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DEVELOPMENT OF AUTOMATIC CONTROL SYSTEM FOR SOLAR DRYING CABINET

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Abstract

This paper presents the design of thin layer direct mode solar drying cabinet with moisture and temperature automatic control system. Two motors with Arduino™ microcontroller were used to control the air inlet and outlet of solar drying cabinet. The speed of two fans was controlled by thermometer and relative humidity sensors. The electric power of motors and controller were supplied by PV-cell with battery for low light and night time drying. The temperature from inlet reached around 36.1ºC to 46.6ºC, the relative humidity reduced from 55%RH to 21%RH in the cabinet. The Chinda Chili was used as a demonstration drying product to compare automatic solar drying cabinet with normal sun drying. Automatic solar drying cabinet could reach the moisture ratio to 0.3 in 7 hours which showed 2 times of Moisture ratio compared with normal sun dryer.

Keywords: Solar dryer, Automatic control system, Drying cabinet, Temperature control

1. Introduction

Nowadays, the energy from fossil emitted carbon dioxide which caused the global warming problem. Renewable energy should be concerned with reducing greenhouse gas and ultimately reduce production cost in many industries. Thailand, which is located in the tropical area, has high solar radiation intensity (higher than 15 MJ/m2) that can give Thailand high, clean and free energy (Janjai, 2017). In the agriculture sector, drying agricultural products, such as crops, fruits and leaves after harvesting, is very popular for extending the product life and also improving the product taste. Normally, farmers dry agriculture products with open air condition which could not prevent insects and uncertain weather, such as cloudy, rain, too high ultraviolet radiation and too high of heat. Many researchers have studied the condition of drying by controlling temperature and humidity. (Phitakwinai, Thepa & Nilnont, 2019). studied the thin layer of coffee bean and showed the predicted model in drying condition.

The indirect mode solar drying with the help of heat collector and forced convection of heat (Ouaabou et al., 2018) showed the appropriate heat between 60ºC to 80ºC for drying the moroccan sweet cherries. The direct mode solar dryer which allowed solar radiation incident on product through transparent material such as polycarbonate reduced heat loss (Nabnean & Nimnuan, 2020). Therefore, this could be applied to many agricultural products for Banana (Nabnean et al., 2020). Some researchers aimed to scale up the drying capacity. The new model by (Nabnean et al., 2016) could reach 100 kilogram of tomato cherry that showed the efficiency of a drying cabinet with temperature around 30ºC to 65ºC. However, the wide range of temperature during the solar drying is one of the obstacles to control the drying product quality, therefore our research team aims to control the drying conditions such as temperature and relative humidity, with the help of drying through the automation control system.

The objective of this study was to develop the automation drying cabinet, by Arduino™ microcontroller, as a pilot drying system with direct mode cabinet to control temperature and relative humidity in the chamber and preserve agricultural products with low cost and provide a feasible system for the local community.

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2. Materials and Methods

2.1 Drying cabinet fabrication

The solar drying cabinet in this study was a direct mode solar drying according to the ease of air flow controlling and there is no heat collector needed. The body of the cabinet was built with aluminium due to the light weight. The cabinet size is 40 cm. ×60 cm. and the height of trapezoid shape were 20 cm. and 22.3 cm. respectively. The cabinet was painted inside with black color for the better absorption of solar radiation. Two motors in the opposite side are for controlling the inlet and outlet air which were powered by 20 watts of PV-cell with a solar charger attached to the cabinet. The top of the cabinet was covered with Polycarbonate sheet for the light weight and safety.

Figure 1. Inside of the automatic solar drying cabinet

Figure 2. The automatic solar cabinet drying

2.2 Automation system

Arduino nano was the microcontroller used in this study. The microcontroller was powered from a solar charger which reduced the voltage from 12V to 5V. This controller collected temperature and humidity data from 3 Arduino DHTT11 sensors on the condition that if the temperature and humidity of the mid sensors that collected data from the middle of the cabinet were over the setting limit, the motors were driven with higher speed which were controlled by the motor drive board. All 3 data from sensors saved in the SD card module (Figure 3.).

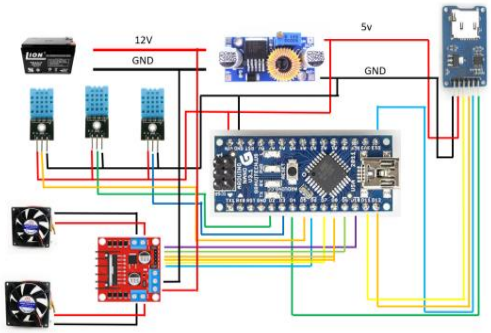

Figure 3. Showed the schematic of automation system for solar cabinet drying

The programming flow chart (Figure 4.) showed a processing diagram; by collecting data from 3 sensors and saved in storage SD card. At the same time, the data from the sensors inside (mid sensor) the cabinet were used as the condition of the controlling 2 steps motors speeds of DC fan motors to control air inlet and outlet inside automatic solar cabinet dryer. In this study, the temperature and relative humidity were set at 60 ºC and 20% respectively as a setting limit. If the temperature and relative humidity reached over the setting limit, the motors speeds of DC fans were raised to higher fans speeds. On the other hand, at the lower setting limit the fans were still at the low speed to keep the heat inside the cabinet and saved the electric power.

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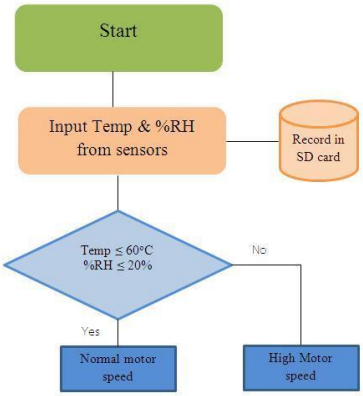

Figure 4. the flow chart of automation programming for solar cabinet drying.

3. Results and Discussion

3.1 Temperature and relative humidity

In this study, we ran the empty solar cabinet dryer to investigate the controlling of temperature and relative humidity from an automation system where we programmed to switch the fan speed if the temperature and relative humidity were getting higher than 60ºC and 20% respectively. The investigation dates were April 23rd 2021 (day1) and April 24th 2021 (day2) for the real weather situations for solar cabinet drying testing. Firstly, the air inlet on day1 showed that the temperature was from 32.4ºC to 36.1ºC and the relative humidity was from 68% to 53% (Figure 5.). When the air moved in the cabinet, the temperature rose to 45.4ºC - 46.6ºC and the relative humidity dramatically dropped to 21% - 25% which showed that the automation system could control the temperature and humidity quite close to the programmed condition although the relative humidity was slightly overshoot. For more precision this automation programming needed to be more complex.

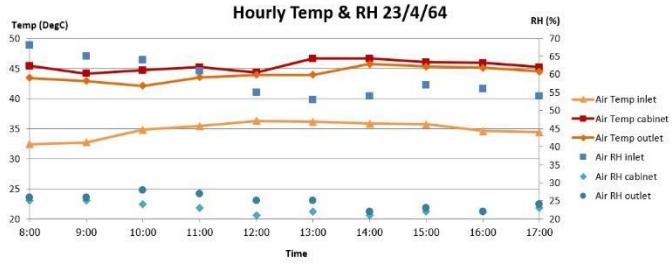

Figure 5. Temperature and relative humidity on 23rd April 2021.

For day2, the automation solar drying cabinet could run as well as day1 due to the clear and partly cloudy sky from 8:00 to 14:00 which could absorb the radiation as normally. The low solar radiation (Figure 6.) and high humidity occurred after 14:00 because of the rain which showed the uncontrollable temperature and relative humidity in this drying cabinet. This situation showed that we need moisture control apparatus and heat assistance for unusual situations.

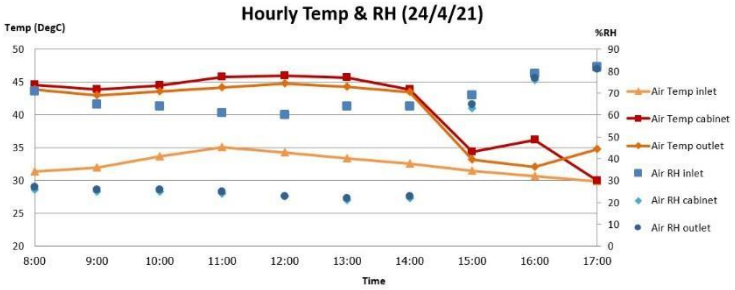

Figure 6. Temperature and relative humidity on 24th April 2021.

3.2 Product drying testing

Chinda chili was carried out as a testing product for this automatic solar drying cabinet. The test was done by drying the Chinda chili in an automatic drying cabinet in comparison to natural sun drying on the same day. The data of drying was interpreted in moisture content and moisture ratio respectively. For the moisture content we calculated in dry basis which was defined as:

$$MC = \frac{M_t - M_d}{M_d} \times 100\% \qquad (1)$$

Where MC: moisture content of the product in dry basis; M_t: mass of the product at any time; M_d: dried mass product. From the MC we could plot the graph of moisture content versus the time as seen in Fig 7. The moisture contents from both normal sun drying and automatic solar drying cabinet were decreased at the similar rate as the early hour, then the MC of normal sun drying was constant at 14:00 and the

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moisture content of automatic solar dryer cabinet was at the constant at 15:00.

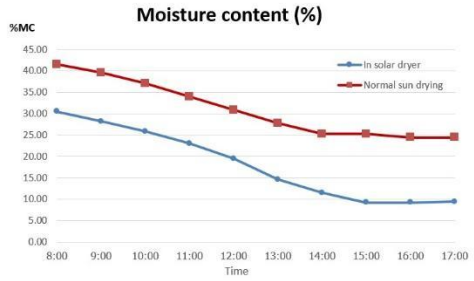

Figure 7. Moisture content of Chinda chili drying with automatic solar dryer cabinet and normal sun drying.

To compare the drying rate of normal sun drying and automatic solar drying cabinet, we needed to carried out by Moisture ratio (MR) as:

$$MR = \frac{MC_t}{MC_o} \quad (2)$$

Where *MR*: Moisture ratio; MC_t: moisture content at any time; MC_o: Moisture content at initial. The *MR* decreasing rate of automatic solar cabinet dryer was more than normal sun drying at the early of the day and the *MR* of normal sun drying was constant at 14:00 earlier than automatic solar dryer for 1 hour which showed the moisture rate at 0.6 and 0.3 respectively (Fig 8.). This result showed that the final *MR* was different 2 times which showed that the automatic solar dryer cabinet could dry the product (Chinda chili) more than normal sun drying on the same day. Not only could the drier reach for the automatic solar cabinet dryer but also prevented the product from desirable outcome, for example, insects and uncontrollable weather conditions.

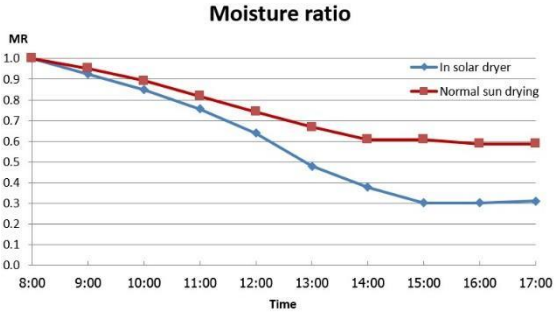

Figure 8. Moisture ratio of Chinda chili drying with automatic solar dryer cabinet and normal sun drying.

4. Conclusions

The automatic solar dryer cabinet could control the conditions of temperature and relative humidity. For normal weather and rainy or low solar radiation situation; the automatic solar dryer cabinet could not control both temperature and relative humidity from programmed conditions which showed that the system needed to improve moisture and temperature control. Chinda chili demonstrated the drying of the automatic solar dryer cabinet in comparison with normal sun drying; this showed the 2 times decrease of moisture ratio of the normal sun drying.

5. Acknowledgement

This research was funded by Dhonburi Rajabhat research and development institute. Thanks to the Food innovation research center, Dhonburi Rajabhat University and faculty of education Dhonburi Rajabhat University for their support.

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Influence of nanosilica on the properties of nanocomposite based on K-153 epoxy resin

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Abstract

This article presents the effects of nanosilica content on some properties of nanocomposite based on K-153 epoxy resin (K-153 epoxy resin was made by modifying ED-20 epoxy resin with thiokol and oligomer acrylate, simultaneously) and polyethylene polyamine (PEPA) (as a hardener). Results show that nanosilica of lower than 1.5 weight percent (wt%) was suitable for K-153 epoxy resin in manufacturing polymer composite. At 80 ^{o}C, gelation of K-153 epoxy resin with 1.5 wt% was 79,15 % in comparison to 75,28 % of K-153 neat epoxy. Tensile strength and flexural strength of nanocomposite with 1.2 wt% of nanosilica were 79.81 MPa and 98,14 MPa higher than those of K-153 respectively (53.30 MPa and 60.81 MPa). Besides that, thermal oxidation resistance and remaining ash of nanocomposite also increased in comparison to K-153 epoxy resin.

Keywords: Polymer composite, K-153 epoxy resin, nanosilica, nanocomposite, mechanical properties, thermal oxidation resistance.

1. Introduction

Epoxy resins were widely used in coating, polymer composite because of their good mechanical, thermal and chemical properties. They were also compatible with a variety of reinforcement materials. Those excellent properties made epoxy resin as a choice resin for many high-performance engineering applications. Despite their high performances, there are many opportunities to further performance and durability improvements of epoxy composites (Goodman, 1998; Liang & Pearson, 2009; Morsch, Liu, Greensmith, Lyon, & Gibbon, 2017; Park, Lee, & Lee, 2017). Some authors used nanoclay, nanographene, carbon nanotube with different contents to investigate flexural strength, tensile strength, thermal performance of epoxy nanocomposite (Li, Liu, Fang, Liu, & Liu, 2018; Papadopoulos, Gkikas, Paipetis, & Barkoula, 2016; Potts, Dreyer, Bielawski, & Ruoff, 2011; Radhi, Mohamad, Abdul Rahman, Abdullah, & Hasan, 2021). Nanocomposite materials based on epoxy resin and nanosilca, rubber particles, glass fiber cured with accelerated methylhexdrophthalic acid anhydride or modified cycloaliphatic amine (H-100), attracted many scientists in order to improve properties such as elasticity, hardness, or fracture toughness of epoxy resins (Blackman et al., 2007; Manjunatha, Taylor, Kinloch, & Sprenger, 2009; Tsai, Huang, & Cheng, 2011). K-153 epoxy resin (K- 153) was produced by modifying ED-20 epoxy resin simultaneously with thiokol and acrylate oligomer (TU 6-05-1584-85) so it is flexible and has a lower viscosity than common epoxy resins and it is easy to use as a composite matrix. In my previous research, the author had investigated the effect of drying temperature on curing and structural morphology of polymer composite based on K-153 with glass fiber (Thanh, 2019, 2020). Current paper presents the influence of nanosilica on some properties of nanocomposite based on K-153 and PEPA as a hardener. In this resaerch, the effect of nanosilica content on epoxy- nanosilica mixture viscosity and some mechanical properties of the final nanocomposite were studied to find the suitable content for manufacturing nanocomposite. In addition, the article also shows results of FT-IR infrared spectroscopy analysis to demonstrate curing reaction of epoxy resin with PEPA and investigate the thermal oxidation resistance of nanocomposite in comparison to K-153.

2. Materials and methods

2.1. Chemicals

- K-153 epoxy resin (Russia):
+ Epoxy content: 19- 22 %.
+ Molecular weight: 390 g/mol.
- Polyethylene polyamine supplied by Chimex

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Ltd (Russia):
+ Molecular weight: 230- 250 g/mol.
+ Third amin group: 5- 9.
- Nanosilica, Sigma-Aldrich:
+ Fine powder.
+ Purity: 99.8%.
+ Average size: 12nm,
+ Specific surface area: 175- 225 m^2/g (according to BET method).

2.2. Sample preparation

- Mixing well K-153 and nanosilica of 0- 2 wt% until getting homogenous mixture. Making nanocomposite samples of above mixtures by adding PEPA as 100 wt% of K-153 with 10 wt% of PEPA repectively (Thanh, 2019, 2020).
- Preparing mold.
- Pouring the above mixture into the mold.
- Getting samples and drying at 50 ^oC, 60 ^oC, 70 ^oC, 80 ^oC, 90 ^oC, 100 ^oC in 6 hours (Thanh, 2020).
- Keeping samples for 07 days at room temperature before testing machenical properties.

2.3. Analysis methods

- Determining degree of curing: Preparing soxhlet device, extracting soluble components in filter paper with acetone on soxhlet device for about 3 hours. Then, drying filter paper to constant weight, weighing filter paper (g_0). Spreading on filter paper a quantity of cured K-153 or nanocomposite, this value was g_1. Samples were dried at 50 ^oC, 60 ^oC, 70 ^oC, 80 ^oC, 90 ^oC, 100 ^oC for 6 hours, cooled and extracted in acetone at room temperature for 20 hours. Then, taking samples out, drying until sample weight was constant, weighing to determine value g_2.

Degree of curing (G) was determined by:

$$G = \frac{g_2 - g}{g_1 - g_0}.100\%$$

Where:
G: Curing degree, %

g_0: Weight of dried filter paper, g
g_1: Weight of dried filter paper + unextracted sample, g
g_2: Weight of dried filter paper + unextracted sample, g

- Infrared spectroscopy (FT-IR) on the Fourier FTIR-8700 series converter.
- Thermal oxidation resistance: Thermal gravimetric analysis (TGA) was analyzed by NETZSCH TG 209F1 LIBRA in air condition with temperature rate of 10 ^oC/minute from room temperature to 600 ^oC.
- Tensile strength was determined as ISO 527-1:2012 on Zwick device with sample pulling speed of 5 mm/minute, at temperature of 25 ^oC, humidity of 70 %.
- Flexural strength was determined as ISO 178:2010 on Instron 5582-100 kN device, bending speed at 5 mm/minute.
- Viscosity of K-153 and K-153/nanosilica was determined by Brookfield Model RVT- Series 93412, at 25 ^oC.
- Hardness of material was determined as ISO 7619-1:2010 by TECLOCK- Jisk 6301A.
- Material abrasion was determined by ISO 4649: 2002.

3. Results and discussion

3.1. Effect of nanosilica content on physical state and viscosity of K-153 epoxy resin

Dispersion of nanosilica particles strongly effected on properties and fabricating of nanocomposite, when nanoparticles were well dispersed in polymer matrix, they would give good reinforcement effect. Influence of nanosilica content on physical state and viscosity of K-153 epoxy resin at 25 ^oC was shown in table 1.

Table 1. Physical state and viscosity of K-153 with different nanosilica content.

No.	K-153, Wt%	Nanosilica, Wt%	Physical state	Viscosity, Cp
1	100	0	Liquidity, transparence	35
2	100	0.5	Liquidity, transparence	73
3	100	1	Liquidity, opaque	217
4	100	1.5	Liquidity, opaque	589
5	100	2	Gel	-

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Table 1 showed with nanosilica content up to 1.5 wt%, mixture remained its viscous liquid state; when nanosilica content reached to 2 wt% then mixture became gel. Nanosilica with a small content (0.5 wt%), viscosity of mixture increased slightly compared to the epoxy resin. When nanosilica content was increased continuously, the viscosity of the mixture increased sharply. It reached maximum value when nanosilica was about 1.5 wt% with viscosity of 589 cP. When nanosilica content reached 2 wt%, the mixture became gel state, which could not be used to make composite. This could be explained with silanol groups (Si-OH) on the surface of nanosilica, when nanosilca in the mixture was high enough, many silanol groups would interact with hydroxyl groups in epoxy resin therefore, leading to gelation. Besides that, nanosilica particles in epoxy resin were too high that they would agglomerate themselves and cause gelation (Ghaemy, Bazzar, & Mighani, 2011).

3.2. Effect of nanosilica content on curing reaction of K-153

Effect of nanosilica content on curing reaction of epoxy was determined by curing temperature and gel content. Samples were investigated with nanosilica content of 1.5 wt%, curing time was 6 hours at temperature of 50 ºC, 60 ºC, 70 ºC, 80 ºC, 90 ºC, 100 ºC (Thanh, 2020). Results were shown in figure 1, in which, M1 was for K-153 and M2 was for nanocomposite.

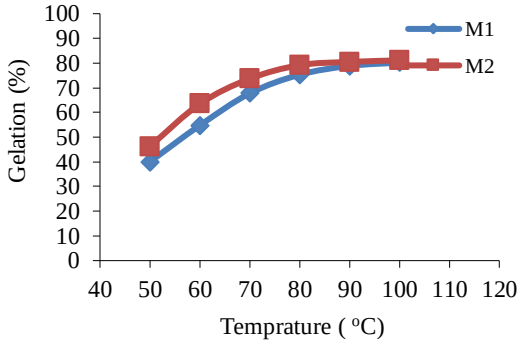

Figure1. Effect of nanosilica content on curing temperature of K-153 and nanocomposite.

Figure 1 showed that, in the investigated temperature range, with nanosilica content of 1.5 wt%, gel concentration of K-153 changed significantly compared to K-153 without nanosilica. For example, at 80 ºC, gel concentration of K-153 with nanosilica was 79.15 %, which significantly increased compared to neat K-153 of 75.28 %. This could be explained that, when adding nanosilica to epoxy resin, nanosilica had played as a catalyst and reduced activation energy of composite, leading to curing reaction of epoxy with PEPA strongly at lower temperatures (Ghaemy et al., 2011).

3.3. Effect of nanosilica content on abrasion and surface hardness of nanocomposite

Abrasion resistance and surface hardness are important information of material applicability. To study the influence of nanosilica content on abrasion resistance and surface hardness of nanocomposite, samples with nanosilica content of 0.5- 1.5 wt% were prepared and cured at 80 ºC in 6 hours (Thanh, 2020). Keeping samples for 07 days at room temperature before determining abrasion resistance and surface hardness. Results were shown in figure 2 and figure 3.

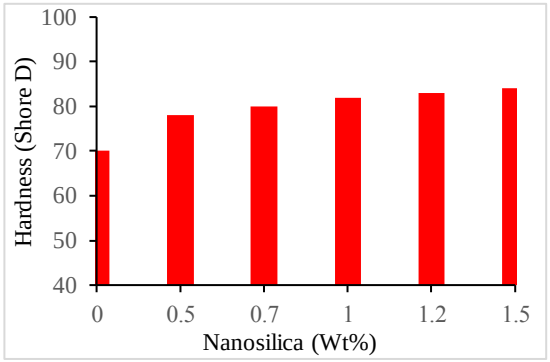

Figure 2. Effect of nanosilica content on surface hardness of nanocomposite.

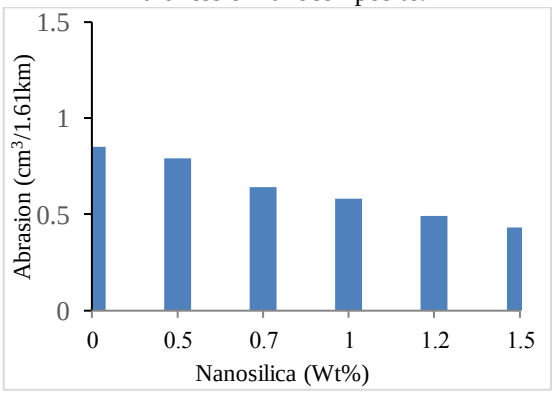

Figure 3. Effect of nanosilica content on abrasion of nanocomposite.

Figures 2 and 3 showed that, surface hardness of nanocomposite increased by nanosilica content. When nanosilica content was 1.5 wt%, surface hardness of nanocomposite reached 84 Shore D (much higher than that of K-153, 70 Shore D). It can be explained that, in this case, epoxy resin played the role of dispersing force applied to nanocomposite material, meanwhile, nanosilica worked as the corresponding force phase and that improved its resistance to deformation due to external forces to nanocomposite. In addition, nanosilica particles have much higher hardness than epoxy resin, so nanosilica content increases hardness of nanocomposite would be increased accordingly. Similarly for abrasion resistance of nanocomposite,

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when nanosilica content increased, abrasion resistance of material improved significantly or in other words, loss of material after testing decreases (Ghaemy et al., 2011; Li et al., 2018; Manjunatha et al., 2009).

3.4. Effect of nanosilica content on tensile strength and flexural strength of nanocomposite

To study the influence of nanosilica content on tensile strength, flexural strength of nanocomposite, samples with nanosilica content of 0.5- 1.5 wt% were prepared and cured at 80 ºC in 6 hours (Thanh, 2020). Keeping samples 07 days at room temperature before determining tensile strength, flexural strength of material. Results were shown in Figure 4.

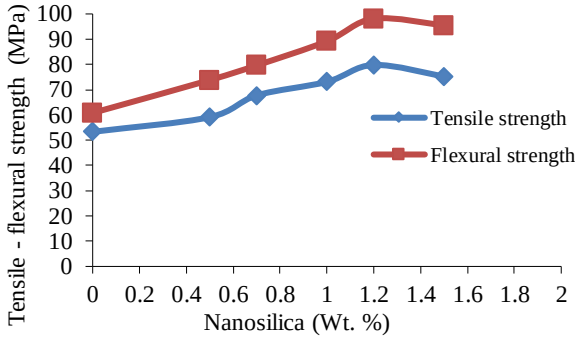

Figure 4. Effect of nanosilica content on tensile strength and flexural strength of nanocomposite.

Figure 4 showed that, when nanosilica content increased from 0.5- to 1.2 wt%, tensile and flexural strength of nanocomposite were significantly improved compared to K-153 (without nanosilica). Maximum tensile strength of nanocomposite was 79.81 MPa when nanosilica content was 1.2 wt%, compared to 53.30 MPa of K-153. Meanwhile, flexural strength of nanocomposite reached maximum value of 98.14 MPa when nanosilica content of 1.2 wt% compared to this value of 60.81 MPa of K-153. Improvement in tensile strength and flexural strength of nanocomposite can be explained that, nanosilica is uniformly dispersed in epoxy matrix up to 1.2 wt% without agglomeration. Due to close interaction between nanosilica surface and epoxy matrix, stress would transfer between two phases. In addition, nanoparticles could act as a agent to prevent crack propagation during the destruction of nanocomposite. Besides that, nanosilica particles had much greater hardness than epoxy, so when nanocomposite was loaded, deformation between two phases would be delayed, leading to more energy absorption and mechanical strength increases. However, if nanosilica content would increase continuously, nanoparticles tend to agglomerate into larger particles to release surface energy with bond between them was relatively weak (hydrogen bond) that was easily broken, so tensile and flexural strength of nanocomposite would decrease (Liang & Pearson, 2009; Papadopoulos et al., 2016; Tsai et al., 2011).

3.5. FT-IR of epoxy resin, PEPA, cured epoxy and nanocomposite

To investigate curing reaction of K-153 epoxy resin with PEPA and indetify the presence of nanosilca in nanocomposite, FT-IR was used for K-153, PEPA, cured K-153 and nanocomposite. Results were shown in figures 5a, 5b, 5c, 5d.

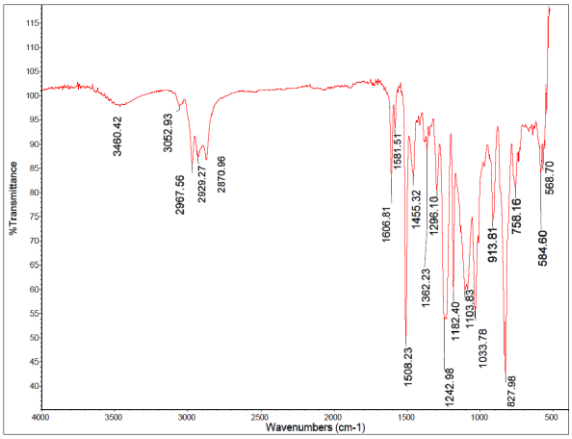

Figure 5a. FT-IR of K-153.

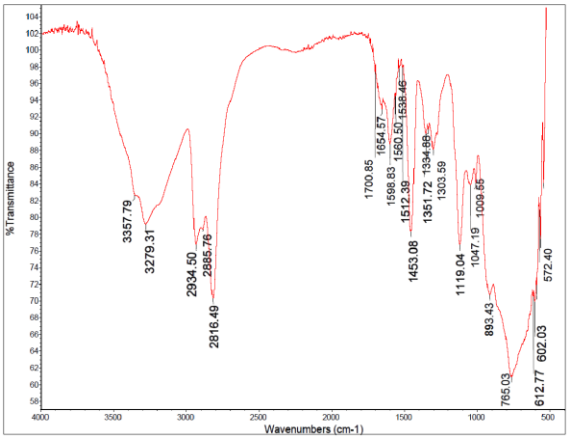

Figure 5b. FT-IR of PEPA.

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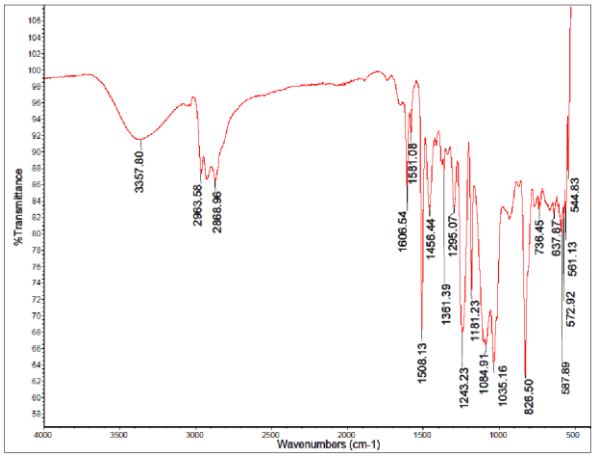

Figure 5c. FT-IR of cured K-153.

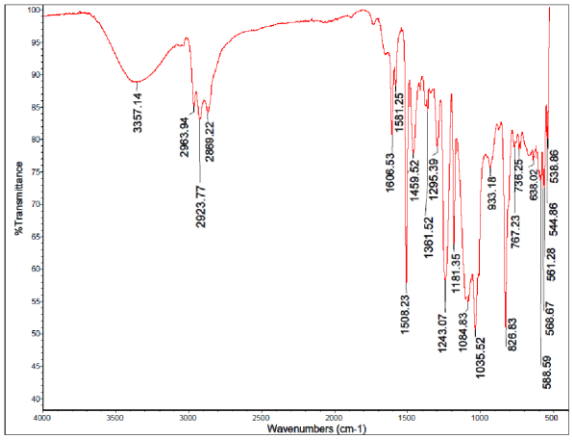

Figure 5d. FT-IR of nanocomposite.

Figures 5a, 5b, 5c, 5d showed that (Moore, 2017), peak 913.81 cm-1 of the oxiran group in epoxy resin (figure 5a) could not be observed at figure 5c and figure 5d. Besides that, peak 3279.31 of the NH group in figure 5b could also not be seen at figure 5c and figure 5d. This indicated that, epoxy ring- opening reaction with PEPA had completely occurred. There were some new peaks on figure 5d, in which, peak 933.18 cm-1 represented the vibration of Si-OH bond, and peak 767.23 was typical for the vibration of the Si-O-C bond, which proved in the captured sample FT-IR spectrum with silica.

3.6. Thermal oxidation resistance of K-153 and nano composite

To investigate thermal oxidation resistance of cured K-153 epoxy and nanocompsite, Thermogravimetric analysis (TGA) was used. Samples were cured K-153 epoxy and nanocompsite with nanosilica of 1.2 wt% . Results were shown in table 2 and figures 6a, 6b.

Table 2. Thermal oxidation resistance of epoxy resin and composite epoxy/nanosilica.

Samples	Weight loss (%)	
	300 ºC	600 ºC
K-153	16.53	94.81
Nanocomposite	3.16	86.09

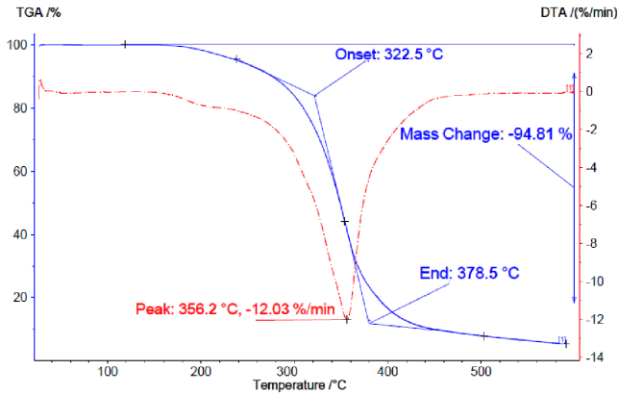

Figure 6a. TGA of K-153.

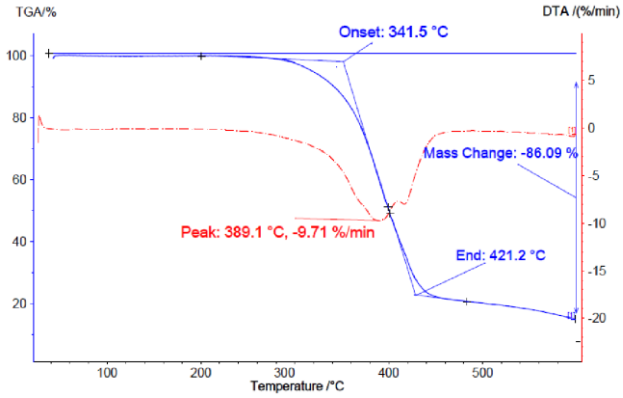

Figure 6b. TGA of nanocomposite.

Figures 6a, 6b and table 2 showed that, compared with K-153, thermal oxidation resistance of nanocomposite increased significantly. Besides that, K-153 had an ash content of 5.19 % and in the presence of nanosilica, ash content of nanocomposite was much higher, up to 13.91 %. Thus, it showed that nanosilica had improved thermal oxidation resistance of epoxy resin. In conditions of high temperature and oxygen, polymer chains were cut and oxidation of organic substances by oxygen also occurred. At that time, oxygen promoted the formation of free radicals, causing polymers to degrade deeply, forming lower molecular compounds containing oxygen. For nanocomposite, nanosilica particles prevented penetration of heat and oxygen into the structure of epoxy, in addition, thermal decomposition of nanosilica would coke to form a stable structure like ceramic (Huang, Xu, Du, Lee, & Wang, 2017).

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4. Conclusions

- Nanosilica is strongly affected by the physical state and viscosity of K153 epoxy resin. Nanosilica content of less than 1.5 wt% was suitable for K153 in manufacturing polymer composite.

- Nanosilica greatly affected the curing temperature of K153, at 80 ºC, gel content was 79.15%, significantly increased compared to K-153 without nanosilica of 75.28 %.

- Nanocomposite's tensile strength was 79.81 MPa and flexural strength was 98.14 MPa with nanosilica of 1.2 wt%, those significantly increased in comparison with those of K-153 were 53.30 MPa and 60.81 MPa respectively.

- Nanosilica with content up to 1.5 wt% enhanced surface hardness of nanocomposite (increased from 70 Shore D to 84 Shore D). Regarding other properties of nanocomposite, nanosilica content of 1.2 wt% was suitable for manufacturing nanocomposite.

- Thermal oxidation resistance of polymer composite was higher than epoxy resin and ash of K-153 epoxy resin was 5.19 % but of nanocomposite was 13.91 %.

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Pulsed electric field (PEF)-assisted Extraction of Phenolic Compounds from Mangosteen Pericarp

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Abstract

Mangosteen (*Garcinia mangostana* Linn.) pericarp is a rich source of phytochemicals. Therefore, It is used as a traditional medicine. This study aims to investigate effects of pulsed electric field (PEF)-assisted extraction of mangosteen pericarp on total phenolic content (TPC) and antioxidant activity using ferric reducing ability power (FRAP) assay. The study conditions were varied by PEF intensity (4, 5 and 6 kV/cm-1) with 1000, 3000 and 5000 pulses. Mangosteen pericarp macerated in water was used as a control. The study revealed that TPC value increased with higher intensity and pulses. The highest TPC was observed, in the pericarp extracted with 6 kV/cm^{-1} and 5000 pulses, at 0.17 mgGAE/gFW. The PEF-assisted extraction showed 425% increment compared to its untreated counterpart. Similar trend was found with FRAP assay where the pericarp extracted with PEF (6 kV/cm^{-1}, 5000 pulses) showed the highest FRAP value at 0.38 mgGAE/gFW. Moreover, TPC value and FRAP value exhibited positive correlation with r = 0.9869.

Keywords: *Pulsed electric field-assisted extraction, mangosteen pericarp, phenolic content, antioxidant activity*

1. Introduction

Mangosteen (*Garcinia mangostana* Linn.) fruit is also known as the "Queen of fruits" because of its excellent flavor. The edible pulp of mangosteen fruit is white, soft and juicy with a slightly acidic, sweet flavor and a pleasant aroma. The fruit is round with a smooth, thick and tough pericarp. The color of the pericarp is dark purple when fully ripe (Satong-aun, Assawarachan, & Noomhorm, 2011). Mangosteen pericarp was used as an alternative treatment, such as heart medications, lowering the blood sugar, malaria medicines, anti-inflammatory agent, antimicrobial, and antioxidants (Muchtaridi, Prasetio, Saptarini, & Saputri, 2018).

There are important components in mangosteen pericarp which possess antioxidant properties and other medicinal properties which called xanthones alpha (α)-, beta (β)- and gamma (γ)-mangostins (Satong-aun et al., 2011). Xanthones are polyphenol compounds that are found abundantly in mangosteen pericarp which contain α-mangostin as the major xanthones compound (Figure 1) followed by γ-mangostin (Mohammad et al., 2018). There are many extraction techniques to recover bioactive xanthones from mangosteen pericarp.

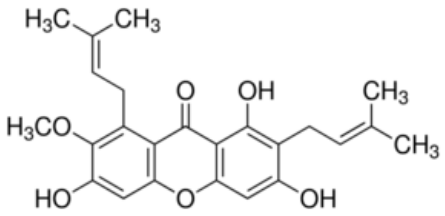

Figure 1. Chemical structure of α-mangostin

Various solvents extraction techniques such as Soxhlet, maceration and ultrasonication, with different solvents (methanol, ethanol, 70% acetone, ethyl acetate etc.) have been commonly used for extracting α-mangostin from mangosteen pericarps (Boonrat & Indranupakorn, 2015). However, it is a toxic solvent with high energy consumption. In addition, the disposal of organic solvents is also a big environmental issue. Meanwhile, temperature played an important role in increasing the solubility of bioactive compounds. However, thermal degradation of bioactive compounds occurred at the same time.

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At present pulsed electric field treatment (PEF) or high-voltage, high-current electrical signal supply for a short time under conductive liquid between high-voltage electrodes, is an emerging technique for environmentally friendly extraction method. It has a variety of applications such as disinfection of ready-to-eat foods such as fruit, meat, beverages, or dairy products. PEF treatment has also been applied to the destruction of plant cell walls to enhance phytochemical compounds released from the cells. A basic principle of this technique is by using a switching type power supply that can generate high voltage up to 20 kV electricity. The high voltage is stored in the capacitor and then the pulse generator supplies a short pulse of high voltage to the plant extraction chamber with the solvent. A short pulse electric field travels through a high voltage electrode and penetrates plant cells causing them to break and the important substances are released in the solvent.

This project aimed to study the effect of pulse number and pulse intensity on phenolic compounds and antioxidant activity extracted from mangosteen pericarp.

2. Methodology

2.1 Raw material

Mangosteens were purchased from a local market in Chiang Mai. Mangosteen pericarp was cleaned with 10% sodium bicarbonate solution then dried at room temperature. The sample was cut into small pieces which were approximately 5 x 5 x 5 mm^3. The sample was treated with an electric pulsed field immediately after processing.

2.2 Chemicals

Folin-Ciocaltue reagent gallic acid, gallic acid, sodium acetate hydrate and ferrous sulphate were purchased from Sigma-Aldrich (Singapore). Potassium chloride, sodium carbonate and hydrochloric acid was purchased from Merck (Darmstadt, Germany). Deionized water was purchased from LABSCAN.

2.3 Sample extraction using pulsed electric field

15 g of chopped mangosteen pericarp and 40 ml of distilled water was added to an extraction chamber. PEF intensity at 4, 5 and 6 kV/cm-1 were studied with 1000, 3000 and 5000 pulses. The pulse frequency used in this study was 2 Hz. After the PEF treatment, the mixture was centrifuged at 5000 rpm for 10 minutes at room temperature and the supernatant was collected. The supernatant was immediately analyzed for total phenolic content (TPC) and antioxidant activity using ferric reducing ability power (FRAP) assay.

2.4 Determination of total phenolic content (TPC)

Total phenolic content (TPC) was measured by Folin- Ciocalteau method as described previously (Folin & Ciocalteu, 1927) with some modifications. A reaction mixture contained 0.2 ml of extract, 0.2 ml of 10% Folin ciocalteu phenol, and 2 ml of 7.5% sodium carbonate solution. The mixture was set aside for 30 minutes in the dark. The absorbance was measured at 765 nm using a spectrophotometer. Gallic acid was used as the standard for the calibration curve.

2.5 Determination of antioxidant activity

The antioxidant activity of the samples was determined by ferric reducing ability power (FRAP) assay according to Benzie and Strain (ref). Briefly, 2 ml of working FRAP reagent (0.1 M acetate buffer: 0.02 M $FeCl_3$: 0.01 M TPTZ = 10: 1: 1) prepared freshly were mixed with 0.2 ml of the mangosteen pericarp supernatant and mixed well. The mixture was set aside for 30 minutes in the dark. The absorbance was measured at 593 nm using a spectrophotometer. Gallic acid was used as the standard for the calibration curve.

3. Results and Discussion

According to the study, PEF-assisted extraction resulted in significant temperature increment ($p < 0.05$) when the pulse intensity and pulse number increased.

Table 1 Temperature (℃) during PEF-assisted extraction at different conditions

PEF intensity (kV/cm-1)	Pulse number		
	1000	3000	5000
4	32	41	47
5	32	44	53.6
6	31	44	62.3

3.1 Effect of pulsed electric total phenolic content

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An analysis of total phenolic contents (TPC) in untreated and PEF treated mangosteen pericarp extract revealed that PEF-assisted extraction showed higher TPC than control samples.

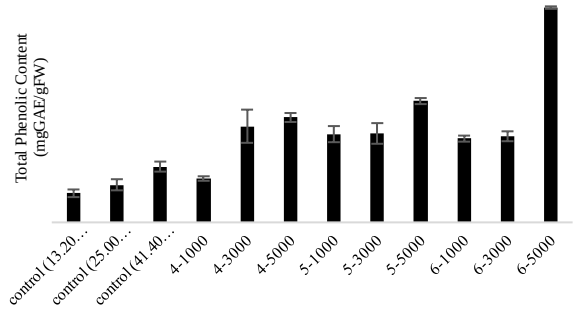

Figure 2 Total phenolic content of mangosteen pericarp extracted with PEF at various condition

As presented in figure 2, the higher PEF intensity resulted in the higher TPC. TPC values were 0.04, 0.08, 0.1 and 0.17 mg GAE/g FW when the extracting conditions were maceration, 4, 5, 6 kV/cm^{-1} with 5000 pulses, respectively. The highest TPC was found with the sample extracted with pulse intensity of 6 kV/cm^{-1} and 5000 pulses. The highest TPC was 425% increment compared to its untreated counterpart.

There are very few studies regarding PEF-assisted mangosteen pericarp extraction. However, TPC values of mangosteen pericarp varied depending on extraction methods. PEF-assisted extraction in plant material has shown to enhance TPC values. A study of Alide and colleagues (2020) showed that TPC values of garlic extracted using PEF was higher than non-PEF extraction. This may also result from temperature increment during PEF treatment. Moreover, PEF also affected cell wall of the plant material which led to more phenolic compounds released in extraction medium (Shaimaa, Mahmoud, Mohamed, & Emam, 2016).

3.2 Effect of pulsed electric field on radical scavenging activities using FRAP assay.

The analysis of FRAP values exhibited a similar trend with TPC values.

As presented in figure 3, the higher PEF intensity resulted in the higher FRAP. FRAP values were 0.02, 0.05, 0.06 and 0.13 mg GAE/g FW when the extracting conditions were maceration, 4, 5, 6 kV/cm^{-1} with 5000 pulses, respectively. The highest FRAP value was found with the sample extracted with pulse intensity of 6 kV/cm^{-1} and 5000 pulses. The highest FRAP value was 650 % increment compared to its untreated counterpart.

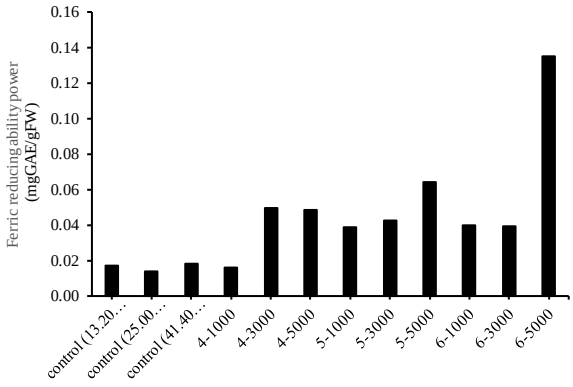

Figure 3 Ferric reducing ability power of mangosteen pericarp extracted with PEF at various condition

According to the findings, increasing pulse intensity and pulse numbers led to temperature increment which subsequently resulted in higher TPC and FRAP values. This may attribute to cell wall damage by PEF. The scanning electron microscope (SEM) exhibited that when the PEF intensity increased, more damages occurred (Figure 4). Similar study on PEF-assisted herb extraction using steam distillation also found that cell wall deconstruction from PEF resulted in higher essential oil extraction (Dobreva, Tintchev, Dzhurmanski, & Toepfl, 2013).

Moreover, a study revealed that the yield of α-mangostin, xanthones polyphenol, extracted from mangosteen pericarp may enhance when exposed to high temperature (65 ℃) which may cause by the shifting of functional group in other mangostin compound to the α-mangostin structure (Mulia, Hasanah, & Krisanti, 2018). The author also stated that polyphenol oxidase enzyme degradation during high temperature treatment may give a rise to the α-mangostin content. Similar study also showed that cytotoxicity of mangosteen pericarp extract positively correlated with temperature used in the experiment.

According to the information on cytotoxicity of α-mangostin therefore extraction method as well as extraction condition must be carefully selected to minimize cytotoxic effect that may occur.

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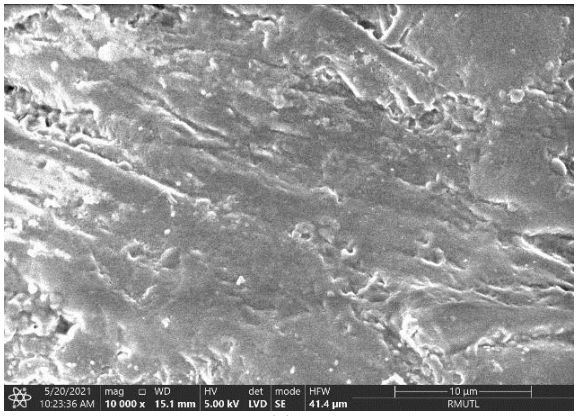

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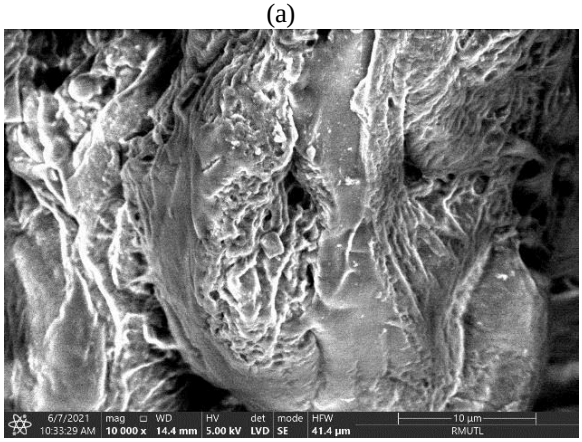

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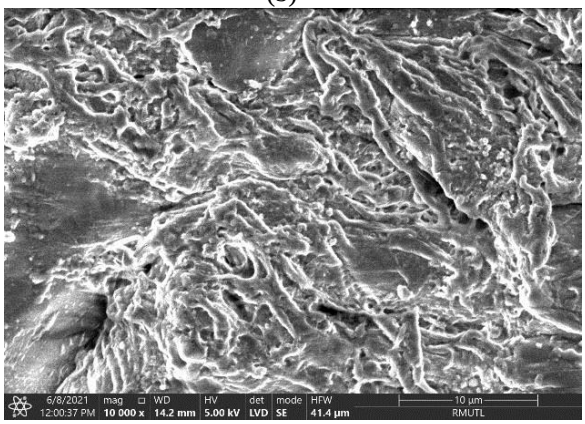

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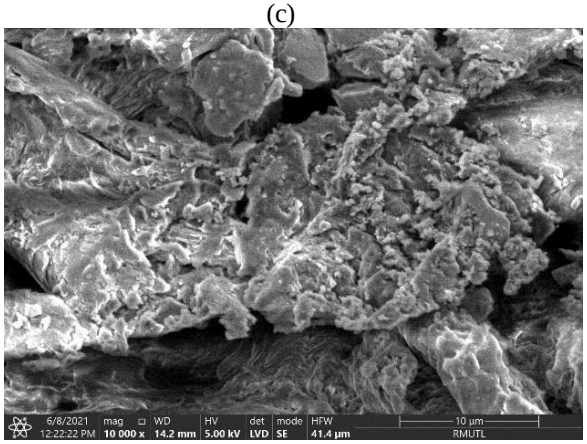

(d)

Figure 4 SEM images of mangosteen pericarp extracted with PEF at various conditions were (a) control (b), (c) and (d) 4, 5 and 6 kV/cm with 5000 pulses, respectively.

Significant positive correlations were found between total phenolic content and FRAP values ($p \leq 0.01$) ($r = 0.9869$). It could be assumed that phenolic compounds in plant extracts contribute significantly to their antioxidant potential. Similar finding was reported that total phenolic content determined by the Folin–Ciocalteu method presented strong correlation with DPPH, ABTS, and FRAP assays (Dudonne, Vitrac, Coutiere, Woillez, & Merillon, 2009).

4. Conclusion

The total phenolic content extracted from mangosteen pericarp was enhanced using PEF-assisted extraction. When the PEF intensity was raised, the extraction capability was elevated. Furthermore, total phenolic content and FRAP value were significantly positively correlated.

5. Acknowledgement

This study was a part of a research project "Development of biological compounds extraction using pulse electric field from Thai herbs and evaluation of their biological activities"**.** The project was supported by Rajamangala University of Technology Lanna (grant number: 64A170000003)

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Development of Artificial Intelligence-Based Application Promoting SMCE and SME for Thailand Organic Valley

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Abstract

Thailand Organic Valley, spearheaded by government officials, is the country's first of its kind, serving as an agricultural template for the organic farmer's community located on Nong Bua Dang's plateau in Chaiyaphum. The community needs a way to promote and to move products digitally. Therefore, the authors have developed an e-commerce application to aid in selling and online marketing for the farmers-owned agricultural organic cooperative. The application also facilitates an artificial intelligence (AI) chatbot to ease the communication between the organic valley community and their buyers. The authors have also assessed the application's quality in serving online promotion. Finally, a customer satisfaction survey evaluates the platform's effectiveness. The population samples are drawn from three main target groups: regular website visitors, small and micro community enterprises (SMCE) and from small and medium enterprises (SME) in the Organic Valley area in the size of 325 people. The study utilizes the developed e-commerce platform, an application performance survey, and a satisfactory survey. Upon completion of the study, the application can be used as an e-commerce platform to connect customers with Organic Valley producers, utilizing a chatbot to ease communication according to the survey results. The assessment by experts has concluded that the application is very satisfactory (average of 4.37). The satisfactory survey conducted on representatives from SMCE and SME and visitors shows an average of 4.30.

Keywords: Development of artificial intelligent application, Digital marketing, Organic valley, Web application

1. Introduction

Thailand is an agricultural society and agriculture is still a way of life for most the Thai people. The agriculture sector is one of the main contributions to the country's economic growth. Small and Micro Community Enterprises (SMCE) and Small and Medium Enterprises (SME) are the main factors sustaining the economy (Ali Qalati, Li, Ahmed, Ali Mirani, & Khan, 2021). The SMCEs and SMEs in Nong Bua Dang, Chaiyaphum comprise many organic producers and farmers. The area has long been known for its rich soil and appropriate climate for cattle and plants. It has been proudly called the first "Organic Valley" of Thailand ever since. Despite its rich soil and suitable weather, the farmers do not succeed financially because of market reach. Fluctuations in demand often lead to lower profits. Most of the organic producers cannot afford branding, sorting, packing, and marketing. Middlemen in the agricultural sector have an important role in bridging the gaps between farmers and the markets (Hatture & Naik, 2019). This also decreases money in the farmers' pockets. Technology in e-commerce applications has become an indispensable tool which enables the farmers to play middleman themselves. The application could do various things: public relation tasks (Jattamart & Kwangsawad, 2018; Suwannasri & Patcharatanaroach, 2018) and online marketing, for example, helping market expansion without the need for middlemen. It's also driving the local economy and creating jobs. There are studies about implementing chatbots to enhance customer services (Asadi & Hemadi, 2018; Vijayakumar, Bhuvaneshwari, Adith, & Deepika, 2019). The application would also help the day-to-day operations such as invoicing, taxing, and payroll utilizing the power of ERP (Elbahri et al., 2019; Mahraz, Benabbou, & Berrado, 2019).

Therefore, the study aims to build a workable e-commerce application with chatbot to

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help the Nong Bua Dang Organic Valley's farmers. The researchers will then perform an accurate customer satisfaction analysis asking multiple target groups how satisfied they are. The application itself will also be measured.

2. Materials and Methods

The study comprises the following components: Application Development, Search Engine Optimization, Structured Questionnaire Survey, and Satisfactory Survey. The authors have decided to conduct this study using research and development strategy as outlined in Figure 1. Workflow of the Research: A 5-point Likert Scale is applied in all statistical analyses and categorized as Very satisfied (5.00 – 4.50), Satisfied (4.49 – 3.50), Neither (3.49 – 2.50), Dissatisfied (2.49 – 1.50), and Very dissatisfied (1.49 – 0.00). The questionnaire surveys have been categorized into two groups for separate assessors: experts in technology-related fields and representatives from SMCEs and SMEs including those assessing the application satisfaction.

1: Preparation

1.1 Study all information pertaining to the area of interest and associated parties such as SMCEs and SMEs.

1.2 Plan the meeting with government entities and interested parties for cooperation in application development to best suit the needs of the following groups:

1.2.1 One representative from each SMCE/SME by means of purposive sampling with a simple random sampling method using Krejcie and Morgan's table (Krejcie & Morgan, 1970: 608)

1.2.2 Government representatives such as the district chief and other officers responsible in SMCE /SME related tasks, in total 25 officers using a simple random sampling method and purposive sampling.

2: Analyzing existing workflow of the SMCE and SMEs (R1)

2.1 The largest possible number of parties to participate in the application development has been sought using Participatory Action Research (PAR) to collect data and to make assessments. The authors have facilitated a focus group discussion and conducted an interview with farmers along with relevant entities using structured questionnaire surveys.

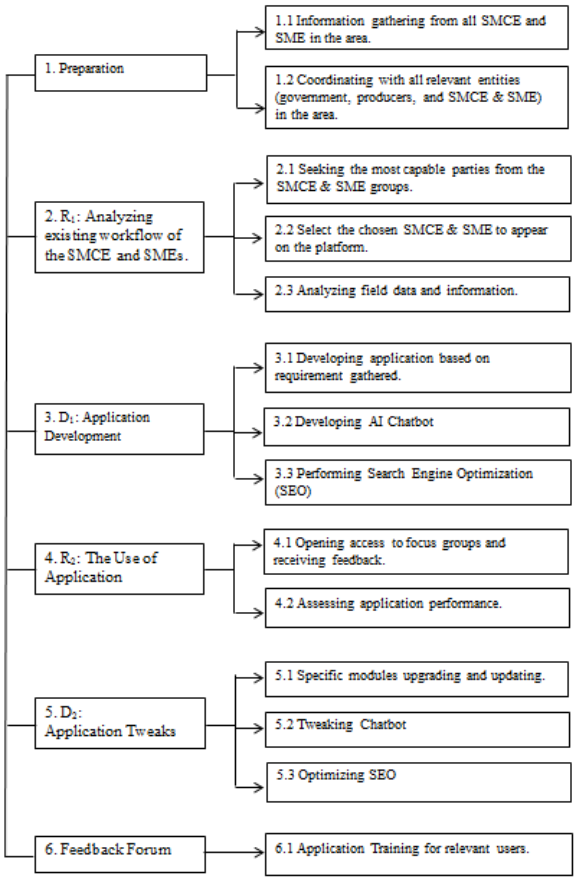

Figure 1. Workflow of the research.

2.2 Information is gathering information on items produced by the selected parties in the Organic Valley to appear in the application. The chosen products are considered as high quality and able to ship to customers immediately.

2.3 The field data is analyzed to use as a requirement of application development. The application comprises several modules tailored to meet the focus groups' expectations.

3: Application Development (D1)

3.1 The application comprises three main components: e-commerce website, application backend, and chatbot. The authors used PHP Laravel and Vue JS for the frontend and later decided to use Odoo Framework for both frontend and backend as a full replacement for easier single-codebase development. The domain name for this application is registered as ThailandOrganicValley.com.

3.1.1 Server:

The authors have utilized a cloud-based Ubuntu 18.04 server on DigitalOcean platform (4

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GB Ram / 2 CPUs, 80 GB SSD storage disk, and 4 TB transfer monthly transfer rate limit) running Dockerized-containers with the following services:

- Dockerdoo contains Odoo version 12.0
- PostgreSQL runs a PostgreSQL database service version 11.0
- Tibco JasperServer Community Edition hosts the Java report engine server.
- Traefik helps reverse proxy and load balancing for the site which maps ports 8069, 8072, 5432, 8080 for Odoo, Odoo LongPolling, Postgres, and JasperServer, respectively. The reverse proxy service exposes ports 80 (HTTP) and 443 (HTTPS) to the Internet.

3.1.2 Application

The existing 'web' Odoo module has been installed for website frontend capability along with 'website' Odoo Community Association (OCA) modules such as 'debrand' and 'logo' for further aesthetic purposes. The 'e-commerce' module has also been utilized for online selling and purchasing. Furthermore, inventory management features have been used to track products on hand by installing a 'stock' module. The operations associated with human resources such as leaves, employee management, work scheduling, and expense reports are vital parts of most businesses; see Figure 2. The authors have decided to use existing Odoo apps with customized modifications to make the app relevant to the Thailand Organic Valley operation. However, the accounting of the business is a general chart of accounts (COA), see Figure 3, since the real operation is still in beta.

GraphQL, a query language for APIs and a runtime for fulfilling those queries with the existing data, is adopted to create, read, update, and delete (CRUD) for the application data. It is considered to be future-proof for further development in the future. The authors have developed a GraphQL schema to manipulate the application's blog for faster and more efficient posting. Furthermore, a modern progressive JavaScript framework application, VueJS, has been created for interaction with the above-mentioned query language.

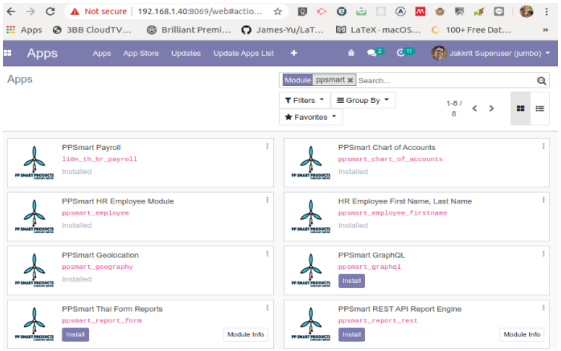

Figure 2. Custom modules**.**

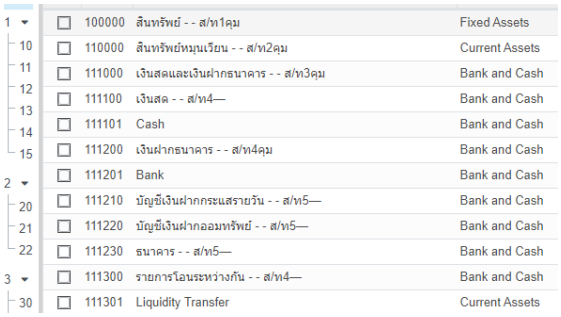

Figure 3. Chart of accounts**.**

3.1.3 Reports

The long-standing JasperReports developed by TIBCO based on Java has been around for at least a decade. It has been proven to be excellent at creating a complex report. The authors have planned to incorporate it into the ecosystem. Meanwhile, the JasperReports application is utilized to develop human resources- related tasks, e.g., a list of employees. We have written customized Python scripts to allow communication between the database and the Jasper Server.

3.1.4 Chatbot

An AI chatbot helps the business to answer client's questions regarding the available products. The chatbot interacts with customers through the Line messaging platform due to its large local user base in Thailand. The bot is based on DialogFlow which is a user-friendly and intuitive platform developed by Google with powerful natural language processing (NLP); see Figure 4.

The algorithm can be described as follows.

- Users input query via Line Messenger or Odoo Chat.

- Odoo Chat or Line webhook forwards requests to Google DialogFlow to perform user's intent classification.

- The available intents are product search, quantity query, and price lookup.

- Once intent has been classified, database query returns result via Line or Odoo Chat.

The chatbot algorithm can be seen in Figure 5. The architecture diagram can be seen in Figure 6.

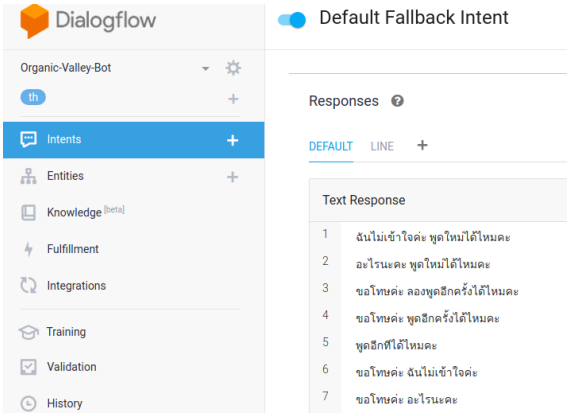

Figure 4. Dialog flow training example**.**

Algorithm 1: User interaction with chatbot

Input : Natural language *query* from user via Line Messenger or Odoo Chat
Output: Retrieved *productData* in JSON

```
do
    query text forwarded to DialogFlow to extract keywords and
     classify intent
    user's intent classification sent back to Server
    for each product p in user intent do
        lookup productData in Odoo database via product API
        return productData
    end
while user makes product inquiries;
```

Figure 5. Chatbot algorithm**.**

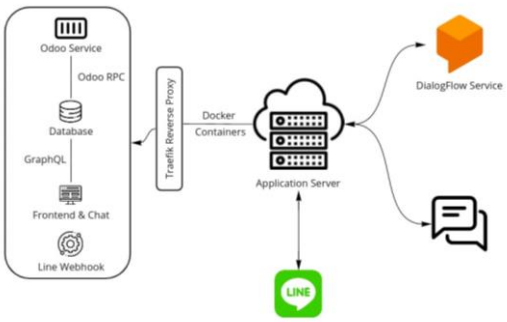

Figure 6. Architecture diagram**.**

3.1.5 Frontend

The frontend consists of two separate parts; administration and customers. The administrative part accommodates all previously mentioned features such as products, data entering etc. The customers have access to the e-commerce components through the website to buy and acquire information through contact form and Line Chatbot. They also received invoicing and receipt via email. The mail servers, both incoming and outgoing, are encrypted and based on Google GSuite services. The appearance of the platform can be seen in Figure 7 and 8.

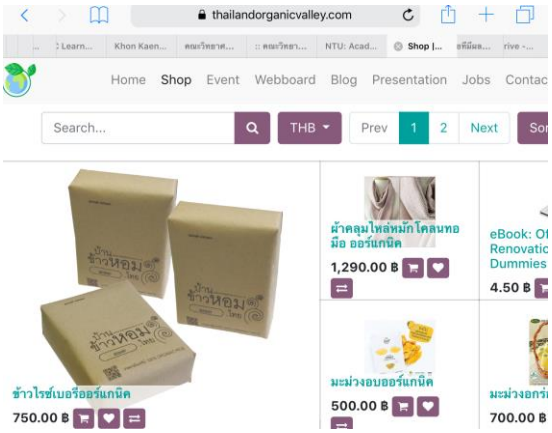

Figure 7. Product page**.**

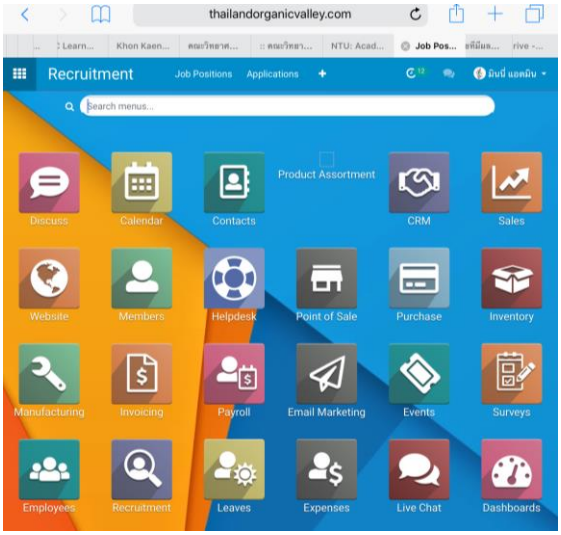

Figure 8. Admin page**.**

3.1.6 SEO

The authors have also developed forum and blog components to accommodate search engine

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optimization (SEO) organically, as organic SEO will eventually mitigate the cost of advertising. The authors have utilized the web traffic of the major social platforms, i.e., Facebook, Instagram, Twitter, YouTube, Google Plus and Pantip, to generate leads back to our website. Tagging photos and videos is also one of the strategies to generate organic web traffic to the site.

4: The Use of Application (R2)

4.1 A qualitative research method, Focus Group Discussion (FGD) has been conducted with representatives from SMCE and SME and stakeholders in the area. The information collected from the FGD is then used in application improvements.

4.2 Application Performance Assessment

4.2.1 Opening application access to focus groups and receiving feedback has been performed utilizing a rating scale like Likert scale survey forms. The authors have surveyed two separate groups; experts in technology-related fields and regular visitors.

4.2.2 Reliability of survey: This study has used Cronbach's α coefficient to assess the internal consistency of the survey for experts' and visitor's assessments. The results were 0.84 and 0.86, respectively.

4.2.3 Sampling Method: Twelve experts and 325 regular visitors have been assessed for satisfaction after using the application. They are from various background including local farmers (SMEs and SMCEs), local government agencies, regular locals, self-employed, office workers, government officers, students, and teachers over 15 years of age using an unknown population technique, and

$$n = \frac{P(1-P)Z^2}{c^2}$$

where n = sampling size

Z = standard normal deviation

P = percentage picking a choice or response

c = confidence interval.

This study set $P = 0.3$, $c = 0.05$ and $Z = 1.96$ (at 95% confidence level)

4.2.4 Application Performance Assessment: The authors have used SPSS Version 15 to calculate the Likert-scale survey results.

3. Results and Discussions

The most-capable participants in manufacturing and producing high quality products selected from the SMCE and SME group are:

- Organic weaving (Figure 9)
- Organic Cavendish banana
- Organic Barracuda mango (Mamuang Plang Yai Ban Loan Group, Mae Ban Thai Jaroen Group)

The selected groups have been in the market for some time and have the need to expand digitally without middlemen.

A few unselected participants could potentially grow in the near future, including mulberry woven thread export group (Ban Non Sri Sanga SMCE), beef cattle group (Ban Lad Wang Muang), and agritourism group (Kon Ton Nam Chee).

Figure 9. Ban Lad Wang Muang Group**.**

1. Application Interface

1.1 Frontend application: Visitors can browse the entire collection of products and local events. They can ask chatbot about products via the Line application and on the website forum. Guests can register to become a member of an app. Blogging is available to users. It is a big contribution to SEO as well.

1.2 Backend Application: Admins have access to all modules such as setting up products, managing inventory, scheduling employees, making transactions through POS (point of sale), payrolling, campaigning sales and accounting as mentioned earlier.

2. Assessment of Satisfaction Surveys

2.1 Results from expert survey

Table 1 shows the application's quality survey result from experts in technology-related fields. The experienced users scored the application at an average of 4.37 (very satisfied). As can be seen in the Application Benefits category, it is agreeable that the application could be used in the real world, as it rated satisfied on all items.

2.2 Visitors

The results from the customer satisfaction survey show an average of 4.30, very satisfied. The customers are pleased with the application's user interface (UI) as shown in Table 2.

4. Conclusions

The application has been developed largely based on Odoo (the open-source ERP and CRM) serving to connect the Organic Valley with online buyers. An AI chatbot has also been created based upon Google Dialog Flow's NLP engine to intelligently chat with customers minimizing the workload in customer management tasks. The application also accommodates system users with several backend management jobs, from accounting to sales promotion, as previously mentioned. The authors have chosen to use Google DialogFlow as a starting point because it provides fast development and deployment at no cost. In the future version, we are aiming to train our own NLP model to achieve better performance.

Visitors can navigate the website and browse the organic products offered by Nong Bua Dang's SMCEs and SMEs. They can participate in the forum to interact with farmers directly. Farmers or government bodies can organize an event to attract people, which in turn boosts the local economy.

Administrators can incorporate new and custom modules to the system to best suit the nature of business. For example, when the SMCEs and SMEs decide to deliver products using their own fleet, a fleet service module can be created and integrated easily.

Maintenance of the computer server, networking, and system maintenance are essential to the business as well as upgrading existing modules or developing new ones. The application operators also need to perform SEO tasks to generate organic traffic to the website. Therefore, a person with computer literacy could be an asset to the whole operation.

The chatbot should be able to handle more advanced conversations with customers. It should be trained with more intents and follow-ups. Also, webhooks should be associated with more backend-related inquiries such as employee's work schedules, coupon notification, etc. Moreover, a bot fluent in Chinese could be very valuable to the farmers in Chaiyaphum.

Table 1. Results of the application satisfaction assessment by experts**.**

Content	Mean	SD	Level
[1] Design			
1. User interface is well-designed and looks modern.	4.75	0.45	Very satisfied
2. The application is not cluttered by menus.	4.17	0.44	Satisfied
3. Font size and background color are easy to look at.	4.38	0.51	Satisfied
4. Products shown on the website are attractive.	4.65	0.39	Very satisfied
Usage			
[2] Visitors			
1. Easy to navigate.	4.52	0.48	Very satisfied
2. Well categorized and easy to search.	4.33	0.61	Satisfied
3. Line chatbot is responsive.	4.14	0.43	Satisfied
4. Website chat box is responsive.	3.91	0.67	Satisfied

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[3] Administrators			
5. Easy to create products.	4.81	0.46	Very satisfied
6. Easy to edit products.	4.71	0.38	Very satisfied
7. Easy to manage inventory.	4.89	0.36	Very satisfied
8. Multiple languages can be added easily.	4.52	0.42	Very satisfied
9. Backend server is fast.	3.88	0.66	Satisfied
[4] Security			
1. Application is encrypted using HTTPS.	3.99	0.53	Satisfied
2. Strong password requirement is hardened.	3.73	0.63	Satisfied
[5] Application Benefits			
1. Application can be used for real transactions.	4.68	0.54	Very satisfied
2. Application can work with external peripherals like thermal printers, etc.	4.82	0.31	Very satisfied
3. Application makes it easier to connect the Organic Valley community with buyers.	4.61	0.45	Very satisfied
4. I'm satisfied with the application overall.	4.78	0.59	Very satisfied
Average ([1],[2],[3],[4],[5])	4.37		Satisfied

Table 2. Results of the visitor satisfaction assessment**.**

Content	Mean	SD	Level
[1] Design			
1. User interface is well-designed and looks modern.	4.51	0.44	Very satisfied
2. The application is not in cluttered by menus.	4.24	0.65	Satisfied
3. Font size and background color are easy to look at.	4.41	0.53	Satisfied
4. Products shown on the website are attractive.	4.23	0.61	Satisfied
[2] Usage			
1. Easy to navigate.	4.34	0.56	Satisfied
2. Well categorized and easy to search.	4.67	0.65	Very satisfied
3. Line chatbot is responsive.	3.98	0.74	Satisfied
4. Website chat box is responsive.	3.95	0.68	Satisfied
[3] Usefulness			
1. Application can be used for real transactions.	4.26	0.52	Satisfied
2. Application can work with external peripherals like thermal printers, and etc.	4.12	0.54	Satisfied
3. Application makes it easier to connect the organic valley community with buyers.	4.35	0.67	Satisfied
4. I'm satisfied with the application overall.	4.48	0.59	Satisfied
Average ([1],[2],[3])	4.30		Satisfied

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Conflict of Interest

The authors do not report any financial or personal connections with other persons or organizations, which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

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Bacterial Contamination of Intensive Care Units at a Federal Medical Centre in Abia State, Nigeria

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Bacterial contamination in the Intensive Care Unit (ICU) is of public health concern because it is one of the leading causes of nosocomial infections and a breeding ground for multi drug resistant (MDR) pathogens. This study evaluated the bacterial contamination in ICU in Federal Medical Centre (FMC), Umuahia. The units sampled were adult ICU, and Newborn special care unit. Samples were processed in the microbiology laboratory by standard methods. The antibiotic sensitivity pattern was done by disc diffusion method. Identification of bacteria was done by Gram stain, Motility and biochemical methods. A total of 166 samples from fomites and air were collected, of which 27 (16.3%) yeided bacterial growth. Thirteen (15.9%) were detected from fomites in adult ICU, and 8 (11.1%) were detected from fomites in newborn special care. Six (50%) were detected from air in both units. The common bacterial isolates were *Staphylococcus aureus*, 8 (29.6%), *Escherichia coli*, 6 (22.2%), Coagulase negative Staphylococci, 6 (22.2%), *Pseudomonas* spp., 1 (3.7%), was the least common bacterial isolate. Antibiotic sensitivity of the bacterial isolates was carried out using disc diffusion method. Gram negative bacterial isolates were more sensitive to Ofloxacin, Peflacine, Ciprofloxacin, and Streptomycin. Gram positive bacterial isolates were more sensitive to Ciprofloxacin, Gentamicin, Rifampicin, Erythromycin, Levofloxacin. However, Coagulase negative Staphylococci was highly resistant to the drugs. This study revealed the presence of bacterial pathogens on fomites in the ICU.

Keywords: Bacterial contamination, Intensive care unit, Antibiotic sensitivity pattern

1. Introduction

Intensive care unit (ICU) is a relevant aspect of an effective health care service that provides care of resuscitating, management and monitoring of life-threatening cases. Some clinical cases in the hospital involve high anti-toxin use, long hospitalization favoring rise of multidrug resistant bacterial strains and rapid dissemination, high morbidity and mortality rate (Blot, 2008; Vincent et al., 2009). Microbes that contaminate inanimate surfaces, equipment and indoor environment are capable of surviving on these surfaces and air for a long time (Kramer, Schwebke, & Kampf, 2006) . Contamination occur by means of cross-transmission and dissemination, occupancy density, use of therapeutic hardware for numerous patient like stethoscope, outfits and dress (Galvin, Dolan, Cahill, Daniels, & Humphreys, 2012; Gupta, Anand, Chumber, Sashindran, & Patrikar, 2007). Health care worker and patient, their accessories and clinical specimen that are contaminated can also cause contamination (Dancer, 2008; Huang, Datta, & Platt, 2006; Ulger et al., 2009) . Non adherence of health care workers to basic standard method of hand washing, contribute to the spread of pathogens, and cross-transmission amid contact with patient or contaminated inanimate surfaces (Hayden, Blom, Lyle, Moore, & Weinstein, 2008; Nseir et al., 2011) . Bacteria that are shed constantly during clinical procedures are harbored by the human skin (Bonten et al. , 1996) . Pathogens can be shed and recouped from the immediate environment of the patient from infected health care worker and patient (Bonten et al., 1996; Pittet et al., 2006; Rohr et al., 2009). The type of organism, source and contamination with the surface, humidity level and size of the inoculum contribute to the spread of infection (Nasser, Abbas, & Hamed, 2013). Wide range of bacterial pathogens have been discovered in ICU contamination. However potentially clinically

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relevant ones include *Staphylococcus aureus*, Coagulase negative *Staphylococcus*, Enterobacteriaceae, and enterococci. These clinically relevant organisms are major causative agents of nosocomial infections, developed as multidrug resistant (MDR) pathogens (Damaceno, Iquiapaza, & Oliveira, 2014; Saka et al., 2016) . These MDR pathogens like Methicillin resistant *Staphylococcus aureus* (MRSA), Vancomycin resistant *Staphylococcus aureus* (VRSA), Extended spectrum Beta lactamase (ESBL) producing Enterobacteriaceae are used as indicator organisms for assessing the level of adherence to fundamental standard procedure in Intensive care units (Hayden et al., 2008; Javed et al., 2008) . Failure in these essential technique tends to build the dissemination of these pathogens within the units and hospital environment. The main objective of this study was to investigate the bacterial contamination of the Intensive Care Unit in FMC, Umuahia by evaluating the presence of potential pathogens.

2. Materials and Methods

2.1 Study location

This study was carried out in the Adult ICU and the Newborn Special Care Unit of Federal Medical Centre, Umuahia, Abia State, Nigeria. The study was approved by the ethical committee of FMC, Umuahia before the commencement of Sampling and analysis.

2.2 Sample collection and processing

Settle plate method and swabbing method were used as described (Cheesbrough, 2006). The fomites in each unit were pre-identified and the point for settle plate spots was pre-designated accordingly. For the swabbing method, sterile swab sticks moistened with sterile water were used to swab the surfaces of the fomites. To ensure maximal coverage of a surface area, the swab was rolled back and forth over each surface before carefully capped and labeled appropriately. The samples were sent for analysis to the laboratory. The swab samples were inoculated onto suitable media (Blood agar, MacConkey agar) which were incubated for 24 hours at 37ºC.

For the Settle plate method, petri dishes containing culture media that are standard were exposed on some tables for 30 minutes at different areas in the rooms and removed before the health care workers came in and were also exposed when there was activity in the units for the same duration of time before it was sent for analysis to the laboratory. Suspected bacterial growths were identified and confirmed by standard bacteriological methods.

2.3 Antibiotic susceptibility test

Antibiotic susceptibility testing was performed using the disk diffusion method and was interpreted by Clinical and Laboratory Standards Institute (2011) on Mueller Hinton agar (Hardy Diagnostics, USA). Mueller Hinton culture plates were inoculated by dipping a sterile cotton wool swab into the overnight growth of the organism in suspension prepared to the density of a McFarland no 0.5 opacity standard; spread plate method was used to express excess liquid from the swab before inoculation.

Antibiotic discs that were used have the following concentrations: Streptomycin 30 µg; Ofloxacin 10 µg; Norfloxacin 10 µg; Gentamicin 10 µg; Amoxil 20 µg; Ciprofloxacin 10 µg; Erythromycin 30 µg; Rifampicin 10 µg; Amoxycillin/Clavulanic acid 30 µg; Cefalexin 10 µg; Nalidixic acid 30 µg; Septrin 30 µg.

After overnight incubation, examination of the control and test plates were carried out to ensure the growth is confluent or near confluent**.** The diameter of each zone of inhibition was measured in mm using a ruler on the plate**'**s buttom**.** Growth starts at the endpoint of inhibition. The control strain used was *Escherichia coli* ATCC 25922.

3. Results

There were a total of 166 samples collected and analyzed from both Adult Intensive Care Unit and Newborn Special Care Unit. The bacterial growth observed that were positive was 16.3%. The bacterial contamination as detected from fomites showed 15.9% from Adult ICU while 11.1% from Newborn Special Care unit. 50% were from air in both Adult ICU and Newborn Special Care unit.

Seven different bacterial isolates were identified. *Staphylococcus aureus*, 29.6%, *Escherichia coli*, 22.2%, Coagulase negative Staphylococci, 22.2% were the majority bacterial isolates while other bacterial isolates were *Enterobacter* spp., 7.4%, *Klebsiella pneumoniae*, 7.4%, *Bacillus* spp., 7.4%, and *Pseudomonas* spp.,

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3.7%. In Table 1, *Staphylococcus aureus*, 8 (29.6%) was the highest isolated bacteria followed by *Escherichia coli*, 6 (22.2%) while *Pseudomonas* spp., 1 (3.7%) was the least isolated bacteria. In Table 2, mattress, 4 (30.8%) and mobile phone, 4 (30.8%) had the highest number of bacterial isolates while clinical coat and monitor had no bacterial isolates. In Table 3, mattress, 3 (37.5%) and mobile phone, 3 (37.5%) had the highest bacterial isolates. There was no bacterial isolate isolated from incubator, measuring tape, clinical coat. In Table 4, *Staphylococcus aureus*, 3 (50.0%) was the highest isolated bacteria in both units. In Table 5, the antibiotic susceptibility pattern of bacterial isolates is seen.

Table 1. Diversity and percentage of bacterial isolates in the study.

ISOLATES	NO OF ISOLATES	PERCENTAGE (%)
Staphylococococcus aureus	8	29.6
Escherichia coli	6	22.2
CoNS	6	22.2
Enterobacter spp.	2	7.4
Klebsiella pneumoniae	2	7.4
Bacillus spp.	2	7.4
Pseudomonas spp.	1	3.7
Total	27	100

KEY: CoNS- Coagulase negative Staphylococci, NO: Number

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Table 2. Distribution of bacterial isolates from fomites in the Adult ICU at FMC, Umuahia.

ITEMS	NO EXAMINED	NO OF BACTERIAL ISOLATES							
		Staph aureus	***E. coli***	***Entero* spp.**	***Kleb pneu***	***Bacil* spp.**	**CoNS**	***Pseudomonas* spp.**	**Total**
Mattress	11	0	2	2	0	0	0	0	4
Bedsheet	13	2	0	0	0	0	0	0	2
Stethoscope	20	1	1	0	0	0	1	0	3
Mobile phone	15	1	1	0	0	0	1	1	4
Clinical coat	15	0	0	0	0	0	0	0	0
Monitor	8	0	0	0	0	0	0	0	0
Total		4	4	2	0	0	2	1	13
Percentage (%)		30.8	30.8	15.4	0	0	5.4	7.6	100

KEY: *Staphylococcus aureus*, *Enterobacter* spp., *Escherichia coli*, *Klebsiella pneumoniae*, *Bacillus* spp., Coagulase Negative Staphylococci, NO: Number

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Table 3. Distribution of bacterial isolates from fomites in Newborn Special Care Unit at FMC, Umuahia.

ITEMS	NO EXAMINED	NO OF BACTERIAL ISOLATES							
		Staph aureus	***E. coli***	***Entero* spp.**	***Kleb pneu***	***Bacil* spp.**	**CoNS**	***Pseudomonas* spp.**	**Total**
Mattress	16	1	0	0	1	0	1	0	3
Stethoscope	15	0	1	0	0	0	0	0	1
Mobile phone	15	0	0	0	0	1	2	0	3
Weighing balance	2	0	0	0	0	0	1	0	1
Incubator	4	0	0	0	0	0	0	0	0
Measuring tape	5	0	0	0	0	0	0	0	0
Clinical cloth	15	0	0	0	0	0	0	0	0
Total		1	1	0	1	1	4	0	8
Percentage (%)		12.5	12.5	0	12.5	12.5	50	0	100

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Table 4. Distribution of bacterial isolates from air using settle plate method.

ISOLATES	AICU	NB	TOTAL	PERCENTAGE (%)
Staphylococcus aureus	2	1	3	50
Escherichia coli	1	0	1	16.7
Enterobacter spp.	0	0	0	0
Klebsiella pneumoniae	1	0	1	16.7
Bacillu spp.	1	0	1	16.7
CoNS	0	0	0	0
Pseudomonas spp.	0	0	0	0
Total	5	1	6	100

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Table 5. Antibiotic sensitivity pattern of isolates.

		NO (%) SENSITIVE TO									
Isolates GNB	**No of isolates**	**OFX**	**PEF**	**CPX**	**AU**	**CN**	**S**	**CEP**	**NA**	**SXT**	**PN**
Klebsiella pneumoniae	2	2 (100)	1 (50)	2 (100)	0	1 (50)	2 (100)	0	1 (59)	1 (50)	0
Escherichia coli	6	4 (66.7)	3 (50)	2 (33.3)	2 (33.3)	3 (50)	3 (50)	0	0	3 (50)	3 (50)
Pseudomonas spp.	1	1 (100)	1 (100)	1 (100)	0	1 (100)	1 (100)	0	0	0	1 (100)
Enterobacter spp.	2	2 (100)	2 (100)	2 (100)	2 (100)	2 (100)	2 (100)	0	0	0	0
GPB		**CPX**	**NB**	**CN**	**AML**	**S**	**RD**	**E**	**CH**	**APX**	**LEV**
CoNS	6	1 (16.7)	0	1 (16.7)	0	0	2 (33.3)	1 (16.7)	2 (33.3)	0	2 (33.3)
Staphylococcus aureus	8	3 (37.5)	2 (25)	4 (50)	1 (12.5)	4 (50)	4 (50)	4 (50)	2 (25)	1 (12.5)	4 (50)

KEY: OFX-Ofloxacin, PEF-Peflacine, CPX-Ciprofloxacin, AU-Amoxycillin-Clavulanic acid, CN-Gentamycin, S-Streptomycin, CEP-Cefalexin, NA-Nalidixic acid, SXT-Septrin, PN-Ampicillin, CPX-Ciprofloxacin, NB-Norfloxacin, CN-Gentamicin, AML-Amoxil, RD-Rifampicin, E-Erythromycin, CH-Chloramphenicol, APX-Ampiclox, LEV-Levofloxa

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4. Discussion

Bacterial contamination of ICU is the major factor responsible for increased incidence of nosocomial infections, with attendant consequential effect on patient and healthcare workers (Huang *et al*., 2006; Vincent et al., 2009). Overall, the bacterial contamination rate recorded in the units was 16.3%. Adult Intensive Care Unit has 15.9% while 11.1% was recorded from fomites in Newborn Special Care Unit. The two units recorded 22.2% from air. The breakdown of bacterial contamination rate as detected from the area of collection showed 15.9% in Adult ICU, and 11.1% in Newborn special care unit. This is in contrast to the study by Yusuf et al. (2017) where the overall bacterial contamination recorded in the ICU's was 62.8%. Differemt contamination rate had been reported in other similar studies. In Maiduguri, Nigeria, 62.5% was reported in adult ICU and 38% in neonatal ICU (Abubakar et al., 2014) while 26.9% was reported in adult ICU by Montero et al. (2015). In Ilorin, 67.8% was reported in newborn ICU (Damaceno et al., 2014), 17.8% in Iraq (Saka et al., 2016), while 81% contamination rate from unused nonsterile gloves in ICU (Mojtahedi, Khoshrang, Taromsari, KazemnezhadLeili, & Hoorvash, 2014), and no bacterial contamination rate recorded in ICU in Labhore, Pakistan (Hall, Trivedi, Rumbaugh, & Dissanaike, 2014). The bacterial isolates from fomites in both Adult ICU and Newborn Special Care Unit were low. This is similar to the findings of Yusuf et al. (2017) in adult ICU but in contrast with his findings in Newborn ICU. The air contamination assessment by settle plate method had 83.3% recorded in Adult ICU, and 16.7% recorded in Newborn special care unit with *Staphylococcus aureus* as the predominant isolates. This compares favourably with the studies carried out by Sapkota et al. (2016), Gizaw, Gebrehiwot, & Yenew (2016) and Nwankwo, Nwachukwu, & Nwankwo (2014) where *Staphylococcus aureus* was the most commonly detected organism. These pathogens are mostly normal flora of human skin, and clothing fabrics that are continuously shed during routine activity and clothing fabrics (Gupta et al., 2007; Pittet et al., 2006; Rohr et al., 2009) of the 7 different isolates of bacterial pathogens. *Staphylococcus aureus*, *Escherichia coli*, and Coagulase negative Staphylococci were predominant in the study. Other studies have reported the predominance of *Staphylococcus* spp. and *Bacillus* spp. (Abubakar et al., 2014; Carlet et al., 2007; Galvin et al., 2012; Gupta et al., 2007; Montero et al., 2015; Saka et al., 2016). The recovery of potentially clinically relevant *Staphylococcus aureus*, Coagulase negative Staphylococci, *Escherichia coli*, and *Klebsiella pneumoniae*, from frequently used fomites, and vital areas within the unit is of Infection control and prevention concern.

In this study, we observed a high resistance pattern with the commonly used antibiotics; Amoxycillin/Clavulanic acid, Ampicilin, Cephalexin, Amoxil, Norfloxacin. Similar pattern was reported in other studies (Abubakar et al., 2014; Montero et al., 2015). The same pattern was seen in Yusuf et al. (2017) work with amoxicillin, ampicillin-cloxacillin and cotrimoxazole being highly resistant. The bacterial pathogens did not exhibit multidrug resistance pattern.

The outcome of this study has provided a data to start with on degree of contamination within the units. There are limitations in this study as the duration was short, and the sampling procedure was not comprehensive enough to capture the pre and post cleaning activities that may give a good epidermiological picture of contamination rate.

5. Conclusion

The outcome of this study is of ultimate importance to the hospital infection control and prevention unit. This study has given an overview of the degree of hygiene/cleanliness, indoor air quality and evaluation of units personnel to adherence to method for infection control. It has formed the template to formulate intervention measures. Apart from the bacterial contamination rate, the recovery of pathogens with clinical significance from frequently used fomites and crucial area is of serious concern because of their clinical implication. The hospital infection control and prevention units should adopt periodic surveillance, effective cleaning of fomites before and after use, and adhere to simple basic standard infection procedure, especially hand washing.

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Conflict of Interest

The authors do not report any financial or personal connections with anyone.

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Ethical approval

The study was approved by the Health Research Ethical Committee of Federal Medical Centre, Umuahia, Abia state, Nigeria (Date; 6th November, 2017). Number of ethics:
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