Asian Journal of Postharvest and Mechanization

Vol. 7 | No. 1
2024

AJPM

Asian Journal of Postharvest and Mechanization
Vol. 6, No. 2. 2023

Goal and Scope

The aim is to produce and publish an international refereed journal published on-line and on-print for the science and academic community worldwide. Through this journal, an accessible venue for sharing research information is provided.

The scope of the journal is specifically on postharvest and mechanization research, development and extension (RD&E). It is divided into the following content categories: Engineering, Biology and Chemistry, and the Social Sciences.

About the Publication

The journal is published semi-anually by the Philippine Center for Post-harvest Development and Mechanization (PHilMech) in partnership with the Sustainable Agriculture, Food and Energy (SAFE) Network. It has a print circulation of 1,000 copies per issue sent to local and international partner institutions and organizations.

Published by the:
Philippine Center for Postharvest Development and Mechanization (PHilMech)
CLSU Compound, Science City of Muñoz, Nueva Ecija, Philippines
Tel. Nos. +63 932 869 6837 (SUN); +63 917 813 0852 (GLOBE)

ISSN: 2546-1346

ASIAN JOURNAL OF POSTHARVEST AND MECHANIZATION

Department of Agriculture
Philippine Center for Postharvest Development and Mechanization
CLSU Compound, Science City of Muñoz, Nueva Ecija, 2023

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CONCENTRATION OF ARSENIC AND HEALTH RISK IN BIGHEAD CARP (*HYPOPHTHALMICHTHYS NOBILIS*) CULTURED IN LAGUNA LAKE FISH PEN IN PILILLA, RIZAL

Ken Darwin B. Hilado[1] and Eleonor F. Santiago[2]

ABSTRACT - *This study focuses on the concentration of arsenic and the health risk assessment of bighead carp (Hypophthalmichthys nobilis) consumption cultured in the Laguna Lake fish pen in Pililla, Rizal. Water and fish samples were collected in three sampling sites in one of the fish pens in the town and immediately submitted to SGS Philippines, Inc. laboratory for water and arsenic analysis. Concentration of arsenic in water was determined using the Atomic Absorption Spectrophotometry Method (3114B). The heavy metal analysis for arsenic (As) in fish was carried out using microwave digestion and quantitation by Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES). Physicochemical properties of water namely temperature, turbidity, pH, dissolved oxygen (DO), and total dissolved solids (TDS) were also analyzed. The data for the physicochemical properties of water and concentration of arsenic in water in all sampling sites are within the standard of water quality for Class C water set by the Department of Environment and Natural Resources (DENR). Estimates of health risk associated with fish consumption in terms of Non-carcinogenic Health Quotient (THQ) values are less than 2.88 x 10-7 which is low and do not pose harm to human health. The carcinogenic health risk values are found to be less than 5.56 x 10-6 is below the threshold value of 1.0 x 10-6 which means that consumption of bighead carp cultured in Laguna Lake fish pen in Pililla, Rizal do not pose risk of developing cancer to consumers.*

Keywords: *Bighead Carp, Hypophthalmichthys nobilis, Concentration of arsenic, Health risk, Laguna Lake*

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Received 3 August 2023; Accepted 31 January 2024

INTRODUCTION

Laguna de Bay is the largest freshwater lake in the Philippines bordered by the province of Laguna in the East, West and Southwest, the province of Rizal in the North to Northeast, and Metro Manila in the Northwest. The lake features three distinct bays, the West Bay, Central Bay and East Bay that diverges to the South (South Bay). The East Bay is the least populated while the West Bay watershed is the most populated and heavily developed, mainly because it includes part of Metro Manila. The West and Central Bay is separated by the biggest and most populated island within the Lake which is the Talim Island. It is located in an industrialized area and at the same time it is home to many native and cultured fishes such as bighead, milkfish, tilapia and others.

Since the lake is within the confine of rapidly growing provinces, uncontrolled development, population growth, and industrialization are major threat to its environmental conditions. It is now regarded that the lake serves as a huge waste sink for solid and liquid wastes coming from households, cropland areas, industries, livestock and poultry production as well as fishery activities. In addition, polluted waters from the Marikina and Pasig Rivers also flow into the lake. (Santos et al., 2006)

The contamination of heavy metals in rivers or lakes has drawn increasing attention, as heavy metals have characteristics of potential toxicity, persistence, and non-biodegradation which pose potential risks on aquatic ecosystems and human health. Heavy metals may enter and accumulate in the human body through ingestions and once toxic levels are reached in organisms, diversity of benthic organisms and reproduction rates can decrease, and growth rates can even be reduced, causing an adverse effect on aquatic ecosystems. (Wan et al., 2016)

One of the heavy metals that poses health risk is arsenic. Arsenic is widely distributed throughout the earth's crust and is found in groundwater. Soluble inorganic arsenic is acutely toxic. Intake of inorganic arsenic over a long period can lead to chronic arsenic poisoning (arsenicosis). Effects include skin lesions, peripheral neuropathy, diabetes, cardiovascular diseases and cancer which can take years to develop depending on the exposure level (WHO, 2019)

Arsenic can be found in food, soil and water. Food wastes, water that discharges in water bodies, soil that are transferred through erosion can be the medium of arsenic transport to bodies of water. Once deposited in bodies of water it can be transferred to aquatic species such as tilapia, milkfish, bighead and others (Guerrero, 2017).

Of the heavy metals associated with fish species such as cadmium, lead, mercury, arsenic and chromium, arsenic is the only confirmed human carcinogen (class A) through the oral route of exposure while chromium, although also carcinogenic, exposure is only through the inhalation route (Molina, 2011).

Big head carp is one of the fishes grown in Laguna Lake fish pens because it is ideal for fishponds and fish pens due to its rapid growth. These carps are now quite well established around the freshwater waterways of Luzon including lakes, rivers and reservoirs. They are often called by many different names such as Imelda, Karpa, and Black Mass because they are a newly introduced specie and unknown to many (FAO, 2013).

Fish pen and cages in Pililla, Rizal area usually raising bighead carp, bangus and tilapia in either monoculture or polyculture environment. The majority of fish pen operations in Laguna Lake use the extensive method of culturing bighead carp which depends on the natural food in the lake for feeding the fish. However, there are also some operations that utilize the intensive method which uses supplemental feed in addition to natural food (Israel, 2008).

Latest figures of Department of Agriculture – Bureau of Agricultural Statistics (DA – BAS) indicated that bighead carp has edged out milkfish as preferred fish for stocking in fish pen in the freshwater lake. Over the years, bighead carp production has increased considerably from 2,500 tons in 1997 to 28.97 thousand metric tons in 2018. The bighead carp has always been a secondary species in milkfish pens where they may be stocked together with milkfish but in low numbers (Fernadez, 2018). Its ability to thrive in varying water conditions make it an ideal fish to be grown in the confines of inland ponds or pens (Sea Port Products, 2018). It is also one of the most commercially important fishes in Laguna Lake (Israel, 2008).

Based on the method developed by United states Environmental Protection Agency (USEPA), health risk assessment has been established to examine the risks of fish consumption. Health risk assessment is the process to estimate the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future (HRA, 2016).

Health risk assessment of heavy metals specifically arsenic in bighead carp is important because it serves as basis in determining and in understanding the element of risks associated with the consumption of the fish in the form of either non-carcinogenic or carcinogenic health risks. This study assesses the chronic non-carcinogenic and carcinogenic health risks associated with arsenic in bighead carp cultured in Laguna Lake fish pen in Pililla, Rizal. Figure 1 represents the conceptual framework of the research.

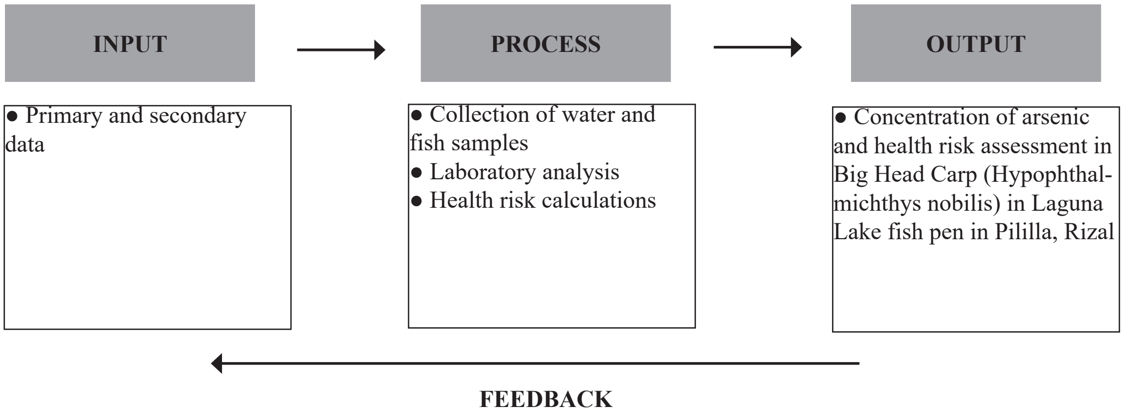

Figure 1. The Conceptual Framework of the Study

The first frame is the **input** which includes the interview and field visit undertaken during the conduct of the study. The second frame is the **process** which shows the collection of fish and water samples, laboratory analysis for water parameters such as temperature, turbidity, pH, dissolved oxygen (DO), and total dissolved solids (TDS) and level of arsenic in big head carp.

The third frame presents the **output** which includes the concentration of arsenic and health risk in the consumption of big head carp (Hypophthalmichthys nobilis) cultured in Laguna Lake fish pens in Pililla, Rizal. The **feedback** is the improvement that needs to be done for better analysis of data on the concentration of arsenic and assessment of health risk in the consumption of big head carp cultured in Laguna Lake fish pens in Pililla, Rizal.

METHODOLOGY

Sampling

Water and fish samples were collected from the site in March 2020 and immediately submitted to SGS Philippines, Inc. laboratory for analysis. Water samples were collected from different locations in the fish pen and the fish samples of the same sizes were gathered from a single fish pen with nearly similar cultural practices particularly feeding habits.

The fish pen has a surface area of one hectare with fish cages inside it with a total population of 5000 bighead carp. Figure 2 shows the location of the sampling site.

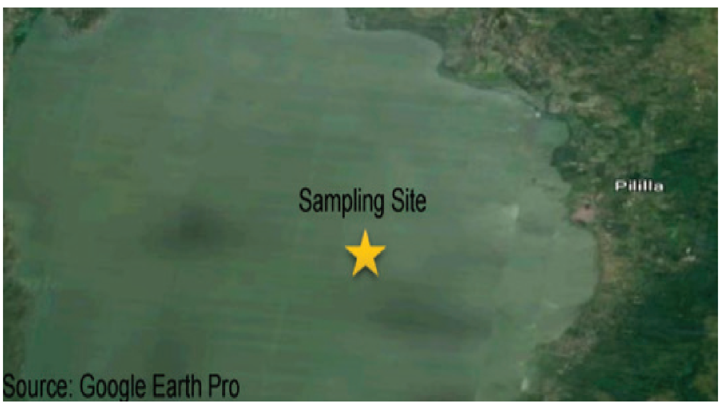

Figure 2. Location map of the sampling site

Laboratory analysis

The levels of arsenic in water were determined using Atomic Absorption Spectrophotometry Method (3114B) while the concentrations of arsenic in the muscles of the big head carp were determined using microwave digestion and quantification through Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES). For the physico-chemical analysis, the parameters considered are temperature, turbidity, pH, dissolved oxygen (DO) and total dissolved solids (TDS).

Estimation of human health risks associated with Arsenic in Bighead Carp

Non-carcinogenic health risks:

Calculation of the non-carcinogenic health risks were done by estimating the daily intake of consumers (CDI) for the toxicant as well as the target hazard quotient (THQ) using the following equations (Micheal et al., 2015):

EQUATION 1:

$$THQ = \frac{CDI}{RfD}$$

Where:

THQ = Target hazard quotient
CDI = Estimated daily intake for the toxicant expressed in mg/kg-day
RfD = Chronic oral reference dose for arsenic = 0.0003 (mg/kg/day) (US EPA, 1998)

CDI is the chronic daily heavy metal intake (mg/kg/day) and RfD is the oral reference dose (mg/kg/day) which is an estimation of the maximum permissible risk on human population through daily exposure (Li and Zhang, 2010). EPA-recommended Rf D values of Fe, V, Cr, Co, Cu, Zn, Mn, Ni, As, Cd, and Pb were used in the above equation. (Li et al., 2013 and US EPA, 2002)

The target hazard quotient (THQ) is the ratio of exposure to the toxic element and the reference dose which is the highest level at which there is no adverse health effects expected. THQ describes the non-carcinogenic health risk posed by exposure to the respective toxic element being assessed. THQ of less than 1 implies that non-carcinogenic health effects are not expected while THQ of greater than 1 implies that there is a possibility that adverse health effects could be experienced. (Antoine, 2017 and Yadola et al., 2017).

EQUATION 2:

$$EDI = \frac{C \times EF \times ED \times IRF \times (kg)/(1000g) \times 0.10}{(365\ days)/(year) \times LT \times BW}$$

Where:

EDI = Estimated daily intake for the toxicant expressed in mg/kg-day
C = Concentration or level of heavy metal in fish
BW = Base on FNRI the average of adult mean body weights of male and female Filipinos (aged 20 and above) at 61.3 and 54.3 kg. The body weight (for Filipino adult) is equivalent to 57.8 kg. (FNRI, 2015)
0.10 = Factor to convert total arsenic to inorganic arsenic.
ED = Exposure duration equivalent to 30 years
EF = Exposure frequency equivalent to 365 days per year
IRF = Ingestion rate of fish (fish consumption) equivalent to 9.86 g/day, this is the mean one-day per capita consumption of tilapia in the Philippines (FNRI, 2016)
T = Lifetime (average), 30 years for non-carcinogenic health effects and 70 years for carcinogenic health effects (Dela Cruz et al., 2017 and Molina, 2011)

Carcinogenic health risks

Exposure to arsenic induces cardiovascular diseases, developmental abnormalities, neurologic and neurobehavioral disorders, diabetes, hearing loss, hematologic disorders, and various types of cancer. Pathways of exposure include ingestion and inhalation and via dermal and parenteral routes. The severity of health effects depends on the chemical form of arsenic, length of exposure and dosage. (Tchounwou, 2004)

The health risk associated with carcinogenic exposure is acceptable if the risk index is higher than the threshold value of 1.0 x 10^{-6} (Lee et al., 2008). The excess lifetime cancer risk was calculated using the following equation:

EQUATION 3:

$$TR = EDI \times SF$$

Where:

TR = Target risk, a unit less probability of an individual developing cancer over a lifetime
EDI = Estimated daily intake or dose in mg/kg-day
SF = Slope factor equivalent to 1.5 mg/kg-day for inorganic arsenic based on Integrated Risk Information System (US EPA, 1998; US EPA, 1984)

RESULTS AND DISCUSSION

Physicochemical properties of water in the sampling site

Table 1 shows the values of the physicochemical properties of water in the Laguna Lake fish pen such as temperature, turbidity, pH, dissolved oxygen (DO), total dissolved solids (TDS) and levels of arsenic.

Table 1. Mean Values of Physicochemical Properties of Water

Physicochemical Properties	Results
Temperature	28 °C
Turbidity	37 NTU
pH	6.76 at 17°C
Dissolved Oxygen	7.6 mg/L
Total Dissolved Solids	384 mg/L
Arsenic	0.002 mg/L

The health and subsequent growth of fish are directly related to the quality of water in which the fish is raised. The average temperature of water in the sampling sites is 28°C. The data are within the standard of Class C water set by the Department of Environment and Natural Resources (DENR). Water temperature is one of the most important physical factors affecting fish growth and production. Fish are cold-blooded animals which assume approximately the same temperature as their surroundings.

Within each temperature classification, fish survival is bounded by an upper and lower temperature, between which an optimum temperature for growth exists (Viadero, 2005). Thus, the temperature recorded in this study are good for growth and survival of Bighead Carp.

The turbidity of the water in the lake is 37 NTU. Turbidity affects the quality of lakes and may result in biological effects on aquatic organisms such as disruption in migrations and spawning, movement patterns, sublethal effects (e.g., disease susceptibility, growth, and development) reduced hatching and direct mortality (Kjelland et al., 2015). The average pH value of water in the sampling sites is 6.76 at 17°C. The pH of water are within the standard range of Class C water set by the DENR which is 6.5 to 9.0. The pH values in the site is good for bighead carp growth.

The result of the analysis indicated that the dissolve oxygen is 7.6 mg/L. This is within the standard of water quality guidelines set by DENR. Based on the guidelines the dissolved oxygen for Class C water should be at least 5mg/L. Dissolved oxygen below 5mg/L is harmful to aquatic organisms (Floyd et al., 2007)

In terms of total dissolved solids, based on the analysis, water in the sampling site has TDS of 384 mg/L. High level of TDS is an indication of high content inorganic salts and small amounts of organic matter present in water. As of this time, the TDS standard for different classes of water is not yet established. These amounts can have many negative effects on aquatic life (Fondriest, 2010). Changes in TDS concentrations in natural water often results from industrial effluent, changes to the water balance or by saltwater intrusion (Weber-Scannell et al, 2007).

The levels of Arsenic in water from the sampling site is 0.002 mg/L. This result is within the water quality standard of Class C water set by the DENR for arsenic which is 0.02 mg/L.

Levels of Arsenic in Bighead Carp Collected from the Sampling Sites

Table 2 shows the concentration of arsenic in bighead carp from the sampling sites.

Table 2. Levels of Arsenic in Bighead Carp

Sampling Sites	Arsenic (mg/kg)
Site 1	<0.05 mg/kg
Site 2	<0.05 mg/kg
Site 3	<0.05 mg/kg

The concentrations of arsenic are below 0.05 mg/kg which means that the bioaccumulation of arsenic in bighead carp is very low.

Estimated non-carcinogenic health risk values associated with arsenic in bighead carp

Table 3 shows the THQ values associated with bighead carp consumption collected from the sampling sites.

Table 3. Target Hazard Quotient (THQ) Values of Arsenic in Bighead Carp

Sampling Sites	THQ Values
Site 1	$<2.88 \times 10^{-7}$
Site 2	$<2.88 \times 10^{-7}$
Site 3	$<2.88 \times 10^{-7}$

The values computed in all the sampling sites are less than 2.88×10^{-7} which implies that consumption of bighead carp harvested in the study site do not pose non-carcinogenic risk due to the concentration of arsenic. (Antoine, 2017 and Yadola et al., 2017)

Estimated carcinogenic health risk values associated with arsenic in bighead carp

Table 4 shows that the average lifetime cancer risk value associated with consumption of bighead carp in all sampling sites is less than 5.56×10^{-6}.

Table 4. Target Risk (TR) Values of Arsenic in Tilapia

Sampling Sites	THQ Values
Site 1	$<5.56 \times 10^{-6}$
Site 2	$<5.56 \times 10^{-6}$
Site 3	$<5.56 \times 10^{-6}$

This result indicates that less than 56 consumers per 1,000,000 population has the probability of having cancer below the threshold value of 1.0×10^{-6} (Lee et al., 2008; EPA, 2019). Based on these computed target risk (TR), the consumption of bighead carp cultured in the Laguna Lake fish pens in Pililla, Rizal do not cause carcinogenic related illnesses to consumers.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The physicochemical properties of water such as temperature, turbidity, pH, dissolved oxygen (DO), total dissolved solids (TDS) and concentration of arsenic are within the guidelines of water quality standard of Class C water set by the Department of Environment and Natural Resources (DENR).

The concentration of arsenic in cultured bighead carp from the sampling sites are below 0.05 mg/kg and do not pose harm to human health. The non-carcinogenic health value is less than 2.88×10^{-7} which implies that consumption of bighead carp in the site do not cause non-carcinogenic risk to consumers (Antoine, 2017 Yadola et al., 2017).

The carcinogenic health risks present the lifetime cancer risk value associated with consumption of bighead carp in all sampling sites is found to be less than 5.56×10^{-6} which is far below the threshold value of 1.0×10^{-6} (Lee et al., 2008; EPA, 2019). Therefore, the consumption of cultured bighead carp in the sampling sites do not pose risk of developing cancer to consumers.

Based on the analysis and findings of the study, the following conclusions are drawn:

1. The physicochemical properties of water in the sampling sites are within the guidelines and standard for Class C waters set by Department of Environment and Natural Resources; and
2. Fish samples from the sites are safe for human consumption in both noncarcinogenic and carcinogenic health risks.

The following are some of the recommendations:

1. Studies identifying the animal food products and establishments that can be possible sources of heavy metals in the lake must also be done to assess the best options in protecting the lake and human health from these contaminants; and
2. There must be a timely monitoring of the Laguna de Bay water quality, sediments, and aquatic species by concerned agencies through in cooperation with the Department of Environment and Natural Resources (DENR), Department of Health (DOH) and Local Government Units (LGUs) to ensure its safety for food consumption in the fishes and that the law will not be violated.

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CONCENTRATION OF ARSENIC AND HEALTH RISK IN TILAPIA (*OREOCHROMIS NILOTICUS)* CULTURED IN LAGUNA LAKE FISH PEN IN PILILLA, RIZAL

Cinderella R. dela Cruz [1] and Eleonor F. Santiago[2]

ABSTRACT - *This paper assesses the concentration of arsenic and health risk of Tilapia (Oreochromis niloticus) cultured in the Laguna Lake fish pen in Pililla, Rizal. Physicochemical properties of water such as temperature, turbidity, pH, dissolved oxygen (DO), and total dissolved solids (TSS) were included. Fish and water samples were collected in three sampling sites in one hectare size fish pen in Pililla. Both of the samples were submitted immediately to SGS Philippines, Inc. for analysis. The levels of arsenic in the muscle of tilapia were determined using microwave indigestion and quantitation by Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) while the level of arsenic in water was determined using Atomic Absorption Spectrophotometry Method (3114B). The physicochemical properties of water namely turbidity, pH, dissolved oxygen (DO), and total dissolved solids (TDS) were also analyzed by SGS Philippines, Inc. while the temperature was determined using laboratory thermometer. The result of the study in fish consumption were estimated according to non-carcinogenic and carcinogenic health risk. Non-carcinogenic THQ value is computed to be less than 2.88 x 10^{-3} in all sampling sites. This implies that tilapia in Pililla areas have no visible non-carcinogenic risk effects of arsenic. The Target Risk (TR) value associated with consumption of tilapia in all sampling sites is less than 5.56 X 10^{-7}. Based on the computed TR value, since the probability is very low, consumption of cultured tilapia collected in the sampling sites in Pililla are generally safe.*

Keywords: *Tilapia, Oreochromis niloticus, Concentration of arsenic, Health risk, Laguna Lake*

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Received 3 August 2023; Accepted 2 February 2024

INTRODUCTION

Laguna de Bay, also known as Laguna Lake, is the largest lake in the Philippines and among the largest lakes in Southeast Asia. It is a significant natural resource that provides a variety of environmental goods and services to the surrounding community such as food, water for irrigation, power supply, cooling of industrial equipment and source of raw water for domestic supply. (Israel, 2007)

At present, it is predominantly used for open water fishing and aquaculture. Hence, it is also valuable in the aquaculture industry. Some fish species including those that are not native to its waters, can be grown in controlled environments in the lake which brought about the rapid aquaculture development within the lake area. (LLDA, 2006)

Aquaculture accounts for a growing share in the global aquatic food production and is important in food and nutrition security and in providing livelihoods for millions of people. Aquaculture covers all forms of farming of aquatic animals and plants in freshwater, brackish water and saltwater. In the same manner as agriculture is the controlled production of food to improve the supply for human consumption, aquaculture is the controlled production of aquatic animals and plants. (FAO, 2014)

Fish produced through aquaculture improves the food supply system and the overall human health and nutrition. Fish is an important source of nutrients such as vitamins A, B and D; calcium; iron; and iodine. Fish also provides essential amino acids that are often lacking in staple foods such as rice and cassava. Therefore, aquaculture is vital to the food security of many of the world's poor population especially those residing near coastal areas and small islands. Protein and nutrient-rich food throughout the year could be produced through aquaculture. Low-income farmers who invest in fish farming will be able to generate additional income and food for their family and for the market. (FAO, 2014)

Aquaculture can be carried out in a pond, river, lake, estuary or in the sea. Planning is essential for an aquaculture operation to be successful. Although climate is not a limiting factor as to the scale of aquaculture, it can influence the choice of species to be grown. Other factors that must be taken into consideration are the available resources such as water and land area, local temperature and other factors that influence the choice of species to be farmed as well as the production system to be used. Availability of high-quality water is usually the most crucial resource when making decisions as to where, what and how much fish to farm. (FAO, 2014)

Tilapia is among the fish species commonly grown through aquaculture in fish pens and cages in the Laguna Lake. Tilapia farming in the Philippines have the highest potential to be "green" or environmentally friendly. Originally, tilapia was promoted as a pond fish for culture to aid poor, rural families in developing tropical countries. It subsequently became the second most farmed fish in the country next to milkfish (Chanos chanos). Tilapia availability for Filipinos is 2.8 kg/year per capita in 2016 compared with 2.5 kg/year per capita for milkfish. However, due to overcrowding strains and water pollution, the number of fish pens in the Laguna de Bay have been reduced to address the negative ecological and social impacts. (FAO, 2009 and Guerrero, 2009)

Arsenic is one of the most toxic metals naturally occurring in the environment and widely distributed in the earth's crust. It may enter the air, water and land from wind-blown dust and may get into water from runoff and leaching. Arsenic in groundwater is a widespread problem with levels that tend to be higher in drinking water coming from ground sources such as wells, as compared to water from surface sources such as lakes and reservoirs. Excessive and prolonged exposure to inorganic arsenic with drinking water causes arsenicosis, a deteriorating and disabling disease characterized by skin lesions and pigmentation on the hands and soles of feet. Inorganic arsenic is a human carcinogen associated with skin, lung, bladder, kidney, and liver cancer. Arsenic poisoning is fatal. Chronic arsenic toxicity results in multisystem disease with the fish species having the highest lifetime cancer risk. (EPA, 2007 and Ratnaike, 2003)

Arsenic toxicity is a global health problem affecting millions of people. Crops irrigated with contaminated water and food prepared with contaminated water are the sources of exposure. Arsenic from natural geological sources leaching into aquifers and those from mining and other industrial processes contaminates drinking water. (WHO, 2018)

The heavy metals associated with fish species are cadmium, lead, mercury, arsenic and chromium. Through the oral route of exposure, arsenic is the only confirmed human carcinogen (class A) while chromium exposure is carcinogenic through the inhalation route (Molina, 2011).

The purpose of this research is to assess the concentration of arsenic in Tilapia (*Oreochromis niloticus*) cultured in the Laguna Lake fish pens in Pililla, Rizal. Figure 1 represents the conceptual framework of the research.

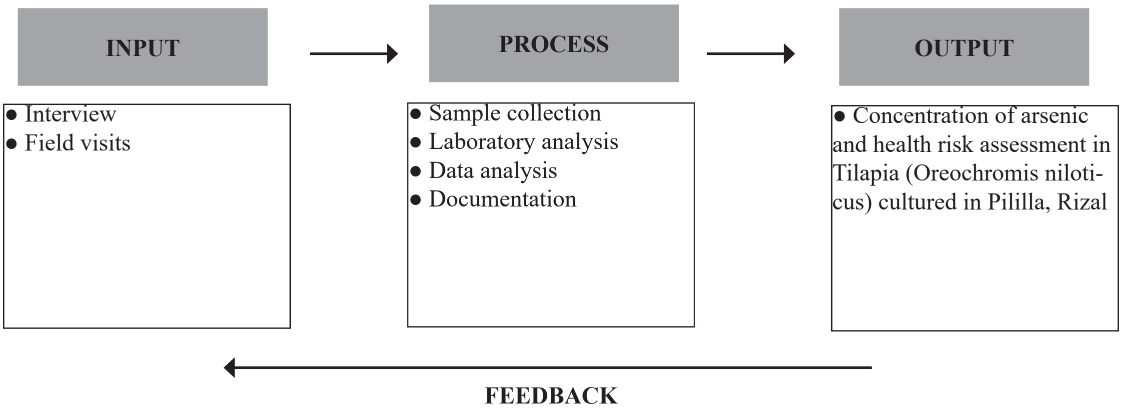

Figure 1. The Conceptual Framework of the Study

The first frame is the **input** which shows the interview and field visit in the area. The second frame is the **process** which shows the data gathering, sample collection, laboratory analysis, data analysis and documentation. The third frame presents the **output,** which is the concentration of arsenic and health risk in Tilapia (*Oreochromis niloticus*) cultured in a fish pen in Pililla, Rizal. The **feedback** represents the information obtained in the study that could be used to further enhance the analysis of the concentration of arsenic and assessment of the health risk in Tilapia cultured in fish pens in Pililla, Rizal.

METHODOLOGY

Sampling and laboratory analysis

The sampling site is located at Central Bay of Laguna Lake (Figure 2). It is adjacent to the town of Pililla, Rizal. The coordinates of the location of the fish pen were determined using Geographic Positioning System (GPS). The fish pen is made up of woods and bamboo secured with fishnets with an area of one hectare. Fish and water samples were collected from the location on March 2020. A 2-liter composite water sample was gathered and three fish samples were collected by randomly choosing tilapia of almost the same size and feeding system from the fish pen. These samples were submitted to SGS Philippines, Inc. laboratory for analysis.

The parameters considered for the physicochemical properties of the water sample are temperature, turbidity, pH, dissolved oxygen (DO) and total dissolved solids (TDS). The concentration of arsenic in the water sample was determined using Atomic Absorption Spectrophotometry Method (3114B) while the levels of arsenic in the muscle of Tilapia were determined using microwave ingestion and quantification through Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES).

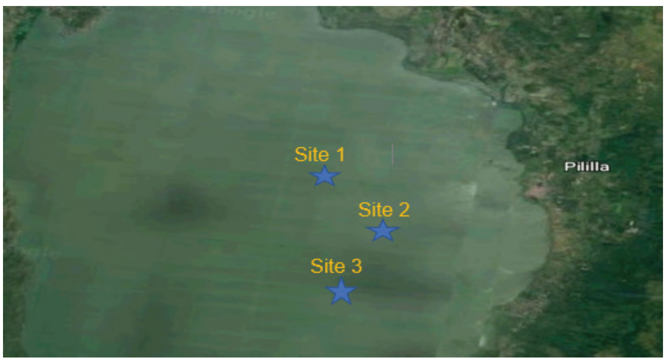

Figure 2. Location of the sampling sites

Estimation of human health risks associated with Arsenic in Tilapia

Non-carcinogenic health risks:

Calculation of the non-carcinogenic health risks were done by estimating the daily intake of consumers (CDI) for the toxicant as well as the target hazard quotient (THQ) using the following equations (Micheal et al., 2015):

EQUATION 1:

$$THQ = \frac{CDI}{RfD}$$

Where:

THQ = Target hazard quotient
CDI = Estimated daily intake for the toxicant expressed in mg/kg-day
RfD = is the oral reference dose (mg/kg/day)

CDI is the chronic daily heavy metal intake (mg/kg/day) and RfD is the oral reference dose (mg/kg/day) which is an estimation of the maximum permissible risk on human population through daily exposure. EPA-recommended Rf D values of Fe, V, Cr, Co, Cu, Zn, Mn, Ni, As, Cd, and Pb were used in the above equation. (Sultana et.al., 2017).

EQUATION 2:

$$\frac{C \times EF \times ED \times IRF \times (kg)/(1000g)}{(365\ days\ /\ year) \times\ LT \times BW} \times 0.10$$

Where:

CDI = Estimated daily intake for the toxicant expressed in mg/kg-day
C = Concentration or level of heavy metal in fish
BW = Base on FNRI the average of adult mean body weights of male and female Filipinos (aged 20 and above) at 61.3 and 54.3 kg. The body weight (for Filipino adult) is equivalent to 57.8 kg. (FNRI, 2015)
0.10 = Factor to convert total arsenic to inorganic arsenic.
ED = Exposure duration equivalent to 30 years
EF = Exposure frequency equivalent to 365 days per year
IRF = Ingestion rate of fish (fish consumption) equivalent to 9.86 g/day, this is the mean one-day per capita consumption of tilapia in the Philippines (FNRI, 2016)
LT = Lifetime (average), 30 years for non-carcinogenic health effects.

Carcinogenic health risks:

Generally, the health risk associated with carcinogenic exposure is acceptable if the risk index is higher than the threshold value of 1.0 x 10^{-6} (Lee et al., 2008). A risk value of 1.0 x 10^{-6} indicates 1 cancer case per 1000,000 populations (Molina, 2011).

To estimate the carcinogenic health risks associated with inorganic As ingestion, the equations and methodology developed by USEPA were used:

EQUATION 3:

$$TR = CDI \times SF$$

Where:

TR = Target risk, a unit less probability of an individual developing cancer over a lifetime
CDI = Estimated daily intake or dose in mg/kg-day
SF = Slope factor equivalent to 1.5 mg/kg-day for inorganic arsenic based on Integrated Risk Information System (US EPA, 1998; US EPA, 1984)

RESULTS AND DISCUSSION

Physicochemical properties of water in the sampling site

Table 1 shows the values of the physicochemical properties of water in a fish pen in Laguna Lake adjacent to the town of Pililla such as temperature, turbidity, pH, dissolved oxygen (DO), total dissolved solids (TDS) and levels of arsenic.

Table 1. Mean Values of Physicochemical Properties of Water

Physicochemical Properties	**Results**
Temperature (°C)	28
Turbidity (NTU)	37
pH	6.76 at 17°C
Dissolved Oxygen (mg/L)	7.6
Total Dissolved Solids (mg/L)	384
Arsenic (mg/L)	0.002

The average water temperature in the study site is 28°C. Tilapia is a warm-water fish which thrive at optimum temperature in the range of 24-34°. Their growth rates decline rapidly at temperature below 20°C. Mortality is often experienced at temperatures of 11°C and below. (Henk, 2020). Thus, the temperatures recorded in this study are suitable for growth and survival of tilapia.

The water turbidity in the study site is measured at 37NTU. Turbidity can fluctuate rapidly during the early life of fishes, impacting foraging behaviors. (Andree 2018 et al.) Turbidity levels in earthen ponds should be kept below 100 mg/L. (Ardjosoediro, 2002) Thus, the water in Pililla is good for the survival and growth of tilapia.

The average pH value of water in the fish pen adjacent to the town of Pililla is 6.76. Fish cannot survive in waters below pH 4 and above pH 11 for long periods. The optimum pH for fish is between 6.5 and 9. Fish will grow poorly and reproduction will be affected at consistently higher or lower pH levels (Yokogawa Philippines 2004). The average pH in the study is considerably good for growth and reproduction of tilapia.

The water in study site has 7.6 mg/L dissolved oxygen. Based on water quality guidelines set by Department of Environment and Natural resources the dissolved oxygen in Type C water body must be at 5 mg/L. Fish growth, feed utilization, and innate immunity were adversely affected by low DO. (Hagras 2015 et al.) The DO of water in the study site shows that the dissolved oxygen is higher than the required DO which implies suitability for fish farming.

The total dissolved solids in Pililla water sample is 384 mg/L. The TDS standard for different classes of water is not yet established (Bernados 2019); however, high concentrations of total dissolved solids may reduce water clarity, which contributes to a decrease in photosynthesis and lead to increase in water temperature. Many aquatic organisms cannot survive in high temperature. A level of 400 ppm (400 mg/L) TDS is recommended for freshwater. Thus, 384 mg/L TDS is nearly suitable for tilapia.

In terms of arsenic, water sample in the study site had 0.002 mg/L. This is equal to the allowed concentration of As for Class C water quality guidelines for secondary parameters-metals set by the Department of Environment and Natural resources.

Levels of Arsenic in Tilapia Collected from the Sampling Sites

Table 2 shows the concentration of arsenic in tilapia from the sampling sites.

Arsenic concentration is less than <0.05 mg/kg. It is considerably lower than concentration of the previous study in Central Bay of Laguna Lake. Based on the study of Molina in 2011, the concentration of As in tilapia at that time is 0.085 mg/kg. The difference in the concentration of As in tilapia could be due to the difference in the exposure such as the location of the fish cages, feeding habits, time and season, either from water borne-arsenic or contaminated food particles.

Estimated non-carcinogenic health risk values associated with arsenic in tilapia

Table 3 shows the THQ values of tilapia consumption with arsenic collected from the sampling sites.

Table 2. Levels of Arsenic in Tilapia

Sampling Sites	Arsenic (mg/kg)
Site 1	<0.05 mg/kg
Site 2	<0.05 mg/kg
Site 3	<0.05 mg/kg

Table 3. Target Hazard Quotient (THQ) Values of Arsenic in Tilapia

Sampling Sites	THQ Values
Site 1	$<2.88 \times 10^{-3}$
Site 2	$<2.88 \times 10^{-3}$
Site 3	$<2.88 \times 10^{-3}$

The computed THQ value in all the sampling sites is less than 2.88×10^{-3}. This implies that consumption of tilapia harvested in the study site do not pose non-carcinogenic risk effects due to the concentration of arsenic in tilapia.

Estimated carcinogenic health risk values associated with arsenic in tilapia

Table 4 reveals that the average lifetime cancer risk value associated with consumption of tilapia in all sampling sites is less than 5.56×10^{-7}.

Table 4. Target Risk (TR) Values of Arsenic in Tilapia

Sampling Sites	TR Values
Site 1	$<5.56 \times 10^{-7}$
Site 2	$<5.56 \times 10^{-7}$
Site 3	$<5.56 \times 10^{-7}$

The data indicates that less than 56 cancer cases may happen per 10,000,000 population. Based on the computed TR value since the probability is very low, consumption of cultured tilapia collected in the sampling sites are generally safe.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

All of the physicochemical properties of water such as temperature, turbidity, pH, dissolved oxygen (DO), total dissolved solids (TDS) and levels of arsenic are within the Class C water quality standard set by the Department of Environment and Natural Resources (DENR). All sampling sites have less than 0.005 mg/kg concentration of arsenic in cultured tilapia and consumption do not pose harm to human health.

In terms of non-carcinogenic health risks, the computed THQ value in all sampling sites is less than 2.88 X 10^{-3} and can be interpreted as very low This implies that the people who consumes tilapia harvested in the study site are not readily exposed to non-carcinogenic health risk associated with tilapia consumption.

In terms of carcinogenic health risks, the average lifetime cancer risk value associated with consumption of tilapia in all sampling sites is less than 5.56 X 10^{-7}. Thus, this result indicates that consumption of cultured tilapia collected in the sampling sites are safe.

Based on the analysis and findings of the study, the following conclusions are drawn:

1. The physicochemical properties of water in the sampling sites are within the set standard for Class C water set by the Department of Environment and Natural Resources.
2. All of the fish samples from the sampling sites do not pose harm to human health as indicated by both non-carcinogenic and carcinogenic health risks.

The following are some of the recommendations:

1. Maintain the regular monitoring of the site including regular and periodic monitoring of the levels of Arsenic and other heavy metals by the Bureau of Fisheries and Aquatic Resources (BFAR) and other concerned government agencies.

2. Conduct more studies on other heavy metals that can be found in the lake and their possible effects on human health.
3. Establish policies and guidelines for sustainable aquaculture, that is, it should be in harmony with the condition of the natural resources, and beneficial to people living in the area.

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DEVELOPMENT OF ARDUINO-CONTROLLED VERTICAL HYDROPONIC SYSTEM

Maria Janelle P. Derpo[1] and Eleonor F. Santiago[2]

ABSTRACT - *The Arduino-controlled vertical hydroponic system was developed for a small-scale production of lettuce under closed and controlled environment. The system consists of the following components: growing chamber, pump and pipe assembly, and control unit. The main control board was the Arduino Mega 2560 and a BME 280 sensor for monitoring temperature and relative humidity. The overall dimensions of the vertical hydroponic system are 1.8 m (length) x 1.0 m (width) x 1.9 m (height) and is capable of growing 72 heads of lettuce. The Arduino is capable of controlling the operation of lighting and fans to maintain a suitable environment inside the chamber. The designed system attains its optimum operating conditions at an outside temperature of 22.67ºC to 23.50ºC. It is 88.90% and 99.86% efficient in controlling the temperature and relative humidity inside the chamber, respectively. The total investment cost of Arduino controlled vertical hydroponic system is Php 14,428.50 while Php 4,630.00 for the traditional hydroponic system. The electricity consumption in utilizing the Arduino controlled vertical hydroponic system is 31.5 kW/month and 2.4 kW/month for traditional hydroponic system. The cost of producing lettuce for both systems is Php 150.00 per kilogram.*

Keywords*: Vertical farming, Hydroponic system, Arduino, Lettuce, Greenhouse*

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Received 3 August 2023; Accepted 9 February 2024

INTRODUCTION

Vertical farming or high-rise farming is an indoor, urban farming technology involving agricultural production in buildings and in greenhouses while hydroponics is one of the methods to produce crops in soil-less nutrient solution (Pascual et.al, 2018). The technology on hydroponic systems is not new. Experiments in growing mint plants without soil can be traced back to 17th century France and England. In 1925, the United States also began experimenting to make plant nutrient solution to replace greenhouse soil that is difficult to maintain (Carandang VI et.al, 2016).

These days, most hydroponic growing is conducted in controlled environments which makes the systems more expensive and more complicated to operate than other growing methods. Therefore, high value cash crops such as tomatoes and lettuce, or specialty crops such as herbs, are frequently chosen for hydroponic production. Although initial cost may be high, hydroponics can be a highly profitable method of crop production (Jones, 2014).

Problems that affect plant growth could be addressed in the hydroponic systems by controlling the parameters necessary for plant growth and development through automation. Arduino is the most common microcontrollers used in automation which makes indoor farming possible with less human intervention. Arduino boards are inexpensive and the software runs on Windows, Macintosh OSX, and Linux operating systems. All Arduino boards and software are open-source empowering users to build them independently and adapt them for their specific needs.

As agriculture advances into smart agriculture, environmental control systems using sensor networks in crop production are becoming more widespread and sophisticated. Using sensors, environmental conditions such as light intensity, temperature, and humidity in target areas can be monitored and controlled to achieve the goal of improving crop yields (Li, 2017).

This research developed a small-scale automated hydroponic production of lettuce within a closed and controlled environment. This offers a new perspective in indoor farming technology aiming for higher crop yield with minimal space and less human intervention. The study may benefit farmers, researchers and urban dwellers in growing their own food in indoor condition with modern technology.

Figure 1 represents the conceptual framework of the study.

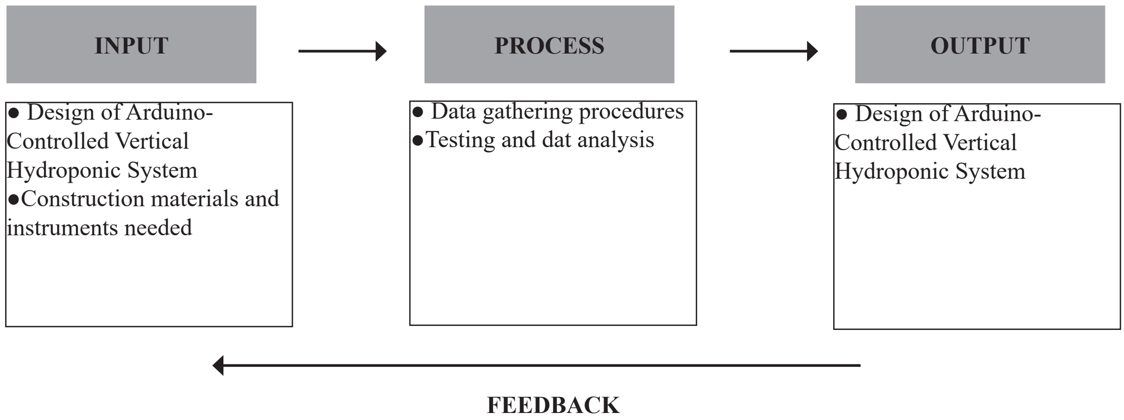

Figure 1. The Conceptual Framework of the Study

The **input** presents the materials and instruments used for the design, construction, setting up and installation of Arduino-Controlled Vertical Hydroponic System. The **process** presents the undertakings in construction and evaluation of the system, cultural management of crops, data gathering procedures, testing and data analysis. The **output** shows the Development of Arduino Controlled Vertical Hydroponic System in an enclosed cultivation system. The **feedback** is the information gathered in this study which can be used to further enhance the development of Arduino-Controlled Vertical Hydroponic System.

METHODOLOGY

The study is focused on the development of an Arduino-controlled vertical hydroponic system. Its performance was evaluated in terms of the system's capability to monitor and control light intensity, temperature and relative humidity based on the environmental requirements of growing lettuce. The system consists of a growing chamber, pump and pipe assembly, control unit, and principle of operation. Figure 2 shows the Arduino-controlled vertical hydroponic system.

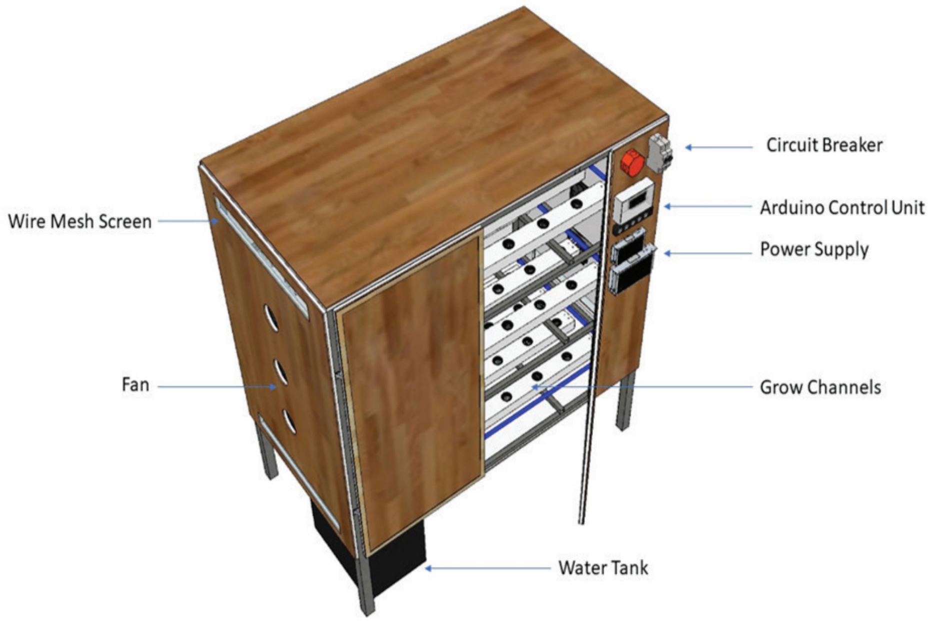

Figure 2. Arduino-controlled vertical hydroponic system

Growing chamber

The growing chamber is made from plywood with dimensions 1.80m in length, 1.00m in width, and 1.90m in height. It was insulated using 5mm of P.E. insulation foam. There was wire mesh screening on the top and bottom sides for natural air movement, and there was a glass window to monitor the inside condition. Rectangular PVC pipes with a length of 1.2m (4ft.) were used as grow channels. There were four channels per layer. There were six holes in every channel. The diameter of the holes is 54mm (2-1/8in.) and the spacing between holes is 190.5mm (7.5in.). The distance from the channels to the light source is 152.4mm (6 in.).

Pump and pipes assembly

The pumping unit consists of a 19-watt, 900L/hr submersible plastic pump with a max lift of 5 meters located at the water reservoir and connected to an LDPE tube. Rectangular PVC pipes were used as growing channels. The pipe assembly consists of an LDPE tube, a flexible tube, a take-off and fittings. A plastic storage box with a capacity of 70 liters was used as a nutrient-rich water tank. This was the storage for nutrient solutions (water and fertilizer mix) to provide nourishment and hydration to crops.

Control unit

The Arduino Mega 2560 was the main control board for the project. It was attached to the side of the growing chamber. It comes with more memory space and I/O pins as compared to other boards available on the market. The board comes with a USB cable port that is used to connect and transfer codes from the computer to the board.

To measure temperature and humidity, a BME 280 sensor was used. This precision sensor can measure humidity from 0-100% with ±3% accuracy and temperature from -40 °C to 85°C with ±1°C accuracy. The module comes with an on-board L6206 3.3V and 5V logic microcontroller. The sensor was placed strategically inside the growing chamber.

A 4-channel relay module was used to switch on/off the lights, fan, humidifier and pump. It is a simple and convenient way to interface 4 relays for switching application in this study since the Arduino can't handle high voltages and high current loads.

Figure 3 shows the circuit diagram for this study.

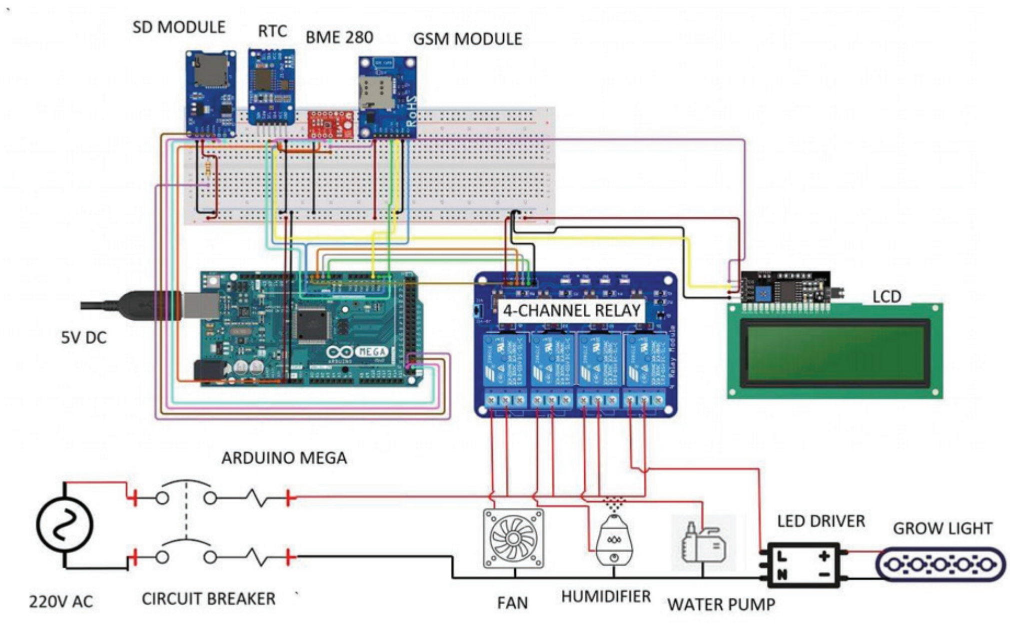

Figure 3. Circuit diagram of the Arduino-controlled vertical hydroponic system

Lighting system

The Arduino was programmed and operated the on and off switching of the lights with the use of relay. The lights were on from 5:00 am to 8:00 am, 9:00 am to 12:00 pm, 1:00 pm to 4:00 pm, and 5:00 pm to 8:00 pm with a total of 12-hour photoperiod. It was off at 8:00 am to 9:00 am, 12:00 m to 1:00 pm, and 4:00 pm to 5:00 pm.

The light source that was used are 15 meters of Red and blue 3:1 LED strip grow light with a power rating of 12 Watts per meter; and 6 pieces 4ft T5 LED tube with a power rating of 18 Watts and color temperature of 6000k – 6500k. The designed growth chamber has a DLI of 11.53 mol/m2/day.

Temperature control

The set point for temperature was 24°C. The fans were operated when the desired temperature in the chamber increased. Six (6) pieces 12V, 120 mm cooling fans were used for air circulation and lowering the temperature within the growing chamber. It was installed at the sides of the chamber. It was connected to a relay for on and off switching.

Humidity control

The set point for humidity was 70%. The system was programmed to monitor and control the humidity inside the growing chamber. When the humidity falls below 70%, the humidifiers automatically turn on and when it exceeds, it turns off. Four pieces USB humidifier was used to attain the humidity requirement for lettuce production. It was placed on the four inside corners of the growing chamber. It was plugged in a USB port which is then connected to a relay for on and off switching.

Principle of operation

The designed Arduino-controlled vertical hydroponic system followed the principle of vertical farming in soilless culture with the application of software-based technologies. The Arduino was the main controlling part of the system. It was used to monitor and control the operation of the lights, the temperature and humidity, and pump operation. The Arduino was programmed with a set of points based on the commodity requirements that will be produced. The set-points were 24°C for temperature, photoperiod of 12 hours, and humidity was set at 70-80%. The Arduino controlled vertical hydroponic system consists mainly of sensors, relay modules, real-time clock modules, microSD card modules, and an LCD screen.

All the components were connected to the Arduino. The sensor was responsible for controlling and monitoring the temperature and humidity as it followed the set points that are programmed into the Arduino. Lights will run based on the recommended photoperiod using a real-time clock module and relay module. A cooling fan and humidifier then worked when the temperature and humidity increased or decreased. It will stop operating once the desired value is achieved. The RTC and SD card module work together as they are responsible for logging the actual date and time of the readings and data storage. The readings are continuous, but the data logging to the SD card is just every hour.

Efficiency of the Arduino-controlled vertical hydroponic system

The efficiency of Arduino-controlled Vertical Hydroponic System was computed using the following formula:

$$Efficiency = \frac{Output}{Input} x100$$

Where:

Output = Temperature and humidity requirements for growing lettuce
Input = Average temperature and humidity of the designed Arduino-Controlled Vertical Hydroponic System

RESULTS AND DISCUSSION

Temperature

The temperature in an hourly basis throughout the conduct of the study is shown in Figure 3. The lowest temperature recorded was 23.2°C on the inside and 22.64°C on the outside. The highest temperature recorded was 31.9°C on the inside and 30.59°C on the outside. The mean temperature inside the growing chamber was 27.0°C while 25.25°C was the mean temperature outside of the chamber. The data implies that the system did not meet the target temperature set to be at 24.0°C since the outside temperature is also high. Improvement in the cooling system is needed. The data also shows that for every increase in the outside temperature, the inside temperature increases by 0.7359°C.

Humidity

Figure 4 shows the hourly humidity data gathered all throughout the conduct of the study. The lowest humidity recorded was 65.28% on the inside and 72.67% on the outside. The highest humidity recorded was 85.83% on the inside and 91.72% on the outside. The mean humidity inside the growing chamber was 75.10% while 83.67% is the mean humidity on the outside. This implies that the designed Arduino-controlled vertical hydroponic system was able to meet the required humidity although there are still some fluctuations in the values. As the outside humidity increases, the inside humidity increases also and the data shows that for every increase in the outside humidity, the inside humidity increases by 0.808%.

Efficiency of the Arduino-controlled vertical hydroponic system

Table 1 shows the efficiency of the system based on temperature and humidity.

Table 1. Efficiency of Arduino-controlled vertical hydroponic system

	Optimal Values	Actual Mean Values	Efficiency (%)
Temperature	24°C	26.9968	88.90
Humidity	75%	75.1049	99.86

Although the designed Arduino-controlled vertical hydroponic system only attained its desired value when the outside temperature ranges from 22.67°C to 23.5°C, it's overall efficiency in controlling temperature was 88.90% while it's overall efficiency in controlling humidity was 99.86%. This implies that further improvements in the control system inside the growing chamber would meet the target temperature and humidity for optimal plant growth. The cost of constructing the system is only Php 14,428.50.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of the study, it can be concluded that the Arduino-Controlled Vertical Hydroponic System is capable of monitoring and controlling the lighting operations.

However, it fails to control and does not meet the temperature requirement. It does not also control the humidity inside the chamber as the values went below and above the required condition. It can also be concluded that growing lettuce in vertical hydroponic system is space-saving.

Based on the result of the study, optimization of humidity control is recommended to maintain the humidity level in the desired range. Cooling system must be improved to attain the desired temperature and relative humidity for growing lettuce. For future directives of the study, automatic nutrient solution application and monitoring system may also be incorporated.

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AUTOMATION OF MANGO SORTING USING COMPUTER VISION SYSTEM

Arlene C. Joaquin[1] and Richard P. Avila[2]

ABSTRACT— *Sorting of fruits can be automated for faster and more accurate process using computer vision system (CVS), which is widely used in the United States, most European countries and very few countries in Asia. Prohibitive cost of such CVS machines prevents its adoption in most Asian countries like the Philippines, which predominantly rely on the labor-intensive, slow and prone to error manual sorting. The development of an automated fruit sorting machine was intended to improve the existing operations of mango cooperatives, consolidators and exporters who were challenged by the strict quality requirements and size provisions of the international market. The developed CVS sorting machine was aimed to provide a less-expensive alternative for faster and accurate sorting of mango fruits based on external defects and size, compliant to the requirements of applicable standards. The machine consisted of two conveyors, an imaging chamber, classification bin and image classification models. Mango fruits used were of Carabao variety, pre-sorted by industry trained human sorters and individually weighed using digital weighing scale. Results of the technical performance evaluation revealed, that the developed CVS sorting machine performs accurately and within the required tolerances and standard requirement set by Philippine National Standard Bureau of Agricultural and Fisheries Product Standard (BAFPS/PNS), CODEX Alimentarius International Food Standards and Del Monte. The highest accuracy however, was observed for CODEX - with 94.44%. Also, the developed CVS sorting machine can complete 720 to 800 pieces of mango fruit per hour based on the existing program. The system can be adjusted to cater to other standard requirements of the potential users. Moreover, a partial budget analysis indicated that using the CVS mango sorting machine is more beneficial compared to the two of traditional manual sorting.*

Keywords: *Computer vision, CVS, Sorting, Grading, Imaging, Mango*

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Received 5 January 2024; Accepted 20 February 2024

INTRODUCTION

Mango or *Mangifera Indica L.* is the world's most favorite tropical fruit and is one of the most important fruit crops of the Philippines. The Carabao variety, popularly known as Manila Super Mango; plays a very important role in the international market (Tharanaj et al., 2009, as cited by Sivakumar et al., 2010). Philippine mangoes are marketed locally and internationally as fresh or processed, but the bulk of the mango exports is in fresh form (Sivakumar et al., 2010). About 3% of the country's average annual mango production was exported from 2012-2020, amounting to an average yearly volume of 10,658 metric tons. It is the third leading fruit export of the country and contributed about Php0.765 billion (2%) in the Gross Value Added (GVA) of the Agriculture and Fishing sector in 2020 at constant prices (Philippine Statistics Authority, 2022; Statista, 2022).

Sorting and grading of fruits is a vital activity before it goes to the market, whether in the local or the export markets. Sorting increases the value of the product, improves packaging and handling, reduces handling losses during transportation, and overall improvement in the marketing system (Londhe et al., 2013). Grading attributes can be divided into three categories: size, quality, and condition (USDA, 1996; Code of Federal Regulations, 1990). The prospect of Philippine mango exports is confronted with strict quality requirements and careful adherence to quality and size provisions by different importing countries (Altmera et al., 2007).

However, the country's and sorting and classification (ether by size or quality) of fruits are primarily done manually. This practice is time-consuming, labor-intensive, costly, not standardized, and prone to errors. Nevertheless, from recent research works, a manual sorter was able to remove bruised fruits from good fruits with acceptable sorting efficiencies at a rate of approximately one fruit per second. A slightly faster rate, 1.2 fruits per second, was identified as the maximum rate for an inspector to reject 72% of severe defects in oranges (Gao, 2011; Ganiron, 2014).

Furthermore, personal interviews with Arenas (2017) and Amores (2017), a mango trader and president of Hilas Marketing Corporation, validated this manual sorting rate of trained and experienced human sorters. Both also expressed the need for automation to improve the traditional sorting operations. The reasons were slow, tedious, and lacking human labor to meet their required volume. This limitation of human skills was an old issue in mechanization which, over the years, was addressed to sustain the fast-increasing number of consumers. Computer imaging and machine vision in sorting and grading are promising advancements in technologies. The computer application allows sorting and grading to work more rapidly and precisely in highly objective ways of command.

This paper presented the technical viability of a locally-developed CVS sorting machine to address the problems associated with the country's current mango sorting practices. The developed CVS mango sorting machine aimed to provide a less-expensive alternative for faster and accurate sorting of mango fruits based on external defects and size; and compliant to the requirements of applicable standards. The first stage was programmed to count the number of good and defective mango fruits based on standard requirements and tolerances. The second sorting stage is based on size classification, calibrated with the mango fruits' geometric characteristics in pixels converted into volume and weight equivalents.

METHODOLOGY

Sample collection

Carabao mango variety was used for the entire study, being the most traded kind in both local and international markets. Samples used for calibration experiments to establish the most appropriate calibration models, were acquired from available mango fruits in Nueva Ecija, Pangasinan, Ilocos Norte, Ilocos Sur, La Union, Manila (Taguig and markets in Binondo), Davao and Cebu. On the otherhand mango samples for the actual performance evaluation were taken from the actual harvested mango fruits in the selected project sites discussed in the succeeding sections. All mango samples subjected to this study were pre-sorted by industry trained human sorters/classfiers based on phsyical defects like bruises, wind damage, thermal damage, mechanical damage, latex stain and other external deffects based on the definition of PNS/BAFPS 13:2004. Moreover, each mango fruit were pre-weighed using a digital balance scale; whereas length and width (mm) were measured using a digital caliper. The samples were separated into training (at least 70% of the total number of samples) and validation set (remaining 30% of the total number of samples). The training set was utilized to develop the Multiple Linear Regression (MLR) model, where the mangoes' length and width, along with their corresponding pixel count, served as input features for weight(-size) prediction.

Development of the CVS mango sorting machine

The hardware system

The developed CVS mango sorting machine was a two-stage sorting system connected to a dedicated personal computer or laptop with USB ports for a camera, keyboard, mouse, and monitor. The CVS mango sorting machine can sort mango based on selected external defects like bruises, wind damage, thermal damage, mechanical damage, latex stain and other external defects based on the definition of PNS/BAFPS 13:2004; and size classification based on user's preference. Most components were assembled at the PHilMech fabrication shop using in-house simulation software and a 3D-printing machine, like the sensing mechanism, eject arm, actuator brackets, and conveyor bridge. Then, the developed

CVS mango sorting machine was tested as a stand-alone sorter with the existing systems of the selected cooperators.

The image processing module

Figures 1a and 1b illustrate the processes and decision matrix for sorting mango fruits using the CVS mango sorting machine. As shown in Figure 1a, the system started with live video capture of individual mango fruit, rotating and fed manually through the conveyor. Next, the mango fruits were classified as either "reject" or "good" quality based on external defects like bruises, latex stains, insect damage and mechanical damage (PNS/BAFPS, 2004). An image classification model for physical quality will then be activated automatically and was programmed to count the number of frames of good and reject quality mangoes under given conditions and tolerances provided by the selected quality standard. The "reject" fruits will be directed and ejected to the first bin and will not be subjected for size classification, while good mango fruits will be conveyed for size classification.

The second and final stage of sorting was based on weight classification as calibrated with geometric characteristics of mangoes (in pixels), converted into volume, and computed to weight equivalent. As shown in Figure 1b, the video-captured images underwent pre-processing to convert the RGB color space into HSV color space to separate the background from the authentic mango images. A grayscale image was then constructed. After pre-processing, the estimated mango volume is determined by the sum of the volume of 10 transverse cuts along the length of the mango.

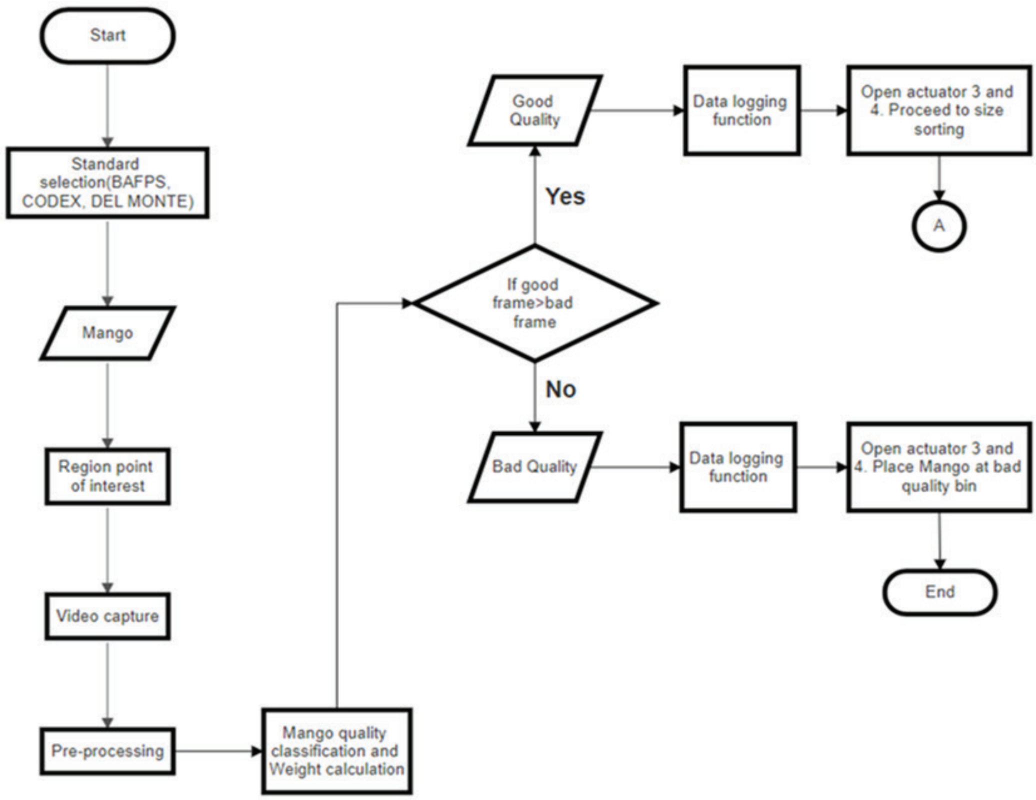

Figure 1a. Process flow of 1st stage mango sorting using the developed CVS mango sorting machine

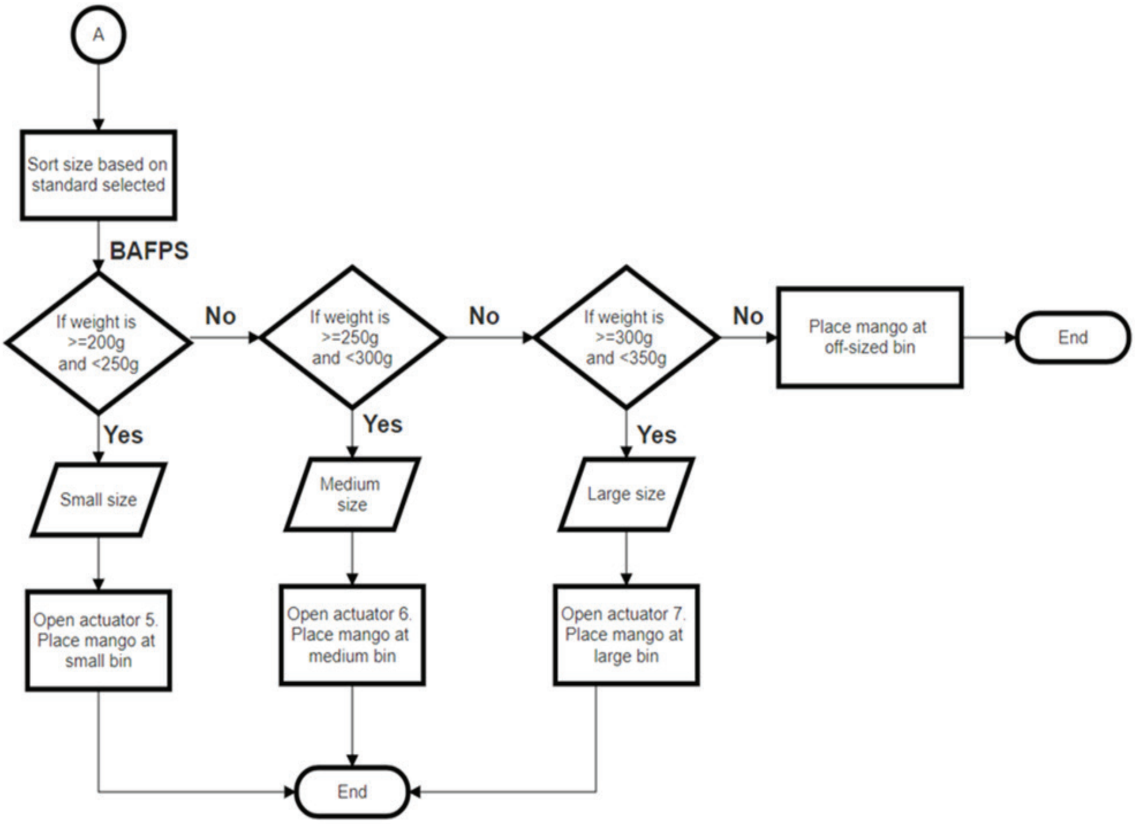

Figure 1b. Process flow of 2nd stage mango sorting using the developed unit CVS mango sorting machine

Analysis was derived from computing the semi-axes a and b at different points along the size of the mango (Figure 2) and the relationship between the values of the semi-axes called Depth Factor (DF). This method was adopted from the study of Bermudez et al. (2013).

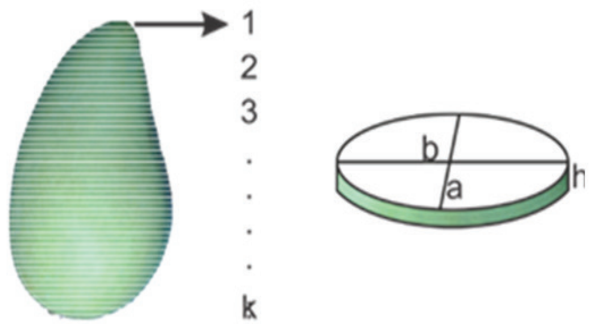

Figure 2. Transverse-cut method of mango weight estimation provided for the CVS mango sorting machine

The external defects recognition and size sorting were simultaneously processed in the system for about five seconds. A region point of interest (ROI) was used to narrow down the camera to focus on a specific area where the mango is located, thus eliminating unwanted objects in the video capture that might affect the classification process. A built-in hardware checker was added to the graphical user interface (GUI) where the operator can run a diagnostic test on the hardware components, such as actuators, cameras, and sensors, for fault identification. A data logging function was also added to automatically record all processed mangoes and generate a summary report in excel format.

Technology performance evaluation of the developed CVS mango sorting machine

External defects recognition between pre-sorted mangoes and use of CVS mango sorting machine

A total of 4390 mango images were used to test the performance of the calibration model generated for the system. About 3,234 or 75% of the images were used for training, while 1,156 (25%) were used to validate the accuracy and precision of the final calibration model. External defects considered were limited to pre-harvest and handling damages as provided by PNS/BAFPS 13:2004 standards. The validation test was conducted using the below formula (Arakeri et al., 2016):

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \; x\ 100 \qquad (1)$$

$$Precision = \frac{TP}{TP + FP} \; x\ 100 \qquad 2)$$

where:

True Positive, TP = number of reject mangoes classified as reject
True Negative, TN = number of good mangoes classified as good
False Positive, FP = number of good mangoes classified as reject
False Negative, FN = number of reject mangoes classified as good

Size (weight) classification of mango fruits between pre-weighed mango fruits and the use of CVS mango sorting machine

The final size (weight) classification model Eqn [3] was derived from the relationship between the spatial geometric configuration of each mango fruit and the corresponding pixel count (count) based on the study of Bermudez, et al. (2013). This activity was initially conducted at the PHilMech laboratory and validated in the selected three sites in Pangasinan, to evaluate the accuracy and precision of the CVS mango sorting machine compared to the pre-sorted weight measurement. Each mango fruit were manually weighed, marked, and labeled before being randomly fed into the CVS mango sorting machine. Size classification was based on the prescribed standards of the Philippine National Standard/ Bureau of Product Standards (PNS/BAFPS PNS: 13:2004); CODEX Alimentarius International Food Standards for Mangoes (CODEX STAN 184-1993); and Del Monte Fresh Produce Standards.

$$Weight = (101=3.3 – 1.040 * length +0.0000452 * pcount – 2.252 * width2 + 0.0002034* pcount2)$$

Partial budget analysis between the traditional method of mango sorting and using the CVS mango sorting machine

A partial budget analysis was used to ascertain whether the adaption of CVS mango sorting machine is more beneficial than the traditional method. As per traditional practice of the project cooperators, two scenarios were considered: the first scenario was the traditional operation using one-time manual sorting. In contrast, the second scenario presented the analysis on occasions where double sorting is done due to the inaccuracy of the traditional sorting method. The accounting period used was four months for the entire process of mango production up to postharvest and its peak season. Results were concluded as beneficial if the difference between the incremental benefits and incremental costs is positive, while non-beneficial if otherwise.

The analysis was based on the actual operation data of a mango farmer cooperative-trader with 11.5ha of mango plantation producing 230,400 kilograms or 11,520 crates. The following were the significant assumptions considered:

- Production area is 11.5ha with 575 mango trees, wherein 230,400 kilograms or 11,520 crates will be harvested and sorted
- Prevailing price of one crate of mango is Php700
- Sorting rate for a traditional method is 800 mangoes per day
- Sorting rate for CVS is seconds per mango

• Labor requirement for traditional in terms of sorting is 20 persons
• Labor requirement for CVS in terms of sorting is two persons.

RESULTS AND DISCSUSSION

Description of the developed CVS mango sorting machine

As shown in Figure 3, the hardware of the CVS–mango sorting machine primarily consisted of a motor-driven belt conveyor, imaging chamber, and classification bins. The imaging chamber was covered and placed between the loading area and sorting unit to factor out the shading effect. An autofocus, 1080p/30 frames per second camera is mounted on the center top of the imaging chamber to capture videos of rotating mango fruits.

Two-6000K daylight surface-mount device light-emitting diode module (SMD-LED) lamps provided the necessary lighting intensity. Pneumatic actuators were used to direct the mango samples to trigger transport to the imaging chamber. Actuators were also used to direct mango fruits to its respective size classification bins. Infrared proximity sensors were positioned before each actuator to detect the presence of mango fruits. Initially, a single mango fruit can be sorted in five seconds, but this could be increased and targeted to be competitive with existing mechanical sorters based on the operation of the intended users. An Arduino Uno was provided to run the actuators. The total fabrication cost of the developed CVS mango sorting machine amounted to Php168,184.80.

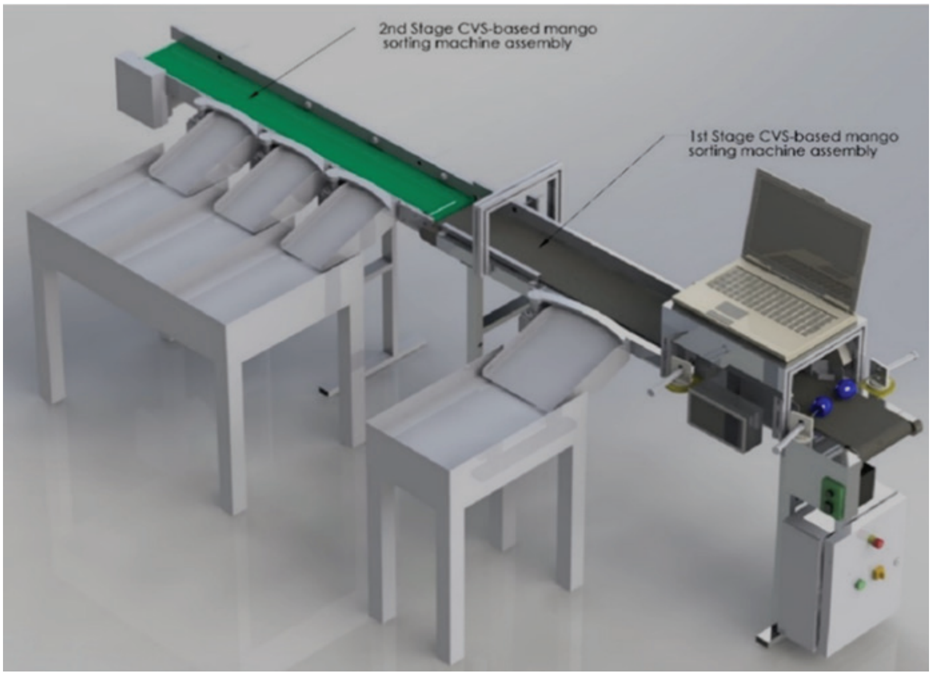

Figure 3. Developed unit for the CVS mango sorting machine.

Performance evaluation of the developed CVS mango sorting machine

First stage sorting (external defects recognition)

The performance evaluation results were presented below using the three (3) most used standards: PNS/BAFPS, CODEX Alimentarius International Food Standards, and Del Monte Fresh Produce Standards. Available Carabao mango samples from the project sites were used for the trials and pre-sorted by industry trained classifiers through ocular inspection. Each mango sample were coded and labeled for all batches conducted.

Table 1 below presents the result of the tests conducted for the first stage sorting process as defined by PNS/BAFPS, CODEX Alimentarius International Food Standards, and Del Monte Fresh Produce Standards. The tests for PNS/BAFPS were conducted for a total of 111 and 220 for good and reject mango fruits, respectively. The assessment for good mangoes revealed that 20 of the 111 samples were erroneously classified as reject or an estimated 18.01% prediction error. On the other hand, five out of the 220 samples, or 2.27% prediction error, was observed for rejected mango samples. On average, 25 out of the 331, or 7.55%, were erroneously classified by the CVS mango sorting machine using the provided system for defects recognition.

Also, the test result based on CODEX Alimentarius International Food Standards was conducted for 15 and 21 for good and rejected mango fruits, respectively. The test for good mangoes revealed two from the 15 samples were erroneously classified to be rejected, or a 13.33% prediction error was estimated. On the other hand, one out of the 21 samples, or 4.76% error of prediction, was observed for reject mango fruits. On average, three out of the 36, or 8.33 %, were erroneously classified by the CVS mango sorting machine in defects recognition.

For the third and last standard and the most frequently used by exporters in Korea and other Asian countries, Del Monte Fresh Produce was tested for the CVS machine. The test was conducted for 12 and 17 for good and reject mango fruits, respectively. The examination for good mangoes revealed that 1 out of 12 samples was erroneously classified to be rejected, or an 8.33% prediction error was estimated. On the other hand, 0 out of the 17 samples or 0% error of prediction was observed for rejected mango samples. On average, one (1) out of the 29, or 3.45%, was erroneously classified by the CVS mango sorting machine in defects recognition using the Del Monte Fresh Produce Standards.

Table 1. Result of first stage mango sorting using the CVS mango sorting machine based on the three classification standards.

Mango Classification		Number of mango fruit: Actual	Number of mango fruit: Correctly Predicted	Error of Prediction: Count	Error of Prediction: Percentage
1. PNS/BAFPS					
Quality	Good	111	91	20	18.01
	Reject	220	215	5	2.27
	Total	**331**	**306**	**25**	**7.55**
2. CODEX Alimentarius International Food Standards					
Quality	Good	15	13	2	13.33
	Reject	21	20	1	4.76
	Total	**36**	**33**	**3**	**8.33**
3. Del Monte Fresh Produce Standards					
Quality	Good	12	11	1	8.33
	Reject	17	17	0	0
	Total	**29**	**28**	**1**	**3.45**

Moreover, accuracy and precision tests were computed, adopting the methodology of Arakeri et al. (2016).

As shown in Table 2 result, a 92.45% accuracy and a precision of 97.73% were recorded using PNS/BAFPS Standards. In comparison, CODEX Alimentarius International Food Standards resulted in an accuracy of 91.67% and a precision of 95.24%.

Moreover, using the Del Monte Fresh Produce Standards, the CVS mango sorting machine recorded an accuracy of 96.55% and a 100% precision level.

The results indicated that among the three classification standards used, the CVS mango sorting machine would attain the highest accuracy level (96.55%) and precision (100.00%) using the standards set by Del Monte Fresh Produce. In addition, the system can be customized to re-train sorting models if a more stringent accuracy level is required.

Table 2. Confusion matrix for rejected and good mango samples using the developed CVS mango sorting machine based on the three selected standards commonly used by the mango industry.

		Predicted Classification (Count): Reject	Predicted Classification (Count): Good	Accuracy (%)	Precision (%)
Actual Classification (count)	***1. PNS/BAFPS***				
		215	5	**92.45**	**97.73**
		20	91		
	2. CODEX Alimentarius International Food Standards				
		20	1	**91.67**	**95.24**
		2	13		
	3. Del Monte Fresh Produce				
		17	0	**96.55**	**100.00**
		1	11		

Second stage sorting (size classification)

PNS/BAFPS

The accuracy and precision of the CVS mango sorting machine were measured in classifying mango sizes during the second stage of sorting. Presented in Table 3 is the validation test result among and between different dimensions of mango sorted using the system.

Results revealed that the highest prediction error was observed in large-sized mangoes at 11.48%, while the lowest prediction error was recorded for off-size mango samples at 3.23%. Moreover, an estimated 91.24% accuracy and precision were calculated using this standard.

Table 3. Confusion matrix for 331 mango samples with different size classification based on PNS/BAFPS and using the CVS mango sorting machine.

Mango Classification		Number of mango fruit		Error of Prediction		Accuracy (%)	Precision (%)
		Actual	Correctly Predicted	Count	Percentage		
Size	Small	98	90	8	8.16	**91.24**	**91.24**
	Medium	141	128	13	9.22		
	Large	61	54	7	11.48		
	Off-size	31	30	1	3.23		

* total of 331 mango samples

CODEX Alimentarius International Food Standard

Presented in Table 4 is the validation test result among and between different sizes of mango sorted using the system. Results revealed that the highest predicted error was observed on the A size classification with 3.45%, followed by the size B classification with 0.17% prediction error.

However, using the CODEX Alimentarius International Food Standard, the system perfectly predicted all other size classifications with an average accuracy and precision level of 94.44%.

Table 4. Confusion matrix for 36 mango samples with different size classification based on CODEX Ali mentarius International Food Standard using the CVS mango sorting machine.

Mango Classification		Number of mango fruit		Error of Prediction		Accuracy (%)	Precision (%)
		Actual	Correctly Predicted	Count	Percentage		
Size	A	29	28	1	3.45	**94.44**	**94.44**
	B	6	5	1	0.17		
	C	-	-	-	-		
	Off-size	1	1	-	-		

Del Monte Fresh Produce Standards

Table 5 below presents the validation test result among and between different sizes of mango sorted using a developed CVS mango sorting machine. Results revealed that only the 20s size classification could record an error of prediction of 0.10% representing the two counts of error out of the 20 mango samples in that size classification.

With this result, an estimated 93.1% accuracy and precision were calculated using this standard.

Table 5. Confusion matrix for 29 mango samples with different size classification based on Del Monte Fresh Produce Standards using the CVS mango sorting machine.

Mango Classification		Number of mango fruit		Error of Prediction		Accuracy (%)	Precision (%)
		Actual	Correctly Predicted	Count	Percentage		
Size	12s	0	0	0	0		
	14s	7	7	0	0		
	20s	20	18	2	0.10	**93.1**	**93.1**
	24s	2	2	0	0		
	Off-size	0	0	0	0		

Comparative analysis of the three classification standards, the CVS mango sorting machine has established the highest accuracy and precision levels using Del Monte Fresh Produce Standards, with a 93.1% level. On the other hand, the lowest accuracy and precision were observed for the PNS/BAFPS size classification at 91.24%.

Technical specifications of the CVS mango sorting machine, as shown in Table 6, was established after a series of field performance evaluation conducted.

Table 6. Technical specifications of the developed CVS mango sorting machine.

PARTICULARS	PARAMETERS
Type	Optical, single-line
Capacity, fruit/hr	720 to 800
Feeding System	manual
Fruit weight range, grams	up to 500/pc
Grade level, number	Five – small, medium, large, extra large*, and off size
Applicable Standards	PNS/BAFPS, CODEX Alimentarius International Food Standard, Del Monte Fresh Produce Standards
Power requirement, W	33W
Dimension, mm	2720(L) x 250(W) x 700(H)

* for Del Monte Fresh Produce Standards

Partial budget analysis

As shown in Tables 7 and 8, the partial budget analysis using 230,400 kilograms of mango fruits for both scenarios of no double sorting and with double sorting of the traditional method; yielded a positive impact in using the CVS mango sorting machine. It was assumed the device was purchased using a loan with a 5% interest rate compounded monthly for one year. The depreciation was computed based on a Php 227,049.75 investment with a 10% salvage value and a life span of 10 years using the straight-line method. Minimal electricity cost was incurred using the CVS since the machine is only at 2.4 watts. However, an added cost for the repairs and maintenance of the CVS amounted to Php4,541.

Regarding price, using the CVS can reduce about Php377, 639.25 worth of labor expenses without double sorting and Php601,636.25 with double sorting. Practically, the personnel needed is much lower than the traditional method, with 20 laborers at a sorting rate of 800 mango fruits per day compared to two laborers at an average sorting rate of 760 mango fruits per hour. Overall, a net effect of Php570,402.19 added income for double sorting and a Php346,402.19 added income for non-double sorting was accounted for.

Non-monetary benefits can also be derived from using the CVS mango sorting machine. The ease of operation and the trust and confidence that can be gained from mango buyers that accurately sorted mangoes will be supplied to them considering the accuracy of the technology compared to the traditional manual sorting.

Table 7. Partial budget analysis between traditional manual sorting (no double sorting) of mango and the using the CVS mango sorting machine.

CVS Partial Budget Analysis (No Double Sorting)

Incremental Benefits (IB.)		**Incremental Costs (IC.)**	
Added Benefits		**Added Cost**	
		Electricity	444.41
		Depreciation	6,811.49
		Repair and Maintenance	4,541.00
		Interest on loan (Machine)	19,437.16
Reduced Cost		**Reduced Benefits**	
Sorting/Grading Labor	377,636.25		
Total Positive Changes	**377,636.25**	**Total Negative Changes**	**31,234.06**
Marginal Benefit (IB-IC):			**346,402.19**

Table 8. Partial budget analysis between traditional manual sorting (no double sorting) of mango and the the CVS mango sorting machine.

CVS Partial Budget Analysis (No Double Sorting)

Incremental Benefits (IB.)		**Incremental Costs (IC.)**	
Added Benefits		**Added Cost**	
		Electricity	444.41
		Depreciation	6,811.49
		Repair and Maintenance	4,541.00
Reduced Cost		Loan (Machine)	19,437.16
Sorting/Grading Labor	377,636.25	**Reduced Benefits**	
Double Sorting Labor	224,000.00		
Total Positive Changes	**601,636.25**	**Total Negative Changes**	**31,234.06**
Marginal Benefit (IB-IC):			**570,402.19**

CONCLUSIONS

A technically viable CVS mango sorting machine for local mango cooperatives, traders and exporters was developed to offer a less-expensive alternative to imported machines of the same kind. The CVS mango sorting machine can perform within the acceptable level of accuracy and tolerances based on selected quality grading standards often used by the mango industry. It has the potential to improve the sorting and grading operations in the country and will eventually increase the potential monetary benefits of the mango stakeholders. The CVS sorting machine was designed to facilitate automated sorting of mango fruits in two stages; external defects identification and weight (size) classification based on local and international standards. For the first level sorting, performance tests indicated that among the three classification standards used, the CVS mango sorting machine has the highest accuracy level (96.55%) and precision (100%) using the Del Monte Fresh Produce Standards.

Also, a comparative analysis of the three (3) classification standards revealed that the CVS mango sorting machine was highest in accuracy and precision for CODEX Alimentarius International Food Standards with a 94.44 % level.

On the other hand, the lowest accuracy and precision were observed for the PNS/BAFPS size classification at 91.24%, but it is still within the standard tolerance.

Moreover, a t-test analysis yielded a P-value of 0.129 which is greater than the pre-determined significant level of 0.05, indicating no significant difference in the mango samples' firmness using the CVS mango sorting machine; an attribute of physical quality.

A partial budget analysis between two scenarios of traditional manual sorting and the CVS mango sorting machine revealed that the system is more beneficial in terms of reduced cost. The CVS sorting machine can reduce Php377,639.25 labor expenses without double sorting and Php601,636.25 with double sorting since the personnel needed is much lower than the traditional method. Overall, a net effect of Php570,402.19 added income for double sorting, and a Php346,402.19 added income for non-double sorting was accounted. In addition, non-monetary benefits, like ease of operation and the trust and confidence gained from mango buyers of the accurately sorted mango fruits, can also be derived from the developed CVS mango sorting machine.

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2. Name of authors must not contain professional or academic titles. The surname should be the last part of the authors' name. Affiliation of the authors should contain name of the agency or university he/she belongs, address, and the country of the authors. Include e-mail addresses of the corresponding authors.

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15. Figures and tables must be centered, spanning across both columns, if needed. Place tables or figures that take up more than 1 column either at the top or at the bottom of the page.

16. Graphics should have adequate resolution. Images should be clear. Colors used must contrast well. Labels should be readable.

17. Figures must be numbered using Hindu Arabic numerals. Figure captions must be in 9 pt regular font. Captions of a single line must be centered whereas multi-line captions must be justified. Place captions of figures at the bottom of the figures.

18. Tables must be numbered using uppercase Roman numerals. Captions with table numbers must be placed above the tables.

19. Place equations flush-left with the text margin. Equations are centered and numbered consecutively starting from 1 as follows:

$$E(F) = E(0) + \sum_i \left(\frac{\delta E(F)}{\delta F_i} \right)_0 F_i \qquad (1)$$

20. Authors should follow instructions, otherwise their papers will be returned for reformatting prior to the peer review.

21. Examples of different reference categories are shown below:

• *Book*

Fawcett, S. E., L.M. Elram, and J. A. Ogden. 2007. Supply Chain Management from Vision to Implementation. New Jersey: Pearson Education Inc. 530 pp.

• *Book portion*

Schuber, S. 1995. Proton release by roots. In: Singh BB, Mengel, K. Editors. Physiology and Biochemistry of Plants. New Delhi: Panama Publishing Corp. pp. 97-119

• *Journal*

Siemens, M.C and D.E. Wilkins. 2006. Effect of residue management methods on no-till drill performance. Applied Engineering in Agriculture. 22(1): 51-60.

• *Theses and Dissertation*

Rodeo, AJ. 2009. Low temperature conditioning to alleviate chilling injury in mango (*Mangifera indica* L. Cv. Carabao fruit (BS Thesis) College, Laguna, Philippines: University of the Philippines Los Baños.

• *Paper from a Proceedings*

M. Wegmuller, J. P. von der Weid, P. Oberson, and N. Gisin, "High resolution fiber distributed measurements with coherent OFDR," in Proc. ECOC'00, 2000, paper 11.3.4, p. 109.

• *Website*

Scofield, A. Undated. Vietnam: Silent Global Coffee Power. Retrieved on August 4, 2007 from http://www.ineedcoffee.com/02/04/vietnam/

• *Standard*

Agricultural Machinery Testing and Evaluation Center (AMTEC). 2003. Philippine Agricultural Engineering Standards. Volume 1. 2003. PAES 124:2002 Agricultural Machinery Walking-type Agricultural Tractor Specifications Part 3: Special Type (Float-Assist Tiller). College, Laguna, Philippines: University of the Philippines Los Baños (UPLB). p.8

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