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Formulation and fuzzy modeling of emulsion stability and viscosity of a gum–protein emulsifier in a model mayonnaise system

Mahmoud Abu Ghoush [a,*], Murad Samhouri [b], Murad Al-Holy [a], Thomas Herald [c]

[a] Department of Clinical Nutrition and Dietetics, Hashemite University, Zarka, Jordan
[b] Department of Industrial Engineering, Hashemite University, Zarka, Jordan
[c] Food Science Institute, Kansas State University, Manhattan, KS 66502, United States

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Abstract

The aim of this study was to employ iota-carrageenan (IC) and wheat protein (WP) as an emulsifier alternative to egg yolk in a model mayonnaise system. A solution of 0.1% IC and 4% WP was prepared and used as an emulsifier in five different mayonnaise formulas. All mayonnaise treatments were evaluated and compared based on emulsion stability and viscosity at 4, 23, and 40 °C. In addition, an adaptive neuro-fuzzy inference system (ANFIS) was used to model and identify the properties of the resulted mayonnaise, with the temperature and ratios. Experimental validation runs were conducted to compare the measured values and the predicted ones. The mayonnaise formulated with the 25:75 (E: CP) at 4 °C was the highest stable system. The maximum viscosity was observed in the 100% egg yolk. The comparison showed that the adoption of this neuro-fuzzy modeling technique (i.e., ANFIS) achieved a very satisfactory prediction accuracy of about 96%.

Keywords: Mayonnaise; Stability; Viscosity; Iota-carrageenan; Wheat protein; Emulsifier; Fuzzy

1. Introduction

Proteins and polysaccharides are present together in many food emulsion products. The presence of polysaccharides in protein stabilized emulsions can have variable effect on stability and rheological properties (Dickinson & Euston, 1991; Dickinson & Pawlowsky, 1996). Hydrocolloids are added to increase the stability of the interfacial film separating the droplets that prevent coalescence (Buffo, Reineccius, & Oehlert, 2001). Carrageenans are commonly used as stabilizers, thickners and gelling agents in milk based products. They are sulphated polysaccharides, and various forms of carrageenan mainly differ in the number and position of the sulphate groups on the polygalactose backbone (Enriquesz & Flick, 1989). Kontogiorgos, Biliaderis, Kiosseoglou, and Doxastakis (2004) demonstrated that cereal β-glucans could be used as stabilizers in model salad dressings. Worrasinchai, Suphantharika, Pinjai, and Jamnong (2006) used spent brewer's yeast β-glucan as a fat alternative in mayonnaise production.

During the formation of an emulsion, oil droplets are dispersed into a continuous phase. The oil droplets tend to flocculate due to attractive forces. One of the keys in preparing a stable mayonnaise is to form small oil droplets in a continuous water phase with sufficiently high viscosity to prevent coalescence of the oil droplets (Wendin, Aaby, Ellkejair, & Solheim, 1997, 1999). The wheat industry has done little to promote the use of wheat protein in emulsions productions. Proteins improve the surface properties of an emulsion by forming a protective steric barrier around the oil droplets (Dickinson, 1997; Prakash, Joseph, & Mangino, 1990). Several types of proteins are used as emulsifiers in foods since they have a high proportion of nonpolar group and surface active (Damodoran, 1996). Wheat protein can be an alternative and compete with other proteins

* Corresponding author. Fax: +962 5 3903350.
E-mail addresses: abulaith@hu.edu.jo (M.A. Ghoush), samhouri@hu.edu.jo (M. Samhouri).

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in emulsion production such as casein and soy proteins due to its functional and dietary benefits.

Fuzzy logic and fuzzy inference system (FIS) is an effective technique for the identification and modeling of complex nonlinear systems. Fuzzy logic is particularly attractive due to its ability to solve problems in the absence of accurate mathematical models. The prediction of properties of the resulted mayonnaise (e.g., viscosity, stability) could be considered as a complex system, so using the conventional technology to model these properties results in significant discrepancies between simulation results and experimental data. Thus, this complex nonlinear system fits within the realm of neuro-fuzzy techniques.

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.

Modeling and identification of food properties and processing has been the subject of many researchers in the food engineering field. Perrot, Me, Trystram, Trichard, and Deloux (2003) presented a hybrid approach based on fuzzy logic and genetic algorithms to control a crossflow microfiltration pilot plant. The results of simulations and pilot tests showed that it becomes possible to impose dynamics to the process that leads to maintain the state variable at a given reference. Tsourveloudis and Kiralakis (2002) applied a rotary drying process to olive stones. They described and modeled the process using fuzzy and neuro-fuzzy techniques based on available expertise and knowledge for a given, industrial size, rotary dryer. They also used ANFIS controller based on data taken from an empirical model of the dryer under study.

Kavdir and Guyer (2003) introduced an apple grading system using fuzzy logic model. Fuzzy logic was applied as a decision-making support to grade apples. Grading results obtained from fuzzy logic showed 89% general agreement with results obtained from human expert, providing good flexibility in reflecting the expert's expectations and grading standards into the results.

In fact, there is no published data in the literature on application of iota-carrageenan (IC) and wheat protein (WP) to partially replace egg yolk in mayonnaise production. Therefore, the gum–protein interaction may play a role in the mayonnaise compared to the single contribution of the individual polymer.

The main motivation behind this work is that consumers have demanded that the use of egg yolks be reduced because of the inherent cholesterol. Therefore, the aim of this research was to take advantage of the gum–protein interaction, formulate a mayonnaise with similar characteristics as mayonnaise prepared with egg yolk, 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 mayonnaise product.

2. Materials and methods

2.1. Mayonnaise production

Five mayonnaise formulations were prepared and physical evaluations were performed. Four of the mayonnaise formulations contained an emulsifier prepared from 1% iota-carrageenan: 4% wheat protein (Midsol WPI 2100 from Midwest Grain, Inc., DWP) mixture. A mayonnaise with a traditional egg yolk formulation was used as a control. The basic formulations included 9 mL vinegar, 0. 94 g salt, 1.3 g sugar and 69 mL corn oil and 10 g egg yolk or mixture as given in Fig. 1. The following includes the different ratios of (egg yolk: gum–protein) mixtures that were used as emulsifiers in the mayonnaise formulations: 100:0 egg yolk (E): 1% iota-carrageenan + 4% wheat protein (CP)

75:25 egg yolk (E): 1% iota-carrageenan + 4% wheat protein (CP)
50:50 egg yolk (E): 1% iota-carrageenan + 4% wheat protein (CP)
25:75 egg yolk (E): 1% iota-carrageenan + 4% wheat protein (CP)
0:100 egg yolk (E): 1% iota-carrageenan + 4% wheat protein (CP)

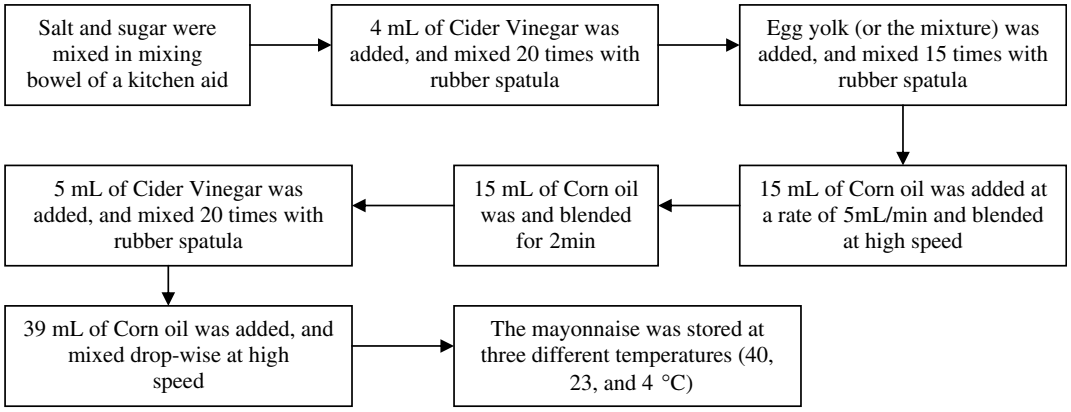

Fig. 1. Mayonnaise production steps.