ANFIS modeling of viscosity in low-fat mayonnaise

Mohebbat Mohebbi, Milad Fathi, Fakhri Shahidi
Department of Food Science and Technology, Ferdowsi University of Mashhad, Iran

The aim of this study was to employ pectin and modified starch as the fat mimetics in mayonnaise. All mayonnaise treatments were evaluated and compared based on viscosity at 4, 25 and 40° C. An adaptive neuro-fuzzy inference system (ANFIS) was used to model viscosity of the resulted mayonnaise. The comparison showed that adaptation of the neuro-fuzzy modeling technique achieved very satisfactory prediction accuracy

Keywords: Mayonnaise, Viscosity, Rheology, ANFIS

1 INTRODUCTION

Mayonnaise is an oil in water emulsion, which contains more than 78.5% oil [1]. Fat consumption has been shown to be associated with an increased risk of obesity, atherosclerosis, coronary heart disease and elevated blood pressure. Therefore, the actual nutritional trend towards low-caloric foods has increased the interest in fat substitutes [2-4]. In order to mimic the different functions of fat in a substantially reduced-fat product, one must consider textural matching and particle size impact on mouth feel characteristics of the system. Fat replacers have been used to stimulate the functional and organoleptic properties of fat with a substantial reduction in calorific value. Some polysaccharides, proteins and lipids such a starch, whey protein and mono and diglyceride are widely used as a fat substitute in food processing. Pectin and fine-granule starch with diameter of 2 μm or in similar size to liquid micelle could be used as fat substitutes with mouthfelling close to fat [3]. In addition, use of gums such as xanthan could improve emulsion stability and textural properties of mayonnaise by increase the viscosity of the system.

Manufacturing process and selection of equipments for mayonnaise production necessitates a complete attention to the details including rheological properties. In order to obtain such knowledge, the ability of prediction process behavior as the results of different formulation is essential which can be reached through modeling. The application of a neuro-fuzzy inference system to prediction and modeling is a novel approach that overcomes limitations of a fuzzy inference system such as the dependency on the expert for fuzzy rule generation and design of the nonadaptive fuzzy set [5-6].

The main motivation behind this work is that consumers have demanded that the use of oil be reduced because of its high caloric value. Therefore, the aim of this research was to take advantage of the gum–starch interaction, formulate a mayonnaise with similar characteristics of full fat mayonnaise and construct a prediction model for the mayonnaise properties using fuzzy modeling that can be used as a tool by the food processors to produce a high quality low-fat mayonnaise product.

2 MATERIALS AND METHODS

2.1 Materials

Modified starch, Pectin, Xanthan, $CaCl_2$ were obtained from Sigma Company. Other ingredients such as sunflower oil, egg, vinegar (5% W/W acetic acid solution) sugar, salt, white pepper and mustard were prepared from local market.

2.2 Mayonnaise preparation

Full-fat mayonnaise with 80% oil was prepared according to Liu *et al* [2] recipe. Low-fat mayonnaise was processed based on modification of method, which described by Pedersen and Christian [3]. Oil was gradually added to solution of vinegar, egg yolk, xanthan, $CaCl_2$, white pepper and mustard in high speed blander (BBC Model, Germany). Then it was mixed with starch, pectin and sugar gel, which were solved in water and heated and cooled in advance. Finally, salt was added to mixture and the mayonnaise kept in suitable glass container. In this study, low-fat mayonnaise whit 40% oil was prepared with different concentrations of starch and pectin, while xanthan gum concentration and other ingredient were kept constant. Percentages of each ingredient are shown in Tab. 1.

2.3 Rheology analysis

The rheological measurements in three different temperatures (4, 25 and 40°C) were performed in a rotational viscometer (Bohlin Model Visco 88, Bohlin Instruments, UK). Appropriate measuring spindles (C14, C25 and C30) were used during the experiment, based on viscosity of mayonnaise. The shear rate was increased logarithmically from 14.2 to 300 s^{-1} and apparent viscosity of samples were determined at the shear rate of 300 s^{-1} [8].

2.4 ANFIS modeling

In this study, modeling is carried out with ANFIS. It determines viscosity from rule base. It is a hybrid neuro-fuzzy inference system that emulates a sugeno model. ANFIS uses a feed forward neural network with 6 layers that is adapted by a

supervised learning algorithm.

Table 1: Mayonnaise formulations

Ingredient	Percentage (W/W)								
	Ff	T1	T2	T3	T4	T5	T6	T7	T8
Oil	80	40	40	40	40	40	40	40	40
Egg yolk	8	8	8	8	8	8	8	8	8
Vinegar	9	9	9	9	9	9	9	9	9
Pectin	-	0.3	0.5	0.7	0.3	0.7	0.3	0.5	0.7
Xanthan	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Starch	-	2	2	2	3.5	3.5	5	5	5
$CaCl_2$	-	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Salt	1	1	1	1	1	1	1	1	1
Sugar	1	1	1	1	1	1	1	1	1
Mustard	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
White pepper	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

3 RESULTS AND DISCUSSION

In this work, a total of 27 fuzzy rules were used to build the fuzzy system for modeling the viscosity of mayonnaise. 60% and 40% of data points were used for training and testing the network while learning epochs were 100. Optimized ANFIS structure was obtained through trial and error. A bell-shaped membership function for each input resulted in high accurate modeling approach and minimum training error. It is well demonstrated that the effect of changing the MF shape will propagate to reach all ANFIS layers and will have a considerable effect on the output of ANFIS network [5]. Comparison between the actual and predicted viscosity after training resulted in RMSE=0.073 which shows that the system is well trained to model the actual viscosity. It is completely clear that this relationship is very complex and nonlinear, so using ANFIS model will be a suitable approach.

4 CONCLUSION

In this study, modeling of low-fat mayonnaise viscosity with ANFIS is proposed. It is well shown that ANFIS is an efficient technique to predict food properties such as viscosity, which is a strong symbol of variation in components of different food products such as mayonnaise and is crucial in designing unit operation equipments and sensory perception of consumers.

REFERENCES

[1] Worrasinchai S, Suphantharika M, Pinjai S, Jamnong P: β-Glucan prepared from spent brewer's yeast as a fat replacer in mayonnaise. Food Hydrocolloid. 20 (2006) 68-78.

[2] Liu H, Xu XM, Guo Sh D: Rheological, texture and sensory properties of low-fat mayonnaise with different fat mimetics. LWT. 40 (2007) 946-954.

[3] Pedersen A, Christian H: No and low fat mayonnaise compositions. United States Patent, (1997) 5641533.

[4] Ma Y, Cai C, Wang J, Sun D: Enzymatic hydrolysis of corn starch for producing fat mimetic. J. Food Eng. 73 (2006) 297-303.

[5] Jang, S.R., Sun, C.T., & Emizutani, E: Neuro-Fuzzy and soft-computing: A computational approach to learning and machine intelligence (1997). Prentice Hall, Englewood cliffs, NY.

[6] Mohebbi M, Barouei J, Akbarzadeh-T MR, Rowhanimanesh AR, Habibi-N MB, Yavarmanesh M: Modeling and optimization of viscosity in enzyme-modified cheese by fuzzy logic and genetic algorithm. Comput. Electron. Agr. 62 (2008) 260-265.

[7] Sing RK, Ou-Yang F: Neuro-fuzzy technology for computerized automation. In : Mittal, G.S. (Ed.), Computerized control system in the food industry (1996). Marcel Dekker Inc., NY.

[8] Steff, J.M: Rheological methods in food process engineering, second edition (1996). Freeman Press, MI.

supervised learning algorithm.

Table 1: Mayonnaise formulations

Ingredient	Percentage (W/W)								
	Ff	T1	T2	T3	T4	T5	T6	T7	T8
Oil	80	40	40	40	40	40	40	40	40
Egg yolk	8	8	8	8	8	8	8	8	8
Vinegar	9	9	9	9	9	9	9	9	9
Pectin	-	0.3	0.5	0.7	0.3	0.7	0.3	0.5	0.7
Xanthan	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Starch	-	2	2	2	3.5	3.5	5	5	5
$CaCl_2$	-	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Salt	1	1	1	1	1	1	1	1	1
Sugar	1	1	1	1	1	1	1	1	1
Mustard	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
White pepper	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

3 RESULTS AND DISCUSSION

In this work, a total of 27 fuzzy rules were used to build the fuzzy system for modeling the viscosity of mayonnaise. 60% and 40% of data points were used for training and testing the network while learning epochs were 100. Optimized ANFIS structure was obtained through trial and error. A bell-shaped membership function for each input resulted in high accurate modeling approach and minimum training error. It is well demonstrated that the effect of changing the MF shape will propagate to reach all ANFIS layers and will have a considerable effect on the output of ANFIS network [5]. Comparison between the actual and predicted viscosity after training resulted in RMSE=0.073 which shows that the system is well trained to model the actual viscosity. It is completely clear that this relationship is very complex and nonlinear, so using ANFIS model will be a suitable approach.

4 CONCLUSION

In this study, modeling of low-fat mayonnaise viscosity with ANFIS is proposed. It is well shown that ANFIS is an efficient technique to predict food properties such as viscosity, which is a strong symbol of variation in components of different food products such as mayonnaise and is crucial in designing unit operation equipments and sensory perception of consumers.

REFERENCES

[1] Worrasinchai S, Suphantharika M, Pinjai S, Jamnong P: β-Glucan prepared from spent brewer's yeast as a fat replacer in mayonnaise. Food Hydrocolloid. 20 (2006) 68-78.

[2] Liu H, Xu XM, Guo Sh D: Rheological, texture and sensory properties of low-fat mayonnaise with different fat mimetics. LWT. 40 (2007) 946-954.

[3] Pedersen A, Christian H: No and low fat mayonnaise compositions. United States Patent, (1997) 5641533.

[4] Ma Y, Cai C, Wang J, Sun D: Enzymatic hydrolysis of corn starch for producing fat mimetic. J. Food Eng. 73 (2006) 297-303.

[5] Jang, S.R., Sun, C.T., & Emizutani, E: Neuro-Fuzzy and soft-computing: A computational approach to learning and machine intelligence (1997). Prentice Hall, Englewood cliffs, NY.

[6] Mohebbi M, Barouei J, Akbarzadeh-T MR, Rowhanimanesh AR, Habibi-N MB, Yavarmanesh M: Modeling and optimization of viscosity in enzyme-modified cheese by fuzzy logic and genetic algorithm. Comput. Electron. Agr. 62 (2008) 260-265.

[7] Sing RK, Ou-Yang F: Neuro-fuzzy technology for computerized automation. In : Mittal, G.S. (Ed.), Computerized control system in the food industry (1996). Marcel Dekker Inc., NY.

[8] Steff, J.M: Rheological methods in food process engineering, second edition (1996). Freeman Press, MI.