 5% vermi meal & 95% other ingredients

Treatment Combinations

A₁B₀= TC fed with commercial feeds

A₁B₁= TC fed with 2% vermin meal & 98% other ingredients

A₁B₂= TC fed with 3% vermi meal & 97% other ingredients

A₁B₃= TC fed with 5% vermi meal & 95% other ingredients

A₂B₀= FR fed with commercial feed

A₂B₁= FR fed with 2% vermi meal & 98% other ingredients

A₂B₂=FR fed with 3% vermi meal & 97% other ingredients

A₂B₃=FR fed with 5% vermi meal & 95% other ingredients

The Layout for the Total Confinement System

A ₁ B ₁	A ₁ B ₀	A ₁ B ₂	A ₁ B ₁	A ₁ B ₃	A ₁ B ₀
A ₁ B ₂	A ₁ B ₃	A ₁ B ₀	A ₁ B ₃	A ₁ B ₁	A ₁ B ₂

The Layout for the Free-range System

A ₂ B ₁	A ₂ B ₀	A ₂ B ₂	A ₂ B ₁	A ₂ B ₃	A ₂ B ₀
A ₂ B ₂	A ₂ B ₃	A ₂ B ₀	A ₂ B ₃	A ₂ B ₁	A ₂ B ₂

Feeding Management Practices

Feed Diets

The formulated chick booster mash, chick starter mash, and broiler finisher mash were fed to the experimental broilers in the different growing stages. In the first two weeks, the birds were fed with formulated chick booster mash (21.70% CP). Then in the next two weeks the birds were fed with starter mash (15.90% CP), in the last one week, they were fed with broiler finisher mash (14.10% CP). The control birds were fed with commercial ration until the end of the study.

Feeding System and Schemes

The experimental birds were fed with formulated feeds following the recommended daily ration based on stages of broiler production. The experimental broilers were fed 50 grams per bird per day with chick booster in 14 days and 75 grams per bird per day with chick starter in 14 days and 110 grams per bird per day with broiler finisher also in 7 days, with a total of 35 days growing period. Three times feeding in a day were applied to all birds under study. Ad libitum feeding and giving water were observed in both commercial and formulated feeds.

Feeds Formulation

Aside from the commercial feeds used in this

study as control, a formulated feeds with three levels of vermi meal was used to produce Chick Booster Mash (CBM), Chick Starter Mash (CSM) and Broiler Finisher Mash (BFM). The level of vermi meal is 2% vermi meal in 98% other ingredients, 3% vermi meal in 97% other ingredients, and 5% vermi meal in 95% other ingredients. Each type of formulated broiler feeds was divided in three levels of vermi, one (1) part contents 2% level, 3% level, and 5%, level respectively. The formulated feeds were subjected for analysis; 300 grams from every type of feeds per sample were collected. Each type of feed sample comprised 100 grams from formulated feeds into each level of vermi. The feed formulation using the different ingredients was computed using the Pearson Square Method and Trial and Error Method. The quantity of feed formulated was based on the age of broilers and the type of feeds such as CBM, CSM, and BFM.

These formulated rations had undergone an analysis of Crude Protein using Automated Kjeldahl Method (Bunchi) by the Department of Science and Technology (DOST)-Food and Nutrition Research Institute Service Laboratory, Taguig, Metro Manila.

Management of Experimental Birds

Before the arrival of chicks, all facilities, and equipment including the area, were disinfected to prevent any disease-causing organisms.

Brooding of day-old chicks lasted for 14 days. The cages were covered, especially at night time, to maintain the required temperature. Old newspapers were used as litter materials during brooding for birds under total confinement and rice straw for the birds under free-range. Water was provided to the birds regularly, and daily replacement of unconsumed water was done and measured. Proper sanitation and management were observed during the entire duration of the study.

Analysis of Data

All observations in each parameter were subjected to Analysis of Variance (ANOVA) for a factorial experiment in a Completely Randomized Design (CRD). The researcher also used the Statistical Tool for Agricultural Research (STAR), Plant Breeding Genetics and Biotechnology Biometrics and Breeding Informatics, Version 2.0.1 (2014) of IRRI. Treatment means were compared using the Least Significance Difference (LSD) at 5% level of significance.

RESULTS AND DISCUSSION

Body Weight

Table 2 shows that the different management systems of the broiler did not significantly affect its body weight in 35 days of this study. Numerically, however, the total confinement (1,053.80 grams) had achieved the higher final weight relative to free-range (1,018.20 grams) with a value of 35.60 grams difference. This could be due to the more energy consumed by the birds in roaming in the free- range area.

Table 2

Body Weight of Broilers in 35 days as Affected by Different Levels of Vermin Meal Subjected to Total Confinement and Free-range

Factors	Body Weight (grams)
Factor A. Management System	
Total confinement	1,053.80 _a
Free range	1,018.20 _a
Factor B. Broiler ration	
A ₁ B ₀	1,304.0 _a
A ₁ B ₁	928.7 _b
A ₁ B ₂	1,007.3 _b
A ₁ B ₃	975.3 _b
A ₂ B ₀	1,292.0 _a
A ₂ B ₁	908.7 _b
A ₂ B ₂	966.0 _b
A ₂ B ₃	956.0 _b
Interaction (A x B)	NS

Means in a column followed by a common letter were not significantly different, based on LSD Test at p<0.05

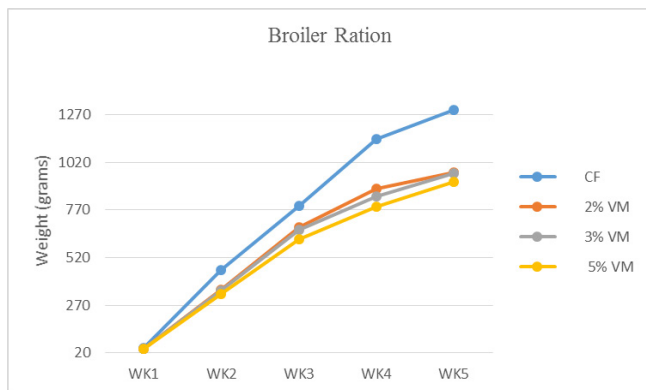


Figure 1. The Average Weight of Broilers in a Different Ration

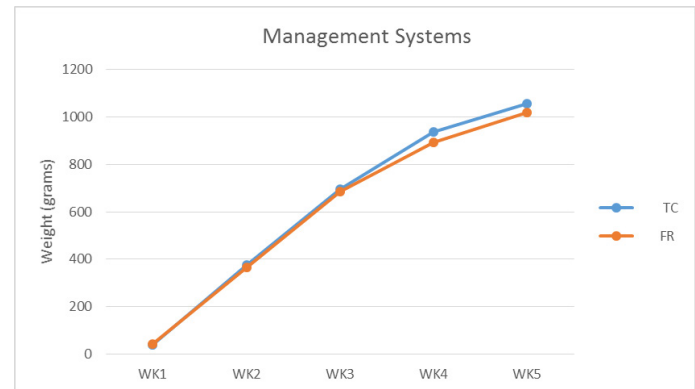


Figure 2. The Average Weight of Broilers under Two Management Systems

Meanwhile, vermi levels had significantly affected the final weight of broilers 35 days after harvest, both from total confinement and free-range. In terms of experimental diets, commercial feeds had a remarkably heavier body weight in both management systems (total confinement and free-range). Indicating such in both management systems, the influence of commercial feeding had shown no difference to the bodyweight performance of broilers. On the other hand, comparable results were observed from different vermi levels from both management systems. It showed that a 2% level of vermi meal was enough to feed the broiler because an optimum level in terms of body weight, weight gain, and feed conversion ratio were already met using the percent described of application. As studied by Kasye, M. B. (2016) the highest body weight increased to 1.3 kg on a diet with 2% vermi meal, the results again indicated that inclusion of earthworm meal in the diets at high levels of earthworm meal (2%) produced body weight values that were equal or superior to those produced by concentrated based diet.

Average Weight Gain of Broiler

Table 3 shows that the average weight gain of

broiler after harvest was not significantly influenced by the management system. However, the total confinement had numerically heavier broiler weight gain at an average difference of 36.90 grams which was consistent with the study of Wang et al. (2009) that the body weight and weight gain of broilers in the free-range treatment were significantly lower than those chickens raised in the indoor treatment.

Regardless of the management system, the average weight gain of broiler after harvest was significantly affected by the different broiler ration. The commercial feeds had significantly heavier weight gain from both free-range and total confinement as compared to the different levels of vermi meal. However, the levels of vermi meal were comparable with each other. The results showed that at an increasing rate of application from 2% to 5% vermi meal, it had inversely affected the broiler weight gained to decrease further. It indicated that the 2% levels of vermi meal were the optimum percentage rate to be applied in the broiler to attain a stable broiler production. Accordingly, hens fed with a diet containing 2% vermi meal gave slightly higher body weight gain than those fed with diet without in other treatments (Kasye, 2016).

Table 3

Average Weight Gain of Broilers in 35 days as Affected by Different Levels of Vermin Meal Subjected to Total Confinement and Free-range

Factors	Average Weight Gain (grams)
Factor A. Management System	
Total confinement	1,013.00 A
Free-range	1,254.70 A
Factor B. Broiler ration	
A ₁ B ₀	1264.00 _a
A ₁ B ₁	885.43 _b
A ₁ B ₂	967.33 _b
A ₁ B ₃	935.04 _b
A ₂ B ₀	1,245.3 _a
A ₂ B ₁	868.67 _b
A ₂ B ₂	874.33 _b
A ₂ B ₃	866.00 _b
Interaction (A x B)	NS

Means in a column followed by a common letter were not significantly different, based on LSD Test at p<0.05

Table 4

Feeds Consumption of Broilers in 35 days as Affected by Different Levels of Vermi Meal Subjected to Total Confinement and Free-range

Factors	Feed Consumption (grams)
Factor A. Management System	
Total confinement	1,761.10 _a
Free-range	1,680.00 _b
Factor B. Broiler ration	
A ₁ B ₀	1,845.30 _a
A ₁ B ₁	1,633.30 _h
A ₁ B ₂	1,763.90 _c
A ₁ B ₃	1,801.90 _b
A ₂ B ₀	1,692.50 _e
A ₂ B ₁	1,649.00 _g
A ₂ B ₂	1,670.90 _f
A ₂ B ₃	1,707.40 _d
Interaction (A x B)	S

Means in a column followed by a common letter were not significantly different, based on LSD Test at p<0.05

Feed Consumption

Table 4 illustrates that the feed consumption of the broiler was significantly influenced by the management system of the broiler. The total confinement (1,761.10 grams) had significantly higher feeds consumption relative to free-range (1, 680.00 grams). The higher feeds consumption experienced by Total Confinement (TC) in comparison with the free-range was mainly due to the broilers focused on feeds ration from TC since no other source of ration was available for them to consume. Unlike, in the free-range area, the birds were more exposed to other ration in which they could freely roam around from

the allotted wider space to look for another source of foods and/or access to pasture with various feeds like grasses, insects, worms, minerals from soil and stones. Furthermore, Wang et al., (2018) also revealed that free-range system of growing broiler has many advantages concerning to uncontrolled environmental factors that might influence the feeds uptake of broilers such as temperature, photoperiod, and light intensity which were inherently variable, as a result, giving the broiler with the more favorable feeding condition.

Meanwhile, the different vermi levels had significantly influenced the feed consumption performance

Table 5

Feeds Conversion Ratio (FCR) of Broilers in 35 days as Affected by Different Levels of Vermin Meal Subjected to Total Confinement and Free-range

Factors	FCR(grams)
Factor A. Management System	
Total confinement	0.20 _a
Free-range	0.19 _b
Factor B. Broiler ration	
A ₁ B ₀	0.16 _c
A ₁ B ₁	0.23 _a
A ₁ B ₂	0.21 _{ab}
A ₁ B ₃	0.22 _{ab}
A ₂ B ₀	0.15 _c
A ₂ B ₁	0.20 _b
A ₂ B ₂	0.20 _b
A ₂ B ₃	0.20 _b
Interaction (A x B)	NS

Means in a column followed by a common letter were not significantly different, based on LSD Test at p<0.05

Table 6

Water Consumption of Broilers in 35 days as Affected by Different Levels of Vermin Meal Subjected to Total Confinement and Free-range

Factors	Water Consumption (liter)
Factor A. Management System	
Total confinement	4.03 _a
Free-range	3.95 _b
Factor B. Broiler ration	
A ₁ B ₀	4.23 _a
A ₁ B ₁	4.00 _b
A ₁ B ₂	4.02 _b
A ₁ B ₃	3.88 _c
A ₂ B ₀	3.76 _d
A ₂ B ₁	3.79 _d
A ₂ B ₂	4.21 _a
A ₂ B ₃	4.04 _b
Interaction (A x B)	S

Means in a column followed by a common letter were not significantly different, based on LSD Test at p<0.05

of the broiler. The higher feeds consumed observed in the commercial feeds of the total confinement (A1B0), but this did not give consistent results when applied to free-range (A2B0). However, the 5% vermi meal of total confinement (A1B3) had significantly higher feeds consumption than from the rest of the vermi meal treatments. This result showed that at total confinement application of a vermi meal of a 5% predominantly improved the feeding habit of the broiler. This result was also true to the free-range in which the consumption of feeds at 5% level had increased the feeds consumption of broiler. Thus, a 5% level of vermi meal was the optimum level in which the birds had consumed more feed from both the management system but were significantly higher in TC. This result was by the study on quail as reported by Prayogi (2011) in which the

5% level of vermi meal consumption gave an optimum level of feed consumption.

Feeds Conversion Ratio

Table 5 illustrates that the Feeds Conversion Ratio was not significantly influenced by the management system as the results were comparable to each other. On the other hand, the feed conversion ratio was significantly influenced by the different broiler ration. The 2% vermi meal (A1B1) had a significantly higher feeds conversion ratio but was comparable to 3% and 5% vermi meal, which was observed in total confinement. This result reflects that there was better feeds consumption in vermi meal as compared to commercial feeds from both managements

Table 7

Dressing Percentage of Broilers in 35 days as Affected by Different Levels of Vermin Meal Subjected to Total Confinement and Free-range

Factors	Dressing Percentage (grams)
Factor A. Management System	
Total confinement	70.67 ^a
Free range	68.58 ^b
Factor B. Broiler ration	
A ₁ B ₀	71.33 ^a
A ₁ B ₁	70.33 ^{ab}
A ₁ B ₂	70.67 ^{ab}
A ₁ B ₃	70.33 ^{ab}
A ₂ B ₀	69.33 ^{bc}
A ₂ B ₁	68.00 ^c
A ₂ B ₂	68.33 ^c
A ₂ B ₃	68.67 ^c
Interaction (A x B)	NS

Means in a column followed by a common letter were not significantly different, based on LSD Test at p<0.05

Table 8

Production, Profitability, and the Return of Investment of Broilers in 35 Days Raised under Two Management Systems and with Vermi Meal Supplementation

Management Systems	Production Cost (PHP)	Profit (PHP)	Return of Investment (ROI)
<i>TOTAL CONFINEMENT (TC)</i>			
A ₁ B ₀ (15 heads)	2,607.00	58.25	2.23%
A ₁ B ₁ (15 heads)	2,804.00	53.00	1.89%
A ₁ B ₂ (15 heads)	2,804.00	59.00	2.10%
<i>FREE-RANGE (FR)</i>			
A ₂ B ₀ (15 heads)	2,804.00	458.25	16.34%
A ₂ B ₁ (15 heads)	2,804.00	455.50	16.24%
A ₂ B ₂ (15 heads)	2,804.00	463.75	16.549%
A ₂ B ₃ (15 heads)	2,804.00	459.25	16.38%

but, in return, produced lower weight gained (Table 3). This result was due to the full availability of nutrients present in commercial feeds, which satisfied the feeding habit of a broiler. Published by Bahadori et al. (2014), the effect of treatment on some carcass components was not significant ($P > 0.05$). In total, the results showed that 2% and 3% of vermi meal improved the feed conversion ratio of broiler chickens.

Water Consumption

The water consumption of the broiler was significantly influenced by the management system of the broiler (Table 6). The total confinement had a significantly higher volume of water consumption relative to the free-range. The higher volume of water consumption influenced by the total confinement was mainly due to the broilers' concentration to drink more water since they had no other

supply of water to deal with. Meanwhile, in contrast to broiler raised in free-range resulted in significantly lower water holding capacity ($P < 0.05$). The causes were due to the temperature fluctuation, especially the relatively high temperature which had affected the water content of the muscle of the birds (Wang et al., 2009).

However, the different ration of broiler had significantly influenced the water consumption of broiler. The commercial feeds in total confinement (A1B0), and 3% vermi meal in free-range (A2B2) showed a significantly higher water consumption as they were comparable from each other. Table 4 shows that the higher consumption of water in A1B0 may be attributed to the higher volume of feeds consumed by broiler. It indicated that broiler consumption of feeds was directly proportioned to water consumption. Whereas, in different vermi meals, there was a higher volume observed in A2B2, which indicated that

Table 9

Difference in the Profitability of Broilers between Total Confinement and Free-range Management Systems

	Management System	<i>t</i>	p-value	Interpretation
TC	55.75			
Profitability		-181.29	<.0005	Significant
FR	459.19			

*tested at .05 level of significance.

Table 10

Difference in the Growth Performance of Broilers Between Total Confinement and Free-range Management Systems

	Management System	<i>F</i>	Wilk's Λ	Partial η^2	p-value	Interpretation
Total Confinement/Free-Range		68.79	.006	.994	.014	Significant

*tested at .05 level of significance

3% vermi meal in a free-range.

There was a significant interaction between the management system and different ration of broiler in which the commercial feeds in the total confinement area or vice versa had a higher rate of water consumption.

Dressing Percentage

Table 7 shows that the dressing percentage of the broiler was significantly influenced by the management system of the broiler. The total confinement had significantly higher in meat recovery which attributed to the volume of water consumption (A1) than the free-range (A2). This attributed that total confinement contained more moisture and fat in the meat. It was emphatically confirmed by (Boskovic et al., 2010) that the free-range rearing system was more favorable than an extensive indoor system, as it resulted in higher protein content and a lower fat content of white and dark chicken meat.

Regardless of the management system, the dressing percentage of broiler was significantly influenced by the different broiler ration. The treatment of commercial feeds was significantly higher than with a 2% level of vermi meal but was comparable with 3% and 5% level of vermi meal. However, the difference among treatments was just numerically small. The higher recovery of weight or dressing percentage of broiler in commercial feeds may be attributed to the content of fat and water of the meat as birds had higher water consumption (Table 6).

Production, Profitability, and Return of Investment

The cost and return analysis of raising broiler were affected by the management systems and different rations (Table 8). The study revealed that the broilers in the free-range had 16.38% ROI, which was higher compared to total confinement with 2.07%. This result was seconded by the result of (Minh, 2005), which implies that free-range chicken systems are sustainable and economical for both local and improved chicken breeds. Economic benefits were 12 to 36 % higher compared to total confinement.

In the different ration or the different levels of vermi, results showed that broilers fed with 2% vermi (B1) had higher net income and return of investment. The results could be concomitant to the expenses in operation in both management systems. The final weight, in comparison with the two management systems, revealed that free-range produce was sold at a higher price than the produce from total confinement (see Table 8).

Management Systems Profitability

The result revealed that broilers in the Free-Range Management System (459.19php) had a significantly higher profit than those in the total confinement management system (55.75), $t(6) = -181.29$; $p = <.0005$.

Management Systems Growth Performance

There was a statistically significant difference in the growth performance of broilers between the two management systems, $F(5,2)=68.8$; $p = .014$; Wilk's $\Lambda = .006$; Partial $\eta^2 = .994$.

The minimum level of vermi meal incorporation in the feed for broiler growth and profitability performances

In this study, different levels of vermi meal; 2%, 3% & 5% were combined with different local ingredients such as rice bran, copra meal, soybean meal, ground yellow corn, and other micro-ingredients. The growth of broilers in the different level of vermi meal was comparable to each other. Numerically, broilers with the 2% vermi meal had a high growth performance in both management systems. Profitability performance of broilers and the ROI showed high in 2% level of vermi meal in both management systems.

Level of the interaction of level meal in the diet of broilers in two management systems

There was an interaction effect between the management system and different broiler ration on the feeds consumption of broiler (Table 4). The significant

difference of total confinement in each different level of broiler ration was observed in the commercial feeds or vice versa. This implicitly meant that broilers in total confinement consumed feed well when using commercial feeds as ration. On the other hand, regarding the influence of different levels of vermi meal, the significant difference of total confinement in each different level of broiler ration was observed in 5% level of vermi meal application and vice versa. The results of interaction indicated that 5% vermi level was more preferred by the birds indicating that it attracted more birds compared to 2% and 3% vermi meal.

CONCLUSIONS

Based on the findings of the study, there were strong conclusions that came out. First, the vermi meal inclusion in the feed of broiler could be optimally given at a 2% level since it significantly increased the broiler's final weight and gain weight, with comparable feed consumption and high Feed Conversion Ratio that of commercial feeds. Water consumption was higher in TC compared to FR, since in FR management broilers can source water from the natural habitat. In TC, significantly higher meat recovery attributed to the volume of water consumption (A1) than the free-range (A2). This attributed total confinement contained more moisture and fat in the meat. In the management aspects, the two systems were not significantly different, although numerically, the total confinement broilers had higher final weight and weight gain.

Second, in the economic aspects, the study revealed that the free-range management system gathered higher in terms of production performance, higher net income, and profitability was attained. In terms of cost and return analysis of raising broiler as affected by the management systems, different rations, and total sales of the live and dressed broilers, the broilers in the free-range had 16.38% ROI while 2.07% only in total confinement.

Third, in the different ration or the different levels of vermi, the broilers fed with 2% vermi were profitable with higher net income.

And lastly, the interaction effect was observed between the management system and broiler ration based on feed consumption of broiler. The significant difference in weight between treatments was observed in the commercial fed. The influence of different levels of vermi meal was observed in broiler consumption at 5% of the vermi meal.

RECOMMENDATIONS

Based on the conclusions, the following recommendations were drawn. In the three different levels of vermi meal, it revealed that their differences in terms of body weight, weight gain, and feed conversion ratio were not significant to each other. Nevertheless, the 2% level of vermi meal was comparable to commercial feeds and had its optimum result. Thus, the study recommends the use of a 2% level of vermi meal for broiler production. The study was not able to submit for analysis the feed formulated samples of the different levels of vermi meal

(2% level, 3% level & 5% level) and the vermi meal due to non-availability of laboratory equipment and the distance from research site to the laboratory facilities which is in Luzon. Hence, it is recommended to conduct other studies that should subject the formulated feed in different levels of vermi meal to laboratory analysis. Due to the limitation of this study, it did not cover other parameters. Thus, it is recommended to conduct related researches that include broiler sensory, carcass yield, meat quality/chemical composition.

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Saluyot (*Corchorus olitorius* L.) Leaves as Acoustic Gel for Ultrasound Imaging

Mark M. Alipio^{1*}, Danielle Loise R. Questo², Danielle Marie I. Subang³, and Lovelyn A. Tan⁴

^{1,4} Department of Radiologic Technology, College of Allied Health Sciences-Davao Doctors,
Davao Doctors College, General Malvar Street, Davao City, Philippines

² Radiology Department, Rivera Medical Center, Inc.-Panabo, Davao del Norte, Philippines

³ Radiology Department, Metro Davao Medical and Research Center-J.P. Laurel Avenue, Davao City, Philippines

ABSTRACT

Ultrasound is aided with acoustic gel to provide an accurate medical diagnosis; however, this product is costly and, thus, may hinder the diagnostic value of the procedure. This research is focused on the evaluation of radiographic image quality parameters of sonograms scanned using Saluyot leaves and commercial acoustic gels. Twelve participants were purposively chosen and subjected to an Ultrasound scan using the acoustic gels. Recorded sonograms were evaluated using the standard radiographic image quality parameters. Results revealed that sonograms obtained using Saluyot leaves were more acceptable, more visible, more detailed, and less distorted compared to commercial acoustic gel. Statistical analysis showed that there is no significant difference in the level of acceptability and distortion of the sonograms obtained using the Saluyot leaves and commercial acoustic gels. However, there is a significant difference in the visibility and amount of recorded detail of the sonograms using the two gels.

Keywords: Health, Saluyot leaves, Acoustic gel

INTRODUCTION

For ultrasound to be effective, a conducting medium must be placed between the probe and the skin. Rumack (2011) and Tempkin (2014) stated that there would be no potent transmission of ultrasound waves if only an air gap exists between the probe and the skin. Odwin and Fleischer (2012) further elaborated that the absence or ineffectiveness of a conducting medium would cause a reflection of more than 99.998% transmitted ultrasound waves from the skin back to the probe. An acoustic gel is formulated to solve this problem. Heinar (2013) defined an acoustic gel as a colorless viscous liquid that contains thickening agents to transfer sound waves and improve its spreadability on the skin. Morley, Donald, and Sanders (2013) characterized the function of an acoustic gel as a substance that excludes air from the region between the probe's head and the patient's skin, allowing the ultrasound wave to pass into the tissue at its highest intensity.

However, despite solving the dilemma, the new product entails an additional financial burden to the public. Several scholarly works of literature have been circulated, pointing out that the burden is accentuated in low-resource settings and medical schools that are implementing ultrasound education. Partners in Health, one of the largest global health care organizations, has studied the application of ultrasound in low-resource settings. They found it to be a teachable skill that is helpful in patient care and a critical component in global health delivery but identified lack of availability and costs of gel as limitations to its use (Shah et al., 2008). Furthermore, the study revealed that some clinics located in low-resource areas have ultrasound machines but are unable to perform the studies due to the ongoing costs of the gel. Another

study of Shah et al. (2015) found out that 32.6% of the 138 respondents representing 44 low- and middle-income countries from the continents of Africa, South America, and Asia, identified the lack of gel as one of the obstacles to ultrasound use. Henwood et al. (2014) also found out that 57% of Emergency Medicine (EM) residents in Colombia recognized the absence of ultrasound materials as a stumbling block to point-of-care ultrasound.

Given these hindrances, there is a need for an alternative. A handful of previous studies have been published examining alternatives to the commercially available acoustic gel. Blaivas et al. (2004) published a case series of seven cases using a water bath as an ultrasound medium. This, however, is only applicable to extremities, and no validation of image quality has been done. Luewan et al. (2007) published a study of 346 cases (692 scans) comparing ultrasound gel to olive oil and found no significant difference in image quality. Both water and oil are potential alternatives to the commercially available gel; however, both have significant drawbacks. It is difficult to create enough contact with the skin using water to obtain adequate images. Oil is messy, can stain clothes, and, again, does not provide enough surface contact to obtain high-quality images. Riguzzi et al. (2016) compared cornstarch-based gel with commercially available gel and found no significant difference in image quality; however, considerations of sterility and contamination of gel to participants was overlooked. In general, there appears to be a scarcity of research on ultrasound gel alternatives.

Corresponding author:

Mark M. Alipio

Email Address: markalipiorrt@gmail.com

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For this reason, the researchers tested the feasibility of saluyot (*Corchorus olitorius* L.) leaves as an acoustic gel for ultrasound imaging.

Saluyot (*Corchorus olitorius* L.) leaf is an edible leafy vegetable that can almost grow anywhere in the Philippines (Nelz, 2016). Potter (2010) described it as a clear thickener in soups. In fact, after extraction of saluyot (*Corchorus olitorius* L.) leaves by Montañó et al. (1997), they found out that the relative viscosity of a 1.0% solution of the mucilage was determined to be 20 millipascal-seconds at room temperature, and the molecular weights were approximated to be 1700 g/mol for the saluyot mucilage. Various studies have been conducted confirming the antibacterial and antimicrobial properties of the leaves, as well as its shelf life. Ilhan et al. (2007) found out that the leaves presented a good antimicrobial activity against *Escherichia coli*, *Staphylococcus aureus*, *Yersinia enterocolitica*, *Geotrichum candidu*, and *Botrytis cinerea* while Zakaria (2006) concluded that the extract of the leaves possesses antibacterial activity that is comparable to some of the standard antibiotics. According to Tulio et al. (2002), the leaves had a longer storage life at 8°C than with the other storage temperatures, and the shelf life was found out to be eight days. However, Abu-Khalaf et al. (2017) showed that at 4°C, the shelf life was two weeks.

Considering these points about saluyot (*Corchorus olitorius* L.) leaves, the researchers identified it as a potential gel alternative that would address the scarcity and cost of commercial acoustic gel and would, therefore, benefit the low-resource community, medical schools that are implementing ultrasound education such as Davao Doctors College and radiology department in the hospital. Moreover, the researchers would like to hypothesize that images obtained using a saluyot (*Corchorus olitorius* L.) gel was not inferior to commercial acoustic gel based on the radiographic image critique, using an experimental crossover design.

METHODOLOGY

Design

In this study, an experimental crossover design was used. In the study, the participants were both subjected to commercial gel and saluyot gel. It is in this light that the method was used because the focal point of this research is to test if the saluyot gel is feasible as an alternative to commercial acoustic gel for ultrasound imaging. Also, this design was used to control the individual differences among participants, as each participant acts as their own control.

Setting

The experiment was conducted at Davao Doctors College, General Malvar Street, Davao City. The researchers conducted the study in this area because of the availability of the materials and machine that were used in the experiment. Specifically, the preparation of saluyot gel was conducted at the 5th Floor General Laboratory, and the scanning of patients was conducted at the 1st Floor Radiologic Technology Laboratory, where the ultrasound

machine is located.

Research Procedure

A letter of permission to conduct the study was given to the Program Chair of the Radiologic Technology Program of Davao Doctors College. Afterward, the researchers proceeded with the actual experimentation of the saluyot (*Corchorus olitorius* L.) leaves.

The saluyot (*Corchorus olitorius* L.) shoots weighing 500 grams were taken from an authorized plant shop at Bankerohan Public Market, Building Number 2, Marfori Street, Barangay 5-A, Davao City, Philippines. These shoots were specified and verified by Dr. Reynaldo G. Abad, a Botanist. The procedure in making an acoustic gel followed the steps of Riguzzi (2016), who found out that a 1:1 water-to-added substance ratio would yield the best consistency of the gel. The following laboratory equipment and materials were used in the study: 500-ml beaker, stirring rods, electric stove, thermometer, strainer, and standard ultrasound gel bottles. The saluyot gel was made before 6 hours of its use in the study. The saluyot leaves were removed from their stems, washed under flowing water and then were set aside. The leaves were weighed, and 300 grams of samples were obtained. The researchers put 300 ml of purified water and 300 grams of leaves inside the 500-ml beaker. These were then heated using the electric stove for 15 minutes under a temperature of 80°C to 90°C. The mixture was removed from the 500-ml beaker, strained using a fine mesh strainer to ensure removal of saluyot leaves and was set aside for 30 minutes. The produced saluyot gel was placed directly into empty, sterilized, standard acoustic gel bottles. The saluyot leaves were disposed to a container for organic waste.

Twelve participants were purposively chosen using the following criteria: female, age range of 30 to 40 years old, weight in the range of 50 to 60 kilograms, no history of pathology in the thyroid gland, physically fit in the recent physical examination, 17 cm anteroposterior diameter and 13 cm transverse diameter of neck, and valid to carry out a written informed consent. Before testing the saluyot gel to the participants of the study, they first underwent patch testing by Lachapelle and Maibach (2012) for 48 hours to determine if they will have any negative side-effects after the application of saluyot gel on the skin. The test allowed relative and rapid assessment of the participant's skin tolerance regarding the application of saluyot gel during the examination proper of the study. The saluyot gel was dabbed on the participant's non-dominant hand using cotton. Cotton with saluyot gel smaller in size was placed on the area with gel and was covered with transpore. The patients were given with saluyot gel and were instructed that every 8 hours, the patch should be changed, and saluyot gel will again be applied to the same area. The participants' patches were checked after every 8 hours. After a total of 48 hours of observation, participants were referred to Mr. Garizaldy A. Masayon, a Registered Nurse.

Subsequently, participants who exhibited false-negative results in any reaction to saluyot gel were considered for the sonographic examination of the thyroid gland. The results showed that all participants exhibited

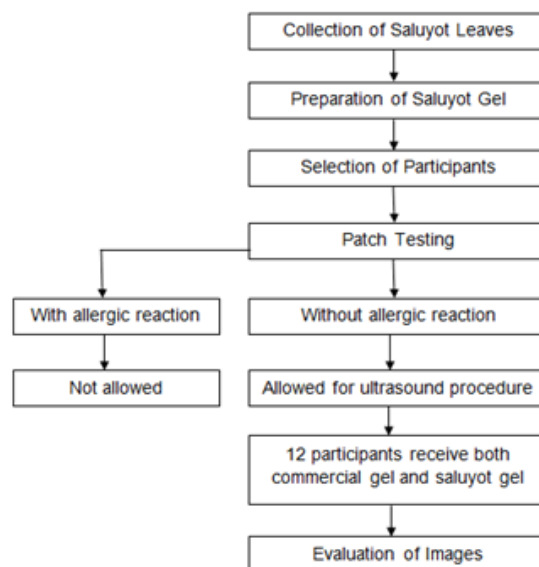


Figure 1. Schematic Diagram of the Procedures of the Study

no allergic reaction to the saluyot gel. The participants underwent a sonographic examination of the same organ, thyroid gland, using the probe with the same scanning time. The linear probe was used, and the scanning time was 1 minute. GE Healthcare Ultrasound Machine was used during the study. There were two sets of sonographic examinations. For the first set, the 12 participants were randomly assigned to either commercial gel or saluyot gel, and for the second set, the same participants were assigned to the other gel. These two sets allowed all participants to be subjected to both the commercial gel and saluyot gel in a random manner. The scanning of participants happened on the same day and in the same room. The researchers followed the sonographic scanning protocols and techniques of Ovel (2014).

For the first set, the participants were asked to remove all accessories in the neck area. They were placed in a supine position with a pillow or cushion placed under the shoulders so that the head and neck were moderately extended. Ten mL of either commercial gel or saluyot gel was placed on the thyroid gland by the ultrasonographer. The same amount of gel was placed throughout the study. The probe was then placed over the outer surface of the thyroid gland, and an image was then captured and saved. After undergoing the first set of sonographic examination in the 12 participants, the gel was removed from the participants, and the probe was cleaned with a cloth soaked in alcohol and then wiped with a dry cloth. For the second set of sonographic examination, the same participants were positioned on the same bed. The other gel was placed on the same surface of the thyroid gland by the same ultrasonographer, and the same amount of gel was placed. The same probe was then placed over the outer surface of the thyroid gland, and an image was then captured and saved.

All of the images were saved with the same size of information, which is 80 kilobytes. All of the settings in the ultrasound machine were the same for each examination. After images were saved, these were sorted according to the type of acoustic gel for evaluation. The images were evaluated by one experienced ultrasonographer, who has more than ten years of experience in the profession. To

avoid observational bias, the ultrasonographer was not informed of the type of acoustic gel during evaluation. The same laptop, the brightness of the screen, and room lighting were used during the evaluation of each image. The images were also evaluated on the same day. Figure 1 shows the schematic diagram of the procedures of the study.

Statistical Treatment

Descriptive and inferential statistics were used in the analysis of data. Mean was utilized to compute the average score of the radiographic image quality parameters obtained using Saluyot leaves and commercial acoustic gels. After satisfying the assumptions for running a parametric inferential test, a t-test for independent samples was used to compare the image quality parameters of sonograms using Saluyot leaves and commercial acoustic gels.

RESULTS AND DISCUSSION

Research findings here are presented in two sections: descriptive and t-test for independent samples. Table 1 presents the radiographic image quality parameters and corresponding means of sonograms obtained using Saluyot leaves and commercial acoustic gels. Table 2 presents the test of significant difference between Saluyot leaves and commercial acoustic gels.

Table 1 shows the radiographic image quality parameters of sonograms obtained using Saluyot leaves and commercial acoustic gels. In terms of the level of acceptability, visibility of detail, amount of recorded detail, and distortion, the sonograms produced using Saluyot leaves gel obtained a mean score of 4.58, 4.42, 4.25, and 1.08, respectively. On the other hand, the sonograms obtained using the commercial acoustic gel obtained a mean score of 4.25, 3.42, 3.33, and 1.25 in terms of acceptability level, visibility of detail, amount of recorded detail, and distortion.

The sonograms produced using Saluyot leaves gel were more acceptable, more visible, more detailed, and

Table 1

Radiographic Image Quality Parameters of Sonograms Obtained using Saluyot Leaves and Commercial Acoustic Gels

Parameters	Saluyot	Commercial
Level of acceptability	4.58	4.25
Visibility of detail	4.42	3.42
Amount of recorded detail	4.25	3.33
Distortion	1.08	1.25

Table 2

Test of Significant Difference Between the Saluyot Leaves and Commercial Acoustic Gels

Parameters	p-value
Level of acceptability	0.11
Visibility of detail	0.00*
Amount of recorded detail	0.00*
Distortion	0.29

Note. *p<0.01

less distorted compared to the commercial acoustic gel. This implies that the quality of Ultrasound images obtained using Saluyot leaves gel as measured by the four standard parameters is higher compared to the images produced using the commercial acoustic gel.

Table 2 illustrates that there appears to be no significant difference in the level of acceptability and distortion of the images obtained using the Saluyot leaves and commercial acoustic gels. However, there is a significant difference in the visibility of detail and amount of recorded detail of the images obtained using the two acoustic gels. This means that the Saluyot leaves gel was found to be superior to commercial gel with respect to visibility of detail (4.42 vs. 3.42) and recorded detail (4.25 vs. 3.33). This suggests that ultrasonographers who want to visualize the detail on the image clearly, identify the structural lines or borders of tissues in the image and decrease the unavoidable amount of blur of the image may use the Saluyot leaves gel (Bushong, 2013). With adequate detail, even the smallest parts of the anatomy are visible, and the radiologist can more readily detect tissue abnormalities (Bushong, 2013). This finding concurs to the study of Riguzzi et al. (2016), which reported a significant difference in the mean image detail score, mean resolution score, and mean image quality score between images obtained using commercial gel and cornstarch gel as the alternative.

CONCLUSIONS

The quality of images obtained from the Ultrasound scan using Saluyot leaves gel is superior compared to that of commercial acoustic gel. Both gels produced images that have statistically the same level of acceptability and distortion. However, the images obtained using Saluyot leaves gel exhibited statistically higher visibility of detail and amount of recorded detail compared to those of commercial acoustic gel. Therefore, the Saluyot leaves gel

may be used as an alternative acoustic gel for Ultrasound imaging. Furthermore, it could possibly be a preferred media because of its lower cost and ease of formulation.

RECOMMENDATIONS

Future researchers may test the Saluyot leaves gel for other parameters such as viscosity to optimize its application to the skin surface and shelf life. Concurrently, considerations of sterility and contamination should be further investigated. Additionally, future studies should increase sample size and enroll actual patients as participants, with a proportion having abnormal ultrasound findings. It is also suggested that the formulation of Saluyot leaves gel may be implemented in low-resource setting and medical schools that are teaching ultrasound education to help determine its feasibility in day-to-day practice.

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Computational Modeling and Simulation of Linear Accelerator Performance for General Radiotherapy

Andelson L. Berondo¹, Lilian V. Rodriguez², and Alwielland Q. Bello³

¹Cancer Center, Davao Doctor's Hospital, Davao City, 8000 Philippines

²Radiotherapy Department, Jose R. Reyes Memorial Medical Center, Sta. Cruz, Metro Manila, 1003 Philippines

³Natural Sciences Department, Bukidnon State University, Malaybalay City, Bukidnon, 8700, Philippines

²Radiology Department, Rivera Medical Center, Inc.-Panabo, Davao del Norte, Philippines

² Radiology Department, Metro Davao Medical and Research Center-J.P. Laurel Avenue, Davao City, Philippines

ABSTRACT

In radiation therapy, Monte Carlo method was a standard procedure for absorbed dose calculations; yet it was often frustrating due to long computation requirements and complex programming. Monte Carlo method was soon revitalized since the introduction of Geant4 framework purely written in C++ object-oriented language. This study utilized open-source Geant4 codes for modeling and simulation purposes. These codes were executed to simulate the performance of an Elekta Compact linear accelerator based on available manufacturer's specifications. A 6-MV photon beam spectrum was modeled by transporting 2 billion 6-MeV primary electrons to hit a tungsten target from a 0.5 mm gun filament radius with spatial energy of 0.127 MeV and angular distribution of $\pm 30^\circ$. Depth-doses were computed at 1.04 to 30 cm along the central axis of a voxelized water phantom. Validity of simulated data was verified by comparison with experimental measurement. There was close agreement between simulated and measured beam data. Normalization errors were equal to 4.6% for 10 x 10 cm²; and 3.9% for 15 x 15 cm² field sizes. Computing efficiency has improved when using condensed-history technique. Therefore, the Geant4 framework can create model and simulate complex geometries of a linear accelerator facility with improved reliability, accuracy, and efficiency.

Keywords: linear accelerator, depth-dose, Geant4, Monte Carlo

INTRODUCTION

Accurate delivery of dose is the ultimate goal in radiotherapy. Many clinical algorithms were developed to estimate the dose distributions in patients. Still, more sophisticated ones (i.e., convolution-superposition) resort to approximations which may result in inaccurate prediction of the dose distributions especially in the vicinity of low density volumes (lung) and air cavities (Mohan, 1997; Parsai et al., 2010; Chetty et al., 2007; Caccia et al., 2007; Frass, et al., 2003). Nowadays, Monte Carlo technique is considered to be the gold standard for dose calculation (Solberg et al., 1998; Ma & Jiang, (1999); Keall et al., 2000; Mohan et al., 2001; Heath et al., 2004; Paenlinck et al., 2005). The method represents an attempt to model nature through direct simulation of the essential dynamics of the system in question. It typically requires long times, but the fact can be overcome by the continuing improvements of computer technology (Hissoinya, 2010).

At present, there are four general purposes Monte Carlo systems used for dose calculation; Electron Gamma Shower (EGS), Monte Carlo N-Particle (MCNP), Penetration and Energy Loss of Positrons and Electrons (PENELOPE), and Geometry and Tracking (GEANT). These systems include well-validated physics models, geometry modeling tools, and efficient visualization utilities. However, the first three codes are all written in formula translation (FORTRAN)

format which requires a thorough knowledge in computer programming.

Geant4 is a free software package composed of tools which can be used to simulate the passage of particles through matter (GEANT4 Collaboration, 2007). It is recognized as one of the first large object-oriented software applications in physics written in C++ language and has become the standard simulation platform for most high energy physics experiments, including three of the four studies at the Large Hadron Colliders. Recently, it has found use in a variety of medical physics applications (Archambault et al., 2004; Verhaegen & Seuntjens, 2003; Poon et al., 2005; Poon & Verhaegen, 2005; Barca et al., 2003; Sardari et al., 2010).

In this study, the researchers used Geant4 Monte Carlo codes to simulate an Elekta Compact Linear Accelerator (Linac). In particular, the study aimed to: model the treatment head assembly of Linac, calculate the depth-dose deposition at the central axis in water phantom for varying field sizes, and compare the simulated beam data to experimental measurements for validation.

Corresponding author:

Alwielland Q. Bello

Email Address: alwielland@gmail.com

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METHODOLOGY

Monte Carlo Simulation

The requirements needed for the Monte Carlo simulation were: (a) the volume geometry, (b) source definition, (c) a physics model, (d) random number generator, and (e) the scoring plane or detector. The calculations were done on a personal computer with 3.07 GHz processor and gcc 4.1.2 compiler on a Linux RedHat5 operating system. Geant4.9.4.p01 and CLHEP2.1.0.1 were used as the computing platforms. Geant4 is an open source code that can be downloaded for free (CERN, 2010). The software applied for the modeling of head components were: (a) MedLinac2 package (Caccia et al., 2010), (b) HepRApp external visualization driver, and (c) OGLIX internal visualization driver.

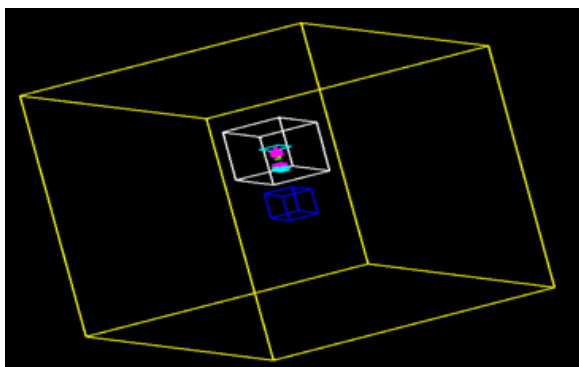


Figure 1. HepRApp snapshot showing mother volume (yellow), accelerator volume (white), and detector volume (blue)

For the geometry construction, we created an air-filled $600 \times 600 \times 600 \text{ cm}^3$ mother volume (Fig. 1) and inside it are the two daughter volumes, accelerator and detector (Fig. 2). The $120 \times 120 \times 120 \text{ cm}^3$ accelerator volume is made of vacuum while the $60 \times 60 \times 60 \text{ cm}^3$ voxelized (10 mm half size) detector volume is composed of water. The isocenter was set at the center of the mother volume. The SSD was fixed to 100 cm.

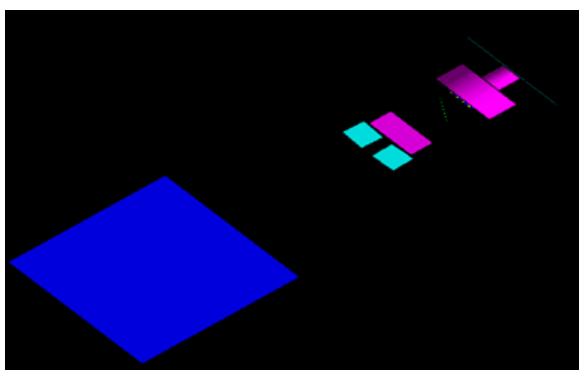


Figure 2. OGLIX snapshot showing Geant4 model of linear accelerator and water phantom

We used the available machine head design information (Clinical Mode User Manual) for the geometry construction of linear accelerator. The following were the components considered on modeling the head assembly (Sardari, 2010; Caccia et al., 2010; Wieslander & Knoos, 2007): (a) the x-ray target made of tungsten and copper plate, (b) the cylindrical tungsten alloy primary collimator

with a conical aperture, (c) the flattening filter, (d) a cylindrical monitoring ionization chamber, (e) the light field mirror, and (f) the lower and upper diaphragms. The exact information of dimension and weighted composition of some components were not obtained from the manufacturer due to confidentiality issue. Simplifications were applied in terms of dimension and material composition to model some parts of the Linac, particularly the mirror and ionization chamber. Figure 3 shows the Geant4 model of accelerator head.

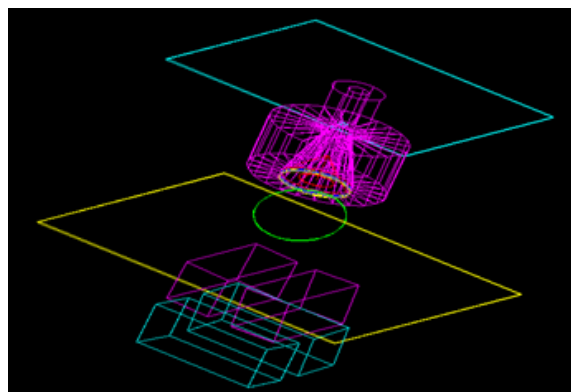


Figure 3. HepRApp snapshot of Linac treatment head assembly showing killer plane (cyan) to avoid backscattering radiation, primary collimator (pink), target (cyan), flattening filter (red), ionization chamber (yellow/blue), light field mirror (green), phase space plane (yellow), and upper (magenta) and lower (cyan) diaphragms

The workflow was divided into two parts to save simulation time. First, we transported two billion 6-MeV electrons with spatial energy of 0.127 MeV from a 0.5 mm gun radius. The primary electrons produced x-ray energy spectrum after hitting a tungsten target. The EmLivermore physics list was chosen to consider low energy electromagnetic processes. A source spectrum with Gaussian distribution passed through the primary collimator and mirror, generating 1.5 Gigabytes phase space file (PSF) that describes the particles produced before the primary jaws. Second, the PSF produced was then repeatedly used (Fig. 4) for varying field sizes ($10 \times 10 \text{ cm}^2$ and $15 \times 15 \text{ cm}^2$) to calculate the dose deposition from depth 1.04 cm to 30 cm (87 interest points) in a water phantom.

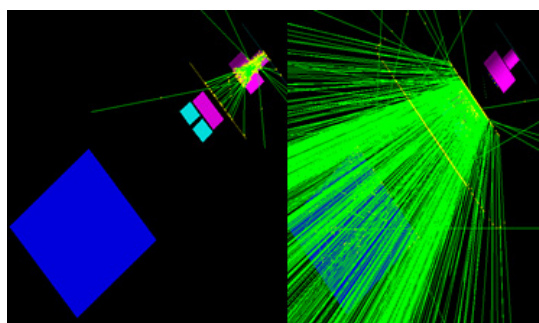


Figure 4. Visualization of the PSF technique using OGLIX. The primary events were saved at the phase space plane (left) and then the stored history was recalled as a new source at other terminal (right) to lessen the calculation time

Beam Data Measurement

We conducted our beam data measurement at the Jose R. Reyes Memorial Medical Center during the commissioning of newly installed machine. The hospital provided all the well-calibrated equipment needed during the experiment. Figure 5 shows the materials used for the procedures. These consisted of the following: (a) Elekta Compact Linac, (b) MEPHYSTO scanning system, (c) PTW MP3 phantom tank, (d) 0.125cc thimble type ionization chambers (field and reference detectors) for relative dosimetry, and (e) dual channel electrometer (T10011 TANDEM).



Figure 5. The major equipment used on beam data measurements showing (i) Elekta Compact Linac, (ii) water phantom, (iii) thimble type ionization chamber, and (iv) dual channel electrometer

Figure 6 shows the water phantom scanning system set-up. The researchers measured the absorbed dose along the central axis in water phantom by the following steps: (i) set the Linac gantry and collimator angles at zero degree, (ii) align the center of the water phantom with the beam central axis, (iii) adjust the level of water in the phantom by using spirit level to be perpendicular with the beam axis at 100 cm SSD, (iv) connect the field detector for photon beam to the scanning system, (v) move the detector manually along X, Y, and Z axes to test that its center would be on these axes during the scanning process, (vi) place the reference detector on air at the border of the beam without interfering the field detector's paths, and (vii) search the depth of the maximum dose in the central axis during beam on then scan the central axis depth-dose with 100% normalization to the maximum dose for 10 x 10 cm² and 15 x 15 cm² field sizes, and 6-MV photon beams.

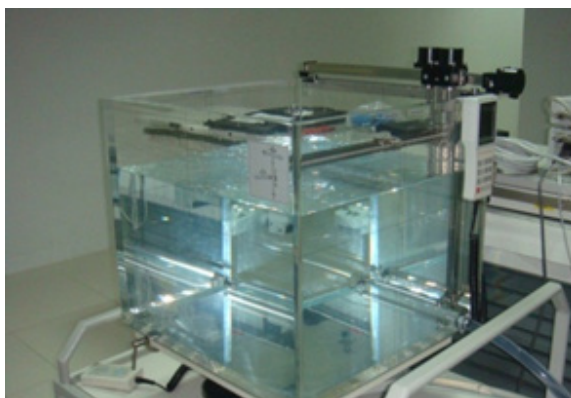


Figure 6. Water phantom and its scanning system.

Data Analysis

The simulated and measured central axis depth dose curves were both normalized at 1.04 cm depth to neutralize their respective units. The comparing region started from depth 1.04 cm to 30 cm to avoid electron contamination at the surface. In this study, simulation results were assessed by calculating the normalization error by using Eq. (1),

$$E_n = \frac{1}{N} \sum_{i=1}^N \left(\frac{|d_i - d_{ref_i}|}{d_{ref_{max}}} \right) \quad (1)$$

where E_n is the error normalized to the reference maximum dose ($d_{ref_{max}}$), i corresponds to a curve point index, N is the number of points, d_i is the dose computed at point i and d_{ref_i} is the reference dose measured at point i . Errors were normalized to the maximum dose in order to increase the error weight at high doses and decrease it at lower values. In high dose-gradient regions, large errors can occur, while the distance-to-agreement can be small. Eq. (1) balance the point-to-point errors according to the dose deposited so that the overall error calculated is more suited to characterize the simulation agreement with measurements.

RESULTS AND DISCUSSION

This study aimed to create a model of the treatment head assembly of Linac; to calculate the depth-dose deposition at the central axis in water phantom for varying field sizes; and to compare the simulated beam data to experimental measurements for validation. The results after conducting computational and experimental measurements are presented in the succeeding discussions.

Simulation Accuracy and Efficiency

The simulation took 144 hours which registered approximately 25 million events inside the detector volume. Table 1 shows that the calculation rate increased to 2566.5 particles per second when the visualization mode was turned off. Moreover, the simulation time was reduced to approximately 72 hours when the PSF technique was applied.

The VoxeltestOut1.txt generated from a provided experimental data file (Voxeltest.txt) was used for the direct comparison between the measured and simulated beam data. The file contains the position of the voxels and experimental dose values as given in the experimental data file accumulative dose/square dose, number of events in the voxels, and accumulative dose/square dose normalized to the experimental data. Table 2 shows that there was a good agreement between the simulated and measured beam data. By using equation (1), normalization errors computed were 4.6 % for the 10 x 10 cm² field size while 3.9 % for 15 x 15 cm².

Table 1

Efficiency of the Simulation Platform Used

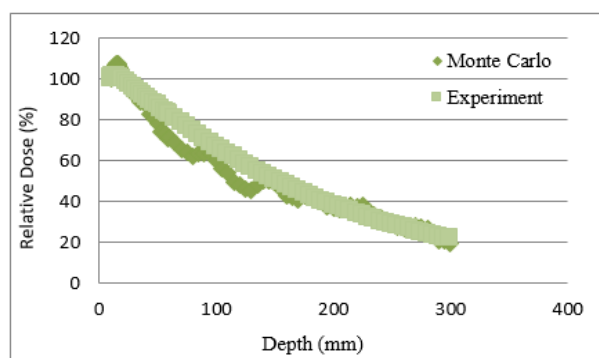
No. of Particles	Visualization Mode	Elapsed Time (seconds)	Rate (particles/second)
1 million	ON	420.04	2380.70
1 million	OFF	389.64	2566.50

Table 2

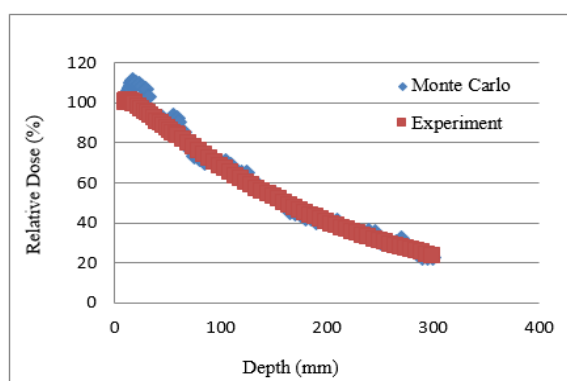
Normalized Error of Monte Carlo Beam Data Compared to the Reference Data

Field Size (cm ²)	Normalization Error (%)
10 x 10	4.6
15 x 15	3.9

Figure 7 illustrates the superimposed plot of calculated and measured central axis depth-dose for 10 x 10 cm² and 15 x 15 cm² symmetrical field sizes, respectively. The dose exponentially decreases after depth 1.6 cm as it goes deeper from the surface



(a)



(b)

Figure 7. Comparison between Simulated and Measured Beam Data at the Central Axis in Water Phantom for Field sizes (a) 10 x 10 cm² and (b) 15 x 15 cm²

CONCLUSION

This study shows that Geant4 can model the complex geometries of Elekta Compact Linac. As a utility tool, Geant4 software can predict dose distribution in water phantom but the data is not enough for patient treatment. However, the simulation time can be lessened by using the phase space file (PSF) technique and turning

off the visualization mode.

RECOMMENDATIONS

Based on the findings and conclusions of the study, the researchers recommend applying a higher end of computation platforms (e.g., i7 processor with graphical processing unit, or computer cluster simulation) to transport more primary events for greater chance of predicting the particle path hence improving the simulation accuracy (within 3% error). Moreover, we also recommend simulating the beam profiles at different depths and varying field sizes may be done to further validate the data, and then compare it with any existing clinical dose computation engine in predicting dose distributions in complex heterogeneous media (e.g., water phantom with lung insert, or CT-scan image). Foremost, the exact material composition and head geometry must be obtained from the manufacturer to improve the calculation process.

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Eggshells as Alternative Shielding Material Against Diagnostic X-rays

Mark M. Alipio

Department of Radiologic Technology, College of Allied Health Sciences, Davao Doctors College,
Davao City, Davao del Sur, 8000 Philippines

ABSTRACT

With the advancement in diagnostic imaging, providing shielding against X-rays has become a significant concern. While Lead has been extensively used as the shielding material, it is costly and toxic to humans and the surrounding environment. This study aims to evaluate the feasibility of eggshells as alternative shielding material against diagnostic X-rays. To this end, the eggshells were collected, ground, sieved and mixed with cement and water with an increasing amount. Radiographic analysis was utilized to measure the performance of the shields. The results showed that increasing the number of eggshells increased its shielding performance; however, more shielding is required at higher X-ray energies. Nevertheless, the performance of the standard Lead shield and the shield with the highest number of eggshells yielded a comparable result. The eggshells can be used as alternative shielding material against diagnostic X-rays.

Keywords: Diagnostic X-rays; Eggshells; Lead alternative; Shielding

INTRODUCTION

While X-rays have immensely aided the medical exploration of various diseases, risks of its exposure have posed daunting issues not just in the healthcare industry, but also in the society as a whole. These highly energetic waves are electromagnetic ionizing radiation capable of disrupting the molecular and atomic structures of the body, causing skin burns, cataracts, leukemia, and life span shortening (Bushong, 2013). In a list of known human carcinogens or cancer-causing substances, the International Agency for Cancer Research (2018), an agency of the World Health Organization, classifies X-rays as carcinogenic to humans. In the same vein, extensive cohort studies provided evidence of the association between cancer risk and X-ray exposure from the medical imaging modalities (Pearce et al., 2012; Mathews et al., 2013; de Gonzalez et al., 2016). Aside from these hazards, high doses of X-rays at a short period are known to induce acute clinical symptoms in the hematologic, gastrointestinal, and central nervous systems, which ultimately result in acute radiation lethality or death (Bushong, 2013).

Given the health risks and escalating utilization of X-rays in the medical practice, the International Commission on Radiological Protection (2007) set standards on radiation safety on all entities which directly or indirectly operationalize radiation. Optimization, justification, and dose limits are the three concepts of the radiation protection model of the International Commission on Radiological Protection (ICRP). The governing body also suggests that doses to individuals from a particular source should be restricted. This recommendation leads to the concept of dose constraints or radiation shielding.

Radiation shielding is based on the principle of attenuation, which is the ability to reduce a radiation effect by blocking or bouncing particles through a barrier material. It is used to protect sensitive organs of the body such as the gonads, eyes, and thyroid glands. The standard shield recommended by ICRP in diagnostic radiology is Lead (Pb). Lead, a shiny blue-white soft metal, has been used as the standard radiation shield in radiology because of its high density, stopping power, and ease of installation. According to Bushong (2013), the standard thickness of protective shielding should be 0.5 cm Pb. This thickness is deemed to be appropriate as the value is approximately equivalent to two Half-Value-Layers, thereby reducing radiation exposure to 25%. However, the shielding material entails additional financial burden in rural hospitals and medical schools that are implementing Radiologic Technology education, which ultimately results in the non-utilization of the protective apparel. Among surveyed hospitals in the United States, Safiullah et al. (2017) found that 40% do not utilize shielding despite the majority acknowledging the principle of As Low As Reasonably Achievable and agreeing that shielding is a beneficial practice. The study further reported that cost is the primary reason for the non-utilization of shielding materials. In the Philippines, the total cost of Lead gown, one of the radiation-shielding materials, is Php 6,300 (Philippine Medical Supplies, 2019).

With these issues, numerous studies have been dedicated to finding alternative materials. Clay-white cement mixture (Akbulut, Sehhatigdiri, Eroglu, & Celik, 2015), silica-based commercial glasses (Yasmin et al., 2018),

Corresponding author:

Mark M. Alipio

Email Address: markalipiorrt@gmail.com

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Ball clay and Kaolin (Olukotun et al., 2018), coated textiles (Aral, Nergis, & Candan, 2015), mortars made with cement, sand, and eggshells (Binici, Aksogan, Sevinc, & Cinpolat, 2015), polymer nanocomposites (Nambiar, Osei, & Yeow, 2012), and fabrics coated with Tungsten and Barium sulfate additives (Aral, Nergis, & Candan, 2016) were found to shield radiation. However, none of these studies compared the linear attenuation coefficients of the experimental and standard Lead shields. Also, none formulated a device that shields X-rays in the diagnostic range. The samples used in the previous studies have economic value, thus may compromise the profit of the manufacturing firms.

According to the Bureau of Agricultural Statistics (2011), the Philippines produced 4.24 million tons of chicken and duck eggs in 2010. These eggs represent a significant ingredient in a large variety of products, such as cakes, salad dressings, and fast foods. However, the production results in several daily tons of eggshell waste and incur considerable disposal costs in the world. It was estimated that there are 250,000 tons of eggshell waste produced annually worldwide (Verma et al., 2012).

Previous studies reported significantly higher shell thickness, specific gravity, and breaking strength in eggshells compared to other domesticated shells (Joseph, Robinson, Renema, & Robinson, 1999; Soria, Bueno, & Bernigaud, 2013). These three parameters are directly proportional to mass density, one of the factors that should be considered in the construction of ideal shielding material (DeHoff, Rummel, LaBuff, & Rhines, 1966; Goel, 2007).

On the other hand, few studies have been carried out concerning the shielding effectiveness of eggshells against radiation. In the study conducted by Fecheyr-Lippens, Nallapaneni, and Shawkey (2017), eggshells had under 10% transmittance of Ultraviolet (UV) radiation. In the same study, the shielding efficacy was 43.5% higher for white eggshells compared to nylon with Titanium dioxide particles. On the other hand, eggshells were used as an additive to increase the radiation absorption property of mortars (Binici et al., 2015). The addition of eggshells improved the linear attenuation coefficient of mortars from 1.49 cm⁻¹ to 1.76 cm⁻¹ at 26.1 keV gamma-ray energy. The result of this study also revealed that an increase in the eggshell powder additive ratio increased the linear attenuation coefficient of the mortars. With these studies, an investigation of the X-ray shielding ability of eggshells is worthwhile to undertake.

There is a significant imperative to find an alternative to address the issues of costs and the non-utilization of radiation shields and solid waste management. However, there is a lack of research that explores the effectiveness of other materials in blocking radiation, such as X-rays. For this reason, the researcher is motivated to evaluate the shielding performance of eggshells against X-rays using a standard radiographic analysis approach. The main thrust of this study is to find an environmentally and economically appealing material that can be effectively used as shielding by both radiation workers and patients against X-rays.

METHODOLOGY

Collection and Preparation of Eggshells

Eggshell wastes were collected from the poultry farms, restaurants and hotels in Davao City. After retrieval, the eggshells were washed immediately with distilled water. The washed eggshells were air-dried for five days at a temperature range of 25-30°C. The eggshells were then ground into powder using a grinding machine. Finally, these shells were filtered through a 75-micron sieve.

Preparation of Eggshells Shield and Controls

Five samples of radiation shield were prepared by mixing powdered eggshells with cement and water. Ordinary Portland cement of 43 grade (Ramco) was used following IS 8112-1989 standards. The mix proportion used in this study was a 5:3 cement-water ratio conforming to the IS 10262-2009 standard mix design. The mix proportion of the materials is shown in Table 1.

The fifth sample was considered as a negative control. The sixth sample was a positive control, which is the standard radiographic Lead shield with 0.5-cm thickness. This sample was labeled as 'PC.' After mixing based on the mix proportions, the first five samples were placed in a concrete mold measuring 0.5 cm x 0.5 cm x 0.5 cm. These were then labeled and set aside for 48 hours at room temperature to ensure complete hardening.

Radiographic Analysis of Shielding Performance of Various Samples

The radiographic analysis of the shielding performance of various samples was undertaken at a Radiologic Technology Laboratory. The test followed the standard radiographic procedures of Bushong (2016). The following radiographic materials were prepared:

Table 1

Mix Proportion of Eggshells Shield and Negative Control (NC)

Shield Name	Eggshell (g)	Cement (g)	Water (g)
E1	25	50	30
E2	50	50	30
E3	75	50	30
E4	100	50	30
NC	0	50	30

radiographic imaging system, X-ray film processor, 400-speed 14 in x 17 in screen-film cassette, 14 in x 17 in X-ray film, Lead marker, view box, and densitometer. A radiographic technique of 30-150 kilovoltage-peak, 5.2 milliampere-seconds, and 40 inches source-to-image distance was used. The 30-150 kilovoltage-peak is the range of energy value of diagnostic X-rays (Bushong, 2013).

The X-ray film processor was warmed up, and a couple of scrap films was run through it to stabilize temperature and circulation. The cassette was then loaded with an X-ray film in the darkroom and placed on the tabletop of the exposure room. Six samples of the shield were placed side-by-side on the cassette. Six different Lead markers were placed 2 inches above the sample of shield to indicate the type of shield used. The light field was then collimated to a 14 in x 17 in the area and centered on the radiographic cassette. The first exposure was taken using the radiographic technique mentioned. Five trials of exposure were taken using the same steps.

After exposure, the cassette was transmitted to the darkroom. After transmission, the X-ray film was taken from the cassette in total darkness at a relative humidity of 40-60% inside the darkroom. The film was then fed in the X-ray film processor and processed for about 90 seconds. After processing, the film was then placed in view box for quantitative calculation of transmitted X-ray intensity. Using the densitometer, the optical density as well as the corresponding transmitted intensity in milliRoentgen (mR), was measured for each area in the X-ray film. From the intensity readings of the densitometer, the linear attenuation coefficient of each shield will be calculated using the formula:

$$\mu = -\frac{\ln\left(\frac{I}{I_0}\right)}{t} \quad (1)$$

Where μ is the linear attenuation coefficient with a unit of cm^{-1} , I is the intensity of X-ray radiation after interaction with shielding material (transmitted X-ray intensity), I_0 is the initial intensity (constant at 1 mR), and t is the thickness of shielding material in centimeters (constant at 0.5 cm).

The linear attenuation coefficient is the fraction of a radiation beam that is absorbed or scattered per unit thickness of the shielding material. According to Bushong (2013), materials with a higher linear attenuation coefficient allow a greater number of absorbed or scattered x-rays when controlling for thickness and, thus, could shield radiation better. Conversely, materials with lower linear attenuation coefficient allow a higher number of transmitted x-rays when controlling for thickness and, thus, have lower shielding performance.

Data Analysis

A One-Way Analysis of Variance (ANOVA) was run to compare the mean of the six samples of the radiation shield. A Post Hoc Test using Tukey's Honest Significant Difference (HSD) was employed to confirm the differences that occurred between groups. A p-value of less than 0.05 was considered significant.

RESULTS AND DISCUSSION

In this study, the shielding performance of eggshells was measured in terms of linear attenuation

Table 2

Summary of ANOVA in the Shielding Performance

X-ray Energy		Sum of Squares	df	Mean Square	F
30kVp	Between Groups	59.94	5	11.99	973.62***
	Within Groups	0.30	24	0.01	
	Total	60.24	29		
60kVp	Between Groups	59.94	5	11.99	973.62***
	Within Groups	0.30	24	0.01	
	Total	60.24	29		
90kVp	Between Groups	59.94	5	11.99	973.62***
	Within Groups	0.30	24	0.01	
	Total	60.23	29		
120kVp	Between Groups	59.94	5	11.99	973.62***
	Within Groups	0.30	24	0.01	
	Total	60.24	29		
150kVp	Between Groups	59.94	5	11.99	973.62***
	Within Groups	0.30	24	0.01	
	Total	60.24	29		

Note. ***p < 0.001

Post hoc analysis using Tukey's HSD (Table 3) indicated that among the comparisons, PC and E4 have statistically similar shielding performance (p>0.05)

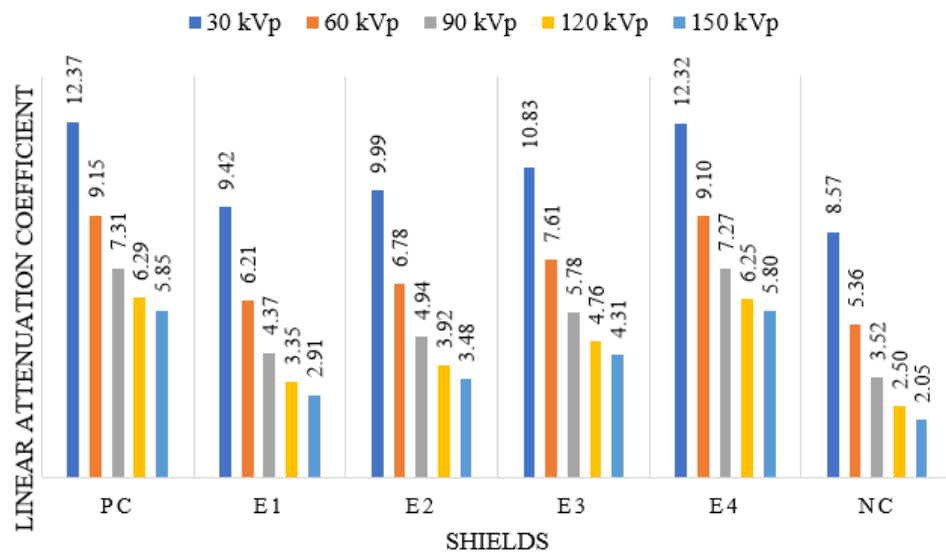


Figure 1. Linear attenuation coefficient (measured in cm⁻¹) of shields

Table 3

Tukey's HSD Comparison for Shielding Performance (Homogeneous Subsets)

X-ray Energy	Group	Subset for alpha = 0.05				
		1	2	3	4	5
30 kVp	NC	8.57				
	E1		9.42			
	E2			9.99		
	E3				10.83	
	E4					12.32
	PC					12.37
60 kVp	NC	5.36				
	E1		6.21			
	E2			6.78		
	E3				7.61	
	E4					9.10
	PC					9.15
90 kVp	NC	5.36				
	E1		6.21			
	E2			6.78		
	E3				7.61	
	E4					9.10
	PC					9.15
120 kVp	NC	2.50				
	E1		3.35			
	E2			3.92		
	E3				4.76	
	E4					6.25
	PC					6.29
150 kVp	NC	2.05				
	E1		2.91			
	E2			3.48		
	E3				4.31	
	E4					5.80
	PC					5.85

Note. No significant difference within the subset; Significant difference between the subsets

coefficient and compared to the standard Lead shield. The shielding performance was analyzed in the 30-150 kVp range to capture the diagnostic X-ray energy range. Figure 1 represents the shielding performance of the six shields used based on X-ray energy. Apparently, at the lowest energy range (30 kVp), the shielding performance was high. However, the shielding performance of all shields reduced rapidly with increments of X-ray energy. Across all energies, PC yielded the highest performance among other shields used. NC, on the other hand, yielded the lowest performance. As shown, an increase in the amount of eggshell increased the shielding performance of the shield.

Due to the extensive use of radiation in the field of medicine, the International Commission on Radiological Protection (ICRP) regulates the doses to the occupational workers and patients to as Low As Reasonably Achievable (ALARA) through requiring all X-ray facilities with shielding. X-ray shielding reduces the total number of X-rays after penetrating through a given thickness of shielding material due to absorption and scattering interactions (Bushong, 2013). Both of these interactions depend on the X-ray energy, and effective atomic number, and mass density of shielding material (Huda, 2010). When controlling for X-ray energy, an ideal shielding material should fulfill several criteria: it must have a high effective atomic number and a high mass density (Allisy-Roberts & Williams, 2008; Fosbinder & Orth, 2011).

In the study, it was observed that an increase in the amount of eggshell powder added to the cement and water increased the linear attenuation coefficient. The increase can be explained by the high ratio of Calcium carbonate, Magnesium carbonate, Calcium phosphate, and organic matter content in eggshells. These molecules were reported to increase the specific gravity, surface area, and weight of the eggshells (Joseph et al., 1999; Soria et al., 2013). The mentioned parameters are directly related to mass density, one of the criteria considered in the development of ideal shielding material (DeHoff et al., 1966; Goel, 2007).

The increase in X-ray energy reduces the shielding performance of all shields used. This reduction of performance can be attributed to the penetrability of X-rays, which increases with energy (Bushong, 2013). Highly penetrating X-rays require greater shielding to attenuate its intensity. The present study observed that there is a rapid decrease in the performance of shields as energy increases; however, the standard Lead shield and the shield with the highest number of eggshells yielded a statistically similar shielding performance across the diagnostic X-ray energy range.

Most diagnostic facilities are lined with Lead shields to protect the patient and radiation workers from radiation. The toxicity of Lead poses hazards to humans, and its disposal is associated with several environmental risks (Moawad et al., 2016). The thick walls and personal protective equipment that are composed of Lead are expensive compared to the eggshells proposed in the study. With the results of the study, the eggshell waste could be assessed as a shielding material.

CONCLUSIONS

X-ray shielding materials are essential in diagnostic imaging facilities. Increasing the number of eggshells increased its shielding performance; however, more shielding is required at higher X-ray energies. Nevertheless, the performance of the standard Lead shield and the shield with the highest number of eggshells yielded a comparable result. This research provides new information on the use of eggshells as alternative shielding material against X-rays in the diagnostic imaging. Future studies may be conducted to include mechanical tests to ascertain the strength and durability of the eggshell shields.

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