

Proximate Composition, Phytochemicals and Heavy Metals in Natural Colourants Applied to Meat Processing and Their Effects on Storage and Sensory Properties of Spatchcock Chicken

*¹Talabi, A.E., ¹Zahradeen, D., ¹Abdu, S.B. ²Jibir, M. and ³Yaqoob, R.

¹Department of Animal Science, Ahmadu Bello University, Zaria

²Department of Animal Science, Usman Danfodio University, Sokoto.

³National Agricultural Extension Research and Liaison Services, Ahmadu Bello University, Zaria.

Corresponding Author: talabiae@gmail.com, +2347060763044

Abstract

This study aimed to evaluate the proximate composition, phytochemical profile, and heavy metal content of natural colorants (hibiscus, turmeric, bell pepper, and beetroot) used in meat processing, compared to the synthetic colorant Ja'wa, and assess their effects on the storage stability and sensory quality of skewer spatchcock chicken (SSC). Broiler chickens were processed into SSC, cured with the colorants, and analyzed for proximate components (dry matter, crude protein, lipid, fiber, ash, nitrogen-free extract) and minerals using standard procedures, heavy metals (arsenic, chromium, cadmium, lead, manganese) via atomic absorption spectrophotometry, and phytochemicals (alkaloids, flavonoids, saponins, phenols, tannins, glycosides). Sensory evaluation involved 30 semi-trained panelists scoring colour, flavour, texture, juiciness, tenderness, and acceptability on a 9-point hedonic scale, with data analyzed using general linear model and Tukey's HSD. Results revealed natural colorants exhibited superior proximate profiles, with beetroot highest in crude protein (14.23%), bell pepper in dry matter (96.11%), and turmeric in flavonoids (70.50 mg/g) and phenols (65.48 mg/g); heavy metal levels were minimal (0.00–0.31 ppm) and within permissible limits, while Ja'wa showed toxic concentrations (lead 7.85 ppm). Sensory scores improved with natural colourants, particularly turmeric (highest flavour 6.21, tenderness 6.46, acceptability 6.63), and short-term storage (0–4 days) enhanced attributes like juiciness and acceptability. In conclusion, natural colorants provide safer, nutrient-rich alternatives to synthetic dyes, improving SSC's nutritional value, safety, and consumer appeal during storage, supporting their adoption in meat processing for healthier products.

Keywords: Natural colorants; Heavy metals; Phytochemical composition; Sensory quality; Spatchcock chicken

Description of Problem

In recent years, consumer preferences have shifted toward clean-label food products, driven by growing awareness of the health risks associated with synthetic additives in processed meats (1). Colour plays a critical role in meat products, influencing perceived freshness, appeal, and overall acceptability, as it is often the

first sensory attribute evaluated by consumers (2). Traditional synthetic colorants, such as azo dyes, have been widely used in meat processing to enhance visual attributes and extend shelf life; however, they pose significant safety concerns, including contamination with heavy metals like lead, cadmium, and arsenic, which can accumulate in the

body and lead to neurotoxicity, developmental disorders, and increased cancer risk (3,4). For instance, studies have linked synthetic dyes to hyperactivity in children, allergic reactions, and genotoxic effects, prompting regulatory bodies to re-evaluate acceptable daily intakes and advocate for stricter limits (3). This has fueled the demand for natural alternatives derived from plant sources, which not only provide vibrant hues but also offer additional bioactive benefits, such as antioxidant and antimicrobial properties, without the toxicological drawbacks of their synthetic counterparts (5; 6).

Natural colourants like turmeric (*Curcuma longa*), hibiscus (*Hibiscus sabdariffa*), beetroot (*Beta vulgaris*), and bell pepper (*Capsicum annuum*) have emerged as promising substitutes in meat applications due to their rich pigment profiles—curcumin in turmeric for yellow-orange tones, anthocyanins in hibiscus for red-purple shades, betalains in beetroot for deep reds, and carotenoids in bell pepper for yellow-red hues (6). These compounds contribute to improved nutritional value by providing flavonoids, phenols, and other phytochemicals that combat oxidative stress and microbial spoilage in meat products, thereby enhancing storage stability (5). Research indicates that incorporating such natural pigments into poultry products can mitigate lipid oxidation, preserve sensory qualities like flavor and tenderness, and align with consumer demands for minimally processed foods (1). However, challenges remain in maintaining color stability under processing conditions like heat and pH variations which can degrade pigments and affect product quality (6).

In the context of poultry processing, skewer spatchcock chicken—a flattened, grilled product popular for its convenience—benefits from colorants that not only impart appealing aesthetics but also influence texture, juiciness, and overall palatability during refrigerated storage (7).

Despite these advantages, limited studies have comprehensively compared the proximate composition, phytochemical content, and heavy metal profiles of these specific natural colorants against synthetic options like *Ja'wa* powder, particularly in relation to their impact on sensory attributes and short-term storage of poultry products (1). Heavy metal contamination in synthetic dyes remains a pressing issue, with levels often exceeding permissible limits set by international standards, posing risks to vulnerable populations such as children (3,4). This study addresses this gap by analyzing four natural colorants for their chemical and safety profiles, evaluating their application in skewer spatchcock chicken, and assessing sensory outcomes to promote sustainable, health-oriented meat processing practices aligned with global trends toward natural additives (5).

Materials and Methods

The birds were processed into skewered spatchcock chicken at Animal Products and Processing Laboratory of the Department of Animal Science, Ahmadu Bello University, Zaria, Kaduna-State. The area is characterized with a relative humidity of 36 % in dry season and 78.5 % for wet season as stated by Institute for Agricultural Research Meteorological Station (8).

Determination of proximate composition

Samples from SSC cured with different natural colourants were collected from each treatment and analysed for proximate composition (dry matter, crude protein, ether extract and ash) and mineral composition (calcium, iron, potassium, magnesium and zinc) according to (9) at Biochemical Laboratory, Department of Animal Science, Ahmadu Bello University, Zaria.

Determination of heavy metals

Samples from SSC cured with natural colourants and *Ja'wa* powder were analysed for the presence of heavy metals, such as arsenic (As), manganese (Mn), lead (Pb), chromium (Cr) and cadmium (Cd), using Atomic Absorption Spectrophotometer, according to the procedure of (10) at the Department of Scientific and Industrial Research Laboratory of National Research Institute for Chemical Technology (NARICT) Zaria.

Sensory evaluation

Samples for sensory evaluation was obtained from the breast and thigh of SSC cured with both natural colourants and *Ja'wa* powder. The meat was cut into chewable size and served to thirty (30) semi-trained panelists comprising of undergraduate, Postgraduate Students and Staff of the Department of Animal Science, Ahmadu Bello University, Zaria. They were instructed on how to assess the sample from each treatment and score it for colour, flavour, texture, juiciness, tenderness and overall acceptability. Cracker biscuit and water was served to panellists to rinse their mouth after tasting each sample to reduce carry over effects.

The panellist scored each sample on a nine-point hedonic scale; 1 =extremely dark, 2= very dark, 3= moderately dark, 4= slightly dark, 5= intermediate, 6= slightly light, 7= moderately light, 8= very light and 9= extremely light according to procedure of Kyakma *et al.* (11) as shown on Appendix VI. Scored obtained were transformed into quantitative values for analysis.

Data Analysis

All data obtained from this study were analyzed statistically using the general linear model (GLM) procedure of statistical analysis systems software package while significant differences between treatment means were separated using Tukey's Test (12).

Results

Proximate composition of natural colourants

The proximate composition of the natural colourants used in meat processing is presented in Table 1. The results show that proximate composition of the same natural colourants. Bell pepper displayed significantly ($P < 0.05$) higher dry-matter and nitrogen-free extract contents than hibiscus, turmeric and beetroot, whereas beetroot recorded significantly ($P < 0.05$) higher crude protein content than the remaining three colourants. Crude lipid was significantly ($P < 0.05$) lower in beetroot compared with hibiscus, turmeric and bell pepper, which were statistically similar to one another. Crude fibre and ash contents showed no significant ($P > 0.05$) difference across all four colourants.

These findings highlight turmeric as the richest source of flavonoids and phenols,

thereby offering the strongest antioxidant protection, while beetroot stands out for its superior crude protein contribution and bell pepper for its high dry-matter and carbohydrate fractions, characteristics

that collectively enhance the nutritional and technological functionality of broiler chicken products when these natural colourants are incorporated.

Table 1: Proximate composition of natural colourants

Composition (%)	Hibiscus	Turmeric	Bell paper	Beet root	SEM
Dry matter	93.30 ^c	93.69 ^b	96.11 ^a	92.57 ^d	0.31
Crude protein	5.53 ^c	9.39 ^b	5.39 ^c	14.23 ^a	0.87
Crude lipid	7.48 ^a	6.84 ^{ab}	6.79 ^{ab}	3.80 ^b	0.52
Crude fibre	3.16	4.62	3.16	2.42	0.39
Ash	1.74	2.84	1.81	1.21	0.29
Nitrogen-free extract	76.31 ^b	70.01 ^c	78.96 ^a	70.84 ^c	1.02

^{abcd}Means with different superscripts along the same row are significantly different (P<0.05), SEM: standard error of means.

Presence of some Heavy Metals in Colourants used in Meat Processing

The concentrations of heavy metals in the natural and synthetic colourants used in meat processing are presented in Table 2. Among the natural colourants, all detected levels of arsenic, chromium, cadmium, lead and manganese were within the maximum permissible limits set by (13, 14 and 15). Turmeric, hibiscus, bell pepper and beetroot powders contained minimal traces of these metals, ranging from 0.00–0.31 ppm, indicating their relative safety for food applications.

In contrast, the synthetic colourant *Ja’wa* powder exhibited alarmingly high concentrations of all analyzed heavy metals, exceeding permissible limits. Arsenic (7.17 ppm), chromium (3.24 ppm), cadmium (4.63 ppm), lead (7.85 ppm), and manganese (13.10 ppm) were all significantly above safe thresholds, denoted as toxic. These findings revealed that while natural colourants are safe and compliant with food safety standards, the synthetic *Ja’wa* dye poses potential toxicological risks when used in meat processing.

Table 2. Presence of some heavy metals in natural colourants powder used in meat processing

Elements	Test Results (ppm)					Max. Permissible Limit (ppm)
	Turmeric	Hibiscus	Bell Pepper	Beetroot	<i>Ja’wa</i>	
Arsenic	0.07	0.11	0.07	0.03	7.17*	0.50
Chromium	0.05	0.01	0.06	0.07	3.24*	0.10
Cadmium	0.13	0.31	0.23	0.00	4.63*	1.00
Lead	0.05	0.07	0.19	0.05	7.85*	1.00
Manganese	0.14	0.13	0.15	0.22	13.10*	1.00

Maximum permissible limit (ppm) (USFDA, 2022), (WHO, 2018), (EFSA, 2019), *Toxic.

Phytochemical composition of natural colourants

The phytochemical composition of the natural colourants; bell pepper, hibiscus, beetroot and turmeric is presented in Table 3. The results show that the phytochemical composition of the four natural colourants evaluated in the study. Turmeric exhibited significantly ($P < 0.05$) higher flavonoid and phenol contents than bell pepper, hibiscus and beetroot, whereas bell pepper recorded significantly ($P < 0.05$) higher tannin

content compared with the other three colourants. Saponin levels were significantly ($P < 0.05$) higher in turmeric than in hibiscus and beetroot, with bell pepper occupying an intermediate position. Glycoside concentration was significantly ($P < 0.05$) higher in turmeric than in hibiscus, while bell pepper and beetroot remained statistically similar to both. Alkaloid content showed no significant ($P > 0.05$) difference among the four colourants.

Table 3: Phytochemical composition of natural colourants

Composition (mg/g)	Bell Pepper	Hibiscus	Beetroot	Turmeric	SEM
Alkaloids	8.36	8.49	8.25	7.93	0.11
Flavonoids	59.56 ^b	48.79 ^c	46.50 ^c	70.50 ^a	1.84
Saponins	9.36 ^b	8.09 ^c	8.45 ^c	10.27 ^a	0.29
Phenols	55.28 ^b	40.65 ^c	45.03 ^c	65.48 ^a	2.16
Tannins	16.93 ^a	8.80 ^b	8.27 ^b	11.27 ^b	0.87
Glycosides	14.67 ^{ab}	13.20 ^b	14.34 ^{ab}	15.20 ^a	0.46

^{abcd}Means with different superscripts along the same row are significantly different ($P < 0.05$), SEM: standard error of means.

Main effect of colourants and storage period on sensory quality of skewer spatchcock chicken

The sensory quality attributes of skewer spatchcock chicken as influenced by different colourants and storage periods are presented in Table 4. Significant ($p < 0.05$) differences were observed among treatments for all sensory parameters. *Ja'wa* (synthetic dye) achieved the highest mean colour score (8.51), reflecting its strong pigmentation effect. However, turmeric-treated samples had the most favourable scores across other sensory traits, including flavour (6.21), tenderness (6.46), juiciness (7.86), and overall acceptability (6.63), indicating

superior eating quality. Among the natural colourants, bell pepper and beetroot also recorded relatively high acceptability scores (6.18 and 6.36, respectively), while hibiscus scored lowest for colour (3.54) but showed moderate improvement in flavour and tenderness. The control sample consistently received the lowest ratings across all parameters, signifying reduced sensory appeal.

Storage duration significantly ($p < 0.05$) influenced sensory characteristics. Colour, tenderness and acceptability improved slightly over time, with day 4 samples showing the highest overall

scores (6.53) compared to day 0 (5.88). This indicates that short-term refrigerated storage enhanced flavour development and juiciness, possibly due to moisture redistribution and softening of muscle fibres. Turmeric-treated spatchcock

chicken achieved the best balance between colour stability, tenderness and consumer acceptability, while *Ja'wa* excelled only in appearance but not in sensory quality parameters associated with eating satisfaction.

Table 4: Main effect of colourants and storage period on sensory quality of skewer spatchcock chicken

Treatment	Colour	Flavour	Tenderness	Juiciness	Acceptability
Natural Colourants					
Control	5.41 ^c	4.58 ^c	5.35 ^c	4.69 ^c	5.56 ^d
Turmeric	6.53 ^b	6.21 ^a	6.46 ^a	7.86 ^a	6.63 ^a
Hibiscus	3.54 ^d	5.68 ^b	5.85 ^b	6.07 ^b	5.91 ^{cd}
Bell pepper	5.56 ^c	5.94 ^a	6.59 ^a	5.96 ^b	6.18 ^{bc}
Beetroot	5.27 ^c	5.86 ^{ab}	6.56 ^a	5.81 ^b	6.36 ^{ab}
<i>Ja'wa</i>	8.51 ^a	5.46 ^{ab}	6.25 ^{ab}	5.65 ^b	6.57 ^{ab}
SEM	0.20	0.23	0.23	0.22	0.21
Storage Periods (days)					
0	4.87 ^b	4.97 ^b	5.47 ^b	5.55 ^b	5.88 ^b
2	5.87 ^a	5.24 ^b	5.88 ^a	5.28 ^b	6.35 ^a
4	5.97 ^a	5.95 ^a	5.98 ^a	6.09 ^a	6.53 ^a
SEM	0.15	0.17	0.17	0.16	0.15

^{abcd}Means with different superscripts along the same column are significantly different (P<0.05), SEM: standard error of means.

Interaction effect of colourants and storage period on sensory quality of skewer spatchcock chicken

Table 5 presents the interaction effect of colourants and storage period on the sensory quality of skewer spatchcock chicken. Both colourant type and storage duration significantly ($p < 0.05$) influenced all sensory parameters. Among the treatments, *Ja'wa* and turmeric consistently produced the highest scores for overall acceptability across storage periods. Specifically, *Ja'wa* at day 4 (7.08) and turmeric at day 0 (7.24) recorded the greatest acceptability values, indicating enhanced consumer preference under these conditions. Turmeric-treated samples maintained superior tenderness (5.96–

6.16), juiciness (5.52–6.80), and flavour (4.96–6.40) throughout storage, outperforming other natural colourants.

The highest juiciness score (6.80) was obtained from turmeric-treated chicken stored for four days, suggesting improved moisture retention during short-term storage. Bell pepper and beetroot treatments showed moderate but consistent sensory scores, with tenderness ranging from 5.80–6.24 and overall acceptability between 6.04–7.08 across storage days, this reflects good consumer appeal. Conversely, hibiscus-treated samples recorded the lowest colour and acceptability ratings throughout the storage period, particularly at day 2 (colour 3.12; acceptability 5.20). The

control group also exhibited relatively lower scores across all parameters, except for slight improvement in colour at day 2 (7.52) due to surface browning during reheating. Generally, sensory scores

improved gradually from day 0 to day 4 in most treatments, implying that short-term refrigeration positively affected meat flavour, tenderness and juiciness.

Table 5: Interaction effect of colourants and storage period on sensory quality of skewer spatchcock chicken

Treatment	Storage Periods (days)	Colour	Flavour	Tenderness	Juiciness	Acceptability
Control	0	6.52 ^{ab}	4.08 ⁱ	5.16 ^{hi}	4.48 ^{cd}	5.96 ^{bcd}
	2	7.52 ^a	4.80 ^{gh}	6.60 ^a	5.04 ^{bcd}	6.08 ^{bcd}
	4	6.72 ^{ab}	5.40 ^{cde}	6.20 ^b	6.24 ^{ab}	6.64 ^a
Turmeric	0	5.24 ^{cd}	4.96 ^{fgh}	5.44 ^g	5.92 ^{abc}	7.24 ^a
	2	6.24 ^b	5.52 ^{bcdef}	6.16 ^b	5.52 ^{abcd}	6.52 ^{abc}
	4	6.28 ^b	6.40 ^a	5.96 ^{cde}	6.80 ^a	6.92 ^a
Hibiscus	0	2.64 ^f	5.24 ^{defg}	5.32 ^{gh}	5.36 ^{abcd}	5.84 ^{bcd}
	2	3.12 ^{ef}	4.64 ^{hi}	4.92 ^j	4.16 ^d	5.20 ^d
	4	4.16 ^{de}	5.56 ^{bcde}	5.44 ^g	5.04 ^{bcd}	5.52 ^{cd}
Bell pepper	0	4.84 ^d	5.32 ^{defg}	6.12 ^{bc}	5.88 ^{abc}	6.04 ^{bcd}
	2	6.56 ^{ab}	5.36 ^{defg}	6.00 ^{cd}	5.00 ^{bcd}	6.56 ^a
	4	5.96 ^{bcd}	5.96 ^{abc}	5.80 ^{ef}	6.28 ^{ab}	6.68 ^{ab}
Beetroot	0	5.00 ^{cd}	5.20 ^{defg}	5.68 ^f	6.32 ^{ab}	6.08 ^{bcd}
	2	5.32 ^{cd}	5.40 ^{cdef}	5.92 ^{de}	5.88 ^{abc}	7.08 ^a
	4	6.12 ^{bc}	6.04 ^{ab}	6.24 ^b	5.92 ^{abc}	6.36 ^{abc}
Ja'wa	0	5.00 ^{cd}	5.00 ^{efgh}	5.08 ^{ij}	5.32 ^{bcd}	4.12 ^e
	2	6.44 ^{ab}	5.72 ^{bcd}	5.68 ^f	6.08 ^{ab}	6.68 ^{ab}
	4	6.60 ^{ab}	6.32 ^a	6.24 ^b	6.24 ^{ab}	7.08 ^a
SEM		0.59	0.30	0.10	0.73	0.49

^{abcd}Means with different superscripts along the same column are significantly different (P<0.05), SEM: standard error of means.

Discussion

Proximate composition of natural colourants

The proximate analysis of the natural colourants reveals their nutritional significance and potential contribution to the quality of processed meat products. The high dry matter content across all samples suggests low moisture levels, which enhance their stability and suitability as dry additives during processing. The relatively high protein

content observed in beetroot and turmeric is consistent with previous reports by (16) and (17), who noted that these plants are rich in bioactive proteins and amino acids that can contribute to the nutritional enrichment of foods. Turmeric's higher ash content (2.84 %) implies a superior mineral contribution, aligning with Njoku *et al.* (18), who found that turmeric contains essential minerals such as calcium, potassium and phosphorus that can enhance meat mineral balance. The

moderate crude fibre values, particularly in turmeric and hibiscus, indicate potential health benefits through improved digestion and antioxidant activity (19). The high carbohydrate (NFE) content in all colourants, especially bell pepper and hibiscus, highlights their potential as sources of natural sugars and polysaccharides that may contribute to desirable flavour and colour stability during heat treatment.

Presence of some heavy metals in natural colourants powder used in meat processing

The observed results highlight the stark contrast between natural and synthetic colourants in terms of heavy metal contamination. The natural colourants, turmeric, hibiscus, bell pepper and beetroot contained metal concentrations far below international safety limits, corroborating earlier findings by (20), who reported that plant-derived pigments are generally free from hazardous contaminants due to their organic origin and minimal industrial processing. Conversely, the synthetic *Ja'wa* powder contained heavy metals well above acceptable limits, aligning with the findings of (21) that Sudan dyes and similar synthetic additives often contain impurities or adulterants introduced during manufacturing. The high levels of lead, cadmium and arsenic in *Ja'wa* are particularly concerning, as these elements are known to accumulate in animal tissues and pose serious health risks to consumers, including nephrotoxicity, neurotoxicity and carcinogenicity. This underscores the urgent need to discourage the use of unregulated synthetic dyes in meat processing and to promote the adoption of safe, natural alternatives that

ensure both food quality and consumer safety.

Phytochemical composition of natural colourants

The observed variation in phytochemical composition among the tested natural colourants reflects differences in their botanical origins and bioactive compound profiles. The predominance of flavonoids and phenols in turmeric and bell pepper indicates their strong antioxidant potential, which plays a critical role in preventing lipid oxidation and maintaining meat quality during processing and storage. These findings are consistent with the reports of (19) and (22), who highlighted that curcumin the major polyphenol in turmeric acts as a powerful free radical scavenger that enhances oxidative stability in food systems. Similarly, the high phenolic content in bell pepper supports its function as a natural preservative and colourant due to the presence of capsanthin and capsorubin carotenoids (23). The moderate levels of alkaloids and saponins across all colourants suggest mild antimicrobial activity, which may contribute to the microbial stability of processed meat (24).

Hibiscus and beetroot, though lower in total phenolic and flavonoid content, remain valuable due to their anthocyanin and betalain pigments, respectively, which impart vivid red hues and provide additional antioxidant benefits (16). The phytochemical richness of turmeric and bell pepper highlights their dual role as safe, natural colouring agents and as bioactive enhancers of meat quality. The results affirm that the use of plant-derived colourants not only improves visual

appeal but also contributes to the nutritional and functional quality of processed meat, supporting their adoption as sustainable alternatives to synthetic dyes like *Ja'wa*.

Main effect on sensory quality

The sensory evaluation results demonstrate that natural colourants, particularly turmeric, significantly enhanced the overall eating quality and acceptability of skewer spatchcock chicken. The superior tenderness and juiciness of turmeric-treated samples may be attributed to the antioxidant properties of curcumin, which prevent oxidative toughening of proteins and maintain moisture during cooking (17,22). Similar findings were reported by (25), who observed improved sensory scores in naturally cured broiler meat due to better flavour retention and reduced rancidity. Bell pepper and beetroot also contributed positively to flavour and tenderness, likely due to their carotenoid and betalain contents that enhance meat aroma and texture (23).

Although *Ja'wa* produced the most intense colour, its lower ratings for tenderness and juiciness reflect the absence of functional compounds such as phenolics and flavonoids that promote protein stability and water retention. This aligns with (21), who noted that synthetic dyes impart strong colour but fail to improve palatability or nutritional quality. The generally poor performance of hibiscus in colour and acceptability could be due to pigment instability during high-temperature roasting, as anthocyanins are sensitive to heat and pH changes (26).

The improvement in sensory attributes with short-term storage (up to 4 days)

corroborates reports by (27) that mild ageing enhances flavour and tenderness in poultry meat due to proteolytic softening. In contrast, prolonged storage may lead to off-flavour development if not properly controlled. The results emphasize that turmeric, among the natural colourants studied, not only enhances the visual appeal but also contributes functionally to improved flavour, tenderness and juiciness, making it the most effective natural additive for producing high-quality, consumer-preferred spatchcock chicken.

Interaction effect on sensory quality

The interaction results indicate that both colourant type and storage duration played crucial roles in determining the sensory appeal of spatchcock chicken. Turmeric-treated samples consistently demonstrated superior sensory attributes especially tenderness, juiciness and overall acceptability throughout the storage period. This can be attributed to the antioxidant properties of curcumin, which help maintain lipid stability and prevent protein oxidation, thereby preserving texture and flavour quality during storage (17; 22). The enhanced juiciness at day 4 suggests that mild ageing facilitated better moisture redistribution within the muscle fibres, improving succulence (27).

Similarly, beetroot and bell pepper maintained high flavour and acceptability scores across storage periods, likely due to their carotenoid and betalain contents, which enhance both visual appeal and taste (12;19). Although *Ja'wa* displayed the most intense colouration, its acceptability was inconsistent across days and was not matched by improvements in

flavour or juiciness, confirming that synthetic dyes contribute more to appearance than to overall sensory quality (17). The relatively poor sensory performance of hibiscus-treated meat may be attributed to the heat and pH sensitivity of anthocyanin pigments, which degrade during processing and storage (27).

Conclusion and Applications

Natural colourants such as turmeric, hibiscus, bell pepper, and beetroot demonstrated superior safety and nutritional profiles compared to the synthetic *Ja'wa* powder, with low heavy metal levels and high phytochemical content contributing to enhanced antioxidant properties. The study highlighted turmeric's excellence in improving sensory attributes like flavor, tenderness, and overall acceptability in skewer spatchcock chicken, while short-term storage further optimized quality parameters. These findings underscore the potential of natural colorants to replace synthetics in meat processing, promoting healthier and more appealing products. It is recommended that meat processors prioritize natural colorants like turmeric in formulations to meet consumer demands for safe, clean-label foods and comply with international safety standards.

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