SHIMADZU
Excellence in Science

Application News

EZTest™ Texture Analyzer

Prediction of Sensory Evaluation Values of Cookies Using Machine Learning

Fumiaki Yano, Natsumi Koike

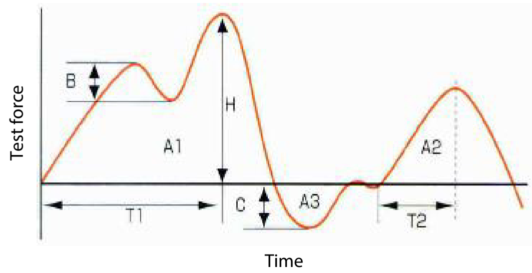
User Benefits

- Texture testing of food products is possible by using the EZTest texture analyzer.
- Various jigs can be exchanged easily by using the jig platform.
- It is possible to predict approximate sensory evaluation values by using machine learning.

■ Introduction

The factors that humans experience as the "deliciousness" of food include factors related the food itself (e.g., flavor, aroma, food texture) and human factors (physiological and psychological factors, eating habits, external factors), but because texture accounts for a large part of the perception of deliciousness, depending on the food, the evaluation of food texture has become one important item in food testing. Methods for evaluating food texture can be divided into sensory evaluation, in which human subjects evaluate the "mouthfeel" of the food when eaten, and evaluation of physical (mechanical) properties such as the hardness of the food using instruments. Mouthfeel is generally evaluated by sensory tests, but the difficulty of reproducing the evaluation results due to individual differences in the human senses and the physical condition of the subjects is an issue in sensory tests. For this reason, measurements using instrument are conducted in order to obtain objective results. As representative mechanical properties of texture, Fig. 1 shows texture profile proposed by Szczesniak. Although the texture profile makes it possible to evaluate the basic mouthfeel of foods, it is difficult to measure more complex characteristics of mouthfeel.

In the previous report [1], the hardness, crispness, and moistness of various types of sample cookies were predicted by multivariate analysis. In order to consider variations in the cookies themselves, the predictions were made using the average values of the mechanical properties of each type of cookie obtained from the texture tests. This article introduces an example of prediction of the sensory evaluation value of one cookie by machine learning using a larger number of explanatory variables [2]. As in the previous report, the target sensory evaluation items in this experiment were hardness, crispness, and moistness, and the measured data of the texture test were also the same.



Hardness	: H	Maximum test force (N)
Brittleness	: B	Force required to break food in the mouth (N)
Adhesiveness	: A3	Force required to remove food adhering to teeth, tongue, or oral cavity (N)
Cohesiveness	: A2/A1	Ratio of 1st and 2nd load areas (energy)
Springiness	: T2/T1	Ratio of time (displacement) to return to peak
Gumminess	: H×A2/A1	Hardness × Cohesiveness
Chewiness	: H×A2/A1×T2/T1	Hardness × Springiness × Cohesiveness

Fig. 1 Szczesniak Texture Profile

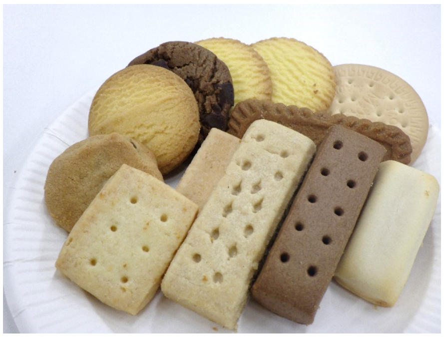


Fig. 2 Measurement Samples (11 Types of Cookies)

■ Sensory Evaluation

As shown in Fig. 2, 11 types of cookies were prepared. Table 1 shows the results of the sensory evaluation. For details, please refer to the previous report.

Table 1 Results of Sensory Evaluation (Statistical Results for 10 Central Subjects)

Sample name	Hardness			Crispness			Moistness		
	Average	Standard deviation	Coefficient of variation	Average	Standard deviation	Coefficient of variation	Average	Standard deviation	Coefficient of variation
A	54.30	7.85	14.45	72.10	5.07	7.03	44.90	8.57	19.09
B	66.10	4.58	6.93	80.20	5.90	7.36	20.30	8.08	39.82
C	20.40	4.70	23.02	25.50	4.28	16.77	79.00	6.99	8.85
D	88.60	3.10	3.50	78.80	6.14	7.80	22.50	7.55	33.54
E	60.20	9.44	15.68	67.60	6.22	9.20	42.10	13.11	31.14
F	52.50	7.23	13.77	70.90	5.20	7.33	40.00	9.43	23.57
G	72.20	4.13	5.72	65.80	4.44	6.75	37.65	5.52	14.66
H	40.30	7.87	19.54	40.10	7.23	18.04	55.70	14.58	26.18
I	54.70	8.21	15.00	68.20	6.43	9.42	37.10	6.21	16.73
J	75.60	5.50	7.28	83.40	3.53	4.24	24.60	7.59	30.85
K	34.50	4.38	12.69	31.30	3.80	12.15	70.00	11.55	16.50

■ Texture Tests

A Shimadzu EZTest texture analyzer was used in the texture measurements. In the previous report, the most suitable method from among the compression test, piercing test, and 3-point bending test was studied. The present paper only describes the compression test, which was considered to be the most suitable among those methods. Details may be found in the previous report. Table 2 shows the instrument configuration, including the jig used, and Fig. 3 shows the condition of the test.

The test speed in the compression test was set to 10 mm/s, and the number of tests of each sample was n = 20. Fig. 4 shows representative test force-strain curves. Large variations were observed in each type of sample because the samples were not uniform. However, general tendencies were apparent in each sample type. For example, with Sample A, some variations in test force were observed as the test proceeded, while the test proceeded smoothly with Sample C and large variations in test force occurred in the case of Sample D.

Table 2 Instrument Configuration

Texture analyzer	: EZTest
Load cell	: 100 N
Test jig	: Φ3 circular cylindsrical pressing jig
Software	: TRAPEZIUM™-X texture

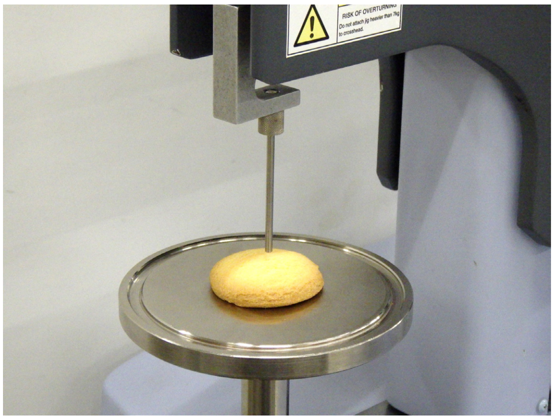


Fig. 3 Condition of Test

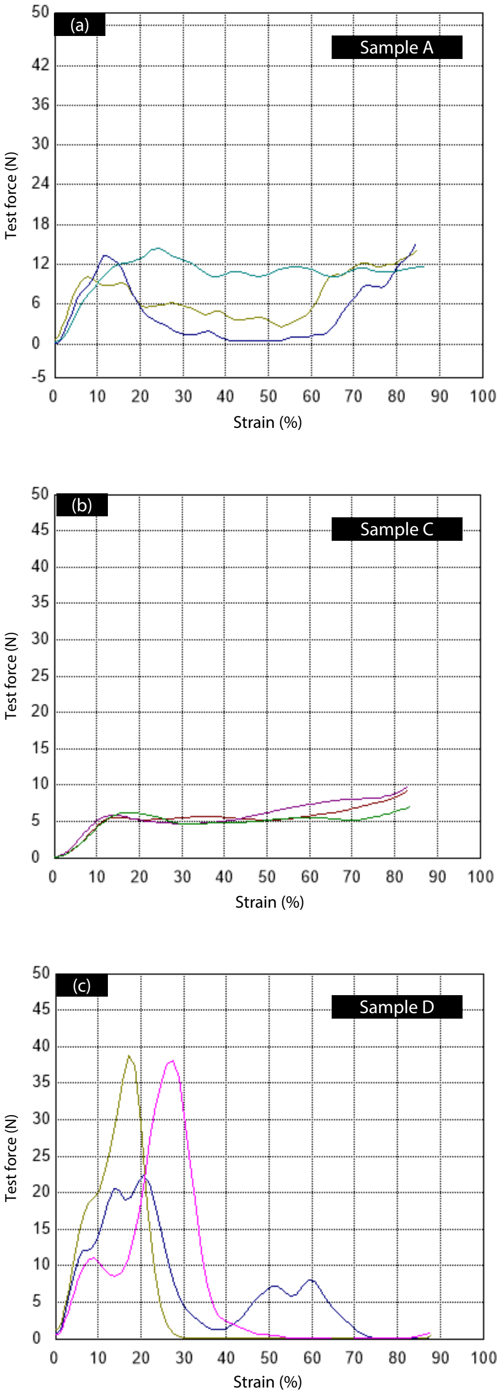


Fig. 4 Examples of Compression Test Results (Test Force-Strain Curves)
Results for (a) Sample A, (b) Sample C, and (c) Sample D

■ Prediction of Sensory Evaluation Values by Machine Learning

As the explanatory variables in machine learning, a total of 11 measured values were selected, including hardness, initial inclination, energy, sample thickness, and average test force. Random forest was selected as the regression algorithm for machine learning, and because the number of samples was small (11 types), the model was evaluated by the leave-one-out method. As an example of the evaluation results by the leave-one-out method, Fig. 5 shows the results of the predictions of moistness. In Fig. 5, the y-axis shows the predicted value, and the x-axis shows the actual sensory evaluation value. In the leave-one-out method, one sample is used as the test data, and a model is created using the remaining samples as the training data, and the model is evaluated based on whether prediction is possible when the test data are applied to the prepared model. In Sample A and Sample B in Fig. 5, the test data are positioned outside the training data. In machine learning, it is generally difficult to predict data that are located in this kind of extrapolation, and deviation from the predicted values was also confirmed from these results. Moreover, even when a sample was located in the interpolation area, there were large differences between the sensory test results and the predicted values, as can be seen in Sample F. It is thought that this result was affected by the composition of the sample, which consisted of both material with moistness and material with crispness, implying that it may be necessary to review the sensory evaluation method and texture test method in order to evaluate this type of sample accurately.

Fig. 6 shows the all prediction results for hardness, crispness, and moistness. Here, only 9 samples are shown in order to eliminate samples that were located in the extrapolation area. Although Fig. 6 shows some variations, the tendency of the values predicted by the random forest method is consistent with the tendency of the sensory evaluation values. Based on these results, it was suggested that the evaluation values of samples with comparatively complex textures, such as crispness and moistness, can also be predicted by this method.

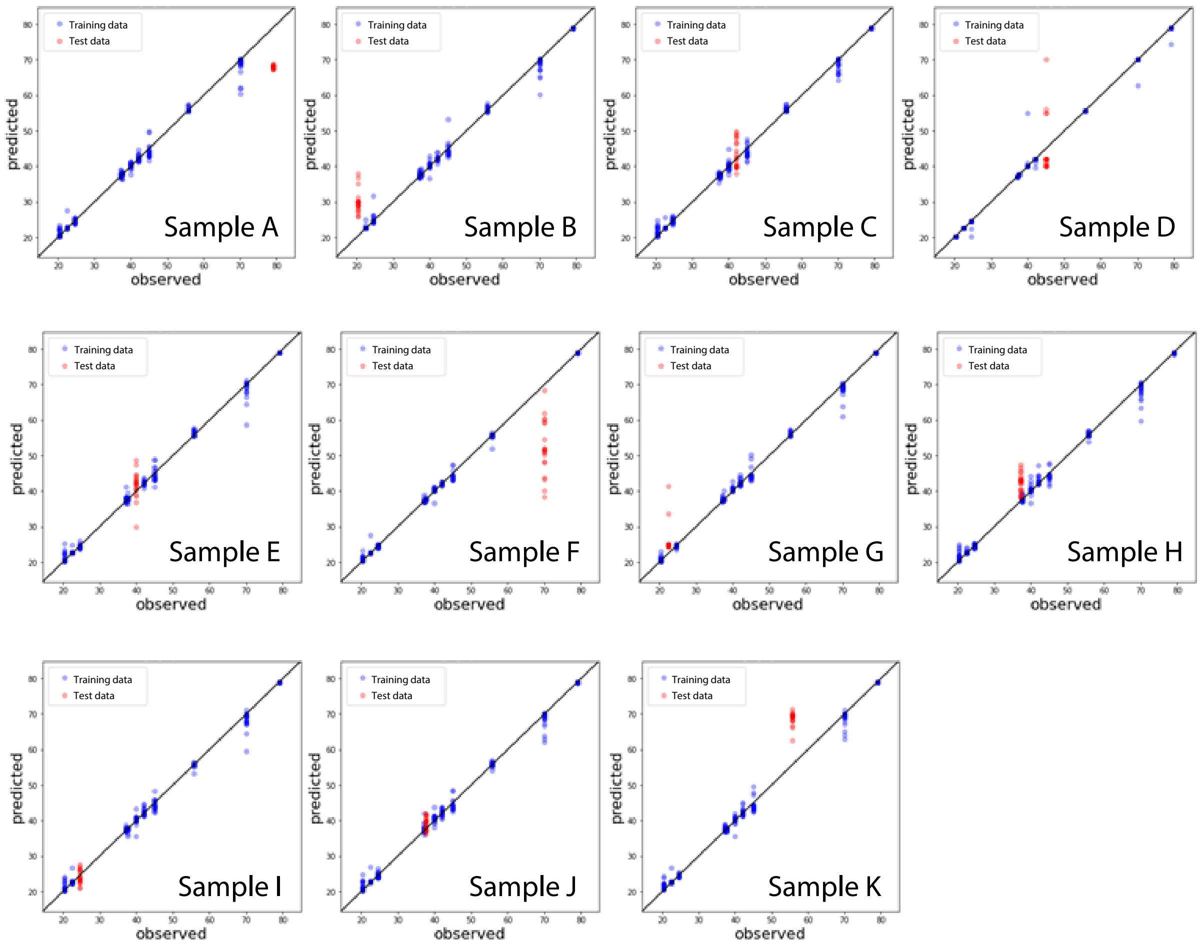


Fig. 5 Example of Results of Prediction by Machine Learning (Moistness)

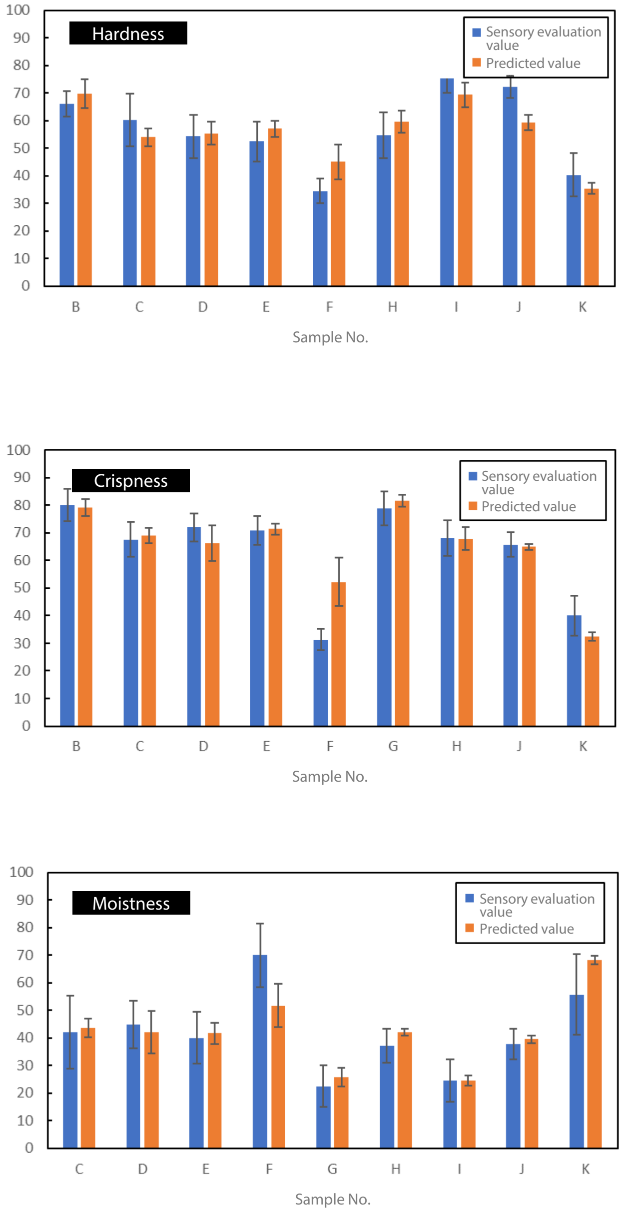


Fig. 6 Results of Prediction by Machine Learning

■ Conclusion

The sensory evaluation values of various sample cookies were predicted by using the Shimadzu EZTest texture analyzer. Although there were some variations from the sensory evaluation values in the predictions by machine learning, the predicted values were consistent with the general tendency of the sensory evaluations. For some sensory evaluation items, such as crispness and moistness, it was not possible to obtain a correlation from the results of a single texture test, but even in those cases, prediction was possible by using multiple explanatory variables. The results described above suggested the possibility that sensory evaluation values can be predicted by using a combination of measurement results from texture tests and machine learning.

<References>

1) Application News No. 01-00377, Prediction of Sensory Evaluation Values of Cookies by Multivariate Analysis
2) Natsumi Koike and Fumiaki Yano, Proceedings of the 70th Anniversary Annual Meeting, The Japanese Society for Food Science and Technology (2023)

SHIMADZU
Shimadzu Corporation
www.shimadzu.com/an/

01-00637-EN First Edition: Jan. 2024