Correlation of machine learning-predicted viscosity of hydrocolloids with texture of plant-based meat analogue

Sungmin Jeong[1], Suin Yun[1], Suyong Lee[1*]

[1] Department of Food Science & Biotechnology and Carbohydrate Bioproduct Research Center, Sejong University, Seoul, Korea

*Corresponding author email: suyonglee@sejong.ac.kr

I. INTRODUCTION

Hydrocolloids have been extensively used in order to control the rheological properties of meat products due to their unique features. Therefore, if there is an efficient way to predict the rheological properties of hydrocolloids, it may be a breakthrough innovation in the meat processing industry. A machine learning framework was thus proposed in order to describe and predict the flow behaviors of six hydrocolloid solutions, and the predicted viscosities were correlated with the textural features of their corresponding plant-based meat analogues.

II. MATERIALS AND METHODS

The steady-shear viscosities of six food hydrocolloids (guar gum, locust bean gum, xanthan gum, konjac, methylcellulose, and sodium alginate) were experimentally measured at different levels of concentration, temperature, and shear rate using a controlled-stress rheometer. Their viscosity behaviors were then fitted into both mathematical and machine learning models, which were constructed in the Jupyter Notebook environment with the python programming language. The established machine learning model was also used to predict the viscosities of the hydrocolloids, which were correlated with the textural features of their corresponding plant-based meat analogues.

III. RESULTS AND DISCUSSION

Different shear-thinning and Newtonian behaviors were observed depending on the type of hydrocolloids and the shear rates. Methylcellulose exhibited an increasing viscosity pattern with increasing temperatures, compared to the other hydrocolloids (Figure 1(a)). The machine learning algorithms (random forest and multilayer perceptron models) in Figure 1(b) showed a better viscosity fitting performance than the constitutive equations (Power-law and Cross models).

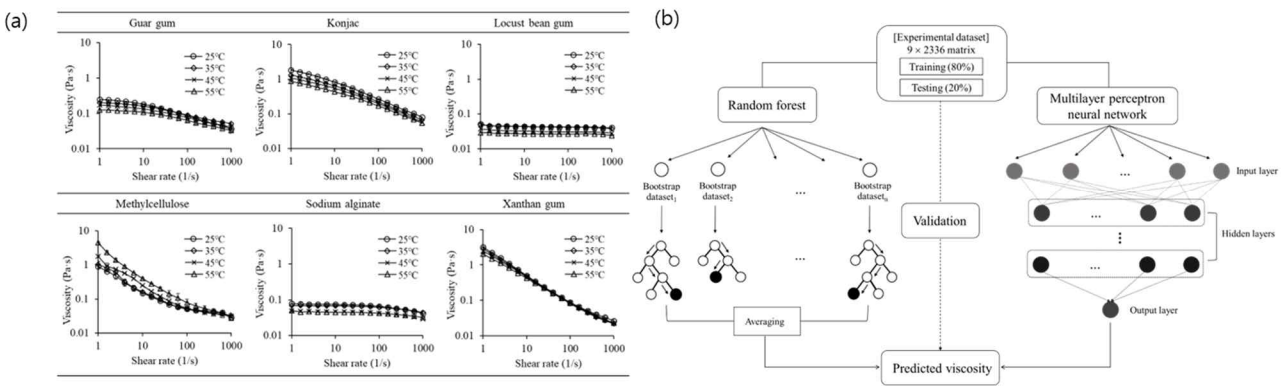

Figure 1. (a) Flow behaviors of hydrocolloids over shear rates and temperatures and (b) machine learning structure

Three hyperparameters of the multilayer perceptron model (optimizer, learning rate, and the number of hidden layers) were tuned using the Bayesian optimization algorithm, leading to the superior performance of the viscosity prediction (Figure 2).

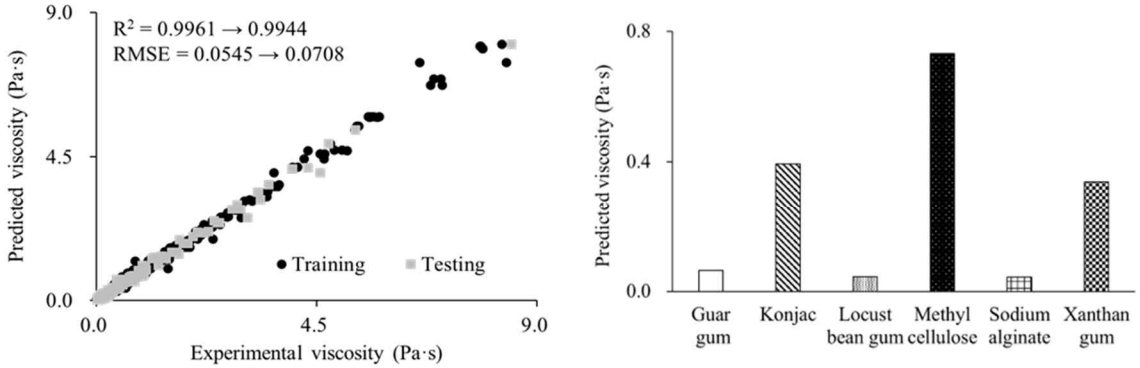

Figure 2. Machine learning predicted viscosity

The patty-making performance was highly dependent on the type of the hydrocolloids used. Methylcellulose was the most effective in preparing the patty samples without any cooking difficulties (Figure 2(a)). The predicted viscosities by machine learning showed similar patterns with the textural features of cooked meat analogues for all the hydrocolloids tested except for xanthan gum as shown in Figure 2(b).

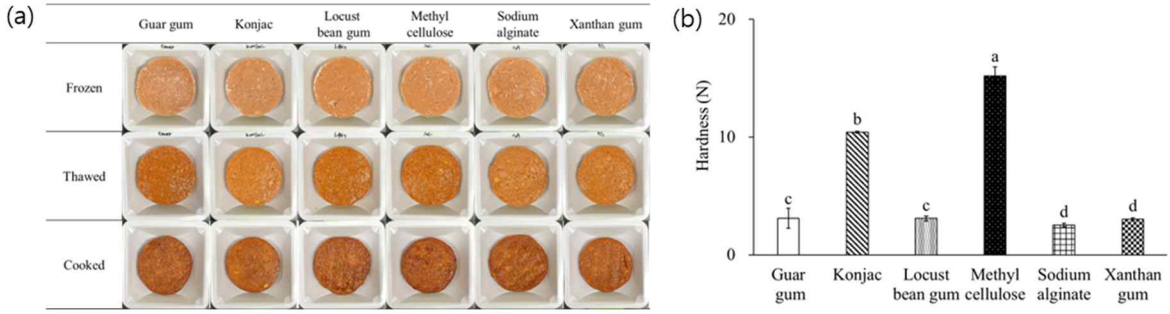

Figure 2. (a) Visual appearances and (b) textural properties of plant-based meat analogues

IV. CONCLUSION

In this study, machine learning might consequently be considered as an efficient tool to predict the rheological behaviors of hydrocolloid solutions under different processing conditions and further to estimate the textural properties of their corresponding end-products.

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