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# LIME EFFECT ON COLOR AND SENSORY PROPERTIES OF THE ANCESTRAL QUISPIÑO MADE FROM THE GRAINS OF QUINOA (*CHENOPODIUM QUINOA* WILLD.)

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## SUMMARY

An investigation of the effects of varying lime concentrations (0.1%, 0.3%, 0.5%, 0.7%, and 0.9%) on the color and sensory properties of quispiño, a traditional product made from the grains of quinoa (*Chenopodium quinoa* Willd.), was the focus of this study. The primary objectives were to evaluate the influence of lime concentrations on color parameters (L*, a*, b*, chromaticity, and hue angle), assess the net color difference (ΔE) between raw and cooked dough, and conduct a sensory acceptability test. The results showed significant variations in the color properties of the dough, with the optimal lime concentration (0.7%) superior for color maintenance and sensory acceptability. The optimal concentration achieved the balance between the visual appearance and flavor. However, the higher lime concentration (0.9%) improved the taste and aroma but affecting the appearance. Sensory evaluation involving 40 untrained panelists confirmed that quispiño with lime concentration at 0.7%

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was the most acceptable for color, taste, and appearance. The latest research highlighted the cultural and biochemical importance of lime in traditional food preparation, providing a scientific basis for optimizing traditional products like quispiño, while maintaining their sensory and cultural significance.

**Keywords:** Quispiño, Quinoa (*C. quinoa*), lime concentrations, color properties, sensory evaluation, traditional food

**Key findings:** For quispiño preparation, the optimal lime concentration (0.7%) proved most appropriate for balancing its color, taste, and appearance. Higher lime level (0.9%) enhanced the flavor and aroma, but negatively affected the appearance.

## INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.) is an annual herbaceous plant belonging to the family Amaranthaceae. It is a highly valued crop since the time of pre-Columbian Andean civilizations, particularly by the Incas, and regarded as a sacred gift due to its exceptional nutritional benefits (Bazile *et al*., 2016). The quinoa grains are known for high-quality proteins and rich nutritional profile, recognizing it as an attractive food source with numerous health benefits, particularly for individuals with specific dietary needs, such as, diabetes, celiac disease, and obesity (Bhargava *et al*., 2006; Xi *et al.,* 2024). Quinoa with low glycemic index supports stable blood sugar levels and is suitable for those managing diabetes and other metabolic disorders (Marak *et al*., 2024).

Quinoa, a dietary staple consumed in various forms, is a key ingredient in traditional dishes like quispiño, grained quinoa, and quinoa soup in the Andean regions (Lápez-Cervantes *et al*., 2021). Its local consumption has deep cultural roots, and regions like Southern Bolivia, have preserved and consumed a considerable amount of quinoa locally, highlighting its nutritional importance (Calizaya *et al*., 2023). In these regions, the persistence of quinoa's consumption demonstrates the integration of this crop into the social fabric and its adaptability to the harsh environmental conditions of Andean highlands (Fuentes *et al*., 2009).

Quispiño is the traditional Andean food made from quinoa flour and has remained largely confined to the region, with limited popularity outside (Miguel, 2018). The quispiño preparation involves a time-honored, artisanal process, including ground quinoa flour in a stone mill (k'hona) and kneading it with lime and salt. Then, shaping and cooking the dough mixture traditionally in a clay pot, give it a unique texture and flavor (Orsini, 2016). The pairing of quispiño is often with other regional staple foods like freeze-dried and boiled potatoes and corn, as well as, enriching with cheese, meat, and salad (Chávez-Zander, 2014). Remarkably, it can also last storage up to six months without refrigeration while maintaining its texture, making it a highly durable food source for long journeys (Bazile *et al*., 2016).

In quispiño preparation, the lime (calcium hydroxide) use is crucial not only for its culinary role but for its biochemical interaction, particularly with saponins found in quinoa that can impart a bitter taste (Filho *et al*., 2017). The lime addition in quinoa flour helps neutralize saponins, improving the flavor, and contributing to the dough's color and texture. Additionally, lime acts as an acidity regulator and enhances the visual appearance of the product through its reaction with the quinoa dough, giving quispiño its distinctive color (Connolly, 2023).

The presented study's objective was to contribute to the knowledge surrounding traditional quispiño preparation, focusing on the impact of lime concentration on its quality. Specifically, the latest research evaluated how different lime concentrations can affect color parameters of quispiño, including L*, a*, b*, chromaticity (C*), and hue (H*), in raw and cooked dough. Furthermore, the study explored the net color difference (ΔE) between the raw and cooked dough with varying lime concentrations to establish a standard for optimal color and quality. Finally, an acceptability test continued to assess consumer perceptions of the flavor, color, appearance, and smell of quispiño, and understand how lime influences the overall consumer acceptance. Thus, this study aimed to enhance the consumption and appreciation of traditional quinoa-based products like quispiño, providing insights into improving its quality and marketability.

## MATERIALS AND METHODS

### Study location

The study transpired in the city of Moquegua, Peru (with an altitude of 1,410 meters above sea level [masl]). The preparation of the quispiño and laboratory analysis proceeded at the Cite Agroindustrial Moquegua, located in the District of Ilo (13 masl, with coordinates 17°41′04″ S 71°20′00″ W) (Gorelick *et al*., 2017). The target population consisted of consumers who provided feedback on the acceptability of quispiño based on flavor, color, appearance, and smell.

### Quispiño samples

The quispiño samples prepared had varying lime concentrations. Quinoa cultivar Salcedo came from the National Institute of Agrarian Innovation (INIA), Agraria Experimental Station ILLPA Puno, cultivated between 2019 and 2020 (15°52′56.6″ S 70°00′08.9″ W). The cleaning of quinoa grains removed impurities, such as, leaves, perigoneum, and foreign seeds. Certified quinoa (lot code ILL1-015-19) with a varietal purity (99.7%) and germination rate (93%) was the simple used. Different ingredients used in the preparation of quispiño included salt, lime, anise, and vegetable oil, sourced from the Laykakota market in Puno.

### Analytical methods

The particle size analyses of Salcedo quinoa and lime powder served to evaluate the quality of raw materials and ingredients. The measurement of color parameters (L*, a*, b*, H*, and C*) of quinoa, lime, salt, and anise occurred. Determining the calcium content in the lime and the saponin content in the quinoa also progressed. The experimental scheme outlining the techniques and treatments used to collect the data on various variables is available in Table 1.

### Color analysis and comparison

The second objective was to compare the net color difference (ΔE) between the raw and cooked dough at different lime concentrations to establish a standard. A color spectrophotometer (NS800, China) served to measure the tristimulus color components of the raw and cooked doughs. The color values recorded had descriptions as L* (lightness), a* (red/green coordinate), and b* (yellow/blue coordinate), with calibration performed using a black reflector plate under illuminant D65 (Nayak *et al*., 2014). The hue angle (H*) and chroma (C*) calculation assessed the color purity, while the net color difference (ΔE) computation used the following formula:

$$\Delta E = (L2*-L1*)2+(a2*-a1*)2+(b2*-b1*)2$$

Where L1*, a1*, and b1* represent the raw dough values, and L2*, a2*, and b2* represent the cooked dough values.

**Table 1.** Particle size of lime powder (ASTM Sieve Method).

| ASTM Sieve No. | Measurement (mm) | Weight (g) | Retained (%) |
|---|---|---|---|
| 140 | 0.106 | 15.17 | 23 |
| 200 | 0.075 | 18.8 | 29 |
| 230 | 0.063 | 31.83 | 48 |
| Total | - | 65.8 | 100 |

**Figure 1.** Quispiño with three different percentages of lime.

**Experimental design**

A complete random design (CRD) 2×5 factorial model helped test the hypothesis for the first objective. For factorial design, the linear model used was as follows:

$$Yij=\mu+Ai+Bj+(AiBj)+\epsilon ijY$$

Where Yij is the response variable, μ is the population mean, Ai represents the effect of treatment A, Bj represents the effect of treatment B, and εij is the experimental error.

For the second objective, the ΔE values between the raw and cooked dough underwent analysis using ANOVA, followed by Tukey's test to determine significant differences among the lime concentrations.

**Sensory evaluation**

For the third objective, a sensory evaluation ensued to assess the acceptability of quispiño based on flavor, color, appearance, and smell. Forty untrained panelists, all students from the Professional School of Agroindustrial Engineering, received three coded samples of quispiño, each prepared with 0.5%, 0.7%, and 0.9% lime concentrations (Figure 1). The panelists rated the samples on a 5-point hedonic scale, with scores ranging from 1 (dislike a lot) to 5 (like a lot) (Vásquez *et al*., 2019). The sensory data analysis used the Friedman and Wilcoxon tests, with R version 4.3.2 employed for statistical analysis.

**Statistical analysis**

For color comparison and sensory evaluation, the analysis of variance (ANOVA) evaluated the significant differences among the treatment means, with a significance level of $\alpha = 0.05$. Statistical analysis also used R version 4.3.2, with the Tukey's test applied for post-hoc analysis, where applicable.

**RESULTS**

**Lime particle size and calcium content**

The ground lime used in the study had a particle size of 0.063 mm, as determined by ASTM 230 mesh, with 48% retained (Table 1). The lime exhibited the highest calcium content of 58.4 ± 0.27 g/100 g. Its light creamy color is an important factor in the preparation of quinoa-based products like quispiño, where lime acts as an acidity regulator.

**Color properties of the ingredients**

The color values of the main ingredients used in the preparation of quispiño, including grains of quinoa cultivar Salcedo, lime, salt, and anise, reached evaluation. The results showed salt exhibited the highest lightness (L*) of 92.54, while quinoa had a cream color with an L* value of 75.28 (Table 2).

**Table 2.** Color results of quinoa, salt, lime, and anise.

| Ingredient | L* (Lightness) | a* (Red/Green) | b* (Yellow/Blue) | C* (Chroma) | H* (Hue) |
|---|---|---|---|---|---|
| Quinoa Salcedo | 75.28 ± 0.4 | 3.41 ± 0.2 | 22.09 ± 0.3 | 22.35 ± 0.2 | 81.23 ± 0.5 |
| Salt | 92.54 ± 0.3 | 0.31 ± 0.0 | 2.54 ± 0.0 | 2.56 ± 0.0 | 83.04 ± 0.4 |
| Lime (Powder) | 90.51 ± 0.1 | 1.10 ± 0.0 | 9.09 ± 0.2 | 9.16 ± 0.1 | 83.08 ± 0.1 |
| Anise | 44.82 ± 1.6 | 2.65 ± 0.8 | 12.16 ± 0.9 | 12.46 ± 1.1 | 77.82 ± 2.9 |

**Table 3.** L* values of raw and cooked quispiño dough at different lime concentrations.

| Lime (%) | L* (Raw Dough) | L* (Cooked Dough) |
|---|---|---|
| 0.1 | 72.32 ± 0.02 | 46.32 ± 0.01 |
| 0.3 | 72.24 ± 0.04 | 39.99 ± 0.04 |
| 0.5 | 68.99 ± 0.03 | 39.98 ± 0.02 |
| 0.7 | 67.59 ± 0.02 | 39.75 ± 0.05 |
| 0.9 | 67.78 ± 0.03 | 39.44 ± 0.00 |

**Table 4.** Net color difference (ΔE) between raw and cooked dough at different lime concentrations.

| Lime (%) | ΔE |
|---|---|
| 0.1 | 26.15 ± 0.02e |
| 0.3 | 32.80 ± 0.03a |
| 0.5 | 30.61 ± 0.02b |
| 0.7 | 29.84 ± 0.03d |
| 0.9 | 30.41 ± 0.01c |

**Color results of quispiño dough at five lime levels**

The analysis of variance indicated significant differences in the L* (lightness) values between the raw and cooked quispiño doughs with five different lime concentrations. The raw dough displayed greater lightness (L* = 69.79), while the cooked dough was notably darker (L* = 44.10). The lime concentrations (0.7% and 0.9%) affected the clarity, yielding similar L* values in the cooked dough (Table 3).

**Net color difference (ΔE) between raw and cooked dough**

The net color difference (ΔE) between raw and cooked quispiño doughs at various lime concentrations was significant, observing the highest ΔE at 0.3% lime (32.80 ± 0.03). The results showed the choice of lime concentration greatly influences the color of the final product (Table 4).

**Sensory evaluation of quispiño**

The sensory evaluation, based on a 5-point hedonic scale, indicated remarkable differences in flavor, appearance, and smell, however, revealed a nonsignificant difference in color perception between different lime levels. The quispiño with 0.9% lime received the highest rating for flavor and smell, while the samples with 0.5% and 0.7% lime were more acceptable for appearance (Figure 2).

These findings suggested the higher lime concentrations may enhance flavor, while lower concentrations could be a preference to maintain a more appealing visual appearance. The study also highlighted the role of lime as a traditional ingredient with both cultural and biochemical significance, facilitating the solubility of phytohormones and enhancing the texture and flavor of quispiño. Moving forward, these outcomes provide a scientific foundation for optimizing the formulation of quispiño and other traditional food products that rely on lime, balancing consumer preferences with cultural heritage preservation.

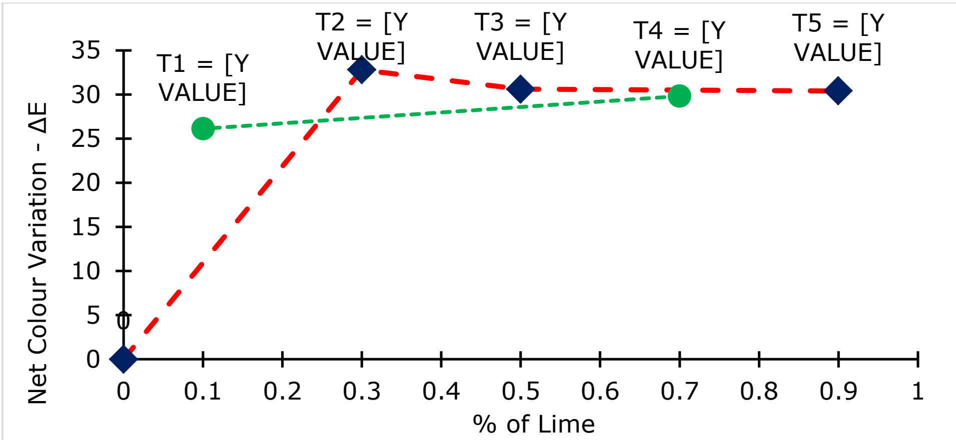


**Figure 2**. Net color difference (ΔE) among the lime treatments. Significant ($p < 0.05$) differences among the values were indicated by different letters.

**DISCUSSION**

In this study, the lime used attained classification as a ground lime, facilitating uniform distribution in the quinoa dough. Lime's highest calcium content (58.4 g/100 g) has proven to enhance the dough texture by interacting with starch molecules, and, thus, improving the structural integrity of the cooked product (Criado *et al*., 2017). Lime also plays a pivotal role in neutralizing the bitter saponins in quinoa, enhancing its taste and nutritional values (Rafik *et al*., 2021).

Lime's cultural significance in preparing traditional dishes like quispiño has complemented its biochemical role in developing an alkaline environment facilitating phytohormone solubility, potentially benefiting the health during hormonal variations, such as menopause (Lima, 2016). In color properties of the key ingredients like quinoa, lime, and salt, significant differences were visible with the L*, a*, and b* values (Chadha *et al*., 2021). The quinoa cultivar Salcedo had a relatively light color (L* = 75.28), which contributes to the desirable appearance of the final product (Dussán-Sarria *et al*., 2019).

In Quinoa, carotenoids' presence was indicative of the positive a* and b* values, which showed red and yellow hues, respectively (Rojas-Garbanzo *et al*., 2016). Lime, with its highest L* value (90.51), contributed to the final product's brightness without imparting any significant coloration (Bibbins-Domingo *et al*., 2010). As lime concentration increased, a decrease was evident in lightness (L*) of both raw and cooked dough, and the cooked dough exhibited more pronounced darkening. This might be due to the interaction between lime and the dough's components during the cooking process, promoting Maillard reactions (Agama-Acevedo *et al*., 2004). The shift in a* values toward the red dimension for cooked dough with the higher levels of lime (0.7% and 0.9%) suggested that lime may influence color development via pH-mediated variations in carotenoid stability (Moreno *et al*., 2003).

The optimal lime concentration for maintaining color integrity appeared as 0.7%, balancing the lightness and overall appearance of both raw and cooked quinoa dough. The net color difference values reflected significant variations between raw and cooked dough across the different lime concentrations. The highest color distinction emerged at 0.3% lime, suggesting the moderate level of lime can develop the most pronounced visual variations (Sánchez-Madrigal *et al*., 2014). The lower ΔE values at the lime concentrations (0.7% and 0.9%) indicate these concentrations stabilize the color difference between raw and cooked dough. These findings underscore the importance of choosing the appropriate lime concentration to achieve the desired color properties in traditional food products (Gonnet, 1999).

The sensory analysis confirmed lime concentration considerably affects the taste and aroma of quispiño. The lime with 0.9% concentration was a preference for flavor and smell, likely due to lime's alkaline properties, enhancing the interaction between starch and proteins, leading to a more pronounced taste (Vásquez *et al*., 2019). However, the quispiño appearance received a more favorable rating at lower concentrations of lime (0.5% and 0.7%), possibly because higher concentrations darkened the dough, making it less visually appealing (Wyness *et al*., 2012; Al-Naggar *et al*., 2023). Overall, the panelists perceived no significant differences in color despite the measured variations, suggesting that subtle variations in color are not noticeable to untrained consumers (Jaimes *et al*., 2017). The results highlighted the need to balance instrumental measurements with consumer preferences by optimizing product formulations.

## CONCLUSIONS

The relevant study demonstrated the significant impact of lime concentration on the color and sensory attributes of quispiño, as an ancestral quinoa-based product. Lime concentration affected both the raw and cooked dough, with notable differences in color parameters (L*, a*, b*), chromaticity (C*), and hue angle (H*). The optimal lime concentration (0.7%) was best for maintaining desirable color properties and consumer acceptability. This optimal level of lime achieved a balanced net color difference (ΔE) between raw and cooked quinoa dough, providing a consistent appearance while preserving the product's traditional qualities. Sensory evaluation revealed higher lime concentrations (0.9%) were more favorable for taste and aroma, likely due to the positive role of lime in enhancing starch-protein interactions and contributing to overall flavor complexity. However, the appearance of the product was more acceptable at lower lime concentrations (0.5% and 0.7%), preserving dough lightness more.

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