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Extraction, analysis and desaturation of gmelina seed oil using different soft computing approaches

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ABSTRACT

Artificial Neural Network (ANN)-Genetic Algorithm (GA) interface and Response Surface Methodology (RSM) have been compared as tools for simulation and optimization of gmelina seed oil extraction process. A multi-layer feed-forward Levenberg Marquardt back-propagation algorithm was incorporated for developing a predictive model which was optimized using GA. Design Expert simulation and optimization tools were also incorporated for a detailed simulation and optimization of the same process using Response surface methodology (RSM). It was found that oil yield increased with rise in temperature, time and volume of solvent but decreased with increase in seed particle size. The maximum oil yield obtained using the numerical optimization techniques show that 49.2% were predicted by the RSM at the optimum conditions of; 60 °C temperature, extraction time 60 min, 150 μm seed particle size, 150 ml solvent volume and 49.8% by ANN-GA at extraction temperature 40 °C, extraction time 40 min, 200 μm seed particle size, 100 ml solvent volume, respectively. The prediction accuracy of both models were more than 95%. Models validation experiments indicate that the predicted and the actual were in close agreement. The extract was analyzed to examine its physico-chemical properties (acid value, iodine value, peroxide value, viscosity, saponification value, moisture and ash content, refractive index, smoke, flash and fire points and specific gravity) and structural elucidation by standard methods and instrumental techniques. Results revealed that the oil is non-drying and edible. Desaturation of the oil further reveal its potential in alkyd resin synthesis.

1. Introduction

The high costs, the environmental impact, and the decrease in fossil resources are the main reasons behind attracting a great deal of attention of the research community towards searching for alternative raw materials in different industrial fields. Now, with the increase in world demand for oil and the challenges to expand the existing oil supply for human consumption and industrial utilization (Basumatary et al., 2012), there is need to utilised less expensive and non-edible product (oil) in the synthesis of the resins or biodiesel and other products in order to meet up with the competitive environment of such industries. One of such product which can be utilised to yield a desirable result both in terms of cost, renewability, biodegradability and non-edibility is gmelina seed oil (GSO).

Gmelina seed oil have been found to be a sustainable material for biodiesel and alkyd resin synthesis in terms of its availability and renewability. Gmelina seed oil based biodiesel have been produced keeping two criteria in mind; the biodiesel met all the technical and industrial standards of ASTM D6751 and EN 14214, and, met all the ecologically relevant

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standards (Basumatary et al., 2012; Sangay et al., 2014). However, there has been doubt over sustained use of gmelina seed oil for large scale production of biodiesel and alkyd resin due to low yields. Most methods of oil extraction seem to be very costly due to inability to control some inherent factors. A lot of researches has been carried out to find alternative ways of producing oil for process industries and for food industry. It has been found that almost all the seeds contain oil, hence, these gives ground for other researchers to consider studies on the possible uses of other oil producing substances found in people's everyday lives. There are various ways of extracting oil from oilseeds but solvent extraction has been reported to be most efficient techniques (Topallar and Gecgel, 2000). There is need therefore, for process industries to optimize current methods of extraction, thereby improving the profitability of production and ensuring a sufficient supply of oil.

Gmelina arborea is a fast growing tree, which grows on different localities and prefers moist fertile valleys, they attain moderate to large height up to 40 m and 140 cm in diameter (Tewari, 1995). It is occurring naturally throughout greater part of India at altitudes up to 1500 m. It also occurs naturally in Myanmar, Thailand, Laos, Cambodia, Vietnam, and in southern provinces of China, and has been planted extensively in Sierra Leone, Nigeria and Malaysia (Adegbehin et al., 1988). Now, gmelina seeds are already proven to produce oil (Adeyeye, 1971), this fact itself is already useful information for researchers who seek to find alternative sources of oil. The ability of the oil to fit depends on its constituents, its compositions, rate of production and availability of the processing technology. The study of these constituents is important for their effective uses. In a previous work (Uzoh and Onukwuli, 2014), we reported kinetics and optimization of gmelina seed oil using response surface methods, in which an optimal yield of 49.90% was predicted.

Mathematical and statistical techniques such as Response Surface Methodology (RSM) and Artificial Neural Network (ANN) can assist in analyzing experimental data, finding optimum situation and predicting results. Statistical design, first applied in industry in the 1930s, was promoted by Box and Wilson (Box and Wilson, 1951) with the development of the response surface methodology (RSM). RSM can be defined as a group of mathematical and statistical techniques used to model and analyze results/data in which the response/property of interest is affected by numerous factors, and the aim is to obtain an optimum response (Montgomery, 2005). Once a system is fully characterized, the objective of process design may be pursued further by formulating a model that may permit a rough local approximation to the actual surface. Such predictive models are usually developed from design of experiment to provide analytical solution(s) for the desired response; obviating the need for experimenting in an ad hoc manner in search of optimal setup. RSM and other designs spread throughout several industries over the next 30 years. The use of experimental design was expanded by Genichi Taguchi and others (Taguchi and Wu, 1980; Taguchi, 1987, 1991). However, the Robust Parameter Designs (RPD) approach initially proposed by Taguchi, caused lots of controversy among statisticians (Wagoner, 1998). With the emergence of Response surface Methodology (RSM), many efficient approaches which could be effectively handle RPD problems are available (Montgomery, 2005).

Most of the traditional optimization techniques based on gradient methods have the possibility of getting trapped at a local optima, depending upon the degree of non-linearity and the initial guess. Hence, it does not ensure the global optimum and also have limited application. Non-traditional search and optimization methods based on natural phenomena; neural networks and evolutionary computation (simulated annealing, genetic algorithm and differential evolution) have been developed to overcome this problem (Babu, 2004). Artificial neural network (ANN) is a highly simplified model of the structure of a biological network (Mandal et al., 2009). The fundamental processing element of ANN is an artificial neuron (or simply a neuron). A biological neuron receives inputs from other sources, combines them, performs generally a non-linear operation on the result, and then outputs the final result (Bas et al., 2007). The basic advantage of ANN is that it does not need any mathematical model since an ANN learns from examples and recognizes patterns in a series of input and output data without any prior assumptions about their nature and interrelations (Mandal et al., 2009). ANN is a good alternative to conventional empirical modeling based on polynomial and linear regressions (Kose, 2008). In recent years, the genetic algorithms have been successfully applied in a variety of fields where optimization in the presence of complicated objective functions and constraints abounds. The reasons of widely used GAs are its global search ability and independence of initial value. Genetic algorithm (GA) is a stochastic general search method which proceeds in an iterative manner by generating new populations of individuals from the old ones. GA uses stochastic operators such as selection, crossover and mutation on an initially random population in order to compute a new population (Holland, 1975). The search feature of the GA is contrast with those of the gradient descent and LM in that it is not trajectory-driven, but population-driven. The GA is expected to avoid local optima frequently by promoting exploration of the search space, in opposition to the exploitative trend usually allocated to local search algorithms like gradient descent or LM (Ghaffari et al., 2006). The central focus of the current research is to develop a predictive model for gmelina seed oil extraction from RSM and ANN and subsequently optimized the process through RSM and ANN-GA interface. Characterize and desaturate the extract in order to examine its applicability as surface coating raw material. In gmelina seed oil extraction process (where the performance of the system were described by many process variables), a proper optimization process would seek to achieve a balance of trade-off among the list of desirable output responses. RSM and ANN-GA are preferable for this objective. Although, Yasin et al. (2014), used the method for lead ions removal from aqueous solutions using intercalated tartrate-Mg–Al layered double hydroxides, it has not yet received much attention. Specifically, it must be highlighted that the ANN-GA combination has not yet been used for modeling and optimization of any oil extraction processes. Gmelina seed has been found most suitable in that; it is not edible, widely available, will not interfere in the food chain and can stand out as sustainable material for energy.

2. Materials and methods

2.1. *Materials*

The gmelina fruits were collected locally from a forest in ministry of forest reserve, Anambra State, Nigeria. It was soaked in water for eight days so as to easily separate the fruit pulp from the seed (de-pulp). The seeds were sun-dried and crushed mechanically using corona blender; the crushed