Chemical Compositions of Fermented and Unfermented Seeds of *Cissus populnea* Obtained from Niger state, Nigeria

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Abstract:
The chemical compositions of fermented (24 and 48 h) and unfermented seeds of *Cissus populnea* obtained from Niger State, Nigeria were determined using standard analytical methods. The % total essential amino acids ranged from 37.62±0.08 (unfermented) to 40.24±0.04 g/100g protein (fermented for 24 h), % total conditionally essential amino acids ranged from 23.36±0.10 (unfermented) to 25.65±0.05 (fermented for 24 h), while % total non-essential amino acids ranged from 34.10±0.07 (fermented for 24 h) to 39.03±0.12 (unfermented) g/100g protein. The food functional properties like the foaming capacities ranging from 1.82±0.12 (unfermented) to 6.05±0.10 % (fermented for 48 h), oil absorption ranged from 0.65±0.01 (unfermented) to 0.70±0.03 mg/g (fermented for 48 h) and water absorption ranged from 1.89±0.53 (fermented for 24 h) to 2.03±0.11 mg/g (unfermented), bulk densities ranged from 0.39±0.33 (fermented for 48 h) to 0.61±0.11 g/cm^3 (unfermented), while swelling capacities ranged from 1.92±0.28 (fermented for 48 h) to 3.50±0.36 % (unfermented) and emulsification capacities ranged from 42.03±0.36 (unfermented) to 54.21±0.52 % (fermented for 48 h). The physicochemical parameters determined were also observed to decrease as the fermentation days increased. Food processing technologies for exploiting the utilisation of *C. populnea* flours both fermented and unfermented should be promoted.
Keywords: *Cissus populnea*, fermented, unfermented, physicochemical, amino acids

1.INTRODUCTION

Recent studies have shown that there are many shrubs and trees in Nigeria; most of them grow fruits containing different seeds and pods that could be explored to increase the available food resources [1]. It is therefore necessary to encourage the use of underutilised species (fruits, vegetables, medicinal plants, starchy crops and condiments) by highlighting their value in their current production areas and by exploring more opportunities to increase their production and consumption [2]. The promotion of these species and the production of their values must be focused on rigorous scientific methods that will allow us to eliminate the stigma of' food for the poor,' which often hinders their popularisation and the creation of new demand. Further development work, including; distribution, conservation, growth, reproduction, post-harvest value-added, nutritional studies as well as consumption as part of a balanced diet, will allow some of these underused species to turn into crops that can support development and quality of life [3].

Cissus populnea Guill et Perr is of the Plantae Kingdom, Ampelidaceae Order, Family of Vitaceae, Genus Cissus and Species: *populnea*, Hausa: Dafara or latutuwa, Nupe: Egbe.

Plate I: *Cissus populnea* fruit, Source: Field Survey (2018)

Cissus populnea, Guill's. & Perr. is a solid woody lame or climbing shrub with a diameter of 8-10 m and a diameter of 71/2 cm. It grows in the savannah and is usually distributed from the coast to the Sudanese and Sahelian forests in West Africa, where it spreads to Senegal and Nigeria. There is plenty of smooth, watery sap when the stems are removed. The flowers are white, and its fruits, when mature, are blackish-purple. The plant has succulent stems that are useful in the construction when dried [4]. The aim of this study is to determine the effect of fermentation on the physico-chemical, food functional properties and amino acids compositions of the seeds of *C. populnae*.

2 MATERIALS AND METHODS

2.1 Collection and Sample Preparation

The seeds of *C. populnea* were obtained from a farmland at Muwo village in Mokwa Local Government Area of Niger State, Nigeria between the months of December and February 2018. Plant was identified and authenticated in the Department of Medicinal Plant Research and Development (MPR&TM) of National Institute for Pharmaceutical Research and Development, Idu (NIPRD). The cotyledons were removed from the dried seeds manually. The cotyledons obtained from the seeds were further dried to constant weight. 250 g of *C. populnea* seeds was weighed and crushed into powder with wooden mortar and pestle, sieved with a mesh size 0.5 mm and stored in well labelled air tight polythene bags for further analysis. The traditional methods of African locust beans fermentation was adopted with modification. 100 g of *C. populnea* seeds powder was weighed into 250 cm^3 conical flask, 30 cm^3 of distilled water was added while 1 g of yeast (*Saccharomyces cerevisiae*) were added to the mixture. It was thoroughly mixed, covered and fermented for 24 h. The same process was repeated for the fermentation at 48 h. The fermentation was terminated using freeze dryer and this was kept for further analysis [5][6].

2.2 Determination of Amino Acid profile

About 200 mg of the ground seed sample was defatted using chloroform/methanol mixture in a ratio of 1:1. From the defatted sample, 30 mg was weighed into a glass ampoule, 7 cm^3 of 6 M HCl was added and oxygen expelled by passing nitrogen into the ampoule. The sealed ampoule was put in the oven at 105 ^oC for 22 h, this was allowed to cool and filtered. The filtrate was then evaporated to dryness at 40 ^oC under vacuum in a rotary evaporator. The residue was dissolved with 5 cm^3 acetate buffer (pH 2.0) and loaded into the amino acid analyzer where the amino acid compositions of the seed samples were determined by Ion Exchange Chromatographic method using the Technicon Sequential Multisample Amino Acid Analyzer [7][8].

2.3 Physico-chemical Properties of the Oil Samples

The contents of Peroxide value and viscosity were accounted [9], saponification value and specific gravity were analysed base on the method of Mathew *et al.* [10]. The procedure of AOAC [8] was used to determine acid value, free fatty acid, temperature, pH and iodine value.

2.4 Determination of Food Functional Properties

The water and oil absorption capacity were analysed base on the method of Ndamitso *et al*. [11]. The method described by AOAC, [8] was utilised in the analysis of swelling capacity while the foam solubility was calculated after the determination of swelling capacity as per 100 g of starch on dry basis [12]. Addition of 5 cm^3 of aliquot of the supernatant was dried to a constant weight at 120 ^oC. The procedure of AOAC [8] was used to determine bulk density and gelation properties.

3. RESULTS AND DISCUSION

The results of the analysis are summarised in Tables 1, 2 and 3.

Table 1: Amino acids profile (g/100g protein) of the Samples

Parameters	Unfermented	Fermented for 24 h	Fermented for 48 h
Leucine	9.00±0.08^{a}	9.53±0.07^{b}	9.64±0.06^{bc}
Lysine	3.82±0.07^{a}	4.72±0.09^{bc}	4.42±0.02^{b}
Isoleucine	3.40±0.04^{a}	4.07±0.07^{bc}	4.00±0.07^{b}
Phenylalanine	3.99±0.04^{a}	5.02±0.09^{c}	4.93±0.05^{b}
Tryptophan	1.00±0.06^{a}	1.03±0.10^{a}	1.00±0.08^{a}
Valine	3.51±0.05^{a}	3.90±0.05^{b}	4.03±0.04^{c}
Methionine	1.39±0.08^{a}	1.85±0.10^{bc}	1.81±0.02^{b}
Histidine	2.43±0.02^{a}	4.03±0.07^{c}	3.86±0.06^{b}
Threonine	3.11±0.04^{a}	3.89±0.02^{bc}	3.80±0.08^{b}
Cysteine	1.33±0.09^{a}	2.82±0.02^{b}	2.83±0.04^{bc}
Proline	4.06±0.02^{a}	4.79±0.04^{c}	4.38±0.05^{b}
Arginine	6.19±0.08^{a}	7.22±0.02^{bc}	7.16±0.08^{b}
Tyrosine	3.27±0.07^{a}	4.92±0.03^{bc}	4.81±0.05^{b}
Glysine	3.56±0.09^{a}	4.50±0.03^{b}	4.88±0.10^{c}
Serine	3.73±0.08^{a}	5.01±0.05^{c}	4.72±0.04^{b}
Aspartic acid	9.99±0.10^{a}	10.50±0.06^{b}	11.36±0.07^{c}
Glutamic acid	13.70±0.06^{a}	14.01±0.03^{b}	14.56±0.09^{c}
Alanine	3.34±0.08^{b}	2.72±0.06^{a}	4.61±0.02^{c}
%TEAA	37.62±0.08^{a}	40.24±0.04^{c}	38.73±0.10^{b}
%TCEAA	23.36±0.10^{a}	25.65±0.05^{c}	24.86±0.04^{b}
%TNEAA	39.03±0.12^{c}	34.10±0.07^{a}	36.42±0.02^{b}

Values in the same row bearing same superscripts are not significantly different at p≥0.05

Table 1 shows the result of amino acid compositions (g/100g protein) of the fermented and unfermented seeds of *C. populnea*. Amino acids are associated with health issues and their deficiencies lead to a number of diseases. Hence, knowledge of the amino acid composition of foods serves as a basis for establishing their nutritive values [13]. Lysine is an essential amino acid which is extensively required for optimal growth and its deficiency leads to immunodeficiency [14]. It is also used for preventing and treating cold sores [14]. The lysine contents ranged from 3.82±0.07 (unfermented) to 4.72±0.09 g/100 g protein (fermented for 24 h). Prolonged fermentation of up to 48 h showed significant decrease in the lysine contents of the samples. Okechukwu *et al.* [15] recorded low lysine concentration for African oil beans (0.40 to 1.40 g/100g protein for unfermented and fermented samples for 48 h). However, lysine contents were lower than 40.60±1.10 (unfermented) to 47.20±0.30 g/100 g (fermented for 72 h) range reported for *Prosopis africana* [16].

Leucine is the only dietary amino acid that can stimulate muscle protein synthesis and has important therapeutic role in stress conditions like burn, sepsis and trauma [17]. In this study, leucine concentrations ranged from 9.00±0.08 (unfermented) to 9.64±0.06 g/100 g protein (fermented for 48 h). Results shows progressive increases in the leucine contents of samples as the period of fermentation increased. The increases observed for this amino acid during the fermentation period might have been as a result of the formation of intermediate compounds which during metabolism, reacted with ammonia and were converted to amino acids which in turn were useful in the formation of other amino

acids [15]. These values were higher than 7.35±0.05 (unfermented) to 8.99±0.10g/100 g protein reported for *Haematostaphis barteri* seed Mathew *et al.* [7]. Also, Buang and Taib [18] recorded progressive increase in leucine values during the fermentation of groundnut [1.74±0.04 g/100 g protein (for the fermentation for 18 h)] to 2.55±0.01 g/100 g protein (for 30 h fermentation), although the values reported were lower compared to the one obtained in this study. The studied plant seeds had leucine content to be lower than 64.50±2.01 (unfermented) to 66.50±2.33 g/100 g (fermented for 48 h) reported for *Ricinus communis* seed [16]. Therefore, leucine contents in this study plant seeds can greatly contribute to the nutritional composition needed in the body.

The phenylalanine contents ranged from 3.99±0.04 (unfermented) to 5.02±0.09 g/100g protein (fermented for 24 h). Extension of fermentation period up 48 h showed significant decrease in the phenylalanine contents of the sample. These values were higher than 1.78±0.02 to 2.17±0.03 g/100 g protein for unfermented and fermented samples reported for garbanzo beans [18]. However, these values were lower than 6.30±0.20 g/100g protein reported for *Anabas testudineus* [19]. In addition, 41.60±3.01 (unfermented) to 67.20±1.21 g/100g protein (fermented for 72 h) range was reported for *P. africana* [16]. This is probably because of the different yeast used during fermentation.

Isoleucine is a branched chain amino acid needed for muscle formation and proper growth. Chronic renal failure patients on haemodialysis have low plasma level of the branched chain amino acids such as leucine, valine and isoleucine [20]. The contents of isoleucine in the studied seeds ranged from 3.40±0.04 (unfermented) to 4.07±0.07 g/100 g protein (fermented for 24 h). There were significant decreases as fermentation reached 48 h in the concentrations of isoleucine which might have been as a result of reactions of intermediate compounds formed during metabolism which reacted with ammonia and were converted to amino acids which in turn were useful in the formation of other amino acids [15]. The concentrations of the samples were higher than 0.84±0.05 (unfermented) to 1.28±0.05 g/100g protein (fermented for 48 h) reported for groundnut seeds [18]. Although, the values were lower compared with 5.41 g/100 g protein reported for African oil beans [15]. Also, the values were lower compared with the 10.40 g/100 g protein isoleucine content reported for *Stolephorus waitei* [19].

Tryptophan which is a precursor for serotonin, melatonin and tryptamine is a brain neurotransmitter theorised to oppress pain. Free tryptophan enters the brain cells to form serotonin. Thus tryptophan supplementation has been used to increase serotonin production in attempt to increase tolerance to pain [21]. The tryptophan contents ranged from 1.00±0.06 (unfermented) to 1.03±0.02 g/100g protein (fermented for 24 h). These values were higher than 0.65 g/100g dietary protein reported for *A. fasciatus* [22]. These were however, lower than the 2.10±0.50 g/100g protein reported for *S. waitei* [19].

Methionine is used for treating liver disorders, improving wound healing and treating depression, alcoholism, asthma, radiation side effects, allergies, copper poisoning, drug withdrawal, Parkinson's disease and schizopherenia [19]. The methionine contents ranged from 1.39±0.08 (unfermented) to 1.85±0.10 g/100g protein (fermented for 24 h). The increase observed in the methionine concentrations during the fermentation period might have been as a result of formation of intermediate compounds during metabolism which might have reacted with ammonia and converted to amino acids which in turn were useful in the formation of other amino acids [15]. These values were lower compared to reported value of *P. africana* (10.40±0.10 to 13.10±010 g/100g protein for unfermented and fermented for 48 h) [16]. These were however, higher than the 1.09±0.02 g/100g protein methionine reported *H. barteri* by Mathew *et al.* [7].

Valine is needed for muscle metabolism tissue repair and the maintenance of proper nitrogen balance in the body. It is helpful in treating liver

and gall bladder disorders, and it is good for correcting the type of severe amino acid deficiencies caused by drug addiction [14]. The concentrations of valine ranged from 3.51±0.05 (unfermented) to 4.03±0.04 g/100g protein (fermented for 48 h). The values obtained in this study were lower than 5.36 (unfermented) to 6.89 g/100g protein (fermented for 48 h) reported for African oil beans [15]. However, the values were higher compared to the 1.00±0.13 (unfermented) to 1.58±0.06 g/100g protein (fermented for 30 h) reported for groundnut [18]. They were however, lower than 40.30±0.80 (unfermented) to 53.20±0.60 g/100g protein (fermented for 72 h) reported for *P. africana* seeds [16].

Histidine plays important roles in protein interaction and is also a precursor of histamine. It is also needed for growth and repair of tissue, for maintenance of the myelin sheaths and in removing heavy metals from the body [23]. The histidine concentrations in the samples of this study ranged from 2.43±0.02 (unfermented) to 4.03±0.07 g/100g protein (fermented for 24 h). Prolonged fermentation up to 48 h showed significant decrease in this amino acid in these plant seeds. These values were however, higher than 0.79±0.01 (unfermented) to 1.29±0.02 g/100g protein (fermented for 30 h) reported for the garbanzo beans by Buang and Taib [18]. On other hand, they were, lower than the 7.90±0.60 g/100g protein reported for *Rastrelliger kanagurta* by Mohanty *et al*. [19]. In a similar observation, Okechukwu *et al*. [15] recorded decreased histidine concentrations after the fermentation of African oil beans (1.81 for the unfermented to 1.43 g/100g protein for fermented for 48 h). This amino acid is very important for the growing and development of infants, therefore incorporation of these plant seeds into infant foods would enhance the growth and development of children particularly in developing nations where animal based-complementary foods are expensive.

Threonine is used for treating various nervous system disorders including spinal plasticity, multiple sclerosis, familial, spastic paraparesis and amyotrophic lateral sclerosis [24]. The contents of threonine ranged from 3.11±0.04 (unfermented) to 3.89±0.02 g/100g protein (fermented for 24 h). From the present study, it is observed that fermentation at 48 h showed significant decrease in this amino acid in the study plant seeds. From this research, the values of threonine in these samples were higher than the 0.73±0.03 (unfermented) to 1.09±0.03 g/100g protein (fermented for 30 h) range reported for groundnut by Bujang and Taib [18]. Also, the values were higher than the 2.54±0.01 (unfermented) to 3.06±0.02 g/100g protein (fermented for 48 h) range reported for African locust beans flour by Ijarotimi and Keshinro [25].

Glycine plays an important role in metabolic regulation, preventing tissue injury, enhancing anti-antioxidant activity, promoting protein synthesis and wound healing. It also improves immunity and treatment of metabolic disorders in obesity, diabetes, cancer, cardiovascular diseases, ischemia reperfusion injuries and various inflammatory diseases [26]. The concentration of glycine ranged from 3.56±0.09 (unfermented) to 4.88±0.10 g/100g protein (fermented for 48 h). These values show that this amino acid decreases in concentrations with fermentation period. The glycine values obtained in this work are lower than 5.92 g/100g protein reported for *Parkia biglobosa* [27]. However, they were higher than 1.21 (unfermented) to 1.69 g/100g protein (fermented for 48 h) range reported for African oil beans by Okechukwu *et al*. [16].

Arginine plays important role in cell division, wound healing, ammonia removal, immune function and hormone release. It is also the precursor for biological synthesis of nitric oxide which plays important roles in neurotransmission, blood clotting and maintenance of blood pressure [13]. The contents of arginine ranged from 6.19±0.08 (unfermented) to 7.22±0.02 g/100g protein (fermented for 24 h). The increase observed in arginine contents of the samples with the fermentation period, might have been as a result the formation of intermediate compounds during metabolism which reacted with ammonia and were converted to amino acids which were useful in the formation of other amino acids

[15]. The values of arginine obtained in this work were higher than 2.74±0.05 g/100g protein reported for *A. fasciatus* by Furuya *et al.* [22]. Also, the values were higher compared to the arginine concentration reported for groundnut (2.89±0.06 unfermented) to 3.04±0.05 g/100g protein (fermented for 30 h) by Bujang and Taib [18]. However, the values were lower when compared to the arginine content analysed for *P. africana* seeds flour: 41.60±1.00 (unfermented) to 49.00±0.51 g/100 g protein (fermented for 72 h) reported by Igwe *et al.* [16].

The proline contents ranged from 4.06±0.02 (unfermented) to 4.79±0.04 g/100 g protein (fermented for 24 h). From the result, it is observed that the contents of this amino acid concentration increased for samples fermented for 24h but decreased on fermentation for 48 h, These values were similar compared to 4.09 (unfermented) to the 4.28 g/100g protein (fermented for 48 h) reported for African locust beans flour by Ijarotimi and Keshinro [25], while the values were higher compared to the 1.50±0.30 g/100g protein reported for *Stolephorus commersonii* by Mohanty *et al*. [28]. Although, the values were lower when compared with the 38.00±0.31 g/100g protein reported for *P. africana* by Igwe *et al*. [16].

The cysteine contents of the plant seeds ranged from 1.33±0.09 (unfermented) to 2.83±0.04 g/100g protein (fermented for 48 h). From the result, it can be inferred that the samples had lower values than the 21.20±0.21 g/100 g protein reported for *P. africana* by Igwe *et al*. [16]. However, the values were higher than 0.40 g/100 g protein (unfermented) to 1.40 g/100 g protein (fermentation at 48 h) reported for African oil beans by Okechukwu *et al*. [15]. The increased observed in cysteine during the fermentation period might have been as a result of formation of intermediate compounds during metabolism that reacted with ammonia and were converted to amino acids which in turn were useful in the formation of other amino acids [15].

Tyrosine concentration analysed in this samples ranged from 3.27±0.07 (unfermented) to 4.92±0.03 g/100g protein (fermented for 24 h). These values were higher compared with 1.18±0.01 g/100 g protein reported for *A. faciatus* by Furuya *et al*. [22]. Also, the values were higher than 0.20±0.00 g/100 g protein reported for *S. commersonii* by Mohanty *et al*. [19]. Although, the values were lower compared with the fermented value of African oil bean reported by Okechukwu *et al.* [15]. In addition, the values were lower than 33.40±0.30 g/100 g protein (unfermented) to 40.60±0.51 g/100 g protein (fermentation at 48 h) reported for *P. africana* by Igwe *et al.* [16]. Since these values are high in those samples, they can serve as sources of this amino acid.

The serine concentration of 3.73±0.08 (unfermented) to 5.01±0.05 g/100 g protein (fermented for 24 h). Base on the result of the serine contents analysed in this work, it was recorded that the concentration of this acid increased on fermentation for 24 h, while when fermentation exceeded that period the contents of serine decreased. These results were higher than the respective values of the 1.22±0.01 and 1.98±0.01 g/100 g protein (for unfermented and fermented for 30 h) reported for groundnut seed by Bujang and Taib [18]. They are however, lower than 46.80±0.60 g/100 g protein (unfermented) to 64.40±1.01 g/100 g protein (fermented for 72 h) reported for *Prosopis africana* by Igwe *et al*. [16].

Glutamic acid plays an important role in amino acid metabolism because of its role in transamination reactions and is necessary for the synthesis of key molecules, such as polyglutamate folate cofactor and glutathione which are required for the removal of highly toxic peroxides [14]. The glutamic acid values ranged from 13.70±0.06 (unfermented) to 14.56±0.09 g/100g protein (fermented for 48 h). The values were lower than 102.20±4.10 g/100 g protein reported for *Prosopis africana* by Igwe *et al*. [16]. Also, the values were lower when compared with 16.90 g/100 g protein recorded for African oil beans by Okechukwu *et al*. [15] but these values are higher than the 11.20±0.07 (unfermented) to 12.18±0.03 (fermented for 24 h) g/100g protein reported for *H. barteri* seed by Mathew *et al.* [7]. However, African locust beans flour had similar values of 14.82±0.01

g/100 g protein as reported by Ijarotimi and Keshinro [25].

The aspartic acid concentration ranged from 9.99±0.10 to 11.36±0.07 g/100 g protein (fermented for 48 h). Similar value was reported for *Parkia biglobosa* (10.02 g/100 g protein) by Ndamitso *et al*. [12]. The value obtained in this work were lower than 22.82±0.01 g/100g protein (unfermented) to 23.15±0.02 g/100 g protein reported for African locust bean flour by Ijarotimi and Keshinro [25]. These values were however, high when compared with the 3.64±0.01 g/100 g protein reported for *A. fasciatus* by Furuya *et al*. [22]. Alanine contents ranged from 3.34±0.08 (unfermented) to 4.61±0.02 g/100 g protein (fermented for 48 h). The value obtained in this work is lower compared with the 7.80±1.10 g/100 g protein reported for *Labeo rohita* by Mohanty *et al*. [19].

Table 2: Food Functional properties of the Samples

Parameters	Unfermented	Fermented for 24 h	Fermented for 48 h
Bulk density (g/cm^3)	0.61 ± 0.11^{c}	0.47 ± 0.22^{b}	0.39 ± 0.33^{a}
EC (%)	42.03 ± 0.36^{a}	47.14 ± 0.62^{b}	54.21 ± 0.52^{c}
GP (%)	33.40 ± 0.20^{a}	36.00 ± 0.67^{b}	37.89 ± 0.28^{c}
FC (%)	1.82 ± 0.12^{a}	3.08 ± 0.60^{b}	6.05 ± 0.10^{c}
WAC (mg/g)	2.03 ± 0.11^{c}	1.89 ± 0.53^{a}	1.96 ± 0.30^{b}
OAC (mg/g)	0.65 ± 0.01^{ab}	0.68 ± 0.14^{bc}	0.70 ± 0.03^{bc}
Foaming stability (%)	98.12 ± 0.14^{a}	101.14 ± 0.22^{b}	106.07 ± 0.16^{c}
Swelling capacity (%)	3.50 ± 0.36^{c}	2.09 ± 0.18^{b}	1.92 ± 0.28^{a}

Values in the same row bearing same superscripts are not significantly different at $p\geq0.05$
EC = Emulsification capacity, OAC = Oil absorption capacity, WAC = Water absorption capacity, FC = Foaming capacity, GP = Gelation properties

The food functional properties of fermented and unfermented samples were presented in Table 2. The swelling index of food determines the amount of water that would be absorbed and the degree of swelling within a stipulated time [29]. This index is influenced by temperature, water availability, carbohydrate and protein [30]. The swelling capacities ranged from 1.92±0.28 (fermented for 48 h*)* to 3.50±0.36 (unfermented). The decrease in the swelling capacities of the samples with fermentation period obtained in this work might be attributed to the fact that unfermented plant seeds had more of their intermolecular starch bound which allowed them to absorb water and swell more than the fermented samples [31]. The values were higher than 1.41±0.24 (unfermented) to 2.05±0.01 % (fermented for 48 h) reported for pigeon pea by Mbaey-Nwaoha and Obetta [32]. Although the values were lower than 4.01±0.50 (fermented for 48 h) to 6.10±0.28 % (unfermented) reported for *H. barteri* seeds by Mathew *et al* [7]. Also, these values were lower than 6.50 % reported by Adebowale and Maliki [33] for unfermented pigeon pea seeds.

Foaming capacity is essential in maintaining constituency, texture and appearance of food that require leavening and aeration properties [29]. The foaming capacities of the plant seeds ranged from 1.82±0.12 (unfermented) to 6.05±0.10 (fermented). Food ingredients with favourable foaming capacities can be used in bakery products [34]. The increase recorded as the fermentation period increased might have been due to the configurations of the protein molecules as they increase [35]. The foaming capacities were lower than 23.50±0.10 % reported for water melon seed by Oyeleke *et al*. [36]. Also, the values were lower when compared with 10.00±0.20 % reported for *P. biglobosa* seeds by Ogunyinka *et al*. [29]. However, the values were higher than 0.62±0.02 % (unfermented) to 0.92±0.30 % (fermented for 48 h) reported for African oil beans seed by Osagie-Eweka and Alaiya [37].

Proteins can function as emulsifiers since they have both hydrophobic and hydrophilic properties that can interact with oil and water in food systems [38]. The emulsification capacities increased significantly with increase in fermentation time with values ranging from 42.03±0.36 (unfermented*)* to 54.21±0.52 % (fermented for 48 h). The increase in the emulsification capacities recorded in this work during the fermentation time could be attributed to the tenability of the protein in the samples to lower the tension at the surfaces of water and oil [39]. The high emulsification capacities obtained from the samples could help in enhancing the additives of these samples in the food industry [36]. However, the values were lower when compared with the 85.00±4.10 % reported for *Cucumeropsis mannii* seed flours by Ogunbusola *et al*. [40]. These values were higher when compared with the 33.33±0.88 (unfermented) to 40.24±0.52 % range reported for African oil seed by Osagie-Eweka and Alaiya [37].

Bulk density explains the packaging requirement and material handling of a food [41]. The bulk densities ranged from 0.39±0.33 (fermented for 48 h) to 0.61±0.11 g/cm^3 (unfermented). There was a decrease in these values as the fermentation period increased. This might be as a result of combined interrelated factors such as the intensity of attraction that is poor, inter-particle forces, particle size and number of contact points [39]. Similar values were reported for *H. barteri* seed 0.32±0.41 (fermented for 48 h) to 0.65±0.36 g/cm^3 (unfermented) by Mathew *et al.* [7]. However, the values were lower than 0.80±0.05 g/cm^3 reported for cowpea as reported by Appiah *et al*. [42]. Also, the values were low when compared with 0.65 (fermented for 48 h) to 0.80 g/cm^3 (unfermented) reported for pigeon pea seed flour by Adebowale and Maliki [33].

Table 3: Physico-chemical Properties of the Oil Extracted from Fermented and Unfermented Seeds of the *C. populnea*

Parameters	Unfermented	Fermented for 24 h	Fermented for 48 h
Texture	fine	sticky	sticky
Smell	pleasant	irritating	choking
Colour	butter	butter	light yellow
pH	5.70±0.21^a	7.80±0.31^b	7.80±0.22^b
Temperature (^{o}C)	23.00±0.21^a	29.00±0.34^c	27.00±0.20^b
Viscosity	58.65±0.15^c	55.90±0.12^b	51.55±0.42^a
Iodine value (gI_2/100g)	46.03±0.20^c	42.10±0.10^b	39.72±0.32^a
PV (Meq KOH/g)	2.82±0.12^c	2.19±0.51^b	1.89±0.22^a
SV (mg KOH/g)	72.33±0.41^a	80.25±0.30^b	82.17±0.25^c
Specific gravity	0.90±0.10^c	0.87±0.25^b	0.83±0.11^a
Acid value (mg KOH/g)	2.44±0.50^c	2.01±0.43^b	1.69±0.23^a
Refractive index	1.4557±0.18^{ab}	1.4562±0.22^{bc}	1.4564±0.24^{bc}
FFA (mg KOH/g)	1.22±0.21^c	1.00±0.23^b	0.85±0.32^a

Values in the same row bearing same superscripts are not significantly different at p≥0.05
SV= saponification value, PV= Peroxide value, FFA= Free fatty acid

The results of the physicochemical properties of oils obtained from the fermented and unfermented seeds of the *C. populnea* were presented in Table 3. The oils extracted were

butter in colour for unfermented and fermented for 24 h, while light yellow in colour for fermented at 48 h. Adejumo *et al*. [43], recorded similar colours during the fermentation of *P. biglobosa* seeds. The textures observed during the fermentation of the plant seeds were fine before fermentation, while sticky were observed for samples fermented for 24 and 48 h. The fermented plant seeds of *P. biglobosa* showed similar texture reported by Adejumo *et al.* [43]. The smell properties observed in this study were pleasant before fermentation, while irritating smell observed for the samples fermented for 24 h and for samples fermented for 48 h had chocking.

The low iodine values of the oils indicated that they have low contents of unsaturated fatty acids. This showed that these oils will not be susceptible to oxidative deterioration and thus they can be easily stored for a long time without spoilage [44]. The iodine contents ranged from 39.72±0.32 (fermented for 48 h) to 46.03±0.20 gI_2/100 g (unfermented). There was a decrease generally in iodine values of the oil samples content in this study as the period of fermentation increased. This may be as a result of decrease in fat contents that might have been converted to protein by the help of microorganisms present during fermentation. The values were low compared to 81.94±1.03 gI_2/100g reported for groundnut oil (gargajiya) by Nkafamiya *et al*. [45]. They were however higher than 38.71 gI_2/100g reported for groundnut oil by Atasie *et al.* [46].

Saponification value is used in checking adulteration [47]. The saponification value is a measure of the alkali reactive groups in fats and oils and is expressed as the number of milligrammes of potassium hydroxide which react with one gramme of sample [48]. The saponification values ranged from 72.33±0.41 (unfermented) to 82.17±0.25 (fermented for 48 h*)*. These values were lower than 179.04±1.60 mgKOH/g reported for the seed oil of *Telfairia occidentalis* by Bello *et al.* [49]. The acid value of oil is a direct measure of the percentage content of free fatty acids in a given amount of the oil. It is a measure of the extent to which the triglycerides in the oil is decomposed into free fatty acids by lipase action. This value depends on the degree of rancidity which is used as an index of freshness [50]. The acid values ranged from 1.69±0.23 (fermented for 48 h) to 2.44±0.50 mgKOH/g (unfermented). These values were higher than 1.48±1.60 mgKOH/g reported for seed oil of *Telfairia occidentalis* by Bello *et al*. [49]. However they were lower compared to pea nut oil of bari (8.89±0.32 mgKOH/g) reported by Shad *et al.* [51]. The low acid value obtained in this study gives an indication of their lower susceptibility to rancidity which depicts a higher shelf life [10].
The peroxide value of oil is a sign of its rancidity, thus a high peroxide value of oil indicates a poor resistance of the oil to peroxidation during storage [52]. Higher peroxide values between 20 and 40 results in a rancid taste while the low peroxide value further confirms the stability of the oil [53]. The peroxide values ranged from 1.89±0.22 (fermented for 48 h*)* to 2.82±0.12 Meq KOH/g (unfermented*).* These values obtained in this work are lower than 5.26±0.06 Meq KOH/g reported for *T. occidentalis* by Bello *et al.* [49]. They are however higher than 1.50 Meq KOH/g reported for groundnut oil by Atasie *et al*. [46]. The peroxide values obtained from this work indicate that, these oils will take long time before they deteriorate.

The refractive index of oil indicates the level of optical clarity of the oil sample relative to water. The refractive indices of oils obtained for unfermented plant seeds ranged from 1.4557±0.18 (unfermented) to 1.4564±0.24 (fermented for 48 h). A similar index of 1.460±0.08 was reported for *T. occidentalis* by Bello *et al.* [49]. However, the samples had higher values when compared to the value reported for groundnut oil (1.449) by Atasie *et al*. [46]. This implies that the oils obtained from this plant seeds are lighter and could be considered to be of high quality and as such find much use in the pharmaceutical industries. Free fatty acids are more susceptible to lipid oxidation, leading to rancidity and production of off-odour compared to intact fatty acids in the triglycerides [48]. The free fatty acid values ranged from 0.85±0.32 (fermented for 48 h) to 1.22±0.25 mgKOH/g (unfermented). Similar

value of 3.01mg/KOH/g was reported for groundnut oil by Atasie *et al*. [46]. However, these values are higher than 1.74±0.49 mgKOH/g reported for seed oil *T. occidentalis* by Bello *et al*. [54]. Since the values obtained from this work is low, it is implied that the oils obtained from these selected plant seeds will take more time before susceptible to lipid oxidation and rancidity.

4. CONCLUSION

Results from this study revealed adequate chemical compositions fermented and unfermented necessary for building the body. The flours possess good functional properties which can be incorporated into human diets not only as protein supplements but also as in processed foods like weaning, baked and soup products. Food processing technologies for exploiting the utilisation of *C. populnea* flours both fermented and unfermented should be promoted.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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