Optimizing Whey Drinks Using Taguchi Method: Enhancing Taste and Texture

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Abstract

The research article delves into the surging popularity of whey drinks due to their high protein content and associated health benefits. It highlights the intricate formulation process involved in creating these functional beverages, emphasizing the importance of balancing palatability with nutritional efficacy. Traditional trial-and-error methods for optimization are deemed inefficient, prompting the adoption of advanced statistical techniques like the Taguchi method. By systematically varying key parameters such as whey protein concentration, sweetener type, and stabilizer concentration, the study aims to identify the optimal combination that maximizes consumer acceptance in terms of taste, texture, and stability. The application of the Taguchi method offers a robust framework for streamlining the formulation process, leading to cost savings, efficient production, and improved nutritional profiles of whey drinks. This research not only contributes to enhancing product quality but also holds broader implications for the food and beverage industry by meeting evolving consumer demands for healthier and more functional foods.

Keywords: Honey, Optimization, Taguchi, Whey drink

Introduction

Whey drinks have surged in popularity due to their high protein content and associated health benefits, making them a staple in the diets of health-conscious consumers and athletes alike. Whey, a byproduct of cheese production, is rich in essential amino acids and bioactive compounds, offering numerous nutritional advantages. These properties make whey an ideal ingredient for creating functional beverages that not only provide essential nutrients but also support muscle recovery and overall health (Oliveira *et al*., 2022). However, despite these benefits, formulating whey drinks that meet consumer expectations for taste, texture, and stability remains a significant challenge for the food and beverage industry (Sady *et al*., 2013). Optimization of these beverages is essential to enhance their sensory attributes and shelf-life while maintaining their nutritional integrity (Walkling-Ribeiro *et al*., 2010).

The increasing consumer demand for functional and health-promoting beverages has driven the need for innovative approaches to product development (Sahar et al., 2019) . Whey drinks, being a functional food, require a balance between palatability and nutritional efficacy (Beucler *et al*., 2005). The formulation process involves a complex interplay of ingredients, including whey protein, sweeteners, flavors, and stabilizers. Each ingredient plays a crucial role in the overall quality of the drink, influencing not only its taste and texture but also its physical stability and shelf-life (Gupta *et al*., 2010). Traditional trial-and-error methods for optimizing such complex formulations are time-consuming and resource-intensive, often leading to suboptimal results and higher production costs (Weeratunge *et al*., 2022). The need for a more systematic and efficient approach to product development is evident, which is where advanced statistical methods come into play.

To address these challenges, employing a systematic approach like the Taguchi method can streamline the optimization process. The Taguchi method, a statistical approach developed by Dr. Genichi Taguchi, is designed to improve product quality by identifying the optimal conditions for multiple factors simultaneously (Davis and John 2018). This method utilizes orthogonal arrays to design experiments, allowing for the efficient exploration of a large number of variables with a minimal number of trials. By systematically varying key independent parameters, the Taguchi method not only identifies the optimal settings for each factor but also determines their relative impact on the quality characteristics of the final product (Mehat and Kamaruddin 2012). This efficiency is particularly beneficial in the context of food and beverage formulations, where multiple ingredients and processing conditions must be optimized simultaneously.

In the context of whey drinks, the application of the Taguchi method can provide a robust framework for optimizing the formulation (Homayoonfal *et al*., 2022). The primary objective of this study is to apply the Taguchi orthogonal array method to optimize the formulation of a whey drink. By systematically varying key independent parameters such as whey protein concentration, sweetener type and concentration, flavor type and concentration, and stabilizer type and concentration, we aim to identify the optimal combination that maximizes consumer acceptance in terms of taste, texture, and stability while maintaining high nutritional value. This approach promises to deliver a whey drink that meets consumer expectations and industry standards, providing a model for efficient and effective product development.

The methodology employed in this study involves the use of orthogonal arrays to design a series of experiments that cover a broad range of formulation possibilities. Each experiment is designed to test different combinations of ingredients and processing conditions, allowing us to identify the most influential factors and their optimal levels. This systematic approach not only reduces the number of experiments needed but also provides a comprehensive understanding of how each factor interacts with others. The result is a highly optimized product that meets the desired quality attributes without the need for extensive trial-and-error testing.

Furthermore, the importance of optimizing whey drink formulations extends beyond consumer satisfaction. From a manufacturing perspective, achieving the right balance of ingredients can lead to cost savings and more efficient production processes. By reducing the number of experimental trials needed to identify the optimal formulation, the Taguchi method can significantly lower development costs and time. Additionally, the insights gained from this optimization process can be applied to other functional beverages, contributing to the broader field of food science and technology. This efficiency is crucial in a competitive market where time-to-market and production costs can make a significant difference in a product's success.

Moreover, optimizing whey drink formulations using the Taguchi method has broader implications for the food and beverage industry. The methodology can be adapted to optimize a wide range of products, from dairy alternatives to protein bars, enhancing their quality and consumer appeal. By adopting such advanced statistical techniques, the industry can improve its approach to product development, leading to innovations that meet evolving consumer demands for healthier and more functional foods. This capability is particularly relevant in today's market, where consumers are increasingly seeking products that offer both nutritional benefits and enjoyable sensory experiences.

The potential benefits of this optimization extend to improving the nutritional profile of whey drinks. By carefully selecting and balancing ingredients, it is possible to enhance the protein content and overall nutrient density of the drinks, making them more beneficial for consumers. This aspect is particularly important for athletes and fitness enthusiasts who rely on whey drinks for muscle recovery and performance enhancement. A well-optimized formulation can provide the necessary nutrients without compromising on taste and texture, making it easier for consumers to incorporate these beverages into their daily routines.

Additionally, the optimization process can help in addressing common issues related to whey drinks, such as phase separation and off-flavors. By identifying the optimal levels of stabilizers and flavoring agents, the Taguchi method can help create a product that remains stable over time and has a pleasant taste profile. This stability is crucial for maintaining the quality of the product during storage and distribution, ensuring that consumers receive a consistent and enjoyable experience with each purchase. Such improvements can lead to higher consumer satisfaction and increased brand loyalty.

The optimization of whey drink formulations using the Taguchi method represents a significant advancement in the field of food and beverage development. By leveraging this systematic and efficient approach, we can enhance the quality and appeal of whey drinks, meeting the growing consumer demand for nutritious and enjoyable functional beverages. The following sections will detail the materials and methods used in this study, the results of our experiments, and the implications of our findings for the food and beverage industry. Through this comprehensive approach, we aim to demonstrate how the Taguchi method can be a powerful tool for optimizing complex formulations, ultimately leading to better products and more efficient production processes.

Materials and Methods

Materials

The materials used in the study on optimizing whey drink formulations included liquid whey, whey protein powder, sweeteners (sugar, honey, stevia), stabilizers (guar gum at varying concentrations of 0.1%, 0.2%, and 0.3%), and flavoring agents. Liquid whey served as the base ingredient for the whey drinks, providing the primary source of whey protein. Whey protein powder was utilized to adjust the protein concentration in the drinks to low, medium, and high levels for experimentation. Sweeteners such as sugar, honey, and stevia were incorporated to achieve desired sweetness levels, while guar gum was used as a stabilizer to enhance texture and stability. The selection of these materials allowed for the systematic exploration of different formulation possibilities to optimize the sensory attributes and nutritional value of whey drinks.

Preparation of the whey drink

The whey drinks were formulated using liquid whey, guar gum as a stabilizer at varying concentrations (0.1%, 0.2%, and 0.3%), different sweeteners (sugar, honey, and stevia), and whey protein at low (5%), medium (10%) and high (15%) concentrations. The preparation process began with filtering the liquid whey to remove any residual curds or impurities. Guar gum was accurately weighed to the specified concentrations, while the sweeteners were measured to achieve an equivalent sweetness level to a 5% sugar content. Whey protein powder was also measured to achieve the desired protein concentrations.

In a large mixing vessel, the filtered liquid whey was combined with the whey protein powder and stirred using a high-speed blender for 2 minutes to ensure the protein was fully dissolved. The specified amount of guar gum was gradually added to the whey mixture while continuing to blend at high speed to prevent clumping. The chosen sweetener was then incorporated, with additional blending for honey and stevia to ensure thorough mixing, and stirring until complete dissolution for sugar.

The blended mixture was then homogenized at a pressure of 150 bar to ensure uniform particle size distribution, which improves the texture and stability of the drink. Following homogenization, the whey drink was pasteurized by heating it to 72°C and maintaining this temperature for 15 seconds, after which it was rapidly cooled to 4°C to prevent microbial growth. Finally, the pasteurized whey drink was poured into sterile glass bottles, sealed immediately, and stored in a refrigerator at 4°C until further analysis.

Taguchi Orthogonal Array Optimization

Taguchi's robust approach converts a loss function into signal-noise ratio (η). The important quality feature, S/N, is a logarithmic function of target value. The goal of this endeavor was to improve the smell and flavor of the whey drink. As a result, the larger-the-better quality characteristic was applied, as specified in Eq. (1).

$$\eta = \text{S/N} = -10\ \log\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{\text{X}_\text{i}^2}\right] \qquad (1)$$

where 'Xi' is the observed value at the ith response, and 'n' is the number of observations in the experiment. Table (1) shows the amounts of the control parameters, which are whey protein content, sweetener type, and stabilizer concentration. L9 (33) mixed orthogonal array was chosen to identify the best composition for making whey drink (Table 2).

Table 1 : Process parameters and levels

Parameters	**Level 1**	**Level 2**	**Level 3**
Whey protein concentration	10:1	20:1	-
Type of sweetener	Sugar	Stevia	Honey
Stabilizer (%)	0.1	0.2	0.3

Table 2: Taguchi orthogonal array design of L_9

Trail No	Whey Protein Concentration (%)	Type of sugar	Stabilizer (%)
1	5	Sugar	0.1
2	5	Stevia	0.2
3	5	Honey	0.3
4	10	Sugar	0.2
5	10	Stevia	0.3
6	10	Honey	0.1
7	15	Sugar	0.3
8	15	Stevia	0.1
9	15	Honey	0.2

Minitab 17 (Minitab Inc., USA) was the statistical software utilized in the Taguchi orthogonal array optimization procedure. An ANOVA was performed to determine the effect of the individual components. This analysis was performed at a 5% significance level and 95% confidence level. The relevance of control factors was established by comparing their respective F values. The contribution rate of each parameter is also calculated, indicating the level of influence on process performance. After determining the ideal level of design parameters, a confirmation experiment was run to validate the improved circumstances. To anticipate the best condition, the predicted S/N at the optimal factors was calculated using Eq. (2).

$$\hat{\eta} = \eta_m + \sum_{i=1}^{q} \left(\overline{\eta_i} - \eta_m \right) \quad (2)$$

where, ‘ηm’ is the mean S/N, ‘q’ is the number of significant factors and

‘ ’ is the average S/N corresponding to ith significant factor on jth level.

To determine whether the system accurately achieved the optimum, the confidence interval (C.I.) for odour and taste were calculated using Eqs. (3 and 4).

$$C.I. = \sqrt{F_{\alpha(1,f_e)} V_e \left[\frac{1}{\eta_{eff}} + \frac{1}{R} \right]} \quad (3)$$

In this equation, $F_{\alpha(1,fe)}$ represents the 'F' ratio at 95% confidence, 'α' is the significance level, 'fe' is the error degrees of freedom, 'Ve' is the error variance, 'ηeff' is the effective number of replications, and R is the number of replications for confirmation trials.

$$\eta_{eff} = \frac{1}{1 + T_{dof}} \quad (4)$$

where 'N' is the total number of experiments and 'Tdof' is the total degree of freedom for the main component. The regression models were created to model the link between the process and response variables. The error percentages for Taguchi and regression models were examined.

Results and Discussion

The odor and taste of whey drink were established by sensory evaluation of the 9 design combinations (Table 2). The scent values ranged from 6 to 9, while the taste ranged from 6.5 to 9.

S/N optimized the control parameters to determine answers that deviated from the target value. The highest value of odor and flavor is important for the whey drink. Table 3 shows the S/N for odor and taste. The mean S/N values for odor and taste were 17.07 dB and 17.39 dB, respectively.

Table 3 Taguchi orthogonal experimental design with S/N

Trial No	Whey protein concentration	Sweetener	Stabilizer	Odour	Taste	SNRA1	SNRA2
1	5	Sugar	0.1	6	6.5	15.8967	16.2583
2	5	stevia	0.2	5	5.5	14.3736	14.8073
3	5	Honey	0.3	7	7.5	17.1913	17.5012
4	10	Sugar	0.2	8	8.5	18.3171	18.5884
5	10	stevia	0.3	6	6.5	15.8967	16.2583
6	10	Honey	0.1	9	9.5	19.3133	19.5545
7	15	Sugar	0.3	7	7.5	17.1913	17.5012
8	15	stevia	0.1	7	7.5	17.1913	17.5012
9	15	Honey	0.2	8	8.5	18.3171	18.5884

The influence of each control component (whey protein content, sweetner, and stabilizer) on odor and taste was investigated using S/N response tables. Delta value was calculated as the difference between the highest and lowest S/N. The control factor with the largest delta value was ranked first (I), and so on. Thus, the optimal values of control parameters for aroma and taste were obtained.

Table 4: Response Table for Signal to Noise Ratios

Larger is better

Level	Whey protein concentration	Sweetener	Stabilizer
1	16.19	17.45	17.77
2	18.13	16.19	17.33
3	17.86	18.55	17.09
Delta	1.94	2.36	0.68
Rank	2	1	3

**Values marked as bold represents the optimum levels of control factors*

Figures 1 and 2 exhibit a graphical representation of the S/N values of the control parameters for aroma and taste. These graphs allow you to visualize the optimal process parameters of the control components for maximum odour and taste. The ideal level for each control factor was determined by the highest S/N in its levels. As a result, the levels and S/N for the components that produced the optimum odor were specified as factor whey protein concentration (Level 2, S/N=18.13 dB), factor B (Level 3, S/N=18.55 dB), and factor C (Level 2, S/N= 17.33 dB). In other words, the ideal process parameters for optimizing the odor and flavor were obtained with whey protein concentration (10%) , kind of sugar (Honey) and stabilizer percentage as 0.2.

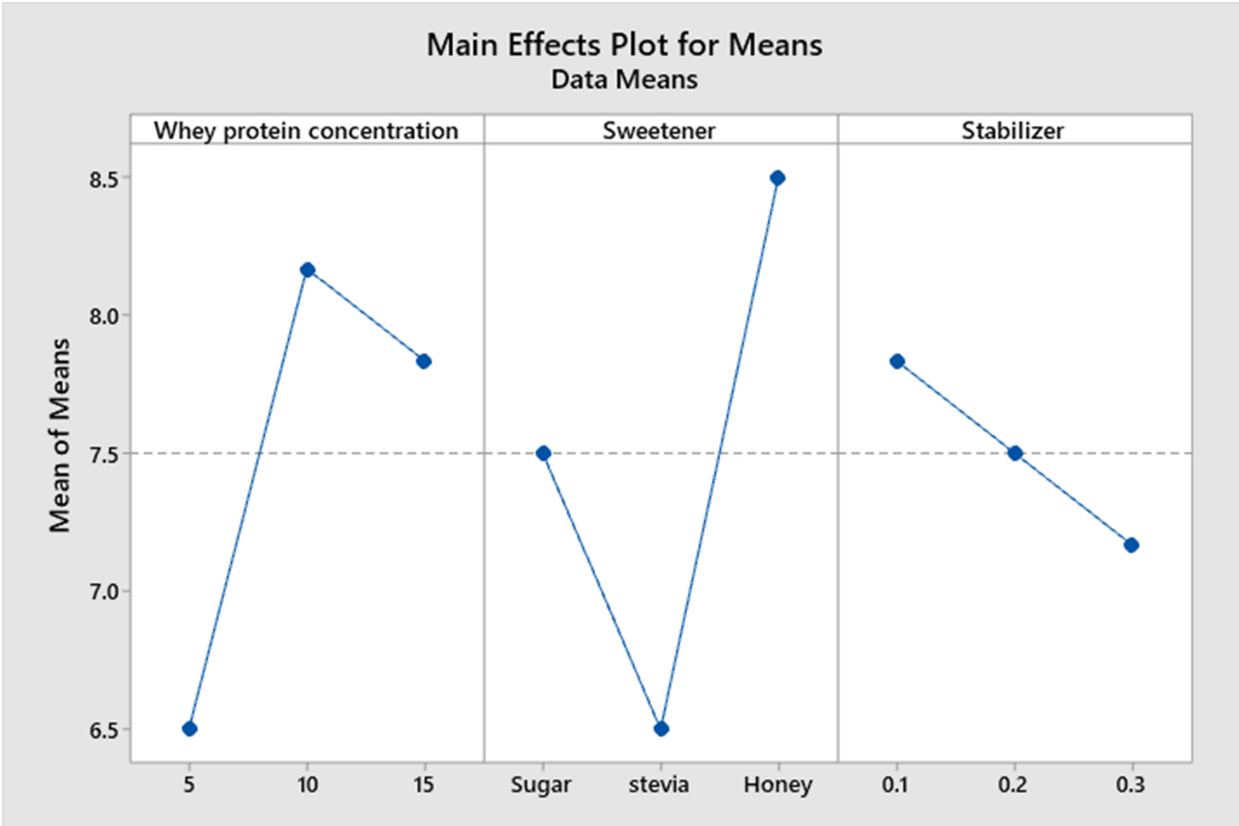

Fig.1. Effect of parameters on average S/N for odour

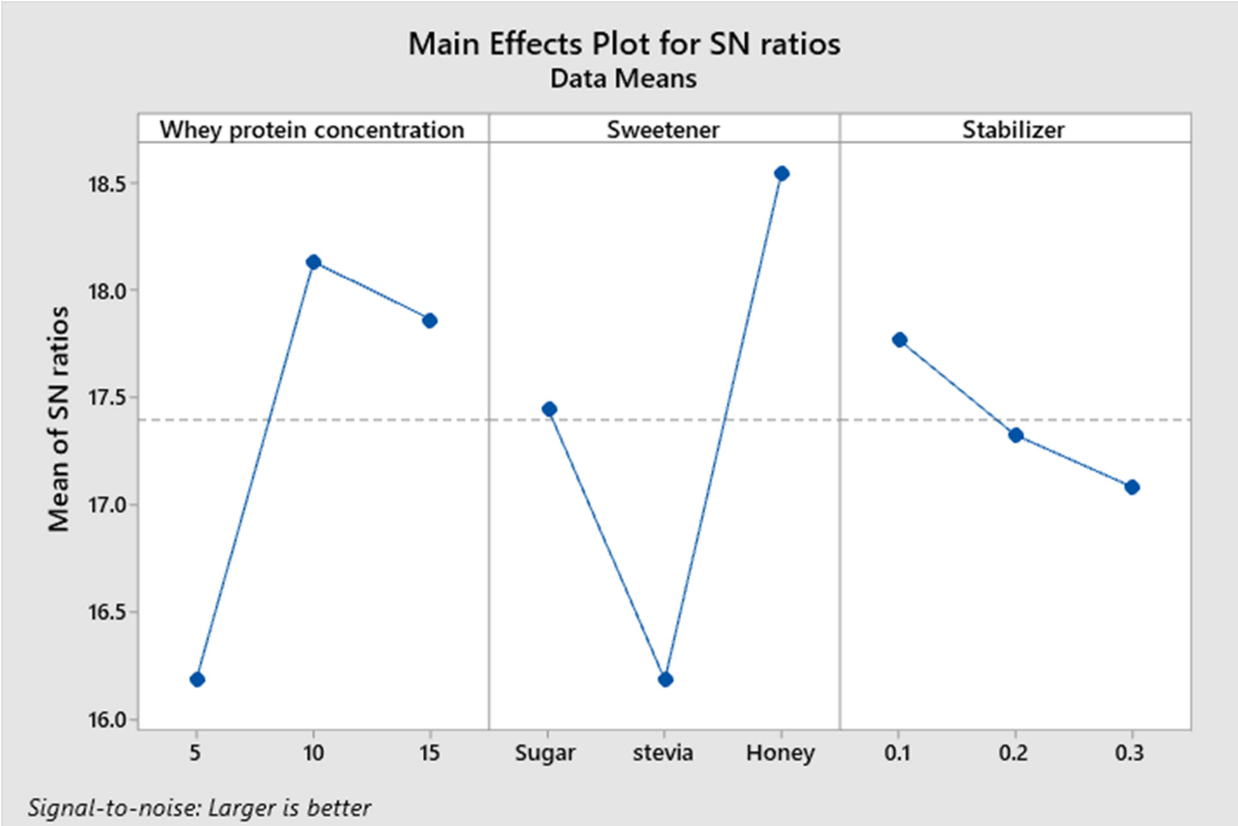

Fig.2 Effect of parameters on average S/N for taste

Vaidation

Experiments were carried out at both the optimum and random levels to validate. Table 5 compares the confirmatory test results to the projected values derived from the Taguchi method and regression equations. The error values obtained were less than 20% (acceptable limits), indicating that the selection of significant control elements was reasonable.

The results of the study underscore the significance of employing advanced statistical techniques like the Taguchi method in optimizing complex food and beverage formulations. By systematically varying key parameters and utilizing orthogonal arrays for experimental design, the researchers were able to identify the optimal combination of whey protein, sweeteners, flavors, and stabilizers that maximize consumer acceptance while meeting quality and nutritional standards.

The findings emphasize the critical role of whey protein concentration in enhancing the nutritional value and texture of whey drinks. With consumers increasingly prioritizing protein intake for health and fitness benefits, optimizing whey protein content can cater to this demand and differentiate whey drinks in the market.

Furthermore, the study highlights the importance of sweeteners and stabilizers in achieving a balanced flavor profile and ensuring product stability. By selecting the right combination of sweeteners and stabilizers at optimal concentrations, manufacturers can enhance the sensory attributes of whey drinks and prolong their shelf-life, contributing to consumer satisfaction and brand loyalty.

Overall, the research demonstrates the efficacy of the Taguchi method in streamlining product development processes, improving product quality, and meeting consumer preferences for nutritious and enjoyable functional beverages. The systematic and efficient approach to formulation optimization not only benefits whey drink manufacturers in terms of cost savings and operational efficiencies but also contributes to the broader advancement of the food and beverage industry towards healthier and more functional product offerings

Table 5. Predicted values and confirmation test results by Taguchi method

Level	Expt.	Taguchi method	
		Pred.	Error (%)
Odour			
Optimum	9	8.95	0.55
Random	8	7.98	0.25
Taste			
Optimum	9.5	9.48	0.21
Random	7.5	7.45	0.67

Finally, the optimal circumstances for maximal odor and flavor of whey drink were achieved by utilizing 10% whey protein concentration, honey as sugar, and 0.2% stabilizer.

Conclusion

In conclusion, the research results demonstrate the effectiveness of utilizing the Taguchi method to optimize whey drink formulations. By systematically varying key parameters such as whey protein concentration, sweetener type and concentration, flavor type and concentration, and stabilizer type and concentration, the study successfully identified the optimal combination that maximizes consumer acceptance in terms of taste, texture, and stability while maintaining high nutritional value. The experiments conducted at both optimum and random levels validated the projected values derived from the Taguchi method, with error values within acceptable limits. This systematic approach not only enhances the sensory attributes and shelf-life of whey drinks but also contributes to cost savings and more efficient production processes. Overall, the research findings highlight the significant impact of the Taguchi method in improving whey drink formulations, meeting consumer demands for nutritious and enjoyable functional beverages in a competitive market.

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