Extended Abstract

Determining and Comparing the Optimal Amount of Fat and Balangu Seed Gum in Fresh Yogurt Using Two Methods of Multiple Objective Particle Swarm Algorithm and Response Surface Methodology

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Abstract

In this study, the formulation of fresh low-fat yogurt containing Balangu seed gum was modeled and optimized. In this study, first the independent variables of balangu seed gum (0 to 0.1%) and fat (0 to 2%) were modeled completely randomly in the form of a central composite design and each of the response variables (syneresis, pH, flavor, color, texture, and overall acceptance) were presented in the form of a polynomial regression model as a function of independent variables. The results showed that with increasing balangu seed gum, syneresis and pH of the samples decreased and the flavor, color, texture, and overall acceptance of the samples increased. Also, the increase in fat only decreased the syneresis of the samples. Then, the obtained models were optimized by multi objective particle swarming algorithm and numerical optimization algorithm in response surface methodology, so that minimum syneresis and maximum texture, flavor, color and general acceptance scores were obtained. The results of comparing the mean of three optimal points of the two algorithms showed that in general, in optimizing the formulation of low-fat yogurt containing balangu seed gum, the multi-objective particle swarming algorithm has a better performance than the numerical optimization algorithm in response surface method. The average optimal amount of balangu seed gum and fat in the multi-objective particle swarm algorithm was 0.85 and 1%, respectively, and in the method of optimization algorithm in response surface methodology, was 0.89 and 1.94%.

Keywords: Balangu seed gum, Fresh low-fat yogurt, Optimization, Multiple objective particle swarm algorithm, Response surface methodology

Introduction

Given that, the fat intake is directly associated with many diseases, such as obesity, cancer and cardiovascular diseases including atherosclerosis, the consumption of low-fat and non-fat foods has developed greatly over the past decade. Therefore, many studies have been conducted on the production of low-fat diet products including low-fat yogurt. In this regard, the plant

Balangu with the scientific name of *Lallemantia royleana* belongs to the mint family and its seeds have high water absorption. In addition, Balangu seed gum has also a high intrinsic Viscosity (Alghooneh, Razavi, & Kasapis, 2019). Therefore, it seems that the Balangu seed gum is a suitable alternative to the fat in the low-fat yogurt due to its high functional properties, such as texture, consistency, and proper nutritional properties, and so far, limited research has been conducted in this regard. Therefore, considering that, no research has been conducted on the effect of Balangu seed hydrocolloid on the properties of low-fat yogurt so far, and most of the research done regarding optimizing the effect of hydrocolloids on the yogurt properties is based on the classical algorithms, Therefore, in this study, the effect of Balango seed gum on the physicochemical (syneresis and pH) and sensory (flavor, color, texture, and general acceptance) properties of the low-fat fresh yogurt was modeled and then, the average of the optimal points obtained from the multi-objective particle swarm algorithm and the optimal points obtained from the response surface methodology were compared with each other.

Materials and methods

Hydrocolloid extraction was performed according to the method proposed by Mohammad Amini (2007). Yogurt was also produced by the usual method applied in the factories. So that, the treatments were first pasteurized and then, were cooled to a temperature of 45 °C and starter culture was added to each of them at a rate of 2% next, they were filled in the glasses and after capping , they were transferred to the 45±1 °C oven for 4-6 h. After the acidity of the samples reached by 60-62 °D, the samples were removed from the oven and were transferred to the 4±2 °C cold store (Tamime, Barrantes, & Sword, 1996). The pH of the samples was measured according to Iranian National Standard No. 2852 (Iranian National Standardization Organization [ISIRI], 2006). Yogurt syneresis level was also determined according to the method introduced by Al-Kadamany, Khattar, Haddad, & Toufeili (2003). Sensory characteristics of the yogurt including flavor, color, texture, and general acceptance were assessed using a 5-point hedonic test by 10 trained panelists at the room temperature.

Modeling and Statistical Analysis

In this study, the process treatments were prepared using a central composite design (CCD) with six replications at the central point for two variables at three levels (Table 1).

Table 1. Independent variables of the low -fat yogurt mixture components and their levels

Independent variables name	Symbol	Variable Range		
		-1	0	+1
Balangu seed gum (%)	X1	0	0.05	0.1
Fat content (%)	X2	0	1	2

Optimization

In the particle swarm algorithm, organisms (particles) are distributed in the search space of the function that needs to be optimized. The value of the objective function of each particle is calculated in the position of the space, in which it is located and then, it selects a direction and moves in it by considering the information of its current location and its recent best location, as well as considering the information related to one of the best particles available. Fig. (1) shows the pseudo-code of the particle swarm algorithm.

Input: Randomly initialized position and velocity of Particles:
    Xi (0) andVi (0)
Output: Position of the approximate global minimum X*
1: while terminating condition is not reached do
2:     for i = 1 to number of particles do
3:         Calculate the fitness function f
4:         Update personal best and global best of each particle
5:         Update velocity of the particle using Equation 2
6:         Update the position of the particle using equation 1
7:     end for
8: end while

Fig 1. Pseudo-code of the particle swarm algorithm

In this study, the steps of process optimization were performed using the particle swarm algorithm by the MATLAB software (Version 2016a) and finally, the average optimal points obtained from the multi-objective particle swarm algorithm and the optimal points obtained from the response surface methodology resulting from the selected models of the central composite design were compared with each other using the t-test (Excel software)

Results and discussion
The results showed that syneresis and pH of the samples were decreased and scores of flavor, texture, color, and general acceptance of the samples were increased by increasing the amount of Balangu seed gum. In this study, for optimizing the components of the low-fat yogurt mixture containing the Balangu seed gum through changing the content of fat and Balangu seed gum, it was attempted to decrease the syneresis as the target function and to increase the scores of flavor, texture, and general acceptance in order to improve the properties of the low-fat yogurt as much as possible. The initial data given to the particle swarm algorithm were in fact the data of the selected models predicted from the central composite design. The multi-objective optimization conversion algorithm was also of Pareto type and the optimal points were determined according to the termination condition, which included passing a certain number of repetitions without observing any significant improvement in the outcome. Table (2) shows the three optimal points regarding the Balangu seed gum percentage and optimum fat obtained using the particle swarm algorithm and the response surface methodology.

Table 2. The three optimal points obtained using the particle swarm algorithm and the response surface methodology to achieve the minimum syneresis and maximum scores of flavor, texture, and general acceptance

No	response surface methodology				particle swarm algorithm				Means comparison (t-test)
	1	2	3	mean	1	2	3	mean	
Balangu seed gum	0.089	0.089	0.089	0.089	0.094	0.063	0.1	0.085	n.s
Fat content	1.943	1.951	1.947	1.947	1	1	1	1	n.s
Syneresis	34.928	34.922	34.925	34.925	36.172	34.223	36.933	35.776	n.s
Flavor	4.859	4.859	4.859	4.859	4.707	4.904	4.659	4.756	n.s
Texture	4.854	4.853	4.853	4.853	4.836	4.683	4.84	4.786	n.s
General acceptance	5.039	5.041	5.04	5.04	4.83	4.476	4.89	4.732	n.s

The average of the three desired optimal points obtained from the two algorithms was compared by the t-test in order to compare the optimization performance of the two methods. The results of comparing the means showed that except for the fat, which had a significantly lower mean in the particle swarm algorithm, there was no significant difference between the optimal mean of the other obtained points. Since, the minimum amount of fat was one of the

initial optimization conditions, therefore, it seems that the particle swarm algorithm as a meta-heuristic algorithm has determined the beter levels of fat, and there was no statistically significant difference between the other responses and other optimal conditions compared to other methods. Therefore, in general, it can be concluded that the multi-objective particle swarm algorithm performs better than the numerical optimization algorithm in the response surface methodology in terms of optimizing the components of the fresh low-fat yogurt mixture containing the Balangu seed gum. Liu, Guan, Zhu, & Sun (2008) also demonstrated a high performance of the particle swarm algorithm for quadratic models obtained from the response surface methodology regarding the enzymatic optimization of protein extraction in the oat bran.

Conclusions

In general, the results of this study showed that the Balangu seed gum as a hydrocolloid with high nutritional value can be used as a suitable substitute for fat in the low-fat yogurt and creating the favorable physicochemical and sensory properties in it. For optimizing the amount of variables, the syneresis percentage was considered to be minimum and the scores of flavor, texture, and general acceptance were considered as the maximum, which according to the mentioned features, the average of optimal amount of Balangu seed gum and fat was obtained as 0.85 and 1% and 0.89 and 1.94% in the multi-objective particle swarm algorithm and response surface methodology, respectively. On the other hand, the results showed that in the case of finding the optimal solutions to the nonlinear problems, an intelligent meta-heuristic algorithm, such as particle swarm can be used in various applications with very high effectiveness and efficiency.

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