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Instrumental colour evaluation of market and laboratory prepared *Kacha gola*: A comparative study

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Abstract

Kacha gola is a traditional soft Bengali sweetmeat made from freshly prepared *chhana* (heat-and acid-coagulated milk protein), appreciated for its mild sweetness, delicate texture, and characteristic whitish-cream colour. Colour is one of the primary sensory attributes influencing consumer acceptability of dairy-based confections. The present study aimed to evaluate the colorimetric profile (CIE L^* , a^* , b^* values) of three commercial market samples of *Kacha gola* (N, J and D) and to assess the influence of Quinoa Seed Powder (QSP) incorporation at 1%, 2% and 3% levels on the colour attributes of laboratory-prepared *Kacha gola*. Colour parameters were determined using a Hunter Lab colorimeter under standardised conditions. Market sample N demonstrated the highest L^* value (85.55), indicative of superior lightness, combined with the most negative a^* value (-2.007) and an intermediate b^* value (12.81), establishing it as the best market sample in terms of colour. Among treatment samples, T_1 (1% QSP) recorded the optimal balance of L^* (82.89), a^* (-1.358), and b^* (13.67), making it the most acceptable variant. In comparison, Sample N was statistically significant different with Sample T_1 across all three CIE $L^*a^*b^*$ color parameters. Progressive addition of QSP caused a systematic decrease in L^* and a^* values alongside an increase in b^* values, indicating enhanced yellowness with increasing QSP concentration. T_1 was identified as the most suitable treatment, offering characteristic colour profile of traditional *Kacha gola*.

Keywords: *Chhana*, Colorimetry, CIE $L^*a^*b^*$, *Kacha gola*, Quinoa seed powder (QSP), *Sandesh*

1. Introduction

India has a rich tradition of dairy-based sweetmeats that form an integral part of its cultural and culinary heritage. Among these, the eastern Indian confections derived from *chhana* occupy a place of singular importance, having evolved over centuries of artisanal practice in Bengal and Odisha. *Kacha gola* is one of the most delicate and prized of these traditional sweetmeats, renowned for its soft, melt-in-the-mouth texture, subtle sweetness and characteristic pale cream colour. The name itself, translating roughly to 'raw spherical mass' reflects its semi-processed nature relative to more elaborately cooked Bengali sweets (Pal and Riar, 2014) [13].

Kacha gola belongs to the broad category of *sandesh* one of the most celebrated families of Indian dairy confections. *Sandesh* is prepared from *chhana*, the freshly made heat-and acid-coagulated indigenous dairy product that serves as the foundational material for a wide array of Bengali sweets. Traditional *sandesh* involves kneading *chhana* with sugar, with or without mild heating, and shaping the mixture into various forms. Within the *sandesh* family, *Kacha gola* represents the softest and least-cooked variant, prepared essentially by working *chhana* and sugar together at ambient or minimally elevated temperatures to achieve a cohesive, smooth, lightly sweetened mass that is then moulded into rounded shapes. This semi-raw preparation method preserves the freshness and delicate flavour of *chhana* to a degree not achieved in more processed varieties such as *sandesh* or *Kancha golla* prepared by extensive cooking (Ganguly *et al.*, 2018; Chandan, 2011) [8, 4].

Sandesh, as a product category, has attracted increasing research interest for its nutritional richness, unique textural properties and potential as a vehicle for functional ingredient incorporation. Prepared without fermentation or extended cooking, *Sandesh* retains the high biological value proteins, fat-soluble vitamins, and minerals of the milk from which it is derived.

Numerous studies have explored modifications to *Sandesh* formulations through incorporation of fruit pulps, vegetable extracts, herbal powders, and other functional ingredients aimed at enhancing its nutritional profile while preserving organoleptic acceptability (Chawla *et al.*, 2017; Bhatt and Patel, 2020) ^[5, 2].

The base material for *Kacha gola* and all *chhana*-derived confections is *chhana* itself. *Chhana* is prepared by coagulating hot whole milk at temperatures between 70 and 90 °C using food-grade acidulants such as citric acid, lactic acid, or vinegar, followed by draining of the whey through muslin cloth. The resulting curd is a soft, white to off-white mass with a characteristic mild, slightly acidic flavour. Its chemical composition, including moisture content, fat, protein, and lactose, critically determines the quality and yield of *chhana* and ultimately governs the textural and colour attributes of *chhana*-based sweetmeats (Bhattacharya *et al.*, 2012; De, 2004) ^[3, 6]. The colour of *chhana*, and consequently of *Kacha gola*, is determined primarily by the Maillard browning reactions involving reducing sugars and proteins during any heat treatment, the carotenoid content of the milk fat, and the degree of syneresis and whey drainage. Colour is among the most immediate and powerful sensory attributes perceived by consumers in evaluating dairy products. In sweetmeats like *Kacha gola*, a pale whitish-cream colour with a slight yellowish tinge is considered the hallmark of freshness and quality, whereas excessive browning, greyness, or dullness is regarded as indicative of poor milk quality, improper processing, or adulteration (Dutta *et al.*, 2019) ^[7]. The CIE L*a*b* colorimetric system provides a standardised, objective, and device-independent means of quantifying colour in three-dimensional colour space: L* denotes lightness (0 = black; 100 = white), a* denotes redness-to-greenness (+ a* = red; -a* = green), and b* denotes yellowness-to-blueness (+ b* = yellow; -b* = blue). This system has been widely adopted in food science research for its perceptual uniformity and ability to detect subtle colour differences that may not be apparent to the naked eye (Hunterlab, 2008; McGuire, 1992) ^[9, 11].

Quinoa (*Chenopodium quinoa* Willd.) has gained remarkable global attention as a functional food ingredient owing to its exceptional nutritional profile. Quinoa seed powder (QSP) is rich in complete protein (containing all essential amino acids), dietary fibre, polyunsaturated fatty acids, vitamins (particularly B-complex and E), minerals (iron, calcium, magnesium, zinc), and bioactive compounds including saponins, flavonoids, and phytosterols (Repo-Carrasco *et al.*, 2003; Navruz-Varli and Sanlier, 2016) ^[14, 12]. Its incorporation into traditional dairy-based confections represents a promising strategy to improve the nutritional density of these products, which, while energy-rich, may be limited in certain micronutrients and dietary fibre. However, QSP possesses a characteristic light beige to yellowish colour and mild earthy flavour that may influence the colour profile of the final product upon incorporation.

Systematic colorimetric data on commercially available market samples is still lacking determining consumer preference and product quality of *Kacha gola*, also effect of functional ingredient incorporation on colour characteristics remain limited. The present study therefore aimed to: (i) evaluate and compare the CIE L*, a*, and b* colorimetric parameters of three commercially procured market samples of *Kacha gola*, (ii) identify the market sample with the most desirable colour profile and (iii) assess the effect of different levels of incorporation of quinoa seed powder (at 1%, 2%

and 3%) on the colorimetric attributes of laboratory-prepared *Kacha gola* in comparison with control sample and treatments.

2. Materials and Methods

2.1 Collection of Market Samples

Three commercially available market samples of freshly prepared *Kacha gola* were procured from three established confectionery outlets from Raipur market and designated as Sample N, J and D to maintain confidentiality of vendors. Samples were collected on the day of preparation in the early morning hours, immediately transported to the laboratory under conditions (approximately 4 °C) in food-grade sealed PET cups and analysed within two hours of collection to minimise post-procurement colour changes due to surface drying, oxidation or Maillard browning. Triplicate samples were collected from each vendor on four separate occasions to account for natural batch-to-batch variation, yielding four colour readings per sample for statistical reliability (AOAC, 2019) ^[1].

All samples were evaluated under identical conditions to ensure comparability of results. The samples were allowed to reach ambient temperature (25±1 °C) prior to colour measurement and care was taken to avoid surface contamination, mechanical deformation or exposure to direct light prior to measurement.

2.2 Preparation of Treatment Samples

For the treatment study, *Kacha gola* was prepared in the laboratory following a standardised recipe. Fresh whole cow milk was used for *Chhana* preparation by hot acid coagulation using 1% citric acid solution. *Chhana* yield was standardised and the freshly prepared *chhana* was kneaded with refined sugar. Quinoa seed powder (QSP) was prepared by cleaning, washing and drying quinoa seeds, followed by grinding in a laboratory blender and sieved in 80 mesh size to obtain a uniform fine powder. QSP was incorporated at 0% (T₀, control), 1% (T₁), 2% (T₂) and 3% (T₃) on a weight basis of the *chhana*-sugar (5%) was used in mixture. All treatment samples were prepared under identical conditions and evaluated in quadruplicate for colorimetric analysis.

2.3 Colorimetric Analysis

Colorimetric measurements were performed using a Hunter Lab colorimeter (Model ColorFlex EZ, HunterLab, USA) calibrated with standard black and white tiles prior to each measurement session. Measurements were conducted under D65 illuminant with a 10° standard observer angle to simulate daylight conditions. The instrument was set to record CIE L*, a* and b* values directly. For each sample, a small portion of *Kacha gola* was placed in a standardised sample holder, ensuring uniform surface coverage and consistent depth. Four readings were recorded for each sample by rotating the sample between measurements to account for surface heterogeneity and the mean values were computed. The derived parameters hue angle ($h^\circ = \arctan(b^*/a^*)$) and chroma ($C^* = \sqrt{a^{*2} + b^{*2}}$) were calculated from the primary L*, a*, and b* values to further characterise the colour (McGuire, 1992; Konica, 2007) ^[11, 10].

All experimental data were subjected to one-way analysis of variance (ANOVA). Treatment means were compared at the 5% level of significance ($p < 0.05$) using the critical difference method. Mean values and standard deviations were calculated for all colour parameters.

3. Results and Discussion

3.1 Colorimetric Profile of Market Samples

The CIE L*, a*, and b* values recorded for the three commercial market samples of *Kacha gola* are presented in Table 1. All samples exhibited characteristic colour profiles of *chhana*-based confections high positive L* values indicative of lightness, small negative a* values reflecting a marginal green bias, and moderate positive b* values indicating yellowness.

Table 1: CIE L*, a*, and b* colorimetric parameters of market samples of *Kacha gola*.

Sample	Mean L*	Mean a*	Mean b*	Hue Angle (h°)	Chroma (C*)
N	85.71	-2.01	12.81	98.9°	12.97
J	81.05	-1.44	12.69	96.5°	12.89
D	85.39	-1.59	11.10	98.2°	11.21

QSP = Quinoa Seed Powder; h° = Hue angle; C* = Chroma. Values represent means of four replicates.

Table 2: Colourimetric values of market samples of *Kacha gola* collected from three retail confectionery outlets in Raipur district

Market sample				
CIE L*a*b* Parameter	(N)	(J)	(D)	F value
L*	85.71±0.23 ^a	81.05±0.25 ^b	85.39±0.18 ^a	130.52*
a*	-2.01±0.04 ^a	-1.43±0.03 ^a	-1.59±0.09 ^a	0.15 ^{NS}
b*	12.81±0.12 ^b	12.69±0.41 ^b	11.10±0.26 ^a	10.85*

Values are mean±SE of four independent replicates. Different superscript letters within the same column indicate that treatment means differ significantly ($p < 0.05$). a values NS were non-significant.

3.1.1 Lightness (L*)

The L* values of market samples ranged from 81.05 (Sample J) to 85.55 (Sample N), with Sample D recording an intermediate value of 85.39. Sample N demonstrated significantly higher mean L* value of 85.55, followed closely by Sample D (85.39) and then Sample J (81.05). The significantly lower L* value of Sample J suggests a comparatively darker appearance, possibly attributable to differences in milk quality (higher carotenoid content, non-standardised fat levels), acid type or concentration used during coagulation, degree of *chhana* drainage affecting moisture and surface reflectance or presence of minor sugar browning during kneading (Bhattacharya *et al.*, 2012; Dutta *et al.*, 2019)^[3, 7]. High L* values in *chhana*-based sweets are generally associated with fresh, high-quality milk and optimal processing conditions, and are preferred by Indian consumers who associate whiteness with purity and freshness (Pal and Riar, 2014)^[13]. The closeness of L* values between Samples N and D indicates that both were prepared from comparable quality milk with similar processing practices.

3.1.2 Redness/Greenness (a*)

All market samples recorded negative a* values, consistent with the expected colour space position of *chhana*-based dairy confections. Negative a* values in the range reported here (-1.44 to -2.007) confirm the slight green bias typical of *Kacha gola*, arising from the absence of significant Maillard browning (which would shift a* towards positive values). Sample N exhibited the most negative a* value (-2.007), indicating the greatest green component and correspondingly the lowest red bias, a characteristic associated with minimal heat processing and high freshness. Sample D (-1.597) and Sample J (-1.44) had less negative a*

values, suggesting marginally greater red-yellow contributions, possibly from slightly more advanced Maillard reactions or differences in milk fat composition (Chawla *et al.*, 2017)^[5]. More negative a* values in *Kacha gola* are generally regarded as desirable as they correlate with fresh, unbrowned *chhana* of high quality.

3.1.3 Yellowness (b*)

The b* values of market samples ranged from 11.10 (Sample D) to 12.81 (Sample N). Sample N recorded the highest mean b* value (12.81), followed by Sample J (12.695) and Sample D (11.10). The b* value in *Kacha gola* is primarily determined by the riboflavin content of the milk, carotenoid pigments in the milk fat and the extent of non-enzymatic browning (Maillard reaction) during processing (De, 2004)^[6]. A moderate positive b* value is considered a desirable quality attribute in *Kacha gola*, contributing to a warm, cream-yellow hue indicative of good fat content and natural milk pigments. The notably lower b* of Sample D suggests either reduced fat content, lower riboflavin levels, or more extensive whey drainage resulting in reduced yellow pigment retention. Sample N's combination of high L* and moderately high b* with the most negative a* places it in the most desirable colour region for this product category.

3.1.4 Identification of Best Market Sample

Based on the holistic evaluation of all colorimetric parameters, Sample N emerged unequivocally as the best market sample of *Kacha gola*. In one-way ANOVA analysis, statistically significant differences were observed among the three market samples for L* ($F = 130.52$, $p < 0.05$) and b* ($F = 10.85$, $p < 0.05$), while a* showed no significant variation ($F = 0.15$, NS), establishing lightness and yellowness as the principal discriminating colorimetric axes. Sample N recorded the highest L* (85.71 ± 0.23) and b* (12.81 ± 0.12) values, along with the most negative a* (-2.01 ± 0.04), collectively yielding the highest estimated chroma ($C^* \approx 12.97$) and hue angle ($h^\circ \approx 98.9^\circ$), which positions it firmly within the consumer-preferred whitish-cream-yellow quadrant characteristic of premium *Kacha gola*. Post-hoc mean separation revealed that while Sample N and Sample D were statistically at par for L* (85.71 ± 0.23 vs. 85.39 ± 0.18 ; superscript 'a'), Sample D was significantly inferior in b* (11.10 ± 0.26 vs. 12.81 ± 0.12 ; superscript 'a' vs. 'b'), indicating a perceptibly duller yellow coloration, while Sample J recorded the lowest L* (81.05 ± 0.25 ; superscript 'b'). These findings are consistent with previous reports demonstrating that higher L* and moderate b* values are positively correlated with consumer acceptability scores in *Chhana*-based sweetmeats (Ganguly *et al.*, 2018; Dutta *et al.*, 2019)^[8, 7]. Sample D, while possessing a comparable L* value to Sample N, was discriminated from Sample N principally by its markedly lower b* value (11.10 vs. 12.81), indicating a less vibrant, duller yellow colour. Sample J, with its considerably lower L* (81.05), was the least preferred market sample in terms of colour.

3.2 Effect of Quinoa Seed Powder addition on Colorimetric Parameters

The effect of progressive quinoa seed powder incorporation on the colour parameters of laboratory-prepared *Kacha gola* is presented in Table 2. A clear and consistent trend was observed across all colour parameters with increasing QSP concentration.

Table 3: Effect of quinoa seed powder (QSP) addition on CIE L*, a*, and b* colorimetric parameters of *Kacha gola*.

Treatment	Mean L*	Mean a*	Mean b*	Hue Angle (h°)	Chroma (C*)
T ₀ (Control)	84.18	-1.47	12.94	96.5°	13.02
T ₁ (1% QSP)	82.88	-1.36	13.67	95.7°	13.74
T ₂ (2% QSP)	81.93	-1.26	14.59	94.9°	14.65
T ₃ (3% QSP)	81.29	-1.10	15.29	94.1°	15.34

T₀ = Control (0% QSP); T₁ = 1% QSP; T₂ = 2% QSP; T₃ = 3% QSP. Values represent means of four replicates.

Table 4: Colourimetric values of lab prepared samples of *Kacha gola*

CIE L*a*b* Parameter	T ₀ (Control)	T ₁ (1% QSP)	T ₂ (2% QSP)	T ₃ (3% QSP)	F-value
L*	84.18±0.45 _a	82.88±0.34 _b	81.93±0.07 _b	81.29±0.28 _c	15.79*
a*	-1.47±0.01 _a	-1.36±0.03 _b	-1.26±0.03 _c	-1.10±0.01 _d	38.32*
b*	12.94±0.18 _d	13.67±0.12 _c	14.59±0.13 _b	15.29±0.02 _a	67.15*

*Values are mean±SE of four independent replicates. Different superscript letters within the same column indicate that treatment means differ significantly ($p < 0.05$).

3.2.1 Effect on Lightness (L*)

The L* values showed a progressive and statistically significant ($p < 0.05$) decrease with increasing levels of QSP incorporation, ranging from 84.19 in the control (T₀) to 81.19 in the highest incorporation level (T₃). T₁ (1% QSP) recorded a mean L* of 82.89, T₂ (2% QSP) recorded 81.93 and T₃ (3% QSP) recorded 81.19. The reduction in L* with increasing QSP is attributable to the intrinsic colour of quinoa seed powder, which carries light beige-to-yellowish pigmentation primarily from flavonoids, phytosterols, and residual carotenoids present in the seed pericarp and germ (Repo-Carrasco *et al.*, 2003; Navruz-Varli and Sanlier, 2016) [14, 12]. As QSP concentration increased, its pigments progressively displaced the white background of *chhana*, resulting in a measurable darkening of the product. These findings are consistent with those of Shobha *et al.* (2018) [15], who reported significant reductions in L* values of dairy-based confections upon incorporation of plant-derived powders, and Bhatt and Patel (2020) [2], who documented similar trends in quinoa-fortified paneer.

3.2.2 Effect on a* Values

The a* values increased progressively (became less negative) with increasing QSP addition, from -1.478 in T₀ to -1.103 in T₃. T₁ recorded a mean a* of -1.358, T₂ recorded -1.265, and T₃ recorded -1.103. This trend indicates a systematic reduction in the green component and a shift towards a marginally less green (more red-neutral) colour space position with increasing QSP. The shift in a* is associated with the presence of reddish-brown pigments (phenolics, flavonoids) in quinoa seeds that partially counteract the natural green bias of *chhana* (Chawla *et al.*, 2017; Repo-Carrasco *et al.*, 2003) [14, 5]. While all a* values remained in the negative range across all treatments, the progressive increase towards zero at higher QSP levels may

become organoleptically perceptible at concentrations beyond 3%, potentially diminishing the fresh whitish appearance characteristic of high-quality *Kacha gola*. T₁ a* value of -1.358, while less negative than the control (-1.478), represented only a minimal deviation from the baseline and was within the range of values considered acceptable for *Kacha gola* (Dutta *et al.*, 2019) [7].

3.2.3 Effect on b* Values (Yellowness)

The b* values increased significantly ($p < 0.05$) and linearly with increasing QSP incorporation, from 12.94 in the control (T₀) to 15.30 in T₃. T₁ recorded a mean b* of 13.67, T₂ recorded 14.60, and T₃ recorded 15.30. The progressive increase in b* with QSP addition reflects the yellow pigmentation contributed by quinoa's flavonoids (particularly quercetin and kaempferol glycosides), carotenoids (beta-carotene and lutein) and riboflavin content of the seed (Navruz-Varli and Sanlier, 2016; Repo-Carrasco *et al.*, 2003) [12, 14]. While moderate yellowness is a desirable and characteristic attribute of good-quality *Kacha gola*, excessively high b* values at 2% and 3% QSP levels (14.60 and 15.30, respectively) represent a significant departure from the typical colour profile of this product and could adversely influence consumer acceptability, as the product would acquire a noticeably yellow hue distinct from the traditional whitish-cream appearance (Ganguly *et al.*, 2018) [8].

3.2.4 Identification of Best Treatment: T₁ (1% Quinoa Seed Powder)

A comprehensive evaluation of all colorimetric parameters across treatment groups clearly identifies T₁ (1% QSP) as the optimal treatment for quinoa incorporated *Kacha gola*. T₁ demonstrated an L* value of 82.89 marginally lower than the control (84.19) but representing only a 1.54% reduction in lightness, which is unlikely to be perceptible to an average consumer under normal viewing conditions given that the just-noticeable difference (JND) for lightness in dairy confections has been reported to be approximately 2-3 L* units (Hunterlab, 2008; Konica Minolta, 2007) [9, 10]. The a* value of T₁ (-1.358) remained comfortably in the negative range, preserving the slight green bias characteristic of fresh *chhana*. Most importantly, T₁ b* value of 13.67 represents only a modest and aesthetically pleasant enhancement of yellowness over the control (12.94), contributing to a slightly richer, creamier visual appearance without introducing the overtly yellow hue observed at higher QSP levels. T₁ chroma (C* = 13.74) and hue angle (h° = 95.7°) similarly fell within the acceptable colour space for premium *Kacha gola*.

In contrast, T₂ and T₃ demonstrated progressively greater colour deviations particularly in b* values (14.60 and 15.30 respectively) that represent statistically and potentially organoleptically significant departures from the control. The total colour difference (ΔE^*) calculated between treatments and the control, using the formula $\Delta E^* = \sqrt{(\Delta L^*{}^2 + \Delta a^*{}^2 + \Delta b^*{}^2)}$, yielded values of approximately 1.44 for T₁, 2.93 for T₂ and 3.69 for T₃. A ΔE^* value below 2.0 is generally considered imperceptible to most observers, between 2.0 and 3.5 is slightly perceptible, and above 3.5 is clearly perceptible (Hunterlab, 2008) [9]. T₁ thus falls comfortably below the perceptibility threshold, confirming that 1% QSP incorporation does not produce a visually distinguishable colour change from the control for the typical consumer.

Furthermore, the nutritional advantages of QSP incorporation at the 1% level are well-established. Even at this relatively modest incorporation level, QSP contributes meaningful quantities of complete protein, dietary fibre, iron, calcium, and bioactive compounds to the product matrix (Navruz-Varli and Sanlier, 2016; Repo-Carrasco *et al.*, 2003) ^[12, 14], making T₁ an optimal trade-off between nutritional enhancement and colour quality preservation. These findings are in agreement with Bhatt and Patel (2020) ^[2], who identified 1% quinoa incorporation as the most acceptable level in quinoa-enriched paneer based on sensory and instrumental colour analysis, and with Chawla *et al.* (2017) ^[5], who reported that low-level fortification ($\leq 1.5\%$) of *chhana*-based products with functional seed powders preserved colour acceptability without compromising product identity.

3.3 Comparative Analysis: Best Market Sample (N) vs. Best Treatment (T₁)

A direct comparison between Sample N (best market sample) and T₁ (best treatment) reveals instructive parallels and differences. An independent samples t-test revealed statistically significant differences between Sample N and Sample T₁ across all three CIE L*a*b* color parameters (all $p < .001$). Sample N was significantly lighter (L^* : 85.72 vs. 82.87), redder (a^* : 2.03 vs. 1.32) and less yellow (b^* : 12.81 vs. 13.66) than Sample T₁. The L^* value of Sample N was higher than T₁, suggesting marginally greater lightness in the commercial sample a difference attributable to the longer commercial experience of the confectioner in sourcing optimal milk and achieving precise *chhana* drainage. The a^* value of Sample N was considerably higher than T₁, reflecting Sample N superior freshness and minimal heat processing relative to the laboratory preparation protocol. The b^* value of T₁ slightly exceeded that of Sample N, indicating modestly greater yellowness in the quinoa-incorporated product, a consequence of the yellow pigmentation contributed by QSP. The overall colour profiles of both samples are within the acceptable range for high-quality *Kacha gola*, and T₁ marginal colour deviations from Sample N are within the slightly perceptible range, confirming its suitability as traditional colour identity of *Kacha gola*.

4. Conclusion

The study revealed that among the three market samples of *Kacha gola*, Sample N showed the most desirable colour characteristics, with the highest lightness ($L^* = 85.55$), the lowest a^* value (-2.007), and the highest b^* value (12.81), indicating superior freshness, minimal browning, and desirable milk pigmentation. Thus, Sample N may serve as a colour quality benchmark for premium *Kacha gola*.

Incorporation of quinoa seed powder (QSP) into laboratory-prepared *Kacha gola* caused a concentration-dependent decrease in L^* and a^* values and an increase in b^* values, reflecting the pigment contribution of quinoa. Among the treatments, T₁ (1% QSP) was found optimal, showing a minimal total colour difference from the control.

The findings suggest that QSP can be effectively used as a functional additive ingredient in *chhana*-based sweets at controlled levels without significantly affecting the characteristic colour quality of *Kacha gola*. Further, studies on sensory attributes, texture, nutritional composition, and

shelf life are recommended to support its commercial application as a nutritionally enriched traditional sweet.

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