Optimization of Hydrocolloid Levels in Medium-Chain Triglyceride-Enriched Soymilk by Response Surface Methodology

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INTRODUCTION

- Dietary fats and oils are widely composed of long-chain fatty acids (LCFA), however, they usually induce negative effects on glucose and insulin balance, as well as in body weight and adipose tissue mass gain [2,3].
- Medium-chain triglycerides (MCT), fractionated from coconut oil, are alternative fat derived from medium-chain fatty acids (MCFA) which may be incorporated into foods and beverages[4-7].
- Emulsifiers and stabilizers enhance emulsion stability [15-17], they act as steric stabilizing agents that provide complete surface coverage and strong adsorption to protect the dispersed molecules from aggregating during processing and storage [18,19].
- Developing an MCT-enriched soymilk emulsion with the optimum level of emulsifier and stabilizers that is consumer-acceptable, stable, and comparable in terms of cost, can help address the need for novel applications of both coconut oil and soymilk in the country.

MATERIALS AND METHODS

PRELIMINARY STUDY

- Based on formulation [20] with 30 mL of MCT oil per 500 mL soymilk; glycerine at 0.2% (v/v) was added
- Stabilizers capability tested – 0.03% (w/v) each of κ-carrageenan, and LBG, and 0.025% (w/v) κ-carrageenan LBG (50% carrageenan : 50% LBG) combination

DETERMINATION OF OPTIMAL CONCENTRATIONS

- Concentration ranges for the independent variables X_1 (glycerine), X_2 (κ-carrageenan), and X_3 (LBG), were based on suggested literature values [22, 23]
- Rotatable, central composite design (CCD) containing six replicate runs at the center point and 14 design points was used to determine the effects on three responses (Y_1 = overall acceptability, Y_2 = emulsion stability, and Y_3 = cost) and were analyzed using Response Surface Methodology (RSM).

OVERALL ACCEPTABILITY EVALUATION

- Fifty-one (51) untrained panelists evaluated the MCT-soymilk formulations
- Overall acceptability through sensory evaluation using a 9-point hedonic scale
- Data gathered were analyzed using one-way analysis of variance (ANOVA) determined at 5% significance level with SPSS Statistics version 22 Software (IBM Corporation, Armonk, New York).

EMULSION STABILITY DETERMINATION

- Degree of emulsion stability was measured based on the volume of intact MCT-soymilk emulsion below the separated oil, if any.
- Phase separation was recorded for 90 min at 5 min intervals.

PRODUCT COST CALCULATION

- Product cost (PC) for each run, PC = (n x PM) + SM + M + K + L + G

Table S1. Software-generated actual concentrations (%) of combinations of glycerine, κ-carrageenan, and LBG for the optimization of hydrocolloid levels in MCT-enriched soymilk with the corresponding data for overall acceptability, emulsion stability, and product cost

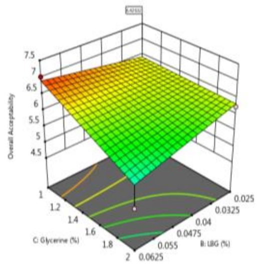
	Independent Variables			Dependent Variables		
Run	X1, Glycerine (%)	X2, κ-Carrageenan (%)	X3, LBG (%)	Overall Acceptability	Emulsion Stability [1] (mL)	Price Cost (Php)
1	2.00	0.06	0.03	6.20 ± 1.15	8.6	306.38
2	1.00	0.03	0.03	6.04 ± 1.30	10.0	292.07
3	1.00	0.06	0.06	6.21 ± 1.24	10.0	293.61
4	1.50	0.04	0.04	4.98 ± 1.75	10.0	299.62
5	2.00	0.03	0.06	4.78 ± 1.54	10.0	306.43
6	1.50	0.04	0.04	6.82 ± 1.18	9.1	299.62
7	2.00	0.06	0.06	5.94 ± 1.38	10.0	307.17
8	2.00	0.03	0.03	6.24 ± 1.26	8.4	305.64
9	1.00	0.03	0.06	7.02 ± 0.93	7.6	292.87
10	1.00	0.06	0.03	6.28 ± 1.34	9.5	292.81
11	1.50	0.04	0.04	6.49 ± 1.39	9.7	299.62
12	1.50	0.0	0.04	6.53 ± 1.33	10.0	299.62
13	0.66	0.04	0.04	6.43 ± 1.20	10.0	288.21
14	1.50	0.04	0.01	6.14 ± 1.28	10.0	298.95
15	1.50	0.01	0.04	6.86 ± 1.28	8.6	299.00
16	1.50	0.04	0.04	6.31 ± 1.09	10.0	299.62
17	1.50	0.04	0.08	6.02 ± 1.35	10.0	300.29
18	1.50	0.08	0.04	5.75 ± 1.66	10.0	300.24
19	1.50	0.04	0.04	6.45 ± 1.27	6.5	299.62
20	2.34	0.04	0.04	6.49 ± 1.05	10.0	311.03

[1] Results are presented as volume of intact MCT-soymilk emulsion at the bottom of the cylinder after having been allowed to stand undisturbed for 90 min.

Table S3. Software-generated actual concentration (%) combinations of glycerine, κ-carrageenan, and LBG generated for model validation of hydrocolloid levels in MCT-enriched soymilk

Run	Model	X1, Glycerine (%)	X2, κ-Carrageenan (%)	X3, LBG (%)
1	Optimal	1.00	0.03	0.03
2	Sub-optimal 1	1.00	0.06	0.03
3	Sub-optimal 2	1.00	0.06	0.04

RESULTS



Effect of Hydrocolloid Concentrations on Overall Acceptability

- A two-factor interaction (2FI) model was selected.

$$OA = 6.19 - 0.10K - 0.07L - 0.17G + 0.02KL + 0.21KG - 0.33LG$$

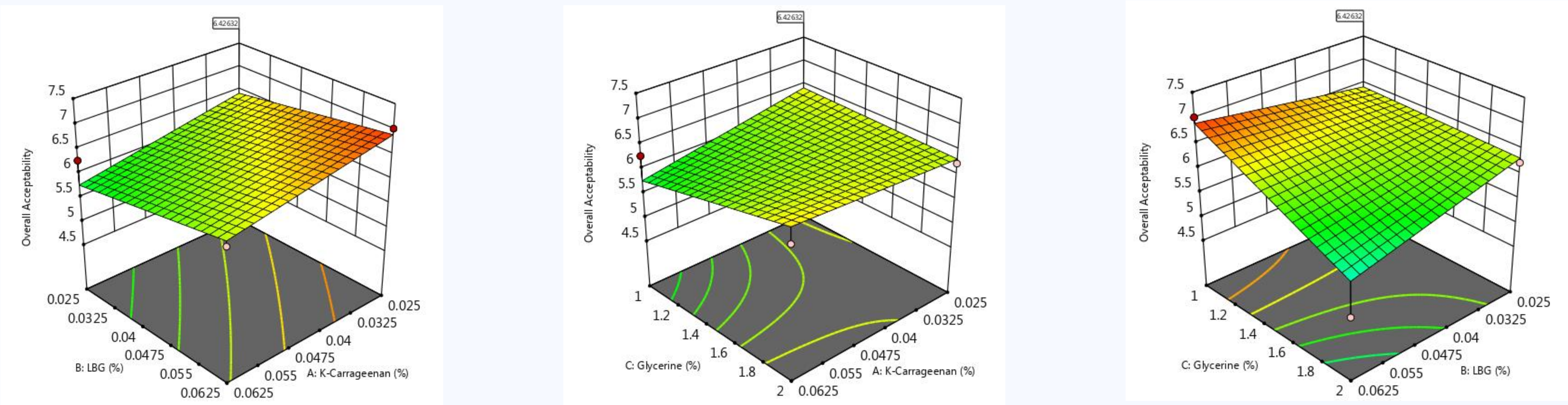
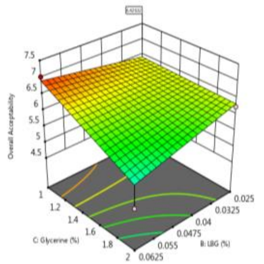


Figure 1. Response surface plots for overall acceptability of MCT-enriched soymilk as affected by varying concentrations of κ-carrageenan (K), LBG (L), and glycerine (G).



Effect of Hydrocolloid Concentrations on Emulsion Stability

- A quadratic model was selected.

$$ES = 9.24 + 0.32K + 0.08L - 0.01G + 0.34KL - 0.21KG + 0.61LG - 0.08K^2 + 0.16L^2 + 0.16G^2$$

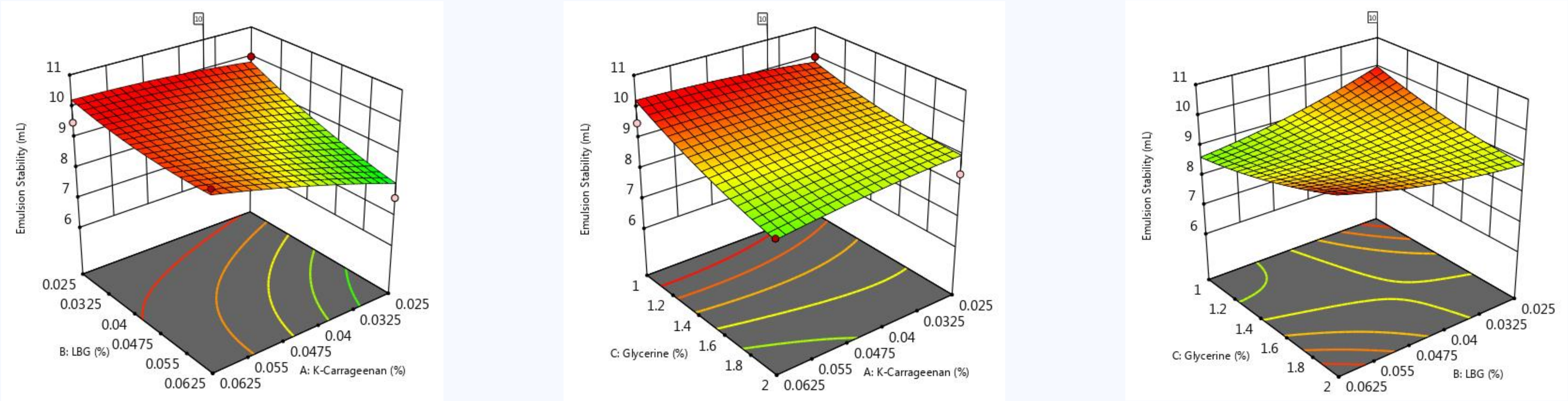
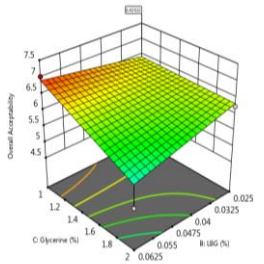


Figure 2. Response surface plots for emulsion stability of MCT-enriched soymilk as affected by varying concentrations of κ-carrageenan (K), LBG (L), and glycerine (G).



Effect of Hydrocolloid Concentrations on Product Costs

- A linear model was selected.

PC = 299.62 + 0.37K + 0.40L + 0.67G

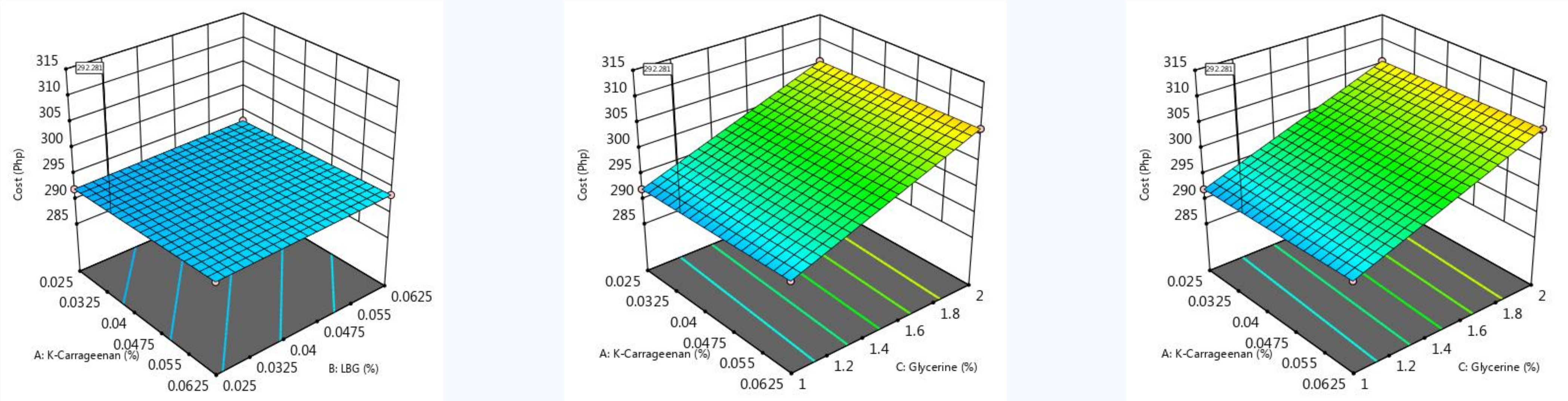


Figure 3. Response surface plots for product cost of MCT-enriched soymilk as affected by varying concentrations of κ-carrageenan (K), LBG (L), and glycerine (G).

Validation of the Models with the Optimal Concentrations

Table 2. Predicted and actual values for overall acceptability, emulsion stability 1, and product cost of optimal and sub-optimal MCT-enriched soymilk formulations

Response	Optimal		Confidence Interval		Prediction Interval	
	Predicted	Actual	Low	High	Low	High
Overall Acceptability	6.39	7.35	5.17	7.68	4.75	8.10
Emulsion Stability (mL)	9.80	9.90	6.58	13.06	5.54	14.10
Product Cost (Php)	292.00	292.00	292.00	292.00	292.00	292.00

[1] Results are presented as volume of intact MCT-soymilk emulsion at the bottom of the cylinder after having been allowed to stand undisturbed for 90 min.

CONCLUSIONS

- An acceptable and stable medium chain triglyceride (MCT)-enriched soymilk was successfully developed through the determination of optimal concentrations of glycerine, kappa-carrageenan, and LBG.
- Incorporation of the hydrocolloids improved not only the emulsion stability but also its overall consumer acceptability as compared to MCT-soymilk emulsion alone.
- With the use of response surface methodology (RSM), the study was able to successfully generate validated models for determining the optimal concentrations of glycerine, κ-carrageenan, and LBG and adequately predict the overall acceptability, emulsion stability, and product cost responses.

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