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Evaluation and Acceptability of Roasted Barley Drink Through Check-All-That-Apply (CATA) Method

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Abstract

Barley-based beverages are gaining attention as caffeine-free, functional alternatives to conventional tea and coffee. This study developed a roasted barley drink from four barley varieties – Sultan-17, JAU-21, Sanober-96, and Rakhshan-10 (AZ-96) – and a blend of the four, flavored with cardamom and cinnamon, and evaluated its sensory quality, consumer acceptance, and emotional response using the Check-All-That-Apply (CATA) method. One hundred untrained panelists rated the samples on a 9-point hedonic scale for flavor, aroma, mouth-feel, appearance, and overall acceptability, while descriptive and emotional attributes were collected using two CATA questionnaires (CATA-1 for sensory descriptors and CATA-2 for well-being/emotional descriptors). Data were analyzed by one-way analysis of variance (ANOVA) under a Completely Randomized Design (CRD), followed by Fisher's Least Significant Difference (LSD) test. Significant differences ($p < 0.05$) were found among varieties for every sensory attribute studied. Sanober-96 received the highest scores for flavor (7.50), aroma (7.35), mouth-feel (7.60), appearance (7.35), and overall acceptability (7.70), while Sultan-17 consistently scored lowest, reflecting a bitterer, over-roasted, and thicker profile. CATA-1 results showed that "malty," "sweet," "smooth," and "roasted" were the descriptors most strongly associated with liking, whereas "bitter," "thick," and "grainy" dominated the least-liked sample. CATA-2 emotional mapping confirmed that Sanober-96 and the blended sample were most closely linked with positive well-being terms such as "refreshing," "soothing," and "nourishing," while Sultan-17 was associated with negative emotional terms. Based on these findings it is recommended that barley

beverage development for the market priorities moderate, controlled roasting and fine, uniform grinding – as achieved with Sanober-96 – and that further work characterize the antioxidant and functional properties of the beverage to support its positioning as a caffeine-free, health-oriented product.

Key Words: Roasted Barley Drink, Sensory Evaluation, Check-All-That-Apply (Cata), Consumer Acceptance, Hedonic Scale, Functional Beverage

Introduction

Barley (Hordeum vulgare), a member of the Poaceae family, is among the earliest domesticated cereal grains and remains an important staple crop worldwide. It ranks as the fifth largest cereal crop globally by dry-matter production, with an annual output of approximately 129 million tons (Byung-Kee and Ulrich, 2008). In Pakistan, barley cultivation is concentrated in Punjab, Khyber Pakhtunkhwa, and Baluchistan, where it serves both as a food staple and as a raw material for the malting and brewing industries. Research institutes such as the Wheat Research Institute (Faisalabad) and the Arid Zone Research Centre (Quetta) have released improved varieties – including Sultan-17, JAU-21, Sanober-96, and Rakhshan-10 (AZ-96) – that combine high yield with disease resistance across the country's diverse agro-ecological zones (Noreen *et al.,* 2025; Tabassum *et al.,* 2021).

Nutritionally, barley is rich in dietary fiber (particularly β-glycan's), protein, B-vitamins, magnesium, selenium, and polyphenolic antioxidants, and it has been associated with the management of chronic conditions such as diabetes, obesity, and cardiovascular disease (Sima Tahmouzi *et al.,* 2024; Byung-Kee and Ulrich, 2008). Roasting further improves the sensory and functional profile of barley: moisture and protein content decrease, starch is partially hydrolyses, and soluble β-glycan, phenolic content, and antioxidant activity increase, while color, flavor, and aroma become more consumer-acceptable (Abid Hussain *et al.,* 2021).

Roasted barley has long been used to prepare caffeine-free beverages, most notably "mugi-cha" in Japan and "Café D'orzo" in Italy, both valued as coffee substitutes with a rich, nutty taste and functional health benefits (Siddavaram *et al.,* 2023; Delfino *et al.,* 2021). The global market for such beverages is expanding rapidly: the barley tea market alone is projected to grow from USD 1.20 billion in 2023 to USD 1.51 billion by 2030, at a compound annual growth rate of 4.4% (Consulting, 2024; Daniel, 2024), driven by rising consumer demand for natural, antioxidant-rich, and caffeine-free functional drinks.

Consumer-centred sensory evaluation is essential for guiding the development of such new beverages. Among the available techniques, the Check-All-That-Apply (CATA) method has become one of the most widely used tools because it is simple, inexpensive, and suitable for untrained consumers, who are simply asked to select all descriptive or emotional terms from a predefined list that apply to a given sample (Gorman *et al.,* 2021; Thinzar Aung *et al.,* 2023). CATA data can further be used for penalty analysis to identify sensory drivers of liking and to guide product reformulation (Ares *et al.,* 2014).

Despite the growing interest in barley-based functional beverages, limited work has combined hedonic sensory evaluation with CATA-based descriptive and emotional profiling to compare barley varieties for beverage formulation.

This study therefore aimed to (i) develop a roasted, spiced barley-based drink as an innovative beverage, (ii) assess its sensory characteristics across five barley-based formulations using hedonic scaling and the CATA method, and (iii) explore the consumer-perceived emotional and functional

attributes of the beverage as an indicator of its market potential as a healthy, caffeine-free alternative to tea and coffee.

Materials and Methods

Experimental Site and Raw Materials

This study was carried out at the Food Science Research Institute (FSRI), National Agricultural Research Centre (NARC), Islamabad, Pakistan. Grains of four barley varieties – Sultan-17, JAU-21, Sanober-96, and Rakhshan-10 (AZ-96) – together with cardamom and cinnamon, were procured from the local market. A fifth treatment consisted of an equal blend of the four varieties.

Preparation of the Roasted Barley Drink

Barley grains were cleaned, washed to remove surface impurities, and sun-dried on trays with occasional stirring. The cleaned, dried grains were pan-roasted by hand over a gas stove with continuous stirring until a golden-to-dark-brown color and a characteristic roasted aroma developed, after which they were cooled at room temperature to stabilize flavor and prevent moisture uptake. The roasted grains were milled to a fine, homogeneous powder. Cardamom and cinnamon were separately ground and blended into the barley powder in an optimized ratio – established through a preliminary pilot study – of two tablespoons of barley powder to one-eighth tablespoon of cinnamon and one-quarter tablespoon of cardamom. The finished powder was packed in moisture-proof zip-lock bags and stored at room temperature until analysis.

For serving, milk was first brought to a boil and the barley drink powder was then added directly (a preparation sequence found in pilot trials to give a creamier texture and richer flavor than dissolving the powder before adding milk). The mixture was allowed to stand for 15–20 minutes to extract flavor and aroma, then strained and served warm; brown sugar was made available for panelists who preferred additional sweetness.

Sensory Evaluation

A total of 100 untrained panelists, divided into five groups of 20, evaluated the five barley-drink treatments – Sultan-17 (A), JAU-21 (B), Sanober-96 (C), Rakhshan-10 (D), and the blended sample (E) – with each group assessing a single sample to avoid cross-sample carry-over effects. Overall liking was rated on a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) for flavor, aroma, mouth-feel, appearance, and overall acceptability.

Descriptive and emotional responses were subsequently collected from an independent set of 50 panelists (five groups of 10) using two Check-All-That-Apply (CATA) questionnaires. CATA-1 presented eight sensory descriptors – malty, sweet, bitter, roasted, smooth, grainy, thick, and thin – selected from the literature and pilot trials to capture the principal flavor and texture dimensions of the drink. CATA-2 presented twelve well-being/emotional statements (coded W1–W12; Table 3) capturing affective, functional, and hedonic dimensions of the consumer experience, such as “it makes me feel good,” “it is filling/nutritious,” and “it has a pleasant taste.” Panelists checked all descriptors they considered applicable to each sample.

Statistical Analysis

Data were analyzed using Statistix 8.1. A one-way analysis of variance (ANOVA) under a Completely Randomized Design (CRD) was used to test for significant differences among treatment means ($p < 0.05$), followed by Fisher's Least Significant Difference (LSD) test for mean separation. Results are reported as mean ± standard deviation, with means sharing no common superscript letter within a column differing significantly. CATA-1 and CATA-2 responses were

analyzed descriptively and explanatively to identify the sensory and emotional terms most strongly associated with each treatment.

Results and Discussion

Sensory evaluation was used throughout this work as the primary tool for quality assessment, combining hedonic scaling with two Check-All-That-Apply (CATA) questionnaires to capture, respectively, overall liking, descriptive sensory character, and emotional/functional response to the five barley-drink formulations.

Hedonic Sensory Evaluation of Barley Drink

Mean hedonic scores for the five barley-drink treatments are presented in Table 1 and Fig. 1. Significant differences ($p < 0.05$) were observed among treatments for every attribute assessed. Sanober-96 (C) achieved the highest mean scores for flavour (7.50), aroma (7.35), mouth-feel (7.60), appearance (7.35), and overall acceptability (7.70), reflecting a favorable combination of controlled roasting, uniform particle size, natural sweetness, and smooth texture. The blended sample (E) performed similarly well, particularly for aroma (7.40), consistent with reports that blending cereal flours increases aroma complexity and consumer liking through the interaction of diverse sugars, proteins, and phenolic compounds during roasting (Katina *et al.*, 2007; Belitz *et al.*, 2009).

Sultan-17 (A) consistently received the lowest scores across all attributes, including overall acceptability (5.75). This variety's higher phenolic content and harder grain structure are associated with harsher, more bitter roasting products and a coarser, thicker mouth-feel, in agreement with earlier findings that high-phenolic, deep-roasted cereals are less favored by consumers (Parras *et al.*, 2014; Parker *et al.*, 2017; Lee *et al.*, 2018). Rakhshan-10 (D) occupied an intermediate position, performing particularly well for aroma and mouth-feel.

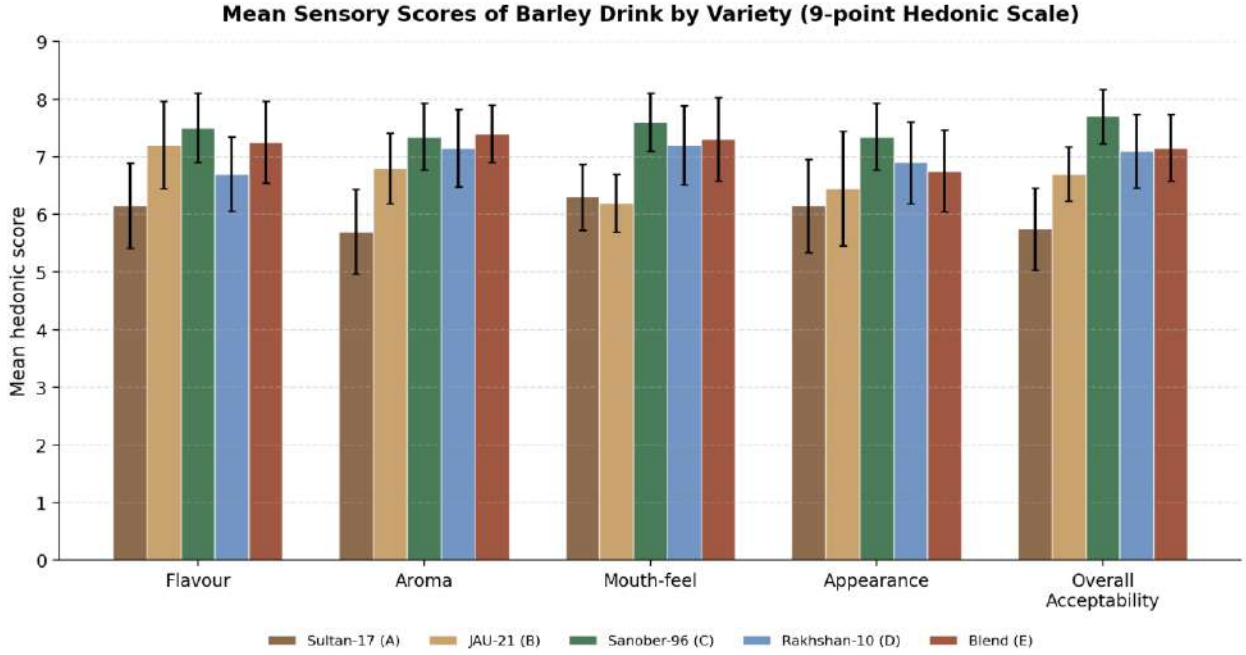

Figure 1. Mean hedonic scores (± SD) for flavor, aroma, mouth-feel, appearance, and overall acceptability of roasted barley drinks prepared from five barley formulations. Bars sharing no common treatment show significant separation by Fisher's LSD test ($p < 0.05$).

Table 1: Mean sensory scores of barley drink prepared from different barley varieties

Treatment	Flavor	Aroma	Mouth-feel	Appearance	Overall Acceptability
Sultan-17 (A)	6.15c ± 0.74	5.70c ± 0.73	6.30c ± 0.57	6.15c ± 0.81	5.75d ± 0.71
JAU-21 (B)	7.20a ± 0.76	6.80b ± 0.61	6.20c ± 0.50	6.45bc ± 0.99	6.70c ± 0.47
Sanober-96 (C)	7.50a ± 0.60	7.35a ± 0.58	7.60a ± 0.50	7.35a ± 0.58	7.70a ± 0.47
Rakhshan-10 (D)	6.70b ± 0.65	7.15ab ± 0.67	7.20b ± 0.69	6.90ab ± 0.71	7.10b ± 0.64
Blend (E)	7.25a ± 0.71	7.40a ± 0.50	7.30ab ± 0.73	6.75b ± 0.71	7.15b ± 0.58

Means within a column followed by different superscript letters differ significantly ($p < 0.05$, LSD test).

CATA-1: Descriptive Sensory Attributes

The CATA-1 questionnaire captured eight descriptive sensory terms – malty, sweet, bitter, roasted, smooth, grainy, thick, and thin – and revealed clear differentiation among treatments (Table 2; Fig. 2). Sanober-96 (C) was most strongly associated with the positive descriptors malty (4.20), sweet (4.40), roasted (4.50), smooth (4.20), and grainy (4.20, indicating a pleasantly textured rather than a coarse mouth-feel context), consistent with its high natural sugar and amino-acid content generating desirable Maillard reaction products such as maltol, farandole, and pyrazines upon roasting (Belitz *et al.*, 2009; Parras *et al.*, 2014).

In contrast, Sultan-17 (A) recorded the lowest scores for malty (1.90), sweet (2.30), and smooth (2.00) attributes, but the highest score for "thick" (4.40) and one of the highest for "bitter" (3.50), reflecting its coarser particle size and greater phenolic content, which promote harsher, more bitter, and heavier sensory perceptions during roasting (Yoon, 2016; Parker *et al.*, 2017). The blended sample (E) and Rakhshan-10 (D) showed intermediate-to-favorable profiles, with the blend scoring particularly high for smooth (4.10) and sweet (4.00) descriptors.

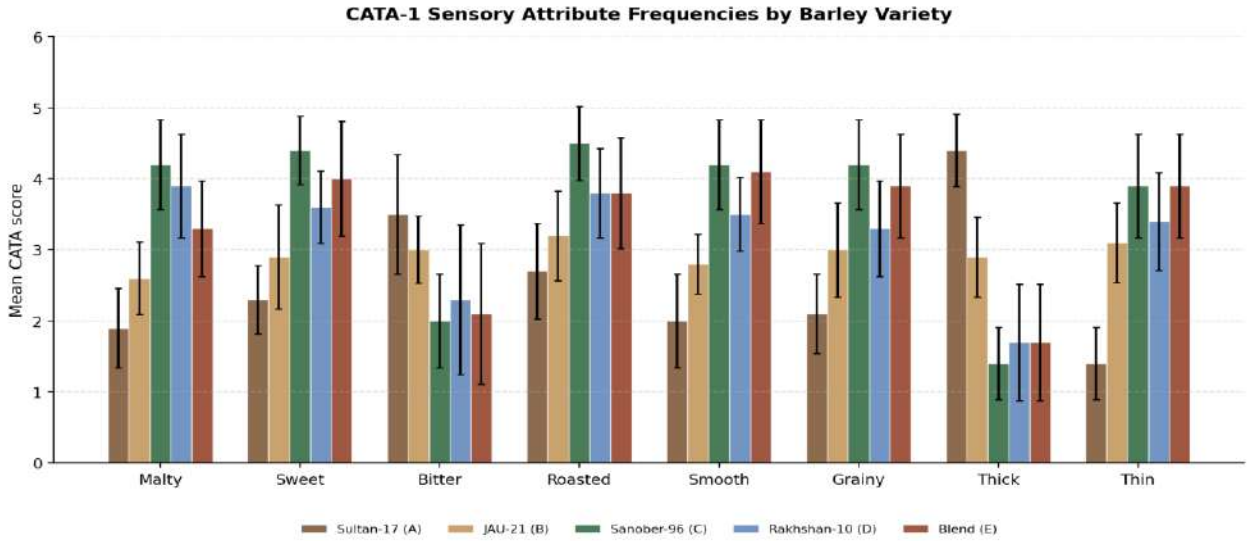

Fig. 2: CATA-1 sensory attribute frequencies (mean scores) for roasted barley drink treatments

Table 2: Sensory attributes of barley drink evaluated by the CATA-1 method

Treatment	Malty	Sweet	Bitter	Roasted	Smooth	Grainy	Thick	Thin
Sultan-17 (A)	1.90d ± 0.56	2.30d ± 0.48	3.50a ± 0.84	2.70c ± 0.67	2.00d ± 0.66	2.10c ± 0.56	4.40a ± 0.51	1.40c ± 0.51
JAU-21 (B)	2.60c ± 0.51	2.90c ± 0.73	3.00ab ± 0.47	3.20c ± 0.63	2.80c ± 0.42	3.00b ± 0.66	2.90b ± 0.56	3.10b ± 0.56
Sanober-96 (C)	4.20a ± 0.63	4.40a ± 0.48	2.00c ± 0.66	4.50a ± 0.52	4.20a ± 0.63	4.20a ± 0.63	1.40c ± 0.51	3.90a ± 0.73
Rakhshan-10 (D)	3.90a ± 0.73	3.60b ± 0.51	2.30bc ± 1.05	3.80b ± 0.63	3.50b ± 0.52	3.30b ± 0.67	1.70c ± 0.82	3.40ab ± 0.69
Blend (E)	3.30b ± 0.67	4.00a ± 0.81	2.10c ± 0.99	3.80c ± 0.78	4.10a ± 0.73	3.90a ± 0.73	1.70c ± 0.82	3.90a ± 0.73

Means within a column followed by different superscript letters differ significantly ($p < 0.05$, LSD test).

CATA-2: Emotional and Well-Being Attributes

The CATA-2 questionnaire assessed twelve emotional and functional well-being statements (W1–W12; Table 3) capturing consumers' affective and perceived-health responses to each treatment. Table 4 and Fig. 3 summarize the mean CATA-2 scores. Sanober-96 (C) was most closely associated with positive well-being statements, recording the highest scores for W1 “makes me feel good” (4.40), W7 “mild, comforting feeling” (4.50), and W12 “fresh or strong flavour” (4.40), together with the lowest score for the negative statement W2 “makes me feel bad” (1.40) and W9 “feeling of emptiness/dissatisfaction” (1.40).

Sultan-17 (A) showed the opposite pattern, recording the highest score for the negative statement W2 (4.40) and the lowest scores for the positive statements W1 (1.80) and W7 (2.70), consistent with its bitterer, thicker, and less balanced sensory profile documented in the CATA-1 and hedonic results. The blended sample (E) and Rakhshan-10 (D) again showed intermediate-to-favorable emotional profiles, particularly for W3 “filling/nutritious” and W4 “refreshing.” These findings indicate that balanced sensory attributes – moderate roasting, natural sweetness, and smooth texture – translate directly into more positive emotional and perceived-wellness responses, in agreement with previous cereal-beverage research (Sloan, 2015; Lee *et al*., 2018).

Table 3: Well-being scale items and their corresponding factors

Item	Statement	Factor category	Interpretation
W1	It makes me feel good	Emotional	Positive affective response
W2	It makes me feel bad	Emotional	Negative affective response
W3	It is filling / nutritious	Physical / Functional	Perceived satiety and nutritional value
W4	The drink is refreshing	Sensory / Hedonic	Perceived refreshing quality

Item	Statement	Factor category	Interpretation
W5	The beverage is good for health	Physical / Functional	Health-related perception
W6	It is a natural source of energy	Physical / Functional	Perceived natural energy provision
W7	It gives a mild, comforting feeling	Emotional	Sense of comfort and calmness
W8	It gives a feeling of satisfaction	Emotional	Sense of fullness and contentment
W9	It gives a feeling of emptiness / dissatisfaction	Emotional	Opposite of satisfaction
W10	It has a relaxing effect	Emotional	Emotional relaxation
W11	It has a pleasant taste	Emotional	Taste pleasantness perception
W12	It provides a fresh or strong flavor	Sensory / Hedonic	Flavor intensity and freshness

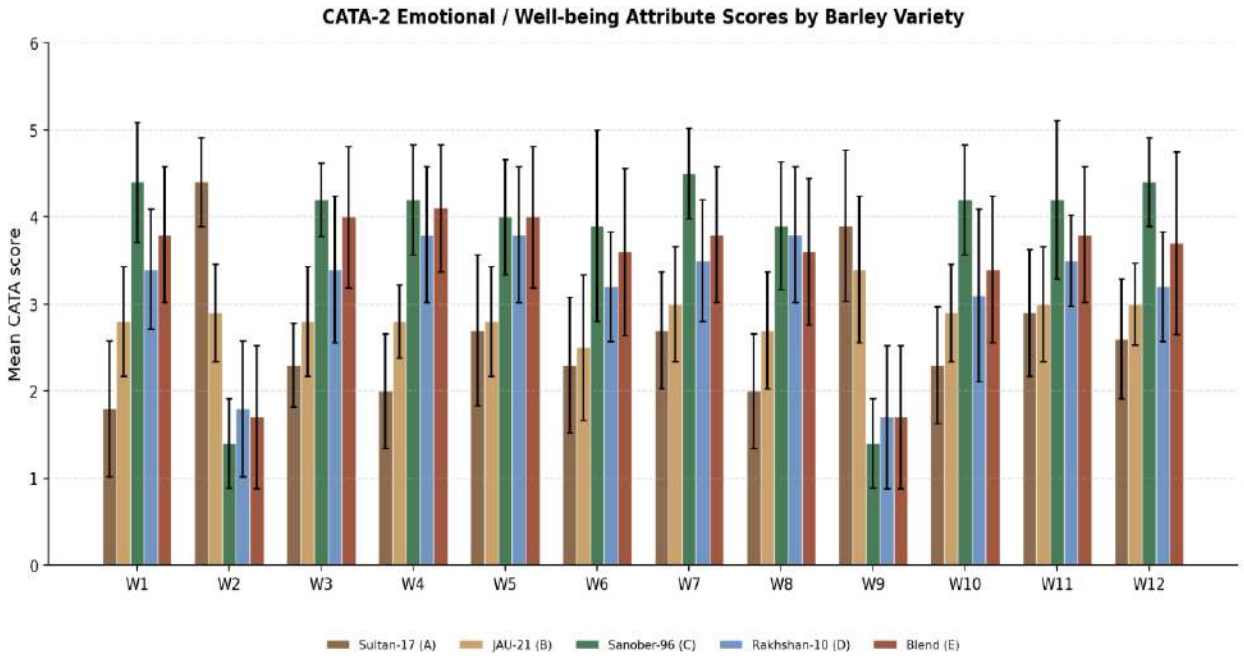

Fig. 3: CATA-2 emotional / well-being attribute scores (W1–W12) for roasted barley drink treatments

Table 4: Sensory attributes of barley drink evaluated by the CATA-2 method (mean ± SD)

Treatment	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
A	1.80d ±0.78	4.40a ±0.51	2.30c ±0.48	2.00c ±0.66	2.70b ±0.87	2.30c ±0.78	2.70d ±0.67	2.00c ±0.66	3.90a ±0.87	2.30c ±0.67	2.90c ±0.73	2.60c ±0.69
B	2.80c ±0.63	2.90b ±0.56	2.80c ±0.63	2.80b ±0.42	2.80b ±0.63	2.50b ±0.84	3.00cd ±0.66	2.70b ±0.67	3.40a ±0.84	2.90bc ±0.56	3.00c ±0.66	3.00c ±0.47

Treatment	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
C	4.40a ±0.69	1.40c ±0.51	4.20a ±0.42	4.20a ±0.63	4.00a ±0.66	3.90a ±1.10	4.50a ±0.52	3.90a ±0.73	1.40b ±0.51	4.20a ±0.63	4.20a ±0.91	4.40a ±0.51
D	3.40bc ±0.69	1.80c ±0.78	3.40b ±0.84	3.80a ±0.78	3.80a ±0.78	3.20ab ±0.63	3.50bc ±0.70	3.80a ±0.78	1.70b ±0.82	3.10b ±0.99	3.50bc ±0.52	3.20bc ±0.63
E	3.80ab ±0.78	1.70c ±0.82	4.00a ±0.81	4.10a ±0.73	4.00a ±0.81	3.60a ±0.96	3.80b ±0.78	3.60a ±0.84	1.70b ±0.82	3.40b ±0.84	3.80ab ±0.78	3.70b ±1.05

Means within a column followed by different superscript letters differ significantly ($p < 0.05$, LSD test).

Conclusions

The present study demonstrated the potential of roasted barley as a natural and caffeine-free beverage with promising sensory and consumer acceptance. Significant differences ($p < 0.05$) were observed among the five formulations for flavor, aroma, mouthfeel, color, and overall acceptability. Among the formulations, Sanober-96 showed the highest acceptance, attributed to its smooth mouthfeel, pleasant sweetness, and desirable roasted aroma, whereas Sultan-17 received the lowest acceptance due to its bitterness, heaviness, and harsh roasted flavor. CATA analysis supported the hedonic results, with sweet, smooth, and roasted identified as positive sensory attributes, while bitter, burnt, and grainy were associated with lower acceptance. Emotional profiling further indicated that sensory-balanced products elicited positive responses such as refreshment, comfort, and enjoyment. Overall, the combined application of hedonic evaluation and CATA effectively identified the key sensory and emotional attributes influencing consumer acceptance. The findings provide a useful foundation for further optimization and development of roasted barley beverages as appealing caffeine-free beverage alternatives.

Recommendations

Based on the findings of the present study, the following recommendations are proposed:

- Future studies should combine CATA sensory evaluation with instrumental analyses, including color, texture, and volatile compound profiling, to establish relationships between sensory perceptions and measurable product characteristics.
- Further research is recommended to evaluate the nutritional composition, antioxidant activity, and functional properties of roasted barley beverages to provide scientific evidence for their potential health benefits.
- The incorporation of natural flavoring agents and sweeteners, such as honey, vanilla, cocoa, and other plant-based ingredients, should be investigated to enhance flavour complexity, consumer appeal, and product variety while maintaining the natural character of the beverage.

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