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Estimation of Carrageenan Concentration by Using Ultra Sonic Waves and Back Propagation Neural Networks

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Abstract: The application of Artificial Neural Networks in chemical engineering field is being under immense research. One of the physical properties of every material has its own intensity to absorb the sound waves. Carrageenans are water-soluble gums, which occur in certain species of red seaweeds. They are sulfated natural polymers made up of galactose units. Carrageenan consists of a main chain of D-galactose residues linked alternately α - (1→3) and β - (1→4). The decibel frequency analyzer dbFA - 32 has been used for this analysis. The sound signals are captured using the hydrophone. The analog signals are then digitized at different octave frequencies. These are used to generate the frequency power spectrum. The change in the spectrum is proportional to the concentration of the material in the solution. The normalized data is used as a input to a feed forward neural network model. In this study, a simple scheme is proposed to estimate the amount of carrageenan present in a solution using under water acoustics and Artificial Neural Networks. This method is useful for the direct estimation of carrageenan in food, pharmaceutical and cosmetic industries. It can be useful for online measurement of compound in the industries.

Key words: Ultra sonic waves, carrageenan, back propagation, neural networks

INTRODUCTION

Carrageenans (Falshaw *et al*., 2001) are water-soluble natural gums, which occur in red seaweeds. They are sulfated natural biopolymers made up of galactose units. Carrageenan consists of a main chain of D-galactose residues linked alternately (Fig. 1) α - (1→3) and β- (1→4). The differences between the fractions are the number, the position of the sulfate groups and to the possible presence of a 3-6 anhydro-bridge on the galactose linked through the 1 - and 4 -positions (Janaswamy *et al*., 2001).

Use of carrageenan is exponentially increasing day by day. As it finds various applications in the process industries (Bono *et al*., 2003).

Especially in the personal care products (shampoos) formulation, the major ingredients are surfactants, thickeners, conditioners and preservatives (Kirk-Othmer). The thickeners used are highly costly and cause side effects. However, the carrageenans are natural biopolymer having properties such as non-harmful, non-toxic, excellent gelling (Mangione *et al*., 2003) and as thickening agent. Due to these properties, it can act as a good thickener and conditioner. Besides, it is very economical than other chemicals. Therefore, the industries are very keen to introduce carrageenan into the personal care product formulations and other process industries. Thus, it leads to emphasize to do research in this particular area to use carrageenan much more effectively.

Ultrasonic material analysis is based on the measurements of parameters of ultrasonic waves propagating through the analyzing samples. This provides information on the interaction of ultrasonic waves with the sample's interior, thus allowing analysis of its physical and chemical properties (Buckin *et al*., 2002). The nondestructive analysis of intrinsic properties of materials (Lorimer and Mason, 1995; Margulis, 1993; Malika *et al*., 2003) is based on measurements of characteristics of signals that have traveled through the analyzed sample. These characteristics reflect the

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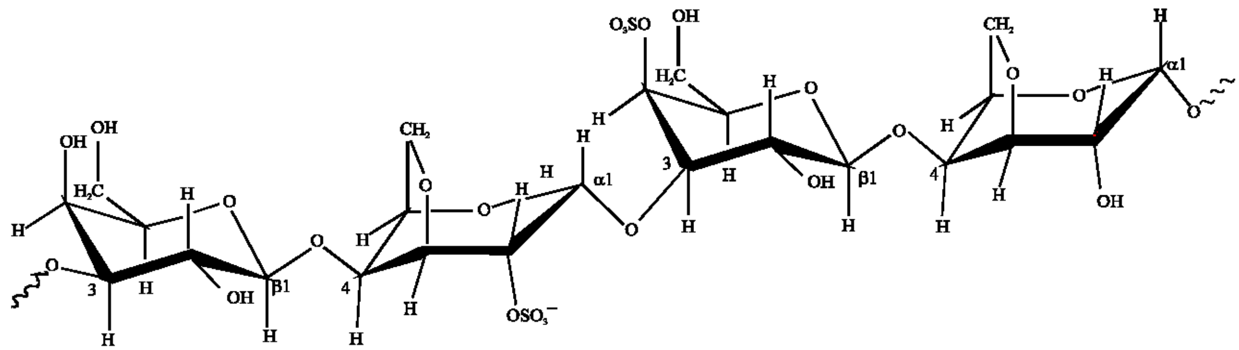

Fig. 1: Molecular structure of Carrageenan

interaction of the signal with the interior of the sample. Benefits of ultrasonic waves for material analysis (Buckin *et al*., 2002).

They propagate through most materials, allowing analysis of a wide variety of samples, including optically nontransparent materials.

They probe the elastic (rather than electric and magnetic) characteristics of materials, which are extremely sensitive to intermolecular interactions. Compression in the ultrasonic wave changes the distances between the molecules of the sample, which responds by intermolecular repulsions. Sound in water propagates much faster (five times) than in air because of the differences in the elasticities of these mediums. This high sensitivity of the ultrasonic parameters to intermolecular interactions permits the ultrasonic analysis of a broad range of molecular processes, which cannot be analyzed or are difficult to analyze with other techniques.

It is relatively easy to generate and change the wavelength of high-frequency ultrasonic waves adsorption on particle surfaces. This allows the construction of robust and multipurpose instruments that perform a multitude of analytical functions for fast, nondestructive analysis.

The online estimation of carrageenan by using underwater acoustic techniques and artificial intelligence (Lauren Faussett) can be immensely useful in the quality control of food and processes industries. The cosmetics industries are highly depending on oligomeric carrageenan products.

MATERIALS AND METHODS

Carrageenan: It is extracted from the *Euchema spinosum* (Sabah seaweed). Seaweed is collected from Borneo Marine Research Institute, University of Malaysia Sabah, Kota kinabalu.

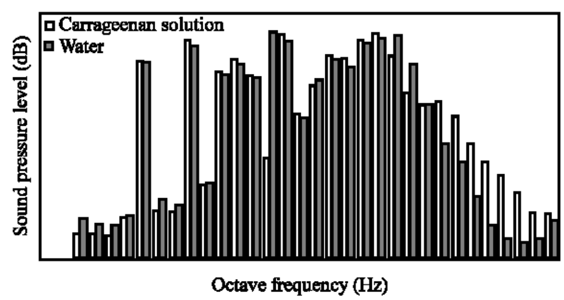

Fig. 2: Octave band frequency distribution of carrageenan solution and water

Hydrophone:
Type: 10CT
Operating Depth: 700 m
Survival Depth: 1000 m
Receiving Sensitivity: -211±3 dB
Transmitting Sensitivity: 132±3 dB

In this study the air spager is used as an underwater sound generator (Alrutz and Schroeder, 1983). A transducer (a wide band hydrophone) is used as the receiving sensor, located near the sound source. The couple of source and receiver is moved on a straight line at constant depth, scanning the bottom profile.

The absorption of sound intensity varies with the amount of carrageenan present in the solution. The quadratic one third octave frequency signals inside the solution is detected by using hydrophone. Through, dbFA -32 analyzer, the analog frequency signals are digitized, captured in the form of broadband spectrum and stored in the personal computer.

The net change in the broadband spectrum (Fig. 2) is directly proportional to the concentration of the carrageenan in the solution. The power spectrum data is associated to the measured value of the concentration and is normalized. The normalized data is used as input to a feed forward neural network model. The experiment is conducted at different distances between the source and the receiver.

RESULTS AND DISCUSSION

In this experiment, a feed forward neural network (FFNN) network shown in Fig. 3 with 32 input neurons, 20 neurons in the hidden layer and 1 output neuron is considered. The activation function used for the hidden and output neuron is bipolar sigmoidal activation function.

The initial weights are randomized between -0.5 and +0.5 and normalized using equation 1. Each trial consists of 50 sets of randomized weight samples. For each weight sample, the FFNN is trained by BP algorithm with the learning rate and momentum factor as 0.1 and 0.4, respectively.

$$x_n = \frac{1.8(x - x_{min})}{(x_{max} - x_{min})} - 0.9 \quad (1)$$

$$NMSE = \frac{\sum_{k=1}^{N}(y_k - t_k)^2}{\sum_{k=1}^{N} t_k^2} \quad (2)$$

Normalized Mean Square Error (NMSE), where, y_k is the actual value and t_k is the target value.

The resulting epoch against cumulative error graph is shown in Fig. 4. The network training parameters and the training time are shown in Table 1. The correlation

Table 1: Network training phases

No. of input neurons - 32	No. of hidden neurons - 20	No. of output neurons - 1
Training tolerance - 0.001	Testing Tolerance - 0.2	Momentum factor - 0.4
Learning rate - 0.1	No. of samples for training - 17	No. of samples for testing - 22
Training time - 20 sec	No. of epochs - 546	Success rate - 86.36%
Normalized mean square error -0.020698		Activation function - $f(x) = 2\,(1+\exp(-x))^{-1} - 1$
Computational time - 88 sec		

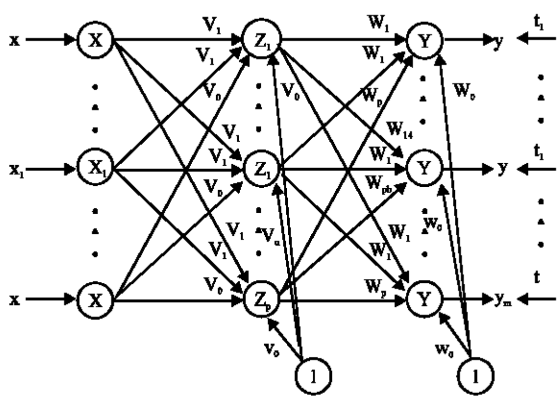

Fig. 3: Architecture of back propagation network

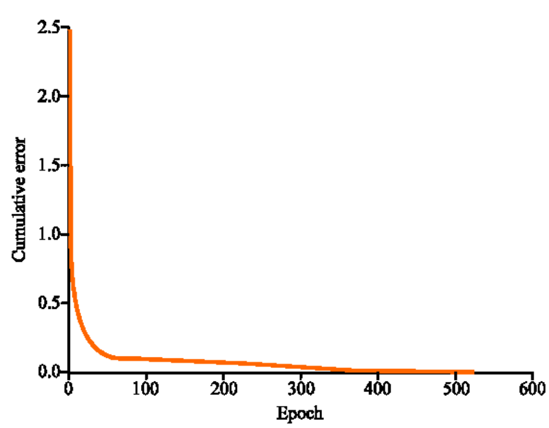

Fig. 4: Cumulative error vs. epoch plot

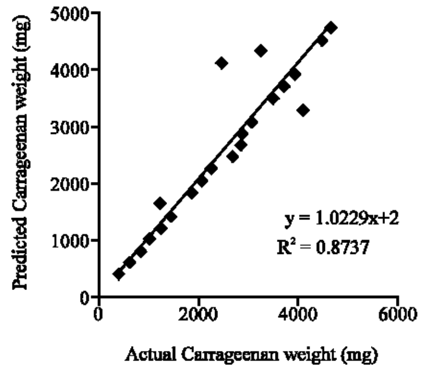

Fig. 5: Actual vs. Predicted Carrageenan weights

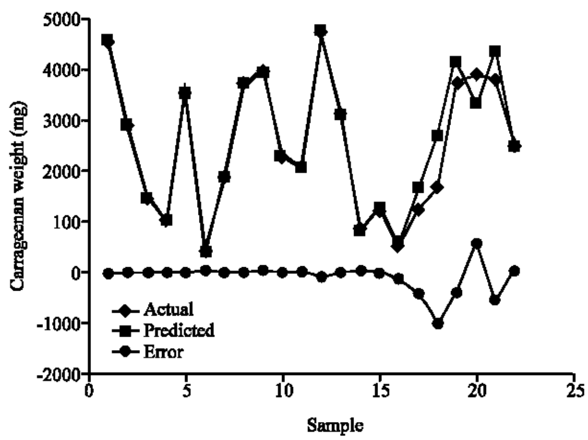

Fig. 6: Actual and predicted Carrageenan weights vs. samples

between the target value and predicted weight value of Carrageenan is shown in Fig. 5. Further, the variance error present in the neural network model is also shown in the Fig. 6.

CONCLUSION

The quantitative analysis of polysaccharides is difficult by using conventional chemical methods. The sonometric and neural network back propagation method is helpful to quantifying the polysaccharides (Carrageenan etc.) in research and processes industries. This approach offer unprecedented tools for research and industry in developing new carrageenan gel-based products and optimization of existing technologies.

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