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Sugar Concentration Determines Soluble Solids and Sensory Quality of Strawberry Syrup Thickened with Eucheuma cottonii Extract

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ABSTRACT

Strawberry syrup quality depends on balancing soluble solids, fruit identity, color, and mouthfeel. This study evaluated four nominal sugar treatments in strawberry syrup containing a fixed amount of Eucheuma cottonii extract as a natural thickener. Each formulation contained 500 mL seaweed extract, 500 mL strawberry juice, and 1,000 mL water, with 2.0, 2.4, 2.8, or 3.2 kg sucrose, designated as 50%, 60%, 70%, and 80%, respectively. Total soluble solids were measured by hand refractometry, and color, aroma, taste, viscosity liking, and overall acceptance were assessed organoleptically. Sugar concentration significantly affected total soluble solids and all reported sensory attributes ($P < 0.01$). Total soluble solids increased from 42.3 °Brix at 50% sugar to 57.2 °Brix at 80%. Color and viscosity liking declined as sugar increased, whereas aroma and taste peaked at 70%, with scores of 4.37 and 4.27. Overall acceptance ranged from 3.7 to 3.8 and was highest at 70%. The 70% treatment provided the most favorable compromise among strawberry flavor, appearance, texture, and overall liking

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INTRODUCTION

Fruit syrups are concentrated beverage ingredients valued for convenience, sweetness, characteristic aroma, and ease of dilution. Their quality depends on the coordinated perception of sweetness, acidity, color, fruit aroma, flavor, and mouthfeel rather than on any single attribute. In Indonesia, syrup is regulated under SNI 3544:2013, which defines the product as a sugar-and-water-based beverage preparation that may contain permitted food ingredients and additives (Badan Standardisasi Nasional, 2013). Refractometric total soluble solids provide a rapid index of dissolved sugars and other soluble constituents, although the reading also includes organic acids, minerals, pigments, and soluble macromolecules (Magwaza & Opara, 2015; AOAC International, 2023).

Strawberry (Fragaria × ananassa) is suitable for syrup processing because of its recognizable red color, sweet-acid flavor, vitamin C, phenolic compounds, and anthocyanins (Giampieri et al., 2012; Newerli-Guz et al., 2023). The fruit is highly perishable, and processing extends its utilization beyond the fresh-fruit marketing period. However, the compounds responsible for fresh color and aroma are sensitive to oxygen, temperature, pH, matrix composition, and storage conditions (Martinsen et al., 2020; Teribia et al., 2021; Salazar-Orbea et al., 2023).

Sucrose simultaneously increases sweetness, soluble solids, body, and preservation potential, but greater sugar addition does not necessarily improve acceptance. Excessive sweetness or thickness may suppress freshness, change aroma release, and reduce fruit-flavor intensity. Hydrocolloids provide an alternative means of increasing body without relying exclusively on sugar. Eucheuma cottonii is a red seaweed associated with carrageenan-rich materials that can increase viscosity and modify suspension stability (Yang & Yang, 2020; Hale et al., 2024).

This study evaluated strawberry syrup formulations containing a fixed amount of E. cottonii extract and four nominal sugar treatments: 50%, 60%, 70%, and 80%. Strawberry juice, seaweed extract, and water were held constant, while sucrose mass increased from 2.0 to 3.2 kg. The objectives were to determine the effect of sugar concentration on total soluble solids and sensory attributes and to identify the most acceptable formulation. It was hypothesized that soluble solids would increase with sugar addition, whereas sensory acceptance would show an intermediate optimum.

LITERATURE REVIEW

Sugar Concentration and Syrup Quality

Sugar influences fruit beverages through sweetness, soluble-solids development, water binding, viscosity, and flavor balance. Studies on fruit syrups and related preserves consistently show that the sugar-to-fruit ratio affects soluble solids, acidity, color, rheology, and sensory acceptance (Ahmed et al., 2016; Melisa & Mardesci, 2016; Fitri et al., 2017; Bastanta et al., 2017; Marwanto et al., 2016). Consequently, formulation optimization should seek a sensory balance rather than the maximum attainable sugar concentration.

Total soluble solids are commonly determined by refractometry. In fruit products, the measurement is dominated by sugars but also reflects organic acids, minerals, pigments, and soluble polysaccharides (Magwaza & Opara, 2015). A high °Brix value therefore indicates a concentrated soluble phase but does not independently establish sensory quality, water activity, microbiological stability, or regulatory compliance.

Strawberry Color and Cross-Modal Sensory Perception

Strawberry redness is largely associated with anthocyanins, whose stability depends on cultivar, oxygen exposure, pH, temperature, enzymes, copigments, and matrix composition. Thermal processing and storage can change lightness, hue, chroma, and anthocyanin retention in strawberry products (Martinsen et al., 2020; Ertan et al., 2020; Teribia et al., 2021; Bingöl et al., 2022). Processing conditions must therefore be controlled when higher sugar concentrations are evaluated.

Sweetness, aroma, and viscosity interact during beverage consumption. Aroma can alter sweetness judgments, while viscosity can modify aroma release and flavor intensity (Bertelsen et al., 2020). This cross-modal relationship explains why a formulation with the highest soluble-solids concentration may not obtain the highest overall acceptance. Product development should therefore evaluate color, aroma, taste, mouthfeel, and overall liking together (Mahato et al., 2020; Skąpska et al., 2020).

Eucheuma Cottonii as a Natural Thickener

Eucheuma cottonii contains carrageenan-rich polysaccharides with water-binding and rheological functions. Carrageenan behavior varies with molecular structure, mineral composition, extraction conditions, temperature, and interactions with sugars and other solutes (Yang & Yang, 2020; Huang et al., 2022; Hale et al., 2024). Seaweed-based ingredients have also been investigated for improving the physical and sensory characteristics of beverages (Yuniarti et al., 2019).

Using an aqueous seaweed extract rather than purified carrageenan introduces uncertainty because the concentration of functional polysaccharide, salts, proteins, and insoluble particles may vary. A formulation containing crude extract must therefore be evaluated within its specific product matrix. The present study addresses this need by combining a fixed seaweed-extract dose with a graded sugar series and measuring both refractometric and sensory responses.

METHODOLOGY

Raw Materials and Seaweed-Extract Preparation

The experimental record identified fresh strawberries, granulated sucrose, water, and Eucheuma cottonii as the principal ingredients. Twenty grams of E. cottonii were subjected to a potassium hydroxide whitening treatment, combined with 200 mL water, and heated to prepare the seaweed extract. The duration, temperature, final extract yield, residual alkali control, and washing or neutralization procedure were not reported.

Strawberry juice was prepared by blending 1,000 g strawberries. The cultivar, maturity stage, sorting procedure, filtration conditions, cooking temperature, cooking time, final batch mass, and filling conditions were not documented. These unreported variables were not reconstructed.

Experimental Formulations

Four formulations were prepared with a fixed liquid base of 500 mL seaweed extract, 500 mL strawberry juice, and 1,000 mL water. Granulated sugar was varied from 2.0 to 3.2 kg. The percentages are retained as nominal designations from the source record because the calculation basis was not specified. Table 1 summarizes the formulations.

Table 1. Reported formulation of strawberry syrup treatments.

Treatment	**Nominal sugar level**	**Sugar (kg)**	**Seaweed extract (mL)**	**Strawberry juice (mL)**	**Water (mL)**
A1	50%	2.0	500	500	1,000
A2	60%	2.4	500	500	1,000
A3	70%	2.8	500	500	1,000
A4	80%	3.2	500	500	1,000

Total Soluble Solids

Total soluble solids were determined using a hand refractometer. A small syrup aliquot was placed on the prism, and the boundary between the light and dark fields was read as the refractometric soluble-solids value. The method follows the general principle used for fruit products (Magwaza & Opara, 2015; AOAC International, 2023). Instrument range, calibration, measurement temperature, temperature compensation, and replicate readings were not reported.

Sensory Evaluation

Organoleptic evaluation covered color, aroma, taste, viscosity liking, and overall acceptance. The numerical results indicate an ordinal scale, but the scale anchors, panel size, panelist training, sample volume, serving temperature, presentation order, random coding, palate cleansing, and ethical-consent procedures were not documented. The findings are therefore interpreted as comparative scores within the tested set rather than population-level consumer estimates (Lawless & Heymann, 2010; Stone et al., 2012; Sirangelo, 2019).

Statistical Analysis and Data Handling

The source record reported analysis of variance and highly significant treatment effects at $P < 0.01$. Pairwise differences in the sensory table were expressed using Tukey's honestly significant difference test at $\alpha = 0.05$; means followed by the same lowercase letter within a row were considered not significantly different. Replication, error terms, degrees of freedom, and statistical software were not reported. Where narrative values conflicted with the structured sensory table, the table was treated as the primary numerical record.

RESEARCH RESULT

Total Soluble Solids

Nominal sugar concentration had a highly significant effect on total soluble solids ($P < 0.01$). The lowest reported value was 42.3 °Brix in A1, which contained 2.0 kg sugar and was designated as the 50% treatment. The highest value was 57.2 °Brix in A4, which contained 3.2 kg sugar and was designated as the 80% treatment. The observed range was therefore 14.9 °Brix.

The results established a positive direction of response: increasing sugar addition increased the concentration of soluble material measured by refractometry. Individual A2 and A3 readings, measures of dispersion, and replicate values were not available; consequently, no dose-response model was fitted.

Sensory Characteristics

Sugar concentration significantly affected color, aroma, taste, and viscosity liking ($P < 0.01$). The complete sensory dataset is presented in Table 2. The attributes followed different response patterns, indicating that increasing sugar did not improve all aspects of quality simultaneously.

Table 2. Effect of nominal sugar concentration on sensory scores of strawberry syrup.

Attribute	**A1 (50%)**	**A2 (60%)**	**A3 (70%)**	**A4 (80%)**
Color	4.20 b	4.16 b	3.23 a	3.20 a
Aroma	3.17 a	3.20 a	4.37 b	4.23 b
Taste	3.23 a	3.23 a	4.27 b	4.17 b
Viscosity liking	4.30 c	4.23 c	3.23 b	3.07 a
Overall acceptance	3.70	3.70	3.80	3.70

Note. Within each attribute row, values followed by the same lowercase letter were reported as not significantly different by Tukey's HSD at a = 0.05. No grouping letters were provided for overall acceptance.

Color scores were highest in A1 and A2, at 4.20 and 4.16, respectively. A3 and A4 scored 3.23 and 3.20 and formed the lower statistical group. The principal color separation therefore occurred between the lower-sugar and higher-sugar pairs.

Aroma showed the opposite pattern. A1 and A2 scored 3.17 and 3.20, whereas A3 and A4 scored 4.37 and 4.23. Taste followed the same pattern: A1 and A2 both scored 3.23, while A3 and A4 scored 4.27 and 4.17. Aroma and taste were therefore maximized at A3 rather than A4.

Viscosity liking decreased progressively as nominal sugar concentration increased. A1 and A2 scored 4.30 and 4.23, A3 declined to 3.23, and A4 reached the lowest score, 3.07. Overall acceptance varied only from 3.70 to 3.80; A3 obtained the highest mean, 3.80, while A1, A2, and A4 each scored 3.70.

DISCUSSION

Sugar Concentration and Soluble-Solids Development

The increase from 42.3 to 57.2 °Brix was expected because sucrose directly contributes to the refractive index of the liquid phase. Because strawberry juice, water, and seaweed-extract volumes were held constant, added sugar was the most plausible driver of the 14.9 °Brix increase. Similar concentration-dependent responses have been reported in fruit syrups, jams, and related preserves (Ahmed et al., 2016; Melisa & Mardesci, 2016; Fitri et al., 2017; Bastanta et al., 2017; Marwanto et al., 2016).

The treatment labels 50%–80% were not accompanied by a calculation basis and should be understood as nominal designations rather than independently verified mass fractions. The absence of A2 and A3 °Brix values, replicate counts, and variability estimates prevents assessment of linearity and precision. Future work should report initial and final batch mass, evaporation loss, refractometer calibration, measurement temperature, and replicate readings.

Soluble solids alone do not establish microbiological stability. No water-activity, microbial, packaging, pasteurization, or storage data were available. The product should therefore not be described as shelf-stable on the basis of °Brix alone.

Color Response and Strawberry Pigment Stability

Color preference decreased sharply between the 60% and 70% treatments. Strawberry anthocyanins are sensitive to temperature, oxygen, pH, enzymes, copigments, and matrix composition (Giampieri et al., 2012; Newerli-Guz et al., 2023). Thermal processing and storage can change strawberry lightness, hue, chroma, and anthocyanin retention (Martinsen et al., 2020; Teribia et al., 2021). The lower scores at A3 and A4 are therefore consistent with a formulation-processing interaction that reduced the preferred bright-red appearance.

Greater sugar concentration may intensify thermal exposure if a more concentrated mixture requires longer heating or follows a different boiling profile. Heating can promote anthocyanin degradation and nonenzymatic browning, while oxygen incorporated during blending can accelerate pigment loss. Strawberry studies show that pigment stability can be improved or impaired by formulation and processing, and that copigmentation effects depend on temperature and pigment composition (Aamer et al., 2021; Ertan et al., 2020; Bingöl et al., 2022; Stübler et al., 2021).

Instrumental color data were not reported. Sensory scores cannot distinguish lower redness from increased browning, altered hue, turbidity, or light scattering caused by seaweed solids. Future experiments should measure CIELAB coordinates, browning index, monomeric anthocyanins, pH, and dissolved oxygen and should compare controlled thermal and nonthermal processing options (Kim et al., 2021; Radziejewska-Kubzdela, 2023; Murray et al., 2024).

Aroma, Taste, and Overall Acceptance

Aroma and taste were maximized at A3, supporting an intermediate sensory optimum. At lower sugar levels, acidity and possible vegetal or marine notes from the seaweed extract may have been more apparent. Increasing sucrose can suppress sourness and bitterness and improve the congruence of sweet aroma with sweet taste (Zaitoun et al., 2018; Mahato et al., 2020). Once sufficient sweetness was reached, additional sugar did not further improve aroma or taste liking.

The parallel aroma and taste responses are compatible with cross-modal flavor perception. Beverage flavor integrates taste, retronasal aroma, and oral texture; aroma can alter sweetness judgments, and viscosity can influence aroma release (Bertelsen et al., 2020). A3 may therefore have provided a more favorable balance among strawberry volatiles, sweetness, acidity, and body than A1, A2, or A4.

A3 obtained the highest overall score, 3.80, even though A1 and A2 were preferred for color and viscosity. Panelists apparently accepted some loss of redness and thickness preference in exchange for stronger strawberry aroma and taste. The small overall-score range, 3.70–3.80, should be interpreted cautiously because no post-hoc groupings or variability estimates were reported for this attribute.

Seaweed Thickening and Mouthfeel

Viscosity liking declined from 4.30 at A1 to 3.07 at A4. This variable represents sensory preference rather than instrumental viscosity because flow curves, apparent viscosity, yield stress, and consistency index were not reported. Higher sucrose generally increases solution viscosity through greater dissolved-solids concentration and hydrogen bonding with water (Vaclavik & Christian, 2014). In a matrix already containing seaweed hydrocolloids, the combined effect may have produced excessive body at the highest sugar level.

Crude E. cottonii extract may vary in carrageenan concentration, salts, proteins, and insoluble particles. Commercial carrageenans themselves show broad structural and functional variation (Hale et al., 2024), while extraction conditions and sugar-related interactions can modify rheology (Yang & Yang, 2020; Huang et al., 2022). These factors provide a plausible basis for the progressive decline in viscosity liking.

The second research question concerned the optimum seaweed concentration, but seaweed extract was fixed at 500 mL in all treatments. The experiment can identify an optimum sugar treatment only. The stated comparison with carboxymethylcellulose also cannot be evaluated because no carboxymethylcellulose control was reported. A factorial follow-up should vary both sugar and standardized seaweed solids and include a conventional hydrocolloid control.

Product-Standard Implications

If the SNI syrup requirement is applied as a 65 °Brix benchmark, none of the reported treatments reached the threshold; the maximum was 57.2 °Brix. Formal compliance cannot be determined from the available record because the standard's sampling and analytical requirements were not documented and the treatment percentages were nominal. Nevertheless, further concentration or reformulation would be required if a 65 °Brix finished-product criterion applies. Raising solids solely by adding more sugar may reduce color and viscosity liking. Controlled evaporation, solids standardization, or adjustment of the fruit-to-water ratio may offer better routes to compliance while retaining the sensory advantages of A3. Confirmatory consumer testing and shelf-life analysis are necessary before commercialization.

CONCLUSIONS AND RECOMMENDATIONS

Nominal sugar concentration significantly affected the total soluble solids and sensory quality of strawberry syrup containing a fixed amount of Eucheuma cottonii extract. Total soluble solids increased from 42.3 °Brix in the 50% treatment to 57.2 °Brix in the 80% treatment. The sensory response was not monotonic: lower-sugar formulations retained higher color and viscosity-liking scores, while the 70% and 80% treatments produced stronger strawberry aroma and taste.

The 70% treatment provided the best overall balance, achieving the highest aroma score (4.37), taste score (4.27), and overall acceptance (3.80), while avoiding the lowest viscosity-liking score observed at 80% sugar. The 70% formulation is therefore the preferred treatment among those tested. Product selection based solely on °Brix would overlook important trade-offs among color, fruit flavor, and mouthfeel.

Further development should standardize seaweed extract by solids or carrageenan content, report complete panel procedures, and measure instrumental viscosity, color, acidity, water activity, anthocyanins, microbial stability, and shelf life. If a 65 °Brix benchmark applies, process optimization should increase finished-product solids without sacrificing the sensory balance achieved by the 70% treatment.

ADVANCED RESEARCH

The study is constrained by an incomplete processing record, uncharacterized seaweed extract, missing intermediate °Brix values, absent instrumental rheology and color measurements, unreported panel design, and no carboxymethylcellulose control. These limitations prevent optimization of seaweed concentration, precise estimation of treatment effects, and direct comparison between natural and conventional thickeners.

A stronger follow-up experiment should use a replicated factorial design combining several sugar levels with standardized E. cottonii solids. A carboxymethylcellulose control should be included, and treatments should be processed at controlled time-temperature conditions. Response variables should include °Brix, pH, titratable acidity, water activity, CIELAB color, anthocyanins, apparent viscosity, flow behavior, microbial counts, and storage stability.

Consumer testing should specify panel size, recruitment criteria, scale anchors, random coding, serving order, dilution, serving temperature, and ethical consent. Statistical analysis should report replication, variance estimates, model assumptions, effect sizes, and post-hoc comparisons. This design would determine whether seaweed-derived thickening can meet product standards while preserving strawberry color, flavor, and consumer acceptance.

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