Adaptive Neuro-fuzzy Inference System and Artificial Neural Network Estimation of Apparent Viscosity of Ice-cream Mixes Stabilized with Different Concentrations of Xanthan Gum

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Abstract:
An adaptive neuro-fuzzy inference system (ANFIS) was used to accurately model the effect of gum concentration (GC) and shear rate (SR) on the apparent viscosity (η) of the ice-cream mixes stabilized with different concentrations of xanthan gum. ANFIS with different types of input membership functions (MFs) was developed. Membership function “the gauss2” generally gave the most desired results with respect to MAE, RMSE and R^2 statistical performance testing tools. The ANFIS model was compared with artificial neural network (ANN) and multiple linear regression (MLR) models. The estimation by ANFIS was superior to those obtained by ANN and MLR models. The ANFIS and ANN model resulted in a good fit with the observed data, indicating that the apparent viscosity values of the ice-cream can be estimated using the ANFIS and ANN models. Comparison of the constructed models indicated that the ANFIS model exhibited better performance with high accuracy for the prediction of unmeasured values of apparent viscosity η parameter as compared to ANN although the performance of ANFIS and ANN were similar to each other. Comparison of the constructed models indicated that the ANFIS model exhibited better performance with high accuracy for the prediction of unmeasured values of apparent viscosity η parameter as compared to ANN although the performance of ANFIS and ANN were similar to each other.

Zusammenfassung:
Ein adaptives, sogenanntes Neuro-Fuzzy-Inferenzsystem (ANFIS) wurde angewandt, um den Einfluss der Gummiharz-Konzentration (GC) und der Schergeschwindigkeit (SR) auf die scheinbare Viskosität (η) von Eiscreme-Mischungen zu untersuchen, die mit unterschiedlichen Konzentrationen von Xanthan stabilisiert wurden. ANFIS mit unterschiedlichen Typen von Eingabefunktionen (MFs) wurden entwickelt. Die Eingabefunktion „the gauss2“ führte generell zu den besten Resultaten hinsichtlich der statistischen Auswertetools MAE, RMSE und R2. Das ANFIS-Modell wurde mit künstlichen neuronalen Netzwerken (ANN) und multiplen linearen Regressions (MLR)-Modellen verglichen. Die Abschätzung durch das ANFIS-Modell war besser als die durch die ANN und MLR-Modelle erhaltenen Abschätzungen. Das ANFIS und das ANN-Modell resultierten in einen guten Fit der Messdaten. Dies zeigt, dass die scheinbare Viskosität der Eiscreme durch das ANFIS und das ANN-Modell abgeschätzt werden können. Der Vergleich der entwickelten Modelle zeigte, dass das ANFIS-Modell eine bessere Darstellung mit höherer Genauigkeit für die Vorhersange nicht gemessener Werte der scheinbaren Viskosität η im Vergleich zum ANN-Modell aufwies, obgleich das ANFIS- und das ANN-Modell eine ähnliche Darstellung aufwiesen.

Résumé:
Un système adaptif “neuro-fuzzy inference” (ANFIS) a été utilisé pour modéliser précisément l’effet de la concentration en gomme (GC) et de la vitesse de cisaillement (SR) sur la viscosité apparente (η) de mélanges de crèmes glacées stabilisées avec des concentrations différentes de gomme de xanthan. Des ANSIS avec des types différents de fonctions de données membres (MFs) ont été développés. La fonction « le gauss2 » a donné les resultats les plus adéquat relativement aux outils de tests de performance statistique MAE, RMSE et R2. le modèle ANFIS a été comparé avec le réseau neural artificiel (ANN) et les modèles de régression linéaire multiples (MLR). L’estimation par ANFIS est supérieure à celles obtenues avec ANN et MLR. Les modèles ANFIS et ANN ont produit de bons ajustements avec les données observées, ce qui indique que les valeurs de la vis-

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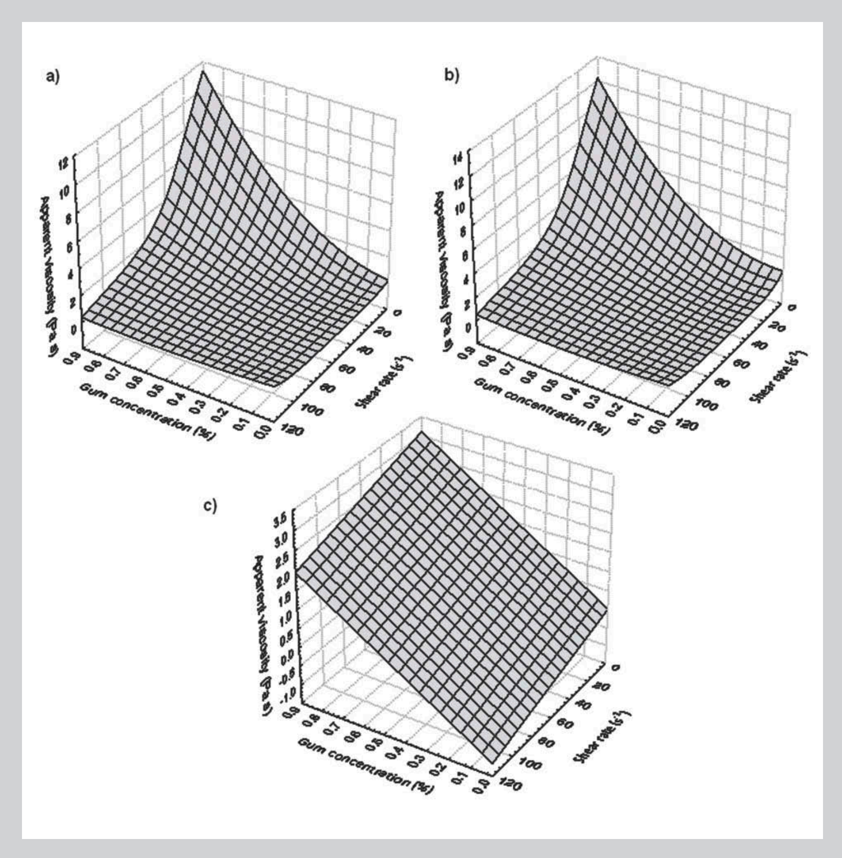

Figure 8:
Comparison of three-dimensional plots generated using the apparent viscosity η values of ice cream samples estimated by (a) ANFIS, (b) ANN and (c) MLR models in checking (validation) period. ANFIS, adaptive neuro-fuzzy inference system; ANN, artificial neural network; MLR, multiple linear regression.

4 CONCLUSIONS

Comparison of the constructed models indicated that the ANFIS model exhibited better performance with high accuracy for the prediction of unmeasured values of apparent viscosity parameter as compared to ANN although the performance of ANFIS and ANN was similar to each other. However, MLR model was found to be inadequate for estimating the η values. These results might be useful for ice-cream industry aiming to control the rheological properties of their products added with different concentrations of xanthan gum because it may enable the ice-cream industry to previously estimate how the product viscosity would be before a large scale of production. Early prediction would also pave the way for the industry to save time and cost if it aims to produce a product with acceptable rheological properties. As a conclusion, ANFIS could be poposed to be the best model in order to estimate unmeasured or untested interval values of rheological properties of the ice-cream mixes added with different levels of xanthan gum.

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