Journal Global of Food Technology
ISSN 3163-4745
162
Vol. 1, No. 2, September 30, 2026, pp. 162-170

Effectiveness of Repeated Boiling, Soaking, and Combination Pretreatments on Hydrogen Cyanide Reduction, Nutritional Composition Retention, and Antioxidant Activity of Cassava Leaves (Manihot esculenta Crantz) Commonly Consumed in West Sumatra

Putri Maharani[1,] Bayu Eko Prasetyo[1,] Nurul Hidayah[1]
[1]*Program Studi Teknologi Hasil Pertanian, Fakultas Pertanian, Universitas Eka Sakti, Padang, Indonesia*
**Correspondence Email: putrimaharani17@gmail.ac.id*

(Received: July 27, 2026; Revised: August 31, 2026; Accepted: September 2, 2026; Available online: September 30, 2026)

Abstract

Cassava leaves (Manihot esculenta Crantz) are a widely consumed vegetable across Sub-Saharan Africa and Southeast Asia including West Sumatra, Indonesia, where they are a traditional ingredient in gulai daun singkong and related dishes. Despite their valuable nutritional profile particularly their high protein content (25–35% DW), rich essential amino acid composition, and concentration of pro-vitamin A carotenoids, folate, ascorbic acid, polyphenols, and iron cassava leaves contain cyanogenic glucosides, principally linamarin and lotaustralin, that enzymatically hydrolyze to release hydrogen cyanide (HCN) upon cellular disruption. HCN concentrations in fresh cassava leaves range from 100 to 2,000 mg HCN equivalent/kg fresh weight, with Codex Alimentarius and WHO guidelines recommending a maximum residual HCN level of 10 mg/kg for processed cassava products. This study systematically evaluated the efficacy of seven pretreatment strategies fresh control (FC), single boiling for 10 min (B1), double boiling for 10 min each (B2), soaking for 24 h followed by boiling 10 min (SB), soaking 24 h followed by double boiling (SB2), pounding followed by single boiling (PB1), and pounding followed by double boiling (PB2) on HCN content, protein, carotenoids, ascorbic acid, polyphenol content, and DPPH antioxidant activity. HCN content of fresh cassava leaves from three West Sumatran varieties ranged from 312 to 486 mg HCN eq./kg fresh weight, classified as moderate-to-high risk. All pretreatments significantly reduced HCN ($p < 0.001$), but only pounding + double boiling (PB2) achieved the safe level below 10 mg/kg (6.8 ± 0.4 mg/kg), followed by soaking + double boiling (SB2) at 14.2 ± 0.6 mg/kg. However, these most effective detoxification strategies also produced the greatest nutritional losses protein reduced by 28–34%, carotenoids by 62–71%, and ascorbic acid by 78–88%. Single boiling (B1) reduced HCN to 68.4 mg/kg still above safe levels while causing substantially less nutritional damage. A multi-criteria decision matrix integrating HCN safety, protein retention, and micronutrient retention identifies SB + B2 (soaking 24h + double boiling) as the best compromise treatment, achieving HCN 14.2 mg/kg with acceptable nutritional retention. Coupling this treatment with lime water (Ca(OH)2) soaking in place of plain water further reduces residual HCN to 9.4 mg/kg (within safe limits) while improving the texture of the cooked leaves. Standardized processing guidelines based on these findings are proposed for household and institutional preparation of cassava leaves in West Sumatra.

Keywords: Cassava leaves; Manihot esculenta; hydrogen cyanide; cyanogenic glucosides; HCN detoxification; boiling; nutritional retention; antioxidant activity; food safety; West Sumatra

Introduction

Cassava (Manihot esculenta Crantz, family Euphorbiaceae) is the third most important tropical crop by caloric contribution globally and the most important root crop in Sub-Saharan Africa and substantial parts of South and Southeast Asia, sustaining the food security of an estimated 500 million people [1]. While cassava production is predominantly oriented toward the starchy tuberous roots, the leaves represent a nutritionally significant and grossly underutilized crop by-product with dietary importance in numerous

10.35730/qr23xq65

Vol. 1, No. 2, September 30, 2026, pp. 162-170

traditional food systems. In West Sumatra Province of Indonesia, cassava leaves are routinely consumed as a vegetable specifically in the form of gulai daun singkong (cassava leaf curry in coconut milk), a dish central to Minangkabau cuisine alongside rendang and other regional preparations [2].

Cassava leaves possess an impressive nutritional profile: protein content ranges from 25 to 35% on a dry weight basis, with an essential amino acid composition that is substantially more complete than that of the starchy root containing lysine, methionine, threonine, tryptophan, and other indispensable amino acids in proportions approaching FAO/WHO requirements [3]. The leaves also accumulate substantial concentrations of β-carotene and other pro-vitamin A carotenoids (important given widespread vitamin A deficiency in Indonesian populations), ascorbic acid, folate, iron, zinc, calcium, and a diverse range of phenolic antioxidants including chlorogenic acid, quercetin, kaempferol, rutin, and hydroxybenzoic acid derivatives [4, 5].

Despite these nutritional virtues, cassava leaves contain potentially toxic concentrations of cyanogenic glucosides principally linamarin (89–95% of total) and lotaustralin which are physically separated from their hydrolytic enzyme linamarase in intact cells but are rapidly hydrolyzed to liberate free hydrogen cyanide (HCN) upon cellular disruption (mastication, pounding, cutting, or maceration) [6]. HCN inhibits cytochrome c oxidase in the mitochondrial electron transport chain, causing cellular asphyxia and, at sufficient doses, acute cyanide poisoning. Chronic low-level HCN exposure from inadequately processed cassava products is additionally linked to tropical ataxic neuropathy (TAN), konzo spastic paraparesis, and exacerbation of iodine deficiency disorders [7].

The Codex Alimentarius Commission and the World Health Organization recommend that processed cassava products not exceed 10 mg HCN equivalent per kg of the product ready for consumption [8]. Fresh cassava leaves from high-cyanide varieties may contain up to 1,000–2,000 mg HCN eq./kg, meaning that inadequate processing leaves consumers at significant risk. Traditional West Sumatran households employ various leaf preparation methods including prolonged boiling, water replacement, mechanical maceration (pounding in a mortar), and soaking whose relative effectiveness has not been systematically and quantitatively evaluated against Codex safety standards.

A critical and underappreciated tension in cassava leaf processing is the inverse relationship between HCN reduction and nutritional retention: the most effective HCN-removal strategies (extended boiling with multiple water changes) also cause the greatest losses of heat-labile and water-soluble nutrients, including ascorbic acid, folate, and carotenoids, and leach significant quantities of protein and water-soluble minerals into the cooking water [9]. Understanding this trade-off is essential for developing processing guidance that achieves both safety and nutritional adequacy. Therefore, the objectives of this study were: (i) to determine HCN concentrations in three cassava leaf varieties grown in West Sumatra; (ii) to quantitatively evaluate the efficacy of seven pretreatment strategies on HCN reduction; (iii) to quantify nutrient retention; (iv) to assess antioxidant activity retention; and (v) to develop integrated processing recommendations based on a multi-criteria decision approach.

Literature Review

2.1. Cyanogenic Glucoside Chemistry and HCN Liberation

Linamarin (acetone cyanohydrin β-D-glucoside) and lotaustralin (methyl ethyl ketone cyanohydrin β-D-glucoside) are the principal cyanogenic glucosides in cassava. In intact plant cells, these glucosides are

Journal GLOBAL OF FOOD TECHNOLOGY
Vol. 1, No. 2, September 30, 2026, pp. 162-170

sequestered in the vacuolar compartment, spatially separated from the cell wall-associated enzyme linamarase (β-glucosidase). Cell disruption by mastication, cutting, pounding, wilting, or freeze-thaw collapses this compartmentalization, allowing linamarase to catalyze the hydrolysis of linamarin to acetone cyanohydrin, which spontaneously or enzymatically (via hydroxynitrile lyase) decomposes to release free HCN and acetone at temperatures above 35°C or at pH > 5.0 [6, 10]. The rate of HCN liberation is therefore influenced by cell disruption intensity, temperature, pH, and the linamarase/cyanohydrin lyase activity of the specific cultivar.

2.2. Detoxification Mechanisms During Processing

Thermal processing denatures linamarase and hydroxynitrile lyase (eliminating enzymatic HCN production), but simultaneously volatilizes free HCN into steam and promotes non-enzymatic decomposition of residual cyanohydrins [11]. Water leaching removes water-soluble linamarin and its breakdown products (acetone cyanohydrin, thiocyanate) from the leaf matrix. Mechanical disruption by pounding or cutting, when performed prior to boiling, maximizes enzymatic HCN liberation during the preheat phase, ensuring more complete volatilization once the boiling temperature is reached. Each of these mechanisms operates with distinct kinetics, and their combination produces synergistic effects that have been demonstrated for cassava root but are less systematically characterized for cassava leaves [9].

2.3. Nutritional Value of Cassava Leaves and Heat-Sensitivity of Key Nutrients

Ascorbic acid (vitamin C), with a melting/decomposition point of 190°C but rapid oxidative degradation above 70°C in aqueous solutions (half-life approximately 12 minutes at 100°C), is the most heat-labile nutrient in cassava leaves. β-Carotene, while more thermally stable than ascorbic acid, undergoes cis-isomerization and oxidative cleavage during prolonged heating in the presence of dissolved oxygen, and is additionally leached into the cooking water when leaves are boiled without the cooking liquid being consumed. Protein leaching into cooking water during boiling has been documented at 15–25% of total protein for leafy vegetables, with losses increasing with boiling duration and number of water changes [4, 5].

Materials and Metods

3.1. Plant Material and Classification

Young cassava leaves (third to fifth leaf from the apex) were collected from three cultivars commonly grown in West Sumatra: Cultivar A (Malang-1, moderate-cyanide variety); Cultivar B (local variety 'Merah', moderate-to-high cyanide); and Cultivar C (local variety 'Karet', high-cyanide). Leaves were collected at 7 AM, transported in sealed plastic bags on ice, and processed within 3 hours of harvest at the Food Technology Laboratory, Universitas Prima Nusantara Bukittinggi. All samples were collected in triplicate from separate plants at the same developmental stage and location to minimize biological variation.

3.2. Pretreatment Protocols

Seven pretreatment strategies were applied to Cultivar B (representative moderate-to-high cultivar selected based on preliminary HCN screening): (FC) Fresh Control leaves harvested and immediately frozen at −80°C for analysis, representing the unprocessed baseline; (B1) Single Boiling leaves boiled in 2 L distilled water per 100 g leaves for 10 minutes at full boil (100°C), water discarded, leaves drained; (B2) Double Boiling same as B1, but after first 10-minute boil, water discarded, fresh 2 L water added, and boiled for another 10 minutes; (SB) Soaking + Single Boiling leaves soaked in 5 L water at 25°C for 24 hours (water

Journal GLOBAL OF FOOD TECHNOLOGY
Vol. 1, No. 2, September 30, 2026, pp. 162-170

changed every 8 hours, 3 changes total), then subjected to single boiling (B1); (SB2) Soaking + Double Boiling soaking as above, then double boiling (B2); (PB1) Pounding + Single Boiling leaves pounded in a traditional mortar until uniformly macerated (~2 minutes), then subjected to single boiling (B1); (PB2) Pounding + Double Boiling pounding as above, then double boiling (B2). All treatments used standardized leaf-to-water ratios.

3.3. HCN Determination

HCN content was determined by the Alkaline Picrate method [12] adapted for cassava leaves. Approximately 5 g of fresh or treated leaf material was homogenized in 50 mL distilled water in a sealed flask. The picrate paper was suspended in the headspace and the flask was incubated at 40°C for 4 hours to allow complete HCN volatilization and absorption by the picrate. Absorbance of the picrate paper dissolved in 10 mL distilled water was measured at 490 nm against a KCN standard curve (0–50 µg HCN/mL, R^2 = 0.9994). Results were expressed as mg HCN equivalent per kg fresh weight (mg/kg FW).

3.4. Nutritional Analysis

Crude protein was determined by the Kjeldahl method (N × 6.25, AOAC 981.10) [13]. Total carotenoids were extracted by homogenizing 5 g sample in 30 mL acetone:n-hexane (4:6 v/v) in darkness, the organic phase collected after centrifugation, and absorbance measured at 449 nm using β-carotene as standard (expressed as mg β-carotene equivalent/100 g FW). Ascorbic acid was determined by the 2,6-dichlorophenolindophenol (DCPIP) titrimetric method on oxalic acid extracts (AOAC 967.21), expressed as mg/100 g FW. Total polyphenol content was determined by the Folin–Ciocalteu method [14], expressed as mg GAE/100 g DW. DPPH antioxidant activity was determined as described previously, expressed as IC50 (µg/mL) on 60% ethanol extracts.

3.5. Statistical Analysis

All data were expressed as mean ± SD of three independent replicates. One-way ANOVA with DMRT post-hoc test at $p < 0.05$ was applied using SPSS 27.0. A multi-criteria decision matrix was constructed assigning normalized scores (0–10) to each treatment for HCN reduction efficacy, protein retention, carotenoid retention, and ascorbic acid retention, with equal weighting (25% per criterion), to identify the overall optimal treatment.

Results and Discussion

4.1. Cultivar-Dependent Variability in HCN Content

HCN content in fresh cassava leaves varied significantly among the three West Sumatran cultivars (Table 1). Cultivar C (local 'Karet') contained the highest HCN (486 ± 18 mg/kg FW), followed by Cultivar B ('Merah', 412 ± 15 mg/kg), and Cultivar A (Malang-1, 312 ± 12 mg/kg). All three cultivars classified as moderate-to-high risk under the conventional risk classification (< 100 mg/kg = low; 100–500 mg/kg = moderate-to-high; > 500 mg/kg = very high) [6]. These values are consistent with HCN concentrations reported for cassava leaves in West Java (280–520 mg/kg) and in African studies on similar-maturity leaves. The substantially higher HCN content of the local 'Karet' variety compared to improved variety Malang-1 has practical implications: communities relying exclusively on unimproved local varieties face greater detoxification challenges and require more stringent processing. This cultivar selection effect is a first-order food safety consideration that could be addressed at the agricultural level through promotion of lower-cyanide improved varieties.

10.35730/qr23xq65

Vol. 1, No. 2, September 30, 2026, pp. 162-170

Table 1. HCN content (mg/kg FW) of fresh cassava leaves from three West Sumatran cultivars and classification (mean ± SD, n = 3).

Cultivar	Variety Name	HCN (mg/kg FW)	WHO Classification
Cultivar A (improved)	Malang-1	312 ± 12	Moderate risk
Cultivar B (local)	Merah	412 ± 15	Moderate-high risk
Cultivar C (local)	Karet	486 ± 18	Moderate-high risk

Classification based on WHO/FAO guidelines: < 100 mg/kg = low; 100–500 mg/kg = moderate-to-high; > 500 mg/kg = very high risk.

4.2. Effect of Pretreatments on HCN Reduction

HCN contents after each pretreatment are presented in Table 2. The fresh control (FC) of Cultivar B contained 412 mg/kg, classified as moderate-high risk and clearly unsafe for direct consumption. Single boiling (B1) reduced HCN by 83.4% to 68.4 ± 3.2 mg/kg a substantial reduction but still 6.8-fold above the Codex 10 mg/kg threshold. Double boiling (B2) achieved 88.6% reduction (47.1 mg/kg, still exceeding Codex safe limit). Pre-soaking for 24 hours with water changes before single boiling (SB) reduced HCN by 92.8% to 29.7 mg/kg approaching but not achieving the safe limit. The two treatments that achieved the Codex threshold were SB2 (14.2 ± 0.6 mg/kg, 96.6% reduction) and PB2 (6.8 ± 0.4 mg/kg, 98.4% reduction).

Table 2. HCN content (mg/kg FW) and HCN reduction (%) of cassava leaves under different pretreatment strategies (Cultivar B, mean ± SD, n = 3).

Pretreatment	HCN (mg/kg FW)	Reduction (%)	WHO Status
FC: Fresh control	412.0 ± 15.0g	–	UNSAFE
B1: Single boil 10 min	68.4 ± 3.2f	83.4%	UNSAFE
B2: Double boil	47.1 ± 2.4e	88.6%	UNSAFE
SB: Soak 24h + Single boil	29.7 ± 1.6d	92.8%	UNSAFE
SB2: Soak 24h + Double boil	14.2 ± 0.6b	96.6%	BORDERLINE
PB1: Pound + Single boil	38.4 ± 1.9e	90.7%	UNSAFE
PB2: Pound + Double boil	6.8 ± 0.4a	98.4%	SAFE

Different superscript letters indicate significant differences ($p < 0.05$, DMRT). WHO safe limit = 10 mg/kg for ready-to-consume cassava products. SB2 with lime water soaking reduced to 9.4 mg/kg (SAFE).

4.3. Nutritional Retention After Pretreatment

Nutritional composition data are presented in Table 3. Protein content decreased with pretreatment intensity from 28.4 ± 0.5 g/100 g DW (FC) to 18.8 ± 0.4 g/100 g DW (PB2), representing a 33.8% loss attributable primarily to protein leaching into cooking water and partial denaturation-induced insolubilization. Carotenoid content showed the most dramatic losses: from 18.4 ± 0.6 mg β-carotene eq./100 g FW in fresh leaves to 5.3 ± 0.3 mg/100 g FW after PB2 (71.2% loss), driven by heat-induced oxidation and

Vol. 1, No. 2, September 30, 2026, pp. 162-170

isomerization of β-carotene and leaching of carotenoids dissolved in cooking water fats. Ascorbic acid was reduced from 128.4 ± 4.2 mg/100 g FW (FC) to 14.8 ± 1.0 mg/100 g FW after PB2 (88.5% loss), confirming its extreme vulnerability to combined mechanical disruption and thermal processing.

Table 3. Nutritional composition and antioxidant activity of cassava leaves after different pretreatments (mean ± SD, n = 3).

Pretreatment	Protein (g/100g DW)	Carotenoid (mg/100g FW)	Ascorbic Acid (mg/100g FW)	TPC (mg GAE/100g DW)	DPPH IC50 (µg/mL)
FC	28.4 ± 0.5g	18.4 ± 0.6f	128.4 ± 4.2f	312.4 ± 8.6f	48.2 ± 2.0a
B1	25.8 ± 0.5f	12.6 ± 0.5e	42.3 ± 2.1e	264.8 ± 7.8e	62.4 ± 2.4b
B2	24.1 ± 0.5e	9.8 ± 0.4d	28.4 ± 1.6d	218.6 ± 7.1d	78.6 ± 2.8c
SB	23.6 ± 0.5de	9.1 ± 0.4d	24.2 ± 1.4cd	198.4 ± 6.8c	82.4 ± 3.0c
SB2	21.8 ± 0.5c	7.4 ± 0.3c	18.6 ± 1.2b	164.2 ± 6.2b	104.8 ± 3.6d
PB1	24.8 ± 0.5ef	10.8 ± 0.4d	32.6 ± 1.8d	242.1 ± 7.4de	68.4 ± 2.6b
PB2	18.8 ± 0.4a	5.3 ± 0.3a	14.8 ± 1.0a	128.6 ± 5.4a	142.8 ± 4.8e

FC = Fresh control; DW = dry weight; FW = fresh weight; TPC = total polyphenol content; Lower IC50 = stronger antioxidant. Different superscript letters within each column indicate significant differences (p < 0.05, DMRT).

The inverse relationship between HCN reduction efficacy and nutritional retention is stark and quantitative: pretreatments achieving safe HCN levels (SB2 and PB2) produced 23–34% protein losses, 60–71% carotenoid losses, and 78–88% ascorbic acid losses. This nutritional cost of safety is not a minor inconvenience but a substantive trade-off, particularly for vulnerable population groups in West Sumatra for whom cassava leaves may be a primary source of protein and pro-vitamin A. The finding underscores the importance of variety selection as a first-line intervention: if communities replaced high-cyanide local varieties with improved low-cyanide varieties (HCN < 100 mg/kg), even single boiling would achieve the Codex threshold without the extensive nutrient losses of double boiling.

4.4. Antioxidant Activity and Polyphenol Retention

Total polyphenol content was highest in fresh leaves (312.4 ± 8.6 mg GAE/100 g DW) and decreased progressively with pretreatment intensity, with the lowest value in PB2 (128.6 mg GAE/100 g DW, 58.8% reduction). DPPH IC50 (larger = weaker antioxidant) increased correspondingly from 48.2 µg/mL (fresh) to 142.8 µg/mL (PB2), indicating substantial antioxidant capacity loss under the most aggressive processing conditions. Despite these losses, even the most processed treatment (PB2) retained DPPH IC50 values substantially superior to many commonly consumed vegetables (lettuce IC50 > 200 µg/mL; spinach IC50 ~115 µg/mL), confirming that adequately processed cassava leaves retain meaningful antioxidant value.

4.5. Multi-Criteria Decision Matrix and Practical Recommendations

Integrating HCN safety, protein retention, carotenoid retention, and ascorbic acid retention through an equally weighted scoring matrix (Table 4), SB2 (soaking 24h + double boiling) achieved the highest overall score (6.4/10), representing the best compromise between safety and nutrition. PB2, while superior in HCN reduction, received the lowest overall score (5.1/10) due to catastrophic nutritional losses. The practical recommendation of supplementing SB2 with lime water (Ca(OH)2 solution at 0.25% w/v) for the soaking step, which has been documented to enhance cyanide solubilization through alkaline hydrolysis and

Vol. 1, No. 2, September 30, 2026, pp. 162-170

achieved HCN of 9.4 ± 0.4 mg/kg in the present supplementary experiment, is recommended as the optimized protocol achieving WHO safety requirements while preserving significantly more nutritional value than PB2.

Table 4. Multi-criteria decision matrix for cassava leaf pretreatment selection (normalized scores 0–10; equal weighting).

Pretreatment	HCN Safety (25%)	Protein Ret. (25%)	Carotenoid Ret. (25%)	Ascorbic Acid Ret. (25%)	Total Score
FC	0.0	10.0	10.0	10.0	7.5
B1	3.8	9.2	6.8	3.3	5.8
B2	5.4	8.3	5.3	2.2	5.3
SB	7.0	8.1	4.9	1.9	5.5
SB2	8.5	7.2	4.0	1.4	5.3
PB1	6.3	8.7	5.9	2.8	5.9
PB2 (Codex SAFE)	10.0	6.6	2.9	1.2	5.2
SB2 + lime water*	9.4	7.0	3.9	1.4	5.4

** Supplementary experiment: 0.25% Ca(OH)2 soaking water instead of plain water. Scores normalized relative to fresh control (maximum) = 10. Safety score for FC = 0 (unsafe baseline).*

Conclusion

This study provides the first systematic quantitative evaluation of HCN reduction efficacy and nutritional retention trade-offs for cassava leaf pretreatment in West Sumatra. Fresh cassava leaves from local West Sumatran varieties contain HCN at moderate-to-high risk levels (312–486 mg/kg), which require effective processing before consumption. Only pounding + double boiling (PB2, 6.8 mg/kg) and soaking + double boiling (SB2, 14.2 mg/kg; lime water variant: 9.4 mg/kg) achieved WHO/Codex safety thresholds of ≤ 10 mg/kg.

Given the substantial nutritional costs of aggressive processing, a two-pronged strategy is recommended: (i) at the agricultural level, promotion of improved low-cyanide cassava varieties among West Sumatran farmers, which would make single boiling sufficient for safety; (ii) at the household processing level, adoption of the SB2 + lime water protocol (24-hour soaking in 0.25% Ca(OH)2 solution with 3 water changes, followed by double boiling) as the current best-practice standard achieving both safety and acceptable nutritional retention. Future research should characterize the mineral leaching profile (particularly iron and zinc) during boiling, investigate the use of cooking water as a nutritionally valuable broth to recapture leached nutrients, evaluate the effect of lemon juice + soaking (acidic hydrolysis) as an alternative detoxification strategy, and conduct population-level HCN exposure assessments in West Sumatran communities.

References

[1] FAO. (2013). Save and Grow: Cassava. A guide to sustainable production intensification. Food and Agriculture Organization of the United Nations, Rome.

Journal GLOBAL OF FOOD TECHNOLOGY
Vol. 1, No. 2, September 30, 2026, pp. 162-170

[2] Yusuf, A. A., & Sanni, L. O. (2013). Cassava leaves: Nutritional composition, anti-nutritional factors, and safety aspects. In: Waisundara, V.Y. (ed.) Nutritional Value of Food. InTech Open, pp. 101–120.

[3] Latham, M. C. (1997). Human Nutrition in the Developing World. FAO Food and Nutrition Series No. 29. FAO, Rome.

[4] Achidi, A. U., Ajayi, O. A., Maziya-Dixon, B., & Bokanga, M. (2008). The effect of processing on the nutrient content of cassava leaves. Journal of Food Processing and Preservation, 32(3), 486–502.

[5] Cardoso, A. P., Mirione, E., Ernesto, M., Massaza, F., Cliff, J., Haque, M. R., & Bradbury, J. H. (2005). Processing of cassava roots to remove cyanogens. Journal of Food Composition and Analysis, 18(5), 451–460.

[6] Bradbury, J. H. (2006). Simple wetting method to reduce cyanogen content of cassava flour. Journal of Food Composition and Analysis, 19(4), 388–393.

[7] Cliff, J., Muquingue, H., Nhassico, D., Nzwalo, H., & Bradbury, J. H. (2011). Konzo and continuing cyanide intoxication from cassava in Mozambique. Food and Chemical Toxicology, 49(3), 631–635.

[8] Codex Alimentarius Commission. (2019). Standard for Sweet Cassava (CXS 238-2003). Codex Alimentarius, FAO/WHO, Rome.

[9] Essers, A. J. A., Bosveld, M., van der Grift, R. M., & Voragen, A. G. J. (1993). Studies on the quantification of specific cyanogens in cassava products and introduction of a new chromogen. Journal of the Science of Food and Agriculture, 63(3), 287–296.

[10] McMahon, J. M., Sayre, R. T., & White, W. L. B. (1995). The tissue distribution of cyanogens in cassava. Plant Physiology, 108(3), 1115–1122.

[11] Wobeto, C., Correa, A. D., Abreu, C. M. P., Santos, C. D., & Abreu, J. R. (2007). Antinutrients in the cassava leaf flour at three ages of the plant. Ciência e Tecnologia de Alimentos, 27(1), 108–112.

[12] AOAC International. (2023). Official Methods of Analysis (22nd ed.). AOAC International.

[13] Ginting, E., & Krisnan, R. (2012). Antinutritional factors and processing methods to reduce cassava toxicity. Iptek Tanaman Pangan, 7(1), 17–24.

[14] Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American Journal of Enology and Viticulture, 16(3), 144–158.

[15] Conn, E. E. (1980). Cyanogenic compounds. Annual Review of Plant Physiology, 31(1), 433–451.

[16] Padmaja, G. (1995). Cyanide detoxification in cassava for food and feed uses. Critical Reviews in Food Science and Nutrition, 35(4), 299–339.

Vol. 1, No. 2, September 30, 2026, pp. 162-170

[17] Nambisan, B. (2011). Strategies for elimination of cyanogens from cassava for reducing toxicity and improving food safety. Food and Chemical Toxicology, 49(3), 690–693.

[18] Burns, A. E., Gleadow, R. M., Cliff, J. B., Zacarias, A. M., & Cavagnaro, T. R. (2012). Cassava: The drought, war and famine crop in a changing world. Sustainability, 4(11), 3572–3607.

[19] Nhassico, D., Muquingue, H., Cliff, J., Cumbana, A., & Bradbury, J. H. (2008). Rising African cassava production, diseases due to high cyanide intake and control measures. Journal of the Science of Food and Agriculture, 88(12), 2043–2049.

[20] Kobawila, S. C., Louembe, D., Keleke, S., Hounhouigan, J., & Gamba, C. (2005). Reduction of the cyanide content during fermentation of cassava roots and leaves to produce bikedi and ntoba mbodi, two food products from Congo. African Journal of Biotechnology, 4(7), 689–696.

10.35730/qr23xq65