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ORIGINAL RESEARCH ARTICLE

Sappan Wood (*Caesalpinia sappan* L.) Powder as a Natural Colorant in Cow's Milk Yogurt: Effects on Viscosity and Instrumental Color

Hasan Muhammad Yusuf[1,2,a], Soegeng Herijanto[1*], Fani Dwi Evadewi[1]

[1] *Faculty of Animal Science, Universitas Wijayakusuma Purwokerto, Purwokerto, Central Java, Indonesia*
[2] *Livestock Product Technology Laboratory, Faculty of Animal Science, Universitas Jenderal Soedirman*
[a] *Undergraduate student, Animal Science Study Program (S1), Faculty of Animal Husbandry, Universitas Wijayakusuma Purwokerto*
Corresponding author: soegengherijanto@unwiku.ac.id

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ABSTRACT

Natural colorants are increasingly sought as replacements for synthetic dyes in dairy products, and sappan wood (*Caesalpinia sappan* L.) is a promising source because its brazilin pigment is both intensely coloured and bioactive. This study evaluated the effect of adding sappan wood powder at different levels on the viscosity and instrumental color (L*, a*, b*) of cow's milk yogurt and identified the level giving the most favorable physical characteristics. A completely randomized design with four treatments — P0 (0%), P1 (1%), P2 (1.5%), and P3 (2% of milk weight) — and five replications was used, and data were analyzed by analysis of variance followed by orthogonal-polynomial and least-significant-difference tests. Sappan wood powder had no significant effect on viscosity ($P>0.05$; overall mean 418.78±62.60 cP) but a highly significant effect on color ($P<0.01$). Lightness (L*) decreased quadratically with increasing powder level (R^2 = 89.6%), while redness (a*) and yellowness (b*) increased quadratically (R^2 = 87.4% and 83.0%, respectively); the overall means were L* = 55.79, a* = 4.76, and b* = 15.62. The color shift is consistent with the pH-dependent behavior of brazilin during acidification, whereas the unchanged viscosity indicates that the protein gel network was not materially altered over the 0–2% range tested. Sappan wood powder can therefore be applied at up to 2% as a natural colorant that markedly enhances the red–yellow appearance of cow's milk yogurt without compromising its consistency.

Keywords: *brazilin; Caesalpinia sappan; instrumental colour; natural colorant; yoghurt viscosity*

INTRODUCTION

Milk is a nutrient-dense animal-source food, and cow's milk is the most widely consumed type because of its availability and balanced composition of lactose, protein, fat, minerals, and vitamins (Amen et al., 2020; Maris & Radiansyah, 2021). Because raw milk is highly perishable and readily contaminated during handling, converting it into fermented products is a long-established preservation strategy. Yogurt, produced by lactic-acid fermentation with Lactobacillus and Streptococcus starters, extends shelf life while developing a characteristic acid flavor and a semisolid, viscous texture, and it has become one of the most popular fermented dairy foods worldwide (Le Ba et al., 2025; Zahra et al., 2024). Its nutritional value and probiotic potential have further positioned it as a carrier for functional and value-adding ingredients (Sharma et al., 2022).

Among such ingredients, natural colorants are of growing interest as replacements for synthetic dyes, both for consumer-safety reasons and because many plant pigments carry additional bioactivity (Jurić et al., 2022). Sappan wood (*Caesalpinia sappan* L.) is a particularly attractive candidate: its characteristic red color originates from brazilin, whose hue is strongly pH-dependent (Meutia et al., 2019), and the wood is rich in bioactive compounds with documented antioxidant, antibacterial, anti-inflammatory, and antitumor activity (Cahyaningtyas et al., 2019; Vij et al., 2023). Sappan wood extract has already been shown to modify the color of a traditional fresh cheese (dangke) without impairing its texture, aroma, or taste (Naheriastuti et al., 2022), and to be acceptable in synbiotic yogurt (Puspadani et al., 2019), suggesting scope for its use as a dual-function natural colorant in fermented dairy products.

Color and viscosity are among the physical attributes that most strongly govern consumer acceptance of yogurt, and both are frequently targeted in natural-additive studies (Akhtaruzzaman et al., 2025; Baria et al., 2021; Dias et al., 2020). However, the specific response of the viscosity and instrumental color (L*, a*, b*) of cow's milk yogurt to sappan wood powder remains poorly documented. This gap matters because the physical behavior of yogurt its protein gel strength, viscosity, and syneresis is markedly affected by milk type, formulation, and processing

(Arab et al., 2023; Setyawardani et al., 2021), so responses observed in other dairy or herbal matrices cannot simply be extrapolated. This study therefore evaluated the effect of adding sappan wood powder at 0, 1, 1.5, and 2% on the viscosity and color of cow's milk yogurt and identified the addition level that produced the most favorable physical characteristics.

MATERIALS AND METHODS

Time and location

The experiment was carried out from 10 to 25 June 2025 at the Laboratory of Animal Product Technology, Faculty of Animal Science, Universitas Jenderal Soedirman, Purwokerto, Indonesia.

Materials

The materials were fresh cow's milk, sappan wood, and a commercial yogurt starter culture (*Lactobacillus bulgaricus*, *Streptococcus thermophilus*, and *Lactobacillus acidophilus*). Equipment included a pasteurizing set (stove, pan, stirrer, thermometer), 300 mL glass jars, a digital balance, an incubator, a refrigerator, a food dehydrator, a grinder, a rotational viscometer, and a colorimeter.

Experimental design

A completely randomized design (CRD) was used with four treatments and five replications, giving 20 experimental units. Treatments were cow's milk yogurt with sappan wood powder added at P0 = 0%, P1 = 1%, P2 = 1.5%, and P3 = 2% of milk weight (Table 1). Figure 1 summarizes the overall workflow, from powder preparation to yogurt manufacture and measurement.

Table 1. Composition of ingredients for cow's milk yoghurt with sappan wood powder addition (per experimental unit).

Ingredient	Unit	P0	P1	P2	P3
Cow's milk	mL	500	500	500	500
Starter culture	g	1.25	1.25	1.25	1.25
Sappan wood powder	%	0	1	1.5	2

Note: Sappan wood powder is expressed as a percentage of milk weight.

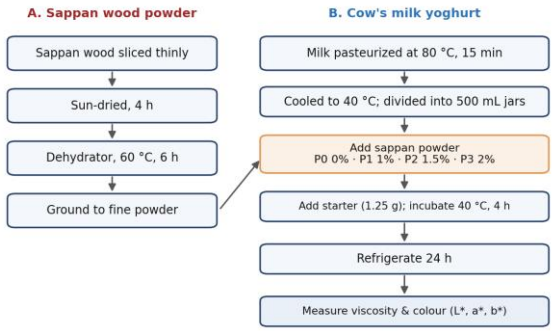

Figure 1. Preparation of sappan wood powder (A) and manufacture of cow's milk yogurt with sappan wood powder addition (B).

Preparation of sappan wood powder

Sappan wood powder was prepared following Fadhlurrohman et al. (2021) with modification to the raw material. Sappan wood was sliced thinly, sun-dried for 4 h, further dried in a food dehydrator at 60 °C for 6 h, and ground to a fine powder (Figure 1A).

Yoghurt manufacture

Yogurt was produced following Setyawardani et al. (2021) with slight modification. For each replication, cow's milk was pasteurized at 80 °C for 15 min and cooled to 40 °C, then divided into 500 mL jars. Sappan wood powder was added according to treatment, followed by 1.25 g of starter culture, and the mixture was incubated at 40 °C for 4 h. The yogurt was then held at refrigeration temperature for 24 h before measuring viscosity and color (Figure 1B).

Viscosity and colour measurement

Viscosity was measured with a rotational viscometer following Prayitno et al. (2020): fresh yogurt was stirred gently for 60 s, and a No. 3 spindle was rotated at 30 rpm for 60 s, with the stabilized reading recorded in centipoise (cP). Color was measured with a colorimeter following Fadhlurrohman et al. (2023): the probe was placed on the surface of a yogurt subsample and L* (lightness), a* (redness), and b* (yellowness) were recorded.

Statistical analysis

Data were analyzed with the CRD model $Yij = \mu + \tau i + \varepsilon ij$, where Yij is the response of treatment i in replication j, μ the overall mean, τi the treatment effect, and εij the experimental error. Analysis of variance (ANOVA) was applied; where the treatment effect was significant ($P<0.05$) or highly significant ($P<0.01$), it was followed by an

orthogonal-polynomial test to identify the response pattern (linear, quadratic, or cubic) and by the least-significant-difference (LSD) test to separate treatment means.

RESULTS AND DISCUSSION

Viscosity

Table 2. Mean viscosity and instrumental color of cow's milk yogurt with sappan wood powder addition (mean ± SD, n = 5).

Treatment	Viscosity (cP)	L*	a*	b*
P0 (0%)	437.40±68.76	61.46±1.54^{a}	0.65±0.18^{b}	9.30±0.66^{b}
P1 (1%)	415.50±33.00	54.68±1.29^{b}	5.06±1.52^{a}	16.27±3.14^{a}
P2 (1.5%)	472.10±49.17	53.51±1.00^{b}	6.29±1.31^{a}	17.86±1.23^{a}
P3 (2%)	350.10±99.48	53.50±1.11^{b}	7.04±0.58^{a}	19.07±1.64^{a}
Overall mean	418.78	55.79	4.76	15.62
Significance	ns	P<0.01	P<0.01	P<0.01

Note: Different superscripts within a column differ significantly (P<0.05, LSD); ns = not significant (P>0.05); P<0.01 = highly significant.

The mean viscosity of cow's milk yogurt with sappan wood powder addition was 418.78±62.60 cP, with the highest value in P2 (1.5%; 472.10 cP) and the lowest in P3 (2%; 350.10 cP). Analysis of variance showed no significant effect of sappan wood powder on viscosity (P>0.05; Figure 2), so the hypothesis that sappan wood powder addition affects yogurt viscosity is rejected.

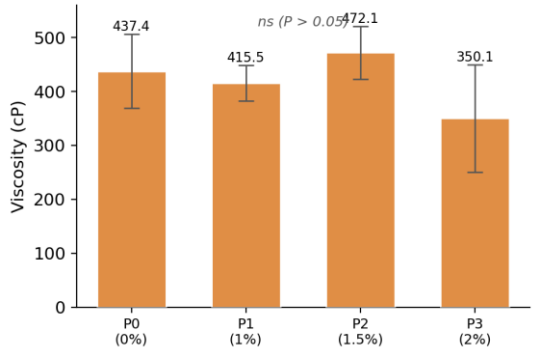

Figure 2. Viscosity of cow's milk yogurt at different levels of sappan wood powder addition (mean ± SD; the difference among treatments was not significant, P>0.05).

The numerically declining trend at the highest level is consistent with a report that adding wedang uwuh extract, of which sappan wood is a component, lowered yogurt viscosity (Anjani et al., 2024), and can be linked to the antibacterial compounds of sappan wood, particularly flavonoids (Cahyaningtyas et al., 2019; Vij et al., 2023). Such compounds may partly suppress lactic-acid-bacteria (LAB) activity during fermentation (Puspadani et al., 2019; Sharma et al., 2022); because LAB lower milk pH and drive the casein coagulation that builds the gel network responsible for yogurt thickness (Krisnaningsih et al., 2018), any inhibition would yield a slightly weaker gel and lower viscosity. That the effect remained statistically non-significant indicates that the protein gel network, the principal determinant of viscosity, syneresis, and acidity in yogurt (Arab et al., 2023; Le Ba et al., 2025; Setyawardani et al., 2021) was not materially altered over the relatively narrow 0–2% range tested. The decreasing trend should nonetheless be interpreted with caution, since lower viscosity is generally associated with a greater tendency toward syneresis and reduced product stability (Arab et al., 2023; Hidayah et al., 2023).

Instrumental colour

In contrast to viscosity, sappan wood powder addition had a highly significant effect (P<0.01) on all three color parameters (Table 2), consistent with reports that natural pigments markedly shift the L*, a*, and b* values of yogurt (Baria et al., 2021; Dias et al., 2020). Orthogonal-polynomial analysis showed a highly significant quadratic effect on lightness (L*), $Y = 2.754x^2 - 9.470x + 61.44$ (R^2 = 89.6%), with L* falling from 61.46 in P0 to 53.50 in P3; redness (a*) rose quadratically, $Y = -1.194x^2 + 5.576x + 0.652$ (R^2 = 87.4%), from 0.65 to 7.04, and yellowness (b*) likewise, $Y = -1.967x^2 + 8.772x + 9.318$ (R^2 = 83.0%), from 9.30 to 19.07 (Figure 3). For all three parameters, LSD separation showed P0 differing significantly from P1, while P1, P2, and P3 did not differ from one another, indicating that most of the colour change occurred within the first 1% of addition.

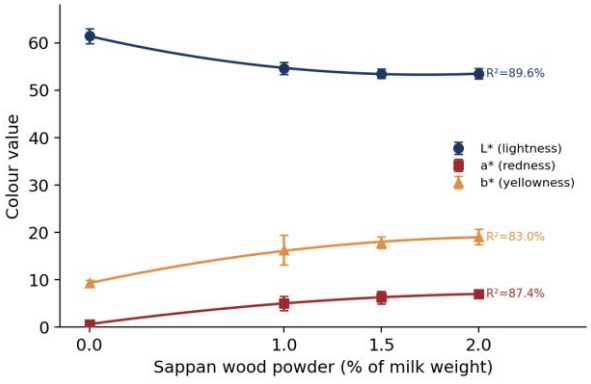

Figure 3. Effect of sappan wood powder level on the lightness (L*), redness (a*), and yellowness (b*) of cow's milk yogurt, with fitted quadratic curves and coefficients of determination.

The darkening of L* follows the general principle that a higher concentration of an added ingredient yields a darker product (Purbowati et al., 2024) and that base-ingredient composition strongly conditions the color of fermented dairy (Fadhlurrohman et al., 2023; Hidayah et al., 2023). The concurrent rise in a* and b* is explained by the pH-dependent behavior of brazilin: it appears yellow at pH 2–5, red at pH 6–7, and reddish-purple above pH 8 (Meutia et al., 2019; Vij et al., 2023). As fermentation lowered yogurt pH, the pigment released from increasing amounts of sappan wood powder shifted toward the red–yellow region, raising both a* and b* simultaneously. These results confirm that sappan wood powder is an effective natural colorant for cow's milk yogurt, consistent with the broader use of natural plant pigments as combined functional and visual enhancers of fermented milk (Akhtaruzzaman et al., 2025; Jurić et al., 2022). A comparable pattern, in which a plant-based additive significantly alters the physical and sensory attributes of goat-milk yogurt, has been reported for red-guava juice (Pasa et al., 2025) and lemon juice (Aprianto et al., 2025), supporting the wider applicability of natural additives in fermented dairy.

CONCLUSION

Adding sappan wood (*Caesalpinia sappan* L.) powder at 0, 1, 1.5, and 2% of milk weight numerically decreased the viscosity of cow's milk yoghurt but without a statistically significant effect ($P>0.05$), indicating that the protein gel structure was preserved over this range. In contrast, sappan wood powder had a highly significant quadratic effect ($P<0.01$) on color, decreasing lightness (L*) while increasing redness (a*) and yellowness (b*), with most of the change occurring by 1% addition. Sappan wood powder can therefore be applied at up to 2% as a natural colorant that enhances the red–yellow appearance of cow's milk yogurt without compromising its consistency. Further work should quantify the accompanying changes in pH, antioxidant capacity, syneresis, and sensory acceptance to define an optimal, storage-stable formulation.

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Author contributions

H.M.Y.: conceptualization, methodology, investigation, data curation, and writing of the original draft. S.H.: supervision, methodology, validation, and writing review and editing. F.D.E.: supervision, formal analysis, and writing review and editing. All authors read and approved the final manuscript.

Ethics statement

This study did not involve live-animal experimentation; only cow's milk as a food raw material was used, and no ethical approval was required.

Conflict of interest

The authors declare no conflict of interest.

Data availability statement

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

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