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Research Article

Quality Evaluation of Paprika-type Spice from *Capsicum annuum* Enriched with Local Ingredients in Guinea

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Abstract

Industrial bouillon cubes dominate seasoning practices in West Africa yet raise public health concerns owing to their high sodium, saturated fat, and monosodium glutamate content. This study aimed to produce and assess the quality of a paprika-type spice from locally grown *Capsicum annuum* L. enriched with garlic, black pepper, and salt. Three formulations were developed (F1: 85% chili/8% garlic/6% black pepper/1% salt; F2: 90%/4.5%/4.5%/1%; F3: 85%/6%/8%/1%) and evaluated for physicochemical, microbiological, and sensory quality against a commercial bouillon cube (Bara Musso, F4). Raw ingredients were dried at 65 ℃ for 24 h, ground, and blended. Physicochemical parameters were determined by AOAC methods; microbiological safety was assessed against JORA (2017) thresholds; sensory evaluation used a nine-point hedonic scale with 31 untrained consumers. All formulations showed high dry matter (90.52-90.84%), protein (17.25-18.18%), and fat (9.67-11.55%) contents, with statistically significant inter-formulation differences ($p < 0.0001$). Microbial loads remained well below regulatory limits; *Salmonella* spp., *Staphylococcus aureus*, thermotolerant coliforms, and sulphite-reducing anaerobes were entirely absent. All paprika soups performed on a par with F4 for taste, aftertaste, and overall acceptability; F3 significantly outperformed the control for aroma and texture, and all paprika preparations received superior colour scores. These findings establish locally produced *C. annuum*-based paprika as a safe, nutritious, and sensorially competitive seasoning for Guinea and the wider West African sub-region.

Keywords

Capsicum annuum, Paprika, Physicochemical Quality, Microbiological Safety, Sensory Evaluation, West Africa

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1. Introduction

Industrial bouillon cubes and flavoured powders have become central to dietary practices throughout sub-Saharan Africa, valued for their convenience, affordability, and capacity to rapidly enhance the palatability of traditional dishes. In West Africa, more than 80% of households regularly use these products [1], constituting a major source of dietary sodium that frequently exceeds the World Health Organization recommendation of less than 5 g of salt per day [2]. Commercial bouillon cubes typically contain 40 to 60% sodium chloride [3], monosodium glutamate (MSG), saturated fats, and various synthetic additives. Chronic consumption of such ultra-processed products is associated with an elevated risk of hypertension and cardiovascular disease, the latter responsible for approximately 1.9 million deaths per year attributable to excessive sodium intake worldwide [4]. Additional health concerns include obesity, type 2 diabetes mellitus, and an increased incidence of certain cancers [5, 6]. Although MSG is generally considered safe at moderate doses, adverse reactions including headaches and hypersensitivity responses have been reported in susceptible individuals [7], and the contribution of dietary saturated fats to dyslipidaemia is well documented [8].

These nutritional and safety concerns, compounded by the global dietary transition toward ultra-processed food consumption [5], have intensified the demand for natural, minimally processed seasoning alternatives. Paprika, produced by drying and grinding the fruits of *Capsicum annuum* L., represents a particularly compelling candidate. Rich in vitamins A, B6, C, and E, carotenoids (primarily capsanthin and capsorubin), and phenolic compounds with significant antioxidant activity, paprika may contribute to the prevention of chronic non-communicable diseases and to the reinforcement of immune function [9]. Its nutritional value can be further enhanced through the incorporation of garlic (*Allium sativum* L.), whose allicin-derived organosulfur compounds exert well-documented antimicrobial, antihypertensive, and cardioprotective effects [10-12], and black pepper (*Piper nigrum* L.), whose principal active alkaloid piperine exhibits antioxidant and anti-inflammatory properties and enhances the bioavailability of co-ingested micronutrients [13, 14].

From an economic standpoint, the global paprika market was valued at approximately USD 588 million in 2024 and is projected to reach USD 886 million by 2032, at a compound annual growth rate of 5.25% [15]. In Guinea, favourable agro-ecological conditions support substantial chili pepper cultivation [16]; however, post-harvest valorization remains limited, resulting in significant losses and missed economic opportunities [17]. Processing locally grown *C. annuum* into paprika offers a strategic avenue to reduce post-harvest losses, generate rural income, and provide consumers with a health-promoting alternative to industrial bouillons.

Despite these prospects, no prior study has evaluated the feasibility or quality of paprika production under Guinean conditions. The present study therefore aimed to: (i) develop three paprika-type spice formulations from locally grown *C. annuum* enriched with garlic, black pepper, and salt at varying proportions; and (ii) evaluate their physicochemical, microbiological, and sensory quality in comparison with a commercially available bouillon cube widely used in West African cuisine.

2. Materials and Methods

2.1. Raw Materials and Study Sites

Raw materials consisting of chili peppers, garlic, black pepper, and food-grade salt were sourced from the local market of Dalaba, Guinea. Paprika production was conducted at the Food Technology Laboratory of the Higher Institute of Veterinary Sciences and Medicine (ISSMV), Dalaba. Physicochemical and microbiological analyses were performed at the National Office for Quality Control (ONCQ), and sensory evaluation took place at ISSMV under standardized conditions.

2.2. Production of Paprika-type Formulations

Paprika-type formulations were produced following a standardized processing sequence. Raw chili peppers, garlic, and black pepper were individually cleaned to remove foreign matter and damaged material, then dried at 65 ℃ for 24 h in a ventilated oven until constant mass was reached. Each dried ingredient was individually ground to a fine powder using a laboratory mill, and the resulting powders were blended with food-grade salt at different proportions resulting in three formulations (Table 1).

Table 1. *Paprika-type formulations.*

Ingredient	**F1**	**F2**	**F3**
Chili pepper (%)	85	90	85
Garlic (%)	8.0	4.5	6.0
Black pepper (%)	6.0	4.5	8.0
Salt (%)	1.0	1.0	1.0

2.3. Physicochemical Analysis

2.3.1. pH Determination

The pH was measured following the procedure described by Goulas et al. [36] with minor modifications. Five grams of sample were homogenised with 20 mL of distilled water for 15 min under continuous rotary agitation, and the pH of the resulting suspension was determined using a calibrated electronic pH meter

(EUTECH INSTRUMENTS, PH510, Singapore).

2.3.2. Dry Matter Content

Dry matter content was determined gravimetrically according to ISO 11465 [29]. Two grams of paprika were dried at 105 ℃ in a ventilated oven (Memmert, Germany) to constant mass. Dry matter (DM,%) was calculated as follows:

$$DM = (M_2/M_1) \times 100 \quad (1)$$

where M_1 is the initial sample mass and M_2 is the dried sample mass.

2.3.3. Titratable Acidity

Titratable acidity was determined following Chabane and Azem [37]. Three grams of ground sample were dissolved in 50 mL of distilled water under magnetic stirring for 15 min and the volume was adjusted to 250 mL. An aliquot of 25 mL was titrated against 0.1 N NaOH with phenolphthalein as indicator to a persistent pink endpoint. Titratable acidity (g citric acid equivalent L^{-1}) was calculated as:

$$A = (V_1 \times N \times Meq \times Vtotal) / (M \times V_0 \times 1000) \quad (2)$$

where V_1 is the volume of NaOH consumed (mL), N = 0.1, Meq is the molar equivalent mass of citric acid (g mol^{-1}), Vtotal = 250 mL, M is the sample mass (g), and V_0 = 25 mL.

2.3.4. Total Fat Content

Total fat content was determined by Soxhlet extraction according to AOAC [25]. One and a half grams of sample were subjected to continuous extraction with hexane at 130 ℃ for 1 h using an automated Soxhlet unit (FOSS Soxtec ST 243, Denmark). Fat content (%) was calculated as:

$$Fat = [(P_1 - P_2) / M_0] \times 100 \quad (3)$$

where P_1 is the mass of the collection flask after solvent evaporation, P_2 is the mass of the empty flask, and M_0 is the initial sample mass.

2.3.5. Total Protein Content

Total nitrogen content was determined by the Kjeldahl method [26]. Two grams of sample were digested with concentrated H_2SO_4 in the presence of a Kjeldahl catalyst disc at 250 ℃ for 1 h then at 420 ℃ for 1 h using a heating block (KT20S, Gerhardt, Germany). Steam distillation was performed with 80 mL of 40% NaOH and 80 mL of distilled water; released ammonia was trapped in 4% boric acid and back-titrated with 0.1 N HCl using an automatic titrator (SCHOTT TL 5000, Germany). A nitrogen-to-protein conversion factor of 6.25 was applied.

2.3.6. Ash Content

Ash content was determined according to AOAC [27]. Two grams of sample were incinerated in a muffle furnace at 900 ℃ for 1 h 30 min. The residue was dried for 15 min, cooled in a desiccator, and weighed. Ash content (%) was expressed as the ratio of ash mass to initial sample mass.

2.4. Microbiological Analysis

Twenty-five grams of each sample were homogenised with 225 mL of buffered peptone water (1: 10 dilution, w/v) and serial decimal dilutions were prepared in tryptone salt broth according to ISO 6887-3 [33]. Total aerobic mesophilic count (TAMC) was performed on Plate Count Agar incubated at 30 ℃ for 72 h [32]. Total and thermotolerant coliforms were enumerated on Violet Red Bile Lactose agar at 30 ℃ and 44 ℃ for 24 h, respectively [32]. Yeasts and moulds were counted on chloramphenicol glucose yeast extract agar at 30 ℃ for 3 to 5 days [34]. Sulphite-reducing anaerobes were determined on Tryptose Sulphite Neomycin agar at 37 ℃ for 24 h [35]. *Staphylococcus aureus* was enumerated on Baird-Parker agar supplemented with egg yolk tellurite at 37 ℃ for 24 to 48 h; presumptive colonies were confirmed using the Staphytect Plus latex agglutination test [30]. Detection of *Salmonella* spp. followed a multi-stage procedure comprising pre-enrichment in buffered peptone water (37 ℃, 24 h), selective enrichment in Rappaport-Vassiliadis Soya broth, isolation on Hektoen Enteric and *Salmonella*-Shigella agars, and confirmation by Kligler Iron Agar, urea-indole biochemical tests, API 20E identification strips, and serological typing [31]. Results were compared against the maximum permissible limits established by the Algerian JORA standard [38], adopted as reference criteria in the absence of Guinean-specific regulations for spice products.

2.5. Sensory Evaluation

Soups were prepared from each paprika-type formulation and from the commercially available bouillon cube Bara Musso (F4), which served as the control. The sensory evaluation was conducted by a panel of 31 untrained consumers (15 women, 16 men). The attributes assessed were colour, aroma, taste, aftertaste, and overall acceptability, each scored on a nine-point hedonic scale ranging from 1 (*dislike extremely*) to 9 (*like extremely*), following the procedure described by Watts et al. [28]. Each panelist independently evaluated all four preparations in randomized order under standardized environmental conditions.

2.6. Statistical Analysis

All data are reported as mean ± standard error of the mean (SEM). Statistical analyses were performed using GraphPad Prism version 5 (GraphPad Software, San Diego, CA, USA). Compliance of microbiological counts with regulatory thresholds was assessed by Student's *t*-test. Differences in physicochemical and sensory parameters among formulations were evaluated by one-way analysis of variance (ANOVA) followed by Tukey's posthoc test for pairwise comparisons. Statistical significance was set at $p < 0.05$ for all tests.

3. Results and Discussion

3.1. Physicochemical Characteristics

***Table 2**. Physicochemical characteristics of paprika-type formulations.*

Parameter	**F1**	**F2**	**F3**
pH	4.86 ±0.04^{c}	5.15 ±0.03^{b}	5.34 ±0.05^{a}
Titratable acidity (g L^{-1})	0.98 ±0.01^{c}	1.15 ±0.03^{b}	1.58 ±0.02^{a}
Dry matter (%)	90.52 ±0.03^{c}	90.72 ±0.01^{b}	90.84 ±0.01^{a}
Fat (%)	10.52 ±0.01^{b}	11.55 ±0.01^{a}	9.67 ±0.01^{c}
Protein (%)	18.18 ±0.06^{a}	17.77 ±0.07^{b}	17.25 ±0.03^{c}
Ash (%)	10.28 ±0.01^{a}	9.36 ±0.01^{c}	9.64 ±0.01^{b}

Means in the same line with different low-case letter are significantly different at $p < 0.05$ (Tukey Test)

3.1.1. pH and Titratable Acidity

Significant differences in pH were observed among the three formulations (Table 2). The values found are consistent with the slightly acidic profile characteristic of dried *Capsicum*-based products, attributable to the presence of organic acids (predominantly citric, ascorbic, and malic acids) in the pepper pericarp [18]. The comparatively lower pH of F1 is likely related to its higher garlic content (8%), since fermentative metabolic activity in garlic contributes additional organic acids during thermal drying [19]. The inverse relationship between pH and titratable acidity confirms this interpretation: F3 exhibited the highest titratable acidity alongside the highest pH, while F1 displayed the lowest acidity and the lowest pH, indicating that the acid-base equilibrium is governed by the buffering capacity of ingredient-specific bioactive compounds rather than by total acid concentration alone. Importantly, all pH values remained below 5.5, a threshold generally considered favourable for microbiological stability, as acidity contributes to inhibition of common foodborne microorganisms in dried spice matrices [39].

3.1.2. Dry Matter Content

All three formulations exhibited high and significantly differentiated dry matter, corresponding to moisture levels below 10% in all products. Such values are characteristic of adequately dehydrated paprika and are essential for reducing water activity, thereby limiting microbial proliferation and enzymatic degradation during storage. Mariani et al. [20] confirmed that moisture levels below 10% ensure physicochemical stability in dried *Capsicum*-based preparations. The marginally lower dry matter content of F1 is consistent with the greater hygroscopicity of garlic (present at 8% in F1 compared with 4.5 to 6% in F2 and F3), which retains residual moisture more readily during hot-air drying, as demonstrated by Jeon et al. [21].

3.1.3. Fat Content

Fat content differed significantly across formulations, with F2 recording the highest value, followed by F1 and F3. In *Capsicum*-based products, the lipid fraction is intimately associated with carotenoid pigments (primarily capsanthin and capsorubin), which occur predominantly in esterified, lipid-bound forms whose extraction efficiency and visual expression are facilitated by the surrounding fat matrix [22]. The elevated fat content of F2, which contains the greatest proportion of chili pepper (90%), likely reflects a richer carotenoid-lipid complex derived from the pericarp. Yu et al. [23] reported that drying conditions significantly influence carotenoid-associated lipid retention in paprika. The values obtained in the present study suggest that the 65 ℃/24-h protocol was adequate for lipid preservation. The fat contents observed (9.67-11.55%) fall within the range reported for commercial paprika by Pereira et al. [24], confirming the suitability of the drying conditions applied.

3.1.4. Protein Content

Protein content decreased significantly from F1 to F2 and F3. These values lie within the upper range reported for dehydrated *Capsicum*-based products [20]. The formulation-dependent gradient in protein content is consistent with the contribution of garlic, which has a relatively higher crude protein content than the *Capsicum* pericarp. The greater garlic proportion in F1 (8%) compared with F2 (4.5%) and F3 (6%) supports this interpretation. It should be noted that the Kjeldahl conversion factor of 6.25 may slightly overestimate true protein content in garlic-rich matrices, as non-protein nitrogenous compounds such as alliin and related organosulfur derivatives contribute to total measurable nitrogen [19]. Nonetheless, the protein levels across all formulations substantially exceed those furnished by industrial bouillons, confirming a meaningful nutritional advantage of the paprika-type products.

3.1.5. Ash Content

Ash content differed significantly among formulations, with F1 recording the highest value, followed by F3 and F2. The elevated mineral content of F1 is primarily attributable to its greater garlic proportion (8%), as garlic is notably rich in potassium, calcium, sodium, magnesium, and phosphorus [10]. These ash values exceed those typically reported for pure paprika powders [20], confirming that ingredients blending substantially augments total mineral content. From a nutritional standpoint, the higher ash content of F1 reflects enhanced mineral availability, a meaningful advantage over mineral-poor industrial bouillons.

3.2. Microbiological Quality

Total Aerobic Mesophilic Counts (TAMC) ranged from 536 ± 24 CFU g^{-1} (F2) to 740 ± 211 CFU g^{-1} (F1), with no significant inter-formulation differences ($p > 0.05$). All values were substantially below the JORA (2017) threshold of 10^5 CFU g^{-1} ($p < 0.05$ vs. regulatory limit). These counts compare favourably with those reported for Argentinian artisanal paprika [39], Moroccan sun-dried paprika [40], and industrial European paprika batches [41]. The markedly lower microbial load obtained in the present study likely reflects the superior and more uniform moisture reduction achieved by controlled hot-air drying at 65 ℃ relative to ambient sun-drying, which is prone to environmental contamination and inconsistent dehydration.

Table 3. Microbial counts of the three paprika-type formulations.

Microorganism	F1	F2	F3	JORA (2017) limit
TAMC (CFU g^{-1})	740 ± 211^{b}	536 ± 24^{b}	556 ± 81^{b}	$\leq 10^{5a}$
Total coliforms (CFU g^{-1})	8.0 ± 8.0^{b}	0.33 ± 0.33^{b}	3.66 ± 2.33^{b}	$\leq 10^{2a}$
Yeasts and moulds (CFU g^{-1})	80 ± 47^{b}	240 ± 107^{b}	310 ± 300^{b}	$\leq 10^{3a}$
Thermotolerant coliforms (CFU g^{-1})	Absent	Absent	Absent	≤ 10
Sulphite-reducing anaerobes (CFU g^{-1})	Absent	Absent	Absent	$\leq 10^{2}$
Staphylococcus aureus (CFU g^{-1})	Absent	Absent	Absent	$\leq 10^{2}$
Salmonella spp. (per 25 g)	Absent	Absent	Absent	Absent

Means in the same line with different low-case letter are significantly different at $p < 0.05$ (Tukey Test)

Total coliforms were detected at very low levels across all formulations, well below the JORA (2017) threshold of 10^2 CFU g^{-1}, with no significant inter-formulation differences ($p > 0.05$). This contrasts with Moroccan paprika, in which fecal coliform counts reached 4.7×10^5 CFU g^{-1} in winter batches, attributable to declining ambient drying temperatures [40]. Yeast and mould counts ranged from 80 ± 47 CFU g^{-1} (F1) to 310 ± 300 CFU g^{-1} (F3), remaining below the acceptable threshold of 10^3 CFU g^{-1} with no significant inter-formulation differences ($p > 0.05$). Thermotolerant coliforms, sulphite-reducing anaerobes, *S. aureus*, and *Salmonella* spp. were entirely absent from all three formulations. The complete absence of *Salmonella* is particularly noteworthy given that this pathogen was implicated in nine Rapid Alert System for Food and Feed (RASFF) notifications linked to paprika powder between 2003 and 2016 [41], and that its minimum infectious dose was estimated at 4 to 45 cells during the 1993 German salmonellosis outbreak associated with paprika-seasoned potato chips [39, 42]. The complete absence of all pathogenic microorganisms confirms the microbiological safety of the production protocol implemented.

3.3. Sensory Quality

Colour was the primary discriminating attribute between the paprika formulations and F4, and was the sole parameter for which all three paprika soups scored significantly higher than the control. The intense orange-red coloration of paprika-enriched soups is attributable to capsanthin and capsorubin, the predominant ketocarotenoids of *C. annuum* [43]. Notably, the ranking of colour scores across formulations mirrored the ranking of fat content, consistent with the predominantly esterified, lipid-bound nature of *Capsicum* carotenoids whose visual expression in aqueous media is facilitated by the surrounding fat matrix [22]. These results confirm that locally produced paprika functions as an effective natural colorant in liquid food systems, a property of high commercial relevance.

Table 4. *Hedonic scores (9-point scale) of soups prepared from paprika-type formulations and the commercial control.*

Attribute	F1	F2	F3	Control
Colour	6.58 ±0.33^{a}	6.45 ±0.38^{a}	6.19 ±0.38^{a}	3.90 ±0.44^{b}
Aroma	5.39 ±0.37^{ab}	5.65 ±0.40^{ab}	6.00 ±0.32^{a*}	4.58 ±0.41^{b}
Taste	4.87 ±0.38^{a}	4.90 ±0.41^{a}	5.19 ±0.35^{a}	5.19 ±0.43^{a}
Texture	5.74 ±0.36^{ab}	5.90 ±0.38^{ab}	6.49 ±0.33^{a*}	4.84 ±0.45^{b}
Aftertaste	4.32 ±0.40^{a}	5.10 ±0.34^{a}	5.26 ±0.32^{a}	5.48 ±0.36^{a}
Overall acceptability	5.26 ±0.40^{a}	6.13 ±0.27^{a}	5.64 ±0.32^{a}	5.48 ±0.34^{a}

Means in the same line with different low-case letter are significantly different at $p < 0.05$ (Tukey Test)

With respect to aroma, a significant advantage over the control was observed exclusively for F3 ($p < 0.05$), whereas F1 and F2 did not differ significantly from either F3 or the control (Table 4). The superior aroma of F3 is most plausibly attributable to its elevated black pepper content (8%), compared with 6% in F1 and 4.5% in F2. *Piper nigrum* contributes terpenic volatile compounds principally sabinene, limonene, and β-caryophyllene that function as potent olfactory stimulants in heated aqueous media [44]. These findings imply the existence of a perceptibility threshold above 6% black pepper for generating a statistically detectable aroma benefit over commercial bouillon, a consideration directly relevant to formulation optimization. F3 also achieved a significantly higher texture score than the control ($p < 0.05$), likely reflecting the greater viscosity and mouthfeel contributed by the higher black pepper content and its associated fibre fraction [13].

No significant differences were detected among any of the four preparations for taste, aftertaste, or overall acceptability ($p > 0.05$ for all; Table 4). The numerically lower taste score of F1 relative to the other formulations may reflect the polarizing cooked sulfurous notes associated with its higher garlic content (8%), as reported for garlic-enriched food systems [19]. The absence of adverse aftertaste across all paprika formulations is consistent with the sweet *C. annuum* cultivar employed, whose capsaicinoid content is expected to be low [45] and thus insufficient to generate the residual pungency that might compromise hedonic acceptability. Taken together, the non-inferiority of all paprika-based formulations to the commercial bouillon across taste, aftertaste, and overall acceptability, alongside significant advantages for colour, and for aroma and texture in the case of F3 constitutes an essential prerequisite for successful market introduction in West Africa.

4. Conclusion

Three paprika-type formulations produced from locally grown *Capsicum annuum* with garlic, black pepper, and salt demonstrated satisfactory physicochemical profiles, full microbiological safety, and sensory quality on a par with a commercial bouillon cube widely used in West African cuisine. Formulation-dependent differences in protein (F1 > F2 > F3), fat (F2 > F1 > F3), and mineral content were consistent with the relative contributions of individual ingredients and conferred distinct nutritional advantages over industrial seasoning cubes. The complete absence of pathogenic microorganisms and the low microbial loads obtained attest to the adequacy of the 65 ℃ hot-air drying protocol and the hygiene practices applied. From a sensory standpoint, F3 outperformed the control for both aroma and texture, and all paprika preparations received superior colour ratings, confirming their competitiveness for consumer acceptance. Collectively, these results establish locally produced *C. annuum*-based paprika as a natural, safe alternative to industrial bouillons with the potential to valorize local agricultural resources and support rural livelihoods in Guinea. Future work should address shelf-life under tropical storage conditions, packaging optimization, and scale-up studies to support commercial production.

Abbreviations

ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
CFU	Colony-Forming Units
DM	Dry Matter
ISO	International Organization for Standardization

ISSMV	Higher Institute of Sciences and Veterinary Medicine of Dalaba
JORA	Journal Officiel de la République Algérienne
MSG	Monosodium Glutamate
ONCQ	National Office for Quality Control
RASFF	Rapid Alert System for Food and Feed
SEM	Standard Error of the Mean
TAMC	Total Aerobic Mesophilic Count

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Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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