J. Food Sci. Gastron. (January - June 2024) 2(1): 1-5
https://doi.org/10.5281/zenodo.13996171
ISSN: 3073-1283

JFSG
JOURNAL OF FOOD SCIENCE AND GASTRONOMY

ORIGINAL ARTICLE

Chitosan as a natural emulsifier in mayonnaise: stability and effects on product quality

Quitosana como emulsionante natural en la mayonesa: estabilidad y efectos sobre la calidad del producto

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Received: 16 June 2023 / Accepted: 19 September 2023 / Published online: 26 January 2024

Abstract In this study, the foaming and emulsifying properties of chitosan and its application in the formulation of food products such as cakes, pancakes, and mayonnaise were evaluated. The results indicated that chitosan exhibits a notable foaming capacity, although it decreased with the addition of salt, which in turn improved foam stability. It was observed that chitosan formed stable emulsions, favored by its molecular structure, although salt reduced the stability of these emulsions. In mayonnaise, chitosan was able to partially replace eggs while maintaining the stability of the emulsions, although concentrations higher than 0.1% resulted in an undesirable aftertaste. Long-term studies were suggested to evaluate the formulation´s stability during storage. These findings highlight the potential of chitosan as an emulsifying and foaming agent in various food applications.

Keywords chitosan, foaming properties, emulsions, foam stability, mayonnaise, salt.

Resumen En este estudio se evaluaron las propiedades espumantes y emulsionantes de la quitosana y su aplicación en la formulación de productos alimenticios como tortas, panqués y mayonesas. Los resultados indicaron que la quitosana presenta una notable capacidad espumante, aunque esta disminuyó con la adición de sal, que a su vez mejoró la estabilidad de las espumas. Se observó que la quitosana formó emulsiones estables, favorecidas por su estructura molecular, aunque la presencia de sal redujo la estabilidad de estas emulsiones. En las mayonesas, la quitosana logró sustituir parcialmente el huevo, manteniendo la estabilidad de las emulsiones, aunque concentraciones superiores al 0.1% generaron un regusto no deseado. Se sugirió realizar estudios a largo plazo para evaluar la estabilidad de las formulaciones durante el almacenamiento. Estos hallazgos resaltan el potencial de la quitosana como emulsionante y agente espumante en diversas aplicaciones alimentarias.

Palabras clave quitosana, propiedades espumantes, emulsiones, estabilidad de espumas, mayonesa, sal.

How to cite
Casariego, A., & Díaz, R. (2024). Chitosan as a natural emulsifier in mayonnaise: stability and effects on product quality. *Journal of Food Science and Gastronomy*, *2*(1), 1-5. https://doi.org/10.5281/zenodo.13996171

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PUBLIS EDITORIAL

Introduction

Chitin is a polysaccharide composed of N-acetyl-D-glucosamine molecules linked by β (1-4) bonds. It is widely found in nature and is the second most abundant polymer after cellulose. It is a non-toxic and biodegradable substance, present in the exoskeleton of insects, crustaceans, and arachnids, as well as in mushrooms, yeasts, corals, zooplankton, butterflies, algae, and fungi (Jiménez-Gómez & Cecilia, 2020).

Chitosan is the main derivative of chitin, obtained through a simple chemical process of deacetylation. This term encompasses a family of copolymers that vary in the number of deacetylated units and molecular weight (Aranaz et al., 2021).

The seafood processing industry generates large volumes of waste, which has led to the investigation of the economic exploitation of chitosan due to its properties, primarily derived from its cationic nature, and its potential to address environmental issues (Teixeira-Costa & Andrade, 2021).

Unlike chitin, chitosan is soluble in dilute acids, which expands its applications to fields such as pharmaceuticals, medicine, food, and agriculture (Baharlouei & Rahman, 2022). Its properties include increasing viscosity in solution, forming gels, foams, and emulsions, precipitating suspended particles, reducing acidity, and forming resistant and biodegradable films, in addition to reducing microbial growth. These characteristics make chitosan valuable in the food industry (Aranaz et al., 2021).

Research has shown that chitosan can be used in mayonnaise to improve emulsion stability and reduce microbial growth, achieving positive results (Li et al., 2022; Ardean et al., 2021; García et al., 2014).

Mayonnaise is a semi-solid oil-in-water emulsion that contains at least 65% vegetable oil, acidifiers, egg yolk as an emulsifier, salt, sweeteners, and seasonings. However, eggs pose challenges due to factors like elevated costs, potential microbiological hazards, and their high cholesterol content (Taslikh et al., 2022).

Currently, the market offers mayonnaise-like dressings that partially replace eggs with other emulsifiers, such as whey protein concentrates, soymilk, and propylene glycol alginate (Rahmati et al., 2014).

Considering the nutritional importance of chitosan, which includes reducing the absorption of fats and cholesterol, and its role in stimulating intestinal flora, the immune system, and bone health, the proposed objective was to evaluate the usage of chitosan as a natural emulsifier in mayonnaise.

Materials and methods

For this work, two types of chitosan were used: chitosan 1, with a medium degree of deacetylation, obtained from the basic chemistry laboratory of Pharmacy and Food Institute (Havana, Cuba), and chitosan 2, with a high degree of deacetylation, obtained from the Mario Muñoz Pharmaceutical Laboratory. Solutions of chitosan 1 were prepared at concentrations of 1, 2, and 3% in 1% acetic acid, stirring in a water bath at 45 °C for one hour. The foaming capacity was measured in duplicate for 12 preparations, both in the absence and presence of 2% NaCl.

Each preparation was stirred in a 150 ml beaker with a 4 cm diameter paddle at 2000 rpm for 10 minutes. The height of the foam was measured using a strip of millimeter paper. Foam stability was evaluated every 10 minutes for 80 minutes. Solutions of chitosans 1 and 2 were prepared at 1, 2, and 3% in 1% acetic acid, first with 2% NaCl and then without it. The emulsions were prepared in duplicate by adding 10 ml of each solution to a 50 ml centrifuge tube, using a turbine-type paddle at 2000 rpm with a drip addition of 10 ml of oil over 5 minutes, followed by 3 more minutes of stirring. Ten ml of each emulsion were centrifuged at 3000 rpm for 6 minutes, recording the volume of separated oil. The stability of the emulsion was calculated based on the volume of non-separated oil compared to the total added.

Mayonnaises were prepared with 0.1-0.5% chitosan using a domestic blender to observe possible organoleptic effects. A total of 500 g of a mayonnaise-type dressing was prepared at the Food Industry Research Institute (IIIA), following a specific order of ingredient addition. The samples were stored in 350 ml glass jars at room temperature until evaluation.

The sensory evaluation was conducted with a panel of judges from the IIIA, following the defect evaluation procedure by Zamora et al. (1996). The pH was determined with a glass electrode potentiometer, moisture was measured using a gravimetric method, and consistency was assessed using the drop test method. The stability of the mayonnaise was evaluated by centrifuging 10 g of each sample at 3000 rpm for 6 minutes, both without prior treatment and after 24 hours at 40 °C.

Results and discussion

The results of the foaming capacity determination are presented in Table 1. These values indicate that chitosan exhibits foaming properties (Song et al., 2022). This characteristic makes chitosan suitable for the preparation of cakes and pound cakes. It was observed that the height of the foam decreased as the concentration of chitosan increased, while its consistency increased.

Table 1. Average values of the height reached by the foam

Preparation	Without salt (cm)	With salt (cm)
1	3.40 d	3.60 bc
2	3.85 b	3.80 b
3	3.80 b	3.75 b
4	4.20 a	3.80 b
5	3.75 b	3.85 b
6	3.70 bc	3.45 cd

The addition of salt generally reduces the foaming capacity. This may be due to NaCl being a strong and soluble salt that completely dissociates in water, allowing its charged groups to interact with acetic acid and the charged groups of chitosan, which decreases its solubility and, consequently, its functional properties (Obisesan et al., 2021). Table 2 presents the results of foam stability, both with salt and without salt.

In all cases, emulsions were formed, which coincided with previous studies highlighting the emulsifying capacity of chitosan (Wei et al., 2022). This polymer, having a structure that combines polar and non-polar parts, was able to encapsulate fat droplets and reduce interfacial tension, favoring the formation of stable emulsions. The viscosity of the emulsions increased with higher concentrations of chitosan, and stability was greater in more concentrated solutions, thanks to a higher amount of available emulsifier and increased viscosity. However, the presence of salt reduced the emulsion stability, possibly by interacting with the charged groups of chitosan and acetic acid.

Mayonnaise prepared with different concentrations of chitosan exhibited excellent emulsions visually. However, an aftertaste was noted that increased with concentration, so a concentration of 0.1% was chosen for subsequent tests, where the aftertaste was minimal.

Table 2. Values of the height reached by the liquid with salt and without salt

Mayonnaise	Preparation	Minutes							
		10	20	30	40	50	60	70	80
With salt	1	0.35	0.55	0.70	0.80	0.85	0.85	0.93	0.95
	2	0.40	0.55	0.68	0.75	0.85	0.90	0.90	0.90
	3	0.55	0.70	0.80	0.85	0.90	0.90	0.93	1.00
	4	0.35	0.45	0.58	0.65	0.70	0.75	0.80	0.83
	5	0.00	0.00	0.00	0.10	0.20	0.28	0.30	0.40
	6	0.00	0.00	0.00	0.00	0.05	0.10	0.20	0.23
Without salt	1	0.40	0.63	0.75	0.83	0.85	0.90	0.90	0.95
	2	0.45	0.65	0.68	0.75	0.80	0.80	0.90	0.98
	3	0.60	0.75	0.80	0.85	0.90	0.95	1.00	1.00
	4	0.60	0.65	0.70	0.73	0.75	0.80	0.85	0.85
	5	0.15	0.20	0.30	0.35	0.45	0.45	0.48	0.55
	6	0.00	0.18	0.25	0.30	0.33	0.40	0.48	0.50

The foam stability increased with the concentration of chitosan, reaching maximum stability in the formulation containing 3% of this polymer. Unlike what was observed in foaming capacity, the presence of salt contributed to foam stability (Risser et al., 2017). This is because salt can affect the interaction between chitosan molecules and air bubbles, helping to stabilize the foam structure by reducing interfacial tension and preventing bubble coalescence.

The influence of salt on the stability of emulsions and foams has been documented. For example, according to Wei et al. (2022), salt can modify the properties of proteins and other emulsifying agents, which might result in greater stability of emulsions and foams by promoting the formation of a more resilient structural network. The emulsion stability for both chitosans is shown in Table 3.

The results obtained from the four determinations: pH, moisture, consistency, and emulsion stability are shown below in Table 4.

The pH of the evaluated samples remained around 4.2, slightly above the limit established by the standard (less than 4.1), which aims to ensure the microbiological safety of the product. However, this slight increase in acidity may be compensated by the antimicrobial action of chitosan. Although this does not represent a technological problem, the pH could be adjusted by increasing the amount of vinegar in the formulation. Samples with 0.1% chitosan showed a

Table 3. Emulsion stability values for chitosan 1 and 2

Chitosan	Emulsion	Chitosan (%)	Mayonnaise stability without salt (%)	Mayonnaise stability with salt (%)
	1	3	100 c	100 c
1	2	2	97 b	86 c
	3	1	82 a	8.0 b
	1	3	97 c	93 c
2	2	2	93 c	91 c
	3	1	63 b	11 a

slightly higher pH than the control, attributed to the amount of added water and the polymer's ability to reduce acidity by positively charging in solution, thus decreasing hydronium ions.

Moisture values varied among the samples, increasing compared to the control due to the substitution of egg with water. In sample 6, the moisture percentage was lower than in the others, as removing part of the egg did not incorporate the corresponding amount of water, resulting in moisture similar to the control. This increase in water content may contribute to greater physical-chemical and microbiological deterioration, although the emulsifying and antimicrobial properties of chitosan could mitigate this effect.

The consistency of the mayonnaises with chitosan was generally lower than that of the control, except in sample 6, which, like the control, did not have added water, resulting in less penetration of the plumb line due to the dilution of the emulsion.

All mayonnaise samples, whether stored at room temperature or at 40 °C for 24 hours, showed maximum stability, indicating that it is possible to substitute part of the egg with water and chitosan without compromising the emulsion.

Table 4. Values of the physical and chemical determinations of the mayonnaise samples

Parameter	Mayonnaise					
	Control	1	2	3	4	5
pH	4.16	4.27	4.26	4.23	4.20	4.22
Humidity (%)	38.00	40.05	40.30	41.20	41.50	39.00
Plummet (cm)	3.5	4.5	4.5	4.5	4.7	4.0
Stability (%)	100	100	100	100	100	100

Although the method used to determine stability provides valuable information, a prolonged study during storage is recommended to gain a more comprehensive view of the future behavior of the emulsions.

Conclusions

The results indicated that chitosan exhibited foaming properties, making it suitable for the preparation of cakes and muffins. As its concentration increased, the height of the foam decreased, but its consistency improved. The addition of salt reduced the foaming capacity but increased foam stability, likely due to its effect on interfacial tension. In emulsions, chitosan demonstrated a notable emulsifying and stabilizing ability, especially at high concentrations, although salt decreased its stability. In mayonnaise, chitosan maintained the stability of the emulsions with a pH slightly higher than the control, although concentrations above 0.1% generated an aftertaste that should be considered. Chitosan proved to be a viable option for reducing egg usage, but long-term stability studies were suggested.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Author contributions

Alicia Casariego and Raúl Díaz: Conceptualization, data curation, formal analysis, investigation, methodology, supervision, validation, visualization, drafting the original manuscript and writing, review, and editing.

Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Statement on the use of AI

The authors acknowledge the use of generative AI and AI-assisted technologies to improve the readability and clarity of the article.

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