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Effect of Ultrasonic Treatment on the Suspension Stability, Zeta Potential and Contact Angle of Celestite

K. Esmeli & A. Ozkan

Abstract—In this study, firstly, the effect of ultrasonic treatment on the stability of celestite suspension was investigated. In this context, the variations of the suspension stability with ultrasonic power, treatment time, immersion depth of ultrasonic probe and treatment regime (batch and continuous) were determined. The experimental results showed that the suspension stability and zeta potential of celestite decreased with ultrasonic treatment. Also, the treatment time, immersion depth of probe and treatment regime affected the stability of celestite suspension. Secondly, the effect of pre-treatment of the suspension with ultrasonic process on the shear flocculation of celestite using sodium dodecyl sulfate (SDS) was studied and the variations of the flocculation, zeta potential and contact angle of the mineral with SDS concentration were presented. It was found that the ultrasonic pre-treatment slightly improved the shear flocculation of celestite particles in accordance with the increase in the contact angles. In addition, the ultrasonic process again relatively reduced the magnitude of the negative potential of celestite particles in the presence of SDS.

Keywords— celestite, contact angle, suspension stability, ultrasonic treatment, zeta potential

I. INTRODUCTION

ULTRASOUND is a three-dimensional pressure wave consisting of successive compression and rarefaction cycles. The rarefaction cycle has negative pressure and following compression cycle has positive pressure. The rarefaction cycle leads to overcome the intermolecular forces binding liquid, resulting in the formation of microbubbles, and the compression cycle also instantaneously causes a localized burst of energy. This phenomenon known as cavitation imposes significant effect on any solid phase within the liquid [1], [2]. Numerous researchers have been investigated the effects of this unique characteristic of ultrasound on processes of cleaning of metal surfaces, waste water treatment, metal precipitation, dewatering and flotation [1]-[6].

The ultrasonic energy in the flotation technique has been investigated to improve efficiency and selectivity of the process. In these studies, it has generally been reported that ultrasonication enhances the effectiveness of the reagent due to its more uniform distribution in the suspension and also improvement of the activity of the chemicals used [1], [7]. On the other hand, the cavitation occurs most easily on solid-liquid interfaces, since solid-liquid interactions are weaker than liquid cohesion forces. The disruptions formed at the solid-liquid interfaces can modify the surface characteristics of minerals leading to changes in the adsorption of collectors on minerals, which cause changes in the flotation performance of minerals [8].

Aggregation of fine particles in mineral suspension systems can be achieved by neutralizing the electrical charge of the interacting particles, which is coagulation, or by bridging the particles with polymolecules, called polymeric flocculation [9]. The fine particles can also be aggregated in a convenient stirring regime after hydrophobization by the adsorption of surfactants, which is shear flocculation. To provide the hydrophobization of particle surfaces, surfactants known as flotation collectors are often used. Hydrophobic electrically charged fine particles can also form stable suspensions. Therefore, the shear flocculation process requires mechanical energy to overcome repulsive energy barrier arising from the electrical charge on the particle surfaces [10].

The first purpose of this investigation is to present the effects of various operating conditions of ultrasonic treatment on the stability of celestite suspension in the absence of any chemical. Secondly, the effect of pre-treatment of the suspension with ultrasonic process on the shear flocculation of celestite using sodium dodecyl sulfate as surfactant is to introduce by using the measurements of suspension stability, zeta potential and contact angle.
II. MATERIALS AND METHODS

A. Materials

The experimental studies were conducted using a high purity celestite sample from Turkey. The mineralogical analysis showed that the sample contained more than 99% SrSO₄. The sample was dry-ground to below 38 μm size fraction in a ceramic ball mill. Sodium dodecyl sulfate (SDS, C₁₂H₂₅SO₄Na) (Merck) was used as anionic surfactant for celestite mineral. Sodium hydroxide and hydrochloric acid (Merck) were prepared as 1 and 5% solutions for modification of pH values and pH of the suspensions was controlled by a digital pH meter. All of these chemicals were analytical grade and distilled water was used for all experimental work. The ultrasound device used in the experimental study is Bandelin HD 3200 model. The experiments were performed using ultrasonic homogenizer and TT 13 model titanium US probe. The device has a constant frequency of 20 kHz and its maximum power is also 200 W.

B. Suspension Stability Experiments and Ultrasonic Treatment

The experiments were carried out in a 400 cm³ cylindrical cell with four baffles using 1 g solid and 300 cm³ water. The dispersed suspension, adjusted to the desired pH, was first conditioned with a magnetic stirrer at a rotation speed of 500 rpm for 2 min. Then, the surfactant was added to the suspension and the suspension was conditioned with the ultrasonic device for 2 min. After the ultrasonic treatment, the suspension was again stirred at a rotation speed of 500 rpm for 2 min. Then, a settling time of 1 min for the suspension was allowed and 20 cm³ of supernatant was taken out, at a fixed distance of 5 cm below the air–liquid interface, by a special system for turbidity measurements. The turbidity of the supernatant was measured by a Velp Scientifica turbidimeter. The stability of suspension was assessed using the formula given below,

\[ \text{stability, } \% = \left( \frac{T_f}{T_0} \right) \times 100 \] (1)

where \( T_0 \) is the turbidity (nepholometric turbidity unit) of well dispersed suspension of celestite at 1 g/300 cm³ of solid concentration and \( T_f \) is the turbidity of supernatant when sedimentation occurs.

The experiments were performed at a pH of 8.2, which was the natural pH of the celestite suspension. The regime of ultrasonic treatment was carried out as batch, i.e. successive pulsation on for 5 sec and pulsation off for 10 sec, and the ultrasonic probe was also centrally located with an immersion depth of 2 cm.

C. Zeta Potential Measurements

The zeta potential measurements were made by a ZetaPlus apparatus from Brookhaven. A 1 g of the sample was added into 300 cm³ of water, and the suspension was stirred for 5 min after adjustment of pH. Thereafter, the suspension was conditioned with the surfactant for 5 min. Then the suspension was kept still for 5 min to let larger particles settle. Thereafter, a sample of supernatant was taken out and transferred into the clear disposable cell and the cell was placed to the zeta potential analyzer. An average of 12 runs was recorded for the measurement of zeta potential of each sample and the average values were reported.

D. Contact Angle Measurements

The contact angles were determined using a KSV CAM 101 contact angle goniometer. After the shear flocculation experiments, the supernatant was siphoned off and then the settled flocs were taken out by filtration and dried. Thereafter, the obtained samples were prepared as pellets with a hydraulic press. A drop of liquid was formed on the pellet surface by means of a special syringe and the resulting contact angle was determined by the goniometer.

III. RESULTS AND DISCUSSION

A. Effect of Ultrasonic Treatment on The Celestite Suspension

Fig. 1 shows the stability of celestite suspension as a function of ultrasonic power in the absence of surfactant at a pH of 8.2. As shown in Fig. 1, the suspension stability showed a decreasing trend with increasing ultrasonic power. The effect of ultrasonic treatment on the zeta potential of celestite mineral as a function of pH is also presented in Fig. 2. The treatment of ultrasonic process slightly reduced the magnitude of the negative zeta potential of celestite mineral. As known, the electrostatic forces resulting from surface charges are responsible mostly for the repulsion between particles in suspensions [11]. Therefore, it can be stated that the decrease observed in the suspension stability with ultrasonic treatment was consistent with the decrease of magnitude of the zeta potential of celestite mineral. Although the application of ultrasonic field appeared to be a method to reduce the electrostatic potential [5], it has sometimes been reported that the ultrasound caused an increase in the zeta potential [12], [13] or no considerable change was observed [14]. Consequently, it may also be noted that the effects of ultrasound vary depending on the treatment conditions. Another likely mechanism is that the ultrasonic treatment decreased collisions between the celestite particles in the suspension and therefore enhanced the aggregation of particles, resulting in the decrease in the suspension stability.
The effect of treatment time of ultrasonic on the suspension stability of celestite is given in Fig. 3. As seen in Fig. 3, the suspension stability at both levels of ultrasonic power decreased towards particular times of treatment, and thereafter the stability values slightly increased, that is the prolonged time of ultrasonic exposure caused aggregates to rupture. Fig. 4 also shows the effect of immersion depth (distance from the air–liquid interface) of ultrasonic probe on the celestite suspension at different values of ultrasonic power. As can be seen, the suspension stability of celestite mineral reached lower values at an immersion depth of 2 cm, especially for high power levels.

The effect of batch and continuous treatment of ultrasonic process on the celestite suspension is presented in Fig. 5. As seen in Fig. 5, the treatment regime of ultrasonic process also markedly affected the suspension stability at especially high values of ultrasonic power. The batch treatment of ultrasonic process led to lower stability levels for the celestite suspension.
B. Effect Of Ultrasonic Pre-treatment On The Shear Flocculation Of Celestite Suspension With SDS

Fig. 6 shows the stability of celestite suspension as a function of pH at an ultrasonic power of 150 W. As shown in Fig. 6, the suspension stability in the absence and presence of sodium dodecyl sulfate (SDS) decreased with increasing pH. However, the decrease in the suspension stability was more significant in the presence of SDS. That is, the shear flocculation of celestite particles using SDS could be successfully achieved at near-neutral and alkaline pH range. The effect of SDS concentration on the stability of celestite suspension at 40 and 150 W of ultrasonic power is presented in Fig. 7. At both levels of ultrasonic power, the shear flocculation of celestite suspension increased rapidly towards approximately 20 mg/dm$^3$ of SDS concentration, and thereafter remained relatively constant. Also, the suspension stability reached relatively lower values at the high value of ultrasonic power. In other words, the increase in the ultrasonic power provided slightly more powerful flocculation.

Figs. 8 and 9 show the effect of ultrasonic treatment on the zeta potential and the contact angle of celestite mineral as a function of SDS concentration, respectively. The decrease in the suspension stability with increased SDS concentration at an US power of 150W is also presented in these figures. In the presence of SDS, the treatment of ultrasonic process again slightly reduced the magnitude of the negative zeta potential of celestite mineral. On the other hand, the contact angle of celestite mineral increased with the increase in the SDS concentration. Furthermore, the ultrasonic treatment led to reach higher values of contact angle, resulting in more successful flocculation. The contact angle of celestite increased and the zeta potential became more negative with increasing of SDS concentration. These findings were attributed to the adsorption of SDS on celestite surfaces and the adsorption density increased with increasing surfactant concentration, based on the increases of the contact angle and the negative zeta potential. It is clear that the flocculation efficiency responded to SDS concentration in the same manner as the contact angle, suggesting a close correlation between the flocculation and the particle hydrophobicity.

Celestite is a salt-type mineral in regard to their physicochemical properties [15] and has a hydrophilic character, therefore the water spreads completely on the mineral surface, i.e. contact angle ($\theta = 0$), when no surfactant is applied to the mineral surface. On the other hand, the celestite mineral has negative charge at pH values above its i.e.p. value (see Fig. 2). Accordingly, the adsorption of SDS onto the negatively charged celestite surfaces was due to the chemical adsorption mechanism, as stated previously [16], [17]. The investigations on the adsorption of sodium dodecyl sulfate and sodium dodecyl sulfonate on celestite mineral indicate that marginal adsorption occurs to a certain surfactant concentration and precipitation of the salt (strontium dodecyl sulfate/dodecyl sulfonate) takes place on the mineral surface beyond such a concentration [16]-[19]. On the other hand, the
shear flocculation of celestite mineral with SDS has been found to closely correlate with the particle hydrophobicity or the contact angle. The efficiency of this technique increased with improving the hydrophobicity depending on the increase in the negative zeta potential of celestite, indicating that hydrophobic interaction between the particles increased much more strongly than electrical double layer repulsion from the adsorption of the sulfate ions.

Fig. 8. The effect of ultrasonic on the zeta potential of celestite as a function of SDS concentration.

IV. CONCLUSIONS

Various operating conditions such as ultrasonic power, treatment time, immersion depth of probe and treatment regime (batch and continuous) affected the stability of celestite suspension in the absence of any chemical. The suspension stability of celestite showed a decreasing trend with increasing ultrasonic power and the zeta potential of the mineral also decreased with ultrasonic treatment. Furthermore, the ultrasonic treatment prior to surfactant addition slightly improved the shear flocculation of celestite particles in accordance with the increase in the particle hydrophobicity. In addition, the ultrasonic process again relatively reduced the surface charge of celestite particles in the presence of SDS.

Similar to the flotation process, the shear flocculation technique also utilizes differences in wettability of minerals. That is, this process is correlated with the hydrophobicity or wettability of particle surfaces. Consequently, it can be stated that the beneficial effects of ultrasonic energy on the flotation process also took place in the flocculation of celestite mineral with sodium dodecyl sulfate.

ACKNOWLEDGMENT

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REFERENCES


The Effect of Fly Ash in Dewatering of Marble Processing Wastewaters

H. A. Taner, V. Önen

Abstract—In the thermal power plants established to meet the energy need, lignite with low calorie and high ash content is used. Burning of these coals results in wastes such as fly ash, slag and flue gas. This constitutes a significant economic and environmental problems. However, fly ash can find evaluation opportunities in various sectors. In this study, the effectiveness of fly ash on suspended solid removal from marble processing wastewater containing high concentration of suspended solids was examined. Experiments were carried out for two different suspensions, marble and travertine. In the experiments, FeCl$_3$ and anionic polymer were used also to compare with fly ash. Coagulant/flocculant type/dosage, mixing time/speed and pH were the experimental parameters. The performances in the experimental studies were assessed with the change in the interface height during sedimentation resultant and turbidity values of treated water. The highest sedimentation efficiency was achieved with anionic flocculant. However, it was determined that fly ash can be used instead of FeCl$_3$ in the Travertine plant as a coagulant.

Keywords—Dewatering, flocculant, fly ash and marble plant wastewater.
Abstract—A suitable choice of flotation parameters and reagents have a strong effect on the effectiveness of flotation process. The objective of this paper is to give an overview of the flotation of chalcopyrite with the different conditions and dispersants. Flotation parameters such as grinding time, pH, type and dosage of dispersant were investigated. In order to understand the interaction of some dispersants, sodium silicate, sodium hexametaphosphate and sodium polyphosphate were used. The optimum results were obtained at a pH of 11.5 and a grinding time of 10 minutes. A copper concentrate was produced assaying 29.85% CuFeS$_2$ and 65.97% flotation recovery under optimum rougher flotation conditions with sodium silicate.

Keywords—Chalcopyrite, dispersant, flotation, copper.

I. INTRODUCTION

Flotation is one of the most important mineral processing technique commonly used to separate valuable minerals from gangue minerals utilizing the surface/interface properties of minerals [1]. In the world, among the total amount of produced copper, about 90% is recovered from the ore containing sulphide minerals [2]. Flotation is also used for the enrichment of chalcopyrite, which is a copper mineral. Flotation of chalcopyrite from the pyrite and gangue minerals is difficult because pyrite and chalcopyrite could have the same flotation performance and gangue minerals could cause problems in flotation. So a proper dispersion between fine mineral particles by dispersants is an essential prerequisite for their successful separation.

The effects of some dispersants such as sodium silicate, sodium hexametaphosphate and sodium polyphosphate have been investigated in order to decrease the effect of a large number of slimes and fines in chalcopyrite, iron and zinc flotation [3]–[5]. In flotation, sodium silicate (Na$_2$SiO$_3$), called water glass, has fairly common use to depress silicate and carbonate minerals present as gangue minerals, and it is also an effective dispersant. Sodium silicate that chemical composition could vary, acts as either a dispersant or a depressant depending on the SiO$_2$/Na$_2$O ratio, also known as a module number [6]–[7]. Sodium hexametaphosphate is a widely used dispersant in the flotation process and in clay industries. Sodium hexametaphosphate is also called Graham’s salts, and commercial sodium hexametaphosphate is typically a mixture of polymeric metaphosphates [8]. Polyphosphate reagents are widely used in mineral processing industries as dispersants and rheological modifiers [9]. Polyphosphates have the ability to adsorb onto metal oxides and clay particle surfaces via electrostatic and/or chemisorption mechanisms. Chemisorption dominates polyphosphate adsorption at alkaline conditions such as pH 9 whilst at acidic condition, such as pH 4, a combination of chemisorption and electrostatic interaction occurs [10]–[11].

The purpose of the present study is to investigate the flotation of chalcopyrite with different conditions and dispersants. Flotation parameters such as grinding time, pH, type of dispersant and dosage of dispersant were studied. In order to understand the interaction of dispersants, three types of dispersants, sodium silicate, sodium hexametaphosphate and sodium polyphosphate were used.

II. EXPERIMENTAL

A. Material

Samples used in this study were taken from chalcopyrite mine which is located in the southeastern Anatolia region Siirt Province (Fig. 1). The size distribution of the representative sample was carried out by Malvern Mastersizer 2000 laser diffraction analyzer and given in Fig. 2. It is observed that the percent passing 80 µm is 80% and 44% of particles are smaller than 20 µm (slime particles).

Fig. 1 Location map of the mine

Fig. 2 Particle size distribution of the sample
For improving the enrichment process, the identification of minerals is important. According to the mineralogical analyses determined by XRD analysis (Fig. 3), it was found that the sample contained chalcopyrite, pyrite, magnetite, kaolinite, illite and chlorite as the main minerals. The chemical composition of the sample is given in Table 1. The dominant elements are iron, sulphur, copper, aluminum and zinc.

![Fig. 3 XRD result of the sample](image)

**TABLE I**

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<tr>
<td>Fe</td>
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<td>Zn</td>
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<td>Pb</td>
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<td>Al</td>
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<tr>
<td>Mg</td>
<td>0.790</td>
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<tr>
<td>Ca</td>
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Aerophine 3418A used in this study as collector was obtained from Cytec Solvay Group. Dispersants used as sodium silicate (NaS), sodium hexametaphosphate (NaHMP) and sodium polyphosphate (NaPP) were obtained from different companies. MIBC (methyl isobutyl carbino) was used as frother obtained from Arkema Innovative Chemistry. Lime and sulphuric acid were used as pH regulators.

**B. Flotation Experiments**

Flotation experiments were carried out in a 1 L conventional laboratory cell (Denver model), at 10% solid ratio, 10 L/min air flow rate, 2 cm froth depth and agitation rate was 1350 rpm. MIBC was used as frother (80 g/ton) and 3418A was used as collector (50 g/t). The mineral suspension was prepared by adding solids and tap water. Firstly, pH of the mineral suspension was adjusted to 11.5 by adding lime stock solutions and conditioned for 5 minutes. Then prepared dispersant solution was added at a desired concentration and conditioned for 3 minutes. With the addition of collector and conditioning 3 minutes, lastly frother added to solution and conditioned for 1 minutes. The froth was handpicked for 3 minutes to collect the concentrate.

For individual mineral flotation, the floated and unflotted particles were collected, filtered and dried. The flotation recovery was calculated based on solid weight distributions between the two products. For mixed minerals flotation, the CuFeS₂ content of the concentrates and tailings were analyzed, and the recovery of chalcopyrite was calculated. The experiments were conducted in 3 parts. In each part, the effect of only one parameter was examined, while the other parameters were kept constant.

**III. RESULTS**

**A. Effect of Grinding Time on Chalcopyrite Flotation**

The effect of grinding time on the flotation of chalcopyrite was studied and the results are shown in Fig. 4. It is evident from the figure that the flotation recovery of chalcopyrite was increased as the grinding time was increased. The grade of chalcopyrite increased until grinding time of 10 minutes, but then fell off. As the grinding time increased, the grain size decreased. So the gangue minerals which are in slime size could mixed with the concentrate. A more efficient enrichment was obtained in the experiments made with the samples obtained at the grinding time of 10 minutes.

![Fig. 4 Effect of grinding time on the flotation of chalcopyrite](image)

**B. Effect of pH on Chalcopyrite Flotation**

The pH of the pulp must be optimized so that the chemicals used in the flotation can react with the mineral surfaces in the pulp. The effect of pH was investigated at 8, 9, 10, 11, 11.5, 12 and 12.70 and the results obtained are given in Fig. 5. Chalcopyrite recoveries increased dramatically as the pH increased. After pH 11.5, recovery of the chalcopyrite was observed to be decreased sharply. On the contrary, the grade of chalcopyrite continued to rise. This result confirms that high pH of the pulp caused to depress pyrite. The surface of chalcopyrite also gains more hydrophobicity and the amount of chalcopyrite coming to the concentrate is higher. In later experiments, flotation was continued at pH of 11.5.

![Fig. 5 Effect of pulp pH on the flotation of chalcopyrite](image)
C. Effect of Dispersants on Chalcopyrite Flotation

An appropriate choice of dispersant quality and quantity has an important effect on the flotation recovery. The dispersant dosage is also an important factor in the flotation process, which affects the recovery seriously. Fig. 6 shows the effect of sodium silicate (NaS) dosages on the recovery and grade of chalcopyrite. Recovery of chalcopyrite increased substantially until the use of 100 g/t dosage of NaS but then slightly decreased. NaS can effectively disperse the chalcopyrite, pyrite and gangue minerals reducing the coverage of pyrite and gangue minerals on chalcopyrite surfaces and improving the flotation recovery of the chalcopyrite.

Fig. 6 Effect of NaS on the flotation of chalcopyrite

Fig. 7 shows the effect of sodium polyphosphate (NaPP) dosages on the recovery and grade of chalcopyrite. The use of NaPP resulted in poor separation with the lowest recovery than NaS.

Fig. 7 Effect of NaPP on the flotation of chalcopyrite

Fig. 8 shows the effect of sodium hexametaphosphate (NaHMP) dosages on the recovery and grade of chalcopyrite. A maximum increase in chalcopyrite recovery was obtained with 100 g/t NaHMP, while higher NaHMP concentrations produced little gain in recovery. Pyrite flotation is depressed when pH is higher than 10.5 and the floatability of pyrite over this pH range is not restored by NaHMP [12]. This result is also matched up with this study.

Optimum dispersant dosages results are given in Fig. 9. According to these findings, it can be concluded that the appropriate dispersant for the flotation of chalcopyrite should be sodium silicate. Sodium polyphosphate and sodium hexametaphosphate gave similar optimum results on grade and recovery of chalcopyrite. Among the dispersants tested, sodium silicate gave a higher chalcopyrite recovery.

Fig. 8 Effect of NaHMP on the flotation of chalcopyrite

Fig. 9 Optimum dispersant dosages

IV. CONCLUSION

In this study, recovery of chalcopyrite was investigated by different conditions and dispersants. The effect of some dispersants, sodium silicate, sodium hexametaphosphate and sodium polyphosphate were evaluated. Optimum flotation conditions obtained as a result of rough flotation experiments; 10 minutes of grinding time, 11.5 of pH and 100 g/t of Na$_2$SiO$_3$ dosage. Flotation experiments showed that flotation of chalcopyrite was much better with sodium silicate and a concentrate of 29.85% CuFeS$_2$ content was obtained with 65.97% flotation recovery. As a result of this study, using sodium polyphosphate and sodium hexametaphosphate as dispersant was not suitable in chalcopyrite flotation.

ACKNOWLEDGMENT

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Hasan Ali Taner was born in Antalya, Turkey on 12th of March in 1986. He graduated from University of Zonguldak Karaelmas, Department of Mining Engineering in 2008. He has a master degree of science in mining engineering from Bulent Ecevit University. He is PhD student at Selcuk University since 2013. His major field is mineral processing. He was published eleven articles in his research field. His current and previous research interests are to flotation of sulphide minerals, leaching, grinding and mineral preparation.

MSc. Taner is a member of Turkish Mining Engineering Chamber Society.
GRINDING OF BORAX PENTAHYDRATE TO NANO DIMENSION

K. Esmeli

Abstract—The aim of this study was to determine the grinding parameters of borax pentahydrate. Another aim was to obtain materials with high quality by using more economic and more practical techniques instead of the traditional grinding methods. Grinding was performed in two stages during the experiments. The materials were grinded and decreased to a certain fine grain size at the intermittent grinder in the first stage. The material grinded at the intermediate grinder was fed to the nano grinder at the second stage. Both dry and wet grinding studies of the sample were conducted. As a result, borax pentahydrate were obtained by nano-size grinding using low energy in a short time by mechanical grinding method.

Keywords—charge ratio, grinding, planetary mill, nano-materials.

BORON compounds, of which Turkey has the largest reserves in the world with over 60% share, are very commonly used almost in all branches of industry in different ways. Huge portions of the Turkey's commercially recoverable boron reserves are colemanite, ulexite and tincal. In Turkey, while borax is used to produce borax pentahydrate and decahydrate, colemanite is used for boric acid production. During borax penta or decahydrate production, tincal is dissolved in a hot recycled borate solution and the gangue minerals are separated from the solution. The clear solution is used to produce penta or decahydrate crystals in vacuum type crystalliser [1]. Boron and boron derivatives have many important uses such as in the production of glass, fibers, heat resistant materials, material processing, nuclear reactors, fire retardants, catalysis and detergents, etc. [2]. So in recent years there have been many studies on boron and its derivatives.

I. INTRODUCTION

Comminution, especially ultra-fine comminution, is an energy-intensive stage in the overall process to provide materials in proper fine size ranges for the required properties of the final product. High energy consumption and inefficiency in comminution technology for such materials as mineral, cement, pigment, chemicals and food have long been regarded as a major area for development, especially for producing particles below micron sizes [3], [4]. Conventional devices (mainly, tumbling ball mills) have been used for comminution for many years, but the basic problem is that the power consumed is limited by the centrifugation occurring at speeds above the critical, and the grinding media could not be too small, for the impact energy of each ball would otherwise be insignificant. To meet these requirements, numerous mills have recently been developed and improved by institutes, universities and companies worldwide [5].

In recent years, much attention has been paid on fine grinding due to its importance for nano-technology and nano-materials. Nanostructured materials are single or multi-phase polycrystals, the crystal size of at least 1 to 100 nanometers in dimension. [6]. As a result, many different types of mills for producing a fine materials were developed. A planetary ball mill, in which rotating pots are installed on the revolving disk, has the potential to generate a high energy to the powder, therefore, it is used for mechanochemistry[7], [8], mechanical alloying [9], [10] and the mechanical milling [11], [12]. The mechanical production method is the process of reducing the materials to micro and macro dimensions by using mechanical procedures. The major production methods used to obtain nano grains with a classical mechanical approach include cutting, rolling, forging, compression and spraying (atomizing). A physical application is generally used in mechanical production methods but there is no chemical change. In this study, mechanical grinding was carried out to reduce borax pentahydrate nano dimensions.
II. MATERIALS AND METHODS

A. Materials

Borax pentahydrate obtained from Eti Mine Facilities were studied at Dokuz Eylül University Electronic Materials Production and Application Center laboratories. Borax Pentahydrate is a refined form of natural sodium borate. Borax Pentahydrate contains 5 mol water. Borax Pentahydrate, with the chemical formula Na₂B₄O₇·5H₂O, is a white, odorless granular substance. The borax pentahydrate sample was grinded while dry and wet. Grinding was performed in two stages during the experiments. The materials were grinded and decreased to a certain fine grain size at the intermittent grinder in the first stage. The material grinded at the intermediate grinder was fed to the nano grinder at the second stage. Both dry and wet grinding studies of the sample were conducted. 10 ml of ethyl alcohol was used for wet grinding. A solid-liquid ratio of 65% was studied. The solubility of borax pentahydrate is less in cold water. However, ethyl alcohol was used as heating will be present during grinding and it will be dissolved. One of the important parameters in grinding studies is the Charge ratio. [13]. The Charge ratio is usually 40%-45% of grinder capacity.

B. Experimental Studies Performed With The Intermediate Grinder (Mortar Grinders RM 200)

The intermediate grinder mills (RM 200), the material between the scraper and the mortar by pressure and friction. The function of the scraper is to feed the material into the area between the mortar and pestle. All the samples are continuously subjected to grinding and at the same time provide intensive mixing. The grinding is achieved with the adjustable spring pressure acting on its own axis and the weight of the rammer. [14]. In order to determine the grain size after grinding, the Horiba Partica LA-950V2 Particle Size Analyzer was used to measure the particle size dimension range of dry powders available at the Dokuz Eylül University Chemical and Environmental Mining laboratories.

Particle Size Analyzer, laser diffraction device (0.01 - 3000 μm) makes measurements in large grain size. We used the intermediate grinder because the material coming out of the nano grinder was large when the intermediate grinder was not used and our aim was to reduce the material to nano size. The opening parameter used was < 1mm and samples of different gram weights were studied.

C. Experimental Studies Performed With The Nano Grinder (Planetary Micro Mill Pulverisette)

In the so called planetary mill, a number of two or four bowls filled with the grinding balls are equidistantly installed on a supporting disk. The bowls and the disk are simultaneously and separately rotated at a high speed in opposite directions. The high speed of rotation of the bowls and the revolution speed of the supporting disk generate extremely high centrifugal forces acting on the balls. This results in, as an attrition effect, the grinding balls running along the inner wall of the bowl, and as an impact effect, the balls impacting strongly against the opposite wall of the bowl and against one another [15]. The grinding may occur in dry or in suspension with the aid of liquids in order to minimize the agglomeration effect between ground particles [16].

III. RESULTS AND DISCUSSION

A. SEM Analyses of Dry Grinding Experiments of a Borax Pentahydrate Sample According to Rotation Speed

One of the important parameters in grinding studies is rotation speed. The nano grinder works at a max. speed of 1000 cycles/min. Optimum grinding speed was identified as 700 cycles/min. In order to determine the grain size after grinding, the nanosizer was used to measure the particle size dimension.

![Fig 1(a). SEM image of borax pentahydrate sample grinded at a rate of 500 cycles/min.](image-url)
Fig 1(b). SEM image of borax pentahydrate sample grinded at a speed of 600 cycles/min.

Fig 1(c). SEM image of borax pentahydrate sample grinded at a speed of 700 cycles/min.

Fig 1(d). SEM image of borax pentahydrate sample grinded at a speed of 800 cycles/min.

Fig. 1 (a). The grains are seen in a spongiform and agglomerated manner. Fine grains are clearly seen to form large grains as agglomerates. Large grains are seen in a spongiform structure and fine grains are seen irregularly. The finest grain has a size of 1 micron. Fig. 1 (b) . Both large and fine grains are present. However, there are more of the large sizes. The large grains are seen to have an irregular structure and the fine grains form tubers. The finest grain has a size of 3 microns. Fig. 1(c). A small number of large grains are found. Large grains have irregular shapes. A finer size has been obtained at this rotation speed. The finest grain has a size of 436 nm. Optimum rotation speed seems to be 700 cycles/min. Fig. 1(d) SEM image of borax pentahydrate sample grinded at a speed of 800 cycles/min. Fine grains are seen in the form of agglomerates depending on the grinding rate. Large grains have a relatively in spongiform shape. The grains seem to be more agglomerated at this rotation speed and thus the grain size has increased.

B. SEM Analyses of Dry Grinding Experiments of a Borax Pentahydrate Sample According to Feeding Amount

One of the significant parameters in grinding studies is the feeding amount. Studies to determine optimum feeding amount were performed by conducting grinding of different grams amounts with the nano grinder.
Fig 2(a). SEM image of 10 gr grinded pentahydrate sample. The grains seem to form large grains as agglomerates. Fine grains are seen in the form of leaflets while agglomerated large grains make up the majority. Fig. 2(b) SEM image of 12 gr grinded borax pentahydrate sample. The 12 gr sample has not been grinded homogeneously and both large and fine grains are present. Fine grains are seen in the form of tubers. Large grains have no specific shape. Fig. 2(c) SEM image of 18 gr grinded borax pentahydrate sample. The grains had an irregular structure. The smallest size was 600 nm. Fine grains formed large grains as agglomerates. The optimum grinding amount was found to be 18 gr.

C. SEM Analyses of Dry Grinding Experiments of a Borax Pentahydrate Sample According to Grinding Time
Fig 3(a). SEM image of 200μ borax pentahydrate sample.

Fig 3(b). SEM image of borax pentahydrate sample dry grinded for 30 minutes.

Fig 3(c). SEM image of borax pentahydrate sample dry grinded for 60 minutes.

Fig 3(d). SEM image of borax pentahydrate sample dry grinded for 360 minutes.

Fig. 3(a). SEM image of 200μ borax pentahydrate sample. It generally has a matrix structure. Phenocrystals are present at rate of about 30%. Microcrystals are also present at the same rate. Although 30% of the microcrystals are in various sizes, they generally have a size of 10x10 μ. Both phenocrystals and microcrystals swim in the matrix. Fig. 3(b) SEM image of borax pentahydrate sample dry grinded for 30 minutes. Phenocrystals have a cauliflower shape at large magnification. Precipitation conditions are stable. A homogeneous appearance could not be obtained. Fine grains are seen to agglomerate. The finest grain is 617 nm in size. Fig. 3(c).
SEM image of borax pentahydrate sample dry grinded for 60 minutes. Fine grains formed large grains as agglomerate. Fine grains are in cubic form. The finest grain size is 900 nm. Large grains form an irregular shape. Fig. 3(d) SEM image of borax pentahydrate sample dry grinded for 360 minutes. The grain size is clearly seen to increase as the grinding duration increases. Approximately 40% of the grains are in the feeding size.

D. SEM Analyses of Wet Grinding Experiments of a Borax Pentahydrate Sample According to Grinding Time

The experiments were carried out rotation speed of 700 cycles/min and with a feed amount of 18 g.

Fig 4(a). SEM image of borax pentahydrate sample wet grinded for 15 minutes.

Fig 4(b). SEM image of borax pentahydrate sample wet grinded for 30 minutes.

Fig 4(c). SEM image of borax pentahydrate sample wet grinded for 45 minutes.

Fig 4(d). SEM image of borax pentahydrate wet grinded for 60 minutes.
therefore high and the grain attraction force is higher with surface areas of fine grains are larger. The surface energy was found to be 700 cycles/min. in our experiments. The average size of 617 nm. We tried to determine rotation speed by grinding at a rate of 400-900 cycles/min. at the nano grinder but large grains were found due to agglomeration and a heterogeneous appearance could not be obtained. The smallest grain size decreased to 617 nm after 30 minutes. Grains of 200 nm - 10 nm were present in the grinded sample, with an average size of 617 nm. We tried to determine rotation speed by grinding at a rate of 400-900 cycles/min. at the nano grinder. The finest grain size with wet grinding was about 437 nm. Grains between 100 nm and 10 nm were present in the grinded sample with a mean size of 437 nm. In experiments, wet grinding was found to be more effective than dry grinding. There was no dissolving in ethyl alcohol in wet grinding studies, but we believe a better result can be obtained if a substance that is a dispersant of borax pentahydrate is used.

IV. CONCLUSIONS

The grain size decreased to nano dimension after 30 minutes dry grinding in experiments performed with the nano grinder but large grains were found due to agglomeration and a heterogeneous appearance could not be obtained. The smallest size decreased to 617 nm after 30 minutes. Grains of 200 nm - 10 nm were also present in the grinded sample, with an average size of 617 nm. We tried to determine rotation speed by grinding at a rate of 400-900 cycles/min. at the nano grinder. The finest grain size has a size of 436 nm. The speed rate was found to be 700 cycles/min. in our experiments. The surface areas of fine grains are larger. The surface energy is therefore high and the grain attraction force is higher with such high surface energy. This causes the grains to form agglomerates. Another reason for agglomerate formation is the increase of the efficiency of the Vander Waals force with the decrease of the distance between the grains [17]. We used a grinder ball charge rate between 35% and 50% and steel balls 10 mm in size. We predict higher productivity if smaller ball sizes are selected. The size was decreased to a nano scale with wet grinding in a shorter time and a more homogeneous appearance was obtained compared to dry grinding studies performed in the nano grinder. The finest grain size with wet grinding was about 437 nm. Grains between 100 nm and 10 nm were present in the grinded sample with a mean size of 437 nm. In experiments, wet grinding was found to be more effective than dry grinding. There was no dissolving in ethyl alcohol in wet grinding studies, but we believe a better result can be obtained if a substance that is a dispersant of borax pentahydrate is used.

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Optimization of Technical and Technological Solutions for the Development of Offshore Hydrocarbon Fields in the Kaliningrad Region

P. Shcherban

Abstract—Currently, LLC «Lukoil-Kaliningradmorneft» is implementing a comprehensive program for the development of offshore fields of the Kaliningrad region. This is largely associated with the depletion of the resource base of land in the region, as well as the positive results of geological investigation surrounding the Baltic Sea area and the data on the volume of hydrocarbon recovery from a single offshore field are working on the Kaliningrad region – D-6 «Kravtsovskoye».

The article analyzes the main stage of the LLC «Lukoil-Kaliningradmorneft»’s development program for the development of the hydrocarbon resources of the region’s shelf and suggests an optimization algorithm that allows managing a multi-criteria process of development of shelf deposits. The algorithm is formed on the basis of the problem of sequential decision making, which is a section of dynamic programming. Application of the algorithm during the consolidation of the initial data, the elaboration of project documentation, the further exploration and development of offshore fields will allow to optimize the complex of technical and technological solutions and increase the economic efficiency of the field development project implemented by LLC «Lukoil-Kaliningradmorneft».

Keywords—Offshore fields of hydrocarbons of the Baltic Sea, Development of offshore oil and gas fields, Optimization of the field development scheme, Solution of multi-criteria tasks in the oil and gas complex, Quality management of technical and technological processes.

I. INTRODUCTION

The development of the hydrocarbon resources of the Kaliningrad region’s shelf has moved to the active phase since 2004 when LLC «Lukoil-Kaliningradmorneft» started development of the D-6 «Kravtsovskoye» field. During 2000 - 2015, a complex of geophysical studies was carried out in the coastal zone of the Kaliningrad region. It was found about 15 structures that are promising for hydrocarbon reserves. In 2015-2016 out of all the structures, were identified: D-2, D-9, D-18, D-19, D-29, D-41 and D-6 (southern) (Figure 1).

From 2015 to the present, exploration and design works are underway to develop hydrocarbon reserves of these fields. Thus, LLC «Lukoil-Kaliningradmorneft» received comprehensive state licenses for geological exploration, exploration and development of these fields. As a result, structures D-33, D-29 and D-41 were approved and placed on the hydrocarbon reserves state balance [2]. In parallel with the work on geological exploration, the engineering-geological and engineering-ecological surveys were carried out, as well as the pre-design work and the analysis of the options for developing the studied structures.

As of 2018, additional exploration works are being carried out; projects of stage-by-stage development of deposits are being developed [4]. In the period from 2020 to 2025 it is planned to put into operation 3 oilfields: D-2, D-33, and D-41. In the article presented, we will consider a number of approaches that allow us to form a comprehensive algorithm for managing processes of design and construction of infrastructure for the development of these oilfields.

In connection with to the multi-factorial process and multi-criteria selection of optimal solutions for the development of offshore, it seems reasonable to construct an algorithm based on the problem of sequential decision making. In order to formulate the conditions of the problem, as well as the main limiting values, it is necessary to decompose it into stages, since for each of them will have its own set of initial data, operating factors, control values and, as a result, the desired optimum [5].

PhD. P. Shcherban. Author is associated professor of Engineering institute of Baltic Federal University of Immanuel Kant, 236006, Kaliningrad. Russia (phone: 84012536260; e-mail: ursa-maior@yandex.ru).
Consequently, we will decompose the whole process of development of oilfields into stages, as well as decomposition and stratification of data in stages. This will allow us to formulate the basic requirements for each of the stages of the optimization problem being solved.

II. ANALYSIS OF THE MAIN STAGES OF DEVELOPMENT OF THE OFFSHORE HYDROCARBON FIELDS OF THE KALININGRAD REGION

The breakdown of the development of offshore hydrocarbon reserves in the Kaliningrad region can be conditionally carried out in the following main stages:

A. The stage of geological exploration and approval of reserves of deposits;
B. Development of a project for work off and development of a field;
C. Collection of baseline data for the water area under development;
D. Development of project documentation for field infrastructure;
E. Development of an environmental impact assessment;
F. Arrangements for tenders for the manufacture and supply of equipment;
G. Delivery of equipment;
H. Offshore equipment installation and testing;
I. Drilling, transition to mining;
J. Field acceptance in operation.

At each stage, the project is affected by a significant amount of external factors. In many ways, the rational management of these factors and correcting the initial values and goals allows us to implement the project of development of these oilfields. It should also be noted that in most cases the design and survey work to reduce the time spent become parallel. The project on the development of hydrocarbon deposits on the shelf of the Kaliningrad region is no exception [6].

As a result, in the temporal plan, there is, as it were, the imposition of one stage on another. Reduction of time costs in this case is partially offset by the inaccuracy of the data, the need to make adjustments as they become available in the project documentation, and an increased probability of errors.

Despite this, existing forms of state reporting in the Russian Federation (setting fields in the State Reserves Balance, obtaining positive expert opinions, including sanitary and epidemiological conclusions, the passage of the project of public hearings and the main state expertise) indicate the existence of so-called "reference points" or "optimum points by stage". That is, in this case, we can talk about specific indicators of the optimality of the result for a particular stage. In Table 1, we represent the groups of optimal solutions for each of the stages, as well as the result of implementing these solutions [10, 14].

It should be noted that alternative (mutually exclusive) solutions can be formed at each of the stages of the implementation of projects for development of the oil and gas fields of the shelf, depending on the entire set of initial data and the pursued objective. These options are evaluated through an integrated assessment of the quality of decisions.

There are two options for making a decision within each of the stages: through the person making the decision (PMD) - option, or through a collegial decision (CMD) - option. As a rule, both decision schemes are applied at different levels within each of the stages. The decision is valid if it satisfies all the constraints imposed on the functions under consideration by stage. The decision is optimal (best) if it is at the extremum of the desired function [1].

The generalized characteristic of each of the solutions for the stage is the efficiency, which is determined through the effect of the solution and the cost of implementing the solution.

Speaking about the implementation of projects to develop the offshore hydrocarbon fields in the Kaliningrad region, it is important to note that LLC «Lukoil-Kalinigradmornefte» completed the stage of geological exploration and approval of reserves at a number of fields. At the present time, calculations and simulations of optimal schemes for field development, baseline data collection and infrastructure layout are carried out in parallel. In the case of the collection of input data or the development of a field development

### Table 1. Optimal solutions and the results of the stage of development of hydrocarbon deposits on the shelf of the Kaliningrad region

<table>
<thead>
<tr>
<th>Stage</th>
<th>The optimal solution for the stage</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>The most accurate determination of general geological and recoverable hydrocarbon reserves in the Kaliningrad shelf offshore fields with the establishment of the entire complex of properties of both fluid and host rocks with the least</td>
<td>Approval of the reserves of the deposit, staging on the state balance sheet.</td>
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<thead>
<tr>
<th>Stage</th>
<th>The optimal solution for the stage</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Maximization of hydrocarbon extraction from deposits at a rational level of costs.</td>
<td>Approval of the development project.</td>
</tr>
<tr>
<td>C</td>
<td>Obtaining an accurate data set for each of the parameters.</td>
<td>Approval of reports on information data.</td>
</tr>
<tr>
<td>D</td>
<td>Rational use of existing infrastructure, technologically and logistically weighted placement of objects, compliance of technical parameters of objects with regulatory requirements.</td>
<td>Formation Technical and Economic Justification, Banking FS.</td>
</tr>
<tr>
<td>E</td>
<td>Minimizing the possible negative impact, reducing the risk of emergency situations.</td>
<td>Holding public hearings. Receiving approval from the services.</td>
</tr>
<tr>
<td>F</td>
<td>Availability of responsible suppliers. Optimal price-quality ratio of materials and equipment.</td>
<td>Obtaining high-quality materials and equipment in time.</td>
</tr>
<tr>
<td>G</td>
<td>Short transport shoulder. Absence or minimization of customs barriers. The minimum period of equipment stay in the warehouse.</td>
<td>Correspondence of the infrastructure and installations of the developed design documentation.</td>
</tr>
<tr>
<td>H</td>
<td>Reduction of the negative impact of the external environment. Compliance with the installation technology. Minimizing the probability of emergencies. Carrying out a complex of tests.</td>
<td>Production of hydrocarbon fluid with expected quality and debit. Maintenance of production rates within the project in time.</td>
</tr>
<tr>
<td>I</td>
<td>Drilling operations in accordance with the requirements of normative and technical documentation and regulations. Application of the simulated mining system. In the presence of process variations prompt the adjustment.</td>
<td>The act of commissioning. Registration in the register of hazardous production facilities.</td>
</tr>
<tr>
<td>J</td>
<td>Preparation and quality control of the final technical documentation. Finalizing the documentation. Capitalization of objects.</td>
<td></td>
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project, there is no particular difficulty in view of the existence of a basic example of a previously discovered and refined D-6 oilfield, but there are a large number of options for infrastructure deployment [3]. Let us consider them in more detail.

III. INFRASTRUCTURAL AND TECHNOLOGICAL SOLUTIONS FOR THE DEVELOPMENT OF HYDROCARBON DEPOSITS OF THE BALTIC SHELF

The main construction used in the development of offshore fields is a mining device (conductor block, platform or subsea production system), drilling rig (fixed or floating) and pipeline. Consider all the designs that can be used in the development of the Kaliningrad shelf. LLC «Lukoil-KMN», in its concept of shelf development, proposes several options for the development of deposits using various devices, as well as various schemes for the construction of communication and transport infrastructure. Thus, 4 main variants of the general arrangement of the shelf and 6 variants of detailed development with use of various technical solutions of all explored deposits of hydrocarbons of the shelf of the Baltic Sea are considered. The main options for the development of the Kaliningrad shelf are presented in block diagrams that illustrate various communication and transport options for the development of the shelf as a single conceptual project in which all fields are involved. In these variants existing infrastructure complexes, projected objects of the first phase, future projected objects, pipelines, as well as other communication objects are represented [4].

Figure 2 presents two versions of the concepts under consideration. From the objects represented in the block diagrams, the primary development areas are the D-41, D-33, D6-southern and D-29 fields. Structures D-2, D-8, D-18 and D-19 have a secondary status of importance at this stage of shelf development. Conventionally, the concept can be divided into 3 separate structures of the complex in close proximity to each other: cluster D-6 (D-6 distribution platform, D-6 (southern), D-29), cluster D-41 (D-41, reconstruction of oil gathering point Romanovo) and cluster D-33 (D-33, D-2, D-8, D-18 and D-19). The D-33 cluster has in its structure not one field, and the D-33 deposit itself is its largest component, therefore, LLC «Lukoil-KMN» offers to install the control platform here.

This platform will control production not only on the D-33 structure, but also on all other fields. The objects are planned to be connected using umbilicals, and transport of hydrocarbons via pipelines from structures D-2, D-8, D-18 and D-19 to structure D33. The control platform D-33 will receive electricity from the existing power plant located on the territory of the Kaliningrad region. Further transport of products takes place on the distribution platform D-6. This platform is a kind of collection point for products from D-33 and D-6 (southern) for subsequent transportation along the old, already built main pipeline to land via D-6 to the oil gathering point Romanovo [5].

The D-6 cluster includes both existing infrastructure facilities and new designed ones. The new facilities are the distribution platform D-6, D-6 (southern) and D-29. The distribution platform is used exclusively for preparing and transporting the extracted raw materials. D-6 (south) and D-29 are connected in series to the distribution platform. Transport of produced hydrocarbon products is also carried out sequentially through the pipeline from D-29 to D-6 (southern) and D-6. The source of electricity will be the existing power plant located on the territory of the Kaliningrad region. Further transportation is carried out via the existing pipeline from D6 to the oil gathering point Romanovo.

The D-41 cluster includes a single deposit, but it also includes the reconstruction of the oil gathering point Romanovo, which is necessary for the implementation of this project. The development of the D-41 structure is planned from the land by drilling five wells with a deviation in the horizontal projection. The depth of the wells will be more than 8 km, the deviation from the vertical of about 6 km and the length of the horizontal wellbore - 1-1.7 km. This is reflected in all the presented variants of hydrocarbon field development concepts. To drill this field, a drilling rig in a marine version with a load capacity of at least 650 tons is used. In the future, this drilling is planned to be used to drill wells on the D-33 structure, which will reduce costs when developing this project [5,6].

The general concept of variant A differs from the concept of variant B in only one single addition. It implies a direct connection of the D-33 cluster with a pipeline to the oil gathering point Romanovo, but does not exclude the construction of a pipeline to the D-6 cluster.

This solution will increase the maximum volume of transported hydrocarbon products, as well as reduce the wear of pipelines and provide an opportunity to have an alternate route for transporting hydrocarbon products. This is a significant advantage in the event of accidents or overhaul requiring a complete stop of operation of the
existing pipeline before the construction of a new parallel threads pipeline scheduled for a later period, and only in the case of development of structures D-2, D-8, D-18 and D-19.

Variants of the location of mining and transport infrastructure C and D, shown in Figure 3, are clearly different from the previous ones. In these concepts on the D-33 cluster, the SFO vessel (Floating, Storage and Offloading Vessel) is also used to store and ship oil.

In version C, the vessel is used exclusively as a source of additional transport without the exception of the pipeline. However, since the ship can only transport crude oil, a gas pipeline from the D-33 to the oil gathering point Romanovo is envisaged [4].

Elimination of costs for the construction of the pipeline from D-33 to D-6 is presented in the overall concept reflected in option D. In this case, all the products are delivered to the ship via a gas pipeline, and oil products are transported to the D-6 distribution platform via the oil pipeline. However, and this time the company wasn’t able to avoid the complete exclusion of the costs for the construction of the pipeline. In total there are approximately 70 vessels of this class in the world, all produced by foreign manufacturers, and the price of each vessel starts from 800 million dollars.

IV. EXAMPLES OF DETERMINING THE INITIAL BOUNDARY VALUES AND PARAMETERS FOR CONSTRUCTING AN ALGORITHM FOR OPTIMIZING SUBSEQUENT STAGES OF DEVELOPMENT OF OILFIELDS.

As it was noted earlier, the problem of optimization of technological and technical solutions at each stage largely depends on the determined boundary values of the system parameters by the stage. These boundary values delineate the so-called "optimum state zone" of the process. Within this zone, the implementation of the work is possible and does not lead to negative consequences for the project as a whole, outside of this zone, the influence of factors / parameters is added in such a way that the system either immediately fails or runs the mechanism of accumulation of errors and failures, leading subsequently to the failure of the system as a whole. In this case, the system is understood as the whole complex of engineering structures for the development of hydrocarbon deposits in the Baltic shelf, as well as the technological processes that ensure its functioning.

Let’s consider both situations of parameter exit beyond the “optimal zone” zone when developing oilfields on the shelf. A vivid example of a sharp malfunction may be the incorrect selection of drilling fluid parameters and drilling regimes, resulting in a drastic increase in the risk of oil-gas-water manifestations and open flowing as a result of environmental pollution and the risk of fire [13].

An example of a gradual malfunction may be incorrect selection of installation and assembling parameters of the pipeline system. As a result, in the underwater pipeline may occur gradually voltage portions with an increased rate of deterioration of corrosion, cracks and eventually disruptions. As can be seen from the presented examples, violation of the boundary values of the system during any stage of its development and functioning can result in fatal consequences.

From the mathematical point of view, the process of functioning and development of the system (development of the hydrocarbon resources of the region's shelf) can be imagined as a complex motion of a point in a multidimensional space with a whole range of limiting values and tolerance zones [7].
To increase the accuracy and speed of decisions at each of the selected stages (see Table 1), it is necessary to identify the most critical processes, establish tolerance zones and carry out a comprehensive control over their implementation in time.

So, for example, we will present a graph reflecting the process of laying an underwater oil pipeline to new deposits. One of the leading parameters in the process of pipeline laying is the accuracy of getting into the target of the route. The boundary value is be the boundary of the tolerance zone for the deviation from the track alignment. As a result, the following picture can be obtained in dynamics (Figure 4).

Summarizing the above provisions, we can say that within each of the identified stages of project development (see Table 1), a set of differential equations describing the main critical processes along the stage and their boundary values should be created [7, 12].

The more detailed this complex will be, the lower is the failure risk. In the article it is impossible to display sets of values main critical processes along the stage and their boundary values should be created [7, 12].

By solving the reduced equation, it is possible to calculate the position of the underwater oil pipeline being laid and control the process. Similar calculations and approaches with the construction of boundary conditions and systems of differential equations are required at other stages of project implementation. However, it is important to notice that the optimization principle consists not only in controlling the compliance of certain processes and parameters with acceptable values, but also in selecting the most rational solutions from the available permissible alternatives.

In this case, we can talk about some kind of "tactical" decisions in the control of processes and "strategic" decisions within the framework of the stages or the whole project [7,15].

Adoption of strategic decisions and search for optimal in their environment requires the creation of a certain mechanism - an optimization decision-making algorithm for each of the stages in the implementation of the project of development of the offshore hydrocarbon fields of the Kaliningrad Region.

V. CONSTRUCTION OF AN OPTIMIZATION ALGORITHM FOR THE DEVELOPMENT OF OFFSHORE HYDROCARBON FIELDS IN THE KALININGRAD REGION

Each of implemented stages can be viewed as a task of finding an optimum using given initial data. So, as an example, the optimum of the first stage (geological exploration of reserves of deposits) is the most accurate determination of the geological and recoverable reserves of hydrocarbons in the fields along with the calculation of properties of both the fluid and the host rocks, processed with the least amount of time and financial costs (see Table 1). Each stage of development of deposits process is the solution for the problem situation L0. The solution to this problem situation is impossible without a complete description and collection of initial data (in case of geological exploration stage it is data on the structure of the deposit), considering imposed time constraints T and restrictions on the available resources M (for example, the number of drilling vessels /installations). These parameters are the basic for the problem on the stage [7].

After that, within the framework of the optimization algorithm, a transition to the solution of the problem occurs. In this part of algorithm it is possible to form a complex of differential equations, comprising: \( a \) – set of objectives, \( \beta \) – set of constraints, \( \gamma \) – set of alternative solutions, \( \eta \) – the preferred solution. The solution of the system of equations allows us to establish a set of acceptable solutions – \( \Delta \).
When a set of acceptable solutions is established, the next stage of the algorithm is the choice of the solution. Formation of the selection criteria - F, (in the case of the geological exploration phase it is the sequence of the opening of fields or the selection of drilling parameters). Established "effective solutions" - ω, (for example, a rational scheme for moving drilling vessels). The final decision is being selected. The final decision on the stage is an alternative with the most favorable overall consequences.

In the presented figure 5 it is clear that almost in each stage of algorithm realization it is possible to return to the previous stage to update either initial input data or pursued purposes. This algorithm allows to search for the optimal solution on each step of the project. Each stage is optimized in order to optimize whole process (i.e. time and material costs are reduced, technical and technological risks are reduced) [10, 15].

At the same time, despite the considerable amount of initial data for each stage, as well as the presence of boundary values of various parameters regulated by normative documentation, in the process of implementation of such a large-scale project as the development of several offshore fields, number of stochastic processes emerges. Those processes cannot be accounted for and solved by means of the previously presented mathematical apparatus. Thus, for example, it is impossible to determine weather conditions during the installation of structures, the behavior and accuracy of workers, drillers and equipment adjusters, the durability of various structures and equipment in the course of exposure to aggressive environment. As a result, in a number of cases, project managers have to make decisions in conditions of incomplete data. We will present the most weighted and adequate approach, which allows to find the best solutions to specific problems in conditions of uncertainty.

VI. SEARCH FOR OPTIMAL SOLUTIONS FOR THE STAGES OF DEVELOPMENT OF OFFSHORE HYDROCARBON DEPOSITS OF THE KALININGRAD REGION IN CONDITIONS OF UNCERTAINTY.

The previously considered approach to determine the leading processes by stages, determine their boundary values and control parameters, as well as the formation of a set of equations describing a particular process, becomes impossible or difficult in the presence of incomplete data or under the influence of random variables. System contains more variables than the number of equations in it. As a result, system has no mathematical solutions. In this case, the process cannot be optimized by the previously proposed approach, and as a result it is impossible to optimize the stage using the above-mentioned algorithm.

In such case (under uncertainty conditions) it is reasonable to use the method of expert assessments. This makes it possible to fill the lack of data based on expert opinions and experience [8].

Application of the method of expert evaluation, based on the ranking of options for the process/problem under investigation, consists in creating an expert group of m experts \( \{ j \} \) \( j = 1, \ldots, m \), \( m \geq 2 \) and analyzing the set of solutions for the process \( V = \{ v(\ i), i = 1, \ldots, n \} \). The objective function of decision-making is formulated in the form of criterion \( q \) or goal \( C \).

An example of such a target function and a problem situation may be selection of the optimal equipment supplier for offshore development (stage F from table 1).

As a result of comparison between the options according to the \( q \) criterion (based on the accumulated experience and professional knowledge), each expert determines the initial vector of the ranks of the options, for the \( j \)-th expert this vector \( y(\ j) \) has the following form:

\[
y(\ j) = \begin{pmatrix} y(\ j,1) \\ y(\ j,2) \\ \vdots \\ y(\ j,n) \end{pmatrix}
\]

Where \( y(\ j, i) \) \( i \in \{1, 2, K, n, - \} \).
- ratings of options (that is, in the case of the choice of the supplier, formation rating of preferences);  
- the degree of agreement between the experts' opinions (calculating the concordance coefficient \( W \) and checking its significance);  
- the optimal variant \( v \) or to form a subset of the preferred variants \( V_0 \) containing the optimal solution.

Here it should be pointed out that with the calculations made it is important to determine Spearman rank’s correlation coefficient \( K_c \) and the concordance coefficient \( W \), which will confirm the optimality of the solution obtained [9].

To determine the rank correlation coefficient according to Spearman \( K_c \) (measures of linear connection between random variables) the following formula is used:

\[
K_c = 1 - \frac{6 \sum_{i=1}^{n} (x(i, j) - x(h, i))^2}{n(n^2 - 1)}
\]

In the course of the expert study, it is important to involve experts with varying degrees of competence in order to obtain a more balanced and comprehensive result. In this case, when calculating the concordance coefficient, the following formula should be used:

\[
W = \frac{\sum_{i=1}^{n} d(i)^2}{m^2n(n^2 - 1) - 12m \sum_{j=1}^{m} T(j) \left( \sum_{j=1}^{m} c(j) / m \right)^2}
\]

The concordance coefficient \( W \) evaluates the degree of agreement between the opinions of \( m \) experts (\( m^2 \) 2) when ranking options. If all experts have equally ranked the options, i.e. their opinions completely coincide, then \( W = 1 \), if there is no connection between the series \( x(j), j = 1, K, m \), i.e., the opinions of experts differ greatly, then \( W \) is close to zero. Thus, the values of the coefficient \( W \) belong to the interval \([0, 1]\).

Based on the application of the expert method to the analyzed process or problem, a pro-rated list of decisions should be obtained. Solution that received the highest evaluation of experts (provided that the concordance, covariance and mathematical expectations are met) is optimal [11].

In particular, with the help of a group of experts, equipment suppliers can be ranked and based on the obtained results, appropriate managerial decisions can be made - on the terms of tenders for the purchase of equipment and materials. In number of cases, the result of the expert method can be verified using heuristic methods [11].

Thus, the presented algorithm (Figure 5) is obliged to include both calculation of deterministic values for processes and individual steps, and when solving problems associated with stochastic processes and lack of data, use expert methods.

VII. CONCLUSION

Presented approaches to the process of search for optimal solutions at each development stage of hydrocarbon fields on the shelf of the Kaliningrad region can significantly improve the quality of management decisions and reduce technical and technological risks.

At the stage of design and survey work of LLC Lukoil-Kaliningradmorneft, a deep analytical work was carried out to determine the stages of work, critical processes and basic technological operations. At present, the collection of the necessary initial data is being carried out, expert groups are being formed among the employees and involved specialists.

Formed database serves as a basis for finding optimal solutions in the course of projects for the development of hydrocarbon deposits on the shelf of the Kaliningrad region, for the development of project documentation for the field infrastructure, for calculations on the impact on the environment, and also for the search of optimal solutions for other stages of project implementation.

Proposed algorithm for optimization of individual technical and technological processes at various stages of development of offshore deposits can be used in other oil and gas projects, since it has great versatility.

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Effect of Design Parameters on Porpoising Instability of High-Speed Planing Craft

Lokeswara Rao P., Naga Venkata Rakesh N., V. Anantha Subramanian

Abstract—It is important to estimate, predict, and avoid the dynamic instability of high speed planing crafts. It is known that design parameters like relative location of center of gravity with respect to the dynamic lift centre and length to beam ratio of the craft have influence on the tendency to porpoise. This paper analyzes the hydrodynamic performance on the basis of the semi-empirical Savitsky method and also estimates the same by numerical simulations based on Reynolds Averaged Navier Stokes (RANS) equations using a commercial code namely, STAR-CCM+. The paper examines through the same numerical simulation considering dynamic equilibrium, the changing running trim, which results in porpoising. Some interesting results emerge from the study and this leads to early detection of the instability.

Keywords—CFD, Planing hull, Porpoising, Savitsky method.

I. INTRODUCTION

Planing vessels are characterized by relatively smaller lengths and much higher speeds and are designed with a characteristic hull shape below the water plane area such that, at speeds above a characteristic threshold speed, they tend to rise out of water. At high speeds, the weight of a planing vessel is supported mostly by the dynamic pressure, which gives a sustained dynamic lift. The running trim and planing craft performance are highly sensitive to the loading conditions and the location of center of gravity. Porpoising is a dynamic instability that is self-excited due to the oscillating hydrodynamic forces acting in the longitudinal plane as the center of pressure oscillates about the longitudinal center of pressure. To avoid porpoising instability, planing hulls voluntarily limit their speed. Above the maximum stable speed, the instability sets in, which causes the hull to violently oscillate with coupled pitch and heave motions. It adversely affects the structural integrity, safety of the passengers and operations onboard. Therefore, it is important to analyze and understand the onset of porpoising.

Various methods are employed in order to identify the limit of trim for porpoising phenomena namely empirical, computational and experiments on a scaled model. [1] performed the pioneering benchmark tests through systematic investigation of porpoising in planing crafts with a series of prismatic model hulls with various deadrise angles. [2] presented empirical equations for estimation of drag and running trim and used the limit of the dynamic trim angle for porpoising phenomena for design purposes. [3] designed a new experimental setup for high-speed planing crafts; the test setup is used to assess the resistance and to verify the porpoising phenomena. [6] investigated the hydrodynamic analysis of planing craft using COMET software. The steady flow simulation gave the complete resistance graph from zero to maximum speed.

This paper considers the effect of the design parameters namely, the longitudinal center of gravity (LCG) and displacement of a planing vessel on the longitudinal dynamic stability using the commercial code STAR-CCM+ v11.06 [5]. Results employing a dynamic change of grid method in the numerical scheme and in a second approach, using the semi-empirical equations of Savitsky enable comparison of the results.

II. SAVITSKY METHOD

Savitsky empirical equations are based on the experimental study conducted by Day and Haag [1]. Fig.1 is used to estimate the risk of porpoising, which represents the limiting curves for the stability for different dead rise angles [4]. It shows that if the combination of trim angle and the lift coefficient corresponds to a point above the limit curve for a given dead rise angle, porpoising will occur. To predict the trim angle limit for the porpoising region, the method uses the following equation:

\[ \tau_{\text{cr}} = -1.87 + 12.54 \left( \frac{C_{Ld}}{2} \right) + 80.87 \left( \frac{C_{d}}{2} \right) + 0.193 \beta - 0.0017 \beta^2 - 0.312 \left( \frac{C_{Ld}}{2} \right) \]

where \( 0.13 \leq \frac{C_{Ld}}{2} \leq 0.3 \), \( 0 \leq \beta \leq 20 \)

Where \( C_{Ld} = Mg / 0.5 \rho V^2 B^2 \) is the lift coefficient and \( \beta \), \( \tau_{\text{cr}} \) are the dead rise and critical trim angles.

![Fig. 1: Porpoising limits of prismatic planing hull by Savitsky (1964)](image)
Based on Savitsky, the occurrence of porpoising is the combination of high trim angle and low lift coefficient. The empirical formula used in this paper for finding the hydrodynamics of planing hulls by Savitsky method [2] are based on the assumption that all forces act through the center of gravity.

### III. NUMERICAL METHOD

A standard RANSE based CFD package (STAR-CCM+) is used in solving the flow field around the vessel in calm water with two degrees of freedom (pitch and heave) and post processing gives the results for estimating the forces and visualizing flow parameters over the hull surface. The simulations are performed using the Overset grid, which is a dynamic mesh suitable for the porpoising because of oscillation of the vessel during running condition. Volume of Fluid (VOF) model is used to capture the free surface. The complete solver parameters of the simulations are given in Table II. Velocity inlet boundary condition is used to define the velocity of the still water for the inlet, top, bottom and side domains. Pressure outlet boundary condition is used for the outlet domain. No flow should penetrate through the vessel; therefore, wall boundary condition is used for the vessel.

#### Table I

<table>
<thead>
<tr>
<th>Principal particulars of the vessel (LOA = 4.7 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity</td>
</tr>
<tr>
<td>Hull length/ LOA</td>
</tr>
<tr>
<td>Hull breadth/ LOA</td>
</tr>
<tr>
<td>Depth/ LOA</td>
</tr>
<tr>
<td>LCG/ LOA</td>
</tr>
<tr>
<td>Dead rise angle</td>
</tr>
<tr>
<td>Volume displaced</td>
</tr>
</tbody>
</table>

#### Table II

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solver</td>
<td>3D, Unsteady, Implicit</td>
</tr>
<tr>
<td>Turbulence model</td>
<td>Realizable k-ε</td>
</tr>
<tr>
<td>Wall treatment</td>
<td>Two layer wall Y+ treatment</td>
</tr>
<tr>
<td>Multiphase flow model</td>
<td>Volume of Fluid (VOF)</td>
</tr>
<tr>
<td>Time discretization</td>
<td>First order upwind</td>
</tr>
<tr>
<td>Momentum discretization</td>
<td>Second order upwind</td>
</tr>
<tr>
<td>VOF Interface scheme</td>
<td>HRIC</td>
</tr>
<tr>
<td>Time step</td>
<td>0.005 [s]</td>
</tr>
<tr>
<td>Pressure Velocity Coupling</td>
<td>SIMPLE</td>
</tr>
</tbody>
</table>

The hull is modeled in Rhinoceros software and is imported into the CFD software with clean geometry suitable for meshing for CFD application. To capture separation of flow from the surface like spray rails and chines in high speed vessels, the spray rails and chines are modeled with minimum of four to six cells along the breadth. Fig. 2 shows the surface mesh of the hull. The prism layer thickness calculated based on the boundary layer thickness over the flat plate.

#### IV. RESULTS

**A. Effect of center of gravity location**

Based on Fig. 1, a forward shift of center of gravity is one of the ways to increase the speed for porpoising-free operation. The effect of forward movement of LCG location on porpoising is investigated for a given displacement by the CFD studies. Fig. 3 shows the time history of pitch at 25 knots speed for different LCG locations. This confirms that the forward movement of the LCG reduces the running trim of the vessel thereby remedying the porpoising.

**B. Effect of displacement**

The effect of displacement on porpoising is studied for the planing hull while the other parameters are constant. From Fig. 1 increase in mass for a given speed reduces porpoising instability because of increasing the lift coefficient $C_L$. However based on the simulations results show that there is no reduction of porpoising with increase in mass.
of displacement to 1.034t but the number of oscillations during running time period reduces when compare to the lesser displacement 0.862t.

Fig. 5: Effect of mass on dynamic trim (deg) monitor plot at 25 knots speed

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Analysis of Waterjet Propulsion System for an Amphibious Vehicle

Nafsi K. Ashraf, C. V. Vipin, V. Anantha Subramanian

Abstract—This paper reports the design of a Waterjet propulsion system for an amphibious vehicle based on circulation distribution over the camber line for the sections of the impeller and stator. In contrast with the conventional waterjet design, the inlet duct is straight for water entry parallel and in line with the nozzle exit. The extended nozzle after the stator bowl makes the flow more axial further improving thrust delivery. Waterjet works on the principle of volume flow rate through the system and unlike the propeller, it is an internal flow system. The major difference between the propeller and the waterjet occurs at the flow passing the actuator. Though a ducted propeller could constitute the equivalent of waterjet propulsion, in a realistic situation, the nozzle area for the equivalent waterjet would be proportionately larger to the inlet area and propeller disc area. Moreover, the flow rate through the impeller disk is controlled by the nozzle area. For these reasons the waterjet design is based on pump systems rather than propellers and therefore it is important to bring out the characteristics of the flow from this point of view. The analysis is carried out using computational fluid dynamics.

Design of waterjet propulsion is carried out adapting the axial flow pump design and performance analysis was done with three-dimensional computational fluid dynamics (CFD) commercial numerical solver.

Generally, a waterjet propulsion system can be parted into the inlet, the pump, the nozzle and the steering device. The pump further comprises an impeller and a stator. With the varying environmental conditions as well as with the necessity of high discharge and low head along with the space confinement for the given amphibious vehicle, an axial pump design is suitable. The major problem of inlet velocity distribution is the large variation of velocity in the circumferential direction which gives rise to heavy blade loading that varies with time. The cavitation criteria have also been taken into account as per the hydrodynamic pump design.

Analytical and numerical approaches such as RANSE solver has been undertaken to understand the performance of the designed waterjet propulsion system. The analysis was based on head flow curve with efficiency and power curves. The stator-rotor interaction is performed using a moving reference frame approach. The realizability k-ε model has been used for turbulence modeling. The appropriate boundary conditions are applied for the domain and domain size.

Keywords—Amphibious Vehicle, CFD, Impeller design, Waterjet Propulsion.

I. INTRODUCTION

Amphibious vehicles operate in fundamentally different propulsion modes on land and in water. As a class, they are frequently used in military applications where, the land movement is via power transmission through wheels or chain tracks and in the water-borne mode, they have different propulsion systems such as conventional propeller or waterjet systems. Due to the contrary nature of operational environment on land and in water, the amphibious vehicle requires arrangement of the waterjet units along the aft end at the upper level rather than at the lower level as in the case of conventional marine vehicles. The amphibious vehicles transit at relatively much higher speed on land terrain. The present vehicle propulsion system design is for a speed of 10 km/h in the water-borne mode. The system design has to consider the effect of the blunt shape of the amphibious vehicle, which is not quite the same as that for regular waterjet units appropriate for ships and ship shaped geometry. Consequently, the investigation on waterjet system for amphibious military vehicle needs to mull over the particular conditions which are unique in relation to customary marine waterjet system [15].

The waterjet system is appropriate choice for propulsion for the amphibious vehicle since the rotating part is well protected by the casing outside. The waterjet system is highly versatile because of maneuverability by the deflector buckets including reversal, sharp turning ability, good maneuverability at low speeds, and operability in shallow waters. The absence of appendage drag, diminished vibration and high thrust at low speeds are additional advantages.

Although the principle of the waterjets was conceived more than 300 years ago [1], [15], Brandau (1968) conducted a first serious study on the different segments of waterjet system where the best appropriate parameters for augmenting the propulsive efficiency with respect to waterjet performance were proposed [2].

A direct optimization technique without estimation of derivatives was carried out by Gill (1978) by varying parameters such as inlet velocity ratio (IVR), Jet velocity ratio (JVR), ratio of diameter of nacelle inlet and maximum diameter of duct [3]. Wislicenus (1973) covered the aspects of preliminary design where the design principles of hydrodynamic pumps, both axial and centrifugal pumps were examined and later on applied the same for waterjet propulsion pumps [4]. In order to calculate the complete propulsive performance, Korsmeyer (1983) designed and experimentally analyzed a scaled down model of waterjet system which incorporated the effect of tip clearance as well as viscous effects and their influence on the propulsive efficiency [5]. Allison (1993) presented a wide survey of marine waterjet propulsion including the fundamental theory and recent outcomes alongside practical design considerations, advantages and challenges [6]. The parametric model exhibited by Terwisga (1996) in the
computational examination gave better-powering characteristics and better physical similarity [7]. The complicated three-dimensional viscous flow interaction between inlet duct, rotor, stator and exit nozzle in an axial flow waterjet pump was contemplated by Park et al (2005) where the incompressible Reynolds Averaged Navier-Stokes (RANS) equations were solved using moving, non-orthogonal multi-block grid system with iterative time marching approach [8].

A waterjet propulsion system is an internal flow system which makes it more like hydrodynamic pumps contrasting with marine propellers [10]. It works on the momentum principle where the inlet fluid is imparted kinetic energy which results in the forward thrust of vehicle. The working point of waterjet propulsion depends on volume flow rate where the head curve matches with the resistance plot of the vessel, which is based on the required head to produce forward thrust as well as to overcome hydraulic losses [10]. Dissimilar to a propeller, the working point can fluctuate depending on the changes in torque and power at given shaft speed. This is on account of the propeller disc area is not having a fixed geometric limit on the shape of stream way through it [6]. Because of the prerequisite of high specific speed, high discharge, low head and considering the space limitations, an axial flow pump design is appropriate [6].

For the design and optimization of pump design, the designers need to have a detailed analysis about the flow characteristics. It is stated that the conventional blade theory cannot predict the overall performance and flow fields of the system. In spite of the fact that the experimental study gives sensible outcomes with regards to pump performance, with the high advancement in computational methods Computational Fluid Dynamics (CFD) gives good overall performance and flow field analysis for waterjet system [9]. This paper examines the three-dimensional rotor-stator coupling flow fields utilizing realizable k-ε turbulence model and finite volume method using RANS solver.

II. AXIAL FLOW PUMP ADAPTATION FOR WATERJETS

A waterjet system comprises of four segments namely, the inlet, a positive displacement pump, the nozzle and the steering device. Generally, the stator bowl and nozzle are integrated into one half. Downstream of nozzle is the steering device so as to make steering and reverse result by redirecting the stream that helps high maneuverability of the system. A waterjet without steering device is termed as a booster waterjet [10].

The design is based on the optimum performance of the waterjet based on operating point. The resistance plot of the amphibious vehicle considered here is different from the conventional hull due to its bluff formed body and a high displacement value. The design is for a twin waterjet system.

At higher speed, due to the external diffusion occurring ahead of the inlet, the static pressure can be large at the inlet entrance whereas the inlet velocity ratio (IVR) is smaller amount than unity. Thus an inlet ought to be styled to cope up with the low IVR as well as the design IVR condition [10], [6].

The axial flow pump used produces the thrust to the nozzle which is further segmented into the impeller and stator. Impeller is the rotating part which imparts pressure energy to the working fluid. Stator streamlines the flow from impeller and avoids unsteady thrust and side force interactions.

The method adopted for design of both impeller and stator blades is termed as direct method or integration method given by Voznisenksi where flow parameters are determined for the given boundary conditions. The net flow function is the sum of plane undisturbed flow and flow due to circulation [13].

The dimensional analysis under geometric similarity can be used to connect pump head (H), rate of flow (Q) and speed of revolution (n) with the impeller diameter (D) which is the standard reference linear dimension for a pump and fluid properties corresponding to viscosity (μ), density (ρ) and gravity (g) for establishing different expression [14]. The specific speed of the pump is defined from the calculated Pump Head of 5.13m, the flow rate of 0.381m3/s and speed of pump as 1400rpm. The hub ratio is obtained from the recommendation given by Pfliederer from a standard plot between specific speed and hub ratio [11]. With the obtained diameter ratio and flow rate, the impeller diameter is calculated as 330 mm. The flow rate in its non-dimensional form is represented by a unit quantity (KQ) and similarly head is represented in its non-dimensional quantity as unit head (KQ). This together gives the value of hydraulic efficiency from the universal graph recommended by Staritzky which is 81% in this case [12].

The number of impeller blades is four for which the stator blade is five and is selected such that inlet flow passage is a square. The blade curvature is selected from the recommended value of 7% at the hub and 2% for the periphery. The relative maximum thickness of the blade chosen at the hub is 10% and that at the tip is 3% considering the cavitation and the suction effect. The calculate value of mean pitch to diameter of both impeller and stator blade is 0.785. The mean line of the profile for both impeller and stator are the arc of the circle which is 81% in this case [11].

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>P/D</td>
<td>0.785</td>
</tr>
<tr>
<td>Z</td>
<td>4</td>
</tr>
</tbody>
</table>

III. NUMERICAL MODELLING

The fluid considered is incompressible as in the real-time case where the Reynold Number is very high in this case. Owing the waterjet-hull interaction effect as well as due to the geometry of the inlet pipe, the velocity distribution to the

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>IMPELLER PARTICULARS</th>
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<tbody>
<tr>
<td>Symbols</td>
<td>Parameters</td>
</tr>
<tr>
<td>H</td>
<td>Head</td>
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<tr>
<td>Q</td>
<td>Quantity</td>
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<tr>
<td>N</td>
<td>Impeller speed</td>
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<td>D</td>
<td>Impeller diameter</td>
</tr>
<tr>
<td>d_s</td>
<td>Hub diameter</td>
</tr>
<tr>
<td>K_Q</td>
<td>Unit quantity</td>
</tr>
<tr>
<td>K_H</td>
<td>Unit head</td>
</tr>
<tr>
<td>n_H</td>
<td>Hydraulic Efficiency</td>
</tr>
<tr>
<td>P/D</td>
<td>Mean pitch to diameter ratio</td>
</tr>
<tr>
<td>Z</td>
<td>Number of blades</td>
</tr>
</tbody>
</table>
inlet of impeller is non-uniform. Additionally vorticity also influences the inlet velocity distribution. Hence a fully turbulent model is used in present case.

![Fig 1 Configuration of axial flow pump](image)

### A. Governing Equations

The differential form of Navier-Stokes (N-S) equations combined with the Reynolds averaged form (RANSE) offers the numerical solution for the governing equations. Finite Volume Method (FVM) is used to solve the governing equations in the control volume. The governing transport equation for control volume "V" bounded by control surface "A" considering a scalar quantity \( \eta \) is given by:

\[
\frac{d}{dt} \int_a \rho \eta dV + \int_a \rho \eta (v - v_g) dA = \int_a \Gamma \nabla \eta dA + \int_a q_{\eta v} dV \tag{1}
\]

Where \( t \) is the time, \( \rho \) is the density of the fluid, \( v \) is the velocity vector with Cartesian coordinate \( u \), \( v_g \) is the grid velocity of control volume surface, \( \Gamma \) is the diffusion coefficient and \( q_{\eta v} \) is the volumetric source term of the conserved scalar quantity.

The governing equation for the turbulent incompressible flow of the present study which is based on conservation of mass and conservation of momentum is given below where \( \rho \) gives the density.

\[
\frac{\partial (\rho u)}{\partial x} + \frac{\partial (\rho v)}{\partial y} + \frac{\partial (\rho w)}{\partial z} = 0 \tag{2}
\]

\[
-\frac{\partial \rho}{\partial x} + \rho \frac{\partial u}{\partial t} + \frac{\partial \tau_{ux}}{\partial x} + \frac{\partial \tau_{uy}}{\partial y} + \frac{\partial \tau_{uz}}{\partial z} = \text{div} (\rho u u) \tag{3}
\]

\[
-\frac{\partial \rho}{\partial y} + \rho \frac{\partial v}{\partial t} + \frac{\partial \tau_{vx}}{\partial x} + \frac{\partial \tau_{vy}}{\partial y} + \frac{\partial \tau_{vz}}{\partial z} = \text{div} (\rho v u) \tag{4}
\]

\[
-\frac{\partial \rho}{\partial z} + \rho \frac{\partial w}{\partial t} + \frac{\partial \tau_{wx}}{\partial x} + \frac{\partial \tau_{wy}}{\partial y} + \frac{\partial \tau_{wz}}{\partial z} = \text{div} (\rho w u) \tag{5}
\]

A Realizable k-\( \epsilon \) turbulence model is used which is a good compromise between robustness and accuracy for a larger range of flow configurations. Moving reference frame approach is tested in analyses of impeller-stator interaction in the numerical model. The current study uses two frames i.e. a rotating frame for impeller and a stationary frame for stator and waterjet casing.

### B. Geometry and Grid Generation

Because of the complex geometry of impeller and stator, an unstructured grid is given for analysis of the waterjet system. Moreover, fine grids are given near the blade tips to capture the vortex flow. An optimum value for mesh size was selected making it coarser to finer for convergence.

### IV. RESULTS AND ANALYSIS

The flow simulations are carried out using the numerical solver STAR CCM+ for analyzing hydrodynamic characteristics of waterjet propulsion system. Generally, the pump performance analysis is given in terms of head coefficient rather than a pressure coefficient [6]. Hence the presentation here calculates the averaged static pressure at the inlet and outlet of the pump and obtains the corresponding value of the Energy Transfer Coefficient (\( \psi \)), represented as:

\[
\psi = \frac{gH}{N^2 D^2} \tag{6}
\]

Where \( H \) represents the static pressure head, \( N \) represents the speed of the impeller and \( D \) is the diameter of the impeller. The energy transfer coefficient is analogous to the non-dimensional thrust coefficient \( K_T \) used in defining the useful thrust obtained from a conventional propeller in the case of a ship.

Similarly the Flow Rate Coefficient \( \phi = \frac{Q}{NR} \) where \( Q \) is the volume rate of flow and \( R \) is the radius of impeller and is analogous to the advance coefficient \( J \), used to represent forward speed in the case of a conventional propeller.

![Fig 2 Comparison of Energy Transfer Coefficient with Flow rate Coefficient](image)
This is analogous to the conventional propeller torque coefficient.

\[ K_p = \frac{P}{\rho N^2 D^5} \]  

(8)

Fig 3 Comparison of Power coefficient with Flow rate coefficient

Fig 4 Comparison of Vehicle speed (m/s) with Net thrust (kN)

Fig. 4 shows the development of Net Thrust from the waterjet system as a function of the speed of the amphibious vehicle.

The paper offers a methodology for the design of the waterjet system for the requirement of speed of the amphibious vehicle. The analysis establishes that the designed waterjet system delivers the required thrust and also gives the characteristics of the Energy Transfer Coefficient and Power Coefficient as functions of the Flow Rate Coefficient.

REFERENCES


Improvement of Oxidative Stability of Edible Oil by Microencapsulation Using Plant Proteins
L. Le Priol, A. Nesterenko, K. El Kirat, K. Saleh

Abstract—Introduction & Objectives: Polyunsaturated fatty acids (PUFAs) omega-3 and omega-6 are widely recognized as being beneficial to the health and normal growth. Unfortunately, due to their highly unsaturated nature, these molecules are sensitive to oxidation and thermic degradation leading to the production of toxic compounds and unpleasant flavors and smells. Hence, it is necessary to find out a suitable way to protect them. Microencapsulation by spray-drying is a low-cost encapsulation technology and the most commonly used in the food industry. Many compounds can be used as wall materials but there is a growing interest in the use of biopolymers, such as proteins and polysaccharides, over the last years. The objective of this study is to increase the oxidative stability of sunflower oil by microencapsulation in plant protein matrices using spray-drying technique.

Material & Methods: Sunflower oil was used as a model substance for oxidative food oils. Proteins from brown rice, hemp, pea, soy and sunflower seeds were used as emulsifiers and microencapsulation wall materials.

First, the proteins were solubilized in distilled water. Then, the emulsions were pre-homogenized using a high-speed homogenizer (Ultra-Turrax) and stabilized by using a high-pressure homogenizer (HHP). Drying of emulsion was performed in a Mini Spray Dryer.

The oxidative stability of the encapsulated oil was determined by performing accelerated oxidation tests with a Rancimat.

The size of the microparticles was measured using a laser diffraction analyzer.

The morphology of the spray-dried microparticles was acquired using environmental scanning microscopy.

Results: Pure sunflower oil was used as a reference material. Its induction time was 9.5 ± 0.1 h. The microencapsulation of sunflower oil in pea and soy protein matrices significantly improved its oxidative stability with induction times of 21.3 ± 0.4 h and 12.5 ± 0.4 h respectively. The encapsulation with hemp proteins did not significantly change the oxidative stability of the encapsulated oil. Sunflower and brown rice proteins were ineffective materials for this application, with induction times of 7.2 ± 0.2 h and 7.0 ± 0.1 h respectively.

The volume mean diameter of the microparticles formulated with soy and pea proteins were 8.9 ± 0.1 μm and 16.3 ± 1.2 μm respectively. The values for hemp, sunflower and brown rice proteins could not be obtained due to the agglomeration of the microparticles.

ESEM images showed smooth and round microparticles with soy and pea proteins. The surfaces of the microparticles obtained with sunflower and hemp proteins were porous. The surface was rough when brown rice proteins were used as encapsulating agent.

Conclusion: Soy and pea proteins appeared to be efficient wall materials for the microencapsulation of sunflower oil by spray drying. These results were partly explained by the higher solubility of soy and pea proteins in water compared to hemp, sunflower and brown rice proteins.

Keywords—Biopolymer, edible oil, microencapsulation, oxidative stability, release, spray-drying.
Influence of Cryo-Grinding on Particle Size Distribution of Proso Millet Bran Fraction

Maja Benković*, Dubravka Novotni, Bojana Voučko, Duška Ćurić, Damir Ježek, Nikolina Čukelj

Abstract—Cryo-grinding is an ultra-fine grinding method used in the pharmaceutical industry, production of herbs and spices and in the production and handling of cereals, due to its ability to produce powders with small particle sizes which maintain their favorable bioactive profile.

The aim of this study was to determine the particle size distributions of the proso millet (Panicum miliaceum) bran fraction ground at cryogenic temperature (using liquid nitrogen (LN₂) cooling, T = -196 °C), in comparison to non-cooled grinding. Proso millet bran is primarily used as an animal feed, but has a potential in food applications, either as a substrate for extraction of bioactive compounds or raw material in bakery industry. For both applications finer particle sizes of the bran could be beneficial.

Thus, millet bran was ground for 2, 4, 8 and 12 minutes using the ball mill (CryoMill, Retsch GmbH, Haan, Germany) at three grinding modes: (I) without cooling, (II) at cryo-temperature, and (III) at cryo-temperature with included 1 minute of intermediate cryo-cooling step after every 2 minutes of grinding, which is usually applied when samples require longer grinding times. The sample was placed in a 50 mL stainless steel jar containing one grinding ball (Ø 25 mm). The oscillation frequency in all three modes was 30 Hz. Particle size distributions of the bran were determined by a laser diffraction particle sizing method (Mastersizer 2000) using the Scirocco 2000 dry dispersion unit (Malvern Instruments, Malvern, UK).

Three main effects of the grinding set-up were visible from the results. Firstly, grinding time at all three modes had a significant effect on all particle size parameters: d(0.1), d(0.5), d(0.9), D[3,2], D[4,3], span and specific surface area. Longer grinding times resulted in lower values of the above-listed parameters, e.g. the averaged d(0.5) of the sample (229.57±1.46 µm) dropped to 51.29±1.28 µm after 2 minutes grinding without LN₂, and additionally to 43.00±1.33 µm after 4 minutes of grinding without LN₂. Only exception was the sample ground for 12 minutes without cooling, where an increase in particle diameters occurred (d(0.5)=62.85±2.20 µm), probably due to particles adhering to one another and forming larger particle clusters. Secondly, samples with LN₂ cooling exhibited lower diameters in comparison to non-cooled. For example, after 8 minutes of non-cooled grinding d(0.5)=46.97±1.05 µm was achieved, while the LN2 cooling enabled collection of particles with average sizes of d(0.5)=18.57±0.18 µm. Thirdly, the application of intermediate cryo-cooling step resulted in similar particle diameters (d(0.5)=15.83±0.36 µm, 12 min of grinding) as cryo-milling without this step (d(0.5)=16.33±2.09 µm, 12 min of grinding). This indicates that intermediate cooling is not necessary for the current application, which consequently reduces the consumption of LN₂.

These results point out the potential beneficial effects of millet bran grinding at cryo-temperatures. Further research will show if the lower particle size achieved in comparison to non-cooled grinding could result in increased bioavailability of bioactive compounds, as well as protein digestibility and solubility of dietary fibers of the proso millet bran fraction.

Keywords—Ball mill, cryo-milling, particle size distribution, proso millet (Panicum miliaceum) bran.
Abstract—Turmeric is a natural plant herb and generally extracted as essential oil and widely used in food, cosmetic, pharmaceutical products including insect repellent. However, turmeric oil is a volatile essential oil which is easy to be lost during storage or exposure to light. Therefore, biopolymers such as protein and polysaccharide can be used as wall materials to encapsulate the essential oil which will solve this drawback. Approximately 60% plasma from porcine blood contains 6-7% of protein content mainly albumin and globulin which can be a good source of animal protein at the low cost biopolymer from by-product. Microencapsulation is a useful technique to entrap volatile compounds in the biopolymer matrix and protect them to degrade. The objective of this research was to investigate the different ratios of two biopolymers (PPP and maltodextrin; MD) as wall materials at 100:0, 75:25, 50:50, 25:75 and 0:100 at a fixed ratio of wall material: core material (turmeric oil) at 3:1 (oil in water) on the qualities of microencapsulated powder using freeze drying. It was found that the combination of PPP and MD showed higher solubility of microencapsules compared to the use of PPP alone ($P < 0.05$). Moreover, the different ratios of wall materials also affected on color ($L^*$, $a^*$ and $b^*$) of microencapsulated powder. Morphology of microencapsulated powder using a scanning electron microscope showed holes on the surface reflecting on free oil content and encapsulation efficiency of microencapsules. At least 50% of MD was needed to increase encapsulation efficiency of microencapsulates rather than using only PPP as the wall material ($P < 0.05$). Microencapsulated turmeric oil powder can be useful as food additives to improve food texture, as a biopolymer material for edible film and coating to maintain quality of food products.

Keywords—Microencapsulation, turmeric oil, porcine plasma protein, maltodextrin.
Association between Dairy Consumption and a Lower Risk of Metabolic Syndrome and Its Components: A Systematic Review and Meta-Analysis

Jihye Kim, Mijin Lee, Hanna Lee

Abstract—A systematic review and a meta-analysis of observational studies were performed to assess the dose-response associations between specific types of dairy foods and the risk of metabolic syndrome (MetS) and its components.

Studies of dairy foods and the risk of MetS and its components published up to June 2016 were searched using PubMed, EMBASE, and a reference search. Random-effects models were used to estimate the pooled relative risk (RR) with 95% confidence interval (CI).

In a dose-response analysis of cohort studies and cross-sectional studies, the pooled RRs of MetS for a one-serving/day increment of total dairy and milk consumption (200 g/d) were 0.91 (95% CI: 0.85–0.96) and 0.87 (95% CI: 0.79–0.95), respectively. The pooled RR of MetS for yogurt consumption (100 g/d) was 0.82 (95% CI: 0.73–0.91). Total dairy consumption was associated with lower risk of MetS components such as hyperglycemia, elevated blood pressure, hypertriglyceridemia, and low high-density lipoprotein cholesterol. A one-serving/day increment of milk was associated with a 12% lower risk of abdominal obesity, and a one-serving/day increment of yogurt was associated with a 16% lower risk of hyperglycemia. These associations were not significantly different by study design, study location, or adjustment factors.

This meta-analysis showed that specific types of dairy consumption such as milk and yogurt as well as total dairy consumption were inversely associated with risk of MetS and its components.

Keywords—Dairy consumption, meta-analysis, metabolic syndrome, milk, systematic review, yogurt.

J. Kim is with the Department of Medical Nutrition, Graduate School of East-West Medical Science, Kyung Hee University, 1732 Deogyeong-daero, Giheung-gu, Yongin 446-701, Republic of Korea (phone: 82-31-201-3497; fax: 82-31-204-8119; e-mail: kjhye@khu.ac.kr).

M. Lee is with the Department of Medical Nutrition, Graduate School of East-West Medical Science, Kyung Hee University, Yongin 446-701, Republic of Korea (e-mail: alwls5151@hanmail.net).

H. Lee is with the Korea Federation of Women’s Science and Technology Associations, Seoul 135-703, Republic of Korea (e-mail: hannah0802@smu.ac.kr).
The Effect of Gamma-Aminobutyric Acid on Mechanical Properties, Water Vapor Permeability and Solubility of Pectin Films

Jitrawadee Meerasri, Rungsinee Sothornvit

Abstract—Pectin is a structural polysaccharide from plant cell walls and can be used as stabilizer, gelling and film-forming agents to improve many food products. Moreover, pectin film as a natural biopolymer can be a carrier of several active ingredients such as antioxidant and antimicrobial to provide an active or functional film. Gamma-aminobutyric acid (GABA) is a well-known agent to reduce neuronal excitability throughout the nervous system and it is interesting to investigate the GABA effect as a substitute of normal plasticizer (glycerol) on edible film properties. Therefore, the objective of this study was to determine the effect of GABA concentrations (5-15% of pectin) on film mechanical properties, moisture content, water vapor permeability and solubility compared with those from glycerol (10% of pectin) plasticized pectin film including a control film (pectin film without any plasticizer). It was found that increase in GABA concentrations decreased film tensile strength, modulus, solubility and water vapor permeability, but elongation was increased without change in the moisture content. The smaller amount of GABA showed the equivalent film properties as using higher amount of glycerol. Consequently, GABA can act as an alternative plasticizer substitute of glycerol at the lower amount used. Moreover, GABA provides the nutritional high value in the food products when the edible packaging material is consumed with products.

Keywords—Gamma-aminobutyric acid, pectin, plasticizer, edible film.

Jitrawadee Meerasri is with the Department of Food Engineering, Faculty of Engineering at Kamphaengsaen, Kasetsart University, Kamphaengsaen Campus, Nakhonpathom, 73140 Thailand (phone: +66-833162621; e-mail: jitrawadee_1412@hotmail.com).
Rungsinee Sothornvit is with the Department of Food Engineering, Faculty of Engineering at Kamphaengsaen, Kasetsart University, Kamphaengsaen Campus, Nakhonpathom, 73140 Thailand (phone: +66-34351404; fax: +66-34351404; e-mail: fengrns@ku.ac.th).
Abstract—Fermented dairy food quality is mainly determined by the sensory perception and influenced by many factors. Today, starter cultures for fermented foods are being developed to have a constant quality in these foods. *Streptococcus Thermophilus* is one of the main species of most starter cultures of yoghurt fermentation. This species produces lactate by lactose fermentation from pyruvate. On the other hand, a small amount of pyruvate can alternatively be converted to various typical yoghurt flavor compounds such as diacetyl, acetoin, acetaldehyde, or acetic acid, for which the activity of three genes are shown to be especially important; *ldh*, *nox* and *als*. Up to date, commercially produced yoghurts have not yet met the desired aromatic properties that Turkish consumers find in traditional homemade yoghurts. Therefore, it is important to select starters carrying favorable metabolic characteristics from natural isolates. In this study, 30 strains of *Str. Thermophilus* were isolated from traditional Turkish yoghurts obtained from different regions of the country. In these strains, transcriptional levels of *ldh*, *nox* and *als* genes were determined via a newly developed qPCR protocol, which is a more reliable and precision method for analyzing the quantitative and qualitative expression of specific genes in different experimental conditions or in different organisms compared to conventional analytical methods. Additionally, the metabolite production potentials of the isolates were measured. Of all the strains examined, 60% were found to carry the metabolite production potential and the gene activity which appeared to be suitable to be used as a starter culture. Probable starter cultures were determined according to real time PCR results. It is a more reliable and precision method for analyzing the quantitative and qualitative expression of particular genes in different experimental conditions or in different organisms.

Keywords—Gene expression, RT PCR, Starter Culture

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E. Coskun Daggecen is with the Kahramanmaras Sutcu Imam University, Kahramanmaras, 38000 Turkey (phone: 090-344-3002136; fax: 090-280-2002; e-mail: elifcoskun@ksu.edu.tr).

S. Dokucu, was with Kahramanmaras Sutcu Imam University, Kahramanmaras, 38000 Turkey (e-mail: seyma.dkc@hotmail.com).

Y. Gezginc, was with Kahramanmaras Sutcu Imam University, Kahramanmaras, 38000 Turkey (e-mail: yekgan@ksu.edu.tr).

I. Akyol is with Kahramanmaras Sutcu Imam University, Kahramanmaras, 38000 Turkey (e-mail: IsmailAkyol@ksu.edu.tr).
Synthesis and Characterization of Carboxymethyl Cellulose from Rice Stubble Cellulose

Rungsinee Sothornvit, Pattrathip Rodsamran

Abstract—Rice stubble consists of a high content of cellulose and can be synthesized as a cellulose derivative such as carboxymethyl cellulose (CMC) to value added products from agricultural waste. Therefore, the synthesis conditions and characterization the properties of CMC from rice stubble (CMCr) were investigated. Hemicellulose and lignin were first removed from the rice stubble using 10% NaOH at 55 °C for 3 h and 5% NaOCl at 75 °C for 15 min, respectively. Rice stubble cellulose was swollen in 30% NaOH and isopropanol as a solvent. The content of chloroacetic acid (5–7 g in 5 g of alkali cellulose), reaction temperature (50 and 70 °C) and time (180, 270 and 360 min) were explored to obtain CMC. It was found that synthesis conditions did not affect significantly on moisture content and pH of CMCr. The best quality of CMCr was synthesized by using 7 g of chloroacetic acid and reacted at 50 °C for 180 min based on 5 g of rice stubble cellulose. Degree of substitution (DS), viscosity and purity of CMCr were 0.64, 36.03 cP and 90.18 %, respectively. Furthermore, Fourier transform infrared (FT–IR) spectroscopy confirmed the presence of carboxymethyl substituents. CMCr was categorized in commercial scale as a low viscosity material and it can be used as film forming packaging materials for food and pharmaceutical product applications.

Keywords—Rice stubble, cellulose, carboxymethyl cellulose, degree of substitution, purity.
Impact of Interdisciplinary Therapy Allied to Online Health Education on Cardiometabolic Parameters and Inflammation Factor Rating in Obese Adolescents

Yasmin A. M. Ferreira¹, Ana C. K. Pelissari, Sofia de C. F. Vicente¹, Raquel M. da S. Campos², Deborah C. L. Masquio³, Lian Tock³, Lila M. Oyama⁴, Flavia C. Corgosinho⁵, Valter T. Boldarine⁴, Ana R. Dâmaso¹

Abstract—The prevalence of overweight and obesity is growing around the world and currently considered a global epidemic. Food and nutrition are essential requirements for promoting health and protecting non-communicable chronic diseases, such as obesity and cardiovascular disease. Specific dietary components may modulate the inflammation and oxidative stress in obese individuals. Few studies have investigated the dietary Inflammation Factor Rating (IFR) in obese adolescents. The IFR was developed to characterize an individual’s diet on anti-to pro-inflammatory score. This evaluation contributes to investigate the effects of inflammatory diet in metabolic profile in several individual conditions. Objectives: The present study aims to investigate the effects of a multidisciplinary weight loss therapy on inflammation factor rating and cardiometabolic risk in obese adolescents. Methods: A total of 26 volunteers (14-19 y.o) were recruited and submitted to 20 weeks interdisciplinary therapy allied to health education website- Ciclo do Emagrecimento®, including clinical, nutritional, psychological counseling and exercise training. The body weight was monitored weekly by self-report and photo. The adolescents answered a test to evaluate the knowledge of the topics covered in the videos. A 24h dietary record was applied at the baseline and after 20 weeks to assess the food intake and to calculate IFR. A negative IFR suggests that diet may have inflammatory effects and a positive IFR indicates an anti-inflammatory effect. Statistical analysis was performed using the program STATISTICA version 12.5 for Windows. The adopted significant value was α ≤ 5 %. Data normality was verified with the Kolmogorov Smirnov test. Data were expressed as mean±SD values. To analyze the effects of intervention it was applied test t. Pearson’s correlations test was performed. Results: After 20 weeks of treatment, body mass index (BMI), body weight, body fat (kg and %), abdominal and waist circumferences decreased significantly. The mean of high-density lipoprotein cholesterol (HDL-c) increased after the therapy. Moreover, it was found an improvement of inflammation factor rating from -427.27±322.47 to -297.15±240.01, suggesting beneficial effects of nutritional counselling. Considering the correlations analysis, it was found that pro-inflammatory diet is associated with increase in the BMI, very low-density lipoprotein cholesterol (VLDL), triglycerides, insulin and insulin resistance index (HOMA-IR); while an anti-inflammatory diet is associated with improvement of HDL-c and insulin sensitivity Check index (QUICKI). Conclusion: The 20-week blended multidisciplinary therapy was effective to reduce body weight, anthropometric circumferences and improve inflammatory markers in obese adolescents. In addition, our results showed that an increase in inflammatory profile diet is associated with cardiometabolic parameters, suggesting the relevance to stimulate anti-inflammatory diet habits as an effective strategy to treat and control of obesity and related comorbidities.

Keywords—Cardiometabolic risk, inflammatory diet, multidisciplinary therapy, obesity.

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¹Post Graduated Program of Nutrition Paulista Medicine School, Universidade Federal de São Paulo (UNIFESP), Rua Marseilha, 650–Vila Clementino, São Paulo, SP 04020-050, Brazil. yasminalaby@hotmail.com
²Department of Physiotherapy, Therapeutic Resources Laboratory, Universidade Federal de São Carlos (UFSCar), São Carlos, SP 13565-905, Brazil
³Weight Science, São Paulo, SP, Brazil
⁴Department of Physiology Paulista Medicine School, Universidade Federal de São Paulo, São Paulo, SP, Brazil
⁵Universidade Federal de Goiás (UFG), Goiânia, Goiás, Brazil
Development of Method for Detecting Low Concentration of Organophosphate Pesticides in Vegetables Using Near Infrared Spectroscopy

Atchara Sankom, Warapa Mahakarnchanakul, Ronnarit Rittiron, Tanaboon Sajjaanantakul, Thammasak Thongket

Abstract—Vegetables are frequently contaminated with pesticides residues resulting in the most food safety concern among agricultural products. The objective of this work was to develop a method to detect the organophosphate (OP) pesticides residues in vegetables using Near Infrared (NIR) spectroscopy technique. Low concentration (ppm) of OP pesticides in vegetables were investigated. The experiment was divided into 2 sections. In the first section, Chinese kale spiked with different concentrations of chlorpyrifos pesticide residues (0.5-100 ppm) was chosen as the sample to demonstrate the appropriate conditions of sample preparation, both for solution or solid sample. The spiked samples were extracted with acetone. The sample extracts were applied as solution samples, while the solid samples were prepared by the dry-extract system for infrared (DESIR) technique. The DESIR technique was performed by embedding the solution sample on filter paper (GF/A) and then drying. The NIR spectra were measured with the transfectance mode over wavenumber regions of 12,500-4000 cm⁻¹. The QuEChERS method followed by gas chromatography – mass spectrometry (GC-MS) was performed as the standard method. The results from the first section showed that the DESIR technique with NIR spectroscopy demonstrated good accurate calibration result with R² of 0.93 and RMSEP of 8.23 ppm. However, in the case of solution samples, the prediction regarding the NIR-PLSR (partial least squares regression) equation showed poor performance (R² = 0.16 and RMSEP = 23.70 ppm). In the second section, the DESIR technique coupled with NIR spectroscopy was applied to the detection of OP pesticides in vegetables. Vegetables (Chinese kale, cabbage and hot chili) were spiked with OP pesticides (chlorpyrifos ethion and profenofos) at different concentrations ranging from 0.5 to 100 ppm. Solid samples were prepared (based on the DESIR technique), then samples were scanned by NIR spectrophotometer at ambient temperature (25±2°C). The NIR spectra were measured as in the first section. The NIR-PLSR showed the best calibration equation for detecting low concentrations of chlorpyrifos residues in vegetables (Chinese kale, cabbage and hot chili) according to the prediction set of R² and RMSEP of 0.85-0.93 and 8.23-11.20 ppm, respectively. For ethion residues, the best calibration equation of NIR-PLSR showed good indexes of R² and RMSEP of 0.88-0.94 and 7.68-11.20 ppm, respectively. As well as the results for profenofos pesticide, the NIR-PLSR also showed the best calibration equation for detecting the profenofos residues in

Keywords—NIR spectroscopy, Organophosphate pesticide, Vegetable, Food safety.

Atchara Sankom, Department of Food Science and Technology, Faculty of Agro-industry, Kasetsart University, Bangkok, Thailand (e-mail: pao.synam@gmail.com).
Warapa Mahakarnchanakul, Department of Food Science and Technology, Faculty of Agro-industry, Kasetsart University, Bangkok, Thailand (corresponding author, e-mail: fagiwpmp@ku.ac.th).
Ronnarit Rittiron, Department of Food Engineering, Faculty of Engineering at Kamphaengsaen, Kasetsart University, Nakhon Pathom, Thailand (email: fengror@ku.ac.th).
Tanaboon Sajjaanantakul, Department of Food Science and Technology, Faculty of Agro-industry, Kasetsart University, Bangkok, Thailand (email: tanaboon.s@ku.ac.th).
Thammasak Thongket, Department of Horticulture, Faculty of Agriculture at Kamphaengsaen, Kasetsart University, Nakhon Pathom, Thailand (e-mail: agrtst@ku.ac.th).
Abstract—Rice bran protein hydrolysates (RBPH) were prepared from defatted rice bran of two different Thai rice cultivars (Plai-Ngahn-Prachinburi, PNP and Khao Dok Mali 105; KDM105) using an enzymatic method. This research aimed to optimize enzyme-assisted protein extraction. In addition, the functional properties of RBPH and their stabilities to environmental stresses including pH (3 to 8), ionic strength (0 mM to 500 mM) and the thermal treatment (30 °C to 90 °C) were investigated. Results showed that enzymatic process for protein extraction of defatted rice bran was as follows: enzyme concentration 0.075 g/5 g of protein, extraction temperature 50 °C and extraction time 4 h. The obtained protein hydrolysat powders had a degree of hydrolysis (%) of 21.05% in PNP and 19.92% in KDM105. The solubility of protein hydrolysates at pH 4-6 was ranged from 27.28-38.57% and 27.60-43.00% in PNP and KDM105, respectively. In general, antioxidant activities indicated by total phenolic content, FRAP, ferrous ion-chelating (FIC), and 2,2'-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid (ABTS) of KDM105 had higher than PNP. In terms of functional properties, the emulsifying activity index (EAI) was 8.78 m²/g protein in KDM105, whereas PNP was 5.05 m²/g protein. The foaming capacity at 5 minutes (%) was 47.33 and 52.98 in PNP and KDM105, respectively. Glutamine, Alanine, Valine, and Leucine are the major amino acid in protein hydrolysates where the total amino acid of KDM105 gave higher than PNP. Furthermore, we investigated environmental stresses on the stability of 5% oil in water emulsion (5% oil, 10 mM citrate buffer) stabilized by RBPH (3.5%). The droplet diameter of emulsion stabilized by KDM105 was smaller (d < 250 nm) than produced by PNP. For environmental stresses, RBPH in O/W emulsions and observed their stabilities to the pH, ionic strength and thermal stresses.

Keywords—Functional properties, oil in water emulsion, protein hydrolysates, rice bran protein.

I. INTRODUCTION

RICE bran, a byproduct of rice milling with low value but high in bioactive compounds and nutraceuticals [1], [2]. In general, rice bran has been used for oil extraction, in animal feed and as a food [3]. Rice bran is a good source of γ-oryzanol, Inositol, Campesterol, β-Sitosterol, and p-Coumaric acid [4]-[6] that attribute to the hypocholesterolemic effects [2]. The main proteins in rice bran are albumins (37%), globulins (36%), prolamins (5%) and glutelins (22%) [5], [7]. The recovery rice bran proteins have been reported using physical, chemical and enzymatic method. The size of the protein and amino acid arrangement of peptide molecules may have shown a variety of protein functionalities [5], [8].

Enzymatic extraction method have been used for recover protein from rice bran including improve the functional properties of protein such as emulsifying ability, foaming capacity, viscosity, gelatinization, and water absorption capacity [5], [8], [10]. Reference [9] reported that proteases were used to hydrolyze rice bran protein for better solubility and greater extractability. Two classes of protease, exoprotease and endoprotease can be utilized of rice bran protein yield about 60-93% and obtain a wide range of hydrolysates [9]. The use of endoprotease and exopeptidases has been studied in reference [8], [9], [11].

Khao Dok Mali 105 (KDM105) is one of the recommended commercial rice cultivars from Thailand. It has been distinctive aroma. Therefore it has been consumed by cooking. Whereas PNP is the traditional rice cultivars obtained from Prachinburi province, Thailand. It is commonly processed as a noodle for consume. In Thailand rice bran usually used as a source of proteins for animal feed.

To increase the value of rice bran and extend its application in food, this research aimed to optimize an enzymatic extraction condition in rice bran. The obtained hydrolyzed rice bran protein extracts was investigated on some physicochemical and functional properties including apply the RBPH in O/W emulsions and observed their stabilities to the pH, ionic strength and thermal stresses.

II. MATERIALS AND METHODS

A. Raw Material and Chemicals

Full-fat rice bran, Khao Dok Mali 105 (KDM105) and PNP were obtained from Suan Dusit Rajabhat, Rice mill factory, Co Ltd. (Prachinburi, Thailand) and passed through a sieve (60 mesh). The defatted rice bran was prepared by solvent extraction in a Soxhlet apparatus using hexane. After completed removal of hexane, the defatted rice bran was stored in LDPE plastic bag under -18°C for further experiment. Chemicals and reagents of analytical grade were purchased from Univar (USA Inc., USA) and Merck
starch protein was packed in laminated aluminium bags and dried (Alpha 1-4 LSC, Christ, Germany). The obtained rice protein was calculated using the AOAC method [12]; and crude protein was determined according to the Kjeldahl method [12] and solubility (%) was calculated as the equation below:

\[
\text{Solubility} = \left( \frac{\text{protein content in supernatant}}{\text{total protein content in sample}} \right) \times 100
\]

**Degree of hydrolysis:** Reactions were observed by measuring the amount of α-amino acid using a modified method [15], [16]. RBPH 100 μl was mixed with 2 ml of phosphate buffer 0.2125 M and 1 ml of 0.02% of 2,4,6-trinitrobenzenesulfonic acid (TNBS) in screw-cap test tube with adjusted pH 8.2 using NaOH/ or HCl. The suspension was heated at 50 °C for 30 minutes under dark condition, then 2 ml of 0.1 M sodium sulfate was add into the suspension and vortexed for 5 second to stop a reaction. Absorbance of the suspension was read at 420 nm using a UV-visible spectrometer (Thermo Electron Corporation, Waltham, MA). Alpha amino acid was expressed in terms of L-leucine. The DH (%) defined as follows:

\[
\text{DH} = \left( \frac{\text{Number of peptide bonds cleaved after hydrolysis}}{\text{Total peptide bonds}} \right) \times 100
\]

**Total phenolic content:** The total phenolic content was determined using Folin-Ciocalteu method [17]. The reaction mixture contained 200 μl of RBPH solution, 150 μl of Folin-Ciocalteu reagent (1:10 v/v) and 1.2 ml of 7.5% NaCO₃. The mixture was incubated in the dark at room temperature for 30 minutes. Then measured at 765 nm. Distilled water was used as the control and gallic acid at 0-10 mg/ 100 ml.

**FIC:** Ferrous Ion-Chelating or FIC assay was determined followed [20]. The solution contained 5 mg of RBPH/ 1 ml distilled water. Pipette sample 100 μl, FeSO₄ 0.1 mM 100 μl, and ferric chloride 25 mM 100 μl. The mixture was shaken and incubated for 10 minutes in the dark at room temperature. The absorption was measured at 562 nm. Distilled water was used as the control and EDTA was used as standard. The inhibition (%) was calculated as the equation below:

\[
\text{Inhibition} = \left( 1 - \frac{A_{\text{sample}} - A_{\text{control blank}}}{A_{\text{control blank}} - A_{\text{control blank}}} \right) \times 100
\]

where Asample is the sample absorbance or standard reagent at 0 mg/100 ml, Acontrol is the sample absorbance or standard reagent at different concentrations.

**ABTS** is the ABTS radical scavenging capacity of RBPH was evaluated described by [19]. Diluted sample with distill water 5 mg RBPH/ 1 ml of distill water. Pipette 20 μl of sample or standard solution (ascorbic acid) and mixed with ABRS solution 280 μL (7 mM of 2,2 Azino-bis (3-ethyl Benothiazoline-6-sulfonic acid, K₂SO₄ 140mM 179 μl kept dark at room temperature before used). The mixture was incubated in the dark at room temperature for 24 h. Then measured at 734 nm. The inhibition (%) was calculated below:

\[
\text{Inhibition} = \left( 1 - \frac{A_{\text{sample}} - A_{\text{control blank}}}{A_{\text{control blank}} - A_{\text{control blank}}} \right) \times 100
\]

where A0 is the sample absorbance or standard reagent at 0 mg/100 ml, A1 is the sample absorbance or standard reagent at different concentrations.

**FRAP:** The assay was performed according to method of [18] with slightly modification. An amount of 30 μl extracted samples were mixed with 270 μl FRAP reagent in test tubes and undergoes vortex. Blank samples were prepared for both methanol and deionized water extracted samples. Samples and blank sample were incubated in dark room for 4 minutes at 37°C and determined against blank at 593 nm. Series of stock solution at 0 mg/100 ml, 1.0 mg/100 ml, 2.0 mg/100 ml, 3.0 mg/100 ml, 4.0 mg/100 ml, and 5.0 mg/100 ml were prepared using aqueous solution of ascorbic acid as standard curve. The values obtained were expressed as mg ASC/ g/ gram dried sample.

**ABTS:** The ABTS radical scavenging capacity of RBPH was evaluated described by [19]. Diluted sample with distilled water 5 mg RBPH/ 1 ml of distilled water. Pipette sample 20 μl of standard solution (ascorbic acid) and mixed with ABRS solution 280 μL (7 mM of 2,2 Azino-bis (3-ethyl Benothiazoline-6-sulfonic acid, K₂SO₄ 140mM 179 μl kept dark at room temperature before used). The mixture was incubated in the dark at room temperature for 24 h. Then measured at 734 nm. The inhibition (%) was calculated below:

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\text{Inhibition} = \left( 1 - \frac{A_{\text{sample}} - A_{\text{control blank}}}{A_{\text{control blank}} - A_{\text{control blank}}} \right) \times 100
\]

where A0 is the sample absorbance or standard reagent at 0 mg/100 ml, A1 is the sample absorbance or standard reagent at different concentrations.
**Foaming:** Foaming capacity was measured by the method as in [21]. RBPH 2.0% w/w was dispersed in deionized water then adjusted pH to 7. The 20 ml of solution was homogenized in a mechanical homogenizer (ULTRA-TURRAX® T25 basic, IKA® WERKE, Germany) at 13,500 rpm for 3 minutes. The foaming capacity was calculated as follows:

Foaming capacity (%) = (Volume of foam after whipping/ Volume of foam before whipping) x 100

**Emulsifying properties:** The emulsifying properties of RBPH were determined as in [22]. Ratio between soybean oil: protein solution was 10:30 gram. The solution was mixed using homogenizer (ULTRA-TURRAX® T25 basic, IKA® WERKE, Germany) at 13,500 rpm for 1 minute. 50 ml of the emulsion was collected and mixed with 5 ml of 0.1% SDS solution using a vortex mixer. The absorbance at 0 (A0) and 10 (A10) was measured at 500 nm using a spectrophotometer (SP300, Optima, Japan). The EAI was calculated as;

EAI (m²/ g protein) = (2 x 2.203 x A0 x dilution factor)/(L x φ x C x 10,000)

where L = the path length of cuvette (cm), φ = oil volume fraction of emulsion, C = weight of protein/ unit volume (g/ml) of aqueous phase before emulsion formation

**Amino acid profiles:** RBPH was analyzed for the amino acid profile by using in house method based on AOAC Official Method 994.12.988.15 (2000) detected by GC-MS.

**D. Preparation of Oil in Water Emulsion and Measurement**

Aqueous phases were prepared by dispersing RBPH 3.5% wt/wt of KDM105 and PNP in aqueous buffer solutions (10.0 mM sodium citrate) followed by stirring at room temperature overnight to ensure complete dispersion and hydration. Rice bran oil-in-water emulsions were prepared by homogenizing 5.0 wt% oil phase with 95.0 wt% aqueous phase at ambient temperature. An emulsion pre-mix was prepared using a high-speed blender (2 minutes, BioSpec Products Inc., Bartlesville, USA), which was then passed through a high pressure homogenizer (Model 101, Microfluidics, Newton, Massachusetts, USA) three times at 9,320 psi.

The stability of the emulsion to pH, ionic strength and temperature was tested. 5% wt oil-in-water emulsions were prepared using RBPH. Stability to pH: Emulsion samples were prepared in aqueous buffer solutions and then the pH was adjusted to pH 3 to pH 8 using NaOH and/or HCl solution, and then transferred into glass test tubes (160 x 15 mm). Stability to ionic strength: Emulsions (pH 7) were diluted with different amounts of NaCl and buffer solution to form a series of samples with same droplet concentration but different salt concentrations (0-500 mM NaCl). The emulsions were stirred for 30 minutes and transferred into glass test tubes (160 x 15 mm). Stability to heating: Emulsions (pH 7) were prepared and then 10 ml sample were transferred into glass test tubes, which were stored in a water bath for 30 minutes at fixed temperature ranging from 30°C to 90°C. The samples were stored at ambient temperature overnight prior to analysis.

**Particle size and charge measurement:** The particle size distribution (PSD) of the emulsions was measured using a laser light scattering instrument (MalvernSizer2000, Malvern Instruments Ltd., Worcestershire, UK). ζ-potential: The electrical charge (ζ-potential) of lipid droplets in the emulsions was determined using a particle electrophoresis instrument (ZEN3600, Nano-series, Zetasizer, Malvern Instruments, Worcestershire, UK). The particle size and zeta-potential were observed during the course of the experiments.

**E. Statistical Analysis**

This research was conducted using 3 x 3 factorial in a completely randomized design (CRD). The study of the interaction between variables and the optimization extraction conditions for rice bran protein extracted measuring by the analysis of variance (ANOVA). All qualities were performed in triplicate and presented as mean±standard deviation. The differences between means were measured by independent t-test and DMRT by using SPSS statistic program version 18.0. The probability value of less than 0.05 was considered significant.

**III. RESULTS AND DISCUSSION**

**A. Optimization of Extraction Conditions**

Rice bran protein extracts from two cultivars had slightly yellowish powder. KDM105 RBPH had slightly light color and a unique aroma than PNP RBPH. The percentage of yield and protein from rice bran protein are presented in Table I. The treatments under low enzyme concentration, low temperature and time for extracted had lowest the percentage of yield, whereas increasing the concentration, temperature and time had more yield. The enzyme concentration, temperature and time were strong influence on extracted yield. These factors resulted in higher %DH. Reference [23] reported that when increased concentration of enzyme the primary amine in solution increased resulting in increased protein solubility due to the formation of small peptides.

Therefore, the optimal conditions for rice bran protein extraction were 0.075 g of enzyme concentration per 5 g of protein, 50°C of extraction temperature, and 4 h of extraction time.

**B. Physicochemical and Functional Properties of RBPH**

The physicochemical properties of two cultivars of RBPH were showed in Table II. The percentages of moisture content and water activity of RBPH were 11.16-11.58% and 0.27-0.29% for PNP and KDM105, respectively. Lightness and yellowness was 81.71-83.06% and 11.81-13.67%. For bulk density (g/ml) of RBPH was 0.43-0.45 g/ml. Under controlled extraction condition, degree of hydrolysis (%) was 19.92% to 21.05% for KDM105 and PNP, respectively, which contribute to the enzyme hydrolyzed peptide bonds in rice bran. Then the concentration of amine group was increased from the protein hydrolysates.
TABLE I
THE PERCENTAGE OF YIELD AND PROTEIN AT DIFFERENT EXTRACTION CONDITIONS OF RBPH

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Extraction conditions</th>
<th>% Yield (g/100 g. dry RBPH)</th>
<th>% Protein (g/100 g. dry RBPH)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enzyme (gram/5 gram of protein)</td>
<td>Temperature (Celsius)</td>
<td>Time (h)</td>
</tr>
<tr>
<td>1</td>
<td>0.025</td>
<td>40</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0.025</td>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>0.025</td>
<td>60</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>0.050</td>
<td>40</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>0.050</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>0.055</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>0.075</td>
<td>40</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>0.075</td>
<td>50</td>
<td>4</td>
</tr>
</tbody>
</table>

Means (±SD) with different superscript letters in the same column (a-f) indicate significant differences (P < 0.05).

TABLE II
PHYSICOCHEMICAL AND FUNCTIONAL PROPERTIES OF THE OBTAINED RBPH

<table>
<thead>
<tr>
<th>RBPH properties</th>
<th>PNP</th>
<th>KDM105</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physicochemical properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>11.16±0.83</td>
<td>11.58±0.56</td>
</tr>
<tr>
<td>Water activity</td>
<td>0.27±0.00 a</td>
<td>0.29±0.01 a</td>
</tr>
<tr>
<td>Color</td>
<td>81.71±1.02 b</td>
<td>83.06±0.58 a</td>
</tr>
<tr>
<td>L* (lightness)</td>
<td>0.95±0.64 b</td>
<td>0.72±0.28 a</td>
</tr>
<tr>
<td>a* (redness)</td>
<td>13.67±0.73 a</td>
<td>11.81±0.42 b</td>
</tr>
<tr>
<td>b* (yellowness)</td>
<td>4.3±0.03 b</td>
<td>4.45±0.01 a</td>
</tr>
<tr>
<td>Bulk density(g/mL)</td>
<td>21.05±0.84 a</td>
<td>19.92±0.53 b</td>
</tr>
<tr>
<td>Solubility (%)</td>
<td>27.28±1.34 a</td>
<td>27.60±0.56 b</td>
</tr>
<tr>
<td>pH 4</td>
<td>27.28±1.34 a</td>
<td>27.60±0.56 b</td>
</tr>
<tr>
<td>pH 5</td>
<td>30.19±2.36 b</td>
<td>41.00±2.16 a</td>
</tr>
<tr>
<td>pH 6</td>
<td>38.57±0.84 a</td>
<td>43.00±1.43 a</td>
</tr>
<tr>
<td><strong>Functional properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total phenolic content (mg Gallic/g sample)</td>
<td>6.77±0.07 b</td>
<td>7.48±0.08 a</td>
</tr>
<tr>
<td>FRAP(mg ASC/g sample)</td>
<td>0.78±0.006 a</td>
<td>0.86±0.005 b</td>
</tr>
<tr>
<td>FIC (mg EDTA/g sample)</td>
<td>0.02±0.003 b</td>
<td>0.04±0.007 a</td>
</tr>
<tr>
<td>ABTS(mg ASC/g sample)</td>
<td>1,605.03±62.25 b</td>
<td>2,495.26±287.10 a</td>
</tr>
<tr>
<td>Emulsifying properties</td>
<td>5.05±0.31 b</td>
<td>4.87±0.70 a</td>
</tr>
<tr>
<td>EAI (m²/g protein)</td>
<td>47.33±4.65 a</td>
<td>52.98±8.78 b</td>
</tr>
</tbody>
</table>

Means (±SD) with different superscript letters in the same row (a-b) indicate significant differences (P < 0.05). The superscript “ns” indicates no significant differences among the means in the same row.

There are several factors involved in protein extracted by enzymatic method such as enzymatic concentration and extraction time. Reference [23] reported that the increasing DH (%) was related to enzymatic concentration and time to decompose the substrate in the seed which increased the protein hydrolysates. Whereas, the different extraction methods as in [6] reported that lightness value (83.88) of rice bran protein extracted using microwave method was dark and more reddish than enzymatic method. Reference [24] reported that 0.3 g/mL of bulk density was found in microwave rice bran isolated.

The solubility (%) of KDM105 at pH 4-6 ranged from 27.60% to 43.00%. The solubility depends on the size of the protein peptide. In general, short chain peptides have higher solubility than long chain peptides protein, which is directly related to –COOH and –NH2 groups of amino acids of the protein. Therefore, the solubility of amino acids, peptides and proteins is strongly dependent upon their net charge due to the zwitterion form of amino acids [25], [26]. The result was consistent with previous reports that the pH and extraction time affected on the solubility of protein extracted from mung bean, when the extraction time at 60 minutes was highest solubility. However the solubility was decrease when adding to 90 minutes [27].

The functional properties of RBPH are presented in Table II. Total phenolic content (mg gallic/ g sample) in RBPH were 7.48 and 6.77 for KDM105 and PNP, antioxidant activity of the RBPH was evaluated using FRAP, FIC and ABTS radical scavenging activity and indicated that the antioxidant activity of KDM105 had higher than PNP. The result also showed that FRAP (mg ASC/g sample) were 0.86 and 0.78 for KDM105 and PNP, respectively. FIC (mg EDTA/g sample) were 0.04 and 0.02 for KDM105 and PNP, respectively. For ABTS (mg ascorbic acid/ g sample) were 2,495.26 and 1,605 for KDM105 and
PNP, respectively. FRAP is a measure of “ferric reducing antioxidant power”, which is the ability to convert Fe(III) to Fe(II). ABTS is a measure of “antioxidants” to scavenge free radical or donate electrons to quench the radical. ABTS method is carry out in aqueous systems. The high-pigmented and hydrophilic antioxidant was better reacted by ABTS method [19]. Reference [26] reported that the formation of short chain peptides may contribute to increasing antioxidant activity of the sample. Not only does the higher antioxidant activity of short chain peptides contribute to the ability to donate electrons to radicals, but it also contributes to the ability to chelate metal ions. It was well-known that metal ions can act as a pro-oxidant that accelerates lipid oxidation, which can be inhibited using metal chelators [27]. FIC assay has the ability to chelate transition metal ions, especially Fe^{2+} and Cu^{2+} in the system. These transition metal’s act as pro-oxidant that induce oxidative stress [20].

Emulsifying and foam properties of the rice bran protein were expressed in terms of the EAI and foam capacity (%). Results showed that EAI was 8.78±0.70%. There were several reports suggesting that emulsifying properties of proteins may be influenced by degree of hydrolysis, protein conformation, molecular weight or size, and net charge of proteins [28]. Peptides and protein with high emulsifying properties could be due to their ability to arrange their structures on the oil/ water interfacial region resulting in decreases in surface tensions between oil and water phases [27]-[30]. For foam capacity (%) of RBPH at 1-5 minutes was 80.19±6.30 to 35.96±3.26. Reference [31] reported that foam capacity of rapeseed proteins treated with Alcalase at 1 minute was 44%. However, foam capacity of the rice bran protein decreased over time. Furthermore, It was suggested that stability of air/ liquid foam structures was strongly influenced by several factors such as ability to form thick layers between air and liquid interfaces, ability to reduce surface tension, and the viscosity of the liquid solution at the air/ liquid interfaces [32], [33].

C. Amino Acid Profile of RBPH

The amino acid composition of KDM105 RBPH is shown in Fig. 1. Glutamine was the highest amino acid content (1.74±0.62 g/100 g) followed with aspartic acid (0.80±0.12 g/100 g), valine (0.80±0.05 g/100 g), alanine (0.77±0.08 g/100 g) and Leucine (0.53±0.03 g/100 g), respectively. Some essential amino acid existed in a large amount (glutamine, aspartic, valine, alanine), whereas the remaining was ranges in the level lower than 0.1 g/100 g. of RBPH (hydroxyproline, hydroxylamine and cystine). Total amino acid content of KDM105 was higher than PNP 1.63 fold, which was 7.41±0.43 g/100 g in KDM105 whereas it was 4.55 ±0.67g/100 g in PNP. Reference [34] reported the content of lysine and histamine in rice bran protein was 5.4 g/g and 3.3 g/g, respectively.

D. Stability of O/W Emulsion Stabilized by RBPH

All RBPH emulsifiers were capable of forming emulsions containing small droplets, with droplets being <1000 nm. The mean particle diameters depended on pH (Fig. 2 (a)). Under pH 3 to pH 7 had mean particle lower than pH 8.

The electrical characteristics of the emulsion are important because they determine the droplets stability to aggregation, as well as their interactions with other charged group. The $\zeta$-potential of the droplets depend on pH: lowest -0.5 mV at pH 4 and highest -4.7 at pH 7 for KDM105 (Fig. 2 (b)).The $\zeta$-potential of the oil droplets coated by RBPH were a negative at all pH values.

The influence of ionic strength (100-500 mM NaCl) on the stability of emulsions: In the presence of salt, the mean droplet diameter of emulsion was 224-254 nm. Furthermore, the results showed slightly increase in droplet at higher salt concentration. For $\zeta$-potential, there was a decrease in the negative charge with increasing salt concentration (Figs. 3 (a) and (b)).

![Fig. 1 Amino acid profile of RBPH using GC-MS](image-url)
Fig. 2 pH dependence of the (a) mean droplet diameter and (b) particle electrical charge ($\zeta$-potential) of diluted 5% O/W emulsions stabilized by RBPH.

Fig. 3 Ionic strength dependence of the (a) mean droplet diameter and (b) particle electrical charge ($\zeta$-potential) of diluted 5% O/W emulsions stabilized by RBPH.

Fig. 4 Heat treatment dependence of the (a) mean droplet diameter and (b) particle electrical charge ($\zeta$-potential) of diluted 5% O/W emulsions stabilized by RBPH.

The influence of thermal process on emulsions stability (30-90°C for 30 minutes): The mean droplet diameter of emulsion was increase when the thermal increased. The mean droplet showed higher than 1000 nm after heat above about 70°C. The electrical characteristics of all emulsions was the negative charge (-3 mV to -5 mV) (Figs. 4 (a) and (b)).
IV. CONCLUSION

The findings of this study showed that the extraction conditions affected the physicochemical and functional properties of hydrolyzed protein, which occurred from protein fractions and differed among rice varieties. Moreover, the investigation of the stability of RBPH in O/W emulsion under different environmental stress during processing showed that RBPH was able to produce the small droplet of O/W emulsion. The emulsions were stable to a wide range of environment stresses: pH below 7, all salt concentration and thermal below 60 °C. These results have important implications for the development of commercial RBPH as a food ingredient and apply to food products.

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Influence of Cryo-Grinding on Antioxidant Activity and Amount of Free Phenolic Acids, Rutin and Tyrosol in Whole Grain Buckwheat and Pumpkin Seed Cake

B. Voučko, M. Benković, N. Ćukelj, S. Drakula, D. Novotni, S. Balbino, D. Ćurić

Abstract—Oxidative stress is considered one of the causes leading to metabolic disorders in humans. Therefore, the ability of antioxidants to inhibit free radical production is their primary role in the human organism. Antioxidants originating from cereals, especially flavonoids and polyphenols, are mostly bound and indigestible. Micronization damages the cell wall which consecutively results in bioactive material to be more accessible in vivo. In order to ensure complete fragmentation, micronization is often combined with high temperatures (e.g. for bran 200 °C) which can lead to degradation of bioactive compounds. The innovative non-thermal technology of cryo-milling is an ultra-fine micronization method that uses liquid nitrogen (LN2) at a temperature of 195 °C to freeze and cool the sample during milling. Freezing at such low temperatures causes the material to become brittle which ensures the generation of fine particles while preserving the bioactive content of the material. The aim of this research was to determine if production of ultra-fine material with cryo-milling will result in the augmentation of available bioactive compounds of buckwheat and pumpkin seed cake.

For that reason, buckwheat and pumpkin seed cake were ground in a ball mill (CryoMill, Retch, Germany) with and without the use of LN2 for 8 minutes, in a 50 mL stainless steel jar containing one grinding ball (Ø 25 mm) at an oscillation frequency of 30 Hz. The cryo-milled samples were cooled with LN2 for 2 minutes prior to milling, followed by the first cycle of milling (4 minutes), intermediary cooling (2 minutes), and finally the second cycle of milling (further 4 minutes). A continuous process of milling was applied to the samples ground without freezing with LN2. Particle size distribution was determined using the Scirocco 2000 dry dispersion unit (Malvern Instruments, UK). Antioxidant activity was determined by 2,2-Diphenyl-1-picrylhydrazyl (DPPH) test and ferric reducing antioxidant power (FRAP) assay, while the total phenol content was determined using the Folin Ciocalteu method, using the ultraviolet-visible spectrophotometer (Specord 50 Plus, Germany). The content of the free phenolic acids, rutin in buckwheat, tyrosol in pumpkin seed cake, was determined with an HPLC-PDA method (Agilent 1200 series, Germany). Cryo-milling resulted in 11 times smaller size of buckwheat particles, and 3 times smaller size of pumpkin seed particles than milling without the use of LN2, but also, a lower uniformity of the particle size distribution. Lack of freezing during milling of pumpkin seed cake caused a formation of agglomerates due to its high-fat content (21 %). Cryo-milling caused an augmentation of buckwheat flour antioxidant activity measured by DPPH test (23,9 %) and an increase in available rutin content (14,5 %). Also, it resulted in an augmentation of the total phenol content (36,9 %) and available tyrosol content (12,5 %) of pumpkin seed cake. Antioxidant activity measured with the FRAP test, as well as the content of phenolic acids remained unchanged independent of the milling process. The results of this study showed the potential of cryo-milling for complete raw material utilization in the food industry, as well as a tool for extraction of aimed bioactive components.

Keywords—Bioactive, ball-mill, buckwheat, cryo-milling, pumpkin seed cake.
Antibacterial Effects of Pure Metals on Clinically Important Bacteria Growing in Planktonic Cultures and Biofilms

Bassam Al Johny, Khalid Al Quthami

Abstract—Antibiotic resistance in pathogenic bacteria is emerging as an issue of serious concern in bio-medical research as well as food and health organizations. Metal complexes are currently being employed in medical devices for their inhibition to bacterial adherence and antibacterial activities. The primary aim of this study was to evaluate the antibacterial activities of pure metals, including selenium, germanium and lithium on planktonic cultures and biofilms of three bacterial species: *S. aureus* SH1000, *P. aeruginosa* PA01 and *E. coli*, O157:H7. The antagonistic effects of selenium, germanium and lithium on these three bacterial species were examined using zone of inhibition assay. The minimum inhibitory concentrations and minimum bactericidal concentrations of antibiotics (rifampicin, mupirocin and ciprofloxacin) and metals (selenium, germanium and lithium) were measured. The minimum biofilm eradication concentrations (MBEC) of metals were determined against biofilms composed of *S. aureus* SH1000 and *P. aeruginosa* PA01. Metal susceptibility tests suggested that biofilms displayed increased resistance over their planktonic state. Differential inhibitory effects were observed for different strains of planktonic and biofilm bacteria in response to different metals and their varying concentrations. Amongst the three metals tested, selenium proved to be the most active against all three species, whereas lithium demonstrated the least inhibitory effects. Scanning electron microscope (SEM) image analysis revealed several detrimental structural changes in bacterial cells exposed to metals compared to those grown in the metal-free culture. In conclusion, the results demonstrate the antibacterial efficacy of pure metals against planktonic and biofilm bacteria paving the way for further similar investigations in search of alternative antibacterial agents.

Keywords—Antibacterial, pure metals, bacteria, biofilms.

Bassam Al Johny, Biological Science Department, Faculty of Science, King Abdulaziz University, P, O, Box 80203, Jeddah 21589, Kingdom of Saudi Arabia (e-mail: boaljohny@kau.edu.sa).
Khalid Al Quthami, Regional Laboratory, MOH, Makkah, Saudi Arabia.
Abstract—The number of giraffe species has been in focus of interest since the exploration of sub-Saharan Africa by European naturalists during the 18th and 19th centuries, as previous taxonomists, like Geoffroy Saint-Hilaire, Richard Owen or William Edward de Winton, recognized two or three species of *Giraffa*. For the last decades, giraffes were commonly considered as a single species subdivided into nine subspecies.

In this study, we have re-examined available nuclear and mitochondrial data. Our genetic admixture analyses of seven introns support three species: *G. camelopardalis* (i.e., northern giraffes including reticulated giraffes), *G. giraffa* (southern giraffe) and *G. tippelskirchi* (Masai giraffe). However, the nuclear alignments show small variation and our phylogenetic analyses provide high support only for the monophyly of *G. camelopardalis*. Comparisons with the mitochondrial tree revealed a robust conflict for the position and monophyly of *G. giraffa* and *G. tippelskirchi*, which is explained firstly by a mitochondrial introgression from Masai giraffe to southeastern giraffe, and secondly, by gene flow mediated by male dispersal between southern populations (subspecies *angolensis* and *giraffa*). We conclude that current data gives only moderate support for three giraffe species and point out that additional nuclear data need to be studied to revise giraffe taxonomy.

Keywords—Autosomal markers, Giraffidae, mitochondrial introgression, taxonomy.
A Study on Real-Time Fluorescence-Photoacoustic Imaging System for Mouse Thrombosis Monitoring


* Division of Electronic Engineering Chonbuk National University, Jeonju-si, Jeonbuk, South Korea (e-mail: magelland608@naver.com)
** Advanced Biomedical Imaging Center, Chonbuk National University, Jeonju-si, Jeonbuk, South Korea

Abstract—A near infrared light source used as a light source in the fluorescence imaging system is suitable for use in real-time during the operation since it has no interference to surgical vision. However, fluorescence images do not have depth information. In this paper, we configured the device with the research on molecular imaging systems for monitoring thrombus imaging using fluorescence and photoacoustic. Fluorescence imaging was performed using a phantom experiment in order to search the exact location, and Photoacoustic image was in order to detect the depth. Fluorescence image obtained when evaluated through current phantom experiments, when the concentration of the contrast agent is 25μg / ml, it was confirmed that it looked sharper. Phantom experiment is has shown the possibility with the fluorescence image and photoacoustic image using an indocyanine green contrast agent. For early diagnosis of cardiovascular diseases, more active research with the fusion of different molecular imaging devices is required.

Keywords—Fluorescence; Photoacoustic; indocyanine green; Carotid Artery.

I. INTRODUCTION

Deep vein thrombosis and pulmonary embolism is a disease that has a relatively high mortality rate, it has been a rare disease in Korea, the frequency of this disease is rapidly increasing recently. Although deep vein thrombosis and pulmonary embolism there is a debate whether or not the same disease but currently, it is regarded as of the same category of disease. Pulmonary embolism, if that is not properly treated, also it can be a dangerous disease which may die soon[1]. As fat accumulated in the cardiovascular ruptures, it causes thrombus which is main cause of blood vessels clogging and it is one of the cardiovascular diseases. These cardiovascular diseases will be easier to treat if they are diagnosed early.

Currently, we use the MRI / CT used for diagnosing blood clots, these devices has the disadvantage that it takes long time in an emergency situations. One of the techniques for improving this drawback is the fluorescence image[2, 3].

Fluorescence is a form of light emitted by the emission of light by a substance that absorbs light or electromagnetic waves. In most cases, the light is low energy of the light is emitted than the energy of light or an electromagnetic wave that has absorbed. Fluorescence imaging system acquires an image with CCD or CMOS camera light. The obtained image allows the output image to monitor in real time. It is has advantages when monitor blood clots in an emergency situation, because it provides real time output video. Also, near infrared light source used as a light source in the fluorescence imaging system is suitable for real-time operation since they do not interfere with the surgical field. [4, 5].

II. MULTI-MODALITY IMAGING SYSTEM

A. Fluorescence system

The proposed fluorescence detection contains optical system a light source which emits light at an appropriate wavelength ranging mainly 785 nm, a zoom lens, an excitation filter and a photodetector built in the preamplifier in the optical path of the system. The excitation filter eliminates the unneeded light.

The laser diode (LD) is applied as the light source in this system due to its advantages. Recently, a single wavelength LED and laser diode are preferred for the light source. In the experiment, 785nm light source was used for Infrared fluorescence image. It shows a good accordance with the characteristics of indocyanine green. Indocyanine green emits 820nm fluorescence when they absorb the energy of 780nm light source. LD can be integrated into our portable fluorescence detection system as it is only a few millimeters in diameter as well as in length so that it may be easily installed.

The prototype of the system is shown in Figure 1. This system employs laser diode, which has a peak emission wavelength of 785 nm. Then the fluorescence light about 820 nm wavelength from the sample is collimated by the zoom lens, and is detected by a photodiode after being filtered by an excitation filter.

![Figure 1. Proposed fluorescence system](image)

B. Photoacoustic system

The system encapsulates the Nd:YAG pulsed laser (NT352-A20-AW; EKSPLA) which could operate at a wavelength ranging from 530nm to 2300nm. In order to deliver the maximum light to the specific region of the subject a fiber optic line of lights was used. A custom developed trigger controller which is dedicated specifically.
to laser emission and to generate timing signal for data acquisition (DAQ) block. The DAQ which is PCI extensions for instrumentation (PXI) platform based with 50 MHz sampling frequency, 64 analog input channel, 12 bit resolution and 192 Mb/sec transmission speed. The data are transmitted to the PC using the direct memory access (DMA) technique. All the control program and graphical user interface are developed in the LabView environment. To collect the ultrasound signal a linear array transducer (L14-5/28; Ultrasonix) is placed towards the sample stage, the transducer has 128 element with 5 MHz center frequency were used to measure the PA signal. A pre-amplifier is placed in between DAQ and transducer with 5 MHz passband, 128 channels and 40dB gain to detect the incoming signal. The overall system architecture is shown in Fig. 1. The image reconstruction takes place in the PXI platform with two synchronized control program. One program to collect the PA signal and other for reconstruction. The custom trigger board is used to synchronization of two control programs. The FPGA program which runs on the FPGA unit detects the transmitted signal and the host program operates in the host computer. A flag bit is used to determine the state of the control program. True indicates the FPGA program and false determines the host program. Once the trigger signal is sent a 2500 data sets of PA signals from the transducer are sampled and stored in DMA buffer. An application specific graphical user interface is developed in LabView environment to communicate with both FPGA and host program and to display raw data and reconstructed image is showed in the same window.

Fig. 2. Architecture of custom developed photoacoustic tomography system

The image reconstruction uses the properties of inverse PA equation property and time domain property. To be specific the universal back projection algorithm [6] which is a traditional PA reconstruction algorithm is used in this system for PA image reconstruction. The fluorescence received by camera delivered to computer via the GigE, and Labview™ (National Instruments, USA). After this process, it creates a GUI system and the monitor provides real time image. Fluorescence imaging device system is capable of controlling the frame rate, gain for a clear fluorescence image.

III. EXPERIMENT

A. Concentrations experiment

It was performed to create a phantom experiment in order to obtain a fluorescent image. Phantom gelatin (Protein: 84 ~ 90%, Water: 8 ~ 10%) to the horizontal, vertical and a height of 73 * 50 * 21mm was prepared in a six-sided shape. An outer diameter of 0.7mm to 10mm below the surface, it was inserted into the transparent polymer tube having an inner diameter of 0.5mm. Phantom was prepared by inserting a tube into a gelatin. Figure 3 is made of gelatin phantom using a different concentration of indocyanine green.

Figure 3. Gelatin phantom image.

Fluorescence imaging experiments were tested by using a contrast agent consisting of various concentrations. Fluorescence imaging experiments were conducted to specify concentration of contrast agent. The intensity of the fluorescent light according to the concentration of the contrast medium was performed prior to experiment to find the optimal density for the experiment because of the different contrast agents. Levels were experiments produced a sample at a concentration of 2500, 250, 25, 2.5, 0.25μg / ml.

Fluorescence images experiments were experiments using the knitting of the contrast agent for each concentration. Fluorescence imaging experiments were conducted to specify concentration of contrast agent. The intensity of the fluorescent light according to the concentration of the contrast medium was performed prior to experiment to find the optimal density for the experiment because of the different contrast agents. Concentration of 2500, 250, 25, 2.5, 0.25μg / ml were tested to produce a sample with the concentration.

Figure 4. Phantom fluorescence imaging

A concentration of 25μg / ml in the experiment, as shown in Figure 4 can be seen that the fluorescent image is clearly visible. When using the phantom same as Figure 3 (a), we can obtain a fluorescent image as Figure 4.
**B. Multi-modality experiment**

It was performed to create a phantom experiment in order to obtain a multi-modality imaging. Phantom gelatin to the horizontal, vertical and a height of 73 * 50 * 21mm was prepared in a six-sided shape. An outer diameter of 0.7mm to 10mm below the surface, it was inserted into the transparent polymer tube having an inner diameter of 0.5mm. Phantom was prepared by inserting a tube into a gelatin. Figure 6 is made of gelatin phantom of 25mg/ml indocyanine green.

![Figure 5. Gelatin phantom of 25mg/ml indocyanine green](image)

Figure 5. Gelatin phantom of 25mg/ml indocyanine green

Figure 6 is an image obtained using the phantom of Figure 5. Figure 6 (a) shows the image overlaid with the photoacoustic image in the ultrasound image, and Figure 6 (b) shows the overlaid photoacoustic image in the fluorescence image. The two images in Figure 6 show that fluorescence can acquire photoacoustic images at the same location as an ultrasound device.

![Figure 6. (a)Ultrasound image and Photoacoustic imaging, (b)Fluorescence image and Photoacoustic image](image)

Figure 6. (a)Ultrasound image and Photoacoustic imaging, (b)Fluorescence image and Photoacoustic image

**C. Animal experiment**

Using a near-infrared fluorescent substance that emits light in the wavelength band of 820nm, experiment was conducted to verify whether fluorescence material was obtained or not when injection was given in a blood vessel. Experimental animals were 8 parking male mouse we used anesthetic solution by mixing the zoletil and saline, rompun by a rate of 1:9:2.5.

![Figure 7. 24 hr Post Imaging after denudation and restriction of the Carotid Artery](image)

Figure 7. 24 hr Post Imaging after denudation and restriction of the Carotid Artery

Restriction of the Carotid Artery model was use when modeling a thrombosis. Restriction of the Carotid Artery model experiment, as shown in Figure 7, an experiment was performed to obtain a fluorescent image by incising the Carotid Artery near the skin and muscle. When obtaining a fluorescence image, the contrast medium of Fig. 8 was injected. Fluorescent images were obtained as shown in figure 7.

![Figure 8. CREKA-PVAX-Tirofiban Micelle](image)

**IV. CONCLUSIONS**

In this study, both fluorescence and photo acoustic tomography imaging were used to supplement depth information which is disadvantage of fluorescence imaging system. Phantom experiment using contrast agent showed that photo acoustic and fluorescence imaging can be used simultaneously. Using photo acoustic and fluorescence imaging together, disadvantage of fluorescence imaging can be supplemented. For early diagnosis of cardiovascular diseases, more active research with the fusion of different molecular imaging devices is required.

**ACKNOWLEDGMENT**

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Detecting the Blood of Femoral and Carotid Artery of Swine Using \textit{in vivo} Photoacoustic Tomography


\textbf{Abstract}—Photoacoustic imaging is the imaging technology that combines the optical imaging with ultrasound. It also provides the high contrast and resolution due to optical and ultrasound imaging, respectively. For these reasons, many studies make experiment in order to apply this method for many diagnoses. We developed the real-time photoacoustic tomography (PAT) system using linear-ultrasound transducer. In this study, we conduct the experiment using swine and detect the blood of carotid artery and femoral artery. We measured the blood of femoral and carotid artery of swine and reconstructed the image using 950 nm due to the HbO$_2$ absorption coefficient. The photoacoustic image is overlaid with ultrasound image in order to match the position. In blood of artery, major composition of blood is HbO$_2$. In this result, we can measure the blood of artery.

\textbf{Keywords}—Photoacoustic tomography, swine artery, carotid artery, femoral artery.

I. INTRODUCTION

PAT, referred to thermo-acoustic tomography or optoacoustic tomography, is hybrid imaging technique with non-invasive, nonionizing. It provides the high sensitivity, good spatial and temporal resolution and imaging depth [1]-[5].

PAT is used to detect the subcutaneous micro vessel, functional imaging of brain and early diagnosis of tumor. PAT also can monitor the oxygen saturation [6]-[8].

PA signal is generated by pulsed laser in the inside the sample. Photoacoustic effect occurs when the pulsed laser is irradiated to target, the temperature of object increases simultaneously and volume of the target is expanded in proportion to the increase of temperature. This sequence conducts in a very short time. Finally, ultrasound signal is generated, and the generated ultrasound signal depends on the shape and size of irradiated laser and has wide bandwidth [9].

Recently, researches are underway on real-time PAT techniques to acquire functional images of biological tissue in non-invasive targets. Real-time photoacoustic image devices are developed using an array transducer embedded with multiple ultrasound transducers. In order to overcome limit of transducers and visualize biological target in 3D, 2D array transducer-based imaging acquisition system was announced [10], [11].

To confirm the reaction due to photoacoustic effect using PAI method \textit{in vivo}, real-time PAT systems have recently been studied in many research groups. In other studies, ultrasound linear array probes that have numerous ultrasound are used as real-time PAT systems, but only for experiments with small animals [12]-[14].

In this study, we measure the femoral and carotid artery. The swine is anaeasthetized and placed on the surgical bed. We incise the left femoral regions and respiratory tract in order to expose the femoral and carotid artery. We use the 950-nm wavelength, which is the best absorption coefficient in NIR region.

II. MATERIAL AND METHODS

A. PAT System

Real-time Photoacoustic system measures PA signals with linear-array ultrasound transducer. Also, pulsed laser, signal acquisition and reconstruction of imaging must be conducted successively. In order to meet these conditions, PXI platform based DAQ board was used. The PXI platform is equipped with 128 analog input, 50 MHz sampling frequency and 12-bit resolution. Also, it can communicate to PC with the 192 Mb/s through direct memory access (DMA).

We used the laser trigger to synchronize between light emission and acquisition of data. We also used a linear array probe (L14-5/38, Ultrasonix) to detect the ultrasound signal with 128 elements, which has central frequency of 7.5 MHz.

In order to amplify signal and reduce the noise, we made the customized pre-amplifier with 128 channel, 40 dB gain, and 7.5 MHz center frequency, and pre-amplifier was placed in the front side of DAQ board. Acquired image has 488 × 400 pixels with resolution of 0.08 mm × 0.08 mm for each pixel.

Fig. 1 is the schematic of real-time PAT system.

B. Anesthesia

Before anesthesia, we conduct the intramuscular injection with Atropine (Jeil pharmaceutical, Korea) 0.05 mg/kg, antibiotic Baytril (Bayer, Germany) 5 mg/kg, Tramadol (Hanallbiopharma, Korea) 5 mg/kg. We used the anesthetic with Alfaxan(Jurox, Australia) 0.2 mg/kg and Rompun (Bayer, Germany) 0.05 mg/kg for induction. Under the experiment, we used the anesthetic machine (Primus, Drager, Germany) in order to keep the anesthesia condition.
C. Back-Projection Algorithm

We used the universal back-projection algorithm in order to reconstruct the image. Universal back-projection algorithm is the most used methods of PA images [9]. This skill reconstructs the PA image in time domain. It produces the exact inverse equations in each geometry. Equation (1) represents the Fourier domain universal back projection equation.

\[
P_0 = \int_{\Omega_0} \frac{d\Omega}{4\pi} \left[ 2p(\vec{r}_0 \cdot \vec{v}_s) - 2\vec{v}_s \cdot \frac{\partial p(\vec{r}_0 \cdot \vec{v}_s)}{\partial \vec{v}_s} \right] (1)
\]

where \(\vec{r}_0\) is the measurement point, \(\vec{v}_s\) is the speed of sound in the medium. The parameter \(t\) is given by,

\[
t = \left| \vec{r} - \frac{\vec{r}_0}{v_s} \right|
\]

The initial distribution of photoacoustic pressure is given by \(P_0\), and the measured photoacoustic pressure is given by \(p(\vec{r}_0 \cdot \vec{v}_s, t)\). When the sound of speed is constant, signals can be exactly reconstructed by back-projection algorithm. The critical point of inverse problem is that the initial distribution \(P_0\) should be calculated by the measured signal \(p(\vec{r}_0, \vec{v}_s, t)\) at \(\vec{r}_0\). This algorithm can be resulted in distortion when the signal is acoustically inhomogeneous.

III. EXPERIMENT

A. Experiment Setting

Before experiment, we sterilized the optical line light and ultrasound transducer in order to avoid the infection. The swine is placed on the surgical bed and anaesthetize.

We conducted three experiments. First, we detected the femoral artery without incision of swine skin; because, the femoral artery is placed near the skin. Second, we detected the carotid artery \textit{in vivo}. In order to expose the carotid artery, we incised the left side of respiratory tract. Third, we extracted the carotid artery after euthanasia and measured it \textit{ex vivo}.

Figs. 2 and 3 are the photographs of \textit{in vivo} and \textit{ex vivo} carotid artery experiment.

In Fig. 2, yellow rectangular box is the carotid artery, and the red line is the position of the ultrasound transducer. In Fig. 3, red line is also the position of the ultrasound transducer. In this photograph, we can show the artery has the blood in bottom side.

IV. RESULT

Before acquiring the PA data, we measured the US image in
order to position the target. We first measured the femoral artery and reconstructed the image.

Fig. 4 US+PA femoral artery image

**A. Photoacoustic Imaging of Femoral Artery**

We detected the femoral artery in swine. We use the 950-nm wavelength because, in NIR region 950-nm, wavelength is the best sensitive about HbO2. In artery, the blood is composed to HbO2 about 90~95%.

US image is the reference image, and PA image is overlaid on US image.

In Fig. 4, we can show the blood generated the signal. Because we select the wavelength in order to only detect the HbO2, there is no signal in vessel wall. We can also know that the femoral artery of swine is placed about 8 mm from skin. From this experiment, PAT can detect the femoral artery without any noises.

**B. Photoacoustic Imaging of Carotid Artery in vivo**

We measured the carotid artery in vivo in swine. Swine is under the anesthesia. The swine is incised in the left of respiratory tract. We fix the ultrasound transducer above the carotid artery, and we measured PA image of the carotid artery.

In Fig. 5, we can show the blood of carotid artery. Compared with femoral artery (Fig. 4), vessel wall of carotid artery is thicker. In this reason, vessel wall absorb the laser and it is reconstructed to image. But, blood also absorbs the laser and generate stronger US signal. In PAT, we can visualize the carotid artery in vivo and detect the HbO2 using 950 nm.

**C. Photoacoustic Imaging of Carotid Artery ex vivo**

After experiment about carotid artery, the swine was sacrificed using KCL after overdosage of anesthetic. We extracted the carotid artery for imaging (Fig. 3). In Fig. 3, the elasticity of carotid artery is low compared with in live condition. Fig. 6 is the US+PA carotid artery ex vivo image.

In Fig. 6, artery became wide compared with Fig. 5. It loses the elasticity because of death. In this image, we can show the blood in the vessel. We mentioned that the bottom side has the blood (Fig. 3). In Fig. 6, it is left side and it clearly visualized.

In this experiment, we knew that we can visualize the blood in the artery.

**V. CONCLUSION**

In this study, we developed the real-time PAT system. The system has 488 × 400 pixels with resolution of 0.08 mm × 0.08 mm for each pixel. We used the back-projection algorithm in order to reconstruct the image. Using this system, we detected blood in femoral and carotid artery. We used the swine model, and swine was anesthetized during experiment. First, we conducted the femoral artery experiment. We did not incise the skin of swine in order to expose the artery, and ultrasound transducer is placed on the skin and detects the femoral artery. In this experiment, about 10 mm under the skin, PAT can detect the biological tissue or chromophore. In this case, the chromophore is blood. Second experiment is the carotid artery in vivo. The carotid artery is exposed due to incising the left of respiratory tract. The vessel wall is thick and it absorbs the laser and is reconstructed to image.
Finally, we conducted the carotid artery experiment ex vivo. In this case, the artery became wide due to death, and the blood is clearly visualized. For this experiment, the PAT can detect the blood in the artery both in vivo and ex vivo. PAT also can detect the chromophore without excision of skin in 10 mm under the skin.

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Abstract—The saltatory conduction is the way the action potential is transmitted along a myelinated axon. The potential diffuses along the myelinated compartments and is regenerated in the Ranvier nodes due to the ion channels allowing the flow across the membrane. For an efficient simulation of populations of neurons, it is important to use reduced order models both for myelinated compartments and for Ranvier nodes and to have control over their accuracy and inner parameters. The paper presents a reduced order model of this neural system which allows an efficient simulation method for the saltatory conduction in myelinated axons. This model is obtained by concatenating reduced order models of 1D myelinated compartments and nonlinear 0D models of Ranvier nodes. The models for the myelinated compartments are selected from a series of spatially distributed models developed and hierarchized according to their modeling errors. The extracted model described by a nonlinear PDE of hyperbolic type is able to reproduce the saltatory conduction with acceptable accuracy and takes into account the finite propagation speed of potential. Finally, this model is again reduced in order to make it suitable for the inclusion in large-scale neural circuits.

Keywords—Saltatory conduction, action potential, myelinated compartments, nonlinear, Ranvier nodes, reduced order models, POD.

I. INTRODUCTION

The myelinated axons have alternating sequencies of myelin covered compartments and Ranvier nodes (Fig. 1). The myelin sheath surrounding the axon made of glial cells works like an insulating layer, increasing the transmission speed of the action potential along the axon and reducing the energy loss across the membrane. However, the diffusion of potential in this section decreases its magnitude at the far end. If the axon were long enough, the signal at the end would not be strong enough to reach the threshold and to trigger an action potential in the next myelinated compartment. The Ranvier nodes are evenly spaced gaps in the myelin sheath, therefore uninsulated and highly rich in ion channels, allowing the exchange of ions required to regenerate the action potential.

This optimal design allows the axons to be no matter how long, provided that the myelinated compartments length is not greater than the maximum transmission length [1], so that the potential is eligible for regeneration when entering a Ranvier node. The transmission of action potential in myelinated axons is called saltatory conduction [2] (from the Latin word saltare, which means to hop), because the potential seems to jump from one Ranvier node to another. Since it has been experimentally observed, the phenomenon of saltatory conduction has been described [3], [4] and modeled in the literature on several occasions [5]-[7]. However, for the efficient simulation of impulse neural circuits, which are very complex circuits in the central and peripheral nervous system, reduced order models should be developed, able to accurately reproduce the saltatory conduction in low simulation times.

The purpose of this paper is to create a numerical model of myelinated axons, having a minimal order for a reasonable accuracy. The global model is obtained by concatenating reduced order models of myelinated compartments with nonlinear models of Ranvier nodes. A final reduction of the resulting nonlinear system is carried out.

The global reduced order model grasps both phenomena, the one occurring in the myelinated compartments (linear and spatially distributed) and the one in the Ranvier nodes (nonlinear, compact). Due to its low order the simulation times of the containing large-scale neural circuits are improved.

II. AXON MODELING

The standard approach currently used to simulate the saltatory conduction [3], [6], [7] is based on compartmental modeling. This approach, where the myelinated segments are compartmentalized and replaced with the simplest models, then linked with nonlinear 0D models of Ranvier nodes [8] is implemented in most neural simulators (GENESIS, NEURON) [9], [10].

The method proposed (Fig. 2) concatenates reduced models of myelinated compartments with 0D models of Ranvier nodes, with accuracy control.

A. Modeling of Myelinated Compartments

The myelinated compartments are replaced with a reduced model from a hierarchical series of models developed before [11]. This series contains 9 types of models, of three spatial geometry classes: 2.5D, 1D and 0D. In each class there are three categories of models: analytical, numerical and reduced...
The best model from this series proved to be the analytical 1D model reduced with the vector fitting (VF) technique [12]. Different lengths were considered for the myelinated compartment: \(0.25 \lambda_0\), \(2.5 \lambda_0\), with \(\lambda_0 = 0.215 \text{ mm}\) representing the characteristic length (the length constant of the line). Figure 3 shows the electric potential at the end of the compartment of length \(\lambda_0\) before and after reduction (order 3). The excitation potential \(e(t)\) is approximated with an expression of two exponentials \(e(t) = V_0 + V_m(e^{-t/\tau_1} - e^{-t/\tau_2})\), with \(V_0 = -80 \text{ mV}, V_m = 2800 \text{ mV}, \tau_1 = 1 \text{ ms}, \tau_2 = 0.9 \text{ ms}\). The potential decreases in amplitude as it diffuses along the insulated compartment.

VF is able to reproduce this variation with very small errors. Fig. 4 shows the relative errors of the reduced 1D analytical model (a multipolar Electric Circuit Element – ECE [13] with three terminals – one ground and the other voltage controlled – with admittances \(Y_{11}\) and \(Y_{12}\)) with VF, for different line lengths and different orders \(q\). Extremely small errors are obtained for orders ranging from 4 to 8; for larger lengths higher orders \(q\) are recommended, but for practical applications an order \(q = 3 \div 5\) provides acceptable accuracy.

The mathematical HH model consists of four nonlinear ODEs, in which one describes a linear capacitive effect, having as state quantity the membrane voltage \(V\), and the other three characterize the voltage-gated channels opening, by the state variables \(n, m\) and \(h\). They are dimensionless quantities between 0 and 1 that describe the potassium channel activation (\(n\)), sodium channel activation (\(m\)) and sodium channel inactivation (\(h\)).

### B. Modeling of the Ranvier Node

The simplified modeling of the Ranvier nodes membrane has had an intense scientific interest, so that there are several non-linear 0D models, of which the most commonly used are: FitzHugh-Nagumo (FHN) [5], Frankenhaeuser-Huxley (FH) [15], Izhikevich (Iz) [16]. These models can be regarded as low-order approximations of the highly nonlinear HodgkinHuxley (HH) model [17], and are preferred in theoretical studies, precisely because of their relative simplicity. However, these non-dimensional reduced models are not able to retain the physical and biological significance of the inner parameters. For this reason, the Ranvier nodes in this study are modeled with the HH model.

### III. Coupling

The coupling is carried out in a circuit simulator as shown in Fig. 5. We generate a chain of sections \(Nx\text{-}Lx\) and the model is completed with a nonlinear bloc. The electric potential at the output of every nonlinear node for a 13 sections (\(Nx\text{-}Lx\)) interconnection is shown in Fig. 6 describing the saltatory conduction obtained when the left end of the axon is excited with an impulse current of 20 nA, having a width of 5 ms.

### IV. Reduction of the Axon Model

The model reduction uses Proper Orthogonal Decomposition (POD), a data-oriented reduction method.
Consider the nonlinear system described by:

\[ \dot{x} = f(x(t), u(t)), \]

and \( X = [x(t_1), x(t_2), \ldots, x(t_N)] \in \mathbb{R}^{M \times N} \) \( (1) \)

a collection of solution samples \( x \in \mathbb{R}^M \) (the state variables at different moments in time \( t_j, j = 1, \ldots, N \)). The samples matrix is decomposed in singular values (SVD):

\[ X = U \Sigma V^* \]

where the matrices \( U, U^* = I_M \) and \( V, V^* = I_N \) are orthogonal, their columns being the left and right singular vectors of \( X \) and \( \Sigma \) is a diagonal matrix of the singular values of \( X \).

The singular values give information on the linearly independent character of matrix \( X \), thus implicitly on the rank of the matrix. If \( \sigma_r > 0 \) and \( \sigma_{r+1} = 0 \), then the rank of matrix \( X \) is \( r \). The SVD factorization expresses \( X \) as a sum of dyadic products \( X = \sigma_1 u_1 v_1^* + \sigma_2 u_2 v_2^* + \ldots + \sigma_r u_r v_r^* \).

The decomposition is then truncated by keeping only the first \( k \leq r \) most important singular values. SVD allows the identification and elimination of the “almost singular” part of the matrix, that is the lines that are almost linearly dependent. The low-rank approximation matrix \( \tilde{X} = U_k \Sigma_k V_k^* \) has the same size as \( X \) and the rank \( k \).

The deviation norm between the initial matrix and the truncated matrix satisfies the inequality:

\[ \sigma_{k+1}(X) < \| X - \tilde{X} \|_2 < \sigma_k(X) \]

(3)

In this way a subspace is identified from the state space where the solution’s time dependency path is located. The other directions of the state space are basically linear combinations of elements in the selected subspace, so they can be approximated with directions from this space.

In our case the matrix \( X \) contains samples for every state variable \( (V, n, m, h) \) from the initial model at different time moments, resulting in a dimension of \( 56 \times 556 \) and rank 56. The full model is reduced to models of orders 1 to 10; the responses are shown in Fig. 7 for a simulation time of 30 ms. The relative error (Fig. 8) is computed as follows:

\[ \varepsilon_{rel} = \frac{\varepsilon_{abs}}{\max(F_e)} = \frac{1}{\max(F_e)} \sqrt{\frac{\sum_k |F_{ek} - F_{ak}|^2}{N}}, \]

(4)

where \( F_e \) and \( F_a \) represent the responses before (exact) and after (approximated) truncation, respectively. The error drops
The exact same results are obtained for all reduction orders for a matrix containing only the electric potential under 30 seconds. The time responses are shown in Fig. 9.

A real axon can however reach a length of 1 meter and the myelinated compartments have around 2 mm [18]-[20]. Neglecting the length of the nonlinear node leads to axons with up to 500 Nx-Lx sections. The reduction details for models with 100 and 500 Nx-Lx sections are given in Table I. The simulation of 320 ms for the model with 500 sections took 15 minutes on a two-core 3GHz, 2GB of RAM, whereas the reduction of this global model to a model of order 70 needed under 30 seconds. The time responses are shown in Fig. 9. Errors smaller than 10% are obtained from order 10 for the 100 sections chain and from order 63 for the 500 sections chain. The results improve if the period simulated, from which the samples matrix is extracted, is larger.

V. CONCLUSION

The main function of an axon is the transmission of information. The saltatory conduction is a proof for the optimality of the myelinated fiber. In order to efficiently simulate complex circuits, it is important to find the equilibrium between the complexity and the accuracy of the comprised models. The extracted model is able to reproduce the saltatory conduction with controlled accuracy. The myelinated compartments are selected from the series based on the imposed modeling error and the Ranvier nodes are modeled with HH zero-dimensional nonlinear model. The hierarchy of myelinated compartments ordered by their modeling error allows the control of accuracy, which is closely related to the models complexity. The 0D nonlinear models are able to regenerate the signal, so that the resulting reduced model gives control on the inner model parameters (geometrical data, material constants, excitation type and value, 0D system parameters). This model is a basis for more complex simulations, of the electric potential measured in the extracellular 3D space of axons and neural circuits.

ACKNOWLEDGMENT

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Unstructured-Data Contents Search Based on Optimized EEG Signal Processing and Multi-Objective Feature Extraction

Qais M. Yousef\textsuperscript{a}, Yasmeen A. Alshaer\textsuperscript{b}

\textsuperscript{a,b}Engineering and Neuroscience Department, ATIT Academy, Amman, Jordan.
\textsuperscript{a}q.yousef@atitgroup.com, \textsuperscript{b}y.alshaer@atitgroup.com

\textbf{Abstract}—Over the last few years, the amount of data available on the globe has been increased rapidly. This came up with the emergence of recent concepts, such as the big data and the Internet of Things, which have furnished a suitable solution for the availability of data all over the world. However, managing this massive amount of data remains a challenge due to their large verity of types and distribution. Therefore, locating the required file particularly from the first trial turned to be a not easy task, due to the large similarities of names for different files distributed on the web. Consequently, the accuracy and speed of search have been negatively affected. This work proposes a novel method using Electroencephalography signals to locate the files based on their contents. Introducing the new concept of natural mind waves processing, this work analyses the mind wave signals of different persons, analyzing them and extracting their most appropriate features using multi-objective metaheuristic algorithm, and then classifying them using the artificial neural network to distinguish among files with similar names. The aim of this work is to provide the ability to find the files based on their contents using human thoughts only. Implementing this approach and testing it on real people proved its ability to find the desired files accurately within noticeably shorter time and retrieve them as a first choice for the user.

\textbf{Keywords}—Artificial Intelligence, Data contents search, Human active memory, Mind wave, Multi-objective optimization.

I. INTRODUCTION

The emergence of the modern concepts of the Internet of Things (IoT), Cloud Computing and Big-data, increased the complexity of data searching processes. However, users who look for specific information may spend relatively longer time looking at useless alternatives or trying different keywords. While similar words point to different items may increase the average searching time [1]. To tackle this problem, this work proposes a novel solution using the user’s mindwave signal to reach the specific item directly and accurately.

Whilst several works attempted to use Electroencephalography (EEG) signal to comprehend human behavior amid the search process [2] [3], this work is the first to conduct the entire search process using human thoughts only. Focusing on the imagery items only for words that have different cases.

In this work, EEG dataset is obtained from a number of volunteers, using NeuroSky Mindwave Mobile+ sensor [4]. Then, the Multi-Objective Artificial Bee Colony (MOABC) algorithm [5] is utilized to define the optimal features to be processed. Hereafter, the dataset is clustered using Feedforward Artificial Neural Network (FFN) algorithm [6]. To validate the effectiveness of the proposed system, real experiments were conducted by a focus group, showing enhanced results in terms of accuracy and delay.

Being a part of the VisualThoughts project by ATIT to build a real Natural Mindwave Processing (NMP) system, this proposed work aims to constitute an initial paradigm for an entire NMP system connected to Natural Language Processing (NLP) systems, to provide a real-time visualization of human thoughts that may reflect on solving several problems in different aspects of human life.

The primary objectives of this work are to build an accurate EEG dataset for the predefined images, moreover, to define the most optimal features to be utilized in order to cluster this and other mindwave datasets. Aiming to provide an approach using mindwave signals only that is able to provide an accurate and fast data contents search. However, this work is limited to the EEG query identification, without concentrating on the database retrieval processes. On the other hand, this work contributes to the literature by being the first work that can interpret mindwave signals from the forehead region only and apply it to data science. Moreover, it is the first work that allows identifying the data contents search results using mindwave signals only, with a wearable and easy to use device. In addition to that, this work introduces the totally genuine NMP field for the first time, including the memory and thoughts visualization processes.

This work tries to answer the following key questions: Is it feasible to retrieve the data based on its contents using mindwave signals only? and how?

Besides this section, the second section illustrates preliminary background concepts. After that, the third section discusses the used methodology and design phases and parameters. The implementation process along with the results are discussed in the fourth section. With some enhancements briefed in the fifth section, finally, yet importantly, the sixth section summarizes the entire work and draws conclusions.

II. PRELIMINARIES

Understanding human’s way of thinking was a dilemma to psychologists and philosophers from the ancient time. For instance, Freud compared between the ego and the id as a relation between the rider and the horse [7] this comparison was a direct allusion to Plato’s description for the horse and rider, as the horse is the origin of the energy and the rider who determines the goal of movements [8]. However, modern science found that the two components (Emotional brain and rational brain) of human thinking and decision-making are dependent on each other. This was explained in Goleman’s writings mentioned in [9] [10], where he
explained the responsibility of emotions as the source that assists in making humans pay attention at the moment, where it is urgent. Moreover, provides an immediate action plan, without wasting time in double thinking, concluding that the emotional component evolved very early, and its response can take over the rest of the brain in a millisecond if threatened.

The emotional brain is particularly valuable at helping humans settle on hard choices. Its huge computational force, in addition to its capacity to process a huge amount of data in a parallel mechanism, guarantees that humans can investigate all the pertinent data while evaluating options at the same time. Big data are separated into sensible pieces, which are then interpreted into practical emotions. The reason these feelings are so shrewd is that they have figured out how to transform botches into instructive occasions. Humans are continually learning by experience, regardless of the possibility that they are not intentionally mindful of the advantages. It does not make a difference in the field of skill or experience, the brain dependably takes similarly, aggregating shrewdness through mistake [11].

The pivotal significance of human's feelings, due to the way that humans cannot settle on choices without them repudiates the ordinary perspective of human instinct, with its antiquated philosophical roots. For the majority of the twentieth century [12], the perfect of rationality was bolstered by logical portrayals of human life structures. The mind was imagined as comprising of four separate layers, stacked in ascending order of multifaceted nature. (The cortex resembled an archeological site: the more profound you burrowed the more remote back in time you voyaged).

Scientists clarified the life structures of the human mind as in [13] [14] [15]: At its base was the brainstem, which represented the most fundamental real capacities. It controlled pulse, breathing, and body temperature. Over that was the diencephalon, which managed hunger strings and rest cycles. At that point came the limbic region, which created human feelings. It was the wellspring of desire, viciousness, and discreet conduct. (Individuals imparted these three cerebrum layers to each other well-evolved creature). Finally, there was the sublime frontal cortex—the perfect work of art of advancement, which was in charge of reason, insight, and ethical quality.

The thinking parts of these components are the limbic region and the frontal cortex, which represents the emotional and rational brains, more details in [16] [17].

The EEG signals of those parts may be sensed using several kinds of sensors, so as to display the medical status of the mind as well as to examine its behavior. In this work, NeuroSky Mindwave mobile+ sensor is used, with the intention to sense the mindwave signals associated with the user’s thoughts.

This sensor [4], which is a wearable and easy to use gadget, looks like a headset, and able to measure numerous emotional and thinking states using one sensor only. This sensor, which is positioned at the user’s forehead whilst wearing the headset, outputs the attention status, Eyeblink, Meditation level, mindwave bands and other raw data, measured through its EEG sensor.

EEG signals represent the process of recording mindwave activities, by means of positioning sensors on the user’s head, these activities are commonly neurotransmitters associated with some processes inside the human’s mind. Those signals typically measured in Hertz (Hz) are labeled into bands, primarily based on their speed, can be grouped into slow, mild and fast mindwaves. Table I, clarifies those bands with their related waves [18].

This selected sensor can measure those waves from the forehead region. It reads the tiny voltage difference of each wave, amplifies it around 8000 times to improve any faint EEG signal, then filters it in the frequency domain and in the time domain with low and high pass filters to preserve the signals among 1Hz to 50 Hz. Then the maintained signals are sampled at 512Hz. and then, the signal is monitored within the frequency domain and the time domain in an effort to restore it against any artifact or noise. After that, it decodes the resulted signal right into a numerical value and sends it to the computer through Bluetooth.

<table>
<thead>
<tr>
<th>Band</th>
<th>Mindwave</th>
<th>Signal (Hz)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infra-low</td>
<td>Infra-low</td>
<td>&lt; 0.5</td>
<td>Slow Cortical Potentials.</td>
</tr>
<tr>
<td>Low</td>
<td>Delta</td>
<td>0.5-3</td>
<td>Produced in dreamless sleep and deep meditation. It is the source of empathy.</td>
</tr>
<tr>
<td>Moderate</td>
<td>Theta</td>
<td>3-8</td>
<td>The gateway to learning, intuition, imaginary, memory and information beyond conscious.</td>
</tr>
<tr>
<td>Moderate</td>
<td>Alpha</td>
<td>8-12</td>
<td>Define the present moment; learn alertness calmness, mind-body integration.</td>
</tr>
<tr>
<td>Fast</td>
<td>Beta</td>
<td>12-38</td>
<td>Decision-making, awareness, engagement in activity.</td>
</tr>
<tr>
<td>Fast</td>
<td>Gamma</td>
<td>38-42</td>
<td>Love, altruism</td>
</tr>
</tbody>
</table>

The above table shows the bands with their corresponding mindwaves and signals. As shown in the table, every mindwave sign has its own functionality and represents special task or occasionally represents the same task but from a different view.

After having sufficient background about the area under study and its components, the following section discusses the steps of the methodology followed for constructing the proposed design with a view to have the proposed solution implemented efficiently.

III. METHODOLOGY

A sample of the used sensor’s output is illustrated in Fig. 1 and Fig. 2, demonstrating the average values of the 15 features for 10 trials by one volunteer thinking of one image. Due to brain’s involvement in various tasks amid the trial, the attributes’ values vary rapidly. Consequently, defining the required attributes for the processing phase is an optimization problem. Thus, MOABC is adopted to define the optimal features; moreover, FFN is utilized to classify them with their corresponding images.

Fig. 3 illustrates the primary stages of the proposed approach, which is comprised of data collection using EEG
mindwave sensor, so as to be pre-processed to ensure its consistency. After that, the most optimal features are extracted using MOABC algorithm, and then the selected features are normalized in order to suit the FFN algorithm in the classification phase. The output of the classification phase is inversely normalized with a purpose to be used in building the database.

Fig. 1 Mind wave features (EEG Raw, Attention, Meditation, Blink Strength, Theta, Alpha-Low, Alpha-High)

Fig. 2 Mind wave features (EEG Raw Value Volts, Delta, Beta-Low, Beta-High, Gamma-Low, Gamma-High)

Fig. 3 Proposed Approach Phases

A. Data Collection
To collect the EEG samples, the focus group of 15 persons (7 males, and 8 females), between 18 and 55 years old, are taken to a dark room, where a data-show projecting 4 different photos for each word case titled with its name, to be stored in the volunteer’s unconscious mind. The dataset was collected by means of mounting the NeuroSky MindWave mobile+ sensor on the head of every individual person of the focus group. Then, they have been instructed to think about every case of each word for 60 seconds, to guarantee their attention. This was carried out three times a day (Morning, Afternoon, and night) for three non-consecutive days (Sunday, Tuesday, and Thursday). Moreover, the surrounding noise was not tuned, so random surrounding noise was taken from the real surrounding environment. This procedure was followed to generalize the samples, to provide random mental, physical, and external status by means of:

1- Including various mental status within the collected samples.
2- Including numerous physical status.
3- Including various external disturbances.
4- Including different ages.
5- Moreover, avoiding false readings or false thoughts from having an excessive influence on the results.

Although, this procedure continued until each volunteer completed thinking of all of the 10 predefined words, passing all of their cases. The selected words and their cases are stated in Table II; those words normally confuse the web search engines and do not generally appear on top of the search results due to the variety of their use in different aspects. Whilst, there have been several different images for each case used in this project, in an effort to pre-program the thoughts of the volunteers.

As shown in this table, a large ratio of the words nowadays refer to different elements; subsequently, when searching out each one of them in any search engine, the desired choice might not appear on top or even on the first results page most of the times, specifically when using short terms or notations. For instance, AUC stands for the Area under ROC Curve, and additionally for the American University in Cairo, and such a lot of other things. While looking for this term in its first meaning, it is too difficult to be able to locate it within the first 10 pages, even using Google, which is the most powerful search engine. All in all, in the extent of retrieving the required choice quickly, users are required to add more keywords to their search, which in most of the situations are not applicable. This issue has worsened at the emerged era of big-data and IoT.

Considering this difficulty, it is been observed that users who search for any information on the web or any database, usually think about the desired information and imagine it in their mind. As a result, while matching this imagination with the corresponding information on the database, the consequences can be retrieved quickly, accurately as a first choice.

<table>
<thead>
<tr>
<th>Number</th>
<th>Word</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Petra</td>
<td>Ancient Site, Factory, News Agency, University</td>
</tr>
<tr>
<td>2</td>
<td>Philadelphia</td>
<td>Ancient Site, city, Organization, University</td>
</tr>
<tr>
<td>3</td>
<td>Lincoln</td>
<td>Name, University, Car brand, City</td>
</tr>
<tr>
<td>4</td>
<td>Georgia</td>
<td>Country, US State, Name, Organization</td>
</tr>
<tr>
<td>5</td>
<td>Agora</td>
<td>Ancient city, Learning hub, Movie, Organization</td>
</tr>
<tr>
<td>6</td>
<td>Jordan</td>
<td>Country, River, Family, Athlete</td>
</tr>
</tbody>
</table>

TABLE II SELECTED WORDS AND THEIR MAIN CASES
In this proposed model, the sample of words with their different cases was selected as input and large samples of their corresponding images have been used as output for the search system.

B. Preprocessing and Features Extraction

After collecting the dataset, it was pre-processed by removing the null and NaN values, which occurred due to some data connection loss between the Bluetooth transmitter antenna of the sensor and the Bluetooth receiver antenna of the computer, though, within the entire collected dataset, there were only 7 rows containing null or NaN values, which indicates that the connection was mostly stable, yet, those rows have been eliminated entirely from the dataset.

After that, the data were tested for outliers, simply by plotting the rows of each accumulated samples in the time domain as well as the frequency domain, a good way to ensure that no outlier element is available in both domains, accordingly as the data transferred by the FFN algorithm, it is going to be consistent. nonetheless, no outliers had been detected in the collected dataset for both domains, which means that that the data collection technique was reliable and accurate.

After cleaning the data, they have been normalized using Equation (1) in order to map them from the current shape to a uniform shape, with a mean of 0 and a standard deviation of 1.

$$y = (x - \bar{x}) \times \left(\frac{\sigma_y}{\sigma_x}\right) + \bar{y}$$

While y is the resulted row of normalized data, x is the row of data with its original shape, $\sigma_x$ and $\bar{y}$ is the target standard deviation and mean of the data, respectively, after normalizing it, $\sigma_y$ and $\bar{x}$ is the current standard deviation and mean of the data, respectively.

This allows the training function of the FFN to converge to the optimal values of weights and bias quickly and smoothly, by minimizing the Mean Square Error (MSE) function. This process, not only provides fast convergence to the optimal values of weights and bias quickly and smoothly, by minimizing the Mean Square Error (MSE) function for the MOABC, as stated in Algorithms I and II, accordingly, in this problem has input and output dependent, and cannot be tackled separately, because the useful features representing the same information but from different channels. For that reason, the selected optimization algorithm should be able to output multiple dependent solutions accordingly; a multi-objective optimization algorithm is required. At the same time, there are different types of optimization algorithms that optimize multi-objective problems, with various behaviors in terms of speed and accuracy.

In this work, the trade-off process of selecting the most suitable algorithm considered the accuracy term only, as speed has lower priority, due to the fact that the features optimization process is required to be executed one time only, and will not return to it again. As a result, once identified, the same features will be used in the training, testing and at any time this proposed application is used.

Numerous multi-objective optimization algorithms were compared together using different multi-modal benchmark functions, following several criteria. Afterward, when calculating the mean results, MOABC algorithm was observed to be the most accurate one of them, minimizing the benchmark functions to zero in most of the instances and sometimes to values very near to zero.

Accordingly, in this work, the MOABC is adopted to select the optimal number and types of features. The processes of the MOABC algorithm, after its adaptation to suit the requirements of this identified problem, are illustrated in Algorithm I.

Moreover, the cost function of MOABC was built entirely using FFN algorithm, as illustrated in Algorithm II, such that the selected solutions by the MOABC particles are sent to the cost function. Where the FFN is trained on them and then MSE is calculated to compare the FFN output with the required target. After that, the value of the MSE is returned back to the MOABC to determine the next solution.

C. Classification

An initial step in the classification phase is to build a code table pointing to each image in the database, as the processing algorithm cannot process images in their original form. Accordingly, the codes used in this table are constituted of sequential integer decimal numbers from 1 to $N$, while $N$ is the number of used imaged for all the cases. Doing this, the inputs, which are the mindwave features and the target, which is the code table, become ready for the processing phase. And hence, this problem has input and target, a supervised algorithm is required to be used. Consequently, in this work, FFN is used to classify the features with their corresponding images.

However, as this proposed technique uses FFN as a cost function for the MOABC, as stated in Algorithms I and II, this design results in two objectives at the same time. Hence, after implementing the entire system and accomplishing the best value for the cost function, the system then provides an accurate identification for the most optimal features to be used, with their samples classified accurately to their corresponding images.

The used settings for MOABC and FFN are illustrated in
Table III. Using these settings, the proposed model identified three features only, to be the most optimal features, representing the thoughts of the users, which are Meditation, Alpha-high, and Theta, so as to be used henceforth to identify the user’s request accurately.

Algorithm I: MOABC Algorithm
1. Start;
2. Define Features Dimension;
3. Generate Features Randomly;
4. Evaluate Features by Cost Function;
5. While (Cost Function not Minimized){
   6. Select New Features;
   7. Evaluate Features by Cost Function;
   8. If (All Particles Distributed?) {
      9. Store Best Selected Features;
      10. Store Best Cost Values;
   } else{
      12. Distribute Particles to New Features;
   } 13. }
14. Update Best Features;
15. } 16. Optimal Features Defined;

Algorithm II: FFN Algorithm (Cost Function)
1. Start;
2. Build FFN;
3. Define Input and Target;
4. Define Random Weight and Bias Values;
5. While (Stopping Criteria not Met){
   6. Train FFN;
   7. Calculate MSE;
   8. Update Weight and Bias Values;
} 9. Store Weight and Bias Values;
10. Return MSE Best Value;

<table>
<thead>
<tr>
<th>TABLE III</th>
<th>MOABC AND FFN ALGORITHMS SETTINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified MOABC Settings</td>
<td>ANN Settings</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>Cost Function</td>
<td>ANN_Cost</td>
</tr>
<tr>
<td>Number of Variables</td>
<td>3</td>
</tr>
<tr>
<td>Minimum Variable</td>
<td>1</td>
</tr>
<tr>
<td>Maximum Variable</td>
<td>15</td>
</tr>
<tr>
<td>Maximum Iterations</td>
<td>250</td>
</tr>
<tr>
<td>Number of Population</td>
<td>300</td>
</tr>
<tr>
<td>Number of Onlookers</td>
<td>‘nPop’</td>
</tr>
</tbody>
</table>

After completing the clustering phase, the resulted output of the FFN is inversely normalized, in order to clarify its results. Finally, having defined the optimal features in addition to the optimal weights and bias values that minimized the MSE function, these values were saved in order to be used in the testing phase and in the application as a close box. The application system is illustrated in Fig. 4.

D. Building the Database

In this phase, the images were stored in the database server with their corresponding codes. Similarly, in large environments, the data, which is probably in different shapes and sizes, can be distributed in different servers on the cloud. Even though, the system will function in the same manner, as described in Fig. 4.

Initially, the user thinks about the data to look for, then the mindwave signals are transferred to the system, to take the Meditation, Alpha-high, and Theta features only. Then it preprocesses them and transfers them to the FFN engine, which identifies their corresponding code and sends it to the database to match the corresponding data (i.e. image) and retrieve it to the user.

IV. IMPLEMENTATION AND RESULTS

After implementing the proposed model, MOABC-FFN determined the optimal number of features. However, as shown in Fig. 5, using the optimal features (Meditation, Alpha-high, and Theta), the lowest mean cost function value of $4.13 \times 10^{-2}$ is reached. They are used in the proposed model over all the conducted tests.

The convergence curve of the MOABC for the three selected optimal features is outlined in Fig. 6. Nevertheless, the best cost value reached during the 250 iterations is right after the iteration 200. However, the cost function was not improved until it reached the maximum iteration.

On the other hand, the MSE values for the FFN algorithm, running on the three optimal features, is illustrated in Fig. 7. The FFN is converged just before the epoch 250, where it reached its minimum MSE value. However, this value remained stable until the epoch number 500. Which means that it is the best value that the FFN can obtain.

Subsequent to finding the optimal number and types of features using MOABC and training the FFN on them, several test cases are conducted in order to validate the developed model. This includes 100 new samples, taken randomly from 7 volunteers and other 7 new persons. The tests are conducted 50 times using different workstations, and the mean values are used to calculate the confusion matrix, considering the True Positive (TP) to be increased only as the required image appears as a first choice only, else, it will be considered a miss, and the True Negative
(TN) will be increased.

After that, the Receiver Operating Characteristic (ROC) curve is built, which is illustrated in the Fig. 8. However, the tests show optimistic results with accuracy ratio around 93%, which means that the objectives of the proposed system are met, and the required image appears as the first choice for 92.8% of the searching times, which is an excellent contribution with clearly large enhancements over the current systems. In other meaning, the use of mindwave signals interpretation is a completely beneficial technique to retrieve the user’s required information accurately and quickly as a first choice, especially in the era of IoT and big-data, which saves a lot of time and efforts for the users.

V. ENHANCEMENTS

This proposed approach is enhanced by adding other phases to the system, considering the features of IoT, big-data and distributed cloud environments. Hence, after collecting the mindwave meditation, theta and alpha-high signals associated only with the imagined information, and taking their corresponding output from the FFN engine. The outputs of a chain of consecutive thoughts are then interpreted using appropriate concepts utilized in NLP and Ontology fields. In order to construct an accurate set of mindwave triplets to turn them into a query understandable by the database engine. This query then is required to be processed accurately using an intelligent algorithm, such as FFN in order to be matched accurately with the optimal information stored in the database. Furthermore, database management algorithms such as MapReduce is required to be used along with the intelligent algorithm so as to identify the location of the information and then retrieve the most optimal answer related to the user’s thought. This technique, which is still under development, at the time of writing this paper, provides an easy, fast and accurate content search technique that constantly provide the user with the required information as a first choice.

VI. CONCLUSION AND CONTRIBUTIONS

This work tried to find a solution to reduce the delays in search results and enhance its accuracy using the user’s mindwave signals, to define the required search information exactly and directly as a first choice. Moreover, it proposed a novel method to extract the optimal number and types of features to be used in the classification process, as it is concluded from this work that the number and also the type of features affect the accuracy of the clustering algorithm.

A large number of various data were collected and various tests were conducted to validate the proposed system, which showed around 93% of accuracy. This finding contributes to the fields of big-data and the emerged fields of IoT, which contain a huge amount of data available on the private and public domains, and reflects positively in saving their users’ times and efforts. Consequently, as a part of the VisualThoughts project, it provided an enhanced easy-to-use system to allow a better understanding of human thoughts; moreover, it represents them into an image.

This may constitute an introduction to complete NMP
system and its applications in the fields of data contents search and queries, understanding brain vision, and rebuilding human memory. Some enhancements could be done on this proposed work, as it used 10 predefined words only, increasing the number of words is necessary to expand its domain. After that, this system can be integrated with techniques of NLP, Ontology and Symantec Web. Which will enhance the search and query for not only multimedia items, but also that goes further to the contents of these items in distributed systems on the cloud with big-data and IoT environments. Hence, this can be extended to provide a visual building for human active memory and thoughts in the shape of storytelling at a real time.

REFERENCES

Design and Implementation of a Wireless Heart Health Monitoring System for Stroke Risk Mitigation

Murtadha Kareem, Oliver Faust

Abstract—Atrial fibrillation (AF) is the most common sustained heartbeat disorder in adults. AF changes the blood flow dynamics and these changes can cause stroke. Even for stroke survivors, the quality of life is reduced through mental and physical disability. That impacts negatively upon care givers and loved ones. Stroke prevalence is predicted to increase. AF diagnosis and long term monitoring can help to establish and mitigate stroke risk. However, in the past it was difficult and in many cases very intrusive to monitor a patient’s heart beat. That difficulty came from the absence of wireless-health technology that covers wide geographical areas. Today, we are in a position to address the heart beat measurement problem with a wireless-heart rate monitoring system. The proposed system is based on internet of things technology and advanced artificial intelligence. The purpose of utilising wireless networks is to establish continuous long-term monitoring for an AF affected subject in a cost-effective way. The proposed system is based on commercial heart rate sensors connected to android devices. MATLAB thingspeak is employed to collect and store heart rate data from the android devices. Deep learning analyses that data in real-time. The analysis results can be disseminated via Twitter. The proposed system has the potential to open up a wide range of application scenarios. For example, the Twitter messages can warn AF patients when the stroke risk increases. Based on the heart rate measurements, the physician can monitor and adjust treatment. To sum up, the proposed wireless heart health monitoring system will benefit both patients and medical practitioners by detecting AF beats through alerting, continuous monitoring, diagnosis support and unintrusive patient led data acquisition.

Keywords—Stroke, atrial fibrillation, internet of things, advanced artificial intelligence.

Murtadha Kareem is with department of materials engineering and research institute at Sheffield Hallam university, city campus, Howard Street, Sheffield, S1 1WB, UK (phone: +447473368754; e-mail: city campus, city Murtadhak.kareem@student.shu.ac.uk).

Oliver Faust is currently with Department of mathematical and engineering, faculty of art, computing, engineering and science at Sheffield Hallam University, city campus, Howard Street, Sheffield, S1 1WB, UK (phone: +441142255555; e-mail: O.faust@shu.ac.uk).

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The Benefit of a Universal Screening Program for Lipid Disorders in Two to Ten Years Old Lebanese Children

Nicolas Georges, Akiki Simon, Bassil Naim, Nawfal Georges, Abi Fares Georges

Abstract—Introduction: Dyslipidemia has been recognized as a risk factor for cardiovascular diseases. While the development of atherosclerotic lesions begins in childhood and progresses throughout life, data on the prevalence of dyslipidemic children in Lebanon is lacking. Objectives: This study was conducted to assess the benefit of a protocol for universal screening for lipid disorder in Lebanese children aged between two and ten years old. Materials and Methods: A total of four hundred children aged 2 to 10 years old (51.5% boys) were included in the study. The subjects were recruited from private pediatric clinics after parental consent. Fasting total cholesterol (TC), triglycerides (TG), low density lipoprotein (LDL), high density lipoprotein (HDL) levels were measured and non-HDL cholesterol was calculated. The values were categorized according to 2011 Expert on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents. Results: The overall prevalence of high TC (≥200 mg/dL), high non-HDL-C (≥145 mg/dL), high LDL (≥130 mg/dL), high TG (≥100 mg/dL) and low HDL (<40 mg/dL) was respectively 19.5%, 23%, 19%, 31.8% and 20%. The overall frequency of dyslipidemia was 51.7%. In a bivariate analysis, dyslipidemia in children was associated with a BMI ≥ 95th percentile and parents having TC >240 mg/dL with a P value respectively of 0.006 and 0.0001. Furthermore, high TG was independently associated with a BMI ≥ 95th percentile (P=0.001). Children with parents having TC >240 mg/dL was significantly correlated with high TC, high non-HDL-C and high LDL (P=0.0001 for all variables). Finally, according to the Pediatric dyslipidemia screening guidelines from the 2011 Expert Panel, 62.3% of dyslipidemic children had at least 1 risk factor that qualified them for screening while 37.7% of them didn’t have any risk factor. Conclusions: It is preferable to review the latest pediatric dyslipidemia screening guidelines by performing a universal screening program since a third of our dyslipidemic Lebanese children have been missed.

Keywords—Cardiovascular risk factors, dyslipidemia, Lebanese children, screening.
Abstract—The operating room is a medical environment full of high-risk, high-complexity and high-cost. In addition to assuring patient safety, the operating room should effort on the efficient and safe medical quality for the surgical patients of high risk, elders, and children. If the nursing staffs of operation room carry on the pre-operative visiting prior to surgery, the patient's anxiety and complications are expected to be alleviated, and the hospitalization days may also be shortened.

Purpose: Applying the information system to enhance pre-operative visiting, case tracking, and effectiveness recording.

Method: 1. Application the information system to screen cases by integrating the operation scheduling, and linking the severe surgery codes, for to shorten the time to track cases of operative visiting. Through the improvement, the time required decreased to 1.5 minutes per day from 20 minutes per day, and nursing staffs’ satisfaction with satisfaction for tracking and visiting procedure of case increased to 86% from 54%. 2. The electronic establishment of the operative visiting record enhanced the integrity of the operative visiting record. The integrity rate was rise to 92% from 66%, while nursing staffs’ satisfaction with the visiting record increased to 82% from 61.3%.

Since information technology continues evolving, the application of information technology is helpful to the integration of nursing information, simplification of processes, and saving of man-hours. This article introduces the application of information systems to simplify the processes and improve the effectiveness of operation visiting and tracking, including the saving of time, improving the integrity rate of record, and improving the satisfaction of nursing staffs.

Keywords—Perioperative nursing, Pre-operative visiting, Information system, Effectiveness, Satisfaction.
Abstract—This article provides an example how can apply the visual communication elements (text, images, symbols, colors) as a framework to design an integrated patient wound site, bedsore site, pain site and tube position. Provide a Patient-centered of body map let nurse can easy to identify, quickly obtain information from a single interface, have a complete and correct of nursing records, shorten the time of shift report and the most important is can increase patient safety.

Keywords—Layer integration, Visual communication, Body map, Quality and Safe.
Abstract—This study was based Quasi-experimental design. The study explored between the relationships of nursing ethics education, nursing students’ moral sensitivity and moral judgments in Taiwan. A total of 242 nursing students (NS) participated the study. The proposed teaching nursing ethics from 2 to 16 weeks. Three questionnaires were adopted in this study. First, Demographic of nursing students questionnaire; Second, questionnaire is Taiwan’s Moral Sensitivity Questionnaire for Student Nurses (TMMSQ-SN); Third, Defining issues Test (DIT). The pre-test data was collected during the first week, and the post-test data was collected during 17th week of the semester.

The purpose of the study is explored evaluating the effect of nursing ethics education on nursing students’ moral sensitivity and moral judgments. The results of the study showed that moral sensitivities and moral judgments have been significantly improved after 16 weeks (Pair-t=-11.10***; Pair-t=-7.393***). Moral sensitivities and moral judgments were significant in the pretest. There was a negative correlation, but there was no correlation between moral sensitivity and moral judgments in the post-test. There was a significant correlation between the moral judgments (DIT) and the hours of work and other ethical courses (r=.28**; r=.015*). Nursing ethics education is necessary for nursing students in Taiwan. The nursing ethics courses is necessary to improve nursing students’ moral sensitivity and moral judgment (DIT).

Keywords—Defining issues Test, Moral Sensitivity, moral judgments.

Hsiao Lu Lee
Assessing the Impact of High Fidelity Human Patient Simulation on Teamwork among Nursing, Medicine and Pharmacy Undergraduate Students

S. MacDonald, A. Manuel, R. Law, N. Bandruak, A. Dubrowski, V. Curran, J. Smith-Young, K. Simmons, A. Warren

Abstract—High fidelity human patient simulation has been used for many years by health sciences education programs to foster critical thinking, engage learners, improve confidence, improve communication, and enhance psychomotor skills. Unfortunately, there is a paucity of research on the use of high fidelity human patient simulation to foster teamwork among nursing, medicine and pharmacy undergraduate students. This study compared the impact of high fidelity and low fidelity simulation education on teamwork among nursing, medicine and pharmacy students. For the purpose of this study, two innovative teaching scenarios were developed based on the care of an adult patient experiencing acute anaphylaxis: one high fidelity using a human patient simulator and one low fidelity using case based discussions. A within subjects, pretest-posttest, repeated measures design was used with two-treatment levels and random assignment of individual subjects to teams of two or more professions. A convenience sample of twenty-four (n=24) undergraduate students participated, including: nursing (n=11), medicine (n=9), and pharmacy (n=4). The Interprofessional Teamwork Questionnaire was used to assess for changes in students’ perception of their functionality within the team, importance of interprofessional collaboration, comprehension of roles, and confidence in communication and collaboration. Student satisfaction was also assessed. Students reported significant improvements in their understanding of the importance of interprofessional teamwork and of the roles of nursing and medicine on the team after participation in both the high fidelity and the low fidelity simulation. However, only participants in the high fidelity simulation reported a significant improvement in their ability to function effectively as a member of the team. All students reported that both simulations were a meaningful learning experience and all students would recommend both experiences to other students. These findings suggest there is merit in both high fidelity and low fidelity simulation as a teaching and learning approach to foster teamwork among undergraduate nursing, medicine and pharmacy students. However, participation in high fidelity simulation may provide a more realistic opportunity to practice and function as an effective member of the interprofessional health care team.

Keywords—Acute anaphylaxis, high fidelity human patient simulation, low fidelity simulation, interprofessional education.

I. INTRODUCTION

UNDERGRADUATE health science students often enter the workforce with little or no experience in interprofessional teamwork, but teamwork is expected in the health care setting [1]-[3]. Teamwork is an important and requisite skill that must be taught, supported and nurtured in undergraduate programs. However, nursing, medicine and pharmacy students have limited opportunities during their undergraduate programs to learn how to collaborate with other members of the health care team. One effective way to promote teamwork is through interprofessional education [4]-[6], but undergraduate students continue to be educated in isolation [7]-[9]. Theoretically, if students from different health care professions learn together through interprofessional education (IPE), they are better prepared to practice more efficiently and effectively as a cohesive health care team. IPE is a collaborative approach to teaching and learning that fosters teamwork among students in health-related fields such as nursing, medicine and pharmacy [10]-[14]. IPE encourages students to use their varied educational backgrounds to learn together for a defined period of time during their education programs. Simulation is a particularly useful teaching and learning approach for IPE, including the use of high fidelity simulation (HF-IPE) to create realistic patient scenarios for active student engagement [15]-[17].

The problem of nursing, medicine and pharmacy students entering the workforce with little or no experience in interprofessional teamwork is further complicated by a lack of opportunities to practice teamwork in the educational or clinical setting. Concerns over patient safety in practice have led faculty to search for appropriate and safe simulated experiences to prepare students for real-life situations [18]. Simulated learning experiences can range from simple (low) to complex (high). HF-IPE involves the use of a life-sized human patient simulator that is programmed to respond to interventions by changing blood pressure, heart rate, breath sounds, and oxygenation. The human patient simulator can respond to medication administration and can talk to the team. Low fidelity simulation such as clinical case discussions, requires the student teams to discuss a clinical case but there is no actual intervention or response implemented.

Medicine, nursing and pharmacy undergraduate programs have been using high fidelity simulation for many years in their respective uniprofessional education activities to foster critical thinking, engage learners, improve confidence, and enhance psychomotor skills. Thus, it would be a natural progression in this field of experiential teaching and learning to move from uniprofessional high fidelity undergraduate education, to interprofessional high fidelity undergraduate education [19]-[24]. Although HF simulation has been used successfully for training teams at the post-licensure level, particularly in the area of advanced cardiac life support, there
are few research studies that address the effectiveness of HF-IPE to foster teamwork with undergraduate students, or provide guidance on how HF-IPE can be integrated into undergraduate curricula [25].

The design of the anaphylaxis simulation scenarios developed for this study was based on Jeffries nursing simulation education framework [26]. The Jeffries Framework has five major components with associated variables: the teacher, the student, educational practices, simulation design (including high or low fidelity) and the learner outcomes (Fig. 1). The Kirkpatrick Model for measuring learning outcomes was also used to guide the measurement of the impact of the learning experience. The Kirkpatrick model identifies five outcomes for measuring the effectiveness of educational initiatives including: reaction – students’ satisfaction; learning – knowledge and skills gained; behaviors – newly learned behaviors that are transferrable to practice; results – benefits, measurable results, and return on investment analysis [27]. This study focused on the outcomes of reaction, student satisfaction, learning and behaviors.

II. METHODS

A. Research Questions

1. Does participation in high fidelity simulation result in a higher level of understanding of team roles, than participation in low fidelity simulation?

2. Does participation in high fidelity simulation result in more improved confidence in communicating with the team to plan care as compared to participation in low fidelity simulation?

3. Does participation in high fidelity simulation result in improved confidence in collaborating with the team to plan care, as compared to participation in low fidelity simulation?

4. Are participants in the high fidelity simulation more satisfied with the teaching and learning approach, than participants in the low fidelity simulation?

B. Research Design

A within subjects, pretest-posttest, repeated measures research design was used in this study. The design involved two interventions; one HF-IPE, and one low fidelity interprofessional education (LF-IPE). There was random assignment of individual subjects to interprofessional teams of two or more professions. The sequence of the simulations depended on students’ schedule and availability of the simulation room. This research design eliminated the need for a separate control group, as participants served as their own control group.

C. Methods

The teams participated in two simulations: one HF-IPE and LF-IPE. Both simulations were based on the medical management of an adult patient experiencing acute anaphylaxis. The high fidelity case involved an acute allergic reaction to contrast medium and the low fidelity case involved an acute allergic reaction to antibiotics (Fig. 2). Patient history, presenting symptoms and the reason for the reaction were different for each simulation, but the treatment protocol for the medical management of acute anaphylaxis was exactly the same. The primary difference between the simulations was
the use of the adult human patient simulator in the high fidelity simulation and the paper based discussion in the low fidelity simulation.

During both the HF-IPE and the LF-IPE simulations, the students had access to a fictitious paper based chart with an admission history and physical, diagnostic reports, nursing notes, nursing care plan, physicians orders, policies and procedures, medication administration records and other charting documents as needed. In both simulations, students were expected to discuss, order and document care including prescribing, and transcribing medications and completing the required documentation. Each simulation session lasted approximately 60 to 90 minutes including a 15-minute pre-briefing, and a 15-minute debriefing session. The pre-briefing session for the HF-IPE included an orientation to the human patient simulator. The debriefing session for both simulations focused on discussion questions related to the role of the interprofessional team, and whether the team provided good care and communicated and collaborated effectively.

<table>
<thead>
<tr>
<th>Low Fidelity Case</th>
<th>High Fidelity Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. John Critch, 50 years old, 6 feet 2 inches, 185 pounds, has been admitted to the Special Care Unit from the Emergency Department with a diagnosis of bacterial pneumonia. He presented with shortness of breadth, and a productive cough that has become progressively worse over the past 24 hours. Intravenous fluid and oxygen were administered. Medications at home include Ramipril, Amlodipine, Metoprolol and Rosuvastatin. He is allergic to Sulfa Drugs. He states he took an antibiotic once before but developed a rash and stopped taking him. He cannot remember the name of the antibiotic.</td>
<td>Mrs. Carly Jones, 50 years old, 5 feet 8 inches, 154 pounds, was admitted last night to the Emergency Department with Undiagnosed Chest Pain. She presented to ER with acute right pleuritic chest pain after returning from an international flight. She is allergic to shellfish. Her medications at home are Ramipril, Amlodipine, Metoprolol, Rosuvastatin, and Metformin. She returned from a computed tomography of the pulmonary arteries about 5 minutes ago. Sub segmental pulmonary emboli were identified in right lower lobe. She is complaining of feeling “itchy” all over.</td>
</tr>
</tbody>
</table>

![Fig. 2 Anaphylaxis Case for Low and High Fidelity Simulations](image)

**D. Sample**

A convenience sample of twenty-four (n=24) undergraduate students participated, including: nursing (n=11), medicine (n=9), and pharmacy (n=4). One hundred and nine (n=109) students were recruited to participate in the study, but only 24 of those who expressed interest were able to find a common time to meet outside of their clinical and classroom schedules. All teams had nursing and medicine students. However due to scheduling issues, only five of those teams had pharmacy students. All students had completed courses containing the theoretical background on the medical management of anaphylaxis.

**E. Setting**

This study took place at the Cahill Simulation Room (CSR) at the School of Nursing, located in the Health Sciences Center in close proximity to the School of Nursing, Faculty of Medicine and the School of Pharmacy. In the HF-IPE the CSR was set up to resemble a standard patient room in an emergency room setting and in the LF-IPE the students sat around a table to discuss the case in a classroom setting. The pre-briefing and debriefing sessions for both simulations occurred in the classroom setting.

**F. Instrument**

The Interprofessional Teamwork Questionnaire (ITQ) was used as a pretest and posttest for both simulations [4]. That tool was modified with permission for use in this study. The ITQ extracts ordinal level data and includes seven statements that are rated by the participant on a five-point Likert scale from “Strongly agree” to “Strongly disagree.” Those statements focus on areas of individual functionality within an interprofessional team, the significance of interprofessional collaboration in the simulation, comprehension of the role of each profession involved, confidence in effectively communicating with the interprofessional team, and confidence in effective collaboration for care planning. In addition to these initial statements, the post-test version of the ITQ included nine items that assessed the participant’s level of satisfaction with the teaching and learning approach. Items included the level of clarity of the learning objectives, the fairness of the workload, the organization of the experience, utility of each component in the simulation experience, (pre-briefing, orientation to the simulator and debriefing), whether they would recommend the scenario to others, and whether the experience was meaningful. The ITQ measured three outcomes from Kirkpatrick’s model for simulation education: the students’ immediate reaction, including satisfaction with the experience; and the students’ perception of the learning that occurred, including changes in knowledge of the importance of interprofessional teamwork, and confidence in communicating and collaborating with the team.

**III. FINDINGS AND DISCUSSION**

**A. Comprehension of the Team Roles and Importance of Teamwork**

Participation in both the HF-IPE and the LF-IPE resulted in statistically significant improvements in students’ understanding of the importance of the role of the interprofessional team and in participants’ understanding of the roles of nursing and medicine. However, only the LF-IPE resulted in a significant change in the understanding of the pharmacy role (Table I). These findings may be due to the fact that not all teams had a pharmacy student present during the HF-IPE simulation. In those teams without a pharmacy student, the Research Assistant played the role of the pharmacist and consulted with the team via telephone, so this may have impacted on the understanding of the role of the pharmacist on the team. These findings may also reflect the importance of students meeting face to face during interprofessional simulations in order to foster an increased
understanding of their roles on the interprofessional team. These findings are in keeping with current research, which identifies simulation as useful teaching and learning approach for IPE, especially HF-IPE because it creates realistic patient scenarios for active student engagement [15]-[17].

B. Individual Functionality Within an Interprofessional Team

Participation in the HF-IPE resulted in a significant improvement in students’ understanding of the importance of the interprofessional team (Table II). However, participation in the LF-IPE did not produce a similar change. This may be due to the fact that prior to participating in the LF-IPE the understanding of the importance of the interprofessional team was already high and this did not significantly change after participation. The same may be true of the lack of change in students’ perception of whether they functioned effectively as a member of the team after participation in the LF-IPE. These findings would indicate that HF-IPE was more effective in enhancing students’ ability to function as a member of the team whereas LF-IPE was more effective in enhancing the understanding of the team. These findings are similar to current research which shows that participation in HF-IPE results in significantly more positive attitudes about team work and collaboration, and undergraduate students are ready to engage in interprofessional education through exposure to an experiential format such as high-fidelity human patient simulation [15].

| TABLE I | UNDERSTANDING OF NURSING MEDICINE AND PHARMACY ROLES ON THE TEAM |
|---------------------|---------------------|---------------------|---------------------|
| Profession          | Low Fidelity N=21   | High Fidelity N=24  |                      |
| Nursing             | 4.14±0.85 4.67±0.48 | 4.17±0.70 4.58±0.50 | 0.008 0.008          |
| Medicine            | 3.90±1.00 4.52±0.51 | 3.75±0.99 4.33±0.76 | 0.004 0.001          |
| Pharmacy b.         | 3.25±1.12 4.40±0.60 | 3.25±1.12 3.50±1.02 | 0.001 0.052          |

* Wilcoxon Signed Ranks Test, CI 95%

| TABLE II | IMPACT ON ATTITUDES TOWARDS INTERPROFESSIONAL TEAMS |
|---------------------|---------------------|---------------------|
| Statement            | Low Fidelity M ± SD | High Fidelity M ± SD |
|                      | Pre Post p          | Pre Post p          |
| Function effectively as a member of the interprofessional team | 4.05±0.59 4.38±0.67 0.035 | 3.63±1.01 4.29±0.69 0.003* |
| Understand the importance of interprofessional teamwork | 4.48±0.51 4.86±0.36 0.005* | 4.75±0.52 4.83±0.38 0.317 |
| Confident can communicate effectively with the team | 3.90±0.44 4.33±0.73 0.013* | 3.79±0.78 4.25±0.85 0.036* |
| Confident can collaborate effectively with the team | 4.10±0.54 4.43±0.68 0.020* | 3.96±0.81 4.46±0.57 0.005* |

* Wilcoxon Signed Ranks Test, CI 95%

Team Communication and Collaboration. Prior to participating in the LF-IPE, 81% agreed and 5% strongly agreed that they were confident they could communicate effectively with the interprofessional team to plan care for a patient experiencing acute anaphylaxis. After participation, 38% agreed and 48% strongly agreed they could communicate effectively with the interprofessional team (Fig. 3). Although there was no change in the percentage of students’ who reported they were neutral on this item (14%), there was a positive shift towards strongly agreeing with this statement. This would further support the finding that participation in the LF-IPE resulted in a positive impact on students’ perception of their ability to communicate effectively with the interprofessional team.

Prior to participating in the HF simulation, 29% of the...
students were neutral about whether they were confident in communicating effectively with the interprofessional team (Fig. 4). This dramatically decreased to 0% post participation with a corresponding 25% positive shift in strongly agreeing they could communicate effectively with the interprofessional team. This would further support the finding that participation in the high fidelity simulation resulted in a positive impact on students’ perception of their ability to communicate effectively with the interprofessional team.

C. Satisfaction with Teaching and Learning Approach

The ITQ mean satisfaction scores for both the HF-IPE and LF-IPE showed that participants were satisfied with both experiences including satisfied with the workload, the organization of the experience and the debriefing sessions. Students also reported that both simulations were meaningful and they would recommend both experiences to others (Table III). However, participants in the LF-IPE reported they were significantly more satisfied with the learning objectives and pre-briefing session, than participants in the HF-IPE. The learning objectives for both sessions were the same, and students were not expected to review those objectives before participating in the simulations. Thus, it is possible that some students had not reviewed, or were not aware that the learning objectives for both sessions were exactly the same. The pre-briefing sessions for the HF-IPE included orientation to the human patient simulator and students may have perceived this orientation differently as this was the first time they had been exposed to the human patient simulator.

Overall, the students were satisfied with the teaching learning approaches used in both the HF-IPE and the LF-IPE and there were no significant differences between the HF-IPE and LF-IPE in relation to satisfaction with workload, organization and debriefing (Fig. 5). All students agreed or strongly agreed that they would recommend both learning experiences to others. These findings would indicate that participation in the HF-IPE did not result in a higher level of student satisfaction with the learning experience as compared to participation in the LF-IPE. However it was clear that students were satisfied with both the HF-IPE and the LF-IPE as a teaching and learning experience.

### TABLE III

<table>
<thead>
<tr>
<th>Statement</th>
<th>Low Fidelity</th>
<th>High Fidelity</th>
<th>Pearson’s Coefficient</th>
</tr>
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<tbody>
<tr>
<td>Learning objectives were clear</td>
<td>4.43</td>
<td>4.21</td>
<td>0.661*</td>
</tr>
<tr>
<td>Workload was fair</td>
<td>4.62</td>
<td>4.29</td>
<td>0.295</td>
</tr>
<tr>
<td>Experience was organized</td>
<td>4.67</td>
<td>4.38</td>
<td>0.293</td>
</tr>
<tr>
<td>Pre-briefing was helpful</td>
<td>4.38</td>
<td>4.29</td>
<td>0.485*</td>
</tr>
<tr>
<td>Debriefing was helpful</td>
<td>4.42</td>
<td>4.48</td>
<td>0.342</td>
</tr>
<tr>
<td>Recommend experience to others</td>
<td>4.7</td>
<td>4.83</td>
<td>0.336</td>
</tr>
<tr>
<td>A meaningful experience</td>
<td>4.65</td>
<td>4.79</td>
<td>0.157</td>
</tr>
</tbody>
</table>

*Note: Significant at p < 0.05, CI 95%*

Fig. 5 Satisfaction with teaching and learning approach

IV. CONCLUSION

Participation in the HF-IPE and the LF-IPE developed for this study resulted in a significant increase in students’ understanding of the importance of teamwork, and enhanced students’ understanding of the role of nursing and medicine, in the interprofessional team when caring for patients experiencing acute anaphylaxis. The HF-IPE was more effective in enhancing students’ ability to function as a member of the team, whereas the LF-IPE was more effective in enhancing the participants’ understanding of the importance of interprofessional teamwork. Participation in both the HF-IPE and the LF-IPE resulted in a positive impact on students’ perception of their ability to communicate and collaborate effectively with the interprofessional team to plan care. Students were equally satisfied with the educational practices and the simulation design of the HF-IPE and the LF-IPE as a teaching and learning approach. However, it is critical to ensure that when simulations are designed for a particular team (nursing, medicine and pharmacy) all members of the team are present during the simulation. HF-IPE and LF-IPE can be effective teaching and learning approaches to foster interprofessional teamwork in undergraduate nursing, medicine and pharmacy students and should be incorporated into the undergraduate curricula of nursing medicine and pharmacy education programs.

REFERENCES


Design and Synthesis of Novel 8-Aryl Substituted 9-Cyclopentyl Purine Derivatives as Potential Cytotoxic Agents

Meral Tuncbilek, Muhammed Fatih Polat, Irem Durmaz, Rengül Cetin Atalay

Abstract—Cancer is a major human health problem and one of the principal reasons for death in both developing and industrialized countries. In our present work, we report on the synthesis and in vitro cytotoxic activity of 9-cyclopentyl-8-[4-(methoxy/phenoxy)phenyl]-6-(4-phenylpiperazin-1-yl)-9H-purine derivatives against selected human cancer cell lines (liver Huh7, colon HCT116, breast MCF7). The purine analogs were analyzed initially by an anticancer drug-screening method based on a sulforhodamine B assay. Compounds 9-12 were more cytotoxic (IC_{50} = 2.9-7.4 µM) than 5-FU, fludarabine on Huh7 cell line. N6- and 8-(4-methoxyphenyl) analog (9) was further analyzed for its cytotoxicity in a panel of a liver cancer cell lines. The compound 9 demonstrated the highest cytotoxic activity against Huh7, HepG2, Mahlavu and FOCUS cells (IC_{50} = 1.8-15.1 µM) compared to fludarabine (IC_{50} = 13.7-28.4 µM).

Keywords—Cytotoxic activity, hepatocellular carcinoma, purine analogs, synthesis.

INTRODUCTION

Cancer is a major human health problem and one of the principal reasons of death in both developing and industrialized countries. Purine and pyrimidine analogues are important anti-cancer drugs used for the treatment of both hematological malignancies and solid tumors in chemotherapy. In 1953 and 1966, among the first anticancer drugs 6-mercaptopurine and 6-thioguanine (Figure 1) were used as an inhibitor of nucleic acid metabolism in childhood acute lymphoblastic leukemia respectively [1-4].

![6-Mercaptopurine, 6-Thioguanine](image)

Figure 1. Structures of 6-mercaptopurine and 6-thioguanine

Furthermore purine nucleosides such as fludarabine, cladribine, and pentostatine (Fig. 2) were approved in FDA for the therapy of hematologic disorders between 1991 and 1992 [5,6].

![Fludarabine, Cladribine, Pentostatine](image)

Figure 2. Structures of fludarabine, cladribine and pentostatine

Hepatocellular carcinoma (HCC) is one of the deadly cancers and effects most of the world population. It is also the fifth most common cancer in men and seventh in women, accounting for 7% of all cancer cases, and the third most common reason of cancer connected death, worldwide with around 700,000 new cases each year [7-9]. Chronic liver damage is due to viral diseases, chemical exposure, environmental toxins or autoimmune diseases that are the risk factors for HCC. These conditions cause an acquired tolerance to genotoxic stress, but finally a cancerous case that does not respond to the mechanism of cell death [10].

The diagnosis of HCC patients is usually very poor and HCC tumors are resistant to chemotherapeutic agents. Lately, a multikinase inhibitor Sorafenib, was approved in the FDA and the EU for the treatment of hepatocellular carcinoma [11]. Sorafenib HCC Assessment Randomised Protocol (SHARP) indicated significantly improved overall survival and the time to progression by almost three months in cases with advanced HCC upon treatment with the antiangiogenic and antiproliferative agent Sorafenib [12-14]. Therefore, it is essential to discover new liver-cancer-specific drugs for hepatocellular carcinoma treatment.

In our present work, we synthesized 9-cyclopentyl-8-[4-(methoxy/phenoxy)phenyl]-6-(4-phenylpiperazin-1-yl)-9H-purine derivatives (6-19) and screened their anticancer activities on selected human cancer cells (liver Huh7, colon HCT116, breast MCF7); and the most potent purine derivative (9) were further tested on a panel of hepatocellular cancer cell.

RESULTS AND DISCUSSION

Chemistry

The synthesis of the novel 6,8,9-trisubstituted purine analogs were carried out starting from commercially available 4,6-dichloro-5-nitropyrimidine in four steps (Figure 3). 5-Amino-4,6-dichloropyrimidine (2) was obtained by as a preparation process reduction of 4,6-
Dichloro-5-nitropyrimidine (1) using tin (II) chloride (SnCl₂) in EtOH. SnCl₂ has an ability for selectively reducing the compound 1 to 2 in excellent yield without cleaving the chloride group. Although the nucleophilic aromatic substitution is easy with pyrimidine derivatives, the corresponding reaction of cyclopentylamine and (2) in refluxing MeOH containing triethylamine, was exhibited significantly lower yields. Access to the desired chemical yield as 89% effectively was accomplished by heating the reaction in a sealed tube at 125 °C without using triethylamine. A major challenge, which was executing the synthesis of compounds 4, 5, was performed by the cyclization of 3 with 4-substituted benzaldehydes in the presence of p-TSA in DMF at 80 °C. 9-Cyclopentyl-8-[4-(methoxy/phenoxophenyl)]-6-(4-phenylpiperazin-1-yl)-9H-purine derivatives (6-19) were readily prepared using our previously reported procedure [15], which includes the substitution of the 6-chloro group was achieved by the nucleophilic aromatic substitution with appropriate N-substituted piperazines.

**Figure 3.** Reagents: (a) SnCl₂, 2H₂O, EtOH; (b) cyclopentylamine, MeOH; (c) appropriate aldehydes, p-TSA, DMF; (d) 4-substituted piperazines, TEA, EtOH.

**Biological Evaluation and Discussion**

The cytotoxicities of the compounds 6-19 were initially analyzed on liver (Huh7), colon (HCT116) and breast (MCF7) carcinoma cell lines by SRB assay for determining the IC₅₀ values (Table 1). The IC₅₀ values after 72 hours of treatment with each molecule were also calculated in comparison with the nucleobase analog 5-fluorouracil (5-FU) and nucleoside analogs fludarabine, cladribine, pentostatine.

**Table 1**

<table>
<thead>
<tr>
<th>Compound</th>
<th>R</th>
<th>R₁</th>
<th>Huh7 (μM)</th>
<th>HCT116 (μM)</th>
<th>MCF7 (μM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>OCH₃</td>
<td>H</td>
<td>57.1</td>
<td>42.3</td>
<td>NI</td>
</tr>
<tr>
<td>7</td>
<td>OCH₃</td>
<td>CH₃</td>
<td>NI</td>
<td>NI</td>
<td>58.4</td>
</tr>
<tr>
<td>8</td>
<td>OCH₃</td>
<td>CF₃</td>
<td>9.8</td>
<td>NI</td>
<td>NI</td>
</tr>
<tr>
<td>9</td>
<td>OCH₃</td>
<td>OCH₃</td>
<td>2.9</td>
<td>30.7</td>
<td>47.7</td>
</tr>
<tr>
<td>10</td>
<td>OCH₃</td>
<td>F</td>
<td>5.9</td>
<td>15.7</td>
<td>NI</td>
</tr>
<tr>
<td>11</td>
<td>OCH₃</td>
<td>Cl</td>
<td>5.5</td>
<td>30.9</td>
<td>69.8</td>
</tr>
<tr>
<td>12</td>
<td>OCH₃</td>
<td>3,4-diCl</td>
<td>7.4</td>
<td>33.6</td>
<td>30.6</td>
</tr>
<tr>
<td>13</td>
<td>OPh</td>
<td>H</td>
<td>17.9</td>
<td>17.2</td>
<td>39.6</td>
</tr>
<tr>
<td>14</td>
<td>OPh</td>
<td>CH₃</td>
<td>14.2</td>
<td>13.7</td>
<td>41.7</td>
</tr>
<tr>
<td>15</td>
<td>OPh</td>
<td>CF₃</td>
<td>41.5</td>
<td>21.8</td>
<td>NI</td>
</tr>
<tr>
<td>16</td>
<td>OPh</td>
<td>OCH₃</td>
<td>23.6</td>
<td>30.4</td>
<td>NI</td>
</tr>
<tr>
<td>17</td>
<td>OPh</td>
<td>F</td>
<td>80.1</td>
<td>19.5</td>
<td>69.2</td>
</tr>
<tr>
<td>18</td>
<td>OPh</td>
<td>Cl</td>
<td>NI</td>
<td>17.6</td>
<td>NI</td>
</tr>
<tr>
<td>19</td>
<td>OPh</td>
<td>3,4-diCl</td>
<td>NI</td>
<td>48.2</td>
<td>NI</td>
</tr>
</tbody>
</table>

| 5-FU     | 30.6 | 4.1   | 3.5      |

Fludarabine 28.4 8.0 15.2  
Cladribine 0.9 <0.1 2.4  
Pentostatine NI NI NI

IC₅₀ values were calculated from the cell growth inhibition percentages obtained with five different concentrations. NI: No inhibition

**REFERENCES**

Use and Relationship of Shell Nouns as Cohesive Devices in the Quality of Second Language Writing
Kristine D. de Leon, Junifer A. Abatayo, Jose Cristina M. Parina

Abstract—The current study is a comparative analysis of the use of shell nouns as a cohesive device (CD) in an English for Second Language (ESL) setting in order to identify their use and relationship in the quality of second language (L2) writing. As these nouns were established to anticipate the meaning within, across or outside the text, their use has fascinated writing researchers. The corpus of the study included published articles from reputable journals and graduate students’ papers in order to analyze the frequency of shell nouns using “highly prevalent” nouns in the academic community, to identify the different lexicogrammatical patterns where these nouns occur and to the functions connected with these patterns. The result of the study implies that published authors used more shell nouns in their paper than graduate students. However, the functions of the different lexicogrammatical patterns for the frequently occurring shell nouns are somewhat similar. These results could help students in enhancing the cohesion of their text and in comprehending it.

Keywords—Anaphoric-cataphoric, cohesive device, lexicogrammatical, shell nouns.

I. INTRODUCTION

Despite the preponderant research on cohesion in a text, it continues to fascinate writing experts because of their complexity and evolving functions in academic writing. In fact, “cohesion does not depend on a single item or class and is based on a complete set of relationships in a text which in turn communicate with the help of various overt and covert types of signals to attribute a text its meaningfulness” [2].

Thus, no research would ever claim that CDs are equal in importance with other types of devices in achieving proper communication. It is therefore, a focal point in many writing researches because there are many factors that can make a text quite different, as it may range from simple to complex. Some of these factors are described through “cohesion or ties and connections within the texts” [3] where cohesion is “the way certain words or grammatical features of a sentence can connect that sentence to its predecessors (and successors) in a text” [4]. This was emphasized by when it was posited that, “To write cohesively means doing many things at once—wrestling with ideas, balancing form and function…. attending to syntax and diction” [5].

There are several types of CDs and one of these is nouns. Nouns may act differently from each other as they create ties in a text since they “can be employed interchangeably as lexical substitutes for other nouns with specific meaning” [1].

Nouns, therefore, become one of the lexical items that rouse the interest of many researchers involved in the study and teaching of writing in the early 90s and they have been labeled as: enumerative [6], signaling [7] and shell nouns [8], [9], among others. Though these nouns are called differently by researchers, the concept behind them still remains the same [9]. For example, enumerative nouns (e.g. advantage, aspect, class and consequence) and resultative nouns (e.g. finish, end, outcome and result) function as referential markers that present new ideas (cataphoric) or refer back to the previous ideas discussed (anaphoric) [6]. Francis stated that cataphoric words allow “the reader to predict the precise information that will follow” and anaphoric words indicate to the reader “exactly how that stretch of discourse is to be interpreted, and this provides the frame of reference within which the subsequent argument is developed” [10].

These nouns, therefore, create contextual ties between ideas in the text to help readers to collect information and comprehend the text. Another study sees coherence as the link between ideas that make the flow of thoughts meaningful and clear for readers [11]. It was therefore concluded that ESL students have higher frequency on sentence transitions when he studied their writing cohesion [6].

Another study examined their functions to signal in order to establish relationships or links across and within clauses to determine the background knowledge. He mentioned that previous studies on nouns as CD emphasized on cataphoric and anaphoric functions. Hence, he added one function to investigate on, which is the exophoric function [7]. The inclusion of exophoric function implies that signaling nouns have also been examined not just across or within the clauses, but also in their use in determining background knowledge since they are essential in the comprehension process [7].

A more recent study on nouns as CD was examined the structure and function of nouns as CD, which they called as shell nouns, in published articles and research articles written by international students. They found out that students used shell nouns differently from published articles/authors. Hence, students have to be taught these nouns not only as vocabulary items but as a CD and they have to be exposed to the appropriate lexicogrammatical patterns to guide them in conveying the communicative purpose of their paper [9]. Another study, which is believed to have established the importance of shell nouns, concluded that “shell nouns are used as CD within text, and studying them and becoming familiar with their functions and patterns can help both learners and writers to comprehend and write better.
respective” [5].

Based on the aforementioned studies, it should be noted that knowing and using the different nouns as CD do not just ensure cohesiveness of a texts. They can also “enclose or anticipate the meaning of the preceding or succeeding discourse” [9]. Thus, it is not surprising that in their study, students used some of these nouns more frequently than published authors. The results “provide valuable information that can be directly applied to English for Academic Purposes (EAP) instruction” since these nouns help them improve their ability to comprehend and recall information from the text they are reading [9].

Indeed the importance of nouns as CD is undeniable, for shell nouns are the most frequently used word class in the English language [5]. Thus, this study wished to examine the cohesion of Filipino published articles and graduate students papers through the use of shell nouns and how they function in different lexicogrammatical patterns. The present study sought to answer the following questions:

1. Which of Hinkel’s [1] “highly prevalent” nouns with cohesive function are frequently used in both published articles and graduate students papers?
2. Which of the lexicogrammatical patterns can be found in the most frequently used shell nouns?
3. How do these commonly used shell nouns function in different lexicogrammatical patterns as CDs?

A. Framework of the Study

This study adopted the structural and functional classification of shell nouns. In the structural analysis, the concept of four lexicogrammatical patterns: N + cl, N + be + cl, th + N and th + be + N [8], and five lexicogrammatical patterns, the + noun, a(n) + N, the + N + of, a(n) + N + of, the same + N, with their anaphoric and cataphoric referential positions in determining the behavior of shell nouns as CD [9] were employed.

In recent study on shell nouns, reference [9] used the lexicogrammatical pattern on the study by reference [8] of shell nouns in published and ESL writing; however, five more patterns were found and these patterns have not been identified before in the use of shell nouns [9]. Thus, the researchers incorporated these lexicogrammatical patterns in the current research since these patterns might likely emerge and can potentially broaden the scope on how shell nouns behave or function in the texts of published authors and graduate students. In the functional analysis, Schmid’s functional classification of the recurring shell nouns was adapted. These functions were

“the semantic function of characterizing complex chunks of information, the cognitive function of temporary concept-formation, and the textual function of linking these nominal concepts with clauses which contain the actual details of information”[9].

II. METHODOLOGY

This study analyzed the usage and functions of shell nouns in Filipino published articles and graduate students papers with topics on Education and Applied Linguistics. The researcher examined 10 published articles and 10 graduate students paper with a length of 15-30 pages in each article or paper. The former were taken from Philippine ESL Journal and The Asia Pacific Education Researcher which were published on the year 2005-2009 while the latter were collected from graduate students taking up Masters in Teaching English (MATEL) and Masters in English Education (MAELED). List of 35 “highly prevalent” abstract nouns [1] acting as a CD was used in analyzing published articles and graduate students papers.

A frequency count was conducted first to determine the most common shell nouns used in published articles and graduate students paper through the use of “Find and Replace” function of Microsoft word and the words that match the aforementioned nouns were highlighted for easier analysis. Some of the words that were highlighted function as a verb, proper noun or terminology were eliminated and nouns found in the tables or examples of articles or papers were eliminated. Therefore, a recount for each noun was done. In addition, nouns with exophoric functions were not included in the study for they did not “conceptually carry the content of the noun and/ or the noun phrase in the text” [9].

The five frequently occurring shell nouns in both published articles and graduate students papers were identified and categorized according to the nine lexicogrammatical patterns: N + cl, N + be + cl, th + N and th + be + N (Schmid, 2000), the + noun, a(n) + N, the + N + of, a(n) + N + of, the same + N, with their anaphoric and cataphoric referential positions in determining the behavior of shell nouns as CD [9] and for the final analysis of the data, the functions of shell nouns in [8], characterization, temporary concept formation and linking, were adapted in categorizing on how shell nouns behave in this particular study.

III. RESULTS AND DISCUSSION

The first research question was addressed and the results show that the prevalent shell nouns in published articles totaled 205, while the students’ papers have only about half of the published articles’ shell nouns. Additionally, the frequency distribution of shell nouns used by the published authors is distributed in various shell nouns compared to the frequency distribution of the graduate students. Though it is easy to suggest that authors in published articles are more familiar in using various nouns as CDs, it may also signify that authors in published articles may have already mastered organizing ideas between sentences that signals relationships among them. This skill allows the use of more CDs in order to form a unified whole. The summary is shown in Table I.

Published authors and graduate students may have different frequency in using shell nouns. However, it can be noted that both groups prefer the shell noun, result. This finding is quite similar to the results in the study of [7] and [9] on nouns as CDs. In their studies, the shell noun “result” is one of nouns with high frequency. Thus, the shell noun, result, is the most commonly used shell noun in the academic writing. However, the similarities end here, the rest of the nouns that are found in this study are totally different from the list of nouns with high occurrences in [7] and [9]. This may be attributed to the
reason that though the studies focused on academic writing, this present study solely focused on articles and student papers of teaching education and applied linguistics, while the other studies analyzed the different writing genres in the academic community.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>SUMMARY OF THE PREVALENT SHELL NOUNS FOUND IN PUBLISHED ARTICLES AND GRADUATE STUDENTS PAPERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell nouns</td>
<td>Published articles</td>
</tr>
<tr>
<td>result</td>
<td>34</td>
</tr>
<tr>
<td>form</td>
<td>2.93%</td>
</tr>
<tr>
<td>type</td>
<td>17</td>
</tr>
<tr>
<td>task</td>
<td>14</td>
</tr>
<tr>
<td>subject</td>
<td>5.37%</td>
</tr>
<tr>
<td>topic</td>
<td>19</td>
</tr>
<tr>
<td>item</td>
<td>20</td>
</tr>
<tr>
<td>TOTAL</td>
<td>101/205</td>
</tr>
</tbody>
</table>

In terms of the frequency distribution of shell nouns, published authors and graduate students frequently used any of the shell nouns in the patterns the + noun and the + N + of. Published authors and graduate students make use of the pattern the + noun over 50% and about 40%, respectively, of the total number of shell nouns found in both published articles and graduate papers. This pattern usually brings new information in the text and emphasis. They also make use of the pattern the + N + of approximately 25% of the total number of shell nouns the graduate students papers. The result on the preferred lexicogrammatical pattern by both groups is similar to the findings of [9] on frequently occurring patterns. Thus, it could be presumed that these two patterns are prevalent in academic writing. The third pattern that is regularly used by the published authors and graduate students is the th + N pattern.

It is worth mentioning that out of nine lexicogrammatical pattern, only seven patterns were used by the published authors and graduate students. The patterns N + be + cl and th + be + N were not found in either published articles or graduate students papers and this finding coincides with [9]. This contrasts the study of [5] which had N+be+cl, conveying cataphoric reference, in the published research articles in the field of Education. This is an interesting disparity since their study and the current research partly used the same type of corpus. A probable reason for this could be ESL students and even authors in the Philippines are not as accustomed with these two patterns.

With the use of functional analysis, it was found that published articles and graduate students papers have only three shell nouns in common out of five frequently occurring shell nouns in both texts. Accordingly, characterization is the use of shell nouns “to characterize a piece of experience in a general way”, while relying on the context for details of information [9]. The lexicogrammatical patterns, N+cl and N+be+cl, belong with this function and these two patterns express cataphoric reference. Though in this study, N+be+cl was never used by either published authors or graduate students, but N+cl was used with the nouns result and topic.

However, only graduate students used the shell noun topic. Below are the examples from published articles and graduate students paper.

a. The results that indicate improvement of students writing skills... (Published articles)
b. They also indicated in the results that the development from “simple knowledge of socio-linguistic principles for politeness (Students’ paper)
c. The topic that they were discussing for them to practice their English communication skills. (Students’ paper)

Published authors used the noun result only once in this pattern, N+cl, while the graduate students never used the noun result; however, they employed the noun topic in this pattern. Seemingly, these two groups have their own preference in using shell nouns in cataphoric function. In addition, published authors and graduate students do not often make use of this lexicogrammatical pattern in their writing. The pattern the + N + of and was used by published authors and graduate students with noun result, topic and type, while a(n) + N + of was use only by the published authors with the noun result. Examples are shown below:

a. the results of the current study are also in consonance with (author name) finding. (Published articles)
b. the types of cohesion used in the oral narratives between students (Students’ paper)

The aforementioned patterns have the attributes of the characterization function, as they add information on the noun phrase preceding it [9]. The high usage of the + N + of may be because these two groups are more familiar and comfortable in using this pattern.

In terms of temporary concept-formation, it was claimed that this function is “created by the repeated use of a word to refer to a certain experience” [9]. In general, this function is integrated with characterizing the pattern the + N + of. An example is shown below:

The results of the manual coding and counting of errors in college freshmen diagnostic essays are shown in order from the most frequent to the least frequent errors (Published articles).

In the sentence above, the shell noun result refers to the manual coding and counting of errors in college freshman diagnostic essay, thus it creates added information to form a more stable concept. Among the three shell nouns, result, topic and type, only the shell noun result has a concept-formation function.

Linking is the interpretation of two linguistic elements which are dependent or related to each other [8]. The th-N is the pattern which is solely closely connected with this function [9]. Examples of this pattern from the shell nouns result and topic are given below:

a. These results are consistent with earlier findings that bilinguals outperform their matched monolinguals in metalinguistic abilities. (Published articles)
b. They comprise more than half of the total obligatory occasions of each structure. This result could be attributed to the interference of the first language in the acquisition (Students’ paper)
c. **This type of cohesion is regarded by Halliday and Hasan as the cohesive effect achieved by the selection of vocabulary. (Published articles)**
d. **Writers may need to reduce using strong words like establish, cause and validate. This type can be achieved by making use of “soft” (Swales and Feak 1994, p. 87) verbs (Students’ paper)**

The usage of result and type in texts with the pattern th-N in published authors and graduate students papers is similar. The nouns referred back to the previous sentences and created a relationship between sentences. In this type of function, it is worth mentioning that graduate students have a preference in using this pattern in creating a link between sentences and that both published authors and graduate students usually use the pattern th-N in supporting a claim or in making a claim. In the functional analysis of shell nouns as CD, one of the differences on the usage of shell nouns between published authors and graduate students are the number of shell nouns being used as CD and the

**IV. CONCLUSION**

The comparative analysis of the use of shell nouns as CD in published articles and graduate students papers revealed that published authors and graduate students used shell nouns in different lexico-grammatical patterns as CDs similarly though published authors used more shell nouns compared to graduate students and the frequency distribution of these shell nouns is scattered. A similar observation was posited when it was claimed that the field of education is concerned with lots of theories, methods and educational practices and implementing and applying methods and practices are often longitudinal and could be the reason for the frequent use of the word processes [5].

It may also be safe to imply that graduate students have to be more exposed to the different shell nouns as used in academic writing and to the usage of shell nouns as a CD, since they should be well thought-out in order to lessen the hasty use that might lead to difficulty in teaching it [12]. With the help of the lexico-grammatical patterns of these shell nouns, it will enhance the organization of their texts but then it should also be emphasized that this is only one type of lexical device [7]. Moreover, knowing the different shell nouns and their functions does not only bring benefits in writing, but it also benefits reading;

“Mature readers use cohesion in text and showed that the increase in the number of CDs, in turn, can improve readers’ comprehension” [13].

Thus, knowledge on lexical cohesion will result to better comprehension, whether in reading or writing, and a wrong or insufficient use of such may affect or break coherence in a text [14].

**REFERENCES**

The Influence of Educational Board Games on Chinese Learning Motivation and Flow Experience

Ju May Wen, Chun Hung Lin, Eric Zhi Feng Liu

Abstract—Flow theory implies that people are persuaded by happiness. By focusing on an activity, people turn a blind eye to external factors. This study explores the influence of educational board games and fundamental Chinese language teaching on students’ learning motivation and flow experience. Fifty-three students studying Chinese language fundamental courses were used in the study. These students were divided into three groups: (1) flash card teaching group; (2) educational original board game teaching group; and (3) educational Chinese board game teaching group. Chinese language teaching was integrated with the educational board game titled “Transportation GO.” The students were observed playing this game as the teacher collected quantitative and qualitative data. Quantitative data was collected from the learning motivation scale and flow experience scale. Qualitative data was collected through observing, recording, and visiting. The first result found that the three groups integrated with Chinese language teaching could maintain students’ high learning motivation and high flow experience. Second, there was no significant difference between the flow experience of the flash card group and the educational original board game group. Third, there was a significant difference in the flow experience and learning motivation of the educational Chinese board game group vs. the other groups. This study suggests that the experimental model can be applied to advanced Chinese language teaching. Apart from oral and literacy skills, the study of educational board games integrated with Chinese language teaching to enforce student writing skills will be continued.

Keywords—Chinese Language Teaching, Educational Board Game, Learning Motivation, Flow Experience.

Ju May Wen is with National Central University, Taiwan (e-mail: wjmnpaper@gmail.com).
The Phonology and Phonetics of Second Language Intonation in Case of “Downstep”

Tayebeh Norouzi

Abstract—This study aims to investigate the acquisition process of intonation. It examines the intonation structure of Tokyo Japanese and its realization by Iranian learners of Japanese. Seven Iranian learners of Japanese, differing in fluency, and two Japanese speakers participated in the experiment. Two sentences were used to test the phonological and phonetic characteristics of lexical pitch-accent as well as the intonation patterns produced by the speakers. Both sentences consisted of similar words with the same number of syllables and lexical pitch-accents but different syntactic structure. Speakers were asked to read each sentence three times at normal speed, and the data were analyzed by Praat. The results show that lexical pitch-accent, Accentual Phrase (AP) and AP boundary tone realization vary depending on sentence type. For sentences of type XdeYwo, the lexical pitch-accent is realized properly. However, there is a rise in AP boundary tone regardless of speakers’ level of fluency. In contrast, in sentences of type XnoYwo, the lexical pitch-accent and AP boundary tone vary depending on the speakers’ fluency level. Advanced speakers are better at grouping words into phrases and produce more native-like intonation patterns, though they are not able to realize downstep properly. The non-native speakers tried to realize proper intonation patterns by making changes in lexical accent and boundary tone.

Keywords—intonation, Iranian learners, Japanese prosody, lexical accent, second language acquisition.

I. INTRODUCTION

A. The Problem

Many studies assume that Japanese has two patterns of lexical accent, with patterns that have a sharp fall from high pitch to low usually called accented and patterns that have no such fall usually called unaccented [1]-[4]. However, Japanese lexical pitch-accent is not typically covered in textbooks, and it is considered a difficult prosodic component for learners of Japanese to acquire [5].

Given the properties of Japanese lexical pitch-accent, earlier studies on the acquisition of Japanese prosody by learners of Japanese concentrated on the realization of lexical accent in isolation [6]-[9]. In other words, the fact that speech is a continuous articulatory stream and lexical accent realization may be affected by prosodic structure has been ignored.

Furthermore, most previous research on second language speech acquisition has focused on the interaction between first (L1) and second (L2) language prosody. Only a few studies on the acquisition of L2 intonation have considered how the phonological and phonetic features of L2 prosody are acquired, which particular features are acquired, and when this acquisition occurs, based on instrumental evidence [10].

Studies on the evaluation of the pronunciation of foreign learners of Japanese assume that a proper production of intonation has more effect on the positive evaluation of foreign learners’ speech [11]. Therefore, recent studies suggest that the teaching of intonation should be a higher priority than segmental or other super-segmental aspects of the Japanese language. Therefore, many studies have been conducted to invent simple but effective methods to facilitate Japanese prosody education [12]. However, current research on the acquisition of Japanese intonation is not sufficient.

B. Intonation Model

Many studies on Japanese intonation acquisition assume a model in which the speech system consists of two components, the phonological and the phonetic [13]. These components, which are independent aspects of intonation, have been strictly differentiated from one another.

For the phonological component, two hierarchical phrasing units at the word level have been defined: the intonational phrase (IP) and the accentual phrase (AP) [14]. The IP is the highest and the largest phrase, consisting of one or more than one AP. Each AP consists of one or more pitch accents.

In the phonetic component, abstract tones are interpolated following certain regularities such as declination (i.e., overall fundamental frequency (F0) downtrends toward the end of the utterance) and downstep (i.e., a stepwise lowering of F0 in high tones) [1], [10].

Ladd [13:9] assumes that the phonological components have various phonetic properties both segmental and super-segmental.

C. Declination Realization in Japanese

Previous studies assume that when an accented word is followed by another accented word in Tokyo Japanese, the F0 peak of the following accented word tends to decrease over the course of the utterance. However, reports of F0 decrease are not limited to accented words, as has been observed by many phonologists and phoneticians [1], [15]. However, Kori [3], [4] suggests that there is also a systematic relation between the syntactic structure of words and downstep. He provides the examples of (1) Na’ra de mo’miji wo Yu’mi to mi’ta (I watched Nara’s autumn leaves with Yumi) and (2) Na’ra no mo’miji wo Yu’mi to mi’ta (in Nara, I watched autumn leaves with Yumi), then indicates instrumentally that although the initial F0 peak of the AP mo’miji wo declines in both structure (1) and structure (2), the F0 peak of mo’miji no in (2) is more declined due to a semantic relation between the two APs. Kori [3], [4] suggested that in (2), the following PA momiji no is restricted by Nara, which is a modification for momoji. However, a similar restriction is not observed in (1). For this reason, he claims that what is known as downstep occurs only in structures that include a semantically restrictive modification.
II. PURPOSE OF STUDY AND HYPOTHESES

In contrast to previous studies that relied on conventional approaches focusing on lexical pitch-accent realization, this study focuses on the effect of syntactic structure on the realization of lexical pitch-accent. It aims to investigate the phonological and phonetic characteristics of Japanese lexical pitch-accent and intonation, as realized by Iranian learners of Japanese.

Based on previous studies [10], we contend that L2 learners acquire the intonational system of the target language in two steps. First, they internalize the phonological structure of L2 intonation, though they still implement these structures using their L1 phonetic habits. Later, learners master native-like phonetic regularities.

Our study focuses on downstep in restrictive modification environments, since downstep affects both the pitch realization and the F0 peak of the APs that follow. Specifically, we made the hypotheses below:

Hypothesis 1. Downstep is a phonetic property observed only in Japanese, not in Persian. However, in Persian, when two APs are in a modification relation they form an IP unit, a tendency similar to that of sentence structure (2). XnoYwo. In other words, since differences in IP formation (which is a phonological property) in restrictive modification structures like XnoYwo between Japanese and Persian are phonologically subtle, it is very likely that the Iranian learners will perceive the L1 and L2 IP formation as similar. Therefore, category formation for L2 IP formation is blocked and a single category will be used for both L1 and L2 IP formation. Given this assumption, we predicted that the Iranian learners may be able to combine the target APs of XnoYwo into one IP, but they would have difficulties in realizing downstep in XnoYwo.

Hypothesis 2. Persian is a stress-accent language, so accent usually falls on the last syllable of nouns, adjectives and most adverbs, and pitch accent contrasts do not exist [16]. In Japanese, downstep affects the initial F0 of the following AP and the degree of the initial F0 rise is affected by the lexical accent type [2], [3]. We thus predicted that Iranian learners of Japanese would have difficulties in producing Japanese lexical pitch-accents, and that lexical accent realization may therefore affect the quality and quantity of the downsteps they realized.

III. EXPERIMENT

A. Subjects

Two major speaker groups were compared: two female native speakers of Japanese (aged 24 and 25) as a control group, and seven female Iranian learners of Japanese (aged from 24 to 28, average age of 24.44) as an experimental group. Subjects in the control group were from Kanagawa and Tokyo, where Tokyo Japanese (standard Japanese) is spoken. Later, two other native speakers (different from the ones in the control group; both females, aged 25 and 35) were paid to evaluate the intonation patterns.

B. Materials

Test sentences were designated to test the degree of declination predicted by the theory of relation between modification restriction and downstep: F0 for a following AP declines due to a semantically restrictive modification by the preceding AP. We applied two sentences consist of similar words with the same number of syllables numbers (two syllables) and lexical pitch-accent (initial mora accented) but with different syntactic structures: Semantically restrictive modification and non-restrictive modification.

The data set for this production experiment is as below:

(1a) ‘Chiba de ‘chizu wo takusan katta.
Chiba-PP map Case many buy-Past Tense
In Chiba, I bought many maps’.

(1b) ‘Chiba no ‘chizu wo takusan katta.
Chiba-Case map-Case many buy-Past Tense
‘I bought many maps of Chiba.

(2a) ‘Naha de ‘umi wo ooi ni tanoshinda.
Naha-PP sea-Case much enjoy-Past Tense
In Naha, I enjoyed the sea much.

(2b) ‘Naha no ‘umi wo ooi ni tanoshinda.
Naha-Case sea-Case much PP enjoy-Past Tense
I enjoyed the sea of Naha much.

C. Procedure

The order of sentences was randomized, and filler sentences were inserted pseudo-randomly to separate each target sentence. The subjects assigned task was to read each sentence t times. The subjects in the experimental group were recorded in a soundproof room at the phonetics laboratory of the Faculty of Foreign Languages at Tehran University in Iran, and those in the control group were recorded at the phonetics laboratory of Tsukuba University in Japan. Finally, in addition to the pitch tracks, to determine which utterances produced by the L2 learners are the most natural and the most native-like, two native speakers were asked to evaluate the nativeness of the target APs in all utterances and score them out of 5.

D. Measurement

For the analysis of phonetic properties, the F0 peak of the two target APs were measured for each sentence. Subsequently, we simply measured the F0 ratio by dividing the F0 peak of the following APs into the F0 peak of the preceding APs. Fig. 1 shows a schematic pitch pattern of the two target sentence types as well as the F0 peak measurement method.

The obtained value reveals the quality and degree of declination. As mentioned earlier, in Japanese, due to declination the following AP is realized with a lower F0 peak in both XdeYwo and XnoYwo structures. Thus, if the value is less than 1, it reveals that a declination has been realized and the possibility for the realization of a normal and native-like intonation increases. If the value is over 1, it shows that the overall intonation is abnormal and less native-like. Furthermore, as it was discussed in IC, since a downstep occurs in XnoYwo, it is expected that the initial F0 in the following AP of XnoYwo is realized steeper and lower than that of XdeYwo.

Fig. 1 Schematic pitch tracks of two heading target APs of sentence type XdeYwo (Solid line) and sentence type XnoYwo (dotted line)
IV. RESULTS AND DISCUSSION

A. Phonology of L2 Intonation

The pitch tracks of representative speakers are shown in Figs. 1-6. These figures can be used to compare the phonological aspects of the speech of both groups, such as lexical pitch-accent and phrasal tones, as well as the phonetic aspects, such as the realization of declination in the following AP Ywo in XdeYwo and the realization of downstep in the following AP Ywo in XnoYwo. In the figures, there are two pitch tracks that show the first two target APs of each sentence. The pitch tracks of the solid line show the structure XdeYwo, and the pitch tracks of the dotted line show the structure XnoYwo.

Figs. 2 and 3 show the pitch tracks of native speakers. As we mentioned earlier and as these figures illustrate, the F0 peak in the following AP Ywo is not realized as sharply as the F0 peak in Xwo, neither in XdeYwo nor in XnoYwo. In other words, in both structures, a declination appears in the second AP. However, there are differences in the intonational phrasing of XdeYwo and XnoYwo: in XdeYwo, the preceding AP Xde and the following AP Ywo are realized in two separated IPs, whereas in XnoYwo, the two APs form a unit IP. In both structures, the AP boundary is realized with an L boundary tone.

Figs. 4-7 show the pitch tracks of representative Iranian speakers. As these figures illustrate, in almost all learners’ utterance of XdeYwo, each prosodic word and its past position are realized as one AP with a proper lexical pitch accent. However, each AP is realized with a rise in the AP boundary. Due to this rise, the F0 of the second AP is realized as high or higher than that of the first. Finally, the preceding AP, as well as the following AP, form separate IPs.

In contrast, the overall intonation pattern of XnoYwo varies by speaker. The first pattern is shown in Fig. 4, in which the intonation of XnoYwo is realized similar to the manner of XdeYwo described above. This type of intonation, in which neither the IP formation nor the downstep is realized properly, is observed in the utterances produced by S1, S2, and S3.

The second pattern is shown in Fig. 5, in which the lexical pitch-accent of the preceding AP Xno is realized as if it were composed of Japanese unaccented words. It is also similar to
the Persian lexical accent, in which the last syllable of the word is realized more prominently. Moreover, the two APs form an IP unit. However, the IP boundary is realized as an H tone.

The third pattern is shown in Figs. 6 and 7, where the overall intonation of XnoYwo is similar to that of the native speakers’ intonation in Figs. 2 and 3. In other words, the lexical pitch-accent, the AP boundary tone, and the intonation formation for S6 and S7 are more native-like than the other speakers.

Fig. 4 Utterances produced by S2. Solid line= Naha de umi wo, dotted line= Naha no umi wo

Fig. 5 Utterances produced by S5. Solid line= chiba de chizu wo, dotted line= chiba no chizu wo
B. Phonetics of L2 Intonation

For *XdeYwo*, almost all learners realized the lexical pitch-accent properly. They also properly realized each AP in separated IPs. However, they did not realize the AP boundary properly. It can be assumed that almost all learners acquired the proper phonology of *XdeYwo*, except for the AP boundary tone. In contrast, S4 and S5 realized the two APs as an IP unit in *XnoYwo* but tended to realize the preceding AP as an unaccented word. Moreover, S6 and S7 realized the lexical pitch-accent properly in all APs and their boundary tone was more native-like. It could therefore be suggested that S6 and S7 successfully acquired the phonology of *XnoYwo*. Does this mean that the acquisition of *XnoYwo* was complete? This remains to be seen. Further examination of the data with respect to phonetic properties may show more contrast between the learners and native speakers.

As mentioned earlier, in order to investigate the phonetic properties of native speakers’ utterances, as well as those of Iranian learners of Japanese, we measured the F0 peak value of the preceding and following AP of each utterance. We also measured the F0 ratio of the two APs for both structures, *XdeYwo* and *XnoYwo*. The results are shown in Fig. 8.

As shown in Figs. 2 and 3, the pitch tracks of the native speakers suggest that, regardless of syntactic structure, the F0 peak in the following AP is always realized steeper than the F0 peak in the preceding AP. Therefore, the F0 ratio must be less than 1. As mentioned earlier, if the mean of the F0 ratio is less than 1, it can be inferred that the learners’ utterance is more native-like. Moreover, if the value of the F0 ratio is around 0.67 (e.g., native speakers’ F0 ratio for *XnoYwo*), it can be inferred that learners can realize downstep as successfully as native speakers.

However, the results reveal that in *XdeYwo* the F0 ratio for S4 and S5 is greater than 1. Further, the F0 ratio of S1, S2, S3, and S6 is near 1. The F0 ratio for S7 is the lowest and is therefore most likely to be native-like.

In *XnoYwo*, though, it was expected that the mean F0 ratio would be less than that of *XdeYwo*. This was not the case. Instead, there was an increase in the F0 peak of the following AP of *XnoYwo* for S1, S2, and S6. In contrast, the mean F0 ratio of *XnoYwo* for S4, S5, S6, and S7 indicates that the F0 peak of the second AP was realized steeper than that of *XdeYwo*. However, there is still a considerable difference...
between the F0 ratio of these speakers and that of the native speakers.

A paired-sample t-test was also conducted in order to compare the F0 ratio of XdeYwo and XnoYwo separately for each speaker. As shown in Fig. 9, there was a significant difference in the F0 ratio of XdeYwo (NS1: M = 0.89, SD = 0.06; NS2: M = 0.84, SD = 0.03) and XnoYwo (NS1: M = 0.67, SD = 0.02; NS2: M = 0.69, SD = 0.02) for the two native speakers (NS1: t(5) = 8.28, p < 0.001; NS2: t(5) = 4.11, p < 0.001). Our results suggest that the F0 peak in the following AP of XnoYwo is realized lower than the F0 peak of XdeYwo. It assumes that in XnoYwo, a downstep is realized in the native speakers’ utterance, as expected. However, considering the mean F0 ratio of all the learners except S7, no one can make such a reduction in the following AP of XnoYwo.

**Fig. 8 Mean of F0 ratio between the first two APs of XdeYwo and XnoYwo**

**Fig. 9 Paired sample t test results for each speaker**

**C. Evaluation of the Native-Like Qualities of Speech**

The results of the native speakers’ evaluation of the speech by the two groups showed that type 3 is the most native-like intonation pattern. Surprisingly, although in intonation pattern type 1, two target APs were realized in two separate IPs, it was shown to be more native-like than intonation type 2, in which the two target APs were phrased and formed one IP unit. The native speakers claimed that none of these intonation patterns were natural. However, since type 1 was realized in two APs with a high AP boundary tone, it reminds them of a Japanese accent realized by a foreign learner. In contrast, type 2—in which the word is pronounced with an unaccented lexical pitch-accent—reminds them of an atypical Japanese person’s accent. However, they were not sure where in Japan this accent originates.

**V. Conclusion**

In this work, we have proposed a framework for the development of instrumental studies about the realization of Japanese intonation, particularly downstep in the speech of Japanese language learners. Specifically, this experiment tested two hypotheses regarding the phonological properties of speech (such as the lexical pitch-accent and IP formation) as well as the phonetic properties of speech (such as downstep) in the speech production of Iranian learners of Japanese. We presented two syntactic structures, both similar in the number of syllables and word order but different in prosodic structure. The first two APs were not in a restrictive modification relation in the first type, but they were in the second type. Comparing these two prosaically different structures, we were able to investigate if the utterances of learners were realized with an appropriate F0 lowering (i.e., declination in XdeYwo and downstep in XnoYwo) in accordance with the prosodic structure. The results of S7 indicate that it is not impossible to acquire native-like downstep in one’s L2. S7 exhibits F0 values which are similar to those produced by native speakers of Japanese. However, it is difficult to explain her success based solely on the data of this study.

Although only a very small number of the subjects produced a Japanese intonation with an almost native-like pitch track, our preliminary results could partially support the theory that the phonological properties of a speech system are acquired earlier than the phonetic properties. Moreover, the results show that at the phonological level most learners failed to produce the AP boundary tones of XdeYwo correctly, though they could all produce the lexical pitch-accent. All this suggests a few key findings: that different phonological aspects are acquired at different stages in the learning process, that lexical pitch-accent is acquired earlier than AP boundary tones, and that AP boundary is the most difficult phonological aspect of speech to acquire.

Moreover, at the phonetic level the results show that most learners were not able to properly realize declination and downstep, as the F0 peak of the following AP was realized even more sharply than the preceding AP. One of the causes of this is that the AP boundary was raised and realized as a high tone. It can be assumed that since the AP boundary was not acquired and realized properly, the F0 peak for the following AP could not be realized steeper.

Another new finding of the study was that learners’ grouping phrases and making greater units is not necessarily equal to a natural and acceptable pronunciation, according to the evaluation of native Japanese speakers.

To our knowledge, this may be the first work that has pointed out that the lexical accent realization of Japanese language learners differs by sentence structure, even when the word order and number of syllables are the same. There have been many studies that focus on Japanese prosody education and claim that is not important to teach Japanese lexical pitch-accent, since it is so complicated [12]. However,
this approach that focuses narrowly on intonation form is not very helpful for learners and can often lead to advanced students producing an uncommon accent of Japanese that is not typical of foreigners or native Japanese speakers. It can be theorized that the application of a more systematic prosody education that covers both lexical pitch accent and intonation properties would motivate learners to learn Japanese prosodic features more deliberately.

Our further work will be comprised of three stages. First, we will focus on extending the size of the data set for a more detailed analysis. We then intend to conduct the same experiment on learners who have acquired the correct intonation and observe if they are able to produce the right intonation consciously. Our final task will be to determine which of the two sentence types are different in degree of declination in the following AP.

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REFERENCES

Abstract—This study investigates a newly emerged usage of Chinese numeral classifier méi (枚) in the cyberspace. In modern Chinese grammar, méi as a classifier should occupy the pre-nominal position, and its valid accompanying nouns are restricted to small, flat, fragile inanimate objects rather than humans. To examine the semantic change of méi, two types of data from Weibo.com were collected. First, 500 méi-included Weibo posts constructed a corpus for analyzing this classifier's word order distribution (post-nominal or pre-nominal) as well as its accompanying nouns' semantics (inanimate or human). Second, considering that méi accompanies a remarkable number of human nouns in the first corpus, the second corpus is composed of méi-involved Weibo IDs from users located in first and third-tier cities (n=8 respectively). The findings show that in the cyber community, méi frequently classifies human-related neologisms at the archaic post-normal position. Besides, the 23 to 29-year-old females as well as Weibo users from third-tier cities are the major populations who adopt méi in their user IDs for self-description and identity expression. This paper argues that the creative usage of méi gains popularity in the Chinese internet due to a humor effect. The marked word order switch and semantic misapplication combined to trigger incongruity and jocularity. This study has significance for research on Chinese cyber neologism. It may also lay a foundation for further studies on Chinese classifier change and Chinese internet communication.

Keywords—Chinese classifier, Humor, Neologism, Semantic change.

Hui Shi is with the Department of East Asian Languages and Literatures, University of Oregon, Eugene, OR 97401 USA (e-mail: hshi@uoregon.edu).
Abstract—The last decade has witnessed more people than ever before using social media and broadening their social circles. Social media users connect not only with their friends but also with professional acquaintances, primarily coworkers and clients; personal and professional social circles are mixed within the same social media platform. Considering the positive aspect of social media in facilitating communication and mutual understanding between individuals, we infer that social media interactions with co-workers could indeed benefit one’s professional life. However, given privacy issues, sharing all personal details with one’s co-workers is not necessarily the best practice. Should one connect with coworkers via social media? Will social media connections with coworkers eventually benefit one’s long-term career? Will the benefit differ across cultures? To answer, this study examines how social media can contribute to organization communication by tracing the foundation of user motivation based on social capital theory, leader-member exchange (LMX) theory and expectancy theory of motivation. Although social media was originally designed for personal communication, users have shown intentions to extend social media use for professional communication, especially when the proper incentive is expected. To articulate the user motivation and the mechanism of the incentive expectation scheme, this study applies those three theories and identify six antecedents and three moderators of social media use motivation including social network flaunt, shared interest, perceived social inclusion. It also hypothesizes that the moderating effects of those constructs would significantly differ based on the relationship hierarchy among the workers. To validate, this study conducted a survey to 329 active social media users with acceptable levels of job experiences. The analysis result confirms the specific roles of the three moderators in social media adoption for organizational communication. The present study contributes to literature by developing a theoretical modeling of ambivalent employee perceptions about establishing social media connections with co-workers. This framework shows not only how both positive and negative expectations of social media connections with co-workers are formed based on expectancy theory of motivation, but also how such expectations lead to behavioral intentions using career success model. It also enhances understanding on how various relationships among employees can be influenced through social media use and such usage can potentially affect both performance and careers. Finally, it shows how cultural factors induced by social media use can influence relations among the coworkers.

Keywords—Social network, workplace, social capital, motivation theory.
Abstract—This paper reports on a joint research project in which a researcher in applied linguistics and elementary school teachers in Japan explored new ways to realize emotional synchrony in a classroom in childhood education. The primary purpose of this project was to develop a cross-curriculum of the first language (L1) and second language (L2) based on the concept of plurilingualism. This concept is common in Europe, and can-do statements are used in forming the standard of linguistic proficiency in any language; these are attributed to the action-oriented approach in the Common European Framework of Reference for Languages (CEFR). CEFR has a basic tenet of language education: improving communicative competence. Can-do statements are classified into five categories based on the tenet: reading, writing, listening, speaking/interaction, and speaking/speech. The first approach of this research was to specify the linguistic proficiency of the children, who are still developing their L1. Elementary school teachers brainstormed and specified the linguistic proficiency of the children as the competency needed to synchronize with others—teachers or peers—physically and mentally. The teachers formed original can-do statements in language proficiency on the basis of the idea that emotional synchrony leads to understanding others in communication. The research objectives are to determine the effect of language education based on the newly developed curriculum and can-do statements. The participants of the experiment were 72 third-graders in Uji Elementary School, Japan. For the experiment, 17 items were developed from the can-do statements formed by the teachers and divided into the same five categories as those of CEFR. A can-do checklist consisting of the items was created. The experiment consisted of three steps: first, the students evaluated themselves using the can-do checklist at the beginning of the school year. Second, one year of instruction was given to the students in Japanese and English classes (six periods a week). Third, the students evaluated themselves using the same can-do checklist at the end of the school year. The results of statistical analysis showed an enhancement of linguistic proficiency of the students. The average results of the post-check exceeded that of the pre-check in 12 out of the 17 items. Moreover, significant differences were shown in four items, three of which belonged to the same category: speaking/interaction. It is concluded that children can get to understand others’ minds through physical and emotional synchrony. In particular, emotional synchrony is what teachers should aim at in childhood education.

Keywords—Elementary school education, emotional synchrony, language proficiency, sympathy with others.

Reiko Yamamoto is with the Department of English Studies for Careers, Kyoto Junior College of Foreign Languages, 6 Kasamecho, Ukyoku, Kyoto, 6158558 Japan (e-mail: re_yamam@kufs.ac.jp).

I. INTRODUCTION

LANGUAGE education for children is expected to improve their basic linguistic proficiency. The first language (L1) for children in Japan is Japanese. In this monolingual country, Japanese is the only subject in elementary school language education. As children can easily interact with others in L1, literacy rather than oral communication is judged as linguistic proficiency. In 2011, however, the Japanese Ministry of Education, Culture, Sports, Science and Technology finally introduced English activities into elementary schools. Since then, many classrooms have been filled with meaningful English interaction through words or gestures. Moreover, it is observed that children are not only likely to move their bodies but also express their emotions in the same way as their teachers. English is their second language (L2), and it has become apparent that L2 education is quite distinct from L1. This radical change—the introduction of English activities—in primary education therefore has the potential to revolutionize language education.

II. LITERATURE REVIEW

When students interact with their teacher, they move their bodies in the same way as the teacher does, with the same rhythm [1]. This reaction is defined as “synchrony,” and in a classroom it is necessary for students in activities to connect with each other [1]. There is evidence that synchrony is an innate and fundamentally necessary part of the human ability to engage in social interaction with other people, since people complete some shared communication tasks in the presence of one another [2]. Synchrony can also more generally facilitate the performance of cognitive or linguistic tasks [3].

In acquiring language, younger students are more influenced by the experience of emotion [4]. Reference [5] argued that the automatic and unconsciously embodied simulation of another’s actions, intentions, and emotions is due to neurological mechanisms, and the embodied simulation constitutes a fundamental and functional mechanism for empathy and understanding another person’s mind. Internal representations of the body states associated with the emotions are evoked in the observer, “as if” he or she were doing a similar action or experiencing a similar emotion [5].

It is easy to imagine that children find it difficult to simulate teachers’ or peers’ emotions in L2 communication. However, some children cannot simulate emotions, even in L1 [6]. This leads to the argument that simulating another’s emotions is a
common underlying proficiency in all languages. Based on the dual-iceberg model, which was propounded by [7] and [8], a model of the lack of such proficiency in L2 is suggested in Fig. 1 [9].

![Fig. 1 The lack of common underlying proficiency in L2 [9]](image)

In order to grow students’ common underlying proficiency, it might be effective to integrate L1 and L2 education with the concept illustrated in Fig. 1. Previous researchers have asserted that physically synchronizing with others leads to sharing the same emotions with them. "Emotional synchrony” is a term to mean sharing the same emotions with others, or understanding others in communication. It is a common underlying proficiency.

The concept of plurilingualism has never been common in Japan. Therefore, it has fallen behind amid the global trend since the 1990s, wherein many non-English-speaking countries have assigned English as a subject in elementary school. This is an opportunity to prove that L2 learning does not hinder L1 acquisition, but rather helps students realize that the essence of communication is the same in any language. The research team for this study consisted of elementary school teachers and researchers at a university, who started a project to integrate Japanese (L1) and English (L2) education.

Plurilingualism is different from multilingualism. The Council of Europe defines multilingualism as a term to express the situation of societies, and plurilingualism as a term to express the competency and worth of each person [10]. To be more specific, plurilingualism describes a situation wherein several languages are used in a society. On the other hand, plurilingualism describes a situation wherein one person has integral competence in using more than two languages, and his/ her values are not limited to only using his/ her L1 for communication. Plurilingualism is a useful term when developing language education goals. Education for plurilingualism is described as a way to develop a learner’s language repertoire, which covers his/her lifelong learning [11]. Language education is not limited to schools, but schools have a central function without an alternative to realize plurilingualism [12].

Unlike Japan, an isolated country, plurilingualism is a common concept in Europe. Can-do statements are used to show standards of linguistic proficiency in any language, which is attributable to the action-oriented approach in the Common European Framework of Reference for Languages (CEFR). There are five categories of can-do statements: reading, writing, listening, speaking/ interaction, and speaking/ speech. A basic tenet of language education in CEFR is improving communicative competence [13].

### III. RESEARCH QUESTIONS

This study is based on the idea that a common underlying proficiency is to simulate another’s emotions. As children can associate bodily states with emotions, physical synchrony with others can be associated with emotional synchrony. Therefore, if both L1 and L2 language classes focus on realizing some kind of synchrony in a classroom, then children’s linguistic proficiency might improve.

The research questions of this study are:
1) What kind of can-do statements list can check common underlying proficiency of L1 and L2?
2) How does linguistic proficiency of children improve through one-year of instruction?

The goal of this study is to answer these research questions.

### IV. METHODOLOGY

#### A. Participants

Uji Elementary School, Kyoto, Japan, took part in this experiment. It is a general-size metropolitan school. The participants were 72 third-grade students, who were divided into three classes.

#### B. Procedure

The process of the research had five steps:
1) Specifying linguistic proficiency,
2) Developing the cross-curriculum of L1 and L2,
3) Forming can-do statements,
4) Creating a can-do checklist, and
5) Executing the experimental lessons for a school year.

The primary purpose of this project was to develop an L1 and L2 cross-curriculum based on the concept of plurilingualism. It was executed by a joint team of a researchers in applied linguistics and elementary school teachers. As for Step 1, Step 2, and Step 3, the details were reported in [14]. All the teachers in Uji Elementary School brainstormed and specified the linguistic proficiency of children as the competency needed to synchronize with others--teachers or peers--physically and mentally. The excerpted data of their utterances in brainstorming is as follows:

The linguistic proficiency of children is:
- To utilize gestures or eye contact to be understood,
- To change voice tones or strength in speaking,
- To notice another’s movement or rhythm, and synchronize with them,
- To feel as if one is in another’s position, and
- To notice one’s friends’ sadness, even when they smile.

Excerpts above referred to synchrony with teachers or peers not by using words, but with the mind. It is interesting to note that the teachers judged non-verbal physical or mental movement as linguistic proficiency.

Next, the joint project members integrated L1 and L2 curriculums into a cross-curriculum by focusing on tasks for arousing synchrony with teachers or peers. Based on this
curriculum, original can-do statements in language proficiency were formulated. Not all factors in the teachers’ definition of linguistic proficiency, however, overlapped with can-do statements. The teachers also determined a kind of metaphysical item that can hardly be judged as can or cannot.

In Step 4, a can-do checklist was created for the experiment. It was intended to let the children evaluate themselves in linguistic proficiency, and was written with simple expressions for them to easily understand. It consisted of 17 items that were developed from the can-do statements formed by the teachers, divided into the same five categories as those of CEFR: reading, writing, listening, speaking/interaction, and speaking/speech. The original list was written in Japanese, but Table I shows the translated English version.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Items</th>
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<tbody>
<tr>
<td>Reading</td>
<td>1. I can read aloud paying attention to sound.</td>
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<tr>
<td></td>
<td>2. I can read aloud conveying contents and scenes.</td>
</tr>
<tr>
<td></td>
<td>3. I can read silently tasting images and beauty.</td>
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<td></td>
<td>4. I can listen tasting sound and rhythm.</td>
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<td></td>
<td>5. I can listen not to miss what is significant.</td>
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<td></td>
<td>6. I can listen to peers’ thoughts, comparing them to my own.</td>
</tr>
<tr>
<td></td>
<td>7. I can speak to make my idea understood.</td>
</tr>
<tr>
<td>Listening</td>
<td>8. I can speak clearly, caring my posture and voice.</td>
</tr>
<tr>
<td></td>
<td>9. I can make presentations showing pictures or some charts.</td>
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<tr>
<td></td>
<td>10. I can change my manner of speaking according to the person I speak to.</td>
</tr>
<tr>
<td>Speaking/Speech</td>
<td>11. I can use gestures or eye contact in speaking.</td>
</tr>
<tr>
<td></td>
<td>12. I can express my feeling of thanks or happiness.</td>
</tr>
<tr>
<td></td>
<td>13. I can change my voice pitch, strength, or pauses.</td>
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<tr>
<td></td>
<td>14. I can react to my peers’ speech.</td>
</tr>
<tr>
<td></td>
<td>15. I can write paying attention to connections of words or sentences.</td>
</tr>
<tr>
<td>Writing</td>
<td>16. I can express my ideas clearly in writing.</td>
</tr>
<tr>
<td></td>
<td>17. I can write with interest in the shape or meaning of Japanese letters.</td>
</tr>
</tbody>
</table>

The experiment consisted of three steps:
1) The children evaluated themselves using the can-do checklist at the beginning of the school year.
2) One year of instruction was given to the children in Japanese and English classes (Japanese: five periods a week; English: once a week).
3) The children evaluated themselves using the same can-do checklist at the end of the school year.

C. Results
The children answered either yes or no to each item. The scale was converted into points (Yes: 1 point; No: 0 points). In Table II and Fig. 2, the average of the children is compared item by item.

Pre- and post-check scores of each item were compared and analysed statistically. A statistical significance between pre- and post-check was found with Item 6, Item 10, Item 12, Item 13, and the total score of 17 items (See Table III).

The average of the total score increased from 11.013 (the full score is 17) to 11.903 between pre- and post-check. No significant difference was found (p> 0.05), but the effect size was proved to be large ($d=16.60$).

V. Findings
The average results of the post-check exceeded that of the pre-check in 12 out of the 17 items in the can-do checklist. Significant differences were proved in the statistical analysis in four of the 17 items. Item 6, I can listen to peers’ thoughts, comparing them to my own, belonged to the category “Listening” in the can-do checklist. Moreover, three items belonged to the category “Speaking/Interaction”: Item 10, I can change my manner of speaking according to the person I speak to; Item 12, I can express my feelings of thanks or
happiness; and Item 13, I can change my voice pitch, strength, or pauses. Significantly, the children paid more attention to interaction with others than before starting the experiment. Most importantly, they now tried to understand the person whom they speak to, to make themselves understood by him/her, and to share emotions.

VI. CONCLUSION

This study had two research questions. The first one was: what kind of can-do statements can check common underlying proficiencies of L1 and L2? Specifying linguistic proficiency in teachers’ brainstorming led to the idea that those linguistic proficiencies incorporate the ability to sympathize with others. It was also proved that the same five categories of can-do statements as those of CEFR can be adopted into the can-do check list for common underlying L1 and L2 proficiencies.

The second research question was: how does the linguistic proficiency of children improve through one-year instruction? The results of the experiment prove that the third graders of an elementary school were conscious of their improvement in linguistic proficiency. Probably unconsciously, they nonetheless utilized facial expressions or gestures, or arranged their ways of speaking, which aroused the reaction of the person they speak to, i.e., the listener’s physical synchrony with them, speakers. On the contrary, the children embodied simulation of teachers’ or peers’ actions and intentions, which led to the feeling that they listened to peers’ thoughts, comparing them to their own.

The main conclusion is that children can understand others’ minds through physical movement or senses in any language when they are instructed appropriately, and that emotional synchrony should be the central concept in language instruction in childhood education.

REFERENCES

Abstract—The proposed paper is a manuscript named Attitudes of Students with Learning Disabilities Toward Participation in Physical Education: A Teachers’ Perspective - Qualitative Examination. Many researchers have confirmed that students with disabilities engage in significantly less physical activity than their nondisabled peers in physical education class. One of the elements that influences students’ participation in physical education class is attitude. This study looks at specifically 2 attitude components of enjoyment and usefulness. Teachers’ perceptions of students’ attitude with learning disabilities toward participation in physical education were assessed through semi-structured interviews of teachers. There is a gap in the literature with respect to investigating the attitudes of students with learning disabilities, emotional/behavioral disabilities, or attention difficulties. While there is research indicating lack of participation in physical education class, there is limited research on how teachers perceive and assist students to participate in physical education.

This qualitative case study was framed by two research questions, which were explored through personal, one-on-one interview sessions. Two components framework of attitude, affective (enjoyment) and cognitive (usefulness) were characterized in the study. The following questions reflected vital elements of teachers’ experiences and perceptions in working with learning disable students and attitude behavior of physical activity during physical education class. The outcome of this research can contribute to assist teachers with the attitudes of learning disabled students in physical education class. The applications emerging from the study shall become part of the best practices that are suggested by the interviews.

Q 1. What are physical education teachers’ perceptions and experiences in working with learning disabled students in their classes with respect to enjoyment and usefulness attitude components?

Q 2. How would physical education teachers describe the attitudes and behaviors of learning disabled students in their classrooms?

Key finding of the study extracted from the interviews revealed seven major dimensions: (a) enjoyment, (b) usefulness, (c) inclusion, (d) co-education, (e) limited lack of physical education, (f) factors in lack of physical education, and (g) suggestions and experiences. Education staff have meaningful jurisdiction throughout all these factors. Considerations of known factors influencing the attitudes of students with learning disabilities toward physical education may result in progressive consequences. Using teachers’ perceptions and suggested strategies, this study was designed to assist and inform future practice related to teaching of physical education to students with learning disabilities. This research may someday shape policies and approaches toward instilling positive outlooks in young people with learning disabilities toward physical activity in physical education.

Ellie Abdi is with Montclair State University, USA (e-mail: ellieabdi@verizon.net).

Keywords—Attitude, Enjoyment, Usefulness, Learning Disabilities.