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Sprouted quinoa flour and fat reduction in shortcrust cookies: effects on nutritional composition, instrumental color and texture, antioxidant capacity, and temporal sensory profile

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ABSTRACT

Undernutrition and overweight coexist as public health burdens in many developing countries, motivating the reformulation of widely consumed snacks. The combined effects of sprouted quinoa flour (SQF) (0% and 20%) and fat reduction (0%, 10%, and 20%) were evaluated on the physicochemical, antioxidant, temporal sensory properties, and consumer acceptance of shortcrust cookies. SQF increased crude fiber, ash, moisture, a*, b*, chroma, and antioxidant capacity, and decreased nitrogen-free extract, hardness, fracturability, L*, and hue angle. Fat reduction increased nitrogen-free extract, hardness, fracturability, cooked weight, and total phenolic compounds, while reducing crude fat and total digestible nutrients. Temporal Dominance of Sensations (TDS) revealed that sweet and crunchy sensations dominated in conventional cookies, whereas hard, quinoa flavor, and bitter sensations became dominant in SQF cookies. Canonical Variates Analysis confirmed SQF as the dominant driver of differentiation (Can1 = 69.5%, Can2 = 22.5%), and Temporal Drivers of Liking (TDL) identified sweet and crunchy as positive drivers and bitter and hard as negative ones. Cookies without SQF received higher acceptance scores (range 6.65–7.10) than SQF cookies (5.34–5.66; $p < 0.05$), with no significant differences across fat reduction levels within each SQF condition. Up to 20% fat reduction can be implemented in conventional shortcrust cookies without compromising acceptance, while SQF substantially enhances the antioxidant profile.

1. Introduction

Undernutrition and overweight constitute concurrent public health challenges of the twenty-first century. More than 390 million children and adolescents aged 5–19 years were overweight or obese in 2022, including 160 million classified as obese (WHO, 2025b). Anemia affects approximately 40% of children under five years of age in low- and middle-income countries (WHO, 2025a). In Peru, moderate or severe food insecurity affects 41.0% of the population, the highest rate in South America (FAO et al., 2025). These trends justify reformulating widely consumed processed foods to enhance nutritional quality, increase bioactive compound content, and reduce dietary fat and sugar.

In the processed foods category, cookies are among the most commercially prevalent snacks worldwide, with an estimated global per capita consumption of 5.6 kg annually (Statista, 2025). Conventional cookies are typically characterized by high caloric density (>450 kcal/100 g), elevated saturated fat content (15–30%), and limited micronutrient value (Smith, 2011). In contrast, the World Health Organization recommends limiting total fat to less than 30% of energy intake and saturated fat to below 10% (WHO, 2025b). Shortening maintains desirable texture and mouthfeel, but it is often manufactured with hydrogenated fat and therefore contributes trans fats to cookies

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(Das & Das, 2024). Reducing shortening increases hardness, reduces spread, and decreases consumer acceptance (Das & Das, 2024; Devi & Khatkar, 2016). Moderate reductions of critical ingredients nevertheless remain sensorially acceptable, as reported for sugar reduction (Alvarez et al., 2025; Saldaña et al., 2025), which preserved high acceptance in children even when combined with quinoa flour (Saldaña et al., 2025).

Quinoa (*Chenopodium quinoa* Willd.) is an Andean pseudocereal recognized by FAO for its complete essential amino acid composition (notably rich in lysine, methionine, and threonine), dietary fiber, minerals (iron, calcium, magnesium), and bioactive compounds such as phenolic acids, flavonoids, and betaines (Pellegrini et al., 2018; Pereira et al., 2020). Partial replacement of wheat flour with quinoa flour in cookies improves antioxidant activity and amino acid profiles (Goyat et al., 2018; Jan et al., 2018; Watanabe et al., 2014). From the sensory perspective, Alvarez et al. (2025) recently showed that replacing up to 15% of wheat flour with quinoa flour and reducing sugar by 10% maintained consumer acceptance in shortcrust cookies.

Germination further enhances the nutritional potential of quinoa by activating endogenous enzymes that hydrolyze antinutritional factors and by promoting the *de novo* biosynthesis of phenolic compounds and γ-aminobutyric acid (GABA), which increases protein digestibility and enhances mineral bioavailability (Alvarez et al., 2026; Bhinder et al., 2021; Lan et al., 2024; Maldonado-Alvarado et al., 2023). The optimal germination period for maximizing nutritional quality and antioxidant activity in quinoa falls within the 36–72 h range (Lan et al., 2024; Ramos-Pacheco et al., 2024), and Altıkardeş & Güzel (2024) showed that ultrasound-assisted germination pre-treatments reduced phytic acid content by up to 83% and enhanced total phenolic content and antioxidant activity in quinoa.

However, sprouted quinoa flour and fat reduction have been studied in cookies only as independent strategies. Quinoa flour has been assessed mainly for its effect on antioxidant activity and amino acid composition (Goyat et al., 2018; Jan et al., 2018), whereas fat reduction has been examined for its impact on dough behavior and final texture (Das & Das, 2024; Devi & Khatkar, 2016). Their combined use has not been reported, and this gap matters because fat and flour act on the same structural matrix, so their effects on texture, color, and flavor are not necessarily additive. Because sweetness, hardness, and off-flavors change during chewing, a temporal sensory method was preferred over static descriptive profiling to identify the temporal drivers of liking (Castura et al., 2016).

In this context, the objective of this study was to evaluate the effects of incorporating sprouted quinoa flour (SQF) and reducing fat content on the physicochemical properties, antioxidant capacity, temporal sensory profiles, and consumer acceptance of shortcrust cookies. The Temporal Dominance of Sensations (TDS) method was applied because it captures the evolution of perceived sensations during oral processing and provides richer insights into consumer experience than static profiling methods (Castura et al., 2016; Nguyen et al., 2023). Linking these dynamic data to acceptance is critical to optimizing reformulated products while maintaining consumer satisfaction (Saldaña et al., 2024).

2. Materials and methods

2.1. Materials

Quinoa seeds (*Chenopodium quinoa* Willd., Blanca de Juli variety) were obtained from the Instituto Nacional de Innovación Agraria (INIA) in Puno, Peru. Hard wheat flour (Doña Vera, Peru), powdered milk (Gloria, Peru), vegetable shortening (Tropical, Peru), baking powder (Royal, Peru), white sugar (Cartavio, Peru), and iodized salt (Marina, Peru) were purchased from the central market in Moquegua, Peru. All chemicals used for analytical determinations were of analytical grade.

2.2. Preparation of sprouted quinoa flour

Quinoa seeds were desaponified using the wet method described by Maldonado-Alvarado et al. (2023). Briefly, seeds were manually selected to remove impurities and washed 4 times with distilled water (2:1 water-to-seed ratio) under gentle agitation until no foam formed. After desaponification, seeds were disinfected with 0.1% sodium hypochlorite (1:5 w/v ratio) for 30 min. For germination, seeds were soaked in distilled water (2:1 ratio) for 6 h (D'ambrosio et al., 2017), drained, spread uniformly on aluminum foil and filter paper trays, covered with another sheet of filter paper, and placed in a seed germinator (Biobase, model BJPX-HT400BII, China) at 24 °C and 85% relative humidity for 72 h (Pilco-Quesada et al., 2020). During this period, distilled water was applied four times daily using a spray atomizer to maintain moisture. The water-to-seed ratios, soaking time, and germination conditions followed protocols validated for quinoa desaponification and controlled germination (D'ambrosio et al., 2017; Maldonado-Alvarado et al., 2023; Pilco-Quesada et al., 2020), and were selected to ensure complete saponin removal, uniform imbibition, and a germination window that maximizes bioactive compound synthesis without excessive rootlet growth.

Sprouted quinoa was dried in the germinator at 40 °C and 20% humidity for 48 hours. Subsequently, the dried seeds (verified by brittle rootlets) were ground in a blender and sieved to obtain flour with a 250 μm particle size. The flour was stored in vacuum-sealed polyethylene bags in a dark environment until the formulation of the cookies (Suárez-Estrella et al., 2020).

Sprouted quinoa flour was characterized in its proximate composition (crude protein, crude fiber, crude fat, ash, and moisture) and antioxidants (total phenolic content, ORAC, DPPH) according to the methods described in sections 2.4 and 2.7 and compared with unsprouted quinoa flour. As shown in Fig. 1, germination increased protein, fiber, phenolic compounds, and antioxidant capacity, highlighting it as a promising process for improving the nutritional quality of cookies (Alvarez et al., 2026).

2.3. Experimental design and cookie preparation

A randomized complete block design (RCBD) with a 2 × 3 factorial arrangement was employed, with factors being SQF incorporation (0% and 20% of wheat flour substitution) and fat reduction (0%, 10%, and 20% of vegetable shortening). The 0% and 20% SQF levels were selected based on the systematic review by Alvarez et al. (2026), which found that substituting wheat flour with quinoa flour at 0% to 25% generally preserves consumer acceptance. Thus, 20% represents the upper bound of that acceptance-preserving range and the level expected to maximize the antioxidant contribution while remaining sensorially viable. Each block represented an independent processing batch, where three blocks were performed. The six treatments were designated as Q0FR0 (control), Q0FR10, Q0FR20, Q20FR0, Q20FR10, and Q20FR20 (Q = quinoa, FR = Fat reduction, Table 1). Cookie formulations were based on the AACC method 10-50D (AACC, 2000) with modifications, following procedures previously reported for shortcrust cookies (Saldaña et al., 2025; Smith, 2011). Distilled water was adjusted to compensate for reduced fat content. Sugar and vegetable shortening were first mixed in a KitchenAid mixer (model 5KSM 70JP EER, USA) until emulsified, then the flours and remaining dry ingredients were gradually incorporated. The dough was kneaded, passed through a laminator (Gastromag, model CLI-300, Brazil) to a thickness of 0.5 cm, and cut into 5 cm-diameter circles. Cookies were baked in a preheated oven (Nova, model Maxito 6B, Peru) at 150 °C for 15 min, cooled to room temperature, covered in aluminum foil, and stored in hermetic bags until analysis.

2.4. Nutritional characterization and physicochemical composition

The proximate composition of SQF and cookies was determined

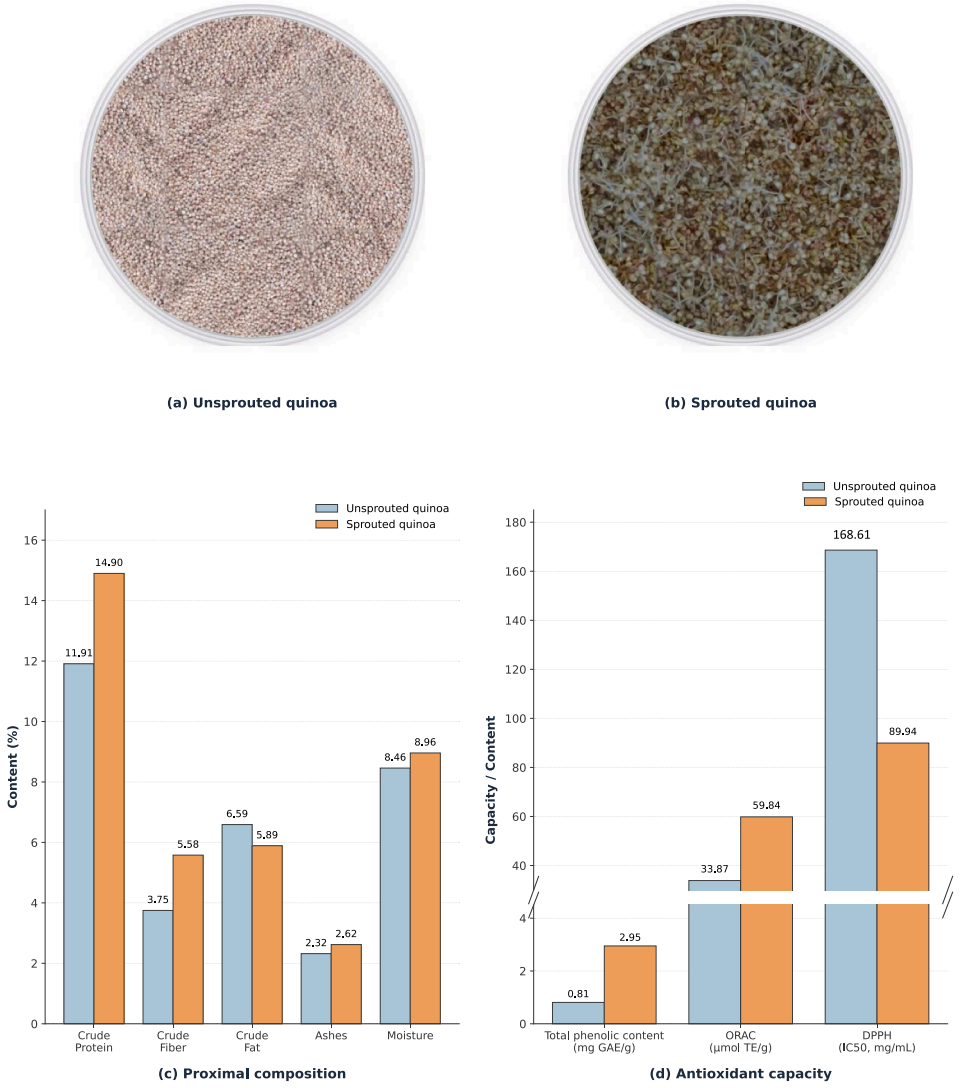


Fig. 1. Comparison between unsprouted (UQ) and sprouted (SQ) quinoa flour: appearance of UQ (a) and SQ (b); proximate composition (c) showing crude protein, crude fiber, crude fat, ash and moisture; and antioxidant capacity (d) expressed as total phenolic content (TPC, mg GAE/g), ORAC (µmol TE/g) and DPPH (IC_{50}, mg/mL). For TPC and ORAC, higher values indicate higher antioxidant capacity; for DPPH IC_{50} lower values indicate higher antioxidant capacity.

Table 1
Formulation of shortcrust cookies with varying levels of sprouted quinoa flour and fat reduction.

Ingredients (g)	Q0FR0	Q0FR10	Q0FR20	Q20FR0	Q20FR10	Q20FR20
Wheat flour	43.83	43.83	43.83	35.06	35.06	35.06
Sprouted quinoa flour	0.00	0.00	0.00	8.77	8.77	8.77
Baking powder	0.53	0.53	0.53	0.53	0.53	0.53
Salt	0.44	0.44	0.44	0.44	0.44	0.44
Powdered milk	9.60	9.60	9.60	9.60	9.60	9.60
Vegetable shortening	21.03	18.93	16.82	21.03	18.93	16.82
Sugar	18.00	18.00	18.00	18.00	18.00	18.00
Distilled water (mL)	6.57	8.67	10.78	6.57	8.67	10.78
Total	100.00	100.00	100.00	100.00	100.00	100.00

following AOAC (2000) standard methods. Moisture content was measured by oven-drying at 105°C until a constant weight was reached (AOAC 925.10), and dry matter was calculated as the remaining weight after moisture removal. Crude fat was quantified by Soxhlet extraction (AOAC 960.39) using petroleum ether as solvent. Crude protein by the Kjeldahl method (AOAC 984.13; N × 6.25), ash by muffle-furnace incineration at 550°C (AOAC 923.03), and crude fiber by digestion (AOAC 962.09). Nitrogen-free extract (carbohydrates) was calculated by difference as 100 minus the sum of moisture, crude protein, crude fat, ash, and crude fiber. The nutritive value was expressed as Total Digestible Nutrients (TDN), calculated as the sum of the digestible fractions of crude protein, crude fat, nitrogen-free extract, and ash, according to the methodology described by Kearl (1982). All analyses were performed in triplicate. The TDN was used as an integrative index that

weights each proximate fraction by its typical digestibility, providing a single comparative measure of the energy-yielding value of the formulations. Although this index originated in feed evaluation, its digestibility coefficients apply to the same macronutrient fractions present in baked products. It is reported here alongside the full proximate composition rather than as a stand-alone nutritional claim.

2.5. Instrumental color measurement

Instrumental color of the cookies was measured using a Hunter colorimeter (MiniScan EZ, model: 400 L, HunterLab Inc., Reston, VA, USA) with a D65 illuminant and a 10° observation angle, calibrated with standard white and black tiles, following the procedure described by Duta & Culetu (2015). The colorimeter was placed directly on the top surface of each cookie. Four measurement points per cookie were recorded, with at least three repetitions per treatment per block. Values for L* (lightness), a* (redness), and b* (yellowness) were obtained. Hue angle ($h = \arctan(b^*/a^*)$) and chroma ($C^* = (a^{*2} + b^{*2})^{0.5}$) were also calculated (Saldaña et al., 2014).

2.6. Physical and textural properties

Cookie diameter and thickness were measured at three positions per cookie using a digital vernier caliper (Mitutoyo, model 530-316, Japan), and the average was calculated. The dispersion factor was estimated as the ratio of diameter to thickness (Ahmad et al., 2022). Baking weight loss was assessed by weighing cookies before and after baking (Yang et al., 2022). Hardness and fracturability were evaluated using a texture analyzer (Shimadzu Corporation, model EZ-SX, Japan) equipped with a three-point bending rig (R2.5 mm). The test used a trigger force of 25 g, a 100 N load cell, pre-test, test, and post-test speeds of 1.5, 1.0, and 10 mm/s, a penetration distance of 10 mm, and a support span set to twice the sample thickness. The maximum force at the breaking point was recorded as hardness (N), and the force at the first fracture as fracturability (N) (Kaur et al., 2023). Ten replicates per treatment per block were analyzed.

2.7. Total phenolic content and antioxidant capacity

Antioxidant compounds were extracted from defatted samples following the procedures of Abderrahim et al. (2011) and Arranz et al. (2009). Specifically, a 1 mL aliquot of methanol:water (1:1 *v*/*v*, pH 2.0) was added to 0.2 g of ground sample, stirred for 1 h at 400 rpm and 30°C, vortexed for 10 min, and centrifuged at 10,000 rpm for 10 min at 4°C. The supernatant was collected and stored at −20°C until analysis. Total phenolic content (TPC) was determined by the Folin-Ciocalteu method (Magalhães et al., 2010) and expressed as mg gallic acid equivalent (GAE)/g of sample.

Antioxidant capacity was evaluated using the DPPH radical-scavenging method, as described by Abderrahim et al. (2013). A 10 μL aliquot of the extract was mixed with 200 μL of a DPPH solution (60 μmol/L in 10 mmol/L Tris buffer, pH 7.5, 1:1 *v*/v). The reaction was monitored at 517 nm for 30 min at 24–25 °C in a microplate reader (Synergy/HTX, BioTek Instruments Inc., Winooski, VT, USA). The results were expressed as the scavenging capacity index (SCI) or the half-maximal inhibitory concentration (IC50), calculated from linear regression of the percentage inhibition versus sample concentration and converted to mg/mL.

The ORAC assay was performed according to Dávalos et al. (2004) with modifications, using a microplate reader (Synergy/HTX, BioTek Instruments Inc., Winooski, VT, USA). Fluorescein (FL) was used as the fluorescent probe and AAPH (12 mM) as the peroxyl radical generator in 75 mM phosphate buffer (pH 7.4). A 20 μL aliquot of the antioxidant solution was added to the microplate wells, and 150 μL of FL (100 mM) was dispensed using the equipment's automatic injector. The mixture was preincubated at 37°C for 10–15 min, and fluorescence (excitation 485 nm, emission 520 nm) was recorded every minute for 60–80 min. The area under the curve (AUC) was used to quantify antioxidant activity, expressed as μmol Trolox equivalents (TE/g) using a Trolox standard curve (1-8 μM). All analyses were performed in triplicate.

2.8. Sensory evaluation

Ethical approval was obtained from the Ethics Committee of Universidad Nacional de Moquegua (Letter N° 001-2024-PCEIC/UNAM). All participants provided written informed consent prior to participation.

2.8.1. Temporal dominance of sensations

One hundred and fifteen consumers (58 females, 57 males; aged 18–35 years) were recruited based on regular cookie consumption (at least once per week), self-declared absence of food allergies, and willingness to participate. TDS evaluations were conducted in individual sensory booths, equipped in accordance with ISO 8589:2007, under white light and positive-pressure ventilation. The seven attributes evaluated, namely sweet, bitter, crunchy, hard, greasy, quinoa flavor, and earthy, were identified in a preliminary session in which a group of target consumers described all the sensations they perceived in the cookies using a free-listing task. The most frequently cited terms were retained and cross-checked against attributes reported in previous temporal dominance studies on cookies and biscuits (Nguyen et al., 2023).

Cookie samples (~8 g) were presented monadically in a balanced order following a Williams Latin square design (Williams, 1949), coded with three-digit random numbers. Consumers placed the entire sample in their mouth, pressed start, and continuously selected the attribute perceived as dominant at each moment. Here, an attribute was considered dominant when it was the sensation that stood out most at a given moment, not necessarily the most intense, following the definition of Pineau et al. (2009). A maximum evaluation time of 200 s was established. Water was provided between samples. The Williams Latin square design balances first-order and carry-over effects across the presentation sequence, and each sample was evaluated monadically, with water rinsing between samples to further minimize carry-over. Before data collection, consumers were familiarized with the temporal dominance sensation task during a preliminary session. In this task, the attribute list and the recording software were explained, and they practiced on a warm-up cookie that was not part of the design to ensure consistency with the procedure. A consumer-based panel was used because the study targets liking-relevant perception rather than trained-panel intensity scaling, an approach that has been applied successfully with untrained consumers for comparable bakery products (Nguyen et al., 2023). The familiarization of the consumer panel and its use for TDS are consistent with current practice in temporal sensory methods, where consumer panels are increasingly applied, and most consumer studies include a familiarization phase (Visalli & Galmarini, 2024). Individual repeatability was not screened before data collection, because consumers are not expected to be repeatable to the same extent as trained assessors, although documenting repeatability is recommended whenever the design allows it (Visalli et al., 2023, 2024). The present design did not include a blind replicate, so repeatability indexes such as those proposed by Frascolla et al. (2023) could not be computed a posteriori. Data were collected using the *Compusense Cloud* software (Compusense Inc., Guelph, Canada) on Android tablets.

2.8.2. Consumer acceptance test

The same 115 consumers rated the overall acceptance of the six cookie treatments on a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) (Peryam & Pilgrim, 1957) in the same session as TDS, immediately after the temporal evaluation of each sample, with a fresh portion of the same coded sample. The serving protocol was identical to that used for TDS.

Table 2
Nutritional characterization and physicochemical composition of shortcrust cookies with varying levels of sprouted quinoa flour and fat reduction.

Variables	Levels	0% Fat reduction	10% Fat reduction	20% Fat reduction	Average
Crude protein (% DM)	SQF 0%	9.23 ± 0.84	9.47 ± 0.39	9.80 ± 0.69	9.50 ± 0.63
	SQF 20%	9.14 ± 0.13	9.53 ± 0.37	9.22 ± 0.33	9.30 ± 0.46
	Average	9.19 ± 0.54	9.50 ± 0.34	9.51 ± 0.58	
Crude fiber (% DM)	SQF 0%	1.33 ± 0.45	1.13 ± 0.20	1.17 ± 0.42	**1.21 ± 0.34^{B}**
	SQF 20%	1.64 ± 0.36	1.91 ± 0.45	1.63 ± 0.31	**1.72 ± 0.43^{A}**
	Average	1.48 ± 0.40	1.52 ± 0.53	1.40 ± 0.42	
Dry matter (%)	SQF 0%	95.63 ± 0.18	95.55 ± 0.32	95.67 ± 0.14	**95.62 ± 0.20^{A}**
	SQF 20%	95.22 ± 0.23	95.18 ± 0.22	95.21 ± 0.23	**95.20 ± 0.28^{B}**
	Average	95.43 ± 0.29	95.36 ± 0.32	95.44 ± 0.30	
Ether extract (% DM)	SQF 0%	25.51 ± 0.98	23.67 ± 0.27	22.00 ± 1.05	23.73 ± 1.69
	SQF 20%	25.70 ± 0.35	24.04 ± 0.14	22.87 ± 0.50	24.20 ± 1.54
	Average	**25.61 ± 0.66^{a}**	**23.85 ± 0.28^{b}**	**22.44 ± 0.88^{c}**	
Ash (% DM)	SQF 0%	1.46 ± 0.07	1.48 ± 0.02	1.54 ± 0.03	**1.49 ± 0.05^{B}**
	SQF 20%	1.59 ± 0.04	1.71 ± 0.00	1.57 ± 0.21	**1.62 ± 0.12^{A}**
	Average	1.53 ± 0.09	1.60 ± 0.12	1.55 ± 0.14	
Nitrogen-free extract (% DM)	SQF 0%	62.48 ± 0.79	64.24 ± 0.82	65.50 ± 1.39	**64.07 ± 1.59^{A}**
	SQF 20%	61.92 ± 0.15	62.82 ± 0.25	64.71 ± 0.88	**63.15 ± 1.65^{B}**
	Average	**62.20 ± 0.59^{c}**	**63.53 ± 0.95^{b}**	**65.10 ± 1.13^{a}**	
Moisture (%)	SQF 0%	4.37 ± 0.18	4.45 ± 0.32	4.33 ± 0.14	**4.38 ± 0.20^{B}**
	SQF 20%	4.78 ± 0.23	4.82 ± 0.22	4.68 ± 0.42	**4.76 ± 0.31^{A}**
	Average	4.58 ± 0.29	4.64 ± 0.32	4.50 ± 0.34	
TDN (%)	SQF 0%	98.68 ± 1.09	97.31 ± 0.06	95.91 ± 0.93	97.30 ± 1.40
	SQF 20%	98.61 ± 0.50	97.05 ± 0.29	96.43 ± 0.27	97.36 ± 1.16
	Average	**98.65 ± 0.76^{a}**	**97.18 ± 0.24^{b}**	**96.17 ± 0.68^{c}**	

Values are mean ± SD (n = 3 blocks). Numbers and letters in **bold** between the same row (lowercase) or column (uppercase) indicate significant differences (Tukey, $p < 0.05$). DM: dry matter; SQF: sprouted quinoa flour; TDN: total digestible nutrients.

2.9. Statistical analysis

Instrumental data were analyzed using analysis of variance (ANOVA) with the model: $Y_{ijk} = \mu + B_i + Q_j + F_k + (Q\times F)_{jk} + \varepsilon_{ijk}$, where Y is the response variable, μ is the overall mean, B is the block effect, Q is the SQF effect, F is the fat reduction effect, Q × F is their interaction, and ε is the experimental error. Residual normality was verified by the Shapiro-Wilk test and variance homogeneity by the Levene test prior to ANOVA. Tukey's test was used for pairwise comparisons at $\alpha = 0.05$.

TDS data were analyzed at three complementary levels. First, the dominance rate of each attribute was computed as the proportion of consumers who selected that attribute as dominant at each standardized time point, and compared against the chance level ($P0 = 1/7 = 0.143$) using the binomial significance threshold of Pineau et al. (2009). Dominance rate was displayed as band plots. Second, the duration during which each attribute was dominant was expressed as a percentage of the total standardized evaluation time per panelist and analyzed by ANOVA per attribute with the model Duration = μ + Treatment + Consumer + ε, where Treatment is the fixed effect of cookie formulation (six levels) and Consumer is the random panelist effect (block); pairwise differences among treatment means were tested by Tukey HSD ($\alpha = 0.05$). Third, multivariate discrimination among the six treatments was assessed using Canonical Variates Analysis (CVA) on the matrix of standardized dominance durations, where the dominance of each attribute was expressed as the proportion of the standardized evaluation time during which it was dominant, computed per consumer and per attribute, following a MANOVA test of the Treatment effect (Hotelling-Lawley statistic). The first two canonical functions were retained, and 90% confidence ellipses around each treatment centroid were derived from the within-treatment covariance matrix of the individual canonical scores, so that each ellipse represents the variability among individual consumers within a treatment rather than replication uncertainty or a bootstrapped region, applying the analytical approach used in previous studies (Galmarini et al., 2016; Peltier et al., 2015).

Consumer acceptance was analyzed using a mixed-model ANOVA accounting for the Williams Latin square presentation design, with Treatment as a fixed effect and consumer and sample presentation order as random effects, followed by Tukey HSD for pairwise comparisons. Temporal Drivers of Liking (TDL), expressed as the Liking-When-Dominant (LWD) index, were computed for each (treatment, attribute) combination following the framework of Thomas et al. (2015). Specifically, for each panelist, the duration an attribute was dominant was regressed on the panelist's hedonic score for that treatment. An attribute was classified as a positive (TDL +) or negative (TDL −) driver when the slope was significant at $\alpha = 0.05$. LWD was computed as the mean acceptance score reported by panelists who rated the attribute as dominant in that treatment, along with its 95% confidence interval. All statistical analyses were performed using R version 4.3.0.

3. Results and discussion

3.1. Nutritional characterization and physicochemical properties of cookies

The proximate composition of cookies is shown in Table 2. The addition of SQF and the reduction of fat significantly modified the proximate composition results, except for crude protein content. The protein level of SQF compensates for the reduction of wheat flour, but despite having comparable protein contents, it has been suggested that quinoa stands out due to the presence of amino acids not found in other cereals, such as lysine, threonine, and methionine (Franco et al., 2021), and that germination further improves nutritional quality by increasing protein digestibility (Bhinder et al., 2021; Maldonado-Alvarado et al., 2023). SQF also had a significant effect on increasing crude fiber and ash, and on decreasing nitrogen-free extract. This pattern is similar to that observed in other studies, which report that quinoa germination allows the biosynthesis of structural polysaccharides, makes minerals available through biochemical and enzymatic reactions, reduces antinutrients, and decreases the amount of nitrogen-free extract; that is, it consumes simple sugars and starch (El-Sohaimy et al., 2025; Ramos-Pacheco et al., 2024). SQF also decreased the dry matter and, at the same time, increased the moisture content of the cookies ($P < 0.05$), which may be due to the greater water retention of quinoa flour compared to wheat flour, as reported by Chopra et al. (2018) in cookies.

On the other hand, fat reduction significantly decreased crude fat and TDN, as expected due to the reduced shortening content in the cookies. Furthermore, fat reduction increased the nitrogen-free extract, an effect that may be related to a mass balance compensation regarding

Table 3
Physical and texture properties of shortcrust cookies with varying levels of sprouted quinoa flour and fat reduction.

Variables	Levels	0% Fat reduction	10% Fat reduction	20% Fat reduction	Average
Diameter (cm)	SQF 0%	4.44±0.12	4.33±0.03	4.31±0.06	**4.36±0.09^{A}**
	SQF 20%	4.34±0.05	4.32±0.06	4.34±0.08	**4.33±0.06^{B}**
	Average	4.39±0.10	4.32±0.04	4.32±0.06	
Thickness (mm)	SQF 0%	5.13±0.03	5.44±0.53	5.80±0.55	5.46±0.48
	SQF 20%	5.09±0.08	5.28±0.19	5.26±0.21	5.26±0.21
	Average	5.11±0.06	5.36±0.37	5.53±0.47	
Baking loss (%)	SQF 0%	13.53±0.09	14.20±1.16	14.70±0.24	14.14±0.78
	SQF 20%	14.47±0.51	13.81±0.66	15.10±0.38	14.46±0.63
	Average	14.00±0.61	14.00±0.87	14.90±0.36	
Cooked weight (g)	SQF 0%	7.70±0.07	7.99±0.28	8.27±0.26	7.99±0.31
	SQF 20%	7.97±0.21	7.80±0.16	8.23±0.08	8.00±0.23
	Average	**7.83±0.20^{b}**	**7.90±0.23^{b}**	**8.25±0.17^{a}**	
Spread factor	SQF 0%	8.66±0.25	7.81±1.01	7.47±0.64	7.98±0.81
	SQF 20%	8.52±0.04	8.19±0.20	8.01±0.41	8.24±0.32
	Average	**8.59±0.18^{a}**	**8.00±0.69^{ab}**	**7.74±0.56^{b}**	
Hardness (N)	SQF 0%	**92.27±1.76^{bA}**	**95.26±2.34^{bA}**	**107.43±0.87^{aA}**	98.32±7.12
	SQF 20%	**57.79±2.36^{cB}**	**80.24±1.08^{bB}**	**86.75±0.90^{aB}**	74.93±18.53
	Average	75.03±18.98	87.75±8.39	97.09±11.36	
Fracturability (N)	SQF 0%	**52.24±1.59^{cA}**	**88.83±1.54^{bA}**	**104.89±1.82^{aA}**	81.99±23.41
	SQF 20%	**41.63±1.69^{bB}**	**57.27±0.84^{aB}**	**58.81±1.01^{aB}**	52.57±24.71
	Average	46.94±5.99	73.05±17.32	81.85±25.27	

Values are mean ± SD (n = 3 blocks). Numbers and letters in **bold** between the same row (lowercase) or column (uppercase) indicate significant differences (Tukey, $p < 0.05$). SQF: sprouted quinoa flour.

Table 4
Instrumental color of shortcrust cookies with varying levels of sprouted quinoa flour and fat reduction.

Variables	Levels	0% Fat reduction	10% Fat reduction	20% Fat reduction	Average
L*	SQF 0%	71.55±0.66	72.47±1.03	72.60±1.53	**72.21±1.10^{A}**
	SQF 20%	67.13±1.31	68.21±1.93	68.13±0.91	**67.82±2.54^{B}**
	Average	69.34±2.59	70.34±2.71	70.37±2.70	
a*	SQF 0%	–1.06±0.01	–1.20±0.01	–1.72±0.37	**–1.33±0.35^{B}**
	SQF 20%	0.41±0.07	0.09±0.01	0.05±0.01	**0.18±0.89^{A}**
	Average	**–0.33±0.81^{a}**	**–0.56±0.71^{a}**	**–0.84±0.99^{b}**	
b*	SQF 0%	34.07±1.26	35.04±1.50	34.83±1.48	**34.64±1.30^{B}**
	SQF 20%	41.01±1.02	40.71±1.63	40.57±0.32	**40.76±2.88^{A}**
	Average	37.54±3.93	37.87±3.41	37.70±3.29	
Hue	SQF 0%	91.79±0.08	91.97±0.08	92.84±0.70	**92.20±0.60^{A}**
	SQF 20%	89.43±0.11	89.87±0.01	89.94±0.01	**89.75±1.45^{B}**
	Average	90.61±1.29	90.92±1.15	91.39±1.65	
Chroma	SQF 0%	34.09±1.26	35.06±1.50	34.87±1.48	**34.67±1.41^{B}**
	SQF 20%	41.01±1.02	40.71±1.63	40.57±0.32	**40.76±0.99^{A}**
	Average	37.55±3.91	37.89±3.36	37.72±3.31	

Values are mean ± SD (n = 3 blocks). Numbers and letters in **bold** between the same row (lowercase) or column (uppercase) indicate significant differences (Tukey, $p < 0.05$). SQF: sprouted quinoa flour; L*: lightness; a*: redness (+)/greenness (−); b*: yellowness.

the percentage decrease in the lipid fraction, as observed by Gutiérrez-Luna et al. (2023) in fat-reduced cookies. Therefore, although the effects of SQF and fat reduction were independent, both factors improved the cookies' nutritional profile.

3.2. Physical and textural properties of cookies

The physical properties of the cookies were examined to determine how the incorporation of SQF and fat reduction affected their dimensional, weight, and textural characteristics (Table 3). The incorporation of 20% SQF significantly decreased cookie diameter (4.33 ± 0.06 cm vs. 4.36 ± 0.09 cm for 0% SQF, $p < 0.05$). Similar observations were reported by Chopra et al. (2018), who attributed the decrease in cookie diameter to the higher water-absorption capacity of quinoa flour relative to wheat flour, thereby increasing dough viscosity and reducing lateral spreading during baking. This hypothesis is consistent with the higher moisture content observed in cookies containing 20% SQF (Table 2). However, beyond diameter differences due to the type of flour, the cookies' weight was not affected by SQF but depended on fat reduction. Thus, cooked weight increased with fat reduction ($p < 0.05$), suggesting that the protein components, whether SQF or wheat flour, are favored to retain water when fat is reduced, a pattern observed by Ashwath Kumar & Sudha (2021). These authors also observed that cookie weight and spread factor were inversely proportional. In the present study, as fat was reduced, the increase in cookie weight was consistent with a decrease in the spread factor, with the highest value at 0% fat reduction (8.59 ± 0.18) decreasing to 7.74 ± 0.56 at 20% fat reduction ($p < 0.05$). Fat contributes to the expansion of cookies by melting during cooking, which coats the protein and starch granules and disrupts the structure these components form (Meral et al., 2024). Thus, reducing fat decreases this expansion effect.

Hardness and fracturability were affected by the interaction of SQF incorporation and fat reduction. At 20% SQF, cookies exhibited lower hardness and lower fracturability, indicating a more fragile texture. These changes can be explained by three mechanisms. First, the absence of gluten-forming proteins in quinoa flour weakens the protein-starch matrix responsible for cookie firmness and reduces the cohesive network formed during mixing (Nadian et al., 2021). Second, the higher lipid absorption capacity of quinoa flour, which encapsulates flour particles and reduces their inter-particle cohesive interactions (Jan et al., 2018). Third, differences in starch architecture, as quinoa starch granules are spherical and polygonal with submicron sizes and lower amylose content (< 15%), resulting in a softer, more gelatinous texture (Jiao et al., 2020; Valdez-Arana et al., 2020).

Table 5
Total phenolic compounds and antioxidant capacity of shortcrust cookies with varying levels of sprouted quinoa flour and fat reduction.

Variables	Levels	0% Fat reduction	10% Fat reduction	20% Fat reduction	Average
Total phenolic compounds (mg GAE/g)	SQF 0%	0.99±0.13	1.16±0.09	1.14±0.04	1.10±0.11
	SQF 20%	0.92±0.27	1.04±0.04	1.58±0.37	1.18±0.38
	Average	**0.96±0.20^{b}**	**1.10±0.09^{ab}**	**1.36±0.34^{a}**	
ORAC (μmol TE/g)	SQF 0%	**8.60±0.61^{cB}**	**15.81±0.47^{aB}**	**13.10±1.04^{bB}**	12.50±3.22
	SQF 20%	**19.14±0.34^{bA}**	**24.01±0.90^{aA}**	**24.76±1.14^{aA}**	22.64±2.75
	Average	13.87±5.79	19.91±4.54	18.93±6.46	
DPPH IC50 (mg/mL)	SQF 0%	**71.33±0.72^{aA}**	**71.33±0.72^{aA}**	**71.88±1.53^{aA}**	71.51±0.95
	SQF 20%	**28.54±1.33^{aB}**	**27.72±1.02^{abB}**	**25.89±0.52^{bB}**	27.38±1.40
	Average	49.93±24.02	49.53±24.47	48.89±25.82	

Values are mean ± SD (n = 3 blocks). Numbers and letters in **bold** between the same row (lowercase) or column (uppercase) indicate significant differences (Tukey, $p < 0.05$). SQF: sprouted quinoa flour. Lower DPPH IC50 indicates higher antioxidant activity.

Within each SQF level, both hardness and fracturability increased significantly as fat was reduced. Fat acts as a plasticizer in the dough matrix, coating flour particles and preventing excessive gluten development; when fat is reduced, more water becomes available for gluten hydration, leading to a rigid and less tender cookie (Devi & Khatkar, 2016; Milićević et al., 2020; van der Sman & Renzetti, 2019). Zoulias et al. (2002) investigated the textural properties of reduced-fat cookies by evaluating the maximum stress (σ_{max}), maximum strain (εmax), and their ratio ($\sigma_{max}/\varepsilon_{max}$). The reduced-fat cookies were characterized by high values of σmax and σmax/εmax, which indicate greater hardness and fracture, respectively, aligning with the findings of the present study. Thus, SQF and fat reduction separately modified some physical properties of the cookies, but their interaction affected the texture, an impact that must be evaluated from a sensory perspective.

3.3. Instrumental color

SQF incorporation significantly affected all color parameters ($p < 0.05$) (Table 4). The L* value decreased, indicating that the cookies were substantially darker. The a* value shifted from negative (greenish tones, −1.33 ± 0.35) to slightly positive (reddish tones, 0.18 ± 0.20), while b* increased, reflecting enhanced yellowness. The hue angle decreased from 92.20±0.60 to 89.75±1.45, values close to yellow, consistent with the a* results and indicating a shift from a hue closer to green towards one closer to red. The chroma value increased with the inclusion of SQF (from 34.7 ± 1.4 to 40.8 ± 1.0; $p < 0.05$), indicating higher color saturation, consistent with the marked increase in b* (yellowness). These color changes are attributable to the higher protein and amino acid content of SQF, which promotes more extensive Maillard browning during baking, and to the inherent phenolic pigments present in quinoa flour (Demir & Kilinç, 2017; Wang et al., 2015). Meanwhile, the reduction in fat decreased the a* value, shifting it towards greener tones (Table 4). The reduction in redness (a*) has been previously reported in studies of fat reduction in cookies (Milićević et al., 2020; Sereti et al., 2023; Xie et al., 2021), which may be related to the higher water activity that inhibits Maillard reactions associated with a greater perception of a* (Sereti et al., 2023). In this study, although moisture content or dry matter did not change with fat reduction (Table 2), the increase in weight (Table 3) indicates greater water retention in the cookies. In this regard, the parameter that more accurately determines water retention than moisture content is water activity (Chaple et al., 2023), which may be related to the weight increase and the reduction in a* of the reduced-fat cookies.

3.4. Total phenolic content and antioxidant capacity

The total phenolic content was not statistically higher with the incorporation of SQF, but rather increased with reduced fat (Table 5). This may be partially explained by the increased proportional contribution of flour-derived phenolics when fat content is reduced, not only due to the contribution of quinoa, which is known for its high content of phenolic acids (ferulic, caffeic, p-coumaric, benzoic) and flavonoids (kaempferol, quercetin, myricetin) (Pellegrini et al., 2018; Pereira et al., 2020), but also from wheat flour, which has been reported to contain important compounds such as *p*-coumaric acid, caffeic acid, and ferulic acid (Barros Santos et al., 2022).

Regarding antioxidant capacity, Table 5 shows the interaction effect between the incorporation of SQF and fat reduction, both of which positively affected the antioxidant potential of the cookies as determined by ORAC and DPPH, except for treatments with reduced fat content and without SQF in the DPPH method, suggesting the improvement of the bioactive profile of the cookies by the presence of SQF. Despite the comparable amounts of total phenolic compounds at the two SQF levels (0% and 20%, Table 5), the superior antioxidant capacity of 20% SQF at all fat levels indicates that sprouting results in an improved phenolic compound profile, as reported Joy Ujiroghene et al. (2019), although the reduction of compounds derived from lipid oxidation due to fat reduction may also be involved. Additionally, the cookies also underwent thermal stress during baking at 150°C, yet the SQF cookies exhibited superior antioxidant capacity, suggesting that germination improves the thermal stability of phenolic compounds in cereal matrices, as reported by Alvarez-Jubete et al. (2010). Therefore, the consistent enhancement of antioxidant activity across all SQF treatments supports using sprouted quinoa as a source of antioxidant compounds in cookies, while fat reduction lowers saturated fat content. Because only in vitro antioxidant capacity was measured, these results describe an improved antioxidant profile rather than a demonstrated in vivo health benefit.

3.5. Temporal dominance of sensations of cookies

The TDS analysis was conducted to characterize how the perceived dominant sensations evolved during the oral processing of the six cookie formulations (Fig. 2). Throughout the results, the terms treatment and formulation refer to the six cookie formulations defined by the 2×3 factorial design (Table 1). In cookies without SQF (Q0FR0, Q0FR10, and Q0FR20), crunchy was the dominant sensation during the early phase of mastication, reflecting the initial fracture of the cookie matrix, while sweet rose to dominance shortly after as sugar dissolved in saliva and remained dominant throughout most of the evaluation window. This temporal sequence, crunchy followed by sweet, represents the characteristic sensory trajectory of conventional shortcrust cookies, where mechanical breakdown progressively releases soluble flavor compounds.

In contrast, cookies with 20% SQF (Q20FR0, Q20FR10, and Q20FR20) exhibited markedly different temporal profiles. Hard was dominant early in mastication, followed by crunchy and subsequently quinoa flavor, which emerged as the dominant sensation during the middle-to-late stages of oral processing. Bitter exceeded the binomial significance threshold during the later phases of consumption, whereas earthy reached dominance only briefly above the threshold (Fig. 2). The emergence of quinoa flavor as a dominant sensation reflects the

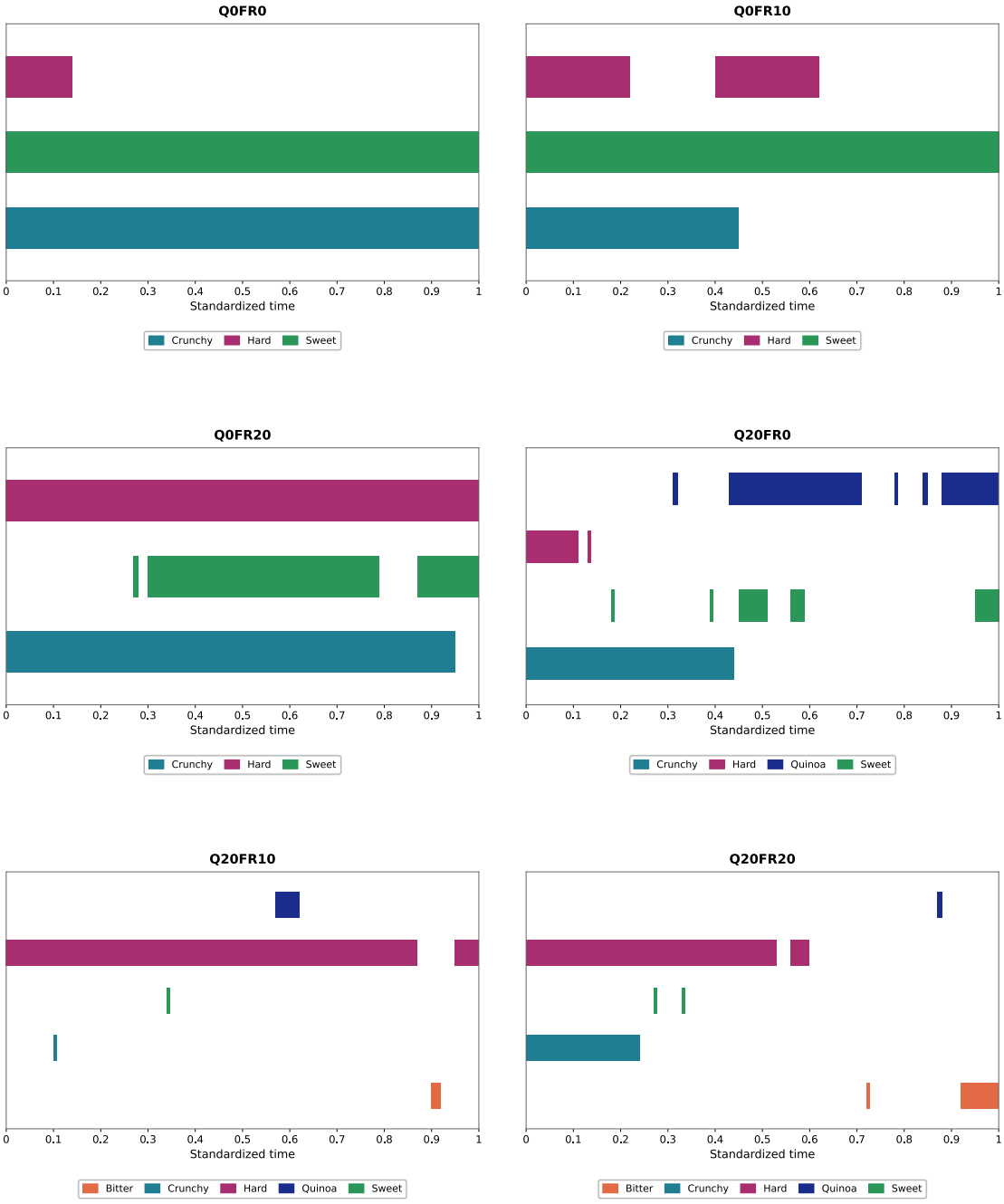


Fig. 2. Temporal Dominance of Sensations (TDS) band plots of dominance rates for the six shortcrust cookie formulations (n = 115 consumers). The horizontal axis is the standardized evaluation time (0 to 1, where 1 corresponds to the maximum evaluation window of 200 s). Colored bands indicate the periods during which the dominance rate of each attribute exceeded the binomial significance threshold at $\alpha = 0.05$ versus chance ($P0 = 1/7 = 0.143$). The seven attributes evaluated were: sweet, bitter, crunchy, hard, greasy, quinoa flavor, and earthy; only attributes that exceeded the significance threshold are shown. Q = level of sprouted quinoa flour; FR = level of fat reduction.

characteristic nutty and earthy volatile compounds present in sprouted quinoa, including pyrazines and other Maillard reaction products (Chen et al., 2025). Sweet was significantly less dominant in SQF cookies even when sugar content was identical across treatments, suggesting that the complex flavor matrix of sprouted quinoa masks sweetness perception through cross-modal interactions.

Fat reduction also influenced the temporal profiles, though to a lesser extent than SQF incorporation. Within the 0% SQF group, increasing fat reduction was associated with slightly reduced dominance of the greasy sensation and a marginal increase in the dominance of hard during early mastication. Within the 20% SQF group, fat reduction enhanced the perception of earthy and bitter notes during the later stages, likely because the reduced fat diminished its characteristic lubricating and flavor-masking effects. These findings are consistent with Nguyen et al. (2023), who reported that ingredient modifications in biscuits significantly altered temporal sensory profiles and that textural attributes such as hard and easy-to-swallow were key drivers of consumer liking.

Quantitative analysis of the duration of dominance periods confirmed the temporal patterns observed in the dominance rate band plots. Table 6 reports the mean proportion of standardized evaluation time during which each attribute was dominant, with the Tukey HSD compact letter display and the pooled standard error of the mean (SEM)

Table 6
Mean dominance duration (% of standardized evaluation time) of the seven sensory attributes across the six cookie treatments.

Attributes	Q0FR0	Q0FR10	Q0FR20	Q20FR0	Q20FR10	Q20FR20	SEM	p-value
Crunchy	22.60 ^{a}	15.21 ^{bc}	16.48 ^{ab}	14.49 ^{bc}	8.77 ^{c}	10.62 ^{bc}	1.70	< 0.001
Sweet	21.35 ^{ab}	23.69 ^{a}	15.81 ^{bc}	12.64 ^{c}	8.79 ^{c}	11.49 ^{c}	1.67	< 0.001
Hard	8.37 ^{b}	12.44 ^{b}	22.13 ^{a}	7.89 ^{b}	21.89 ^{a}	14.96 ^{ab}	1.87	< 0.001
Quinoa	4.85 ^{bc}	3.23 ^{c}	5.72 ^{abc}	10.81 ^{a}	10.14 ^{a}	9.76 ^{ab}	1.26	0.008
Bitter	1.33 ^{b}	0.23 ^{b}	1.26 ^{b}	6.92 ^{a}	7.85 ^{a}	9.66 ^{a}	1.02	< 0.001
Greasy	4.69 ^{a}	5.22 ^{a}	4.87 ^{a}	4.51 ^{a}	2.66 ^{a}	1.94 ^{a}	0.86	0.035
Earthy	5.50 ^{a}	5.42 ^{a}	3.93 ^{a}	8.55 ^{a}	6.74 ^{a}	6.90 ^{a}	1.12	0.079

Different letters within a row indicate significant differences (Tukey HSD, $p < 0.05$). SEM = Standard error of the mean from the per-attribute ANOVA model (Duration ~ Treatment + Consumer).

from the ANOVA model. The treatment effect was highly significant for six of the seven attributes ($p < 0.001$), the only exception being earthy ($F = 1.99$, $p = 0.0787$); greasy showed a significant overall treatment effect ($F = 2.42$, $p = 0.0349$), although Tukey HSD post-hoc tests did not detect pairwise differences among treatments (all letters = a in Table 6). Crunchy dominance was highest in the control formulation (Q0FR0 = 22.60%) and decreased with both increasing fat reduction and SQF incorporation, falling to 8.77% in Q20FR10. Sweet showed the same direction, from 23.69% in Q0FR10 down to 8.79–11.49% in the SQF cookies. Hard increased markedly with the most intense reformulations (Q0FR20 = 22.13%, Q20FR10 = 21.89%, both significantly above the control), confirming the textural penalty of high fat reduction already detected in the texture analyzer measurements (Table 3). Quinoa flavor was negligible in cookies without SQF (3.23–5.72%) and rose to 9.76–10.81% with 20% SQF; bitter showed an even steeper contrast (≤ 1.33% without SQF vs. 6.92–9.66% with SQF). These results provide statistical evidence for the qualitative shift visualized in Fig. 2: SQF incorporation displaces the dominant sensory profile from a sweet- and crunchy-driven pattern to one in which quinoa flavor, bitter, and hard become temporally dominant. Hard was also dominant in the full-fat control without sprouted quinoa flour (Q0FR0 = 8.37%), which indicates that hardness is partly an intrinsic sensory feature of the short-crust matrix and not a property created only by the experimental factors. Both fat reduction and quinoa flour amplified this baseline hardness rather than introducing it, in agreement with the instrumental texture results (Table 3).

Multivariate discrimination among the six cookie treatments was further assessed by CVA on the standardized dominance durations (Fig. 3). The MANOVA test indicated that the treatment effect was highly significant (Hotelling-Lawley, $p < 0.001$), and the first two canonical functions jointly explained 92.0% of the between-treatment variance (Can1 = 69.5%, Can2 = 22.5%). The 90% confidence ellipses revealed three well-separated clusters along Can1: cookies without SQF (Q0FR0 and Q0FR10) projected on the positive side of Can1 in

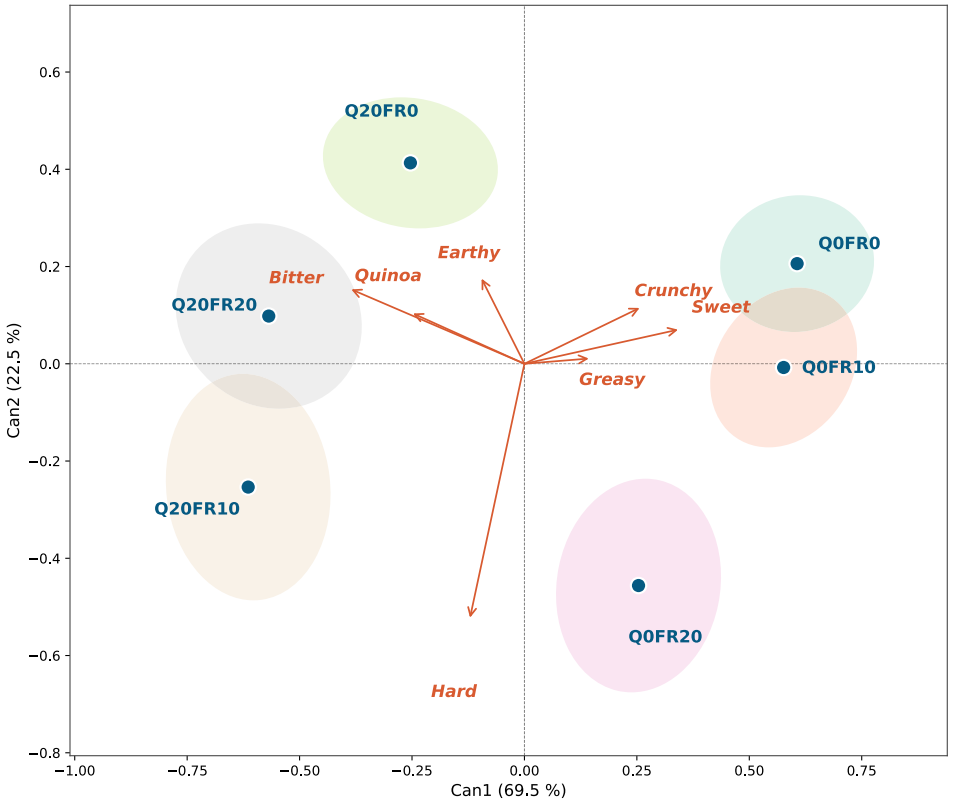


Fig. 3. Canonical Variates Analysis (CVA) biplot of dominance durations of the seven sensory attributes for the six cookie treatments. Filled circles are treatment centroids; 90% confidence ellipses around each centroid are derived from the within-treatment covariance matrix of individual canonical scores. Arrows represent the structure correlations (loadings) between each sensory attribute and the canonical functions; arrow direction and length indicate the sign and magnitude of the correlation, so that an attribute lying along the positive direction of a canonical function correlates positively with that function and vice versa. Q = sprouted quinoa flour level; FR = fat reduction level. n = 115 consumers.

association with sweet (structure correlation r = 0.62), crunchy (r = 0.46), and greasy (r = 0.26), whereas the three SQF treatments projected on the negative side of Can1 in association with bitter (r = −0.70), quinoa flavor (r = −0.45), and earthy (r = −0.17). Q0FR20 was separated from the rest of the no-SQF cluster on the negative side of Can2, in the direction of hard (r = 0.94), reflecting the textural impact of 20% fat reduction in a wheat-only formulation. Within the SQF cluster, Q20FR0 was distinguished on the negative side of Can2, suggesting that fat reduction modulates hardness within each SQF level rather than introducing a new dominant attribute. The CVA biplot therefore confirms that SQF is the dominant driver of sensory differentiation (Can1), whereas fat reduction primarily acts along the textural axis (Can2). This multivariate separation reflects the temporal patterns observed in the band plots (Fig. 2). Cookies without quinoa flour exhibit a positive Can1 position, indicating their early crunchy texture and persistent sweetness. In contrast, quinoa cookies show a negative Can1 position, corresponding to the mid-to-late appearance of quinoa flavor and bitterness. Thus, the canonical map succinctly captures the sequential treatment differences displayed in the band plots within a single representation.

3.6. Consumer acceptance

Consumer acceptance scores, as illustrated by the box distributions (Fig. 4) revealed two clearly differentiated groups. Cookies without SQF (Q0FR0, Q0FR10, Q0FR20) received significantly higher mean acceptance scores (range 6.65–7.10) than those with 20% SQF (5.34–5.66) ($p < 0.05$). Box plot analysis provided additional information on data dispersion, demonstrating that the Q0 treatments had higher ratings. They were characterized by consistently high median scores of 7 and a narrow interquartile range (IQR), concentrated between 6 and 8. In contrast, the Q20 group showed greater variability in consumer responses, with a wider IQR (4–7) and lower median scores of 6. Furthermore, while the Q0 group had only isolated negative outliers (scores of 1 and 2), the Q20 treatments spanned the entire scale range down to 1, indicating highly polarized consumer opinions. Within the 0% SQF group, no significant differences were observed among the three fat-reduction levels, indicating that up to 20% fat reduction can be implemented without compromising consumer liking. This finding is of considerable practical relevance for the food industry, as it indicates that a substantial fat reduction is feasible while maintaining sensory quality comparable to the full-fat control.

The significantly lower acceptance and wider score variability of SQF-enriched cookies can be attributed to the sensory changes revealed by TDS, particularly the emergence of quinoa flavor, earthy, and bitter notes that replaced the desirable sweet and greasy sensations characteristic of conventional cookies. Although all SQF treatments scored above the midpoint of the hedonic scale (scores > 5), indicating moderate rather than negative acceptance, the broader distribution of scores implies that while a segment of consumers accepted the product, another segment strongly rejected it. Future studies should explore lower SQF concentrations (5–10%), flavor masking strategies using ingredients such as cocoa powder or vanilla extract, and gradual exposure approaches to familiarize consumers with the novel flavor profile (Eduardo et al., 2024; Saldaña et al., 2024).

3.7. Temporal drivers of liking

To establish a quantitative link between the temporal sensory experience captured by TDS and consumers' hedonic responses, the Temporal Drivers of Liking (TDL) framework was applied alongside the Liking-When-Dominant (LWD) index (Fig. 5). The TDL framework classifies an attribute as a positive (TDL +) or negative (TDL −) driver of liking in a given treatment when the slope of the regression of the panelist's hedonic score on the time during which the attribute was dominant is significant ($\alpha = 0.05$). Furthermore, LWD is the average acceptance score given by panelists who reported the attribute as dominant in that treatment, and provides a treatment-conditional measure of how favorably the attribute was perceived. This analysis

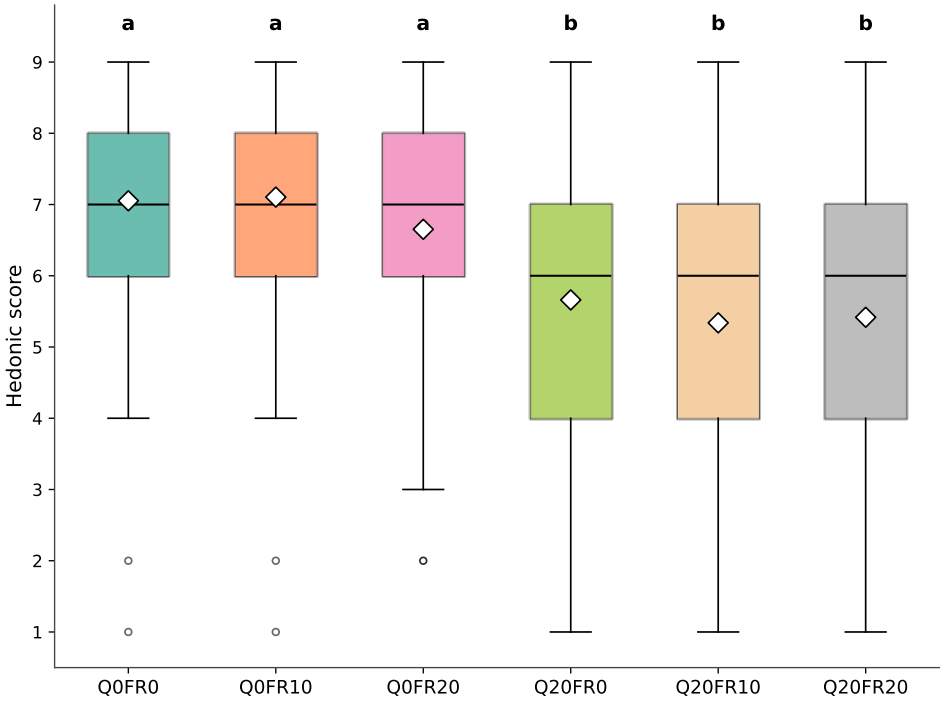


Fig. 4. Boxplot of consumer acceptance scores (9-point hedonic scale; 1 = dislike extremely, 9 = like extremely; n = 115 consumers) of shortcrust cookies with varying levels of sprouted quinoa flour (SQF: 0%, 20%) and fat reduction (FR: 0%, 10%, 20%). Boxes show the interquartile range (Q1–Q3), the central line is the median, whiskers extend to 1.5 times the interquartile range, and white diamonds inside each box indicate the mean. Different letters above the boxes indicate significant differences among treatments (Tukey HSD, $p < 0.05$).

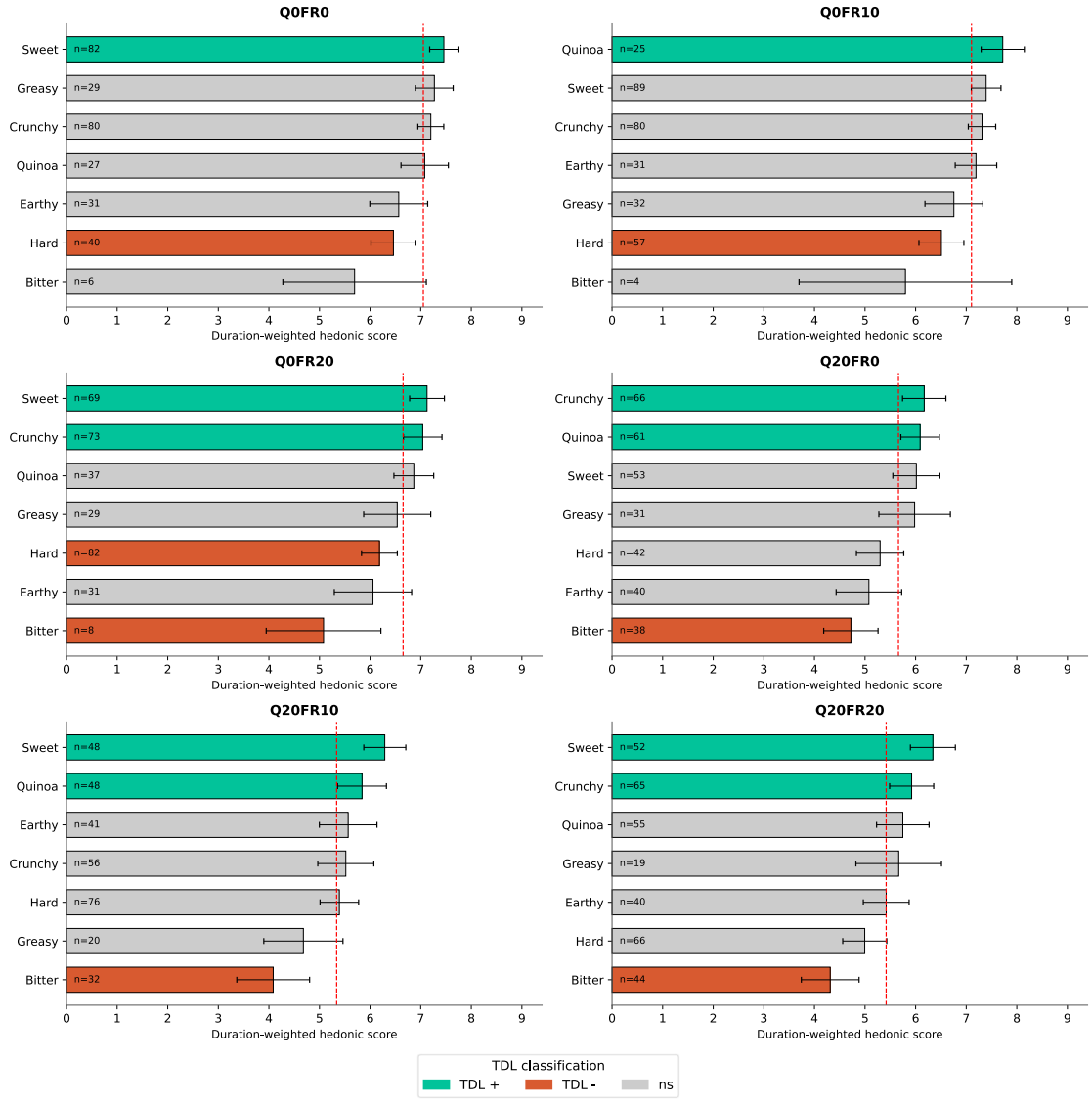


Fig. 5. Temporal Drivers of Liking (TDL) and Liking-When-Dominant (LWD) of the seven sensory attributes across the six cookie treatments (n = 115 consumers). LWD values are mean acceptance scores with 95% confidence intervals, and the vertical dashed line indicates the overall mean acceptance score of the cohort. Bar color denotes the TDL classification. TDL + (positive driver) and TDL− (negative driver) indicate a significant relationship between the hedonic score and the dominance duration of the attribute (α = 0.05), whereas ns indicates a non-significant relationship. Q = sprouted quinoa flour level; FR = fat reduction level.

provides the link between several temporal attributes and the single overall acceptance score, and quantifies the relative hedonic weight of each attribute rather than treating them as equally important. It therefore explains how the multi-attribute temporal data converge into a single hedonic response used to compare formulations.

Across the six treatments, sweet was the most consistent positive driver of liking (TDL+ in four of the six treatments; mean LWD = 6.77). This confirms that perceiving sweetness as dominant translated directly into higher acceptance scores. Crunchy was a positive driver in three of the six treatments (mean LWD = 6.53), indicating that the textural break of the cookie matrix is also rewarded by consumers, albeit less universally than the sweet sensation. Conversely, bitter emerged as the most consistent negative driver, with TDL in four of the six treatments and recorded the lowest mean LWD of the seven attributes (4.95), falling more than one full hedonic point below the overall sample mean. Hard was a negative driver in three treatments (mean LWD = 5.81), consistent with the textural rejection indicated by the hardness instrumental measurements (Table 3). Earthy and greasy did not show a significant association with liking across any of the six treatments and can be considered neutral attributes from a hedonic standpoint. Quinoa flavor behaved as a positive-to-neutral driver rather than a negative one. It was classified as a positive driver (TDL +) in three formulations, including Q0FR10, and was never classified as a negative driver; its mean LWD (6.56) was close to the cohort mean. The high liking associated with dominant quinoa flavor in these formulations confirms that this attribute did not, in itself, reduce acceptance. Accordingly, the lower acceptance of the quinoa cookies is explained less by quinoa flavor than by its co-occurrence with dominant bitter and hard sensations.

These findings provide a quantitative explanation for the lower acceptance of SQF-enriched cookies and establish actionable targets for reformulation. Substituting wheat flour with SQF shifted the dominant sensory profile from sweet- and crunchy-driven (positive drivers) to one in which bitter and hard became temporally prominent (negative drivers). The convergent evidence from TDS dominance rates (Fig. 2), dominance durations (Table 6), CVA (Fig. 3), and the present TDL/LWD analysis (Fig. 5) consistently identifies bitter mitigation and texture restoration as the two highest-leverage directions for SQF cookie optimization. Practical strategies to address these challenges include

incorporating bitter-masking ingredients such as cocoa powder, vanilla extract, or maltodextrin (Eduardo et al., 2024; Saldaña et al., 2024). Additionally, applying partial sucrose replacement can effectively compensate for the suppressed sweetness perception in SQF formulations, and the use of gluten-rich wheat-flour blends or hydrocolloids to recover the gluten matrix weakened by quinoa starch architecture (Jiao et al., 2020; Valdez-Arana et al., 2020). Ultimately, the TDL framework thereby translates the temporal sensory description into prioritized reformulation decisions, in line with the application of dynamic sensory methods to product optimization as advocated (Castura et al., 2016; Nguyen et al., 2023).

4. Conclusions

This study evaluated the combined effects of SQF (0% and 20%) and fat reduction (0%, 10%, and 20%) on the physicochemical, antioxidant, and temporal sensory properties, as well as consumer acceptance, of shortcrust cookies. SQF increased crude fiber, ash, moisture, a*, b*, chroma, and antioxidant capacity, and reduced nitrogen-free extract, hardness, fracturability, L*, and hue angle, whereas fat reduction increased nitrogen-free extract, hardness, fracturability, cooked weight, and total phenolic compounds and reduced crude fat and total digestible nutrients. TDS showed that SQF replaced the crunchy-then-sweet trajectory of conventional cookies with a hard-then-quinoa-flavor sequence, CVA confirmed SQF as the dominant driver of multivariate discrimination, and TDL identified sweet and crunchy as positive drivers, bitter and hard as negative drivers, and quinoa flavor as a comparatively neutral attribute. A 20% fat reduction is therefore feasible in conventional shortcrust cookies without sensory drawbacks, whereas 20% SQF should be treated as a functional enrichment strategy that still requires bitterness masking and texture recovery. Three limitations frame these conclusions. Only the 0% and 20% SQF levels were tested, so intermediate levels (5–15%) should be explored using response-surface or multilevel designs. The panel comprised young adults aged 18–35 rather than the intended beneficiaries, so the inference to children and vulnerable youth must be confirmed with the target group. Finally, the design included no blind replicate, so individual repeatability could not be quantified; future temporal studies should include a replicated sample and report repeatability indexes as routine good practice.

Ethical review

This study was approved by the Ethics Committee of Universidad Nacional de Moquegua (Letter N° 001-2024-PCEIC/UNAM).

Informed consent

Privacy rights of human subjects have been observed and written informed consent was obtained from all subjects involved in the study.

Statement for studies in humans/animals

This study involved human participants exclusively in the context of sensory evaluation. No animal experiments were conducted at any stage of this research. The sensory evaluation sessions were conducted as part of the research project titled “Desarrollo de galletas reducidas en grasa enriquecidas con quinua germinada destinadas a niños y jóvenes nutricionalmente vulnerables”, approved and funded under Contrato N.° SI-001-2024-UNAM, issued by the Universidad Nacional de Moquegua (UNAM). All procedures involving human participants were conducted in accordance with the ethical principles of the Declaration of Helsinki of the World Medical Association (WMA) and its subsequent amendments. This study was approved by the Ethics Committee of Universidad Nacional de Moquegua (Letter N° 001-2024-PCEIC/UNAM).

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CRediT authorship contribution statement

Darwin Tique: Writing – original draft, Methodology, Investigation, Formal analysis. **Karina Eduardo:** Writing – review & editing, Validation, Methodology, Investigation, Conceptualization. **Jennifer Alvarez:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Milagros Coaguila-Gonza:** Writing – review & editing, Methodology, Investigation. **Juan D. Rios-Mera:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Erick Saldaña:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors have no conflict of interest in the manuscript “Sprouted quinoa flour and fat reduction in shortcrust cookies: effects on nutritional composition, instrumental color and texture, antioxidant capacity, and temporal sensory profile”.

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Data availability

Data will be made available on request.

References

AACC. (2000). *Approved methods of the American association of cereal chemists (Number v. 1-2)*. AACC. https://books.google.com.pe/books?id=xJwQAQAAMAAJ.

Abderrahim, F., Arribas, S. M., Carmen Gonzalez, M., & Condezo-Hoyos, L. (2013). Rapid high-throughput assay to assess scavenging capacity index using DPPH. *Food Chemistry, 141*(2), 788–794. https://doi.org/10.1016/j.foodchem.2013.04.055

Abderrahim, F., Estrella, S., Susín, C., Arribas, S. M., González, M. C., & Condezo-Hoyos, L. (2011). The antioxidant activity and thermal stability of lemon verbena (Aloysia triphylla) infusion. *Journal of Medicinal Food, 14*(5), 517–527. https://doi.org/10.1089/jmf.2010.0102

Ahmad, S., Naz, A., Usman, M., Amjad, A., Pasha, I., & Farooq, U. (2022). Impediment effect of chemical agents (additives) on gluten development in cookie dough. *Journal of Food Science and Technology, 59*(4), 1396–1406. https://doi.org/10.1007/s13197-021-05149-7

Altıkardeş, E., & Güzel, N. (2024). Impact of germination pre-treatments on buckwheat and quinoa: Mitigation of anti-nutrient content and enhancement of antioxidant properties. *Food Chemistry: X, 21*. https://doi.org/10.1016/j.fochx.2024.101182

Alvarez, J., Eduardo, K., Gonza, M. M. C., de Araújo, C. D. L., Contreras-Castillo, C. J., & Saldaña, E. (2025). Sugar reduction and replacement of wheat flour with quinoa flour in shortcrust cookies: Effects on nutritional, physical, and sensory properties. *Food Production, Processing and Nutrition, 7*(1). https://doi.org/10.1186/s43014-025-00323-2

Alvarez, J., Tique, D., Eduardo, K., Coaguila-Gonza, M. M., Rios-Mera, J. D., & Saldaña, E. (2026). Sensory and technological innovation in quinoa cookies: A systematic review and a methodological framework for future research. *Food and Humanity, 6*. https://doi.org/10.1016/j.foohum.2026.101148

Alvarez-Jubete, L., Wijngaard, H., Arendt, E. K., & Gallagher, E. (2010). Polyphenol composition and in vitro antioxidant activity of amaranth, quinoa buckwheat and wheat as affected by sprouting and baking. *Food Chemistry, 119*(2), 770–778. https://doi.org/10.1016/j.foodchem.2009.07.032

AOAC. (2000). *Official methods of analysis of AOAC international, 17*. AOAC International. Number vn. https://books.google.com.pe/books?id=TDAbAQAAMAAJ

Arranz, S., Saura-Calixto, F., Shaha, S., & Kroon, P. A. (2009). High contents of nonextractable polyphenols in fruits suggest that polyphenol contents of plant foods have been underestimated. *Journal of Agricultural and Food Chemistry, 57*(16), 7298–7303. https://doi.org/10.1021/jf9016652

Ashwath Kumar, K., & Sudha, M. L. (2021). Effect of fat and sugar replacement on rheological, textural and nutritional characteristics of multigrain cookies. *Journal of Food Science and Technology, 58*(7), 2630–2640. https://doi.org/10.1007/s13197-020-04769-9

Barros Santos, M. C., Ribeiro da Silva Lima, L., Thomaz dos Santos D'Almeida, C., Mayrinck Victorio, V. C., Cameron, L. C., Bourlieu-Lacanal, C., & Simões Larraz Ferreira, M. (2022). Foodomics in wheat flour reveals phenolic profile of different genotypes and technological qualities. *LWT, 153*. https://doi.org/10.1016/j.lwt.2021.112519

Bhinder, S., Kumari, S., Singh, B., Kaur, A., & Singh, N. (2021). Impact of germination on phenolic composition, antioxidant properties, antinutritional factors, mineral content and Maillard reaction products of malted quinoa flour. *Food Chemistry, 346*. https://doi.org/10.1016/j.foodchem.2020.128915

Castura, J. C., Antúnez, L., Giménez, A., & Ares, G. (2016). Temporal check-all-that-apply (TCATA): A novel dynamic method for characterizing products. *Food Quality and Preference, 47*, 79–90. https://doi.org/10.1016/j.foodqual.2015.06.017

Chaple, S., Sarangapani, C., Dickson, S., & Bourke, P. (2023). Product development and X-ray microtomography of a traditional white pan bread from plasma functionalized flour. *LWT, 174*. https://doi.org/10.1016/j.lwt.2022.114326

Chen, D., Lu, T., Huang, Y., He, R., & Chen, X. (2025). Coffee pulp as a flour substitute in biscuits: The effects on physicochemical properties, sensory quality, and flavor characteristics. *LWT, 230*. https://doi.org/10.1016/j.lwt.2025.118305

Chopra, N., Dhillon, B., Rani, R., & Singh, A. (2018). Physico-nutritional and sensory properties of cookies formulated with quinoa, sweet potato and wheat flour blends. *Current Research in Nutrition and Food Science, 6*(3), 798–806. https://doi.org/10.12944/CRNFSJ.6.3.22

D'ambrosio, T., Amodio, M. L., Pastore, D., De Santis, G., & Colelli, G. (2017). Chemical, physical and sensorial characterization of fresh quinoa sprouts (*Chenopodium quinoa* Willd.) and effects of modified atmosphere packaging on quality during cold storage. *Food Packaging and Shelf Life, 14*, 52–58. https://doi.org/10.1016/j.fpsl.2017.08.003

Das, M., & Das, A. (2024). A comprehensive review on strategies for replacing saturated fats in bakery products. *Discover Food, 4*(1), 156. https://doi.org/10.1007/s44187-024-00240-2

Dávalos, A., Gómez-Cordovés, C., & Bartolomé, B. (2004). Extending applicability of the oxygen radical absorbance capacity (ORAC-fluorescein) assay. *Journal of Agricultural and Food Chemistry, 52*(1), 48–54. https://doi.org/10.1021/jf0305231

Devi, A., & Khatkar, B. S. (2016). Physicochemical, rheological and functional properties of fats and oils in relation to cookie quality: A review. *Journal of Food Science and Technology, 53*(10), 3633–3641. https://doi.org/10.1007/s13197-016-2355-0. Number.

Duta, D. E., & Culetu, A. (2015). Evaluation of rheological, physicochemical, thermal, mechanical and sensory properties of oat-based gluten free cookies. *Journal of Food Engineering, 162*, 1–8. https://doi.org/10.1016/j.jfoodeng.2015.04.002

Eduardo, K., Bedoya-Perales, N., Escobedo-Pacheco, E., & Saldaña, E. (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*(2), 251–267. https://doi.org/10.17268/sci.agropecu.2024.019

El-Sohaimy, S. A., Mehany, T., Shehata, M. G., Zeitoun, A. A., Alharbi, H. M., Alwutayd, K. M., & Zeitoun, M. A. M. (2025). Optimizing functional, stability, and sensory attributes of quinoa beverages through bioprocessing, ultrasonication, and hydrocolloids. *Food Chemistry: X, 30*. https://doi.org/10.1016/j.fochx.2025.102923

FAO, IFAD, UNICEF, WFP, & WHO. (2025). The state of food security and nutrition in the world 2025 – Addressing high food price inflation for food security and nutrition. *The state of food security and nutrition in the world 2025*. FAO; IFAD; UNICEF; WFP; WHO. https://doi.org/10.4060/cd6008en

Franco, W., Evert, K., & Van Nieuwenhove, C. (2021). Quinoa flour, the germinated grain flour, and sourdough as alternative sources for gluten-free bread formulation: Impact on chemical, textural and sensorial characteristics. *Fermentation, 7*(3). https://doi.org/10.3390/fermentation7030115

Frascolla, C., Visalli, M., Cardot, H., & Schlich, P. (2023). Indexes of individual repeatability and product discrimination in TDS and TCATA and their statistical inference. *Food Quality and Preference, 110*, Article 104929. https://doi.org/10.1016/j.foodqual.2023.104929

Galmarini, M. V., Symoneaux, R., Visalli, M., Zamora, M. C., & Schlich, P. (2016). Could Time-Intensity by a trained panel be replaced with a progressive profile done by consumers? A case on chewing-gum. *Food Quality and Preference, 48*, 274–282. https://doi.org/10.1016/j.foodqual.2015.10.006

Goyat, J., Passi, S. J., Suri, S., & Dutta, H. (2018). Development of chia (*Salvia hispanica*, L.) and quinoa (*Chenopodium quinoa*, L.) seed flour substituted cookies-physicochemical, nutritional and storage studies. *Current Research in Nutrition and Food Science, 6*(3), 757–769. https://doi.org/10.12944/CRNFSJ.6.3.18

Gutiérrez-Luna, K., Astiasaran, I., & Ansorena, D. (2023). Fat reduced cookies using an olive oil-alginate gelled emulsion: Sensory properties, storage stability and in vitro digestion. *Food Research International, 167*. https://doi.org/10.1016/j.foodres.2023.112714

ISO 8589. (2007). *Sensory analysis—General guidance for the design of test rooms (Amd 1: 2014)*.

Jan, K. N., Panesar, P. S., & Singh, S. (2018). Textural, in vitro antioxidant activity and sensory characteristics of cookies made from blends of wheat-quinoa grown in India. *Journal of Food Processing and Preservation, 42*(3). https://doi.org/10.1111/jfpp.13542

Jiao, M., Gao, Y., & Tian, Y. (2020). Study the relationship between the microstructure and characteristics of quinoa starch by compared with common cereal starches. *American Journal of Biochemistry and Biotechnology, 16*(4), 561–567. https://doi.org/10.3844/ajbbsp.2020.561.567

Joy Ujiroghene, O., Liu, L., Zhang, S., Lu, J., Zhang, C., Lv, J., Pang, X., & Zhang, M. (2019). Antioxidant capacity of germinated quinoa-based yoghurt and concomitant effect of sprouting on its functional properties. *LWT, 116*. https://doi.org/10.1016/j.lwt.2019.108592

Kaur, S., Panesar, P. S., & Chopra, H. K. (2023). Extraction of dietary fiber from kinnow (*Citrus reticulata*) peels using sequential ultrasonic and enzymatic treatments and its application in development of cookies. *Food Bioscience, 54*. https://doi.org/10.1016/j.fbio.2023.102891

Kearl, L. C. (1982). *Nutrient requirements of ruminants in developing countries. International Feedstuffs*. Institute, Utah Agricultural Experiment Station, Utah State University.

Lan, Y., Wang, X., Wang, L., Zhang, W., Song, Y., Zhao, S., Yang, X., & Liu, X. (2024). Change of physiochemical characteristics, nutritional quality, and volatile compounds of *Chenopodium quinoa* Willd. during germination. *Food Chemistry, 445*. https://doi.org/10.1016/j.foodchem.2024.138693

Magalhães, L. M., Santos, F., Segundo, M. A., Reis, S., & Lima, J. L. F. C. (2010). Rapid microplate high-throughput methodology for assessment of Folin-Ciocalteu reducing capacity. *Talanta, 83*(2), 441–447. https://doi.org/10.1016/j.talanta.2010.09.042

Maldonado-Alvarado, P., Pavón-Vargas, D. J., Abarca-Robles, J., Valencia-Chamorro, S., & Haros, C. M. (2023). Effect of germination on the nutritional properties, phytic acid content, and phytase activity of quinoa (*Chenopodium quinoa* Willd). *Foods, 12*(2). https://doi.org/10.3390/foods12020389

Meral, R., Kına, E., & Ceylan, Z. (2024). Low-calorie cookies enhanced with fish oil-based nano-ingredients for health-conscious consumers. *ACS Omega, 9*(37), 39159–39169. https://doi.org/10.1021/acsomega.4c06050

Milićević, N., Sakač, M., Hadnađev, M., Škrobot, D., Šarić, B., Hadnađev, T. D., Jovanov, P., & Pezo, L. (2020). Physico-chemical properties of low-fat cookies containing wheat and oat bran gels as fat replacers. *Journal of Cereal Science, 95*. https://doi.org/10.1016/j.jcs.2020.103056

Nadian, N., Azizi, M. H., Abbastabar Ahangar, H., & Aarabi, A. (2021). Textural and sensory characteristics of sugar-free biscuit formulated with quinoa flour, isomalt, and maltodextrin. *Food Science and Nutrition, 9*(12), 6501–6512. https://doi.org/10.1002/fsn3.2564

Nguyen, Q. C., Castura, J. C., Nguyen, D. D. L., & Varela, P. (2023). Identifying temporal sensory drivers of liking of biscuit supplemented with brewer's spent grain for young consumers. *Food Research International, 170*. https://doi.org/10.1016/j.foodres.2023.113049

Pellegrini, M., Lucas-Gonzales, R., Ricci, A., Fontecha, J., Fernández-López, J., Pérez-Álvarez, J. A., & Viuda-Martos, M. (2018). Chemical, fatty acid, polyphenolic profile, techno-functional and antioxidant properties of flours obtained from quinoa (*Chenopodium quinoa* Willd) seeds. *Industrial Crops and Products, 111*, 38–46. https://doi.org/10.1016/j.indcrop.2017.10.006

Peltier, C., Visalli, M., & Schlich, P. (2015). Comparison of canonical variate analysis and principal component analysis on 422 descriptive sensory studies. *Food Quality and Preference, 40*(PB), 326–333. https://doi.org/10.1016/j.foodqual.2014.05.005

Pereira, E., Cadavez, V., Barros, L., Encina-Zelada, C., Stojković, D., Sokovic, M., Calhelha, R. C., Gonzales-Barron, U., & Ferreira, I. C. F. R. (2020). *Chenopodium quinoa* Willd. (quinoa) grains: A good source of phenolic compounds. *Food Research International, 137*. https://doi.org/10.1016/j.foodres.2020.109574

Peryam, D. R., & Pilgrim, F. J. (1957). Hedonic scale method of measuring food preferences. *Food Technology, 11*(Suppl), 9–14.

Pilco-Quesada, S., Tian, Y., Yang, B., Repo-Carrasco-Valencia, R., & Suomela, J. P. (2020). Effects of germination and kilning on the phenolic compounds and nutritional properties of quinoa (*Chenopodium quinoa*) and kiwicha (*Amaranthus caudatus*). *Journal of Cereal Science, 94*. https://doi.org/10.1016/j.jcs.2020.102996

Pineau, N., Schlich, P., Cordelle, S., Mathonnière, C., Issanchou, S., Imbert, A., Rogeaux, M., Etiévant, P., & Köster, E. (2009). Temporal dominance of sensations: Construction of the TDS curves and comparison with time-intensity. *Food Quality and Preference, 20*(6), 450–455. https://doi.org/10.1016/j.foodqual.2009.04.005

Ramos-Pacheco, B. S., Choque-Quispe, D., Ligarda-Samanez, C. A., Solano-Reynoso, A. M., Palomino-Rincón, H., Choque-Quispe, Y., Peralta-Guevara, D. E., Moscoso-Moscoso, E., & Aiquipa-Pillaca, Á. S. (2024). Effect of germination on the physicochemical properties, functional groups, content of bioactive compounds, and antioxidant capacity of different varieties of quinoa (*Chenopodium quinoa* Willd.) grown in the high Andean zone of Peru. *Foods, 13*(3). https://doi.org/10.3390/foods13030417

Saldaña, E., Alvarez, J., Eduardo, K., Gonza, M. M. C., Rios-Mera, J. D., & Contreras-Castillo, C. J. (2025). Improving the sensory quality of sugar-reduced quinoa biscuits targeted to children based on young adult feedback. *Journal of Sensory Studies, 40*(4). https://doi.org/10.1111/joss.70062

Saldaña, E., Eduardo, K., Mayta-Hancco, J., Huamán-Castilla, N. L., & Escobedo-Pacheco, E. (2024). Application of sensory and consumer science for the development of novel food products. *Current Food Science and Technology Reports, 2*(2), 183–199. https://doi.org/10.1007/s43555-024-00027-7

Saldaña, E., Siche, R., Castro, W., Huamán, R., & Quevedo, R. (2014). Measurement parameter of color on yacon (*Smallanthus sonchifolius*) slices using a computer vision system. *LWT, 59*(2P2), 1220–1226. https://doi.org/10.1016/j.lwt.2014.06.037

Sereti, V., Kotsiou, K., Biliaderis, C. G., & Lazaridou, A. (2023). Emulsion gel enriched with a barley β-glucan concentrate for reducing saturated fat in biscuits. *Food Hydrocolloids, 145*. https://doi.org/10.1016/j.foodhyd.2023.109163

Smith, H. C. (2011). The position of biscuits in nutrition. In D. Manley (Ed.), *Manley's technology of biscuits, crackers and cookies* (4th ed., pp. 373–385). Woodhead Publishing. https://doi.org/10.1533/9780857093646.3.372.

Statista. (2025). Cookies & crackers – Worldwide. https://www.statista.com/outlook/cmo/food/confectionery-snacks/cookies-crackers/worldwide.

Suárez-Estrella, D., Cardone, G., Buratti, S., Pagani, M. A., & Marti, A. (2020). Sprouting as a pre-processing for producing quinoa-enriched bread. *Journal of Cereal Science, 96*. https://doi.org/10.1016/j.jcs.2020.103111

Thomas, A., Visalli, M., Cordelle, S., & Schlich, P. (2015). Temporal drivers of liking. *Food Quality and Preference, 40*(PB), 365–375. https://doi.org/10.1016/j.foodqual.2014.03.003

Valdez-Arana, J. D. C., Steffolani, M. E., Repo-Carrasco-Valencia, R., Pérez, G. T., & Condezo-Hoyos, L. (2020). Physicochemical and functional properties of isolated starch and their correlation with flour from the Andean Peruvian quinoa varieties. *International Journal of Biological Macromolecules, 147*, 997–1007. https://doi.org/10.1016/j.ijbiomac.2019.10.067

van der Sman, R. G. M., & Renzetti, S. (2019). Understanding functionality of sucrose in biscuits for reformulation purposes. In *Critical reviews in food science and nutrition, 59* pp. 2225–2239). Taylor and Francis Inc. https://doi.org/10.1080/10408398.2018.1442315. Number.

Visalli, M., & Galmarini, M. V. (2024). Multi-attribute temporal descriptive methods in sensory analysis applied in food science: A systematic scoping review. *Comprehensive Reviews in Food Science and Food Safety, 23*, Article e13294. https://doi.org/10.1111/1541-4337.13294

Visalli, M., Galmarini, M. V., & Schlich, P. (2023). Use of temporal sensory evaluation methods with consumers: A position paper. *Current Opinion in Food Science, 54*, Article 101102. https://doi.org/10.1016/j.cofs.2023.101102

Visalli, M., Mahieu, B., Peltier, C., Cordelle, S., & Schlich, P. (2024). Temporal precision and resolution of TDS and TCATA used with consumers. *Food Quality and Preference, 117*, Article 105172. https://doi.org/10.1016/j.foodqual.2024.105172

Wang, S., Opassathavorn, A., & Zhu, F. (2015). Influence of quinoa flour on quality of cookie, bread and steamed bread. *Journal of Texture Studies, 46*(4), 281–292. https://doi.org/10.1111/jtxs.12128

Watanabe, K., Kawanishi-Asaoka, M., Myojin, C., Awata, S., Ofusa, K., & Kodama, K. (2014). Amino acid composition, oxidative stability, and consumer acceptance of cookies made with quinoa flour. *Food Science and Technology Research, 20*(3), 687–691. https://doi.org/10.3136/fstr.20.687

WHO. (2025a). Anaemia. https://www.who.int/news-room/fact-sheets/detail/anaemia.

WHO. (2025b). Obesity and overweight. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

Williams, E. J. (1949). Experimental designs balanced for the estimation of residual effects of treatments. *Australian Journal of Scientific Research, Series A: Physical Sciences, 2*(2), 149–168. https://doi.org/10.1071/CH9490149

Xie, Y., Lei, Y., Rong, J., Zhang, X., Li, J., Chen, Y., Liang, H., Li, Y., Li, B., Fang, Z., Luo, X., Pei, Y., Zhong, C., & Liu, S. (2021). Physico-chemical properties of reduced-fat biscuits prepared using O/W cellulose-based pickering emulsion. *LWT, 148*. https://doi.org/10.1016/j.lwt.2021.111745

Yang, L., Wang, S., Zhang, W., Zhang, H., Guo, L., Zheng, S., & Du, C. (2022). Effect of black soybean flour particle size on the nutritional, texture and physicochemical characteristics of cookies. *LWT, 164*. https://doi.org/10.1016/j.lwt.2022.113649

Zoulias, E.I., Oreopoulou, V., & Tzia, C. (2002). Textural properties of low-fat cookies containing carbohydrate-or protein-based fat replacers. Journal of Food Engineering, 55(4), 337-342. doi:org/10.1016/S0260-8774(02)00111-5.