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Development of Neural Network Analysis Program to Predict Shelf-life of Soymilk by Using Electronic Nose

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Abstract

Neural network analysis program for prediction of shelf life of soymilk by using electronic nose was developed. Known data of soymilk were used as database to learn the neural network system. Input patterns and target patterns were programmed for back propagation of learning algorithm. The input database was constructed from the determinations of volatile compounds in soymilk by using six sensors of the electronic nose at 5, 20, 35 and 50°C during storage. After learning the input database by neural network system, the measured data of unknown sample by electronic nose were analyzed by the learned neural network analysis program for prediction of shelf life of soymilk. The correct probability which predicted shelf life of unknown soymilk samples were 97, 87, 97 and 67 percentages at 5, 20, 35 and 50°C, respectively.

Key words: soymilk, electronic nose, artificial neural network, shelf life

Introduction

An electronic nose is a digitalized system which functions as a human nose (Persaud and Dodd, 1982). The multi-sensor array of the electronic nose is composed of metal oxide sensors or conducting polymers and reacts with flavor components (Hong *et al.*, 1995). Resistance of each sensor depends upon flavor component and its concentration. The electronic nose has been used to analyze flavors of food (Gardner and Bartlett, 1994; Persaud and Dodd, 1982; Hong *et al.*, 1995; Bartlett *et al.*, 1997; Thomlinson, 1995; Schaller *et al.*, 1998). The flavor components of a stored food are changed in proportion to shelf life and can be detected by electronic nose system (Schaller *et al.*, 1998). The sensor signals of electronic nose are, however, so complex that a pattern recognition analysis is inevitable. The signals from multi array sensor of the electronic nose are processed and recognized as patterns. Pattern of the sensor signals is a peculiar character in food and plays a part as fingerprint of food (Bartlett *et al.*, 1997). A neural network has been used to perform pattern recognition (Bartlett *et al.*, 1997; Gardner and Hines, 1997). The neural network is an artificial mathematical model on the basis of cranial nerve system (Kim and Lee, 2000). Because artificial neural cells are connected parallel among them, the rate of information process is fast and self-association learning is possible. The neural network builds up inner knowledge by varying inner status according to simple rule it is so called, "learning". After learning the obtained information, the neural network system analyzes correspondence of unknown input pattern (Lee, 1995).

The neural network has been reported to analyze and discriminate flavors of food. The adulteration of olive oils was analyzed by the neural network which was learned with GC/MS analysis data (Goodacre *et al.*, 1993). The electronic nose and neural network pattern recognition were applied to identification of gases such as CH_3SH, $(CH_3)_3H$, C_2H_5OH and CO (Hong *et al.*, 1996). The ripeness of banana was determined using a neural network-based electronic nose (Llobet *et al.*,

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1999). The food quality was predicted using the neural network (Ni and Gunasekaran, 1998). The shelf life of milk was predicted on the basis of artificial neural networks and headspace gas chromatography (Vallejo-cordoba *et al.*, 1995).

In this study, neural network analysis software to predict shelf life of soymilk was developed and applied to unknown samples.

Materials and Methods

Soymilk sampling

Soymilks (Maeil dairy industry) of the same expiration date were purchased from a wholesaler and stored at 5, 25, 35 and 50°C, respectively. The volatile components of soymilk (10g) were extracted at 40°C for 5 min using the head space analysis method. The analysis by the electronic nose was carried out during storage period.

Electronic nose

The electronic nose (Hanbit Instrument Co., Korea) with six metal-oxide sensors was used to measure soymilk samples (Noh *et al.*, 1998). The characteristics of sensors are shown in Table 1. Response outputs of the sensors were acquired by a computer.

Measurement of soymilk sample

The electronic nose system for dynamic headspace analysis of soymilk was constructed as shown in Fig. 1 (Hong *et al.*, 1996). Fresh air was used as input gas and supplied by way of a micro pump. To prevent from humidity effect, dried fresh air was supplied into a glass bottle through a silica gel-filled air filtering pipe. The soymilk sample was analyzed under the condition listed in Table 2.

Table 1. Metal oxide sensors in the electronic nose (odormeter ver 2.1)

Sensor No.	Sensor model	Specification
1	TGS825	Hydrogen sulfide
2	TGS824	Ammonia
3	TGS880	Hydrocarbon volatile vapors
4	TGS822	Alcohol & organic solvent vapors
5	TGS800	Air contamination
6	TGS813	Combustible gas

Table 2. Configuration of electronic nose to analyze soymilk sample

Time variables	Time (sec)
Sampling time	0.1
Heater cleaning time	10.0
Purging time	10.0
Tuning time limit	600.0
R_{air} measuring time	10.0
R_{gas} measuring time	10.0
Tuning check interval	2.0

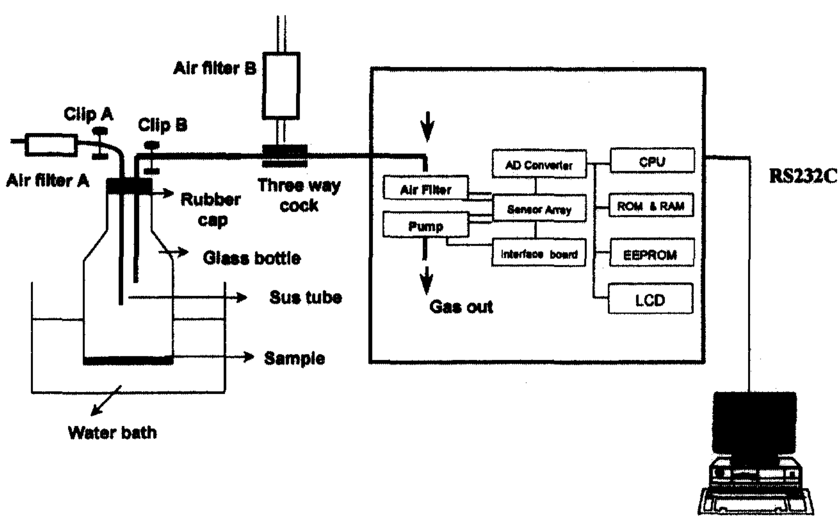

Fig. 1. The electronic nose system for dynamic headspace analysis of soymilk.

Programming tool

Lab Windows/CVI (National Instrument Co., USA) was used to develop neural network analysis program. The programming tool is a software development system on the basis of C language. The graphic user interface built to carry out neural network analysis is shown in Fig. 2.

Results and Discussion

Neural network analysis mechanism

The neural network mechanism was developed to predict the shelf life of food on the basis of SNC_680311 simulated neural chip program (Lee, 1995). Known data of food samples were used as database to learn the neural network. On the basis of the database, input patterns and target patterns were built up for back propagation learning algorithm. After supervised learning, unknown food sample data were inputted into the learned neural network system and analyzed to predict the shelf life. The analyzed results were monitored on the screen of personal computer and stored in the form of text file. The neural network analysis mechanism for prediction

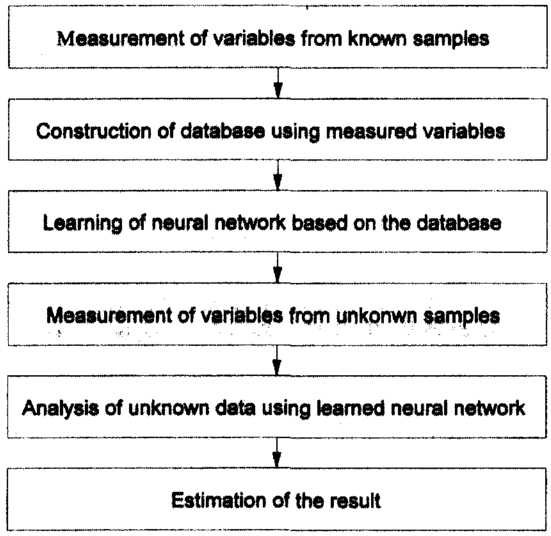

Fig. 3. Neural network analysis mechanism for predicting shelf life of food.

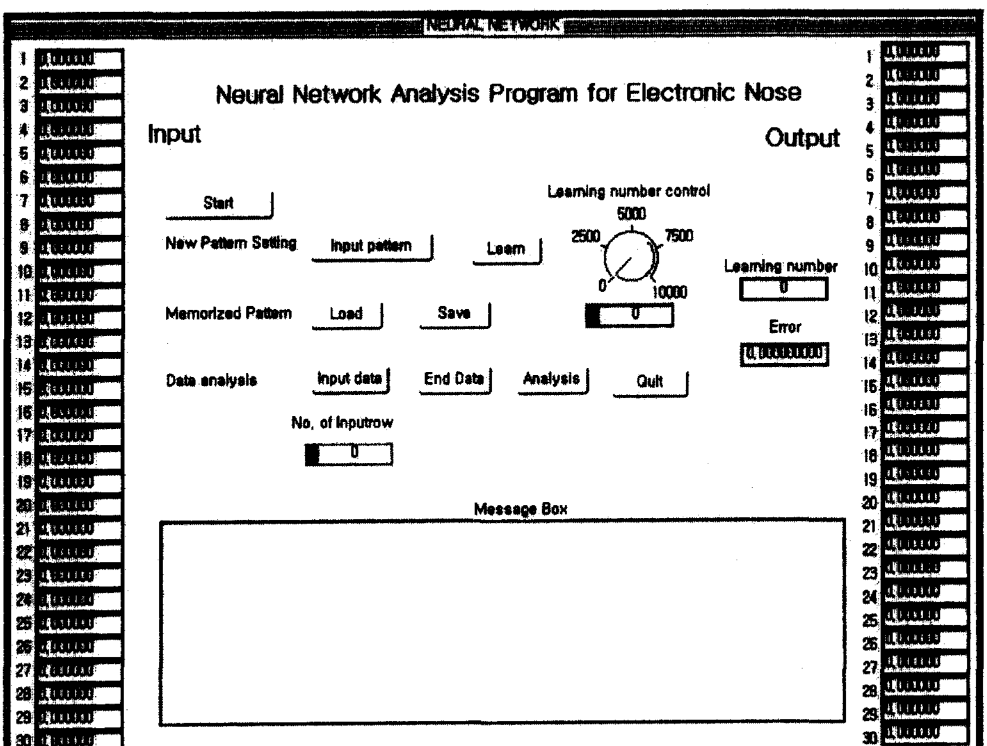

Fig. 2. The graphic user interface to carry out neural network analysis.

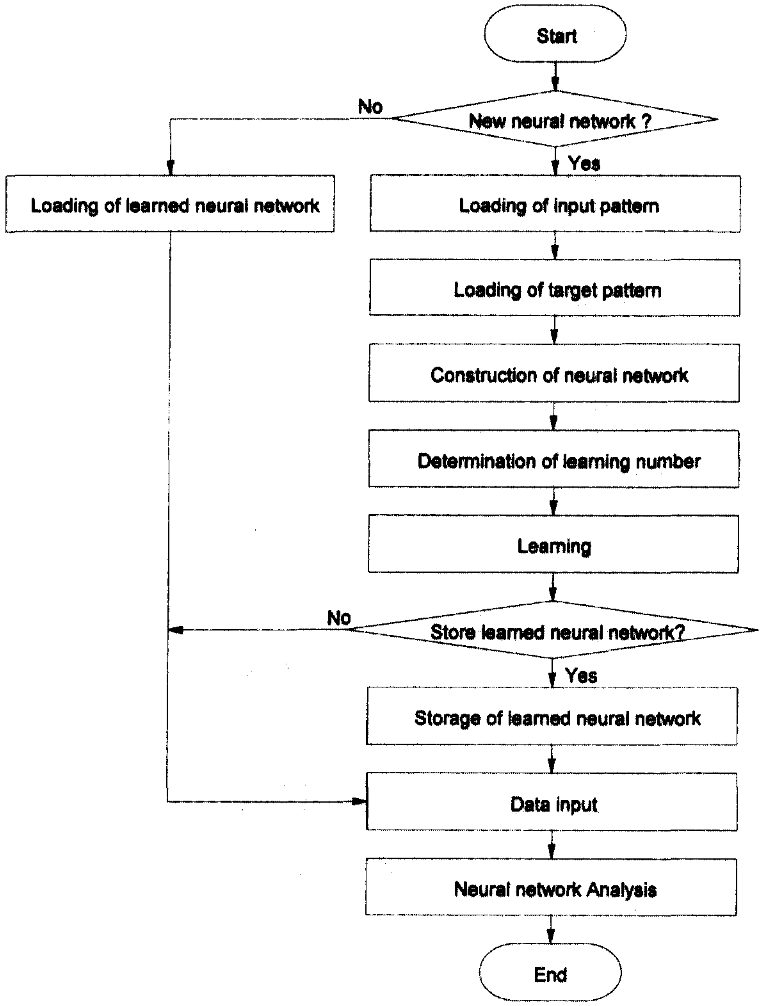

Fig. 4. Overall procedure of neural network analysis.

Construction of the soymilk database to learn neural network (input pattern)

Six-arrayed response outputs of the known soymilk samples measured by using six sensors of the electronic nose at interval of 2 day were used to construct the database of the neural network. The soymilk samples stored at each temperature were measured repeatedly and the mean values of response outputs were applied to the database. Six-arrayed mean values of the database were recognized as input patterns and were offered to the neural network. The neural network carried on learning by experiencing the input patterns successively.

The supervised learning using back propagation algorithm (target pattern)

To acquire the desired output pattern by neural network, target pattern was assigned to the neural network. The input pattern was processed in the artificial neural cells systematically and the processed results were output pattern. When the input patterns were learned, the neural network classified output patterns according to the target pattern. The target pattern was constructed in the form of n-order unit matrix depending on the desired number of output pattern.

Learning of the neural network

The neural network experienced the input patterns with constructing inner intelligence during a learning

Table 3. Prediction of shelf life for soymilk stored at 5°C

Storage time (day)	Predicted day			Correct probability (%)
	0	15	29	
0	9	1		90
15		10		100
29			10	100
Average correct probability (%)				97

Table 4. Prediction of shelf life for soymilk stored at 20°C

Storage time (day)	Predicted day				Correct probability (%)
	9	20	30	41	
9	10				100
20		7	2	1	70
30			9	1	90
Average correct probability (%)					87

Table 5. Prediction of shelf life for soymilk stored at 35°C

Storage time (day)	Predicted day					Correct probability (%)
	5	10	15	29	35	
5	10					100
15			100			100
35				1	9	90
Average correct probability (%)						97

Table 6. Prediction of shelf life for soymilk stored at 50°C

Storage time (day)	Predicted day					Correct probability (%)
	3	12	15	18	24	
3	10					100
9		2	5	2	1	0
24					10	100
Average correct probability (%)						67

time and repeated the learning schedule with reducing the extent of error according to learning rule. The learning degree of neural network was determined by error value (Lee, 1995)

Neural network analysis of unknown soymilk samples

The data measured from the unknown soymilk samples by 6-arrayed sensors of the electronic nose were offered to the learned neural network in the form of pattern. The data analyzed by the learned neural network were stored in the form of text file. The input patterns of unknown soymilk samples were analyzed by the competition mechanism through the inner intelligence. Among inner information recalled by the input patterns, the most adequate information supported by the competition mechanism was selected finally. Overall procedure of neural network analysis is shown in Fig. 4.

Prediction of the shelf life of unknown soymilk samples

The output patterns analyzed by the neural network analysis system indicated the shelf life of unknown soymilk samples. The correct probability which predicted shelf life of unknown soymilk samples were 97, 87, 97 and 67 percents at 5, 20, 35 and 50°C, respectively. At each temperature, the prediction probabilities of unknown soymilk samples are listed in Table 3, 4, 5 and 6, respectively. Except for soymilk samples on the ninth day at 50°C, the shelf life of unknown soymilk samples was predicted successfully.

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