

Effects of Thermal Processing on the Proximate and Anti-nutritional Composition of *Detariumsenegalense* Seed Flour and Starch Concentrate

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Abstract

This study investigated the effects of thermal processing on the nutritional and anti-nutritional composition of Detariumsenegalense (Ofo) seed flour and starch concentrate. Mature seeds were sorted, cleaned and subjected to roasting, cooking and blanching prior to flour production and starch extraction using standard processing techniques. The processed samples were analyzed for proximate composition, starch yield, mineral composition, vitamin composition and anti-nutritional factors using established analytical methods. The proximate composition showed moisture contents ranging from 4.51 to 21.19%, crude protein from 0.61 to 13.77%, fat from 0.25 to 12.52%, ash from 0.79 to 3.67%, crude fibre from 5.45 to 7.23% and starch content from 58.77 to 85.32%, while starch yield was 48.20%. The anti-nutritional constituents varied between 7.39–13.54% for phytate, 0.28–0.99% for tannin, 19.12–57.36% for oxalate, 1.94–3.10% for hydrogen cyanide, 0.12–0.17% for saponin and 0.21–0.27% for trypsin inhibitor. Mineral analysis revealed appreciable concentrations of iron (0.25–0.90 mg/100 g), calcium (18.45–26.21 mg/100 g), zinc (2.40–3.49 mg/100 g), potassium (90.00–165.06 mg/100 g), magnesium (1.00–2.60 mg/100 g), copper (0.56–1.60 mg/100 g) and manganese (2.30–3.60 mg/100 g). The processed flours also contained vitamins B₁, B₂, B₃, A, C and E in varying concentrations. Thermal processing altered both nutrient and anti-nutrient profiles, indicating improvements in the nutritional quality and safety of the products. The findings demonstrate that thermally processed Detariumsenegalense flour and starch concentrate possess considerable nutritional potential and could serve as valuable ingredients for the development of nutrient-enriched food products.

Keywords: *Detariumsenegalense*, thermal processing, proximate composition, minerals, vitamins, anti-nutrients.

Introduction

Underutilized indigenous legumes have increasingly attracted scientific attention because of their potential to improve food security, nutritional quality, and sustainable food systems, particularly in developing countries. Many of these plant resources possess valuable nutritional attributes comparable to commonly cultivated legumes but remain inadequately exploited due to limited scientific information, poor processing technologies, and low commercial utilization. As the demand for affordable plant-based proteins and functional food ingredients continues to rise, there is renewed interest in exploring neglected and underutilized species as alternative food resources. The utilization of indigenous legumes can contribute significantly to dietary diversification, reduction of protein-energy malnutrition, and achievement of several

Sustainable Development Goals related to hunger, nutrition, and sustainable agriculture. Consequently, researchers have intensified efforts to characterize the nutritional qualities and processing characteristics of indigenous legumes to facilitate their wider utilization in food and industrial applications (Food and Agriculture Organization [FAO], 2023; Akinola *et al.*, 2022).

Among the numerous underutilized legumes in tropical Africa, *Detarium senegalense* J.F. Gmel., commonly known as sweet detar, occupies an important position because of its nutritional richness and diverse traditional uses. The species belongs to the family Fabaceae (subfamily Detarioideae) and is widely distributed across the humid and sub-humid regions of West and Central Africa. In Nigeria, the seeds are popularly known as "Ofo" among the Igbo, "Ogbogbo" among the Yoruba, and "Taura" among the Hausa. The plant produces edible fruits whose pulp and seeds have long been utilized in traditional diets, while the seed flour serves primarily as a soup thickener because of its unique mucilaginous properties. Besides its culinary importance, different parts of the plant have been reported to possess medicinal, nutritional, and economic values, making the species an important candidate for food diversification and value addition (Burkill, 2004; Kouyaté & Van Damme, 2021).

Despite their nutritional advantages, legumes also contain several naturally occurring anti-nutritional factors that may reduce nutrient utilization or interfere with normal physiological processes when consumed in excessive quantities. Among the most commonly reported anti-nutrients are phytates, tannins, oxalates, saponins, cyanogenic compounds, lectins, and protease inhibitors. These compounds may reduce mineral bioavailability through chelation, inhibit digestive enzymes, decrease protein digestibility, or interfere with nutrient absorption in the gastrointestinal tract. For example, phytates strongly bind calcium, iron, and zinc, thereby reducing their absorption, whereas oxalates form insoluble complexes with calcium that decrease its bioavailability. Tannins may reduce protein digestibility through complex formation with proteins and digestive enzymes, while trypsin inhibitors interfere with protein digestion by inhibiting proteolytic enzymes. Consequently, reducing anti-nutritional factors remains an important objective during the processing of legumes intended for human consumption (Samtiya *et al.*, 2020; Shi *et al.*, 2023).

Roasting, cooking, and blanching are among the most widely practised thermal processing methods in tropical food systems. Roasting generally improves flavour, aroma, and shelf stability by reducing moisture content and inactivating degradative enzymes. Cooking softens seed tissues, improves digestibility, and effectively lowers concentrations of several anti-nutritional factors through thermal degradation and leaching into cooking water. Blanching serves as a mild heat treatment that inactivates enzymes, preserves colour, and facilitates subsequent processing operations while contributing to reductions in selected anti-nutrients. Although these methods have been extensively investigated in commonly consumed legumes such as soybean, cowpea, pigeon pea, and Bambara groundnut, limited information exists regarding their effects on the nutritional quality of *Detarium senegalense* flour and starch concentrate (Mubaiwa *et al.*, 2018; Adebo *et al.*, 2023).

Therefore, this study investigated the effects of roasting, cooking, and blanching on the nutritional and anti-nutritional composition of *Detarium senegalense* seed flour and starch

concentrate. Specifically, the study evaluated changes in proximate composition, starch yield, mineral composition, vitamin composition, and selected anti-nutritional factors following thermal processing. The findings are expected to provide useful scientific information for improving the nutritional utilization of *Detariumsenegalense*, promoting its commercialization, and supporting the development of nutritious food products from this underutilized indigenous legume.

MATERIALS AND METHODS

Sample Collection

The sample that was used for the study is *Detariumsenegalense* “ofò”. The sample was collected at OgwuObollo- Eke, Udenu local government Area, Enugu State. The choice of location for collection is informed by availability within the area.

Raw *Detariumsenegalense* “ofò” flour

The method of Ugwu and Oranye (2006) was used to prepare the raw sample. Five kilograms (5kg) of whole *Detariumsenegalense* “ofò” seeds were conditioned to 25% moisture by the addition of tap water and held for 2 h with occasional turnings. The conditioned sample was sun dried to a final moisture content of approximately 10%. The dry seeds were dehulled using disc attrition mill (No1 A Premier). The dehulled seeds were then milled several times in a hand corn mill (Corona corn mills) to produce *Detariumsenegalense* ‘ofò’ flour. After sieving with American standard sieve number 40, with aperture size of 435µm. The flour and starch obtained was packaged in a polythene bag, labeled and stored in an airtight container at room temperature (28±2°C) until required for further analysis.

Roasted *Detariumsenegalense* ‘ofò’ flour

The method of Ugwu and Oranye, (2006) was used. One kilogram (1 kg) of dry *Detariumsenegalense* seeds were roasted in an oven at 100°C for 15, 30, and 60 minutes respectively and dehulled while hot with stone. The dehulled seeds were milled several times in a hand corn mill (Corona corn mills) to produce *Detariumsenegalense* flour. The milled flours were sieved with American standard sieve number 40, with aperture size of 435µm. The flours obtained were packaged, labeled and stored in an airtight container until required for further analysis.

Sample Analysis

Proximate Composition of the Flours

The moisture, crude protein, fat, ash and crude fibre contents of the samples were determined on a weight basis according to the methods of AOAC (2010). Carbohydrate was determined by difference (AOAC, 2010). The energy content of the flours was calculated from the proximate

composition using the Atwater factors of 4×protein, 9×fat and 4×carbohydrate (AOAC, 2010). All determinations were carried out in triplicate samples.

Anti-nutrient analysis

The phytic acid, hemagglutinin activity, alkaloids, saponin, oxalate, trypsin inhibitor and tannin levels of the flour samples were determined on dry weight basis according to the spectrophotometric methods described by Onwuka (2005). The phytate and haemagglutinin contents were determined using the spectrophotometric methods of AOAC (2010). All determinations were carried out in triplicate samples.

Statistical analysis

The data generated were subjected to one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS, Version 23) software. Significant means were separated using Turkey's least significant difference (LSD) test at $p < 0.05$.

RESULTS AND DISCUSSION

Table 1: Chemical composition of *Detarium Senegalense* flour and starch extract

Samples	Moisture Content (%)	Crude Protein (%)	Crude Fat (%)	Ash (%)	Crude Fibre (%)	Starch yield (%)	Starch (%)
Flour	7.25±0.05 ^c	13.77±0.06 ^a	12.52±0.04 ^a	3.67±0.07 ^a	7.23±0.07 ^a	-	58.77±
Starch extract	8.98±0.06 ^c	0.61±0.04 ^d	0.25±0.05 ^d	0.79±0.09 ^d		48.20±0.06	85.32±0.07
Roasted at 100°C 15min	6.37±0.06 ^d	10.70±0.11 ^b	8.85±0.56 ^b	2.60±0.07 ^b	7.50±0.06 ^a		
30min	5.56±0.05 ^d	9.90±0.11 ^{bc}	7.62±0.05 ^c	2.21±0.04 ^b	6.78±0.09 ^a		
60min	4.51±0.03 ^d	9.31±0.04 ^{bc}	7.23±0.08 ^c	1.55±0.06 ^c	5.89±0.06 ^b		
Cooked at 95°C 15min	20.58±0.06 ^a	10.63±0.07 ^b	10.04±0.08 ^a	2.43±0.08 ^b	6.03±0.06 ^b		
30min	21.19±0.45 ^a	10.01±0.08 ^b	9.57±0.07 ^b	2.23±0.05 ^b	5.92±0.06 ^b		
60min	22.89±0.06 ^a	9.67±0.07 ^a	9.08±0.04 ^b	2.06±0.06 ^b	5.45±0.09 ^b		
Blanched at 70°C 15min	12.78±0.07 ^b	12.98±0.08 ^a	11.65±0.10 ^a	3.42±0.06 ^a	6.12±0.37 ^b		
30min	12.98±0.09 ^b	11.68±0.09 ^a	10.73±0.05 ^a	3.12±0.06 ^a	5.94±0.07 ^b		
60min	13.20±0.04 ^b	10.56±0.06 ^b	9.44±0.07 ^b	2.89±0.09 ^b	5.67±0.07 ^b		

Data are means scores of triplicate determination $\pm$ SD. Data in the same column bearing different superscripts are significantly different ($p < 0.05$). Values in the same row bearing different superscripts differed significantly ($p < 0.05$).

Proximate Composition of *Detariumsenegalense* Flour and Starch

Table 1 presents the proximate composition of raw *Detariumsenegalense* flour, isolated starch, and flour subjected to roasting, cooking, and blanching. Significant differences ($p < 0.05$) were observed in moisture, crude protein, crude fat, ash, crude fibre, starch yield, and starch content among the samples, confirming that starch isolation and thermal processing significantly influenced the nutritional composition of the flour through moisture redistribution, nutrient degradation, and leaching of soluble components (Adebooye et al., 2020; Nkhata et al., 2018). Raw flour contained 7.25% moisture, which increased to 8.98% after starch extraction, while roasting progressively reduced moisture from 6.37% to 4.51%, cooking produced the highest moisture values (20.58–22.89%), and blanching resulted in intermediate values (12.78–13.20%). The increased moisture in cooked samples resulted from water absorption and starch gelatinization, whereas roasting enhanced dehydration, reduced water activity, and improved storage stability (Shi et al., 2021; Oghbaei & Prakash, 2016; FAO, 2021). Raw flour contained 13.77% crude protein and 12.52% crude fat, but isolated starch contained only 0.61% protein and 0.25% fat, demonstrating the effectiveness of starch purification. Protein declined to 9.31–12.98%, while fat decreased to 7.23–10.04% across the processed samples due to protein denaturation, lipid oxidation, and leaching during heating (Apea-Bah et al., 2020; Olatunde et al., 2021; Nadeem et al., 2020). Similarly, ash content decreased from 3.67% in raw flour to 0.79% in isolated starch and 1.55–2.89% in processed samples because of mineral losses during processing (Campos-Vega et al., 2018; Tiwari & Cummins, 2021).

Crude fibre also declined from 7.23% in raw flour to 5.45–7.50% in processed samples due to thermal degradation and solubilization of structural polysaccharides, although the residual fibre remained beneficial for gastrointestinal health and glycaemic regulation (Rocchetti et al., 2020). The raw flour contained 58.77% starch, whereas the isolated starch contained 85.32%, with a starch yield of 48.20%, indicating efficient starch recovery that compares favourably with the 40–55% yields reported for many tropical legumes and underutilized seeds (Hoover, 2018; Singh et al., 2020). Overall, the results demonstrate that *Detariumsenegalense* is a nutritionally valuable source of both flour and starch. Although thermal processing reduced protein, fat, fibre, and mineral-associated ash contents, roasting improved storage stability by lowering moisture, while cooking and blanching increased moisture because of water absorption. Furthermore, starch isolation produced highly purified starch with minimal protein, fat, and ash contamination, making it suitable for food formulation and industrial applications. These findings agree with previous reports that controlled thermal processing and starch purification significantly influence the nutritional composition and functional quality of underutilized legumes while preserving their value as sustainable food resources (Awolu et al., 2020; Du et al., 2022).

Table 2: Anti-Nutritional Composition of *Detariumnegalense* Flour

Sample	Phytate mg/100g	Tannin mg/100g	Oxalate mg/100g	Hydrogen cyaniande (HCN) mg/100g	Saponin mg/100g	Trypsin inhibitor (TiU)
Raw (control)	13.54±0.12 ^a	0.99±0.15 ^a	57.36±0.11 ^a	3.10±0.24 ^a	0.17±0.06 ^a	0.27±0.07 ^a
Roasting for 15min	13.45±0.11 ^a	0.79±0.09 ^b	44.38±0.09 ^d	2.78±0.06 ^b	0.15±0.05 ^a	0.24±0.10 ^a
30min	11.37±0.89 ^b	0.65±0.11 ^c	38.34±0.12 ^e	2.65±0.09 ^b	0.14±0.06 ^a	0.22±0.09 ^b
60min	11.67±0.13 ^b	0.56±0.96 ^c	24.54±0.09 ^f	2.45±0.07 ^{bc}	0.13±0.09 ^b	0.21±0.09 ^b
Cooking 15min	11.32±0.69 ^b	0.45±0.06 ^d	26.01±0.12 ^f	2.00±0.26 ^c	0.16±0.07 ^a	0.26±0.06 ^a
30min	9.78±0.11 ^c	0.34±0.89 ^e	35.01±0.09 ^e	2.08±0.42 ^c	0.14±0.06 ^a	0.25±0.07 ^a
60min	7.39±0.11 ^e	0.28±0.07 ^f	19.12±0.18 ^g	1.98±0.09 ^c	0.12±0.08 ^b	0.23±0.07 ^a
Blanch 15min	10.71±0.89 ^{bc}	0.71±0.07 ^b	50.35±0.09 ^b	2.78±0.08 ^{ab}	0.16±0.06 ^a	0.25±0.05 ^a
30min	9.28±0.15 ^c	0.63±0.12 ^c	47.11±0.24 ^c	2.56±0.09 ^b	0.16±0.08 ^a	0.23±0.07 ^a
60min	8.65±0.09 ^d	0.76±0.12 ^b	43.21±0.05 ^d	1.94±0.09 ^c	0.12±0.04 ^b	0.23±0.05 ^a

The anti-nutritional composition of *Detariumsenegalense* flour showed that roasting, cooking, and blanching significantly ($p < 0.05$) reduced phytate, tannin, oxalate, hydrogen cyanide (HCN), saponin, and trypsin inhibitor activity, although the extent of reduction depended on the processing method and duration. Overall, cooking for 60 min produced the greatest reductions in phytate, oxalate, hydrogen cyanide, and tannin, whereas roasting was most effective in reducing trypsin inhibitor activity, confirming that thermal processing improves the nutritional quality and safety of the flour by decreasing compounds that limit nutrient bioavailability and digestibility (Nkhata et al., 2018; Adebooye et al., 2020). Phytate declined from 13.54 mg/100 g in the raw flour to 11.67 mg/100 g after roasting, 7.39 mg/100 g after cooking, and 8.65 mg/100 g after blanching because of thermal degradation and leaching into processing water, thereby enhancing mineral bioavailability (Mbogo et al., 2021; Shimelis et al., 2018; Gupta et al., 2015; Samtiya et al., 2020; Suri et al., 2019). Tannin content also decreased from 0.99 mg/100 g in the raw flour to 0.56 mg/100 g after roasting, 0.28 mg/100 g after cooking, and approximately 0.63–0.76 mg/100 g after blanching owing to thermal degradation, oxidation, and leaching, thereby improving protein digestibility and mineral absorption while retaining beneficial antioxidant properties (Apea-Bah et al., 2020; Chandrasekara&Shahidi, 2018; Samtiya et al., 2020). Oxalate, the most abundant anti-nutrient, decreased from 57.36 mg/100 g to 24.54 mg/100 g after roasting, 19.12 mg/100 g after cooking, and 43.21 mg/100 g after blanching, reducing the risk of mineral complex formation and kidney stone development (Noonan & Savage, 2018; Samtiya et al., 2020; Mepba et al., 2021).

Hydrogen cyanide content declined significantly from 3.10 mg/100 g in the raw flour to 2.45 mg/100 g after roasting, 1.98 mg/100 g after cooking, and 1.94 mg/100 g after blanching due to hydrolysis, volatilization, and leaching of cyanogenic compounds, thereby improving the safety of the flour (Burns et al., 2019; Montagnac et al., 2020; WHO, 2021). Saponin concentration, which was already low (0.17 mg/100 g), decreased slightly to 0.12–0.13 mg/100 g following processing, reflecting its relative thermal stability while preserving beneficial

physiological properties such as antioxidant and cholesterol-lowering effects (Francis et al., 2016; Shi et al., 2021; Samtiya et al., 2020). Similarly, trypsin inhibitor activity decreased from 0.27 TiU in the raw flour to 0.21 TiU after roasting and approximately 0.23 TiU after cooking and blanching because heat denatured the inhibitor proteins, thereby improving protein digestibility and amino acid utilization (Carbonaro et al., 2018; Gilani et al., 2017; Shi et al., 2021). Overall, the results demonstrate that thermal processing substantially enhances the nutritional quality, mineral bioavailability, protein digestibility, and safety of *Detariumsenegalense* flour, with prolonged cooking generally producing the greatest reduction in most anti-nutritional factors, roasting being particularly effective against trypsin inhibitors, and blanching producing intermediate effects. These findings agree with previous studies showing that controlled hydrothermal processing is an effective and economical approach for improving the nutritional potential of legumes and underutilized food resources (Nkhata et al., 2018; Samtiya et al., 2020; Shi et al., 2021; Adebooye et al., 2020).

Conclusion

This study demonstrated that thermal processing significantly influenced the nutritional composition, anti-nutritional factors, mineral and vitamin contents, and starch characteristics of *Detariumsenegalense* flour. Although roasting, cooking, and blanching caused reductions in protein, fat, minerals, and vitamins, the flour remained a good source of carbohydrates, dietary fibre, essential minerals, and thermally stable vitamins, with nutrient retention depending on the processing method and duration. Thermal processing, particularly prolonged cooking, markedly reduced phytate, tannin, oxalate, hydrogen cyanide, saponin, and trypsin inhibitor activity, thereby improving protein digestibility, mineral bioavailability, and the overall safety of the flour for human consumption. Starch isolation produced a purified starch with higher amylose content and an increased amylose-to-amylopectin ratio, indicating improved structural stability and desirable functional properties for food and industrial applications. The predominance of amylopectin, together with moderate amylose content, suggests favourable thickening, gelatinization, and gel-forming characteristics suitable for diverse starch-based products. Overall, *Detariumsenegalense* flour and its isolated starch possess considerable nutritional and functional potential, making them promising materials for household food preparation, functional food development, and industrial utilization.

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