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VALORACIÓN DE DESECHOS DE BANANO (MASA ACUMINATA CAVENDISH SUBGROUP) Y CACAO (THEOBROMA CACAO) MEDIANTE PRODUCCIÓN DE COMPOST Y BIOL

EVALUATION OF BANANA WASTE (MASA ACUMINATA CAVENDISH SUBGROUP) AND COCOA (THEOBROMA CACAO), THROUGH THE PRODUCTION OF COMPOST AND BIOL

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RESUMEN

El presente proyecto se centra en el aprovechamiento ecológico de desechos de banano (*Musa Acuminata* Cavendish Subgroup) y cacao (*Theobroma cacao*), tomando como caso de estudio la hacienda Secadal del cantón Naranjal (Guayas-Ecuador). En apenas cinco semanas, la mezcla de *B. subtilis*, melaza, *Trichoderma*, desechos de cacao y banano, y tierra para sembrar, fue el mejor tratamiento para mineralizar la materia orgánica y así producir una fracción sólida considerada como compost y una fracción líquida considerada como biol. Se reportan los siguientes resultados: pH cercano a 7, temperatura mesofílica, contenidos de materia orgánica > 7,6 %, carbono > 4,40 %, conductividad eléctrica > 11,38 mS/cm, sólidos totales > 67,89% y sólidos volátiles > 25,34%. De la cantidad de desechos orgánicos tratados, aproximadamente un 50% fue compost y 22% biol.

PALABRAS CLAVES

Biol, Desechos orgánicos, Biotransformación, Eco-balance, Digestión anaeróbica.

ABSTRACT

*The present project focuses on the ecological use of banana waste (*Musa acuminata* Cavendish Subgroup) and cocoa (*Theobroma cacao*), taking as a case study the Secadal farm of the Naranjal canton (Guayas-Ecuador). In just five weeks, the mixture of *B. subtilis*, molasses, *Trichoderma*, cocoa and banana wastes, and land for sowing, was the best treatment to mineralize organic matter and thus produce a solid fraction considered as compost and a liquid fraction considered as biol. The following results are reported: pH close to 7, mesophilic temperature, organic matter contents > 7.6%, carbon > 4.40%, electrical conductivity > 11.38 mS / cm, total solids > 67.89% and solids volatile > 25.34%. Of the amount of organic waste treated, approximately 50% was compost and 22% biol.*

KEYWORDS

Biol, Organic waste, Biotransformation, Eco-balance, Anaerobic digestion.

1. INTRODUCCIÓN

En las últimas décadas, la población mundial aumentó a 6.000 millones de habitantes, trayendo como consecuencia que los países de altos ingresos generen alrededor de 683 millones de toneladas de desechos, y esto solo representa un 34 % de desechos a nivel mundial (Aslam *et al.*, 2019; Kaza *et al.*, 2018). Se han proyectado 3,40 billones de toneladas de desechos para 2050, en donde los desechos generados por persona promediarían a 4,54 Kg diarios (Aslam *et al.*, 2019; FAO, 2019). Contribuyen también las malas prácticas agrícolas, puesto que alrededor del 14 % de los alimentos producidos se pierde desde la postcosecha hasta la etapa de comercio minorista (FAO, 2019; Ferronato y Torretta, 2019; Paritosh *et al.*, 2017). Por ejemplo, el cacao es uno de los primeros eslabones de la cadena agroindustrial mundial generando más de 120 mil millones de dólares, pero también con grandes aportes al desecho agrícola (Arvelo *et al.*, 2016).

La gestión de residuos sólidos (GRS) en los países en desarrollo representa una verdadera preocupación ambiental y social pues la opción de “tratamiento” es solamente una disposición final en vertederos abiertos o en rellenos sanitarios inadecuados (Bayard *et al.*, 2018; Ferronato *et al.*, 2019) leaching behavior, contents in biochemical constituents (determined by Van Soest’s acid detergent fiber method. Por ejemplo, en Ecuador, cada habitante produce en promedio alrededor de 0,58 kilogramos de residuos sólidos, de los cuales el 54% es residuo orgánico (Morán, 2018). En específico, tomando como ejemplo al cacao y al banano, principales motores de la economía de Ecuador, se ha tratado de buscar solución a la gestión de residuos agrícolas sin éxitos de gran impacto. Por tanto, en el presente trabajo se reporta la aplicación de medidas sostenibles basadas en el compostaje de desechos del banano y cacao de una pequeña hacienda de Ecuador.

2. MATERIALES Y MÉTODOS

Se recolectaron y secaron al sol desechos fibrosos del raquis de banano, cáscaras de cacao y cáscaras de naranja. Para el presente proyecto se utilizaron aproximadamente 2 Kg de desechos orgánicos. Mediante

trituration, se pulverizaron los desechos hasta un tamaño de partícula menor a 1 cm. Los desechos fueron colocados en lechos de madera; cada lecho tuvo 37 cm de ancho y 23 cm de alto. Como cultivos iniciadores, se utilizaron disoluciones de *Bacillus subtilis* y *Trichoderma* (2 g del cultivo en un litro de agua). La mezcla de los triturados y cultivos iniciadores, así como desechos de cáscaras de naranja, y frutos en descomposición de banano, fueron mezclados y mezclados periódicamente, según los respectivos tratamientos que se muestran en la Tabla 1.

Tabla 1. Tabla de tratamientos.

Componentes	Trat. 1	Trat. 2	Trat. 3	Trat.4
(i) <i>B. subtilis</i>	250 ml	250 ml	-	-
(ii) Melaza	20 ml	20 ml	20 ml	-
(iii) <i>Trichoderma</i>	70 ml	-	70 ml	-
(iv) Desechos de cacao y banano	370 g	-	-	185 g
(v) Tierra para sembrar	100 g	100 g	100 g	100 g
(vi) Banano (Fruto)	-	370 g	-	92,5 g
(vii) Cáscara de naranja	-	-	370 g	92,5 g

El pH y la temperatura fueron medidos periódicamente en cada lecho mediante sondas paramétricas. La concentración de carbono y materia orgánica se determinó mediante titulación. Se agregó 0,5 g de muestra y 5 ml de dicromato de potasio y ácido sulfúrico dejándolos por 30 minutos; luego, se agregó 35ml de agua destilada, y bajo calentamiento a 100°C se mantuvo durante 1 hora. Una vez que se terminó el proceso, esto fue filtrado y colocado en una celda, para medición en espectrofotómetro.

Para la determinación del porcentaje de sólidos totales (ST), se utilizó el método ISO11465:1993. Se pesó aproximadamente 20 g de muestra sólida en una cápsula de porcelana seca y pre-pesada en una balanza analítica (Sartorius, USA). Esta muestra se secó en una estufa (POL-EKO) a 105°C durante 24 horas. La muestra seca se enfrió en un desecador y se volvió a pesar.

Para obtener el contenido de sólidos volátiles (SV) mediante gravimetría, se colocó la cápsula con muestra a 105°C en una mufla (Snol, USA). Se aumentó lentamente la temperatura hasta llegar a 550°C, donde permaneció por 2 horas (calcinación). Luego se enfrió en un desecador para luego pesar la cápsula en una balanza analítica (Sartorius, USA).

Para establecer la normalidad de las poblaciones, se utilizó la prueba estadística de ANOVA. Se estableció el método de un solo factor dentro del programa MINITAB para así saber si existe una diferencia estadísticamente significativa entre las poblaciones. Cada una de estas pruebas se las evaluó con los resultados del valor de la probabilidad. Se utilizó el 95% de nivel de confianza dentro de las pruebas. Debido a que son más de 2 poblaciones y el valor de p resultó $p < 0,010$, también a la falta de muestras del proyecto, no se pudo completar el análisis propuesto: la prueba t-Student. Por ende, se realizó un análisis donde se establecieron los supuestos, lo que involucró a la normalidad en las poblaciones para establecer esta nueva estadística no paramétrica de Wilcoxon.

3. RESULTADOS

Se determinaron los cambios de pH y temperatura durante 5 semanas (Figuras 1 y 2). Todos los datos que se obtuvieron durante el muestreo fueron ingresados en el programa estadístico Minitab 16. Durante las 5 semanas, los lechos de compostaje liberaron calor, así como vapor de agua.

Figura 1. Cambio de temperatura en función de 5 semanas. Valores mostrados de todos los tratamientos.

Figura 2. Cambio de pH para todos los tratamientos en 5 semanas.

Los tratamientos 1, 2 y 4, fueron los únicos que produjeron un producto sólido y uno líquido. En la Figura 3, del total de desechos orgánicos que fueron utilizados para el compostaje (1880 g), aproximadamente un 50,3% (947,2 g) fueron materia sólida, considerada como compost según los resultados de materia orgánica y carbono total; además, de la cantidad total de muestra inicial, un 22,1 % (415,3 g) estuvieron en estado líquido, lo que se consideraría como biol, según los análisis químicos realizados.

Figura 3. Obtención de compost y biol a partir de desechos orgánicos.

Como se observa en la Figura 4, el contenido de materia orgánica se mantuvo entre 8 y 14 % en los cuatro tratamientos; y la cantidad de carbono en los tratamientos, estuvo entre 4 y 8 %. De los cuatro tratamientos, los tratamientos 1 y 2 obtuvieron mayores contenidos de materia orgánica y carbono, ambos con la adición de melaza, *Trichoderma* y *Bacillus subtilis*; se obtuvo una concentración de materia orgánica entre 8,86 y 11,25% y de carbono total entre 5,11 y 6,51 %; estos valores son primordiales debido a que éste establecerá la calidad del compost y el biol antes de que sean utilizados.

Figura 4. Porcentajes de análisis químico de carbono y materia orgánica.

Los tratamientos 1, 2 y 4, fueron los únicos que obtuvieron un producto líquido, conocido como biol. Como se observa, los valores más altos de conductividad eléctrica los obtuvo el tratamiento 2, con cantidades entre 45,9 – 52,6 mS/cm.

Figura 5. Tabla de conductividad eléctrica de los tratamientos T1, T2 y T4.

En el presente estudio, se utilizó el método de calcinación para determinación de sólidos volátiles (SV), el cual consistió en llevar a la estufa a 105°C por un tiempo de 24 horas; luego después de este proceso se llevó a la mufla por un periodo de 2 horas, obteniendo resultados de estas pruebas un valor promedio de sólidos totales (ST) entre 67,89 - 81,28%, que se encuentran presentes en la muestras de compost y biol, así mismo de SV entre 25,34 y 42,33 %.

Figura 6. Porcentajes de sólidos totales y volátiles de los tratamientos.

4. DISCUSIÓN

La temperatura es el factor primordial para indicar el desarrollo del proceso de descomposición de la materia orgánica, pues este incremento en la temperatura facilita acelerar la descomposición y eliminar o reducir las poblaciones de los microorganismos existentes (Acosta *et al.*, 2018; Arnawa *et al.*, 2018; Chaniago y Ramlan, 2017; Fan *et al.*, 2018). Como parámetro de control del proceso de compostaje, la temperatura debería oscilar entre 55 – 65°C cuando el proceso es termofílico. Según los resultados aquí presentados, el presente proceso está en el rango mesófilo (Ogunlade *et al.*, 2019; Rahim *et al.*, 2018; Vitinaqailevu y Rajashekhar Rao, 2019).

En cuanto al pH, éste varía según la composición microbiana y según los sustratos del lecho. Según los estándares de compostaje, el rango de pH establecido es 6,5 a 8,0 como evidencia de procesos de desmineralización de la materia orgánica volátil (Ogunlade *et al.*, 2019). La acción de hongos y bacterias ayuda a la conformación de ácidos orgánicos que posteriormente reducen el pH (Arnawa *et al.*, 2018).

En el tratamiento 2 y 3, con melaza y Trichoderma, se obtuvo un pH menor a 4,84, mientras que los tratamientos con Bacillus subtilis (1 y 4) el pH se mantuvo entre 6,5 hasta 7,0, siendo estos tratamientos los aptos para utilización como producción de compost y biol.

Tabla 2. Valores de prueba para uso de compost y biol.

CALIDAD DE COMPOSTAJE	
Materia orgánica	> 30%
Temperatura	45 – 60 0C
pH	6,5 – 8,5
Carbono	15 %

Fuente: Environmental Protection Agency (EPA).

La conductividad eléctrica corresponde al contenido de electrolitos que se encuentran presentes en el suelo y son solubles en el agua; la conductividad sirve también como un indicador de la salinidad del suelo (Chaniago y Ramlan, 2017). Aproximadamente entre 8 – 16 mS/cm se establece como fuertemente salino y mayor a 16 mS/cm como muy fuertemente salino (Dadi *et al.*, 2019). Según los presentes resultados, los Tratamientos 1 y 2 fueron muy fuertemente salinos, a diferencia del Tratamiento 4.

Los sólidos volátiles (SV) garantizan la energía suficiente para elevar la temperatura en los procesos celulares. Si dividimos el contenido de sólidos volátiles en función de los sólidos totales (ST), obtendremos una relación que indicará la fracción de materia orgánica mineralizada. Según estándares internaciones de la Agencia de Protección Ambiental (EPA US), la producción de biosólidos se confirmaría cuando la relación entre SV y ST es mayor que un 0,60. Según los resultados experimentales, el Tratamiento 1 (Mezcla de B. subtilis, melaza, Trichoderma, desechos de cacao y banano, tierra para sembrar) obtuvo un 0,54 de relación SV/ST, muy cercana a lo establecido por la EPA. Tomando en cuenta que su pH estuvo dentro de los rangos recomendados, es esta mezcla la recomendada para la producción de compost y biol. Los otros tratamientos tienen la desventaja de ser muy ácidos y de mineralizar cantidades insuficientes de materia orgánica.

5. CONCLUSIONES

En apenas cinco semanas, la mezcla de *B. subtilis*, melaza, *Trichoderma*, desechos de cacao y banano, y tierra para sembrar, fue el mejor tratamiento para mineralizar la materia orgánica y así producir una fracción sólida considerada como compost y una fracción líquida considerada como biol; esto a un rango mesófilo de temperatura. Los cambios de pH demuestran que no todos los procesos aquí estudiados permitieron una estabilización a un rango neutro de pH. 7,0. Como perspectiva, el aprovechamiento integral de desechos agrícolas es de amplio potencial para su aplicación práctica, y así contribuir con la solución ambiental a problemáticas antiguas en tiempos modernos.

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/02/

EFFICACY OF TALAROMYCES FLAVUS COATED WITH NANOPARTICLES IN THE GROWTH INHIBITORY OF FUSARIUM OXYSPORUM F.SP. CUCUMERINUM

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ABSTRACT

In this study, nanobioformulations were prepared containing the fungus *Talaromyces flavus* including two types of nano-capsules (F1 and F3), one type of nanoemulsion (F2), and one type of powdered nanoformulation (F4). Comparative *in vitro* studies were performed on nanoformulations and formulations made based on rice bran from *T. flavus* in terms of inhibitory effect on the colony growth the pathogenic fungus *Fusarium oxysporum* f. sp. *cucumerinum* in a completely randomized design. These studies began three months after the production of nanoformulations and continued at 3 months intervals for one year. The results showed that the nanopowder was the most effective nanoformulation in increasing the inhibitory effect on the growth of the examined pathogen.

KEYWORDS

Nanoformulation, *Talaromyces flavus*, Biological control, Plant pathogens.

1. INTRODUCTION

Studies conducted in Iran have demonstrated favorable results of the antagonist fungus, *Talaromyces flavus*, for the control of some important pathogenic pathogens such as *Verticillium dahliae*, *Verticillium albo-atrum*, *Fusarium oxysporum*, and *Rhizoctonia solani* in some crop varieties including cotton, sugar beet, potatoes, tomatoes, and greenhouse cucumbers (Naraghi *et al.*, 2010a; Naraghi *et al.*, 2010b; Naraghi *et al.*, 2010c).

Also, the application of this fungus as solid fermentation in the field on plant residues or their mixture with peat soil reduced the incidence of disease and increased the yield of the above-mentioned crops. Reduction of *Verticillium* wilt (50%), reduction in seedling death rate (37%), and 30% increase in yield were found in cotton plant, and 40% decrease in disease percentage and 17% yield increase were reported in potato plant (Naraghi *et al.*, 2014b). A 93% increase in the number of healthy seedlings and a 50% increase in yield were observed in sugar beet plants (Naraghi *et al.*, 2014a). A 27% decrease in disease severity and a 23% rise in yield were noticed in tomato (Niya *et al.*, 2015). And a 30% reduction of disease severity and a 7% yield increase were achieved in greenhouse cucumber (Naraghi *et al.*, 2017). Since marketing and attracting consumers are considered as important issues in mass production and commercialization of biological agents (Husen *et al.*, 2006; Alimi *et al.*, 2006; Kaewchai, Soyong, & Hyde, 2009; Pereira *et al.*, 2009), the commercialization of *T. flavus* as a biological agent and the importance of producing its various bioformulations, including nanoformulations, seem to be necessary at present time.

In recent decades, nanotechnology has expanded dramatically in various fields of chemistry, pharmacology, medicine, and agricultural chemical pesticides. The phenomenon of pest resistance to pesticides is an issue that necessitates research and development in the field of nano-pesticides. Therefore, the introduction of nano-pesticides to researchers will flourish in research and development in this field. The environmental problems, costs of consuming large quantities of conventional pesticides, and the problems caused by pest resistance to these pesticides raise the necessity of research and development in the field of nano-pesticides.

The use of biodegradable polymers in the production of high-performance nanoemulsions and nanocapsules made of natural and biodegradable materials can be an effective step in this regard. To increase efficacy and reduce environmental hazards, encapsulation formulation seems to be the best option (Maji *et al.*, 2014). Therefore, the production of nano and micro bioformulation creates controlled ability, increased strength and stability, and protection of active ingredients under adverse environmental conditions such as light and moisture. The use of nanocapsulated formulation also helps remarkably in cost reduction of pesticide consumption dose, economic benefit, protection of the environment, and reduction of its environmental risks, and better export of the crop (Martín *et al.*, 2010).

Nanoparticles have a larger surface area than the microparticles, which increases their active surface area and controlled release. Moreover, another advantage of nanometer particles is that they do not stimulate the immune system of humans and animals, and rapidly exit the body (Guan *et al.*, 2008).

The technology of nanocapsules containing nano-scale fungicide or pesticide molecules is a method of pesticide formulation that facilitates and accelerates pest elimination (Guan *et al.*, 2008). An emulsion is a heterogeneous system consisting of two immiscible liquids, one of which is dispersed as droplets in the other. Emulsions with a droplet size of about nanometers, typically in the range of 1-2 nm, are called nanoemulsions (Ostertag, Weiss, & McClements, 2012). Compared with conventional emulsions, the unique structure and properties of nano-emulsions have provided advantages for their application in many industries. Industrial applications of nano-emulsion systems include their role in the elimination of the coating and controlled release of beneficial compounds such as essential oils, vitamins, and so forth (Kah & Hofmann, 2014).

2. METHODS

2.1. IN VITRO EXAMINATIONS

2.1.1. PRODUCTION OF NANOCAPSULES CONTAINING THE BIOLOGICAL FUNGUS TALAROMYCES FLAVUS

The production of nanocapsules combines polymerization and lattice formation. It was performed through modifications matching the biological fungal growth conditions (changing the amount or type of polymer, surfactants, and oils, fatty acids, stirrer speed, and temperature). In the polymerization process, the organic phase consisted of vegetable oil with a mixture of the biological fungus, which was added to the aqueous phase consisting of hydrophilic polymeric monomers, such as a mixture of either formaldehyde or alginate polymers, starch, and chitosan. Then, such cross-linkers as calcium chloride, surfactants and associated materials, and fatty acid oils were added to the two phases and homogenized with a homogenizer (5000-10,000 rpm) at 35 °C. Finally, lattice polymer particles were encapsulated around the particle's biological fungus.

2.1.2. PRODUCTION OF NANOEMULSIONS CONTAINING THE BIOLOGICAL FUNGUS T. FLAVUS

A self-assemble model was used to prepare nanoemulsions containing the biological fungus *T. flavus*. Finally, a nanoemulsion was formulated containing hydrophobic nanoparticles of vegetable oil in a biocompatible formulation. Components of this formulation were active ingredients of the biological fungus and vegetable oils (e.g. hydrophobic castor oil), twin surfactant, viscose materials of carboxymethyl cellulose, coconut moisturizer, fatty acid ethanol amide, and polyvinyl acetate stabilizer (e.g. alcohol polyvinyl), linkers (e.g. calcium chloride), and biocompatible polymers (e.g. ethylene glycol, and starch). First, a homogeneous solution of biocompatible polymers was prepared, followed by the addition of such surfactants as a tween and the associated materials to the solution. A completely homogeneous mixture of polymer and solvent was prepared using a homogenizer (2000-12000 rpm) at 25 °C. Then,

the suspension containing the spores of biological fungus was added drop wise together with castor oil and coconut fatty acids. Next, a cross-linker (calcium chloride) was added to both the two phases to form nanoparticles around the biological fungal spores. Finally, the nanoparticles were coated around the biological fungal spores.

2.1.3. PRODUCTION OF NANOPOWDERS CONTAINING THE BIOLOGICAL FUNGUS *T. FLAVUS*

The suspension containing biological fungal spores was dispersed in the aqueous phase including maltodextrin, xanthan gum, methyl xanthan, fatty acid ethanolamide, and oleic acid. It was then fully powdered in a homogenizer (2000-12000 rpm) at 25 °C.

2.1.4. COMPARISON OF GROWTH INHIBITORY EFFICIENCIES OF DIFFERENT NANOFORMULATIONS CONTAINING *T. FLAVUS* AGAINST *FUSARIUM* WILT PATHOGEN IN GREENHOUSE CUCUMBERS

The efficiencies of different *T. flavus* nanoformulations for growth inhibition of soil pathogen (*F. oxysporum* f. Sp. *cucumerinum*: FOC) were evaluated in a completely randomized design three months after production and continued at three-month intervals for one year. To investigate each nanoformulation, a petri dish containing the PDA medium was subdivided into two halves using an assumed line. A 0.5 mm piece of the pathogen was placed by a cork borer in one half and the other half received 0.1 g of a nanoformulation. Each of the afore mentioned pathogens was examined separately in a completely randomized design with five treatments (four new and control nanoformulations) in three replications. For the control petri dish, the pathogen fragment was placed in only half of the petri dish. The colony diameter was measured in the treatment and control 7 days after placement of the pathogen and formulation on the petri dish to determine the inhibition percentage for each studied pathogen by the nanoformulation, which was calculated using the following formula:

Inhibition percentage = $(D_t - D_c) / D_c \times 100$, where D_t and D_c are the growth diameters of pathogen colonies in the treatment and the control, respectively.

Data analysis and comparison of mean growth inhibition percentages of pathogen colonies by the nanoformulation were performed by Duncan's multiple range test using the MS TAT C software.

The pathogen, *F. oxysporum* f. sp. *cucumerinum* studied here was confirmed earlier in terms of pathogenicity, which was obtained from the collection of the research laboratory for useful microorganisms in the Iranian Institute of Botanical Research.

3. RESULTS

3.1. QUALITATIVE AND QUANTITATIVE INTRODUCTION OF COMPOUNDS USED IN 100 G OF PREPARED NANOFORMULATIONS

Four nanoformulations, namely two types of nanocapsules, one type of nanoemulsion, and one type of nanopowders were produced in this study (Figure 4), and the compounds used in 100 g of the nanocapsules are shown qualitatively and quantitatively in (Table 1).

Figure 1. The prepared nanoformulations (right to left): Nanocapsules 1 (F1), Nanoemulsions (F2), Nanocapsules 2 (F3), and Nanopowders (F4).

The biological fungus was prepared using *T. flavus* suspension with a concentration of 10 spores/ml.

******Because the nano-formulations were prepared under non-sterile conditions, butanol was used to prevent bacterial and fungal contamination in the evaluation of the nano-formulation efficacies in growth inhibition of the fungal pathogen.

Table 1. The types of prepared nanoformulations and the amounts of compounds used in 100 g of each nanoformulation type.

Types of nanoformulations prepared and the number of compounds used in 100 grams of each nanoformulation							
Nanocapsules 1 (F1)		Nanoemulsions (F2)		Nanocapsules 2 (F3)		Nanopowders (F4)	
Compound	Amount (g)	Compound	Amount (g)	Compound	Amount (g)	Compound	Amount (g)
Biological fungus *	19	Biological fungus *	35	Biological fungus *	53	Biological fungus *	5
Alginate	8	Lauryl alcohol	5.17	Urea	9	Maltodextrin	5.14
Castor oil	16	Castor oil	9	Castor oil	5.4	Castor oil	5.33
Coconut fatty acids	32	Coconut fatty acids	5.17	Coconut fatty acids	5.4	Fatty acid) diethanolamide - Oleic acid(	5.8
Sodium chloride	2	Sodium chloride 1.0 %	2	Sodium chloride 1.0%	2	Xanthangam	5.8
		Twin surfactant	4	Twin surfactant	4		
Polyethylene glycol	20	Polyethylene glycol	12	Formaldehyde	5.18	-	-
Butanol**	3	Butanol	3	Butanol	3	Butanol	3

*For preparation of biologic fungi, suspension of *Talaromyces flavus* with concentration of 10⁹ spore per liter was used.
** Due to the preparation of nanoformulation in non-sterile conditions, butanol was used to prevent bacterial and fungal contamination to evaluate the efficacy of nanoformulation in inhibiting the growth of the disease agent.

3.2. COMPARISON OF GROWTH INHIBITORY EFFICIENCIES OF DIFFERENT NANOFORMULATIONS CONTAINING T. FLAVUS AGAINST FOC

In the first and the second trimester after production, the efficiency of nanoformulation in inhibition of FOC colony growth (Figure 2) and (Figure 3) decreased from the first to the second trimester in all nanoformulations (Table 2). From the third trimester, the inhibition was only observed for nanopowders on FOC colony growth (Figure 4 and Table 2). The efficacies of different nanoformulations in inhibition of FOC colony growth were significant in the first, second, third, and fourth trimesters after production at a 1% probability level.

In the first trimester of production, a comparison of average FOC colony growth inhibition of each formulation revealed that the formulations were in two statistical groups, with nanocapsule 1, nanoemulsions, and nanopowders being most effective in terms of inhibition level (Table 2). Comparison of FOC inhibition averages from each formulation in the second trimester also indicated that the formulations were in two statistical groups and nanopowder and nanocapsule 2 nanoformulations presented the highest efficacy in growth inhibition of FOC colony (Table 2). The third and fourth-trimester comparisons of FOC inhibition averages represented that the formulations were also in two statistical groups and only an inhibition effect on FOC colon growth was observed only in the nanopowders in these periods (Table 2).

Figure 2. Growth inhibition rate of *Fusarium oxysporum* f. sp. *cucumerinum* by different nanoformulations on PDA media in the first trimester after production. CONTROL, F1 (nanocapsule 1), F2 (nanoemulsion), F3 (nanocapsule 2), and F4 (nanopowder).

Figure 3. Growth inhibition rate of *Fusarium oxysporum* f. sp. *cucumerinu* by different nanoformulations on PDA medium in the second trimester after production. CONTROL, F1 (nanocapsule 1), F2 (nanoemulsion), F3 (nanocapsule 2), and F4 (nanopowder).

Figure 4. Growth inhibition of *Fusarium oxysporum* f. sp. *cucumerinum* colony growth by the nanopowder (right) compared with the control (left) in the fourth trimester after production.

Table 2. Comparison of mean growth inhibition rates of *Fusarium oxysporum* f. sp. *cucumerinum* (FOC) in different nanoformulation treatments.

Formulation	Mean FOC growth inhibition (%)			
	1 st trimester	2 nd trimester	3 rd trimester	4 th trimester
F1(Nanocapsule 1-polyalginate)	a25·31	c00·10	b0	b0
F2 (Nanoemulsion-polyethylene glycol)	ab12·26	bc44·14	b0	b0
F3 (Nanocapsule 2-polyurea formaldehyde)	b00·20	ab61·16	b0	b0
F4 (Nanopowder-maltodextrin, xanthan gum)	a77·27	a42·21	a00·24	a42·20
Without nanoformulation (control)	-	-	-	-

*Means with similar letters are not significantly different at 1% probability level.

**The inhibition rate of the pathogen colony growth in nanoformulation treatments was compared to the without nano-formulation (control) and no inhibition was observed in the control.

4. DISCUSSION

Overall, the present results showed that the nanopowder had the uppermost efficiency among the prepared nanoformulations (two types of nanocapsules, nanoemulsions, and nanopowders) in terms of *Fusarium* wilt growth inhibition. The results obtained from the effect of prepared nanoformulations on the growth of some plant pathogens are in line with those of previous research (Khan & Jameel, 2016) on the inhibitory effect of a nanoformulation containing *Penicillium fellutanum* on *Candida albicans*. The *in vitro* study observed inhibition zones of the pathogenic fungal growth in petri dishes around nanoformulation tablets.

Naratghi *et al.* (2012) reported that some mechanisms play a more effective role in different plant pathogens than other mechanisms. For example, the above study found that mycoparasitism was the most effective mechanism for *Fusarium* growth inhibition. On the other hand, the effective metabolites of

the production mechanisms of non-volatile compounds and mycoparasitism were reported to be glucose oxidase and chitinase, respectively (Kim, Fravel, & Papavizas, 1990; Inbar & Chet, 1995) and levels of these metabolites and their activity to be variable depending on time and environmental conditions (Zhai *et al.*, 2016). Thus, the effects of different nano compounds cannot be ignored on the amount and intensity of different *T. flavus* metabolites. In the present study, the time and environmental conditions in the second trimester were likely such that the intensity and activity of the Fusarium effective metabolite (chitinase) were lower than those of other *T. flavus* metabolites present in the nanoformulation.

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/03/

INVESTMENT SYSTEM FOR RENEWABLES OBJECTS USE GENERATING

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ABSTRACT

In this article single legal questions of investment into creating the objects of generation based on renewables are considered. The issues connected with lack of terminological unity in the regulations regulating this sphere are touched; the noncompetitive environment of realization of the relations under the contract of power delivery; the contract subject blurring, lack of the proprietary relations description evolving from RES owing to creating new objects of generation.

The relations system of investment for renewables use is considered as a complex of the legal means organized in the most consecutive way for creating objects of generation and obtaining by sellers the right for sale of electric energy and power in the wholesale market. In this regard, features of the parties and subject of the contract of power delivery were studied.

KEYWORDS

Investments into power industry, Subjects of the wholesale market, The regulator of the power industry market on the basis of RES use, Generation of electric energy on the basis of renewables use, Contract of power delivery, Subject of the contract about granting power.

1. INTRODUCTION

Increase in power efficiency of power industry based on renewables use (further - RES) promotes involvement of innovative high technologies and the equipment in the power sphere and implementation of the international obligations of Russia for restriction of emissions of greenhouse gases. Investment into building of generation of electric energy on the basis of RES use is supposed by means of the contracts of power delivery signed by results of the closed competitions according to the development plan for renewables approved by the Government of the Russian Federation (The resolution of the Government of the Russian Federation of 15.04.2014 No. 321, 2014).

Meanwhile, the structure “The “Council for Organizing Efficient System of Trading at Wholesale and Retail Electricity and Capacity Market” non-profit partnership offered by Association (further NP Market Council) the standard contract of power delivery is represented very tangled what can not only complicate further control of its execution, but also in general reduce investment appeal of the offered project on creating generation on the basis of RES. First of all, it is shown in the contract subject blurring - discrepancy of the purpose for the sake of which the mechanism (investment) given right to the actual contents of the contract was developed, and also in absence in the contract of the instruction for the real rights arising on again created objects of generation including the land plots and buildings which are on them and constructions, and also infrastructure facilities (also communications are expensive).

According to a standard form of the contract on granting power (further - the contract on granting power, the PDM) (<http://www.np-sr.ru>) data contracts are signed concerning objects of generation (<http://digitalcommons.wcl.american.edu>) for which any of the following circumstances - commissioning, certification (testing), obtaining by sellers the right for sale of electric energy and power in the wholesale market - arises after the conclusion of the agency contracts providing the conclusion of contracts on granting power. At the same time, attracts attention insufficiently worked competences of all participants of the considered relations.

2. METHODS

The complex of methods was used (a method of induction and deduction, a method of the analysis and synthesis, an ascension method from abstract to concrete, a comparison method) that allowed to investigate with the greatest reliability difficult and multipurpose relations system of power delivery for investment into the generating objects of RES. The theoretical analysis of the regulatory base and right realizable practice allowed to consider the contract granting power as the mechanism of creating objects of generation in the sphere of RES. Analyzing the separate facts, grouping, systematizing them, we reveal in them the general and special.

The analysis is followed by synthesis that helped to get into essence of the studied system. The comparison method allowed defining distinctions or a community of the studied object with adjacent contractual categories (<http://www.renewableenergyworld.com>). The method of induction and deduction, in relation to a research allowed to pass from separate elements to formation of complete idea of power delivery as means of investment into the generating objects of RES and gave the chance to connect all communications and the relations and to draw partial conclusions.

3. RESULTS AND DISCUSSION

The analysis of relations system of investment for renewables use allows speaking about the special subject list of participants. The group of participants acts as the parties of the contract on granting power.

- (1) As the buyer the participant of the wholesale market included in NP Market Council in the Register of subjects of the wholesale market which signed the Contract on accession always acts and carries out acquisition of power, including for own production needs and (or) for the subsequent sale, but anyway as the usual economic activity provided by the charter of the Buyer.

The organization joins in the register of subjects of the wholesale market according to the decision of the supervisory board of NP Market Council. For obtaining this status several requirements are imposed on the participant:

- compliance of the power accepting and generating equipment to the quantitative characteristics applied in groups of points of delivery of electric energy and power;
- holding actions of technical character: on equipment of each point of delivery, the measuring instruments providing collecting, processing and transfer of commercial infrastructure of data of the commercial account to the organization; on the equipment the communication system providing transfer of the data to the system operator necessary for implementation of the centralized supervisory control within UES of Russia;
- coordination with the system operator and the organization of commercial infrastructure of group of points of delivery with which use the organization plans to participate in trade in electric energy and (or) power in the wholesale market.

Let's note that any participant of the wholesale market of electric energy (power) can act as buyers (URL: <http://www.np-sr.ru>):

First, it is ***suppliers of electric energy and power*** - owners of the generating equipment. It agrees, to data of the register 101 participants among which there is, for example, PJSC Mosenergo, JSC Tatenergo, LLC Lukoil Kubanenergo, JSC SIBECO, LLC Vorkuta Combined Heat and Power Plants, LLC Ulyanovsk-Kogeneration (<https://www.cia.gov>), etc. are registered.

Secondly, ***buyers of electric energy and power***:

From which *the power marketing organizations*, for example, such as to JSC Transservisenergo are separately distinguished, to JSC EK Vostok, JSC Atomsbyt, LLC Lukoil-powerservice, JSC Mosgorenergo, etc. (116 participants are registered).

Large consumers, for example, PJSC Novolipetsk Steel, the Kazan PJSC Organichesky sintez, LLC LADA Izhevsky Avtomobilny Zavod, JSC Vodokanal, LLC Lenta, etc. (26 subjects are registered).

The guaranteeing suppliers, for example, JSC Pyatigorsk Electric Networks, JSC Lipetsk Energy Retail Company, PJSC Mosenergosbyt, LLC Zarinsk City Electric Supply Company, JSC Tatenergosbyt, etc. (99 participants are registered).

As the organization which is carrying out export-import transactions only one subject of PJSC Inter RAO UES is registered.

The territorial network organizations for implementation of functions of the guaranteeing supplier eight subjects are registered: PJSC IDGC of Volga, PJSC IDGC of the Northwest, PJSC IDGC of the North Caucasus, JSC IDGC of Ural, PJSC IDGC of Centre, PJSC IDGC of Centre & Privolzhya, JSC Chechenenergo, PJSC IDGC of the South.

(2) The following participant - the Seller who is a subject of the wholesale market (are considered above), the participant of the address of electric energy and power in the wholesale market, is included by NP Market Council in the Register of subjects of the wholesale market and signed the Contract on accession to trade system of the wholesale market, and also is the subject of power industry which is carrying out activities for production and sale of power as provided by the existing charter of the Seller of usual economic activity.

It should be noted that on behalf of the Seller the Agency contract is acted by the agent under - Center of Financial Calculations Joint-stock company (further - CFC). At the same time CFC is the organization of commercial infrastructure in understanding of paragraph 9 of article 33 Federal Law “About Power Industry” and Contract on accession which according to the Contract on accession renders complex service in calculation of requirements and obligations of participants of the wholesale market, PJSC FGC UES and System operator.

The infrastructure organizations act as other parties of the contract.

(3) “System Operator of the Unified Energy System” joint-stock company (further - the System operator).

The system operator is according to the Federal Law “About Power Industry” (The federal law of 26.03.2003 N 35-FZ, 2003) a subject of supervisory control in power industry into which power implementation of the centralized round-the-clock and continuous management of the electrical power mode of a power supply system, and also control of timely and appropriate implementation of the investment program by the Seller (investment projects) of construction of the generating objects with which use trade in power in the wholesale market is carried out, including for ensuring power delivery with use of the objects of generation specified in the contract (further - control of implementation of the investment program), and also carrying out according to Rules of the wholesale market of certification of the generating equipment including which is again put into operation is included.

(4) “Trading System Administrator of the Wholesale Market of the Electric Power” joint-stock company (further - automatic telephone exchange).

The automatic telephone exchange according to paragraph 7 of article 33 Federal Law “About Power Industry” and the Contract on accession renders to subjects of the wholesale market, participants of the address of electric energy and power in the wholesale market the service in the organization of trade in the wholesale market connected with the conclusion and the organization of execution of transactions on the address of electric energy, power and other objects which address is allowed in the wholesale market and also carries out other functions of the Commercial operator of the wholesale market according to the rules of the wholesale market understood in that sense as it is established in the paragraph the seventh article 3 Federal Law “About Power Industry” (further - Rules of the wholesale market) and the Contract on accession including is given authority to determine the volume and the cost of the power bought under contracts on granting power.

- (5) “Council for Organizing Efficient System of Trading at Wholesale and Retail Electricity and Capacity Market Non-profit Partnership” association.

NP Market Council is Market Council in understanding of article 33 Federal Law “About Power Industry” into which power the statement of a form of the Contract on accession and changes to it, standard forms of the contracts providing implementation of trade in the wholesale market with electric energy, power which address is carried out in the wholesale market, including control of observance of Rules of the wholesale market and regulations of the wholesale market by the Seller and the Buyer - subjects of the wholesale market and the organizations of commercial and technological infrastructure (automatic telephone exchange, CFC, the System operator) is included.

Several problems allowed revealing studying of the regulatory base governing the relations on investment into construction of facilities of generation, the renewable sources of power industry functioning based on use (further RES).

First, it is the problems of terminological character connected with lack of uniform approach to designation, the contractual designs used for this purpose. So, by means of which contract is supposed to carry out financing of processes of creating generation of RES in different regulations can be called differently: contract of purchase and sale of power, contract of power delivery, contract on granting power (See also General terms and conditions for the supply of Energy). At the same time often these terms are considered as synonyms, alternating with each other, and being sometimes shared (The resolution of the Government of the Russian Federation of 28.05.2013 No. 449, 2013).

Meanwhile, from the point of view of approaches, traditional for the Russian civil law, the contract of delivery though is a kind of the contract of purchase and sale, nevertheless has the distinctive features connected with subject structure and the purpose of the conclusion. Besides, use from the point of view of etymology of the word “granting” does not reflect a being of the arising relations in the name of this type of contracts of the term “granting power”: putting into operation of a new object of generation

of the electric power on the basis of RES due to repayment of the power made to data of objects in the future.

It is represented that the used legal technology of rule-making has defective character as lack of unity in terms leads to difficulties of differentiation of adjacent contractual designs, to complexity of perception, and eventually, to decrease in trust to the most investment project.

In turn, the analysis of maintenance of the electric power of a standard form of the contract on providing the generation to the power of an object functioning on the basis of use of renewable sources of power industry as means of investment of construction of these objects developed by the regulator of the market allowed to reveal a number of the moments complicating not only perception of this contract, but also the most built model of the relations in general.

First, it concerns subject of the contract. So, according to item 2.1. The PDM the seller undertakes to begin in due time delivery and during all term established by the contract to deliver power, and the buyer undertakes to accept it and to pay. Meanwhile, the formulation of subject of the contract does not reflect its essence. As, power delivery is only means by means of which financing of again created object of generation of RES is carried out. The purpose of the conclusion of a similar contractual design - creation or modernization of an object of generation - is indistinct in the text of the contract and looks through only in some points. In particular: in item 1.10. The PDM is mentioned that the person who assumed liabilities on construction and/or modernization of an object of generation assumes liabilities to agree on the concrete list of works with the regulator (NP Market Council); according to item 3.3. it is provided that the period of power delivery of each object of generation terminates the last date of which end of 10-year term from start date of execution of the obligation for power delivery of this object of generation is the share; in item 14.5 in a context for delay of execution of the obligation on deliveries of power, regarding assignment the person who assumed liabilities on construction and/or modernization of a duty to send to the regulator the name and planned dates of commissioning of the objects of generation specified concerning which the delay of the beginning of performance of

obligations on power delivery is allowed, with application of documents, proving the specified planned dates of input of objects of generation; in item 15.1. Regarding regulation of the relations on transfer of rights of duties it is specified by the PDM that for the purpose of application of the rules established in the present section is understood as object of generation as the object of generation put into operation and certified (tested) System operator object of generation concerning which the right of sale of its power in the wholesale market is acquired not finished by construction and (or) not put into operation and (or) not tested concerning which the specified right is not acquired.

It would be desirable to note that in the analysis of this contract total absence in it of the conditions regulating the real rights for again created objects of generation of RES is special surprising. In offered by the regulator of the PDM to the matter only one norm reflecting a possibility of the person which assumed obligation for creating this object of generation to make alienation by sale of the created or created object (item 15.1 is devoted. contracts). Meanwhile, it is represented that similar provisions of the contract are not only not fair, but also not based on requirements of the law. As financing of construction of the created object of generation is carried out not at the expense of available funds of the buyer, and due to inclusion of the investment expenses made by it in the price for end users. The most amazing that on the created object of generation there are no real rights, not only the buyer has capacities, but also at the state which in fact and acts as the customer of process on increase in efficiency of a power system and works in public interests.

4. SUMMARY

The relations system of investment for renewables use is considered as a complex of the legal funds allocated for creating objects of generation for increase in power efficiency of power industry. The contract on granting power acts as the main means of this system. At the same time, the analysis of its conditions revealed the following problems: 1) lack of terminological unity in standard regulation; 2) insufficiently thought over competences of participants of the adjustable relations; 3) not full compliance

of subject of the contract to a being of the considered relations; 4) the question of pricing during creating new objects of generation of RES is represented disputable; 5) lack of the conditions regulating the real rights for again created objects of generation of RES (<http://www.ucsusa.org>).

5. CONCLUSIONS

Increase in efficiency of power industry based on RES use, is necessary for long-term and steady power supply of economic development of the Russian Federation, is directed to attraction of innovative technologies and the equipment in power branch and development of domestic production of the hi-tech generating equipment. Meanwhile, legislative regulation in the field demands essential amendments for increase in the competition, transparency and decrease in a corruption component.

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/04/

CONSTRUCTION OF SPECIALIZED COMPUTER AIDED SOFTWARE ENGINEERING (CASE) TOOLS FOR THE DEVELOPMENT OF EXPERT SYSTEMS

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ABSTRACT

This report presents an approach to building specialized computer-aided software engineering (CASE) tools for the development of expert systems. These tools form an integrated development environment allowing the computer aided development of different applications in the appropriate field. The integrated environment which we consider in our report represents the combination of SWI-PROLOG and Data Base Management System (DBMS) PostgreSQL tools. SWI-PROLOG provides the most appropriate tools for the solution of logical tasks in expert systems. However, SWI-PROLOG cannot manage large amounts of data. Therefore, we need to apply an appropriate data base management system to extend the capability of the knowledge base. For this purpose we used the most advanced open source PostgreSQL tools. As a result of our research we have created tools enabling the compatibility of SWI-PROLOG and DBMS PostgreSQL within the integrated development environment.

KEYWORDS

CASE tools, SWI-PROLOG, PostgreSQL database management system, Expert system.

1. INTRODUCTION

Intelligent information systems and technologies are ones of the most promising and rapidly developing fields in theoretical and applied information technologies. It has had a significant impact on all areas of research and technology related to the use of computers, and it already today gives society what is expected from science - practically meaningful results, many of which contribute to cardinal changes in their applications (Vladimir, 2009). Expert systems (ES) occupied a special place in the development and use of intelligent information systems.

Various types of software tools can be used to create ES, among which SWI-PROLOG seems to be the most appropriate. However, SWI-PROLOG cannot manage large amounts of data. Therefore, we need to include an appropriate data base management system to boost the potential of the knowledge base.

For this purpose we used the most advanced open source PostgreSQL tools. As a result of our research we have created tools enabling the compatibility of SWI-PROLOG and DBMS PostgreSQL within the integrated development environment.

2. METHODS

The report describes the tools and methods which were used to create an integrated development environment.

The integrated development environment includes:

- SWI-PROLOG.
- XPCE for the graphics component.
- PostgreSQL.
- ODBC Driver PostgreSQL DBMS.

SWI-PROLOG is an open release of Prolog. Being formed from the initial data in the form of a chain of reasoning (decision rules) from the knowledge base ES can decide in unique situations for which the algorithm is not known in advance. What is more, problem solution is expected to be carried out in conditions where the initial information is incomplete, unreliable, and ambiguous, during qualitative process assessment (Yuriy, 2004). PROLOG tools appear to be the most appropriate to the solution of the above mentioned problems.

To develop graphics applications, the SWI-PROLOG distribution package includes tools that enable the development of a graphical user interface. These tools for SWI-PROLOG are provided by XPCE.

XPCE is a platform-independent tool for SWI-PROLOG, Lisp and other interactive dynamically typed programming languages.

T is a toolkit for developing graphical applications in Prolog and other interactive and dynamically typed languages. XPCE follows a rather unique approach of for developing GUI applications, which we will try to summarise using the points below.

2.1. ADD OBJECT LAYER TO PROLOG

XPCE's kernel is an object-oriented engine that allows for the definition of methods in multiple languages. The built-in graphics are defined in C for speed as well as to define the platform-independence layer. Applications, as well as some application-oriented libraries are defined as XPCE-classes with their methods defined in Prolog.

Prolog-defined methods can receive arguments in native Prolog data, native Prolog data may be associated with XPCE instance-variables and XPCE errors are (selectively) mapped to Prolog exceptions. These features make XPCE a natural extension to your Prolog program.

2.2. HIGH LEVEL OF ABSTRACTION

XPCE's graphical layer provides a high abstraction level, hiding details on event-handling, redraw-management and layout management from the application programmer, while still providing access to the primitives to deal with exceptional cases.

2.3. EXPLOIT RAPID PROLOG DEVELOPMENT CYCLE

Your XPCE classes are defined in Prolog and the methods run naturally in Prolog. This implies you can easily cross the border between your application and the GUI-code inside the tracer. It also implies you can modify source-code and recompile while your application is running.

2.4. PLATFORM INDEPENDENT PROGRAMS

XPCE/Prolog code is fully platform-independent, making it feasible to develop on your platform of choice and deliver on the platform of choice of your users. As SWI-Prolog saved-states are machine-independent, applications can be delivered as a saved-state. Such states can be executed transparently using the development-environment to facilitate debugging or the runtime emulator for better speed and space-efficiency (Merrit, 1989).

2.5. POSTGRESQL

PostgreSQL, often simply Postgres, is an object-relational database management system (ORDBMS) with an emphasis on extensibility and standards compliance. As a database server, its primary functions are to store data securely and return that data in response to requests from other software applications. It can handle workloads ranging from small single-machine applications to large Internet-facing applications (or for data warehousing) with many concurrent users; on macOS Server, PostgreSQL is the default database; (Wierse, Grinstein, & Lang, 1996; Shoham, 2014; Bench-Capon, 1990) and it is also available for Microsoft Windows and Linux (supplied in most distributions).

PostgreSQL is ACID-compliant and transactional. PostgreSQL has updatable views and materialized views, triggers, foreign keys; supports functions and stored procedures, and other expandability (Habaroy, 2013).

PostgreSQL is developed by the PostgreSQL Global Development Group, a diverse group of many companies and individual contributors. It is free and open-source, released under the terms of the PostgreSQL License, a permissive software license (Machad, Souza, & Catapan, 2019).

Connection between PostgreSQL and Prolog is provided by an ODBC driver.

An ODBC driver uses the Open Database Connectivity (ODBC) interface by Microsoft that allows applications to access data in database management systems (DBMS) using SQL as a standard for accessing the data. ODBC permits maximum interoperability, which means a single application can access different DBMS. Application end users can then add ODBC database drivers to link the application to their choice of DBMS (Guida & Tasso, 1989).

The ODBC solution for accessing data led to ODBC database drivers, which are dynamic-link libraries on Windows and shared objects on Linux/UNIX. These drivers allow an application to gain access to one or more data sources. ODBC provides a standard interface to allow application developers and vendors of database drivers to exchange data between applications and data sources (Companys, Falster, & Burbidge, 1990; Ardeleanu, 2016).

3. RESULTS

The following basic functions were developed, which enable work with PostgreSQL DBMS inside SWI-PROLOG.

3.1. CONNECTING TO A DATABASE SERVER

```
openDatabase :-  
  
odbc_connect('PostgreSQLProlog', _, [ user(postgres),  
password('1234'), alias(PostgreSQLProlog), open(once)]).
```

3.2. DISCONNECTING FROM THE DATABASE SERVER

```
closeDatabase:-  
  
odbc_disconnect(PostgreSQLProlog).
```

3.3. GETTING THE LIST OF TABLES FROM THE CONNECTED DATABASE

```
getTables:-  
  
odbc_current_table(PostgreSQLProlog, Table),  
  
write(Table).
```

3.4. GET THE LIST OF COLUMNS FROM THIS TABLE

```
getColumns(Table):-  
  
odbc_table_column(PostgreSQLProlog, Table, Column),  
  
write(Table-Column).
```

3.5. RETRIEVE ALL RECORDS FROM SPECIFIED TABLE

```
getList(Table):-  
  
openDatabase,
```

```

concat('SELECT * from "', Table, X),

concat(X, '"', Y),

odbc_query(PostgreSQLProlog, Y , Row, [types([integer, string,
string, string]))],

write(Y),

write(Row),

write_in(Row) .

```

3.6. RECEIVING A RECORD FROM CURRENT TABLE WITH A SPECIFIED ID

```

getList(Table, Id):-

openDatabase,

concat('SELECT * from "', Table, X),

concat(X, '"', Y),

odbc_query(PostgreSQLProlog, Y , Row, [types([integer, string,
string, string]))],

write(Y),

write(Row),

write_in(Row) .

```

3.7. SELECTION OF TABLE RECORDS FOR A SPECIFIED FILTER

```
selectList(Table, Name, Value):-  
    openDatabase,  
    concat('SELECT from "', Table, X1),  
    concat(X1, '" WHERE ', X2),  
    concat(X2, Name, X3),  
    concat(X3, ' = ', X4),  
    concat(X4, Value, X),  
    odbc_query(PostgreSQLProlog, X, Row, [types([integer, string,  
    string, string]))],  
    write(Row).
```

3.8. DELETE RECORDS FOR THE SPECIFIED FILTER

```
deleteList(Table, Name, Value):-  
    openDatabase,  
    concat('DELETE from "', Table, X1),  
    concat(X1, '" WHERE ', X2),  
    concat(X2, Name, X3),  
    concat(X3, ' = ', X4),
```

```
concat(X4, Value, X),  
  
odbc_query(PostgreSQLProlog, X, Affected, [types([integer,  
string, string, string]))],  
  
write(Affected).
```

4. DISCUSSION

4.1. PROLOG AND POSTGRESQL INTERACTION

In order to interact and manage XPCE objects from within the SWI-PROLOG kernel environment, the necessary predicates are added to the program, such as:

- new (? Reference, + Class (... Arg ...))
- send (+ Reference, + Method (... Arg ...))
- get (+ Reference, + Method (... Arg ...), -Result)
- free (+ Reference)

ODBC (Open Database Connectivity) is an application interface (API) for providing access to databases (a MICROSOFT product). In order to access to the database, it is necessary to select the data source in the “Data source administrator” window.

Figure 1. ODBC Data Source Administrator.

As the result of the research we have developed a knowledge base and tools for the selection of data from databases using the logical programming language SWI-PROLOG and DBMS PostgreSQL.

Based on the necessary predicates enabling the compatibility of SWI-PROLOG and PostgreSQL, the following files were created, namely:

- UserInterface.pl - User interface.
- LocalBase.pl - Local Database.
- DataConnection.pl - Contains the functions for interaction with the ODBC driver.

In the future, it is also necessary to envisage the possibility of adding not only a certain set of data to the knowledge base, but also adding new inference rules not existing at the time of system development. Thus, all this confirms the fact that the development of a fully-fledged expert system of this kind is a complex and expensive task.

4.2. SQL DATA REPRESENTATION IN PROLOG

Databases have a poorly standardized, but very rich set of data types. Some types of data have analogues with PROLOG. To fully correlate with data types when developing CASE tools, you need to define PROLOG data types for SQL types that do not have a standard analog with PROLOG (for example, timestamp). For example, many variants of the SQL DECIMAL type cannot be mapped to an integer number of PROLOG. However, matching to an integer can be the right choice for an application. That's why it is important to understand how SQL data types can be represented in Prolog.

The PROLOG/ ODBC interface defines the following types of PROLOG data with the specified default conversion.

4.3. ATOM

It is used by default for SQL types char, varchar, longvarchar, binary, varbinary, longvarbinary, decimal and numeric. Can be used for all non-structural types.

4.4. STRING

A string of the extended SWI-PROLOG type.

4.5. CODES

List of code characters. Can consist of any amount of text.

4.6. INTEGER

Used by default for the SQL, tiny int, small int and integer bit types.

4.7. FLOAT

Used by default for SQL real, float and double types.

4.8. DATE

The PROLOG date (Year, Month, Day) of form used by default for SQL dates (Year, Month, Day).

4.9. TIME

A PROLOG term for the time format (Hour, Minute, Second) used by default by SQL.

4.10. TIMESTAMP

In the PROLOG language, the term 'timestamp' (Year, Month, Day, Hour, Minute, Second, Fraction) is used by default for SQL type timestamps.

5. SUMMARY

On the basis on conducted research the following program and GUI was developed:

Figure 2. The main window of the program

Figure 3. The menu for working with database

Figure 4. Adding form

Figure 5. Downloading from database form

Program, which is presented in this report, is an Open Source management tool for Postgres and Prolog. It can download, edit and delete data from PostgreSQL database. User can manually choose the database to work with. After the download, all information is stored in .pl file and ready to work. Using this program user also can add, search, edit and delete rows from this file. So we think, That this program can probably become a part or a module of complete CASE tool software to work with both PostgreSQL and Prolog. It is designed to meet the needs of both novice and experienced Postgres users alike, providing a powerful graphical interface that simplifies the creation, maintenance and use of PostgreSQL databases.

6. CONCLUSIONS

An important feature of the expert system is that the user cannot only receive a consultation, but also to access all the knowledge from system storage by asking relevant questions.

The use of expert systems makes it possible to make decisions in unique situations for which the algorithm is not known in advance and is formed from the initial data in the form of a chain of reasoning (decision rules) from the knowledge base.

The novelty of the new CASE tool presented is that it ensures the compatibility of SWI-PROLOG and DBMS PostgreSQL within the framework of a single integrated development environment. In the future this will be applicable to the development of various expert systems.

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ERROR ESTIMATION OF BILINEAR GALERKIN FINITE ELEMENT METHOD FOR 2D THERMAL PROBLEMS

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ABSTRACT

This study demonstrates a two-dimensional steady state heat conduction Laplace partial differential equation solution using the bilinear Galerkin finite element method. Heat transfer analysis is of vital importance in many engineering applications and devising computationally inexpensive numerical methods while maintaining accuracy is one of the primary concerns. The method uses structured mesh grid over a two-dimensional rectangular domain and solved using a stiffness matrix for the bilinear elements, calculated using the proposed modified numerical scheme. Several numerical experiments are conducted by controlling the number of nodes and changing element sizes of the presented scheme, and comparison made between analytical solution and software generated solution.

KEYWORDS

Galerkin method, Bilinear element, Heat conduction, Error analysis, Partial differential equation.

1. INTRODUCTION

Finite element Analysis is a robust numerical approach for solving partial differential equations (PDEs) used in various branches of science such as solid mechanics, fluid mechanics, electromagnetics, thermodynamics etc. (Kreyszig, 2011; Deb, Babuška, & Oden, 2001). One of the most powerful techniques for solving PDEs with weak formulation is using a weighed residual method called the Galerkin finite element method (GFEM). The formulation requires generating a basis function (Ainsworth & Oden, 1997) based on the elemental boundary conditions. This trial function is substituted in the partial differential equation and the first derivative of the trial function is taken for each nodal variable (Burden & Faires, 2001) to construct the residual function. The weighed form of the residual function for the whole domain is integrated by setting it equal to zero. Green's theorem can be applied over the boundary if necessary (Afzal, Sulaeman, & Okhunov, 2016). The corresponding numerical model is set up by discretizing the rectangular domain into smaller elements where each element consists of nodal coordinates and nodal variables, which are used to perform the Galerkin approximation of the PDEs. This is followed by the generation of an element matrix and vector matrix of the boundary by integrating the total number of elements. The set of linear equations represented by the matrices are consecutively solved using the Galerkin approach. For comparison purposes, an exact solution already available for the non-linear PDE (time independent and no heat source) used in 2D heat conduction rectangular domain with both Dirichlet and Neumann boundary condition, is presented. Finally, a stiffness matrix applicable for homogenous rectangular domain consisting of structured mesh grid elements is presented, the solution scheme of which significantly reduces the CPU performance cost.

2. MATHEMATICAL CONSTRUCTION

A homogeneous domain represented by a time independent heat conduction problem with zero heat extraction is considered and can be mathematically formulated by Laplace equation with Neumann

or Dirichlet boundary conditions as shown in Figure 1 (Gerald & Wheatly, 2003; Gockenbach, 2002; Burden & Faires, 2001; Kreyszig, 2011).

Figure 1. Physical domain of Ω bounded by Γ .

Two dimensional time independent heat-conduction problem can be represented by the following partial differential equation.

$$\nabla^2 u = \frac{\partial^2 u}{\partial x^2}(x, y) + \frac{\partial^2 u}{\partial y^2}(x, y) = 0, \text{ in } \Omega \quad (1)$$

where, $0 < x < a$ and $0 < y < b$

The boundary conditions are given by:

$$\begin{aligned} u &= u_b \text{ on } \Gamma_e \\ \frac{\partial u}{\partial n} &= f_b \end{aligned} \quad (2)$$

where u_b and f_b are Dirichlet and Neumann boundary conditions respectively.

The weighed residual w is applied on Eqs (1) and (2) to generate its strong formulation as given:

$$I = \int_{\Omega} w \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) d\Omega + \oint_{\Gamma} w \frac{\partial u}{\partial n} d\Gamma \quad (3)$$

Consequently, the weak formulation is generated using integration by part over eq. (3) as given below:

$$I = - \int_{\Omega} w \left(\frac{\partial w}{\partial x} \frac{\partial w}{\partial x} + \frac{\partial w}{\partial y} \frac{\partial w}{\partial y} \right) d\Omega + \oint_{\Omega} w \frac{\partial u}{\partial n} d\Gamma \quad (4)$$

The stiffness matrix is generated by discretising the solution domain into smaller elements and performing integration for each element.

3. BASIS FUNCTION AND STIFFNESS MATRIX

The 2D computational domain is represented by bilinear rectangular elements where each element is constructed with a node at each of its four edges as shown in Figure 2. The nodal points are represented by (x_1, y_1) , (x_2, y_2) , (x_3, y_3) and (x_4, y_4) , while the nodal variables are represented by u_1 , u_2 , u_3 and u_4 . The nodal variable u at any given location (x,y) for a bilinear element is approximated by the basis function, which is written as:

$$u = a_1 + a_1 x + a_1 y + a_1 xy \quad (5)$$

Figure 2. Bilinear element.

The above-mentioned basis function can be represented in matrix form:

$$u = \begin{bmatrix} 1 & x & y & xy \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix} \quad (6)$$

Considering each bilinear element composed of four nodal points and nodal variables, the corresponding basis function in matrix form is represented as:

$$\begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix} = \begin{bmatrix} 1x_1y_1x_1y_1 \\ 1x_2y_2x_2y_2 \\ 1x_3y_3x_3y_3 \\ 1x_4y_4x_4y_4 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix} \quad (7)$$

The corresponding shape function is formulated as:

$$u = H_1(x, y)u_1 + H_2(x, y)u_2 + H_3(x, y)u_3 + H_4(x, y)u_4 \quad (8)$$

The individual shape function is based on the four geometric bilinear coordinates for each element located in a structured mesh grid:

$$H_1 = \frac{1}{4A} [(x_3y_3 - x_2y_2 + x_4y_4 + 4x^2) + 2x_1 - 2x_4 + \dots + 2y_1 - 2y_2)x] \quad (9)$$

$$H_2 = \frac{1}{4A} [(x_3y_3 - x_2y_2 - x_4y_4 + x_1y_1) + 2(y_2 - y_1)x \dots + 2(x_1 - x_4)y - 4xy] \quad (10)$$

$$H_3 = \frac{1}{4A} [(x_3y_3 - x_2y_2 - x_4y_4 + x_1y_1) + 2(y_2 - y_1)x \dots + 2(x_4 - x_1)y + 4xy] \quad (11)$$

$$H_4 = \frac{1}{4A} [(x_3y_3 - x_2y_2 - x_4y_4 + x_1y_1) + 2(y_1 - y_2)x \dots + 2(x_4 - x_1)y - 4xy] \quad (12)$$

Where the rectangle Area, A is given by:

$$A = x_3y_3 - x_4y_4 - x_2y_2 + x_1y_1 \quad (13)$$

As it can be observed from Eq. (5) to (11), the trial function u is dependent on the nodal variables at the corners of the bilinear finite elements and the shape functions. The first derivative of this trial function gives the weighed function w in Eq. (4)

$$w = \frac{\partial u}{\partial u_i} \quad (14)$$

In order to determine the elemental stiffness matrix, the first integral of the weak formulation in Eq. (4) is carried out sequentially given below:

$$k^e = \int_{\Omega^e} \left(\frac{\partial w}{\partial x} \frac{\partial u}{\partial x} + \frac{\partial w}{\partial y} \frac{\partial u}{\partial y} \right) d\Omega \quad (15)$$

$$k^e = \int_{\Omega^e} \left[\begin{array}{c} \frac{\partial H_1}{\partial x} \\ \frac{\partial H_2}{\partial x} \\ \frac{\partial H_3}{\partial x} \\ \frac{\partial H_4}{\partial x} \end{array} \right] \left[\frac{\partial H_1}{\partial x} \frac{\partial H_2}{\partial x} \frac{\partial H_3}{\partial x} \frac{\partial H_4}{\partial x} \right] + \left[\begin{array}{c} \frac{\partial H_1}{\partial y} \\ \frac{\partial H_2}{\partial y} \\ \frac{\partial H_3}{\partial y} \\ \frac{\partial H_4}{\partial y} \end{array} \right] \left[\frac{\partial H_1}{\partial y} \frac{\partial H_2}{\partial y} \frac{\partial H_3}{\partial y} \frac{\partial H_4}{\partial y} \right] d\Omega \quad (16)$$

The matrix generated is a 4×4 matrix as given by:

$$\left[K^e \right] = \frac{1}{4A} \begin{bmatrix} k_{11} & k_{12} & k_{13} & k_{14} \\ k_{21} & k_{22} & k_{23} & k_{24} \\ k_{31} & k_{32} & k_{33} & k_{34} \\ k_{41} & k_{42} & k_{43} & k_{44} \end{bmatrix} \quad (17)$$

The diagonal values as follows:

$$K_{11} = \frac{1}{3} \frac{x_2^2 + y_2^2 - 2x_2x_4 - 2y_2y_4 + x_4^2 + y_4^2}{x_2y_4 - x_2y_2 + x_4y_2 - x_4y_4} \quad (18)$$

$$k_{12} = \frac{1}{3} \frac{\frac{1}{2}x_2^2 - y_2^2 - x_2x_4 + 2y_2y_4 + \frac{1}{2}x_4^2 - y_4^2}{x_2y_4 - x_2y_2 + x_4y_2 - x_4y_4} \quad (19)$$

$$k_{13} = \frac{1}{6} \frac{-x_2^2 + y_2^2 + 2x_2x_4 - 2y_2y_4 - x_4^2 + y_4^2}{x_2y_4 - x_2y_2 + x_4y_2 - x_4y_4} \quad (20)$$

$$k_{14} = \frac{1}{3} \frac{-x_2^2 + \frac{1}{2}y_2^2 + 2x_2x_4 - y_2y_4 - x_4^2 + \frac{1}{2}y_4^2}{x_2y_4 - x_2y_2 + x_4y_2 - x_4y_4} \quad (21)$$

Since:

$k_{22}=k_{11}$, $k_{23}=k_{14}$, $k_{24}=k_{13}$, $k_{33}=k_{11}$, $k_{34}=k_{12}$ and $k_{44}=k_{11}$ the matrix is symmetric about its diagonal.

$$\left[K^e \right] = \begin{bmatrix} k_{11} & k_{12} & k_{13} & k_{14} \\ & k_{22} & k_{23} & k_{24} \\ & & k_{33} & k_{34} \\ & & & k_{44} \end{bmatrix} \quad (22)$$

symmetry

4. RESULTS AND DISCUSSION

In this section a set of numerical experiments are carried out for the evaluation and analysis of the results. A rectangular 2D domain is developed and steady state heat conduction with no heat source is applied. The domain measures 5 units and 10 units in the x and y direction respectively. GFEM is used by implementing the weighed residual approximation approach on each bilinear element for solving the Laplace PDE governing the 2D heat conduction problem. Both Dirichlet and Neumann boundary conditions are specified for the solution domain as given in Figure 3. The boundary conditions are below:

$$u(0, y) = 0 \quad \& \quad u(x, 0) = 0$$

$$u(x, 10) = 100 \sin(0.1 \pi x) \quad \text{and} \quad \frac{\partial u}{\partial x}(5, y) = 0$$

Figure 3. Steady state heat conduction problem of rectangular domain.

Solving the above mentioned problem required calculating the stiffness matrix of the bilinear elements using the Galerkin finite element approach. The accuracy of the approach largely depends on the element size and number of elements considered. It has been observed increasing the number of elements and decreasing the element size increases the accuracy of the solution by achieving higher convergence rates.

Comparison is made with the exact solution of the Eq. (23) below and Figure 4 shows the graphical analysis.

$$u = 100 \sin(0.1\pi x) \sinh(0.1\pi y) \sinh\pi \quad (23)$$

Figure 4. Comparison between Galerkin FE solution and exact solution.

The Figure 5 represents the solution domain discretized into a numbers of smaller bilinear elements each consisting of nodes at the corners.

Figure 5. Physical domain with bilinear mesh.

The errors analysis of the Galerkin approach solution and analytical solution are given by the following equations:

$$H^1 = \frac{\sum_{i=1}^N |\tilde{u}_i - \bar{u}_i|}{N} \quad (24)$$

$$L^2 = \sqrt{\frac{\sum_{i=1}^N |\tilde{u}_i - \bar{u}_i|^2}{N}} \quad (25)$$

$$L^\infty = \max \sum_{i=1}^N |\tilde{u}_i - \bar{u}_i| \quad (26)$$

Table 1 below lists the set of errors analysis for different numerical experiments using various number of elements and element sizes. The equation form $\|\tilde{u}_i - \bar{u}_i\|_0$ represents the L^2 norm, $\|\tilde{u}_i - \bar{u}_i\|_1$ represents H^1 norm and $\|\tilde{u}_i - \bar{u}_i\|_\infty$ represents L^∞ norm (He, Lin, & Lin, 2010).

Table 1. L^∞ , L^2 and H^1 errors of the Galerkin method solution.

Number of elements	$\ \tilde{u}_i - \bar{u}_i\ _0$	$\ \tilde{u}_i - \bar{u}_i\ _1$	$\ \tilde{u}_i - \bar{u}_i\ _\infty$
4×4	5.06E-01	8.90E-01	2.20E+00
8×8	1.19E-01	1.68E-01	3.71E-01
16×16	2.85E-02	3.74E-02	2.85E-02
32×32	6.96E-03	8.88E-03	1.86E-02
64×64	1.72E-03	2.17E-03	4.49E-03
128×128	4.27E-04	5.35E-04	1.11E-03
256×256	1.06E-04	1.33E-04	2.74E-04
512×512	2.66E-05	3.31E-05	6.83E-05

It can be observed from Table 1 that increasing the number of elements while decreasing the element size has a converging on both the exact and GFEM solution on all three of the calculated norms, H^1 , L^2 and L^∞ with convergence rates of $O(h^2)$, $O(h)$ and $O(h^2)$ respectively. This validates convergence towards the expected exact solution and accuracy of the presented Galerkin finite element scheme. Figure 6 below show the graphical illustration of the convergence of decreasing the size and increasing the number of elements on the rate of errors respectively for the generated scheme.

Figure 7. Error analysis vs number of element.

Figures 8 and 9 shows the 2D rectangular solution domain where, the surface plot and contour plot are taken from the results. The temperature distribution is governed by time independent heat conduction with no heat source.

Figure 8. Surface plot of temperature variation in the GFEM solution domain using Matlab.

Figure 9. Contour plot using Matlab.

5. CONCLUSION

It is shown that GFEM is an inexpensive and powerful technique to accurately model and has demonstrated solving a time dependent and external heat source independent 2D heat conduction Laplace partial differential equation, governing a rectangular planar domain, using bilinear elements. Increasing the number of elements while decreasing the element size representing the solution domain shows optimal convergence towards the exact solution, thereby validating the accuracy of the scheme.

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