World Journal of Food Science and Technology
2026, Vol. 10, No. 1, pp. 7–14
https://doi.org/10.11648/j.wjfst.20261001.12

Research Article

Effect of Deodorization on Nutrients and Antinutrients Compositions of Fermented Food Condiment from *Prosopis africana* (African Mesquite) Seeds

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Abstract

Fermented food condiments remain of interest since they do not require refrigeration during distribution and storage. The traditional fermented condiments have not attained commercial status due to the objectionable packaging materials, stickiness and the characteristic putrid and unpleasant odor. The aim was to determine the effect of deodorizing agents on nutrient and antinutrient compositions and evaluate the physicochemical characteristics of the deodorized fermented condiment. The condiment was prepared in the laboratory and Deodorization was achieved using five different concentrations (0.5, 1.0, 1.5, 2.0 and 2.5g) of the deodorants per 100g of the control, CD and PAC treated samples. Triplicate determinations of proximate composition to determine the average value of the Nutrients. Atomic absorption spectrophotometry (AAS) was used for Minerals and flame photometry for K analysis. UV- Spectrophotometry was used for vitamins estimation. The crude protein content of control sample was (40.30±0.14g/100g) while deodorized fermented condiment CD and PAC treated sample were (33.18±0.23g/100g) and (54.50±0.25g/100g) respectively. The crude protein content of the control sample differed significantly with CD and PAC ($p \leq 0.05$). The lipids, carbohydrates, crude fibre and ash content were all higher in PAC treated sample than CD and Control. While Ca, Fe, Mg, Zn, K and P were higher in CD than PAC treated samples. PAC has lower trypsin inhibitors and α-amylase inhibitors. The cyclodextrin and powdered activated carbon are suitable and effective in reducing various antinutritional compounds most especially the inhibitors except flavonoids and tannins, with significant increase in the nutrient contents of fermented condiment from *Prosopis africana* seeds.

Keywords

Deodorization, Condiment, Cyclodextrin, Powdered Activated Carbon, Prosopis Africana Seeds, Nutrient, Antinutrient

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Received: 19 January 2026; **Accepted:** 30 January 2026; **Published:** 21 February 2026

1. Introductions

In many countries in Africa including Nigeria, protein malnutrition is a major problem. The food diet of Nigerians is mostly from roots, tubers and cereals [1]. The low protein content in the Nigerian diet contributes to the low nutrition security of the people [15]. The high cost of animal protein has also directed interest towards several leguminous seed proteins as potential sources of vegetable protein for human food [13]. Most of the fermented vegetable proteins reported are from leguminous seeds [9]. Quite often, seeds that are used for fermentation are inedible in their raw unfermented or cooked state [4]. The seeds of legumes may account for up to 80% dietary protein and be the only source of protein for some groups of people [3]. Although fermented food condiments have constituted a significant proportion of the diet of many people, Nigerians exhibit an ambivalent attitude in terms of consumer tastes and preferences for such foods [9]. *Prosopis africana* seed commonly known as *African mesquite* but also known by different native Nigerian names such as Kirya (Hausa), Kohi (Fulani), Sam chi lati (Nupe), Ayan (Yoruba), Kpaye (Tiv), Ubwa (Ibo) and *okpehe* (Idoma) is one of the lesser known legume seed crops which can be fermented and used as a food condiment known as *okpehe* [15]. *Okpehe* is used as a food condiment in Nigeria by the Idoma and Igala people of the middle belt region and some parts of the Eastern, Southern and *Daddawa* by hausa in northern part of Nigeria [19]. It adds variety and pleasure to the otherwise monotonous traditional diet. Fermented food condiments remain of interest since they do not require refrigeration during distribution and storage [19]. The traditional fermented condiments have not attained commercial status due to the objectionable packaging materials, stickiness and the characteristic putrid and unpleasant odor [10]. Fermented condiments often have a stigma attached to them despite serving not only as a nutritious non-meat protein, they are often considered as food for the poor due to the off odor associated [11].

Malnutrition is considered to be of public health concern in Nigeria. Global nutrition survey indicates that deficiency in Macro and Micronutrients are most prevalent, because the sources of essential nutrients are expensive and beyond the reach of majority of the population [11]. Consumptions of monosodium glutamate and salts that are rich in sodium as flavour enhancers has been associated with health related cardiovascular disorders, thus there is need to substitute them with natural fermented condiments [10].

2. Aim

The aim of the study is to determine the effect of deodorizing agents on nutrient and antinutrient compositions and evaluate the physicochemical characteristics of the deodorized fermented condiment.

3. Null Hypothesis

There is no significant effect of potential chemical deodorants; cyclodextrin, and powdered activated carbon on the off-odor, nutrients and antinutrients of fermented food condiment from *Prosopis africana* seeds.

4. Methodology

4.1. Collection of Seed Samples

The *Prosopis africana* seeds and leaves were purchased from the new Monday market, popularly known as Kasuwan Amaru/new Katafawa market in Zaria city and identified with voucher number; V/N 06919 in Botany Department, Faculty of Life Sciences, Ahmadu Bello University, Zaria, Nigeria.

4.2. Laboratory Preparation of Food Condiment

The boiling step in the traditional process is long, tedious and wasteful; it also requires more volume of water. Thus boiling by fuel (kerosene) or fire wood was replaced by boiling in an autoclave in the laboratory [19]. Two kilograms (2kg) of *Prosopis africana* seeds were boiled in 2000ml of water at 121 ℃ for 2h in an autoclave and later dehulled. The cotyledons were separated from the coats and later rinsed in sterile water, before boiling again in an autoclave for about 30 min to soften the cotyledons [19]. The cotyledons were drained through a sterile sieve and cooled to about 35 ℃, then wrapped in paw-paw leaves already disinfected with alcohol and wrapped in a foil [19]. The wrapped cotyledons were then incubated in an incubator for 5-9 days to produce the fermented mash of food condiment. A modified method of Balogun *et al.*, [9].

4.3. Deodorizing Process

A varying amount of (0.5, 1.0, 1.5, 2.0, and 2.5g) of deodorizing agents: cyclodextrin and powdered activated carbon in 100g of fermented condiment each of the deodorizing agents were mixed with the sample fermented condiment and deodorized the off odor separately for 24h at room temperature [19].

Fermented condiments were grouped as follows:

GROUP 1: Fermented condiment without treatment (Negative control).

GROUP 2: Fermented condiment mixed with cyclodextrin.

GROUP 3: Fermented condiment mixed with powdered activated carbon.

4.4. Proximate Analysis

Proximate analysis was carried out on deodorized fermented condiment to determine the nutritional values with regards to moisture, ash, crude protein, fat, crude fiber and total carbohydrate, using standard methods as described by AOAC [7].

4.5. Vitamins and Minerals

Atomic absorption spectrophotometry (AAS) was used for Ca, Mg, Zn and Fe and flame photometry was used for K analysis. UV- Spectrophotometry was used for vitamin A, B, C and vitamin E estimations according to AOAC [7].

4.6. Anti-nutritional Factors

The methods described by AOAC [7] was used for the estimation of Oxalates, Tannins, Saponins, Alkaloids, Flavonoids While Methods of McCue and Shetty, [14] and Onwuka [16] were adopted for α-Amylase and Trypsin inhibitors estimations respectively [2].

4.7. pH Measurement

The pH of the samples was measured using pH meter already calibrated with standard buffer solution.

4.8. Water and Oil Absorption Capacity

Beuchat ́s method (1977) was employed for the determination of water and oil absorption capacity.

4.9. Titratable Acidity (TA)

Titratable acidity was determined using the method described by AOAC [6].

4.10. Bulk Density

The bulk density of the fermented condiments was determined using the method described by AOAC [7]. Using the formula:

$$D_b = W/V.$$

Where;

D_b is bulk density of deodourised fermented food condiment (g m^{-3});

W is weight of sample (g) and V is volume (m^3).

5. Statistical Analysis

Results were expressed as mean ± SD. The data were analysed using one way (ANOVA) where applicable. Differences between mean were determined using Dunnett post-hoc test ($p \leq 0.05$). Statistical analysis was carried out with the Statistical package for social science (SPSS version 21).

6. Result

The proximate compositions of deodorized fermented condiment from *Prosopis africana* seeds are presented in Table 1. The crude protein content of control sample was (40.30±0.14g/100g) while for deodorized fermented condiment CD treated sample and PAC treated sample were (33.18±0.23g/100g) and (54.50±0.25g/100g) respectively. The crude protein content of the control sample differed significantly with CD and PAC ($p \leq 0.05$). The protein content of CD treated sample was significantly lower (33.48±0.23g/100g) while PAC treated sample significantly higher (54.50±0.25g/100g) than the control (40.33±0.14g/100g). The crude lipid content of the control sample was (39.60±0.33g/100g), while the CD treated sample (17.46±0.54g/100g) and PAC treated sample was (13.73±0.11g/100g) and the two samples had a lower lipid content than the control with significant differences ($P \leq 0.05$), about 2/3 reduction 65.48% of lipid content of PAC treated sample and more than a half 56.10% reduction of lipid content of CD treated sample. The ash content of the CD treated sample (5.72±0.12g/100g) and PAC treated sample (7.12±0.04g/100g) were significantly higher ($p \leq 0.05$) compared with control (5.28±0.02g/100g) and PAC treated sample recorded the highest value of the ash content. The crude fiber content of control sample was (5.82±0.32g/100g) and significantly differed ($p \leq 0.05$) from CD treated sample (14.06±0.13g/100g) and PAC treated sample (14.58±0.29g/100g). There was no significant difference ($p > 0.05$) between CD treated sample and PAC treated sample crude fibre contents. The moisture content of CD treated sample and PAC treated sample were significantly lower than that of control ($P \leq 0.05$); CD treated sample was (2.44±0.14g/100g) while PAC treated sample was (5.08±0.26g/100g), with CD treated sample recorded the lowest moisture content compared to control (8.79±0.04g/100g) and PAC treated sample. The carbohydrate content of control (6.03±0.17g/100g) was significantly differed ($P \leq 0.05$) from CD treated sample (41.20±0.24g/100g) and PAC treated sample (19.57±1.04g/100g). The CD treated sample recorded the highest carbohydrate content and significantly differed ($p \leq 0.05$) from PAC treated sample.

Table 1. *Effect of Deodorizing Agents on Proximate Compositions of Deodorized Fermented Condiment from Prosopis africana seeds.*

SAMPLES	MOISTURE (g/100g)	ASH (g/100g)	LIPID (g/100g)	PROTEIN (g/100g)	Crude FIBRE (g/100g)	TOTAL CARBOHYDRATE (g/100g)
CONTROL	8.79 ± 0.04^a	5.28 ± 0.02^c	39.60 ± 0.33^a	40.30 ± 0.14^b	5.82 ± 0.32^b	6.03 ± 0.17^c

SAMPLES	MOISTURE (g/100g)	ASH (g/100g)	LIPID (g/100g)	PROTEIN (g/100g)	Crude FIBRE (g/100g)	TOTAL CARBOHY-DRATE (g/100g)
CD	2.44±0.14c	5.72±0.12b	17.46±0.54b	33.18±0.23c	14.06±0.13a	41.20±0.24a
PAC	5.08 ±0.26^b	7.12 ±0.04^a	13.73 ±0.11^c	54.50 ±0.25^a	14.58 ±0.29^a	19.57 ±1.04^b

Values are expressed as Mean ± SD of triplicate determination and values with different superscripts on the same column are significantly different ($p \leq 0.05$)

The vitamin compositions of deodorized fermented condiment from *Prosopis africana* seeds are presented in Table 2. The vitamin A content of CD treated sample and PAC treated sample were significantly ($p \leq 0.05$) higher than that of control sample (639.17 ±16.67RAE/100g); CD treated sample was (975.83 ±25.83RAE/100g) while PAC treated sample was (881.67 ±39.17RAE/100g). The CD treated sample recorded the highest value of vitamin A content. The vitamin B_1 content of CD treated sample and PAC treated sample were also significantly ($p \leq 0.05$) higher than control sample (276.65±2.33mg/100g), CD treated sample was (308.61 ±1.57mg/100g) while PAC treated sample was (291.61 ±2.27mg/100g). The vitamin B_2 content of control sample was (5.79 ±0.15mg/100g) and differed significantly ($p \leq 0.05$) from CD treated sample (13.51±0.60mg/100g) and PAC treated sample (13.73 ±0.98mg/100g). But there was no significant difference ($p>0.05$) of vitamin B_2 contents between the CD treated sample and PAC treated sample. In addition, there was no significant difference ($p>0.05$) between vitamin B_3 contents of all the samples; control sample (3.06 ±0.04mg/100g), CD treated sample (3.26 ±0.22mg/100g) and PAC treated sample (3.26±0.06mg/100g). There was a significant difference ($p \leq 0.05$) in vitamin B_5 content between CD treated sample (733.56 ±0.09mg/100g) with PAC treated sample (481.62 ±2.30mg/100g) and control sample (471.92 ±0.82mg/100g). Statistically, there was no significant difference ($p>0.05$) between the control (471.92±0.82mg/100g) and PAC treated sample (481.62 ±2.30mg/100g) in their vitamin B_5 contents. There was significant difference ($p \leq 0.05$) in vitamin B_6 contents of CD treated sample (22.69 ±0.40mg/100g) and PAC treated sample (16.63 ±0.66mg/100g), with the PAC treated sample recorded the highest value of vitamin B_6 content compared with control sample (12.15 ±0.22mg/100g). Similarly, there was significant difference ($p \leq 0.05$) in vitamin B_9 content of CD treated sample (37.25 ±0.35mg/100g) and PAC treated sample (15.05 ±0.01mg/100g), with CD treated sample recording the highest value of vitamin B_9 content compared with control sample (2.80 ±0.42mg/100g). The vitamin C content of CD treated sample (19.43 ±0.59mg/100g) and PAC (17.41 ±0.49mg/100g) were significantly different ($p \leq 0.05$), with CD treated sample and recorded the highest value of vitamin C content compared with control (12.46 ±0.68mg/100g). Lastly, there were significant differences ($p \leq 0.05$), in vitamin E content of CD treated sample (33.37 ±0.57IU/100g) and PAC treated sample (31.12 ±1.42IU/100g), with CD treated sample recorded the highest value of vitamin E content compared with control sample (12.39 ±0.06IU/100g).

Table 2. *Effect of Deodorizing Agents on Vitamins Composition of Deodorized Fermented Condiment from Prosopis africana Seeds.*

SAM-PLE	Vitamin A (RAE/100g)	Vitamin B_1 (mg/100g)	Vitamin B_2 (mg/100g)	Vitamin B_3 (mg/100g)	Vitamin B_5 (mg/100g)	Vitamin B_6 (mg/100g)	Vitamin B_9 (mg/100g)	Vitamin C (mg/100g)	Vitamin E (mg/100g)
Control	639.17 ±16.67^c	276.65 ±2.33^c	5.79 ±0.15^b	3.06 ±0.04^a	471.92 ±0.82^b	12.15 ±0.22^b	2.80 ±0.42^c	12.46 ±0.68^c	12.39 ±0.06^b
CD	975.83±25.83^a	308.61±1.57^a	13.51±0.60^a	3.26±0.22^a	733.56±0.09^a	22.69±0.40^a	37.25±0.35^a	19.43±0.59^a	33.37±0.57^a
PAC	881.67 ±39.17^b	291.61 ±2.27^b	13.73 ±0.98^a	3.26 ±0.06^a	481.62 ±2.30^b	16.63 ±0.66^b	15.05 ±0.01^b	17.41 ±0.49^b	31.12 ±1.42^a

Values are expressed as Mean ± SD of duplicate measurement and values with different superscripts in the same column are significantly differ ($p \leq 0.05$).

The effect of deodorizing agents on mineral elements compositions of deodorized fermented condiment from *Prosopis africana* seeds are presented in Table 3. The calcium (Ca) content of CD treated sample (292.5 ±1.80mg/100g) and PAC treated sample (257.67 ±1.95mg/100g) were higher and significantly differed ($p \leq 0.05$) from that of control fermented condiment (222.50 ±2.50mg/100g). Similarly, the magnesium (Mg) content of CD treated sample (192.52 ±1.50mg/100g) and PAC treated sample (187.17 ±2.52mg/100g) were significantly increased ($p \leq 0.05$), from that of control sample (143.25 ±1.00mg/100g). Meanwhile, there were significant differences ($p \leq 0.05$) between potassium (K) content of the deodorized fermented condiments CD treated sample (594.83 ±2.50mg/100g) and PAC treated sample (652.57 ±2.10mg/100g) from control sample

(754.5±25.60mg/100g). Statistically, there was significant difference ($p \le 0.05$) of iron content. The iron (Fe) content of PAC treated sample was lower (72.50±2.10mg/100g) than the control sample (96.57±0.80mg/100g) and CD treated sample (94.70±2.50mg/100g), but there was no significant difference ($p > 0.05$) between (Fe) contents of CD treated sample (94.70±2.50mg/100g) and control sample (96.57±0.80mg/100g). Also, there were no significant differences ($p \le 0.05$) in Zinc (Zn) contents of the deodorized fermented condiments of both CD treated sample (16.60±0.75mg/100g) and PAC treated sample (14.81±0.18mg/100g) with control sample (18.25±1.56mg/100g). There was decrease in phosphorus of PAC treated sample (536.24±1.85mg/100g) and increased in CD treated sample (894.26±4.70mg/100g) from phosphorus content of control sample (617.19±1.53g/100g) and significantly differed ($p \le 0.05$).

Table 3. *Effect of Deodorizing Agents on Mineral Elements Composition of Deodorized Fermented Condiment from Prosopis africana Seeds.*

Sample	**Ca (mg/100g)**	**Mg (mg/100g)**	**K (mg/100g)**	**Fe (mg/100g)**	**Zn (mg/100g)**	**P (mg/100g)**
Control	222.50±2.50^c	143.25±1.00^c	754.50±2.56^a	96.57±0.80^a	18.25±1.56^a	617.19±1.53^b
CD	292.50±1.80a	192.52±1.50a	594.83±2.50c	94.70±2.50a	16.60±0.75a	894.26±4.70a
PAC	257.67±1.95^b	187.17±2.52^b	652.57±2.10^b	72.50±2.10^b	14.81±0.18^a	536.24±1.85^c

Values are expressed as (Mean ±SD) of triplicate determinations and values with different superscripts in the column are significantly different ($p \le 0.05$).

The effect of deodorizing agents on antinutrients composition of deodorized fermented condiment from *Prosopis africana* seeds are presented in Table 4. There was significant difference ($p \le 0.05$) in antinutritional compounds between control and the treated samples, the levels of these compounds reduced significantly. The alkaloids concentration in the CD treated sample (4.10±0.02mg/100g) and PAC treated sample (4.95±0.01mg/100mg), were significantly decreased ($p \le 0.05$) from control sample (7.21±0.01mg/100g), with CD treated sample recorded the lowest alkaloids value. Similarly, the Saponins content of CD treated sample (34.55±0.13mg/100g) and PAC treated sample (35.86±0.06mg/100g) were significantly reduced ($p \le 0.05$) from of control sample (47.45±0.07mg/100g), and CD treated sample had the lowest value of saponins content. The flavonoids content of CD treated sample (61.35±0.22mg/100g) and PAC treated sample (56.18±0.00mg/100g) were significantly increased ($p \le 0.05$) compared with control sample (46.21±0.02mg/100g), and CD treated sample recorded the highest value of flavonoids content. Similarly, the tannins content of CD treated sample (3.90±0.21mg/100g) and PAC treated sample (4.69±0.02mg/100g) were increased significantly ($p \le 0.05$) with control sample (2.70±0.03mg/100g), and PAC treated sample recorded the highest value of tannins concentration. There was no significant difference between the control, CD and PAC treated samples in their oxalates contents ($p > 0.05$); PAC treated sample recorded (0.84±0.02mg/100g), CD treated sample recorded (0.68±0.06mg/100g) while control sample recorded (0.55±0.01mg/100g). The trypsin inhibitors content of CD treated sample (9.92±0.01TUI/100g) and PAC treated sample (6.72±0.01TUI/100g) were significantly reduced ($p \le 0.05$) compared to control value of (11.23±0.03TUI/100g) with PAC recorded the lowest value of trypsin inhibitors. Similarly, the α-Amylase inhibitors of CD treated sample (6.40±1.57mg/ml) and PAC treated sample (5.77±0.50mg/ml) were also significantly reduced ($p < 0.05$) compared to control sample (13.05±0.88mg/ml) with the PAC treated sample recorded lowest α-amylase inhibitors.

Table 4. *Effect of Deodorizing Agents on Antinutrients Composition of Deodorized Fermented Condiment from Prosopis africana Seeds.*

SAMPLES	**ALKALOIDS (mg/100g)**	**FLAVONOIDS (mg/100g)**	**SAPONINS (mg/100g)**	**TANNINS (mg/100g)**	**OXALATES (mg/100g)**	**TRYPSIN INHIBITORS (TUI/mg)**	**α-AMYLASE INHIBITORS (mg/ml)**
CONTROL	7.21±0.01^a	46.21±0.02^c	47.45±0.07^a	2.70±0.03^c	0.55±0.01^a	11.23±0.03^a	13.05±0.88^a
CD	4.10±0.02c	61.35±0.22a	34.55±0.12c	3.90±0.21b	0.68±0.06a	9.92±0.01b	6.40±1.57b
PAC	4.95±0.01^b	56.18±0.06^b	35.86±0.06^b	4.69±0.02^a	0.84±0.12^a	6.72±0.01^c	5.77±0.50^c

Values are expressed as Mean ±SD of duplicate measurement and values with different superscripts in the same column are significantly differ ($p \le 0.05$).

The effect of deodorizing agents on physicochemical characteristics of deodorized fermented condiment from *Prosopis africana* seeds are presented in Table 5. The pH value of CD treated sample (7.20±1.00) was increased significantly (p≤0.05) compared control sample (6.56±1.50) and PAC treated sample (6.76±1.50), but there was no significant difference (p>0.05) in pH value between the control sample (6.56±1.50) and PAC treated sample (6.76±1.50). The Titratable acidity of CD treated sample (8.50±1.60) and PAC treated sample (13.80±0.50) were increased significantly (p≤0.05) from the control sample, with PAC treated sample recorded the highest value of titratable acidity. The water absorption capacity of CD treated sample (2.05±0.10g/ml) and PAC treated sample (3.24±0.06g/ml) were also significantly increased (p≤0.05) from control sample (1.80±0.01g/ml) with PAC treated sample recorded the highest value of water absorption capacity, and there was no significant difference (p>0.05) between the CD treated sample (2.05±0.10g/ml) and control sample (1.80±0.01g/ml). The oil absorption capacity of CD treated sample (1.52±0.40g/ml) and PAC treated sample (1.10±0.11g/ml) were also reduced significantly (p≤0.05) from control (2.05±0.05g/ml), and PAC treated sample recorded the lowest value of oil absorption capacity. There was no significant difference (p>0.05) between the bulk densities of control sample (1.25±0.05g/m^3), CD treated sample (1.00±0.95g/m^3) and PAC treated sample (1.13±0.57g/m^3).

Table 5. *Physicochemical Characteristics of Deodorized Fermented Condiment from Prosopis africana Seeds.*

SAMPLES	pH Value	Titratable acidity	Water Absorption Capacity (g/ml)	Oil Absorption Capacity (g/ml)	Bulk Density (g/m^3)
Control	6.56±1.50^b	3.80±0.20^c	1.80±0.01^b	2.05±0.05^a	1.25±0.05^a
CD	7.20±1.00a	8.50±1.60b	2.05±0.10b	1.52±0.40b	1.00±0.95a
PAC	6.76±1.50^b	13.80±0.50^a	3.24±0.06^a	1.10±0.11^c	1.13±0.57^a

Values are expressed as (Mean ±SD) of triplicate determinations and values with different superscripts in the column are significantly different (p≤0.05).

7. Discussion

Prosopis africana seeds are processed to produce local fermented food condiment [19]. In this study, the laboratory prepared fermented food condiment from *Prosopis africana* seeds were deodorized with potential chemical deodorants β-Cyclodextrin (CD), and powdered activated carbon (PAC) and their effects on nutrients and antinutrients composition were investigated [19]. The results of crude protein revealed that the CD treated sample recorded the lowest protein content while PAC treated sample recorded the highest value of protein content of the condiment. Meanwhile, the CD and PAC treated samples had a lower lipid content compared to the control sample, this corraborate with study reported by Balogun *et al*, [9], in which the crude protein content of *Prosopis africana* seeds inoculated with mono- and mixed cultures of bacterial isolates were increased as the days of fermentation increases. The crude protein increased significantly for both the mono and mixed culture inoculated samples, *B. subtilis* had the highest while *B. pumilus* had the lowest crude protein for the mono inoculated seeds. The highest crude protein content was obtained when *B. subtilis* and *B. licheniformis* were combined, while the lowest protein content was obtained for combination of *B. megaterium* and *B. pumilus*. The fermented seeds obtained from the mixed culture had a higher crude protein than both the monoculture inoculated and control samples [17].

The ash content of the CD and PAC treated samples were increased compared to control. Similarly, the crude fiber contents of CD and PAC treated samples were increased compared to control sample. The increased was associated with additions of chemical deodorants (CD and PAC). The crude fibre content of the CD treated sample was lower than that of PAC treated sample [18]. The moisture content of CD and PAC treated samples were reduced, with CD treated sample recorded the least moisture content. The reduced moisture content of CD and PAC treated samples is of remarkable significance because of the consequential impartment in shelf-life of the condiment. Very low moisture content increases shelf-life as microbial spoilage is minimized. The carbohydrate content of control sample was lower from that of CD and PAC treated samples. The CD treated sample recorded the highest carbohydrate content and the increase was associated with the fact that cyclodextrin is a hydrolytic form of starch.

The vitamins A, B, C and E contents of the CD and PAC treated samples increased significantly compared to control sample. CD treated sample recorded the highest value of these vitamins. The increase in these vitamins are associated with the fact that, cyclodextrins create a conducive environment for microbial activities and formed inclusion complexes with degraded products of protein, lipids and the polyglucopyranose units of cyclodextrin [20]. Therefore, the noticeable increase in the vitamin A, B vitamins, vitamins C and E content of the fermented condiment makes it a good source of these vitamins.

The calcium (Ca), magnesium (Mg), and phosphorus (P) content of CD treated sample were increased significantly and this noticeable increase makes the condiment a good source of these essential minerals. The increased calcium content in the condiment is good because the element is needed for bone development and strong teeth [5]. Zinc was also found in an appreciable amount and this is desirable as it is known to aid digestion, body functions and lower the risk of diarrhea in children. Iron carries oxygen to the cells and is necessary for the production of energy, synthesis of collagen and the proper functioning of the immune system. The appreciable amount of potassium is good because the element helps in regulation of body fluids and maintenance of normal body pressure. It helps in controlling kidney failure, heart oddities and respiratory flaw [8].

In addition, there was significant difference in antinutritional compounds between control and the treated samples, the levels of these compounds reduced in an appreciable amount. The alkaloids, Saponins, oxalates, trypsin inhibitors and α-amylase inhibitors concentrations in the CD and PAC treated samples were reduced, with CD treated sample recorded the least alkaloids and Saponins, while PAC treated sample recorded lowest value of trypsin and α-Amylase inhibitors. The flavonoids content of CD and PAC treated samples were increased and CD treated sample recorded the highest value. These bring out the fact that reduction of antinutritional factors Saponins, alkaloids and inhibitors such as trypsins and α-Amylase improve the nutritional quality of the condiment while the increase in the flavonoids content enhances the antioxidant capacity of the condiment.

The result also revealed that the pH value of CD treated sample was higher compared to control and PAC treated samples. The rise in pH is due to the high proteinase activity of the microorganisms involved which ultimately results in the liberation of ammonia as is reported for some other fermenting protein foods [15]. The increased in titratable acidity of both CD and PAC treated samples makes it a good condiment. Desirable flavour components of the condiment are presumably developed after an alkaline titratable acidity is reached. Organic acids which may result from protein decomposition may contribute to the darkening of colour [9]. The titratable acidity of condiment being alkaline agrees with earlier reports of Ogunshe *et al.* [15] that recorded alkaline titratable acidity in fermented food condiments from vegetable proteins. Most fermented vegetable-protein condiments are characterized by a very strong pungent smell. The increase in titratable acidity is generally due to the production of ammonia, which is characterized by the pungent smell of alkaline fermented condiments [15].

The increased water absorption capacity of CD and PAC treated samples and also the decreased oil absorption capacity of both CD and PAC treated samples may probably increase its acceptability and market range. The appreciable amount of oil absorption capacity suggests that cyclodextrin treated sample has more hydrophobic interaction sites than powdered activated carbon. Variations in the presence of non-polar side chains, which might bind the hydrocarbon side chains of oil among the condiments, could explain differences in the oil binding capacity of the treated samples [8]. However, the condiments are potentially useful for their structural interactions in food, especially for flavor retention, and to improve palatability and extension of shelf life, in which fat absorption is desirable [12].

8. Conclusion

In conclusion, the present study depicted the potentiality of cyclodextrin (CD) and powdered activated carbon (PAC) as good chemical deodorants for the deodorization of fermented food condiment from *Prosopis africana* seeds. The cyclodextrin and powdered activated carbon are suitable and effective in reducing various antinutritional compounds most especially the inhibitors except flavonoids and tannins, with significant increase in the nutrient contents of fermented condiment from *Prosopis africana* seeds.

Abbreviations

CD Cyclodextrin
NC Negative Control
PAC Powdered Activated Carbon

Data Availability Statement

Data described in the manuscript will be made available upon request pending application and approval.

Conflicts of Interest

The authors declare no conflicts of interest.

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