



Effect of Fermentation Duration and Co-fermentation Materials on the Proximate Composition, Fibre Fractions and Tannin Content of *Parkia Biglobosa* Husk

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ABSTRACT

This study evaluated the effects of fermentation duration and co-fermentation materials on the proximate composition, fibre fractions and tannin content of *Parkia biglobosa* husk at the Agriculture Laboratory, College of Education, Oro, Kwara State, Nigeria. The experiment was arranged as a 3 × 3 factorial comprising three co-fermentation materials: rice husk ash (PRHA), poultry droppings (PPD) and fruit exudates (PPE), and three fermentation durations of 7, 14 and 21 days, with three independent fermentation batches per treatment combination, giving 27 experimental units (n = 27). Fermented samples were analysed for moisture, residual moisture, crude protein, ash, crude fibre, crude fat, carbohydrate (CHO), neutral detergent solubles (NDS), neutral detergent fibre (NDF) and tannin. Data were subjected to two-way analysis of variance (ANOVA), and means were separated using Tukey's honestly significant difference (HSD) test at $P \leq 0.05$. Co-fermentation material and fermentation duration significantly affected most parameters, with significant interactions for moisture, residual moisture, crude protein, ash, crude fibre, CHO, NDS, NDF and tannin, whereas crude fat showed no significant interaction. PRHA recorded the highest crude protein (9.13%) and ash (13.55%), while PPE had the highest crude fibre (43.09%), crude fat (2.05%) and NDS (41.44%). Fermentation for 21 days increased crude protein (8.84%) and ash (9.85%) but reduced crude fibre (37.04%), crude fat (1.39%), CHO (30.19%) and tannin (5.21%). Fermentation produced distinct changes in the nutritional and fibre characteristics of *P. biglobosa* husk, indicating its potential for improving the feed value of this under-utilised agro-processing residue.

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INTRODUCTION

Parkia biglobosa (African locust bean) is a significant indigenous multipurpose tree of West Africa that is traditionally processed to produce food, particularly a fermented seed condiment (iru/dawadawa). The overwhelming research focus has been on the utilisation of seeds and fermented cotyledons. Still, a significant amount of non-seed residues is also generated during processing and remains relatively underutilised. Recent studies have demonstrated that the by-products from the processing of *P. biglobosa* can constitute significant proportions of the total material and include fibre and other potentially useful components, making them more akin to resources than to wastes (Oludipeet al., 2024). The valorisation of agricultural residues is gaining significance due to the potential to obtain materials with improved nutritional, functional, or industrial properties through solid-state fermentation (Chilakamarryet al., 2021).

Of particular interest is the husk of *P. biglobosa* since it has a fibrous texture which could affect its direct nutritive value but could also be used as a substrate for microbial processing. The enzymatic hydrolysis of complex substrates, changes in fibre structures, release of bound compounds and changes in nutrient availability due to fermentation of plant residues (Postigo et al., 2021). These changes are highly dependent on substrate, moisture, fermentation conditions, microbial population and fermentation time (Perwez & Asheh, 2024). Therefore, fermentation cannot be seen as merely a

preservation process; it can significantly modify the chemical properties of agricultural by-products.

Fermentation has already been adopted as a processing technology for *P. biglobosa* seeds. *Bacillus* species are the predominant microorganisms in traditional fermentation of locust beans, with a relatively low oxygen condition of fermentation resulting in a higher proportion of *Bacillus* species than other genera (Ogbadu&Okagbue, 1988); biochemical changes during fermentation have been correlated to changes in protein, fibre, ash, fat and carbohydrate content (Azokpotaet al., 2006). Further studies on fermented locust bean showed that antinutrients such as tannins, phytates, and saponins were reduced, and nutrient digestibility and functional properties were improved (Yakubu et al., 2022). It has also been reported that the proximate composition and antinutrient content of locally processed *P. biglobosa* products can be altered by fermentation in Nigeria (Ndukwe & Solomon, 2017).

The resulting fermented residue might also be affected by the selection of co-fermentation material. The nutrient content of agricultural ashes, animal-derived products, and fruit-derived substrates differs, and they can also create distinct mineral, carbon, and nitrogen environments for microbial activity. Fruit residues, for instance, are rich in fibre, carbohydrates, and bioactive compounds and have been gaining popularity for value-added processing and fermentation (Ariwaodo & Olaniyan, 2024). Likewise, microbial fermentation of agro-industrial wastes has been proposed as a viable process to enhance the nutrient quality of materials used for feed or other

purposes while simultaneously reducing antinutritional factors (Yafetto et al., 2023).

Although fermentation of *P. biglobosa* is important, there is little information on the nutritional response of its husk to controlled, long-term fermentation with different co-fermentation materials. Specifically, limited data compare the performance of rice husk ash, poultry droppings, and fruit exudates across different fermentation periods. The proximate composition, fibre fractions and tannin content of all the *P. biglobosa* husk co-fermented with rice husk ash, poultry droppings and fruit exudates for 7, 14 and 21 days were thus evaluated. The study aimed to define the nutritional changes that occurred during these treatments and to determine the fermentation combinations that presented the best nutritional trends.

MATERIALS AND METHODS

Study Area

The experiment was conducted at the Agriculture Laboratory, College of Education, Oro, Kwara State, Nigeria.

Experimental Design and Fermentation

The experiment was arranged and laid out as a 3×3 factorial experiment comprising three co-fermentation materials and three fermentation durations (7, 14, and 21 days), with three independent fermentation batches per treatment combination. The co-fermentation materials were rice husk ash, poultry droppings, and fruit exudates, designated PRHA (*Parkia biglobosa* husk + rice husk ash), PPD (*P. biglobosa* husk + poultry droppings), and PPE (*P. biglobosa* husk + fruit exudates), respectively. The nine treatment combinations were 7-PRHA, 7-PPD, 7-PPE, 14-PRHA, 14-PPD, 14-PPE, 21-PRHA, 21-PPD, and 21-PPE.

The *P. biglobosa* husk was dried, screened to remove extraneous materials, chopped, and milled prior to fermentation. For PRHA and PPD, 3 kg of prepared husk was thoroughly mixed with 1 kg of rice husk ash or poultry droppings, respectively, and 2 L of clean water. For PPE, 3 kg of prepared husk was mixed with 1.5 L of fruit exudate obtained from fermented pineapple, orange, and watermelon. The mixtures were thoroughly homogenised and transferred into labelled polythene bags, which were sealed and placed in airtight containers to facilitate fermentation.

Fermentation was carried out under ambient laboratory conditions without artificial temperature control, and the fermentation temperature was monitored throughout the experimental period. The fermentation was spontaneous (natural), without the addition of an external microbial inoculum; consequently, fermentation was initiated by the indigenous microorganisms present in the substrates and fermentation materials. The fermentation batches were maintained under the same laboratory conditions throughout the experimental period. At 7, 14, and 21 days, the respective

treatment batches were opened and representative samples were collected for laboratory analyses.

Laboratory Procedures

Proximate composition was determined according to the standard methods of the Association of Official Analytical Chemists International (AOAC International), 22nd edition (Association of Official Analytical Chemists International, 2023). Moisture, crude protein, crude fat, ash, and crude fibre were determined using AOAC Official Methods 925.10, 2001.11, 920.39, 923.03, and 978.10, respectively. Carbohydrate content was calculated by difference.

Neutral detergent fibre (NDF) was determined using the detergent fibre procedure described by Van Soest et al. (1991), while neutral detergent soluble (NDS) was calculated by difference as $NDS (\%) = 100 - NDF (\%)$. Tannin concentration was determined using the vanillin colourimetric method of Price et al. (1980) and expressed as mg/100 g sample.

Statistical Analysis

Data obtained from the laboratory analyses were subjected to two-way analysis of variance (ANOVA) appropriate for a 3×3 factorial arrangement, with co-fermentation material and fermentation duration as the main factors and their interaction included in the model. The three replicates represented independent fermentation batches, rather than subsamples from a single fermentation batch, and were therefore treated as the experimental units for statistical analysis. Analysis was performed using SPSS version 22.0. Where significant differences were detected, treatment means were separated using Tukey's honestly significant difference (HSD) test at the 5% probability level ($P < 0.05$).

RESULTS AND DISCUSSION

Effect of Co-Fermentation Material and Fermentation Duration on Proximate Composition (%) of Fermented *Parkia Biglobosa* Husk

The proximate composition of fermented *Parkia biglobosa* husk as influenced by co-fermentation material and fermentation duration is presented in Table 1. Moisture content ranged from 39.36% in PRHA to 50.17% in PPD, residual moisture ranged from 9.38% in PPD to 11.29% in PPE, crude protein ranged from 7.08% in PPE to 9.13% in PRHA, ash content ranged from 3.94% in PPE to 13.55% in PRHA, crude fibre ranged from 36.44% in PPD to 43.09% in PPE, crude fat ranged from 1.36% in PRHA to 2.05% in PPE, and carbohydrate ranged from 27.82% in PRHA to 36.90% in PPD. Across fermentation duration, moisture, residual moisture, crude protein and ash generally increased from 7 to 21 days, whereas crude fibre, crude fat and carbohydrate declined over the same period.

Table 1: Effect of Co-Fermentation Material and Fermentation Duration on Proximate Composition (%) of Fermented *Parkia Biglobosa* Husk

Treatment	Moisture	Residual moisture	Crude protein	Ash	Crude fibre	Crude fat	CHO
Co-fermentation material (C)							
PRHA	39.36 ^c	10.05 ^b	9.13 ^a	13.55 ^a	38.09 ^b	1.36 ^c	27.82 ^c
PPD	50.17 ^a	9.38 ^c	8.12 ^b	7.53 ^b	36.44 ^c	1.63 ^b	36.90 ^a
PPE	44.03 ^b	11.29 ^a	7.08 ^c	3.94 ^c	43.09 ^a	2.05 ^a	33.14 ^b
SE (C)	0.200	0.100	0.067	0.100	0.167	0.033	0.167
LS (C)	*	*	*	*	*	*	*
Duration (D)							
7 days	43.33 ^b	5.85 ^c	7.46 ^c	7.20 ^c	41.38 ^a	1.99 ^a	36.13 ^a

Treatment	Moisture	Residual moisture	Crude protein	Ash	Crude fibre	Crude fat	CHO
Co-fermentation material (C)							
14 days	46.33 ^a	11.58 ^b	8.03 ^b	7.98 ^b	39.21 ^b	1.66 ^b	31.54 ^b
21 days	43.91 ^b	13.29 ^a	8.84 ^a	9.85 ^a	37.04 ^c	1.39 ^c	30.19 ^c
SE (D)	0.200	0.100	0.067	0.100	0.167	0.033	0.167
LS (D)	*	*	*	*	*	*	*
LS (C × D)	*	*	*	*	*	NS	*

Key: PRHA = *P. biglobosa* husk + rice husk ash; PPD = *P. biglobosa* husk + poultry droppings; PPE = *P. biglobosa* husk + fruit exudates; SE = standard error; LS = level of significance; * = significant at $P \leq 0.05$; NS = not significant. Means with different superscripts within a column differ significantly by Tukey's test at $P \leq 0.05$.

Moisture content was significantly affected by co-fermentation material, fermentation duration and their interaction. PPD recorded the highest moisture content (50.17%), followed by PPE (44.03%), while PRHA had the lowest value (39.36%). This result aligns with the established influence of substrate characteristics on moisture dynamics during solid-state fermentation, where the physical and chemical properties of the materials used determine water availability and retention within the fermentation matrix (Sadh et al., 2018). Moisture increased from 43.33% at 7 days to 46.33% at 14 days before declining slightly to 43.91% at 21 days, a non-linear pattern indicating that moisture

dynamics were governed by the interaction between microbial activity, substrate transformation and moisture retention rather than duration alone; this corroborates the dynamic biochemical changes documented during *P. biglobosa* fermentation by Esse et al. (2022). The significant C × D interaction further confirms that the effect of duration on moisture depended on the co-fermentation material used, since PPD increased progressively across duration while PPE declined and PRHA fluctuated, demonstrating that fermentation duration cannot be optimized independently of the co-fermentation material.

Table 2: Interaction Effect of Co-Fermentation Material and Fermentation Duration on Residual Moisture Content

Co-fermentation material	7 days	14 days	21 days
PRHA	37.67 ^f	43.76 ^d	36.65 ^f
PPD	44.36 ^d	50.72 ^b	55.43 ^a
PPE	47.95 ^c	44.51 ^d	39.64 ^e
SE	0.346	0.346	0.346
C × D	P < 0.001		

Key: PRHA = *P. biglobosa* husk + rice husk ash; PPD = *P. biglobosa* husk + poultry droppings; PPE = *P. biglobosa* husk + fruit exudates; SE = standard error; LS = level of significance; * = significant at $P \leq 0.05$; NS = not significant. Means with different superscripts within a column differ significantly by Tukey's test at $P \leq 0.05$.

Table 3: Interaction Effect of Co-Fermentation Material and Fermentation Duration on Crude Protein Content

Co-fermentation material	7 days	14 days	21 days
PRHA	8.57 ^b	9.45 ^a	9.36 ^a
PPD	7.25 ^d	7.93 ^c	9.17 ^a
PPE	6.56 ^e	6.70 ^d	7.98 ^c
SE	0.115	0.115	0.115
C × D	P < 0.001		

Key: PRHA = *P. biglobosa* husk + rice husk ash; PPD = *P. biglobosa* husk + poultry droppings; PPE = *P. biglobosa* husk + fruit exudates; SE = standard error; LS = level of significance; * = significant at $P \leq 0.05$; NS = not significant. Means with different superscripts within a column differ significantly by Tukey's test at $P \leq 0.05$.

Residual moisture followed a related but distinct pattern. It was significantly influenced by co-fermentation material, with PPE recording the highest value (11.29%), followed by PRHA (10.05%) and PPD (9.38%). This agrees generally with Urua et al. (2013), who observed changes in moisture following processing and fermentation of *P. biglobosa* seeds, although the direction of change differed in some of their treatments, indicating that the response depends on the specific substrate and processing system. Residual moisture also increased significantly with fermentation duration, from 5.85% at 7 days to 13.29% at 21 days, and the significant interaction shows that this increase was most pronounced in PPE, which reached 14.49% at 21 days, while PPD recorded the lowest value at 7 days (4.75%), demonstrating that the co-fermentation material influenced both the initial moisture environment and its subsequent development during fermentation.

Crude protein was significantly affected by both co-fermentation material and fermentation duration. PRHA recorded the highest crude protein concentration (9.13%), followed by PPD (8.12%) and PPE (7.08%). This finding agrees with Abiola-Olagunju et al. (2024), who reported similar improvements in crude protein following biological treatment of fibrous agricultural wastes, supporting the general capacity of fermentation to raise the apparent protein concentration of agricultural residues through microbial biomass formation and preferential utilization of other organic constituents. However, the present result should be interpreted as an increase in measured crude protein concentration rather than definitive protein synthesis, as microbial biomass and nitrogen balance were not directly measured. Crude protein increased significantly with duration, from 7.46% at 7 days to 8.84% at 21 days, consistent with the pattern of duration-dependent protein enrichment

reported by the same authors. The significant interaction indicates that this response depended on the co-fermentation material: PRHA reached 9.45% at 14 days and remained high thereafter, PPD increased progressively to 9.17% by 21 days, while PPE increased but remained lowest throughout, showing that nutritional responses to fermentation depend on both substrate composition and duration.

Ash content was significantly higher in PRHA (13.55%) than PPD (7.53%) and PPE (3.94%), which strongly aligns with the mineral-rich nature of rice husk ash and its high silica content, as reported by Islam *et al.* (2024), providing a clear basis for the substantially higher ash content observed in

PRHA. Ash also increased with fermentation duration, from 7.20% at 7 days to 9.85% at 21 days; this increase should not be interpreted as the creation of new minerals through fermentation, but rather as a relative concentration effect arising as degradation or utilization of organic matter increases the proportion of inorganic material measured as ash. The significant interaction was dominated by the strong ash response of PRHA, which increased from 11.54% at 7 days to 15.80% at 21 days, while PPD remained relatively stable and PPE increased only modestly, aligning particularly well with the mineral contribution expected from rice husk ash.

Table 4: Interaction Effect of Co-fermentation Material and Fermentation Duration on Ash (Total Mineral) Content

Co-fermentation material	7 days	14 days	21 days
PRHA	11.54 ^c	13.32 ^b	15.80 ^a
PPD	7.32 ^d	7.35 ^d	7.93 ^d
PPE	2.73 ^f	3.27 ^f	5.81 ^e
SE	0.173	0.173	0.173
C × D	P < 0.001		

Key: PRHA = *P. biglobosa* husk + rice husk ash; PPD = *P. biglobosa* husk + poultry droppings; PPE = *P. biglobosa* husk + fruit exudates; SE = standard error; LS = level of significance; * = significant at $P \leq 0.05$; NS = not significant. Means with different superscripts within a column differ significantly by Tukey's test at $P \leq 0.05$.

Table 5: Interaction Effect of Co-fermentation Material and Fermentation Duration on Crude Fibre Content

Co-fermentation material	7 days	14 days	21 days
PRHA	39.75 ^c	38.75 ^c	35.78 ^d
PPD	38.70 ^c	35.36 ^d	35.27 ^d
PPE	45.68 ^a	43.53 ^b	40.06 ^c
SE	0.289	0.289	0.289
C × D	P < 0.001		

Key: PRHA = *P. biglobosa* husk + rice husk ash; PPD = *P. biglobosa* husk + poultry droppings; PPE = *P. biglobosa* husk + fruit exudates; SE = standard error; LS = level of significance; * = significant at $P \leq 0.05$; NS = not significant. Means with different superscripts within a column differ significantly by Tukey's test at $P \leq 0.05$.

Crude fibre differed significantly among co-fermentation materials, with PPE recording the highest value (43.09%), followed by PRHA (38.09%) and PPD (36.44%). The lower fibre concentration in PPD may indicate comparatively greater transformation of structural components during co-fermentation, although the relatively high fibre content under PPE indicates that the extent of fibre modification was dependent on the co-fermentation material. Crude fibre decreased significantly from 41.38% at 7 days to 37.04% at 21 days, aligning with the established capacity of microbial fermentation to hydrolyse structural carbohydrates through extracellular enzymes (Sadh *et al.*, 2018). The significant interaction indicates that crude fibre declined with duration across all materials, though the magnitude varied: PPE retained the highest fibre concentration at every duration point but still declined from 45.68% to 40.06%, while PPD

showed a particularly strong reduction between 7 and 14 days.

PPE recorded the highest crude fat content (2.05%), followed by PPD (1.63%) and PRHA (1.36%), while crude fat declined significantly from 1.99% at 7 days to 1.39% at 21 days. This decline is broadly consistent with progressive microbial utilization of lipid components during prolonged fermentation, but it differs in direction from the increase in fat reported in fermented *P. biglobosa* seed treatments by Uruet *et al.* (2013), reinforcing the importance of substrate type and fermentation conditions in determining the direction of lipid change. The C × D interaction for crude fat was not significant (NS), so the Effects provide the appropriate basis for interpreting this parameter; although numerical values declined across duration within each material, the overall pattern did not reach statistical significance for the interaction.

Table 6: Interaction Effect of Co-fermentation Material and Fermentation Duration on Carbohydrate (CHO) Content

Co-fermentation material	7 days	14 days	21 days
PRHA	32.80 ^c	25.71 ^e	24.94 ^e
PPD	40.02 ^a	36.70 ^b	33.97 ^c
PPE	35.56 ^b	32.21 ^d	31.66 ^d
SE	0.289	0.289	0.289
C × D	P < 0.001		

Key: PRHA = *P. biglobosa* husk + rice husk ash; PPD = *P. biglobosa* husk + poultry droppings; PPE = *P. biglobosa* husk + fruit exudates; SE = standard error; LS = level of significance; * = significant at $P \leq 0.05$; NS = not significant. Means with different superscripts within a column differ significantly by Tukey's test at $P \leq 0.05$.

PPD recorded the highest carbohydrate content (36.90%), followed by PPE (33.14%), while PRHA had the lowest value (27.82%); as noted above, the relatively low carbohydrate concentration in PRHA likely reflects the substantial mineral contribution from rice husk ash, which increases the proportion of inorganic matter in the resulting mixture. Carbohydrate decreased significantly with duration, from 36.13% at 7 days to 30.19% at 21 days, consistent with microbial utilization of readily available carbohydrates for growth and metabolism during fermentation. The significant interaction indicates that carbohydrate concentration declined with duration for all materials, but the magnitude of reduction varied: PRHA showed the greatest reduction, while PPD retained the highest carbohydrate concentration throughout,

reflecting differential microbial consumption of fermentable carbohydrate across the co-fermentation materials.

Effect of Co-Fermentation Material and Fermentation Duration on Fibre Fractions of Fermented *Parkia Biglobosa* Husk

The fibre fractions of fermented *Parkia biglobosa* husk, namely nitrogen-free extract (NDS) and neutral detergent fibre (NDF), as influenced by co-fermentation material and fermentation duration, are presented in Table 2. NDS ranged from 29.29% in PPD to 41.44% in PPE and increased with fermentation duration up to 14 days before declining slightly by 21 days, while NDF ranged from 58.56% in PPE to 70.75% in PPD and generally declined with duration, though not uniformly.

Table 7: Effect of Co-fermentation Material and Fermentation Duration on Nitrogen-free Extract (NDS) and Neutral Detergent Fibre (NDF) (%) of Fermented *Parkia Biglobosa* Husk

Treatment	NDS	NDF
Co-fermentation material (c)		
PRHA	30.10 ^b	69.90 ^b
PPD	29.29 ^c	70.75 ^a
PPE	41.44 ^a	58.56 ^c
SE (C)	0.133	0.133
LS (C)	*	*
Duration (d)		
7 days	30.21 ^c	69.82 ^a
14 days	36.07 ^a	63.93 ^c
21 days	34.54 ^b	65.46 ^b
SE (D)	0.133	0.133
LS (D)	*	*
LS (C × D)	*	*

Key: PRHA = *P. biglobosa* husk + rice husk ash; PPD = *P. biglobosa* husk + poultry droppings; PPE = *P. biglobosa* husk + fruit exudates; SE = standard error; LS = level of significance; * = significant at $P \leq 0.05$; NS = not significant. Means with different superscripts within a column differ significantly by Tukey's test at $P \leq 0.05$.

PPE recorded the highest NDS content (41.44%), whereas PPD recorded the lowest (29.29%). This aligns with differences in the soluble and readily available carbohydrate fractions contributed by the co-fermentation materials, since fermentation can modify these fractions through simultaneous hydrolysis of complex carbohydrates and microbial utilization of soluble compounds (Sadh et al., 2018), and agrees with the general biochemical transformations associated with fermentation of *P. biglobosa* reported by Esse et al. (2022). NDS increased from 30.21% at 7 days to 36.07% at 14 days before declining slightly to

34.54% at 21 days, aligning with a possible initial release of soluble carbohydrate fractions followed by microbial utilization as fermentation progresses; this interpretation agrees with the dynamic substrate transformation described by Sadh et al. (2018) and Esse et al. (2022), although because soluble sugars and individual carbohydrate fractions were not directly measured, this mechanism should be regarded as an interpretation rather than a direct demonstration of hydrolysis. Because the C × D interaction for NDS was significant, the pattern is examined further in Table 3.

Table 8: Interaction Effect of Co-fermentation Material and Fermentation Duration on Nitrogen-free Extract (NDS) (%) of Fermented *Parkia Biglobosa* Husk

Co-fermentation material	7 days	14 days	21 days
PRHA	30.87 ^c	29.15 ^f	30.27 ^f
PPD	23.12 ^g	31.68 ^c	33.06 ^d
PPE	36.65 ^c	47.39 ^a	40.28 ^b
SE	0.231	0.231	0.231
LS (C × D)	*		

Key: PRHA = *P. biglobosa* husk + rice husk ash; PPD = *P. biglobosa* husk + poultry droppings; PPE = *P. biglobosa* husk + fruit exudates; SE = standard error; LS = level of significance; * = significant at $P \leq 0.05$; NS = not significant. Means with different superscripts within a column differ significantly by Tukey's test at $P \leq 0.05$.

The significant interaction demonstrates contrasting NDS responses among the co-fermentation materials. PPE increased sharply from 36.65% at 7 days to 47.39% at 14 days before declining to 40.28% at 21 days. PPD increased

progressively, whereas PRHA remained relatively stable. This aligns with the concept that fermentation involves simultaneous hydrolysis and microbial utilization of soluble and structural carbohydrate fractions (Sadh et al., 2018), and

agrees with Esse *et al.* (2022), who demonstrated that *P. biglobosa* fermentation involves dynamic biochemical transformations over time.

Turning to NDF, this fraction differed significantly among the co-fermentation materials. PPD had the highest NDF (70.75%), followed closely by PRHA (69.90%), whereas PPE recorded the lowest value (58.56%). This aligns with differences in the degradation of structural carbohydrate components among fermentation substrates, agreeing with Shrivastava *et al.* (2014), who demonstrated that microbial treatment can reduce structural fibre components in agricultural residues, and corroborating Abiola-Olagunju *et al.* (2024), who reported reductions in NDF and related fibre

fractions following fungal treatment of fibrous agricultural wastes. NDF decreased from 69.82% at 7 days to 63.93% at 14 days but increased slightly to 65.46% at 21 days, a non-linear response suggesting that different substrate fractions were degraded at different rates during fermentation, aligning with the dynamic nature of microbial degradation described by Sadh *et al.* (2018) and agreeing with Shrivastava *et al.* (2014). Although a lower NDF concentration may indicate a potentially more favourable fibre profile, it should not be interpreted as direct evidence of improved digestibility without digestibility measurements. Because the $C \times D$ interaction for NDF was also significant, this is examined further in Table 4.

Table 9: Interaction Effect of Co-fermentation Material and Fermentation Duration on Neutral Detergent Fibre (NDF) (%) of Fermented *Parkia Biglobosa* Husk

Co-fermentation material	7 days	14 days	21 days
PRHA	69.13 ^c	70.85 ^b	69.73 ^b
PPD	76.98 ^a	68.32 ^c	66.94 ^d
PPE	63.35 ^c	52.61 ^e	59.72 ^f
SE	0.231	0.231	0.231
LS ($C \times D$)	*		

Key: PRHA = *P. biglobosa* husk + rice husk ash; PPD = *P. biglobosa* husk + poultry droppings; PPE = *P. biglobosa* husk + fruit exudates; SE = standard error; LS = level of significance; * = significant at $P \leq 0.05$; NS = not significant. Means with different superscripts within a column differ significantly by Tukey's test at $P \leq 0.05$.

The significant interaction demonstrates that fermentation duration affected NDF differently depending on the co-fermentation material. PPD declined substantially from 76.98% at 7 days to 66.94% at 21 days. PPE recorded its lowest NDF at 14 days (52.61%) before increasing to 59.72% at 21 days, while PRHA remained comparatively stable. This aligns with microbial degradation of structural carbohydrate fractions during fermentation, corroborating Abiola-Olagunju *et al.* (2024), who similarly reported reductions in NDF following biological treatment of agricultural residues.

Effect of Co-Fermentation Material and Fermentation Duration on Tannin Content (mg/100g) of Fermented *Parkia Biglobosa* Husk

The tannin content of fermented *Parkia biglobosa* husk as influenced by co-fermentation material and fermentation duration is presented in Table 10. Tannin ranged from 5.09 mg/100 g in PRHA to 7.61 mg/100 g in PPD and declined progressively with fermentation duration, from 6.95 mg/100 g at 7 days to 5.21 mg/100 g at 21 days.

Table 10: Effect of Co-fermentation Material and Fermentation Duration on Tannin Content (mg/100 g) of Fermented *Parkia Biglobosa* Husk

Treatment	Mean (mg/100 g)
Co-Fermentation Material (C)	
PRHA	5.09 ^c
PPD	7.61 ^a
PPE	5.36 ^b
SE (C)	0.017
LS (C)	*
Duration (D)	
7 days	6.95 ^a
14 days	5.90 ^b
21 days	5.21 ^c
SE (D)	0.017
LS (D)	*

Key: PRHA = *P. biglobosa* husk + rice husk ash; PPD = *P. biglobosa* husk + poultry droppings; PPE = *P. biglobosa* husk + fruit exudates; SE = standard error; LS = level of significance; * = significant at $P \leq 0.05$; NS = not significant. Means with different superscripts within a column differ significantly by Tukey's test at $P \leq 0.05$.

Tannin content differed significantly among the co-fermentation materials, with PPD recording the highest concentration (7.61 mg/100 g), followed by PPE (5.36 mg/100 g) and PRHA (5.09 mg/100 g). This aligns with evidence that fermentation conditions and substrate composition influence the extent to which antinutritional compounds are degraded, and agrees with Yakubu *et al.* (2022), who reported substantial reductions in tannins following fermentation of *P. biglobosa*, demonstrating the

potential of fermentation to modify antinutritional compounds. Tannin concentration declined significantly from 6.95 mg/100 g at 7 days to 5.21 mg/100 g at 21 days, which strongly agrees with Yakubu *et al.* (2022), who observed a progressive reduction in tannin concentration with increasing fermentation time, and corroborates the broader literature showing that microbial fermentation can reduce antinutritional compounds through biochemical transformation and enzyme-mediated degradation. However,

although microbial tannase activity provides a plausible mechanism, tannase activity and microbial populations were not measured in the present study; therefore, tannase activity

should not be presented as a confirmed mechanism. Because the C × D interaction for tannin was significant, the pattern is examined further in Table 11.

Table 11: Interaction Effect of Co-fermentation Material and Fermentation Duration on Tannin Content (mg/100 g) of Fermented *Parkia Biglobosa* Husk

Co-fermentation material	7 days	14 days	21 days
PRHA	6.65 ^c	5.07 ⁱ	3.56 ^a
PPD	8.24 ^a	7.35 ^b	7.23 ^b
PPE	5.97 ^d	5.28 ^e	4.84 ^g
SE	0.029	0.029	0.029
LS (C × D)	*		

Key: PRHA = *P. biglobosa* husk + rice husk ash; PPD = *P. biglobosa* husk + poultry droppings; PPE = *P. biglobosa* husk + fruit exudates; SE = standard error; LS = level of significance; * = significant at $P \leq 0.05$; NS = not significant. Means with different superscripts within a column differ significantly by Tukey's test at $P \leq 0.05$.

The significant interaction demonstrates that tannin reduction was strongly dependent on both the co-fermentation material and fermentation duration. PRHA produced the greatest reduction, declining from 6.65 mg/100 g at 7 days to 3.56 mg/100 g at 21 days. PPE declined from 5.97 to 4.84 mg/100 g, whereas PPD showed only a modest reduction from 8.24 to 7.23 mg/100 g. This aligns strongly with Yakubu *et al.* (2022), who reported substantial fermentation-associated reductions in tannins in *P. biglobosa*, and agrees with the broader application of solid-state fermentation for detoxification and reduction of antinutritional compounds in agricultural residues. The comparatively high tannin concentration retained by PPD indicates that the presence of a co-fermentation material does not necessarily produce equivalent antinutritional-factor reduction, which corroborates the substrate-specific nature of fermentation and suggests that the chemical environment produced by each co-fermentation material may influence the extent of tannin transformation. Nevertheless, the present experiment did not directly determine microbial composition or tannase activity, so these mechanisms remain plausible explanations rather than experimentally demonstrated causes.

CONCLUSION

The present findings indicate that co-fermentation provides a promising approach for modifying the nutritional quality of *P. biglobosa* husk. The reductions in fibre fractions and tannin, together with the increase in apparent crude protein, suggest potential for further evaluation as a feed-resource ingredient. However, the observed chemical changes should not be equated directly with improved animal performance or digestibility. Further studies involving in vitro and in vivo digestibility, microbial characterization, enzyme activity, mineral bioavailability and feeding trials would be required to establish the nutritional value of the fermented husk conclusively.

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