



## Research Article

# Effect of Replacing Egg with Whole Milk in the Production of Mayonnaise: Physicochemical and Sensory Analysis

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**Abstract** | The use of raw eggs in the preparation of artisanal mayonnaises can cause illness in consumers because the egg may contain salmonella. This study aimed to analyze the effect of replacing eggs with whole milk in the production of mayonnaise. This involves assessing the physicochemical variables: fat and pH; and performing a sensory analysis. For the analysis of fat, the Soxhlet method was used, and the pH was measured with a potentiometer at 20°C. In the sensory analysis, a descriptive analysis was carried out followed by discriminative duo-trio tests, triangular tests, and an affective sensory evaluation using hedonic flavour scale. The study was carried out through the Completely Randomized Experimental Design (CRD) with different concentrations of milk; T1=22%, T2= 35%, T3= 65%, and the control was mayonnaise with egg =T4. The T2 sample is the one that most resembles the control sample and after the inferential statistical analysis with the ANOVA and Tukey test. The treatment that varies in terms of pH is T3. In terms of fat percentage, all treatments are different from the control sample, with a 13% reduction in fat percentage in T2. There were no significant differences in the discriminative sensory tests between the T2 and T4 treatments which indicates that the normal consumer of the product will not notice a difference between T2 and the mayonnaise with 100% egg T4. Additionally, 48.9% of the consumers reported that they extremely liked the mayonnaise T2. It is concluded that it was possible to develop a mayonnaise made with pasteurized whole milk as an alternative to the use of eggs, with physical-chemical and sensory characteristics similar to the control mayonnaise.

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## Introduction

Mayonnaise is defined as a product that is presented in the form of an oil-in-water

emulsion, obtained from refined edible vegetable oils, vinegar, eggs, and salt, with or without the addition of seasonings, spices, and aromatic herbs ([Ecuadorian Technical Standard of Mayonnaise Requirements](#)

NTE INEN 2 295:2010). Each ingredient in mayonnaise determines the quality characteristics of the emulsion (Tasliikh *et al.*, 2021). The egg yolk is a determinant factor because of its globular proteins and phospholipids which are stabilizers and textural modifier (Ariizumi *et al.*, 2017). The use of raw eggs in the preparation of artisanal mayonnaises is widespread and can cause contamination. This occurs because the egg may contain salmonella and therefore when used in mayonnaise it can proliferate and make the consumer sick. At the time of oviposition, the eggs have a certain degree of surface contamination due to passage through the hen's cloaca (Rincón *et al.*, 2011). However, in a relatively short period after laying, many microorganisms can be found on the outside which, under appropriate conditions, can penetrate the eggs, grow inside, and alter them. Among the bacteria found in the eggs, there are representatives of genera such as *Pseudomonas*, *Acinetobacter*, *Proteus*, *Aeromonas*, *Escherichia*, *Salmonella*, *Serratia*, *Enterobacter*, *Flavobacterium* and *Staphylococcus* (Rincón *et al.*, 2011).

Because of these food born pathogens, this study analyzes the use of milk as an emulsifier for the preparation of mayonnaise, as a safer alternative to the use of eggs. Several studies explore the use of eggs replacers such as shrimp shells (Cano *et al.*, 2017), Canned Beans Aquafaba (Sachko *et al.*, 2023), clover sprouts (Darabi *et al.*, 2021), chia (*Salvia hispánica* L.) mucilage (Fernandes and Mallado, 2017), chickpea (Toledo *et al.*, 2020), avocado and sacha inchi (Echeverri and Bulla, 2020). In this investigation, the egg was replaced by milk due to its low cost and its easy acquisition. This study aimed to analyze the effect of replacing eggs with whole milk in the production of mayonnaise. This involves assessing the physicochemical variables: fat and pH, the main requirements for mayonnaise according to NTE INEN 2534:2016 in Ecuador. Fat content is the main component of mayonnaise, and it is related to texture, mouth feel, and calorie content (Codex Alimentarius, 1989). The pH level is related to the product safety and stability of mayonnaise (McClements, 2004). Additionally, a sensory analysis was performed to determine whether the differences introduced by the substitution are perceptible, to evaluate the sensory similarity between the traditional formulation and the proposal, and to validate the success of the reformulation from the consumer's point of view.

The duo-trio and triangular tests are among the objective tests, belonging to the discriminative group and require semi-trained or trained judges (García *et al.*, 2017). These tests were used to identify significant differences between products that are widely used in companies that produce food. The duo trio tests have a 50 percent random success, while the triangular tests have a 33.33% (1/3) random success (Espinosa, 2007). Using the two tests allows us to corroborate the results and prevent the hits from being random.

## Materials and Methods

The study employed a quantitative approach with a Completely Randomized Experimental Design (CRD) to evaluate the physicochemical and sensory properties of mayonnaise using milk as an emulsifier substitute for egg. Four treatments were performed as shown in Table 1, regarding the proportion of milk and egg. Treatment 4 (T4) was the control sample, obtained from the preparation of mayonnaise with 100% egg as an ingredient that provides the emulsifying agent. Three treatments and a control (T4) were designed, with three repetitions per treatment, the treatments were constituted by the different percentages of milk, following the linear model:

$$Y_{ij} = \mu + t_i + \epsilon_{ij}$$

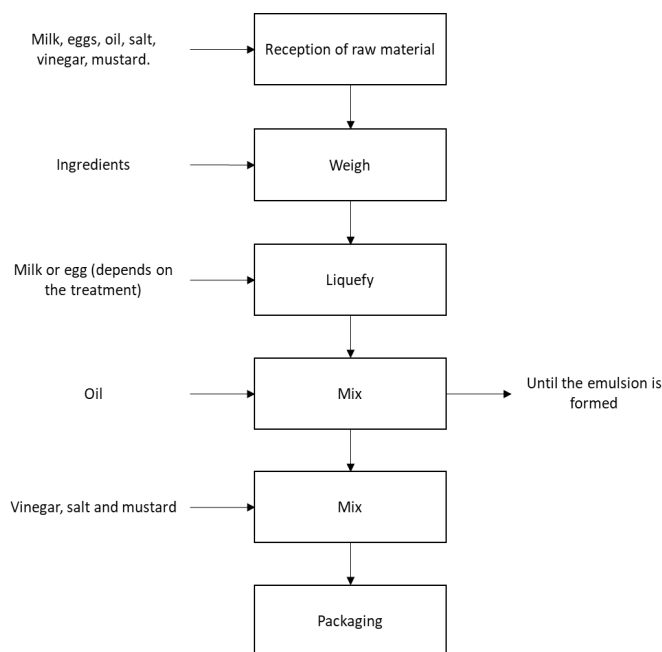
Where:  $Y_{ij}$ = Value of the parameter being determined;  $\mu$  = Effect of the mean per observation;  $t_i$ = Effect of treatments;  $\epsilon_{ij}$ = effect of experimental error.

**Table 1:** Experimental design for a mayonnaise substitute.

Treatments	% milk	% egg
T1	22%	0%
T2	35%	0%
T3	65%	0%
T4 control	0%	100%

As shown in Figure 1, the mayonnaises were prepared in the agro-industrial workshop of the (Experimental Technology Research University, Yachay Tech), following the scheme: Reception of the raw material, weighing the ingredients for each treatment, blending the milk or eggs depending on the case, adding the oil little by little, add the other ingredients, pack. The ingredients for the elaboration of the product were mustard, vinegar, and salt in the same concentrations

for the samples T1, T2, T3 and, T4.



**Figure 1:** Flow chart for the production of mayonnaise.

Samples were analyzed in triplicate in the Biochemistry Laboratory of the Faculty of Health Sciences of the Nutrition Career at the Técnica del Norte University. The samples were duly labeled, both for physical-chemical and sensory analyses. Among the physical-chemical dependent variables that were measured for the treatments were fat and pH. These parameters were carried out under the regulations of NTE INEN 2 295:2010 for Mayonnaise Requirements. The determination of fats, they were carried out using the Soxhlet equipment using a methodology according to (The Association of Official Analytical Chemists (AOAC, 2016) and the pH was measured by potentiometry.

The sensory analysis was carried out by a panel of trained judges from the Universidad de las Américas (UDLA), which has 16 people trained for this exercise. For sensory analysis, discriminative tests such as the duo-trio described in NTE INEN-ISO 10399 were used. According to NTE INEN-ISO 10399 a minimum of 12 correct responses and 16 judges are needed to conclude that significant differences exist based on a duo trio trial with a 5% error. For the triangular test, NTE INEN-ISO 4120 was used. According to NTE INEN-ISO 4120, a minimum of 9 correct responses and 16 judges are needed to conclude that significant differences exist based on a duo trio trial with a 5% error. Additionally, a hedonic flavor scale from 1 to 7 was used where 7 means Like

extremely and 1 means Dislike extremely (Meilgaard *et al.*, 2007). The surveys of the hedonic flavor scale were applied to 88 consumers.

Statistical analysis were performed in the Jamovi program, applying Analysis of variance (ANOVA) and Tukey's post-hoc test to identify significant differences between treatments.

## Results and Discussion

The observations obtained from the analysis of pH and fat percentage in the different treatments are presented in Table 2. According to NTE INEN 2295, the Ecuadorian Normative allows a maximum value pH of 4.1. Therefore, the treatment outside that range is T3. In treatments T1 and T2 the pH complies with the norm. The low pH in a food makes it last longer and is better preserved, preventing the proliferation of pathogenic bacteria (McClements, 2004). The ANOVA was carried out between the treatments with the pH variable, obtaining statistically significant differences. The Tukey test determined that the T3 treatment was different, this treatment was discarded because the pH value does not contribute to the safety of the product.

**Table 2:** Result of analysis of physical chemical characteristics of the treatments.

	(T1)	(T2)	(T3)	(T4)	p-valor
Fat media	61.01% +	58.28% +	34.3% +	70.37% +	*0.003
+/-ds	0.012**	0.179**	0.113**	0.48**	
pH media	4.06 +	4.1 +	4.7 +	4.1 +	*0.001
+/-ds	0.035	0.021	0.081**	0.012	

\*p-value less than 0.001 means statistically significant differences by ANOVA ( $\alpha < 0.05$ ). \*\* Tukey test difference between treatments.

The percentage of fat in the treatments was different in all of them since they had various concentrations of milk, being T4 the one that contained more fat, followed by T1, T2, and T3. The treatment T1 contains a greater amount of oil in which the milk has broken the emulsion. The treatment T3 contains more milk and it didn't have a good consistency. It is concluded that T2 in terms of fat is the most similar to T4, however, it has 13% less fat. In accordance with NTE INEN 2295, it would fall into the category of low-calorie mayonnaise. Except for T3, the other treatments have a pH level in accordance with the norm (pH 4.1). Similar results were found in other studies where it was determined that with the

increase in milk in the formulation, the fat content was reduced (from 61 to 34% approximately) and the pH increased slightly (from 4.06 to 4.70) due to the addition of water from the milk (Campos *et al.*, 2021). The ANOVA was performed for the fat percentage variable, obtaining statistically significant differences between the treatments, the Tukey test determined that all the treatments were different.

the judges were the yellow color, where the standard sample has a 6/10 while the T2 sample has a 4.5/10 because the egg also provides a yellow color. The umami flavor was also higher in T2 since milk has that characteristic flavor. Regarding consistency, T2 was the most similar to T4 of all the samples.

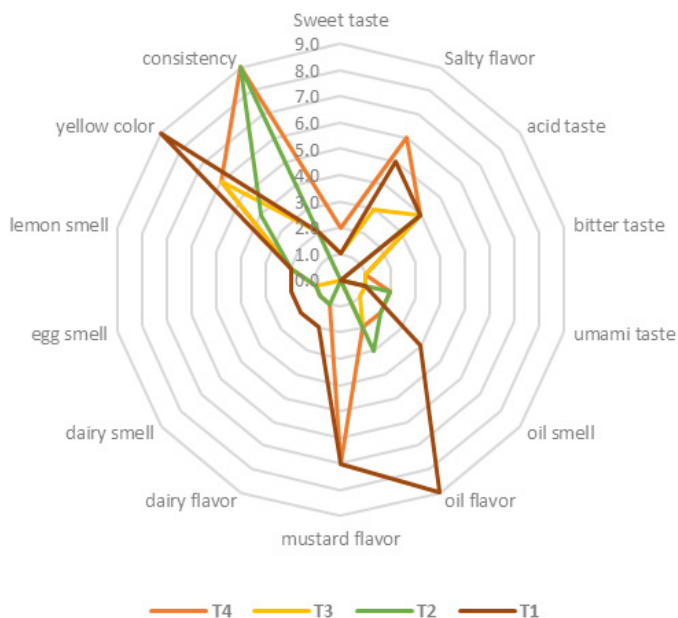
Two discriminative tests were carried out, the duo trio and the triangular test. Table 3 indicate the Duo trio and triangular sensory tests between treatments T2, T3. Regarding the comparison of the T2 and T4 treatments, it was found that there were no statistically significant differences, which means that the judges found no differences between the T2 samples made with 35% milk and T4 made only with egg. The samples of the T1 treatment were discarded from the sensory analysis because an emulsion was not achieved due to the small amount of milk that was formulated.

**Table 3:** Duo trio and triangular sensory tests between treatments T2, T3.

Test	Correct	Incorrect
Duo trio test samples T2 y T4	4	12
Duo trio test samples T3 y T4 *	12	4
Triangular test samples T3 y T4	7	9
Triangular test samples T3 y T4 *	14	2

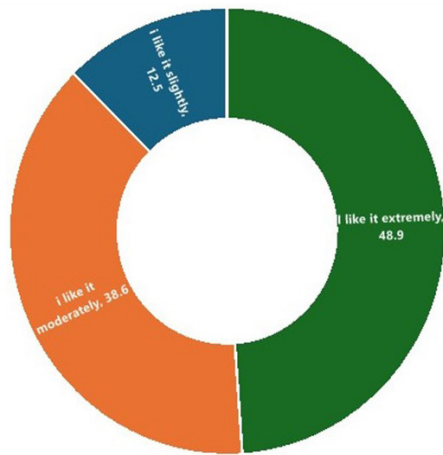
Not having a significant difference between the T2 and T4 treatments indicates that the normal consumer of the product will not notice a difference between the mayonnaise with 100% egg (T4) and the mayonnaise that replaces the egg with 35% milk (T2). But with the mayonnaise at 65% milk (T3) the panelists did detect a difference since the mayonnaise is more liquid. Proteins are used to facilitate formation and improve stability in oil-in-water emulsions. By having the egg replaced by milk, the protein content of the product also changes and, in this way, the emulsion is affected and, in this case, the judges detected a change in texture (McClements, 2004).

Figure 3 explains the results of the hedonic flavor scale which was applied using T2 because the T2 treatment is the one that most resemble to T4. 48.9% of the consumers reported that they extremely like the mayonnaise, 38,6% reported that they liked it moderately and 12.5% of the consumers found the mayonnaise slightly likable.



**Figure 2:** Flavor star of descriptive profiles of the treatments.

Then, a sensory analysis was performed to determine whether the differences introduced by the substitution are perceptible, to evaluate the sensory similarity between the traditional formulation and the proposal, and to validate the success of the reformulation from the consumer’s point of view. Sensory analysis is very important for decision-making. Figure 2 shows a comparison of the flavor profiles of the four treatments. The profile was made using the scales proposed by the panel, which scale were from 1 to 10. It is observed that between T1 and T4 the stars are very different, especially in the consistency attribute, since T1 failed to emulsify, obtaining a very noticeable separation of the phases and therefore the consistency was not like T4. Another of the attributes that is very different in T1 is the oil flavor which had a higher score on a scale of 1 to 10. The judges determined at this point not continue with more tests and exclude T1. The T3 star is also different, especially due to the consistency of the mayonnaise, which was very dripping and not very spreadable compared to the control sample. The flavor stars that are very similar were T2 and T4 because most of the attributes had the same scores in both treatments. The perceptible differences between



**Figure 3:** Responses of the hedonic scale T2.

The tendency in the development of mayonnaises is especially oriented towards replacing the fat source, especially vegetable oils with lipid profiles of greater benefit to health and proteins due to the desire for different ingredients or a different emulsifying capacity. By modifying the type of oil and the amounts, the characteristics of the final product can be manipulated and potentially replace commercial mayonnaise (Echeverri and Bulla, 2020). In some cases, these replacements can improve lipid profile, emulsion, and stability (Guzmán *et al.*, 2022).

The most common technique for creating emulsions that resemble mayonnaise is to include animal proteins for example, casein, whey protein, and meat protein (Mirzanajafi-Zanjani *et al.*, 2019). Additionally, some dairy products were studied such as Cheddar and Camembert powder (Da Silva *et al.*, 2021) finding that in terms of rheological properties and consistency index, the best results were using Cheddar products. The dairy by products were also studied, the whey protein had a good performance with 15% substitution in the development of low-fat mayonnaise (Satriawan *et al.*, 2022). Powdered milk is a structure-forming agent, since milk proteins swell in the presence of moisture, increasing the water-retaining capacity of mayonnaise (Bredikhin *et al.*, 2022). Xanthan gum was used as an additive (hydrocolloid) and gradually replaced egg yolk with whole milk analyzed physical and rheological properties and found in all samples the same relationship of force and shear rate and the same non-Newtonian thixotropic behavior, despite being different formulations, probably because whey proteins are capable to alter their adsorption capacity at fluid interfaces and macro - interactions between whey protein in milk and Xanthan gum (Morna, 2020). However, milk proteins and their ability as an

emulsifying agent depend on the form of aggregation and particle size of the droplets (Ye, 2011). Milk proteins are molecules with surface-active properties that adhere to the interface between oil and water, reducing interfacial tension and forming a protective layer around oil droplets. At this interface, proteins also generate repulsive forces, such as steric and electrostatic forces, which contribute to the stability of oil droplets in emulsions. These repulsive forces prevent the union of oil droplets, delaying processes such as creaming, flocculation, coalescence, and, finally, phase separation in emulsions (Ayunta *et al.*, 2019).

## Conclusions and Recommendations

The physical, chemical, and sensory quality of mayonnaise made with pasteurized whole milk as an egg substitute was analyzed, obtaining that the best treatment was T2 in which 35% milk was added in the formulation with 13% less fat and a pH of 4.1 which complies with the norm and organoleptic characteristics very similar to the control sample of the T4 treatment. The most important attribute that the judges mentioned was consistency which is the determinant when preparing an emulsion such as mayonnaise.

## Acknowledgments

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## Novelty Statement

This study addresses public health concerns related to Salmonella contamination by substituting raw eggs for pasteurized whole milk in mayonnaise production.

## Author's Contribution

**Alejandra Gómez, Geovanny Rodriguez:** Contributed to the creation and design of the study, designed the statistical plan and interpreted the data. **Manuel Coronel and Elena Balarezo:** Conducted the literature search, performed the analyses, and wrote the first draft with the help of **Valeria Almeida, Emilia Vintimilla.**

All authors critically reviewed this and previous

versions of the paper. All authors read and approved the final manuscript.

### Conflicts of interest

The authors have declared no conflict of interest.

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