Check for updates

Journal of Sensory Studies

WILEY

Journal of Sensory Studies

ORIGINAL ARTICLE

Improving the Sensory Quality of Sugar-Reduced Quinoa Biscuits Targeted to Children Based on Young Adult Feedback

Erick Saldaña[1] | Jennifer Alvarez[1] | Karina Eduardo[1] | Milagros Maribel Coaguila Gonza[2] | Juan D. Rios-Mera[3] | Carmen J. Contreras-Castillo[2]

[1]Sensory Analysis and Consumer Study Group, Escuela Profesional de Ingeniería Agroindustrial, Universidad Nacional de Moquegua, Moquegua, Peru | [2]Departamento de Agroindústria, Alimentos e Nutrição (LAN), Escola Superior de Agricultura "Luiz de Queiroz" (ESALQ), Universidade de São Paulo (USP), Piracicaba, SP, Brazil | [3]Grupo de Investigación en Reformulación de Alimentos (GIRA), Instituto de Investigación de Ciencia y Tecnología de Alimentos (ICTA), Universidad Nacional de Jaén, Carretera Jaén-San Ignacio, Jaén, Peru

Correspondence: Erick Saldaña (esaldanav@unam.edu.pe)

Received: 22 May 2025 | **Revised:** 21 June 2025 | **Accepted:** 7 July 2025

Funding: This work was supported by Universidad Nacional de Moquegua.

Keywords: child nutrition | hedonic perception | quinoa flour | sensory evaluation | sugar reduction

ABSTRACT

Childhood obesity and undernutrition pose significant global challenges, particularly in Peru, where sweet biscuits are widely consumed but often nutritionally unbalanced. To improve the sensory quality of biscuits for children, we proposed selecting biscuits with better characteristics through evaluation with young adults. This study evaluated the impact of reducing sugar and incorporating quinoa flour on the sensory and hedonic perception of biscuits among young adults and school-aged children. Biscuit formulations were assessed using a 9-point hedonic scale and a Check-All-That-Apply (CATA) questionnaire. Young adults ($n = 115$, 18–25 years) showed moderate acceptance of all treatments, but the selection of the best treatments was influenced by the attributes "crunchy," "honey," and "sweet." The selection of three treatments containing moderate levels of quinoa flour (15%–30%) and reduced sugar (10%–20%) resulted in higher scores of overall liking in children ($n = 113$, 6–13 years) compared to the evaluation in young adults, with positive attributes (sweet, crunchy, honey, brittle, and buttery) and absence of negative drivers of liking, which demonstrates the effectiveness of the proposed strategy. This reformulation strategy offers a practical approach to addressing malnutrition without compromising sensory quality, providing valuable insights for food industries and policymakers seeking to promote healthier snacks for children.

1 | Introduction

Nutritional imbalance, whether excess or deficiency, poses a significant global challenge (Swinburn et al. 2019; WHO 2024a). The excessive consumption of energy-dense, nutrient-poor foods has contributed significantly to the increasing prevalence of conditions related to overnutrition, such as obesity, type 2 diabetes, and cardiovascular diseases. These health issues are now among the leading causes of morbidity and mortality worldwide (WHO 2024a). Similarly, nutritional deficiencies that result in undernutrition—characterized by wasting, stunting, and underweight—remain prevalent in many regions worldwide. These situations highlight the dual burden of malnutrition affecting 340 million children and adolescents, underscoring the urgent need for effective dietary interventions that improve nutritional balance while retaining the sensory quality of food products (WHO 2024b). Various studies have focused on reducing sugar content in food products by using nonnutritive sweeteners (NNS)

© 2025 Wiley Periodicals LLC.

Practical Applications

This study presents a two-stage sensory evaluation strategy designed to develop healthier biscuits for children by incorporating quinoa flour and reducing sugar content. Utilizing young adults to preselect formulations helped optimize the sensory profiles before testing with children, thereby increasing acceptance. The selected biscuits, which contained 15%–30% quinoa flour and a 10%–20% reduction in sugar, were well received by children, preserving their sensory quality while enhancing nutritional value. This practical approach can be adopted by food industries and public health programs targeting malnutrition in children by reformulating popular snacks without compromising sensory quality.

to maintain the perception of sweetness without increasing caloric value, particularly in foods targeted at children (Velázquez et al. 2021). However, this strategy has shown limitations because NNS often leave a bitter, metallic aftertaste that can negatively impact children's acceptance of them (Li et al., 2014, 2015). In addition, evidence regarding the long-term effects of sustained NNS use in children raises concerns in the scientific literature, particularly in the Latin American context, where childhood obesity and malnutrition coexist (Sambra et al., 2020). In contrast, the present study proposes an innovative strategy that moves away from the use of NNS by focusing on reformulation through sugar reduction while maintaining sensory acceptability by incorporating quinoa flour (*Chenopodium quinoa* Willd.), an Andean pseudocereal with high nutritional value. This proposal not only addresses public health needs in countries like Peru, where dual malnutrition is a growing concern, but also incorporates a regional, culturally accepted, and sustainable ingredient.

In Peru, childhood obesity has become increasingly prevalent, with the National Institute of Statistics and Informatics (INEI) reporting that 9.1% of the population under 5 years of age is overweight or obese (INEI 2023). At the same time, undernutrition remains a significant issue, as evidenced by the fact that 43.1% of children are affected by anemia (INEI 2024). Both overnutrition and undernutrition highlight the urgent need for tailored regional strategies to address these health concerns, particularly in areas such as southern Peru, where socioeconomic and dietary patterns exacerbate these challenges (Eduardo et al. 2025; INEI 2024; Phelps et al. 2024). Both issues require collaboration among academia, industry, and policymakers to develop effective and sustainable solutions, especially considering the impact of widely consumed, nutritionally unbalanced foods (Eduardo, Aredo, et al. 2024).

Sweet biscuits are widely consumed globally, including in Peru, and their reformulation offers a practical way to improve nutritional quality. Frequently criticized for their high sugar and saturated fat content, as well as poor protein and vitamin levels, strategies such as reducing added sugar (Kawakami et al. 2025) and enriching them with nutrient-rich ingredients like Andean cereals (e.g., quinoa, amaranth, and cañihua) are impactful approaches to improving the nutritional quality of biscuits (Luque-Vilca et al. 2024; Valenzuela-González et al. 2022). While sugar reduction contributes to lower calorie intake and a reduced risk of diet-related diseases (Khan et al. 2019; Warshaw and Edelman 2021; WHO 2016), it poses challenges for texture, stability, and sensory acceptance (Deliza et al. 2021; Kawakami et al. 2025; Velázquez et al. 2021). The inclusion of Andean cereals enhances the protein, fiber, and micronutrient content (Martínez-Villaluenga et al. 2020), aligning with regional dietary traditions and addressing health concerns simultaneously, making these products both healthier and culturally relevant (Eduardo, Bedoya-Perales, et al. 2024).

Despite efforts to commercialize food products with reduced added sugar or those enriched with Andean cereals, these formulations have not been effectively incorporated into the daily diets of children and young people in urban areas (Biguzzi et al. 2015; Sandvik et al. 2021) due to the lack of products specifically designed for this age group, unappealing packaging, and unpleasant sensory properties (de Scudine et al. 2024; Faralla et al. 2023). Understanding how reformulation affects sensory quality, such as taste and texture, is essential for developing nutritious and acceptable products targeted at children (Laureati and Pagliarini 2018). However, sensory evaluation with children is challenging because their cognitive skills and sensitivity are lower than those of adults (Guinard, 2000). In this sense, sensory sessions with children should be shorter than those with adults, with the aim of not diminishing their attention spans (Issanchou 2015). For this reason, the number of samples that children evaluate should be small. However, in studies of product reformulation toward a healthier profile, it is common to assess different levels of incorporation or reduction of components that have positive or negative effects on health. A wide range of treatments allows for more comprehensive information about the sensory acceptance of a product. However, this was not possible in the present study due to the need to limit the number of treatments, given that the evaluation was carried out by children. This population has particular characteristics, including shorter attention spans, difficulties with understanding the tests, and a greater susceptibility to sensory fatigue. To overcome this issue, evaluating products in stages can lead to better decisions regarding which products should be sensorially evaluated by children. Thus, in a first stage, young adults should assess products to select the best prototypes for children. This approach has been little explored in sensory and consumer studies involving children, which could yield higher acceptance rates for products with healthier characteristics. In this context, the present study aimed to sensorially evaluate biscuits with reduced sugar levels and quinoa incorporation in two stages. The first stage included young adults whose biscuit consumption patterns are similar to those of children, and the second stage involved school-aged children.

2 | Materials and Methods

This study received ethical approval from the Scientific Research Ethics Committee of the Universidad Nacional de Moquegua (UNAM) under letter N°. 001–2024-PCEIC/UNAM. All participants, whether young adults or parents of school-aged children, signed an informed consent form indicating their voluntary participation in the study. They were provided with basic information about the study, without disclosing details that could influence their responses to the reformulation process. Participants were asked about their sociodemographic profiles, including age, sex, and frequency of sweet biscuit consumption, with a written commitment not to reveal their identities for any

17454598, 2025, 4, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joss.70062 by University Of Sao Paulo - Brazil, Wiley Online Library on [19/02/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

reason. After completing the sensory procedures, participants received a small gift as a token of appreciation.

2.1 | Biscuit Preparation and Technological Characterization

The quinoa flour used in the biscuit formulations contained 4.23% fat, 5.74% moisture, 2.45% ash, and 11.97% protein, with a water activity of 0.49. It exhibited 2.382 mg GAE/g polyphenols and strong antioxidant capacities (DPPH: 105.32 mg/mL; ORAC: 31.98 μmol ET/g), presenting its nutritional and functional potential for biscuit formulation. The biscuit-making process adhered to the AACC (2000) guidelines with modifications. The ingredients used in the preparation were white durum wheat flour (from 28.3% to 40.4%), quinoa flour (from 0% to 12.12%, replacing up to 30% wheat flour), baking powder (0.5%), salt (0.4%), powdered milk (6.1%), vegetable shortening (19.4%), sugar (from 13.6% to 19.4%), and water (13.8%). The dough was kneaded and rolled to a thickness of 0.5 cm, then cut into 5 cm diameter circles. Finally, the biscuits were baked and cooled for further analysis. Seven formulations were developed with varying sugar reductions (10%, 20%, and 30%) and partial substitution of wheat flour with quinoa flour (15% and 30%), including a control, as described by Alvarez et al. (2025).

2.2 | Hedonic and Sensory Characterization by Young Consumers

2.2.1 | Young Participants

A convenience sample of 115 young consumers aged 18–25 participated in the study (mean age: 21.5 years). The group consisted of men (51.79%) and women (48.21%), all of whom voluntarily participated after signing an informed consent form. Participants were recruited from the surroundings of UNAM, including students and administrative staff. The inclusion criteria required that participants be regular consumers of sweet biscuits, not have celiac disease or eating disorders, and be interested and available to participate in the study. Figure 1 presents the sociodemographic profile of the young participants, detailing the distribution by gender and age. The number of participants involved in the study was statistically valid for hedonic tests without a segmentation purpose (Hough et al. 2006; Issanchou 2015) and for CATA tests with stable sample and descriptor configurations (Ares et al. 2014).

2.2.2 | Procedure

Before starting the formal test, participants were instructed to complete the Check-All-That-Apply (CATA) questionnaire and the 9-point hedonic scale. Each participant was then seated in an individual sensory evaluation booth, receiving samples sequentially in a monadic manner following a Williams Latin (Macfie et al. 1989) square design, collected on tablets using the *Compusense Cloud* software. First, participants rated their acceptance of the biscuits using a 9-point hedonic scale, ranging from "dislike extremely" to "like extremely" (Peryam and Pilgrim 1957). Then, they performed the CATA task, checking the attributes (dark, greasy, buttery, sweet, salty, honey, crunchy, hard, and brittle) selected based on our previous study (Alvarez et al., 2025). Attributes were also presented monadically in balanced form. To cleanse consumers' palates between samples, they took a sip of water. The sensory procedure was conducted in a single session.

2.3 | Hedonic and Sensory Characterization by School-Aged Children

2.3.1 | Children Participants

The sensory evaluation was conducted with 113 children, comprising 61.95% boys and 38.05% girls, aged between 6 and 13 years (mean age 9.5 years). Participants were conveniently recruited from

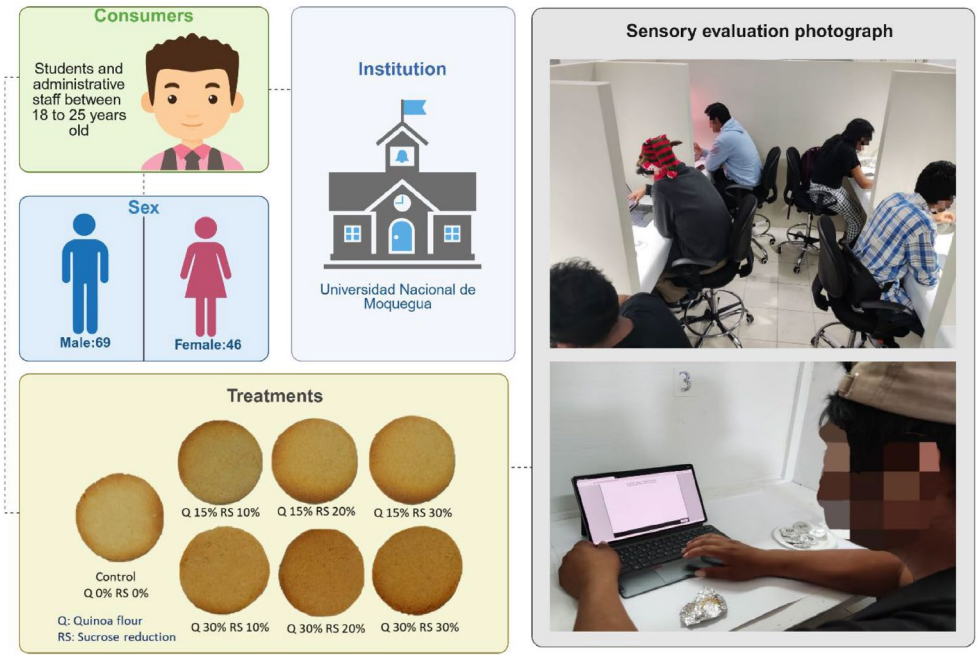


FIGURE 1 | Sociodemographic profile and sensory procedure of young adults.

17454549x, 2025, 4, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joss.70062 by University Of Sao Paulo - Brazil, Wiley Online Library on [19/02/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

the elementary public school in Moquegua, Peru. The inclusion criterion was that participants consumed sweet biscuits at least once a week and did not have any dietary restrictions. Figure 2 shows the sociodemographic profile of the participating children, detailing the distribution by gender and age. The sensory evaluation was conducted in the classroom, set up to simulate sensory laboratory conditions, and data collection was facilitated using a printed ballot. The number of participants in the test ($n = 113$) exceeded the minimum recommended sample size for children in sensory tests ($n = 39$), as established by Novello et al. (2021). Furthermore, similar to the young population, the number of children exceeded the recommended range (60–80 participants) for the CATA task (Ares et al. 2014). Therefore, the results are methodologically valid.

2.3.2 | Procedure

To minimize distractions and maintain the children's concentration during the sensory evaluation of the cookies, we selected only those treatments that performed best in a previous evaluation conducted with young adults. This methodological strategy is in line with the recommendations established in studies on sensory evaluation with children, which highlight the importance of reducing the number of samples to avoid fatigue, loss of attention, and decreased reliability of responses (Guinard and Brun 1998; Issanchou 2015), previously exposed in the introduction section of this paper.

Before conducting the formal test, a brief explanation of the procedure was provided to familiarize the children with the CATA questionnaire and the emoji-based hedonic scale (Schouteten et al. 2018). Following this, the formal test began, during which the children were given printed sensory evaluation ballots and biscuit samples coded with random three-digit numbers. The biscuit samples were presented sequentially in a monadic manner, following a Williams Latin (Macfie et al. 1989) square design to eliminate first-order and carry-over effects. The children tasted each sample and rated their acceptance using an emoji-based hedonic scale with the following anchors: 😖 (dislike extremely), 😐 (neither like nor dislike), 🤩 (like extremely). Subsequently, they selected the appropriate attributes to describe the biscuit samples sensorially.

To ensure direct comparability between age groups, a single list of sensory attributes was used for both children and young adults. This approach prevents variability due to differing terminology and enables the construction of directly comparable sensory maps. The attributes were initially selected from specialized literature and previous studies, prioritizing terms that were relevant, understandable, and easily recognizable by both groups (Jaeger et al. 2013; Lazo et al. 2016).

To confirm the list's suitability for children, a rigorous, multistage validation process was conducted. First, their ability to associate attributes with familiar food examples was verified (e.g., "sweet" with sugar). Subsequently, to ensure comprehension beyond simple associations, children were asked to explain each term in their own words, identify examples from visual and taste stimuli, and apply them in simulated sensory tasks. This entire procedure confirmed that children understood both the semantic meaning and the contextual use of each attribute for a sensory characterization task (Galler et al. 2020; Laureati et al. 2017).

2.4 | Data Analysis

The results of the CATA questionnaire were analyzed using Cochran's Q test, a nonparametric univariate method to identify significant differences in the frequency of a given attribute across biscuit samples. Multiple pairwise comparisons were performed using the McNemar/Bonferroni test. Subsequently, correspondence analysis (CA) was conducted to evaluate the multivariate associations between biscuit samples and their sensory characteristics, using Chi-square (X^2) distances. On the other hand, acceptance data were treated using analysis of variance (ANOVA), considering the consumers and the order of sample presentation as random factors and the biscuit formulation as a fixed factor. Tukey's test was then applied for pairwise comparison of means. Finally, the penalty-lift analysis evaluated the significant mean

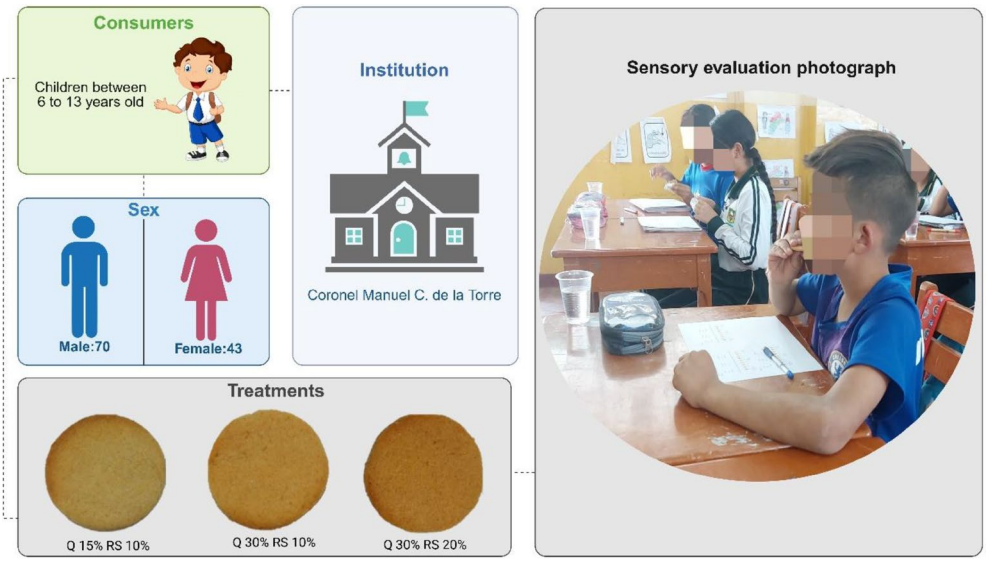


FIGURE 2 | Sociodemographic profile and sensory procedure of school-aged children.

17454598, 2025, 4, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joss.70062 by University Of Sao Paulo - Brazil, Wiley Online Library on [19/02/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

differences in liking scores (Student's *t*-test) based on the presence or absence of specific sensory attributes in the CATA questionnaire. Positive values indicated attributes that increased liking, while negative values reflected those that decreased acceptance. A significance level of 5% was used for all analyses. All data analyses were conducted using the XLSTAT software.

3 | Results and Discussion

3.1 | Hedonic and Sensory Characterization by Young Consumers

In Figure 3, the acceptance of biscuits among young consumers is displayed. All samples received an acceptance score above 6, corresponding to "like slightly," indicating a moderate level of acceptance. Similar observations were reported by Nadian et al. (2021) on the sensory acceptance of low-sugar cookies containing quinoa flour as a substitute for wheat flour, suggesting that it is feasible to improve the nutritional profile of biscuits. However, while the samples were statistically similar, biscuits with a greater reduction in sugar (T15Q.30S) and including quinoa (T30Q.30S) tended to receive slightly lower scores. This trend is expected due to the innate human preference for sweet tastes (Deliza et al. 2021) and the presence of bitter compounds, such as saponins, that reduce the acceptance of cookies with high quinoa content (Suárez-Estrella et al., 2018). However, the textural properties of products containing quinoa are also crucial in sensory acceptance (Eduardo, Bedoya-Perales, et al. 2024). In this context, examining the complete sensory profile of cookie samples is crucial for a better understanding of hedonic responses.

The sensory profile of the biscuits was evaluated using a predefined list of sensory attributes, as defined by experts in our previous study (Alvarez et al., 2025). The attributes were related to the appearance, flavor, and texture of the biscuits. Table 1 presents the proportions of citations for sensory attributes across different biscuit treatments formulated with varying percentages of quinoa flour and sugar reduction. The sensory attributes that exhibited statistically significant differences across the biscuit treatments were related to flavor and texture. As expected, sweetness decreased proportionally with sugar reduction, but texture attributes, including greasy, brittle, crunchy, and hard, exhibited significant variations across treatments. Generally, the changes are observed to be due to the combined effect of sugar reduction and the incorporation of quinoa flour. Under this premise, greasy and brittle tended to increase, hard tended to decrease, and crunchy was lowest at the maximum sugar reduction and quinoa incorporation (T30Q.30S).

The sensory profile from the multivariate perspective presents complementary results to the elicitation proportions. The CA in Figure 4 shows that for the first dimension (81.20% of data variability), the control biscuit was associated with the hard attribute, being different from the reformulated treatments, confirming the observation in Table 1. The second dimension, despite having little representation in the data variability (8.85%), shows that the reformulated biscuits are differentiated mainly by the sugar reduction. Thus, in the upper vertical part, the treatments with the greatest sugar reduction were associated with salty, brittle, dark, and buttery flavors, while in the lower part, the treatments with the least sugar reduction were associated with crunchy, honey, and sweet flavors.

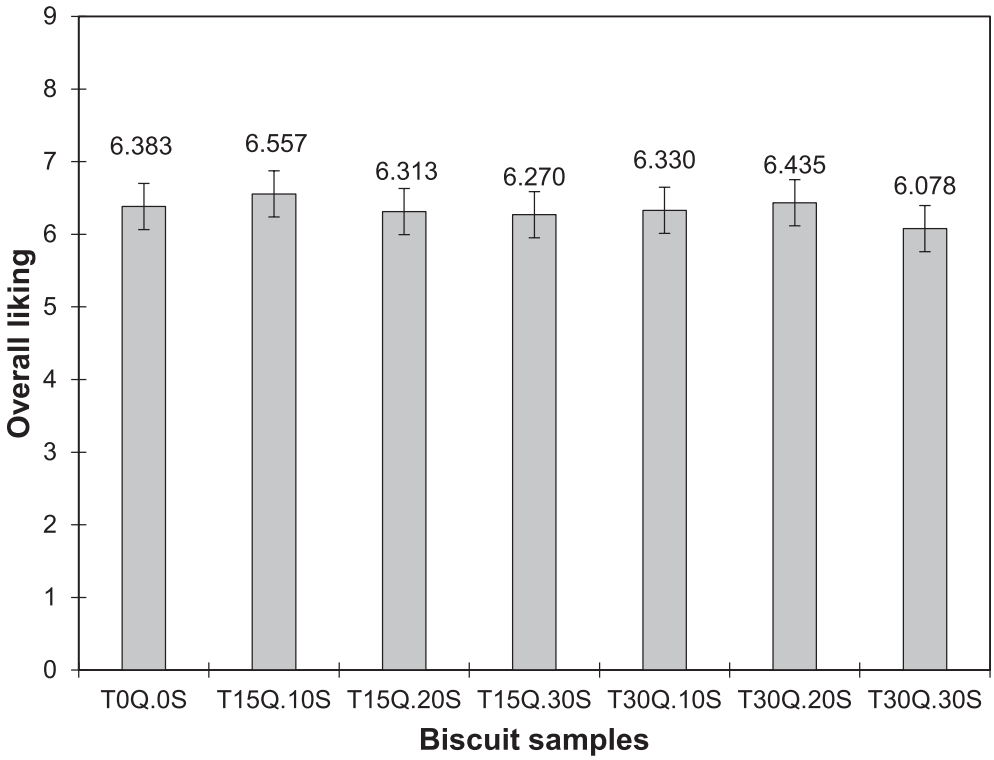


FIGURE 3 | Overall liking of biscuits evaluated by young adults. Treatments: T0Q.0S (0% quinoa flour, 0% sugar reduction), T15Q.10S (15% quinoa flour, 10% sugar reduction), T15Q.20S (15% quinoa flour, 20% sugar reduction), T15Q.30 S (15% quinoa flour, 30% sugar reduction), T30Q.10S (30% quinoa flour, 10% sugar reduction), T30Q.20S (30% quinoa flour, 20% sugar reduction), and T30Q.30S (30% quinoa flour, 30% sugar reduction).

1745459x, 2025, 4, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joss.70062 by University Of Sao Paulo - Brazil, Wiley Online Library on [19/02/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

These findings are consistent with the sensory effects of sugar and quinoa flour in other studies. Thus, sugar crystallizes in biscuits, resulting in a crispier surface (Luo et al., 2019), while quinoa flour, as a substitute for wheat flour in moderate amounts, decreased the hardness of biscuits (Wang et al., 2015). Therefore, a less crunchy and less hard texture is expected with greater sugar reductions and the incorporation of quinoa flour. Other contributions of quinoa flour may be related to its mineral and fat content, which, together with the reduction in sugar, may have contributed, respectively, to the perception of saltiness and a greasy or buttery texture. In terms of appearance, the perception of a darker color in baked goods containing quinoa flour may be associated with their high protein content, particularly the amino acid lysine, which is notably abundant in quinoa. Lysine plays a key role in initiating the Maillard

TABLE 1 | Proportions of elicitation for sensory attributes of biscuits evaluated by young adults.

Attributes	T0Q.0S	T15Q.10S	T15Q.20S	T15Q.30S	T30Q.10S	T30Q.20S	T30Q.30S
Dark	0.157 (a)	0.200 (a)	0.174 (a)	0.235 (a)	0.200 (a)	0.183 (a)	0.209 (a)
Salty	0.087 (a)	0.104 (a)	0.157 (a)	0.191 (a)	0.165 (a)	0.157 (a)	0.183 (a)
Honey	0.322 (a)	0.261 (a)	0.278 (a)	0.209 (a)	0.330 (a)	0.313 (a)	0.270 (a)
Greasy	0.130 (a)	0.226 (a)	0.278 (b)	0.226 (ab)	0.287 (b)	0.270 (b)	0.270 (ab)
Buttery	0.487 (a)	0.461 (a)	0.478 (a)	0.513 (a)	0.435 (a)	0.548 (a)	0.530 (a)
Brittle	0.235 (a)	0.470 (b)	0.426 (ab)	0.409 (ab)	0.478 (b)	0.417 (ab)	0.591 (b)
Sweet	0.783 (c)	0.739 (bc)	0.635 (abc)	0.565 (ab)	0.696 (bc)	0.661 (abc)	0.522 (a)
Crunchy	0.617 (ab)	0.704 (b)	0.626 (ab)	0.678 (ab)	0.626 (ab)	0.687 (ab)	0.513 (a)
Hard	0.730 (c)	0.261 (ab)	0.304 (b)	0.313 (b)	0.191 (ab)	0.139 (a)	0.174 (ab)

Note: Attributes in bold indicate a statistically significant difference between samples according to Cochran's Q test at 5% significance. Different letters indicate pairwise comparisons according to the McNemar/Bonferroni test at 5% significance. Treatments: T0Q.0S (0% quinoa flour, 0% sugar reduction), T15Q.10S (15% quinoa flour, 10% sugar reduction), T15Q.20S (15% quinoa flour, 20% sugar reduction), T15Q.30S (15% quinoa flour, 30% sugar reduction), T30Q.10S (30% quinoa flour, 10% sugar reduction), T30Q.20S (30% quinoa flour, 20% sugar reduction), and T30Q.30S (30% quinoa flour, 30% sugar reduction).

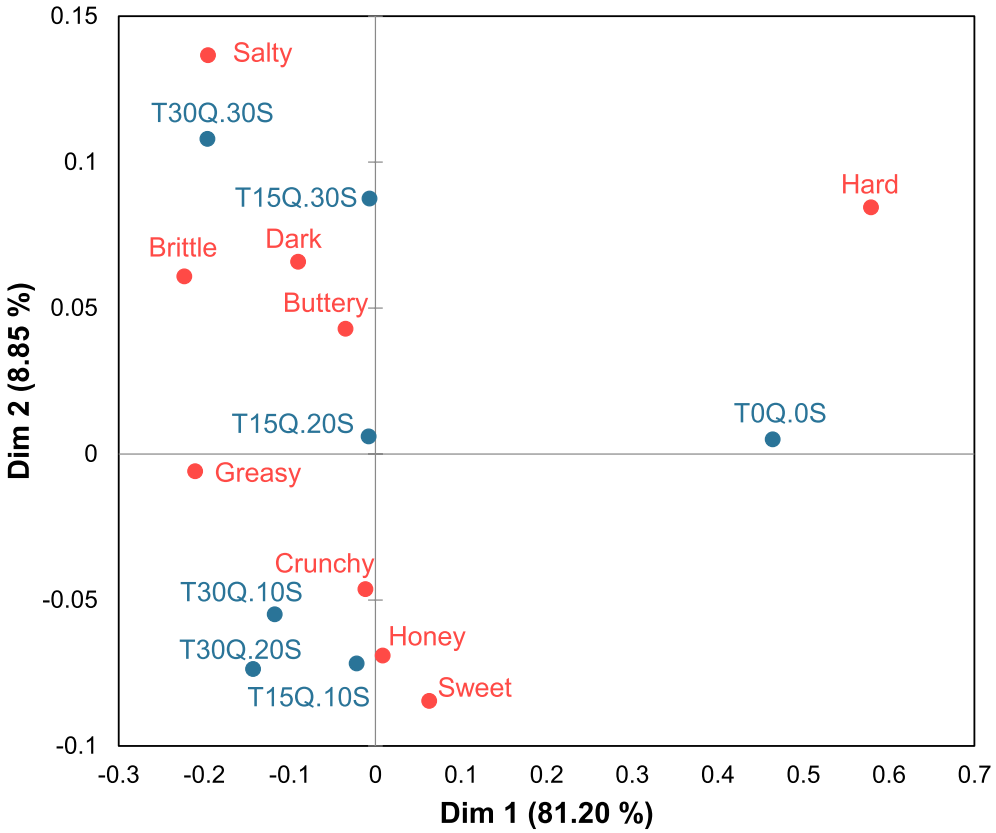


FIGURE 4 | Correspondence analysis of biscuits and their sensory attributes evaluated by young adults. Treatments: T0Q.0S (0% quinoa flour, 0% sugar reduction), T15Q.10S (15% quinoa flour, 10% sugar reduction), T15Q.20S (15% quinoa flour, 20% sugar reduction), T15Q.30 S (15% quinoa flour, 30% sugar reduction), T30Q.10S (30% quinoa flour, 10% sugar reduction), T30Q.20S (30% quinoa flour, 20% sugar reduction), and T30Q.30S (30% quinoa flour, 30% sugar reduction).

17454598, 2025, 4, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joss.70062 by University Of Sao Paulo - Brazil, Wiley Online Library on [19/02/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

reaction, a nonenzymatic browning process that occurs during baking and is responsible for the development of the characteristic brown tones and flavor profiles in baked goods (Nitasha Wasi et al., 2024). In addition, quinoa contains phenolic compounds, such as flavonoids and phenolic acids, which, upon oxidation, can also contribute to the formation of dark pigments, thereby intensifying the overall coloration (Brito et al. 2015). The visual scale of color can also influence the sensory perception of the product, particularly in evaluations conducted with children, as several studies have demonstrated that the visual elements present in products can affect their sensory perception (Dixon et al., 2024; Mediano Stoltze et al., 2023).

The impact of sensory attributes on sensory acceptance, as determined by young adults, was analyzed using penalty-lift analysis. As shown in Figure 5, attributes with blue bars toward the right indicate a positive effect on acceptance, with crunchy and sweet having the greatest impact. Conversely, a higher incidence of hard and greasy attributes is negative for acceptance (red bars). The negative impact of hard aligns with Rodríguez-García et al. (2013), who reported that overly dense or rigid textures are less desirable in biscuits.

The results of young consumers demonstrate that a moderate reformulation of the biscuits was necessary to promote positive sensory attributes and reduce negative ones, which aligns with previous research indicating that consumers value a balanced sweetness profile and an appealing texture in reduced-sugar baked products (Kawakami et al. 2025). In this sense, taking into account the positive drivers of liking and their location in the multivariate sensory profile, the most notable treatments were T15Q.10S, T30Q.10S, and T30Q.20S, whose main shared characteristic is the intermediate reduction of sugar, which was associated with the attributes crunchy, honey, and sweet (Figure 4), and did not present univariate statistical differences with the control treatment (Table 1) for those attributes. Therefore, those treatments were selected for sensory analysis with school-aged children.

3.2 | Hedonic and Sensory Characterization by School-Aged Children

It has been recommended that sensory evaluation with children should be carried out in a shorter time than with adults, to optimize children's attention span during the evaluation (Issanchou 2015). In this regard, the proposal of a prior evaluation stage with young adults resulted in the selection of three biscuit treatments with quinoa flour and moderate sugar reduction, based on acceptance scores, univariate and multivariate sensory profiles, and the sensory attributes that drive liking.

Figure 6 shows the acceptance scores for treatments T15Q.10S, T30Q.10S, and T30Q.20S, which reached values above 7 points and can be interpreted as “like moderately.” Also, there were no significant differences between treatments. Interestingly, the acceptance scores were higher than those of young adults; these results suggest that the implementation of a two-stage evaluation strategy contributed to greater sensory acceptance of the cookies by school-aged children. Furthermore, it has been reported

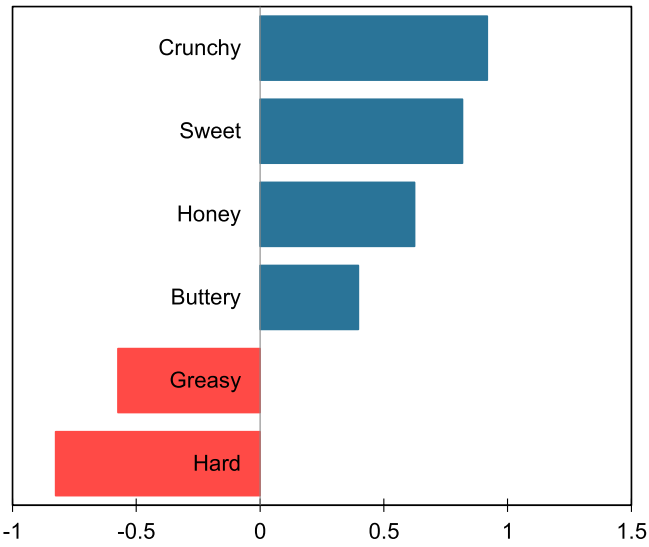


FIGURE 5 | Penalty-lift analysis of positive (blue bars) and negative (red bars) drivers of liking in biscuits evaluated by young adults.

that children have a high preference for sweet tastes (Mennella et al. 2012; Mennella et al. 2014), but despite these antecedents, the moderate sugar reduction did not significantly decrease the liking of the reformulated biscuits. Quinoa flour may have contributed to improving the liking of the biscuits, which is in line with Eduardo, Bedoya-Perales, et al. (2024), who, through a bibliometric review, reported that 67% of publications on the application of quinoa in bakery products suggest that sensory acceptance is similar to the control products, as long as the proportions of quinoa are between 5% and 30% of the formulation. However, this finding aligns with evaluations of adults, whereas sensory evaluations of bakery products containing quinoa among children are scarce. In this sense, it is necessary to understand children's sensory responses through the sensory profile of the biscuits, which was addressed using the same methodology as that employed with young adults in this study.

According to the univariate sensory profile in Table 2, significant differences were observed among treatments only for the attributes of dark, salty, and greasy. An increase in quinoa flour (T30Q.10S) emphasized the presence of dark and salty flavors, but these attributes decreased with greater sugar reduction (T30Q.20S). Conversely, the highest citation proportion for greasy was recorded with the lowest sugar reduction and addition of quinoa flour (T15Q.10S).

The multivariate sensory profile showed greater discrimination between treatments (CA in Figure 7, which explains 100% of the data variability). Thus, similar to the univariate analysis, the attributes dark and salty were associated with the highest quinoa content and lowest sugar reduction (T30Q.10S); conversely, the highest incorporation of quinoa and intermediate sugar reduction (T30Q.20S) were associated with the attribute brittle. On the other hand, lower sugar reduction and lower incorporation of quinoa flour (T15Q.10S) were associated with fatty and buttery attributes. The attributes honey, sweet, hard, and crunchy tended to occupy an intermediate position in the CA, consistent with the citation proportions in Table 2, where there were no significant differences for these attributes.

1745459x, 2025, 4, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joss.70062 by University Of Sao Paulo - Brazil, Wiley Online Library on [19/02/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

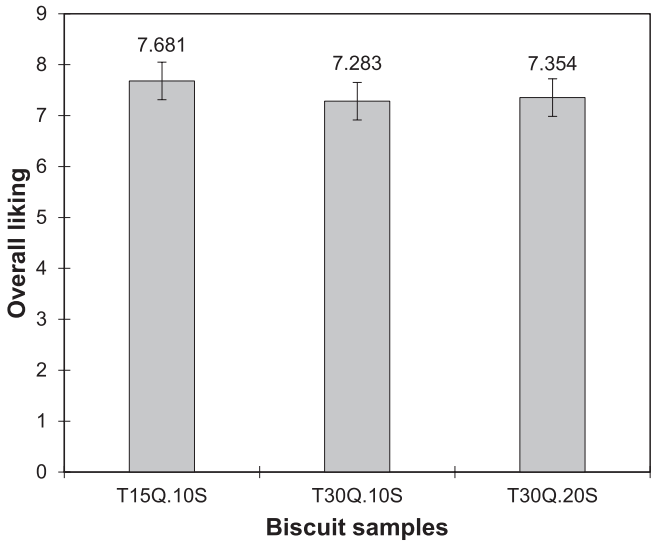


FIGURE 6 | Overall liking of biscuits evaluated by school-aged children. Treatments: T15Q.10S (15% quinoa flour, 10% sugar reduction), T30Q.10S (30% quinoa flour, 10% sugar reduction), and T30Q.20S (30% quinoa flour, 20% sugar reduction).

Compared to the evaluation by young adults, the results are consistent for the attributes "brittle," "dark," and "salty," which were perceived in both stages when biscuits contained a higher quinoa flour content and reduced sugar. Interestingly; however, this association did not extend to the greasy and buttery attributes. These characteristics showed no consistent trend in relation to either the incorporation of quinoa flour or the reduction of sugar content. Hence, in the evaluation involving young adults, the attribute greasy tended to increase in univariate frequency for biscuits with greater sugar reduction and quinoa flour, while occupying an intermediate position in the CA; conversely, the attribute buttery did not show univariate differences but was linked to greater sugar reduction in the multivariate analysis (see Table 1 and Figure 4).

TABLE 2 | Proportions of elicitation for sensory attributes of biscuits evaluated by school-aged children.

Attributes	T15.Q10S	T30.Q10S	T30.Q20S
Dark	0.159 (ab)	0.248 (b)	0.106 (a)
Salty	0.283 (ab)	0.416 (b)	0.212 (a)
Honey	0.425 (a)	0.398 (a)	0.354 (a)
Greasy	0.336 (b)	0.230 (ab)	0.177 (a)
Buttery	0.425 (a)	0.372 (a)	0.319 (a)
Brittle	0.292 (a)	0.212 (a)	0.292 (a)
Sweet	0.699 (a)	0.611 (a)	0.673 (a)
Crunchy	0.735 (a)	0.673 (a)	0.743 (a)
Hard	0.522 (a)	0.451 (a)	0.504 (a)

Note: Attributes in bold indicate a statistically significant difference between samples according to Cochran's Q test at 5% significance. Different letters indicate pairwise comparisons according to the McNemar/Bonferroni test at 5% significance. Treatments: T15Q.10S (15% quinoa flour, 10% sugar reduction), T30Q.10S (30% quinoa flour, 10% sugar reduction), and T30Q.20S (30% quinoa flour, 20% sugar reduction).

Similarly, in our previous study, it was noted that greasy was associated with biscuits containing a higher amount of quinoa flour (30%), whereas buttery was linked to biscuits with a lower incorporation of quinoa flour (15%) and moderate reductions in sugar (10% and 20%) (Alvarez et al., 2025), with the latter being more consistent with the evaluation involving children in this study. In light of this, complementary studies are necessary with trained assessors or experts to analyze the intensity of each sensory attribute and measure its impact on sensory quality.

Differences in the perception of greasy and buttery attributes between children and young adults may be due to variations in sensory sensitivity, differences in cognitive interpretation of the terms used, or specific emotional or cultural associations with certain flavors or textures (Jeong & Lee, 2021). Example: Adults might interpret "buttery" as a desirable quality related to smoothness, while children might associate "greasy" with a less positive or more intense sensation. These types of differences suggest the importance of considering consumer profiles when interpreting sensory data (Worch et al., 2010).

The drivers of liking are shown in Figure 8. Unlike the assessment with young adults, no negative drivers of liking were identified, which reinforces the assessment strategy used with young adults to select the best treatments to increase the likelihood of liking in children. The attribute with the greatest impact on overall liking was sweet. However, the positive drivers of liking were generally similar to those of young adults, except for the attribute brittle. Previous sensory studies indicate that texture and sweetness are primary drivers of liking in children, often influencing their food choices more than other attributes such as aroma or color (Álvarez, 2025; da Quinta et al. 2023).

The attributes sweet, crunchy, and honey did not present significant univariate differences (Table 2) and tended to occupy a central position in the sensory map (Figure 7), that is, they were

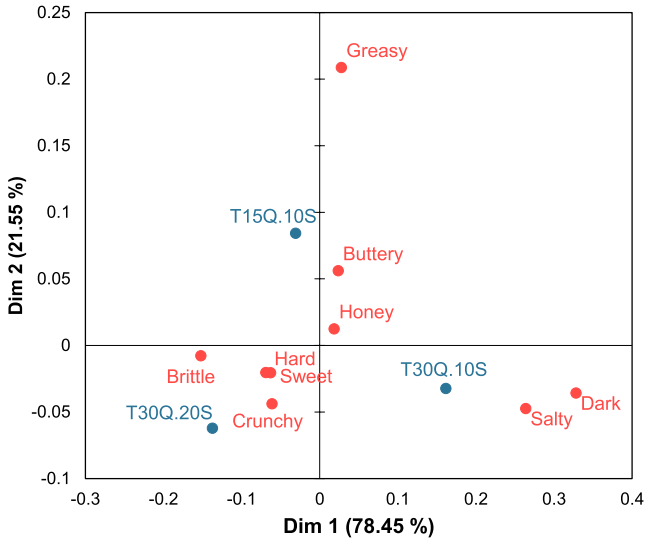


FIGURE 7 | Correspondence analysis of biscuits and their sensory attributes evaluated by school-aged children. Treatments: T15Q.10S (15% quinoa flour, 10% sugar reduction), T30Q.10S (30% quinoa flour, 10% sugar reduction), and T30Q.20S (30% quinoa flour, 20% sugar reduction).

17454598, 2025, 4, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joss.70062 by University Of Sao Paulo - Brazil, Wiley Online Library on [19/02/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

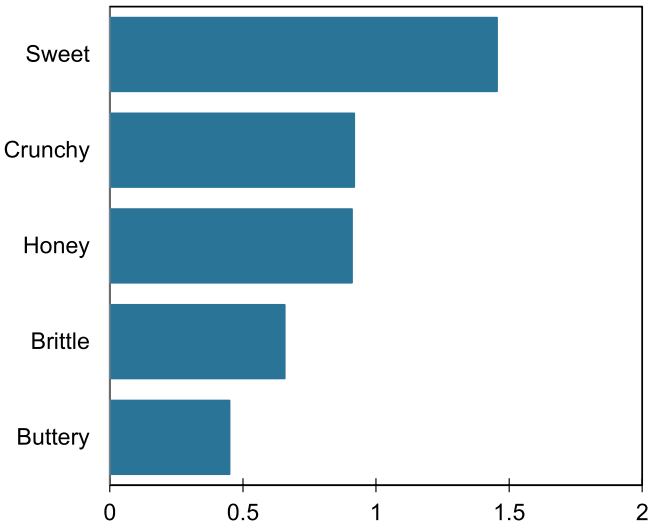


FIGURE 8 | Penalty-lift analysis of positive (blue bars) drivers of liking in biscuits evaluated by school-aged children.

characteristics shared among the three treatments evaluated, which explains the statistical similarity in the overall liking (Figure 6). These findings highlight the significance of sensory optimization in catering to the specific preferences of different consumer groups, particularly children. They tend to respond favorably to formulations that effectively balance sweetness and texture with the benefits of functional ingredients, reinforcing the need for a multidisciplinary approach in product innovation that integrates sensory science, nutritional improvements, and consumer-driven strategies (Venditti et al. 2020).

4 | Conclusion

This study proposes a sequential strategy to enhance the sensory quality of reduced-sugar quinoa biscuits for children, based on prior evaluation with young adults to select the best treatments. This selection resulted in three treatments, containing moderate quantities of quinoa flour (15% and 30%) and sugar reductions (10% and 20%), with balanced sensory properties in flavor and texture. Key attributes such as sweet, crunchy, honey, brittle, and buttery significantly increased product liking, while the negative attributes observed in the study with young adults were eliminated in the children's evaluation. This result, together with the high levels of acceptance in children (exceeding seven on the 9-point hedonic scale), even higher than the acceptance scores in adults, demonstrates the effectiveness of the proposed strategy. These findings contribute to addressing the dual burden of malnutrition by promoting nutritionally improved, culturally relevant, and sensorially appealing foods for children. Further studies are recommended to validate these findings across larger and more diverse populations, and a wider range of food products.

Acknowledgments

This study received funding from the Universidad Nacional de Moquegua through the "scientific research seedbed Andean Golden Seeds" (Resoluciones de Comisión Organizadora No. 865-2023-UNAM, and No. 778-2024-UNAM) and thesis grant offered by the same institution (Resolución de Comisión Organizadora No. 778-2024-UNAM).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

Alvarez, J., K. Eduardo, M. M. Coaguila Gonza, C. D. Leal de Araújo, C. J. Contreras-Castillo, and E. Saldaña. 2025. "Sugar Reduction and Replacement of Wheat Flour with Quinoa Flour in Shortcrust Cookies: Effects on Nutritional, Physical, and Sensory Properties." In *Food Production, Processing and Nutrition*. Springer Nature.

American Association of Cereal Chemists AACC. 2000. *Approved Methods of the American Association of Cereal Chemists*. 10th ed. American Association of Cereal Chemists.

Ares, G., A. Tárrega, L. Izquierdo, and S. R. Jaeger. 2014. "Investigation of the Number of Consumers Necessary to Obtain Stable Sample and Descriptor Configurations From Check-All-That-Apply (CATA) Questions." *Food Quality and Preference* 31: 135–141. https://doi.org/10.1016/j.foodqual.2013.08.012.

Biguzzi, C., C. Lange, and P. Schlich. 2015. "Effect of Sensory Exposure on Liking for Fat- or Sugar-Reduced Biscuits." *Appetite* 95: 317–323. https://doi.org/10.1016/j.appet.2015.07.001.

Brito, I. L., E. L. de Souza, S. S. S. Felex, M. S. Madruga, F. Yamashita, and M. Magnani. 2015. "Nutritional and Sensory Characteristics of Gluten-Free Quinoa (*Chenopodium quinoa* Willd)-Based Cookies Development Using an Experimental Mixture Design." *Journal of Food Science and Technology* 52, no. 9: 5866–5873. https://doi.org/10.1007/s13197-014-1659-1.

da Quinta, N., Y. Ríos, R. Llorente, A. B. Naranjo, and A. B. Baranda. 2023. "The Effect of Food Shape on Children's Implicit and Explicit Emotional Response." *Food Quality and Preference* 109: 104921. https://doi.org/10.1016/j.foodqual.2023.104921.

de Scudine, K. G. O., P. M. Castelo, J. P. M. Hoppe, A. K. Portella, and P. P. Silveira. 2024. "Early Influences on Development of Sensory Perception and Eating Habits." *Advances in Nutrition* 15, no. 12: 100325. https://doi.org/10.1016/j.advnut.2024.100325.

Deliza, R., M. F. Lima, and G. Ares. 2021. "Rethinking Sugar Reduction in Processed Foods." *Current Opinion in Food Science* 40: 58–66. https://doi.org/10.1016/J.COFS.2021.01.010.

Eduardo, K., J. C. Velásquez, J. Mayta-Hancco, J. D. Rios-Mera, M. Lozada-Urbano, and E. Saldaña. 2025. "Reasons Behind (Un)Healthy Eating Among School-Age Children in Southern Peru." *Food* 14, no. 3: 348. https://doi.org/10.3390/foods14030348.

Eduardo, K., N. Bedoya-Perales, E. Escobedo-Pacheco, and E. Saldaña. 2024. "Sensory and Consumer Science as a Valuable Tool to the Development of Quinoa-Based Food Products: More Than Three Decades of Scientific Evidence." *Scientia Agropecuaria* 15, no. 2: 251–267. https://doi.org/10.17268/sci.agropecu.2024.019.

Eduardo, K., V. Aredo, J. D. Rios-Mera, C. M. S. Ambrosio, R. Siche, and E. Saldaña. 2024. "Market Needs and Consumer's Preferences for Healthier Foods." In *Strategies to Improve the Quality of Foods*, edited by J. M. Lorenzo, 337–355. Academic Press. https://doi.org/10.1016/B978-0-443-15346-4.00013-6.

Faralla, V., L. Savadori, L. Mittone, M. Novarese, and A. Ardizzone. 2023. "Color and Abundance: Influencing Children's Food Choices." *Food Quality and Preference* 109: 104918. https://doi.org/10.1016/j.foodqual.2023.104918.

1745459x, 2025, 4, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joss.70062 by University Of Sao Paulo - Brazil, Wiley Online Library on [19/02/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Galler, M., T. Næs, V. L. Almli, and P. Varela. 2020. "How Children Approach a CATA Test Influences the Outcome. Insights on Ticking Styles From Two Case Studies With 6–9-Year Old Children." *Food Quality and Preference* 86: 104009. https://doi.org/10.1016/J.FOODQUAL.2020.104009.

Guinard, J. X., and P. Brun. 1998. "Sensory-Specific Satiety: Comparison of Taste and Texture Effects." *Appetite* 31, no. 2: 141–157. https://doi.org/10.1006/APPE.1998.0159.

Hough, G., I. Wakeling, A. Mucci, E. Chambers IV, I. M. Gallardo, and L. R. Alves. 2006. "Number of Consumers Necessary for Sensory Acceptability Tests." *Food Quality and Preference* 17, no. 6: 522–526. https://doi.org/10.1016/j.foodqual.2005.07.002.

INEI. 2023. "Desnutrición Crónica." https://m.inei.gob.pe/media/MenuRecursivo/noticias/nota-de-prensa-no-070-2023-inei.pdf.

INEI. 2024. *ANEMIA 2023 Nota de Prensa N 40–2024*. Instituto Nacional de Estadística e Informática (INEI).

Issanchou, S. 2015. "Sensory & consumer studies with special populations: children and elderly." *Current Opinion in Food Science* 3: 53–58. https://doi.org/10.1016/J.COFS.2015.02.004.

Jaeger, S. R., S. L. Chheang, J. Yin, et al. 2013. "Check-All-That-Apply (CATA) Responses Elicited by Consumers: Within-Assessor Reproducibility and Stability of Sensory Product Characterizations." *Food Quality and Preference* 30, no. 1: 56–67. https://doi.org/10.1016/J.FOODQUAL.2013.04.009.

Kawakami, C. A., M. M. Selani, E. Saldaña, N. de Jesus Pimentel-Filho, and M. A. F. Domingues. 2025. "Sensory Dynamic Profile and Consumer Acceptance of Short-Dough Biscuits With Reduced Sucrose and Thaumatin Addition." *Food Research International* 200: 115524. https://doi.org/10.1016/j.foodres.2024.115524.

Khan, T. A., M. Tayyiba, A. Agarwal, et al. 2019. "Relation of Total Sugars, Sucrose, Fructose, and Added Sugars With the Risk of Cardiovascular Disease: A Systematic Review and Dose-Response Meta-Analysis of Prospective Cohort Studies." *Mayo Clinic Proceedings* 94, no. 12: 2399–2414. https://doi.org/10.1016/j.mayocp.2019.05.034.

Laureati, M., and E. Pagliarini. 2018. "New Developments in Sensory and Consumer Research With Children." In *Methods in Consumer Research*, edited by G. Ares and P. Varela, vol. 2, 321–353. Woodhead Publishing. https://doi.org/10.1016/B978-0-08-101743-2.00013-3.

Laureati, M., C. Cattaneo, V. Lavelli, V. Bergamaschi, P. Riso, and E. Pagliarini. 2017. "Application of the Check-All-That-Apply Method (CATA) to Get Insights on Children's Drivers of Liking of Fiber-Enriched Apple Purees." *Journal of Sensory Studies* 32, no. 2: e12253. https://doi.org/10.1111/JOSS.12253.

Lazo, O., A. Claret, and L. Guerrero. 2016. "A Comparison of Two Methods for Generating Descriptive Attributes With Trained Assessors: Check-All-That-Apply (CATA) vs. Free Choice Profiling (FCP)." *Journal of Sensory Studies* 31, no. 2: 163–176. https://doi.org/10.1111/JOSS.12202.

Luque-Vilca, O. M., J. Y. Paredes-Erquinigo, L. Quille-Quille, et al. 2024. "Utilization of Sustainable Ingredients (Cañihua Flour, Whey, and Potato Starch) in Gluten-Free Cookie Development: Analysis of Technological and Sensorial Attributes." *Food* 13, no. 10: 1491. https://doi.org/10.3390/foods13101491.

Macfie, H. J., N. Bratchell, K. Greenhoff, and L. V. Vallis. 1989. "Designs to Balance the Effect of Order of Presentation and First-Order Carry-Over Effects in Hall Tests." *Journal of Sensory Studies* 4, no. 2: 129–148. https://doi.org/10.1111/j.1745-459X.1989.tb00463.x.

Martínez-Villaluenga, C., E. Peñas, and B. Hernández-Ledesma. 2020. "Pseudocereal Grains: Nutritional Value, Health Benefits and Current Applications for the Development of Gluten-Free Foods." *Food and Chemical Toxicology* 137: 111178. https://doi.org/10.1016/j.fct.2020.111178.

Mennella, J. A., S. Finkbeiner, and D. R. Reed. 2012. "The Proof is in the Pudding: Children Prefer Lower Fat but Higher Sugar Than Do Mothers." *International Journal of Obesity* 36, no. 10: 1285–1291. https://doi.org/10.1038/ijo.2012.51.

Mennella, J. A., S. Finkbeiner, S. V. Lipchock, L. D. Hwang, and D. R. Reed. 2014. "Preferences for Salty and Sweet Tastes Are Elevated and Related to Each Other During Childhood." *PLoS One* 9, no. 3: e92201. https://doi.org/10.1371/JOURNAL.PONE.0092201.

Novello, D., A. dos Anjos, J. M. Soares, et al. 2021. "Number of Children Needed to Evaluate Products Made in Cooking Workshops." *Food Quality and Preference* 94: 104301. https://doi.org/10.1016/j.foodqual.2021.104301.

Peryam, D. R., and F. J. Pilgrim. 1957. *Hedonic Scale Method of Measuring Food Preferences. Food Technology*. Vol. 11, 9–14. Institute of Food Technologists (IFT).

Phelps, N. H., R. K. Singleton, B. Zhou, et al. 2024. "Worldwide Trends in Underweight and Obesity From 1990 to 2022: A Pooled Analysis of 3663 Population-Representative Studies With 222 Million Children, Adolescents, and Adults." *Lancet* 403, no. 10431: 1027–1050. https://doi.org/10.1016/S0140-6736(23)02750-2.

Sandvik, P., M. Laureati, H. Jilani, et al. 2021. "Yuck, This Biscuit Looks Lumpy! Neophobic Levels and Cultural Differences Drive Children's Check-All-That-Apply (CATA) Descriptions and Preferences for High-Fibre Biscuits." *Food* 10, no. 1: 21. https://doi.org/10.3390/foods10010021.

Schouteten, J. J., J. Verwaeren, S. Lagast, X. Gellynck, and H. De Steur. 2018. "Emoji as a Tool for Measuring Children's Emotions When Tasting Food." *Food Quality and Preference* 68: 322–331. https://doi.org/10.1016/J.FOODQUAL.2018.03.005.

Swinburn, B. A., V. I. Kraak, S. Allender, et al. 2019. "The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission Report." *Lancet* 393, no. 10173: 791–846. https://doi.org/10.1016/S0140-6736(18)32822-8.

Valenzuela-González, M., O. Rouzaud-Sández, A. I. Ledesma-Osuna, et al. 2022. "Bioaccessibility of Phenolic Compounds, Antioxidant Activity, and Consumer Acceptability of Heat-Treated Quinoa Cookies." *Food Science and Technology* 42: e43421. https://doi.org/10.1590/fst.43421.

Velázquez, A. L., L. Vidal, P. Varela, and G. Ares. 2021. "Sugar Reduction in Products Targeted at Children: Why Are We Not There Yet?" *Journal of Sensory Studies* 36, no. 4: e12666. https://doi.org/10.1111/JOSS.12666.

Venditti, C., K. Musa-Veloso, H. Y. Lee, et al. 2020. "Determinants of Sweetness Preference: A Scoping Review of Human Studies." In *Nutrients*. Vol. 12. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/nu12030718.

Warshaw, H., and S. V. Edelman. 2021. "Practical Strategies to Help Reduce Added Sugars Consumption to Support Glycemic and Weight Management Goals." *Clinical Diabetes* 39, no. 1: 45–56. https://doi.org/10.2337/cd20-0034.

WHO. 2016. "WHO Urges Global Action to Curtail Consumption and Health Impacts of Sugary Drinks." https://www.who.int/news/item/11-10-2016-who-urges-global-action-to-curtail-consumption-and-health-impacts-of-sugary-drinks.

WHO. 2024a. "Malnutrition." https://www.who.int/news-room/fact-sheets/detail/malnutrition.

WHO. 2024b. "Obesity and Overweight." https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

1745459x, 2025, 4, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joss.70062 by University Of Sao Paulo - Brazil, Wiley Online Library on [19/02/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License