



The Relative Influence of Location and Tree Morphology on *Allanblackia parviflora* Oil Stability Properties

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Abstract

Vegetable oils are increasingly valued for their nutritional and industrial applications, which has driven interest in underutilised tree oil crops such as *Allanblackia parviflora*. This study aimed to evaluate the relative influence of tree morphology, location, and ecological zone on the oil stability properties and fatty acid composition of *A. parviflora* seed and kernel oils in Ghana, with implications for domestication and breeding. Oils were extracted from kernel (dehulled seed) and whole seed samples obtained from 157 trees across 16 communities spanning three ecological zones. Free fatty acid content and peroxide values were determined, and their relationships with tree morphological traits, oil yield, soil properties, community, and ecological zone were assessed. Free fatty acid values ranged from 0.12% - 0.50% (mean 0.37%) for kernel oils and 0.12% - 0.69% (mean 0.53%) for seed oils, while peroxide values ranged from 1.59 - 4.00 meq/kg (mean 2.11 meq/kg) and 2.00 - 6.00 meq/kg (mean 3.84 meq/kg), respectively. Although substantial tree-to-tree variation was observed, oil stability indices were not significantly influenced by tree morphology, soil properties, community, or ecological zone. These findings indicate that *A. parviflora* oil quality is relatively stable across ecological and morphological gradients, suggesting that individual tree selection rather than site-specific factors may be more critical for breeding and domestication programmes. The results provide a scientific basis for selecting superior trees to enhance the commercialisation and sustainable development of *A. parviflora* as a high-value indigenous oil crop.

Subject Areas

Food Science & Technology

Keywords

Allanblackia parviflora, Stability Properties, Free Fatty Acid, Peroxide Value, Tree Morphology, Location Influence

1. Introduction

Vegetable oils play a central role in human nutrition and industrial manufacturing, and their suitability for food and non-food applications is largely determined by oil yield and physicochemical composition [1]. In response to growing demand for healthier fats and sustainable raw materials, recent research has increasingly shifted toward under-exploited forest tree species as alternative oil sources [2] [3]. Vegetable oils are valued not only for culinary use but also as key inputs in cosmetics, pharmaceuticals, lubricants, biofuels, and surface coatings, necessitating a comprehensive evaluation of their chemical stability and functional properties [4] [5]. Despite extensive documentation of conventional oil crops, knowledge on oils derived from unconventional and indigenous species remains limited and fragmented [6] [7].

In Ghana, this knowledge gap is particularly pronounced. Although several plant-derived oils are consumed locally, the processing of vegetable oils such as palm oil, palm kernel oil, and shea butter remains largely traditional, and the chemical properties of many plant by-products incorporated into daily diets are poorly characterised. This limitation extends to *Allanblackia* oil production, which is predominantly artisanal despite its growing commercial relevance. The absence of systematic quality evaluation under traditional processing conditions constrains both local value addition and broader market integration.

Allanblackia parviflora, an indigenous tree species distributed across the moist semi-deciduous, moist evergreen, and wet evergreen forest zones of Ghana, has emerged as a promising but underutilised oil crop [8] [9]. The species is commonly retained on farms, particularly in cocoa agroforestry systems, where its large fruits contain oil-rich kernels [10]. Traditionally, *Allanblackia* oil is extracted and used locally either alone or blended with palm kernel oil for cooking, as well as for cosmetic and medicinal applications. Scientific interest in *Allanblackia* oil intensified following its safety assessment by the European Food Safety Authority (EFSA), which confirmed that refined *Allanblackia* oil meets international quality standards for edible vegetable oils and complies with EU contaminant limits [11]. This regulatory endorsement facilitated entry into European markets and stimulated initiatives aimed at promoting sustainable production, biodiversity conservation, and livelihood enhancement [12]-[14].

Several studies have reported on the phytochemistry, fatty acid composition, and functional properties of oils from different *Allanblackia* species [5] [8] [9] [15]-[19]. However, important gaps remain in the existing literature. First, most studies employed solvent-based extraction techniques, particularly Soxhlet extrac-

tion, which do not reflect the manual screw-press methods predominantly used by farmers and small-scale processors in producing *Allanblackia* oil for domestic and commercial purposes. Second, previous research has largely treated *Allanblackia* oil as a uniform product, with limited attention to tree-to-tree variability or the potential influence of ecological and morphological factors on oil stability. Third, despite the relevance of oxidative stability indices to shelf life, safety, and industrial applicability, oil stability properties have received comparatively less systematic investigation across diverse production environments.

Moreover, although genetic, ecological, and reproductive studies have demonstrated substantial variability among *Allanblackia* trees [8] [20]. The extent to which this variability translates into differences in oil stability characteristics remains poorly understood. In particular, the relative influence of tree morphology, geographic location, ecological zone, and associated soil conditions on oil stability has not been comprehensively evaluated under extraction conditions that mirror local processing practices.

Against this background, the present study investigated the relative influence of location and tree morphology on the stability properties of manually expressed seed and kernel oils of *Allanblackia parviflora* across its principal ecological zones in Ghana. By comparing key oil stability indices of seed and kernel oils obtained using a manual screw press and examining their relationships with tree morphological attributes, community location, and ecological zone, this study provides empirical evidence on the factors governing oil quality consistency. The findings demonstrate that while considerable tree-to-tree variation exists, oil stability properties are largely independent of tree morphology and geographic location, suggesting a high degree of inherent stability in *A. parviflora* oil. These results have important implications for quality assurance, large-scale sourcing, and commercialisation, and they support the suitability of *A. parviflora* oil for expanded industrial and food applications without the need for location- or morphology-specific segregation.

2. Materials and Methods

The study was conducted across the three ecological zones that define the natural distribution of *A. parviflora* in Ghana: the semi-deciduous forest (SD), moist evergreen forest (ME), and wet evergreen forest (W) zones, which differ primarily in annual rainfall regimes. A total of 157 mature and healthy trees were sampled from 16 communities distributed across these zones, with sampling intensity proportional to zone size.

Tree selection and fruit harvesting were carried out between December 2014 and April 2015. Trees were georeferenced using GPS and selected based on health status, maturity (DBH ≥ 10 cm), and spatial independence (≥ 100 m apart). Recently fallen, mature fruits were collected, fermented briefly to facilitate seed extraction, and processed for morphological assessment.

Tree, fruit, and seed morphological traits, including tree height, DBH, fruit size

and mass, seed dimensions, kernel-to-shell proportions, and shell thickness, were measured using standard field and laboratory techniques. Mean values per tree were computed from replicated measurements.

Oil extraction was carried out using a manual screw press to reflect local and small-scale commercial practices. For each tree, both kernel and whole-seed oils were extracted following controlled pretreatment, milling, and heating protocols. Oil yield was expressed as the percentage of oil recovered relative to sample mass. In total, 314 oil samples (kernel and seed oils from 157 trees) were obtained.

Extracted oils were stored under ambient conditions and analysed for stability-related parameters. Free fatty acid content and peroxide values were determined using standard analytical methods. All measurements were used to assess the relative influence of ecological location and tree morphology on oil stability properties.

2.1. Reagents and Solvents

All chemicals and solvents were analytical reagents (AR), unless otherwise stated. Sodium hydroxide (97%) was obtained from Emsure, Australia; sodium thiosulphate (99.9%) from Merck; potassium iodide (99.9%) from PubChem; glacial acetic acid (80%) from Chem-Supply; ethanol (96%) from Univar, Australia.

2.2. Peroxide Value

Five (5.0) g of the stored oil/fat was weighed into 250 mL flasks with a glass stopper. Thirty (30.0) mL of 3:2 glacial acetic acid-chloroform solution was added and swirled to dissolve the sample. Saturated KI solution (0.5 mL) was added, and the solution was allowed to stand with occasional shaking for exactly 1 min, after which 30 mL of distilled water was immediately added. It was then titrated with 0.10 N sodium thiosulphate, by adding it gradually and with constant agitation. The titration continued until the yellow iodine colour almost disappeared. Starch indicator solution (0.5 mL) was then added, and the titration continued with agitation until the blue colour just disappeared. A blank was also performed at the same time. The peroxide value was calculated using the formula below [21].

$$\text{Peroxide Value (meq/kg)} = \frac{(V - V_0) \times N \times 1000}{W} \quad (1)$$

where,

N = Normality of sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) solution (eq/L).

V = Volume of sodium thiosulfate solution ($\text{Na}_2\text{S}_2\text{O}_3$) used for titration of the sample (mL).

V_0 = Volume of sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) used for the blank (mL).

W = Weight of oil sample (g).

1000 = Conversion factor from grams to kilograms.

2.3. Free Fatty Acids

The fat was melted at 50°C, mixed, and 1.4 g of it was weighed into a flask to which

fifteen (15) mL of hot neutralised alcohol and 0.4 mL of phenolphthalein indicator were then added. The content was titrated with 0.10 N NaOH and shaken vigorously until the appearance of the first pink colour (regarded as permanent if it persisted for 30 sec) of the same intensity as that of the neutralised alcohol before the addition of the sample. The free fatty acid value (FFA) was calculated (as oleic acid) using the formula below [21].

$$\%FFA(\text{asoleic acid}) = \frac{V \times N \times 28.2}{W} \quad (2)$$

where,

V = Volume of standard alkali (NaOH) used for titration (mL).

N = Normality of the alkali solution.

W = Weight of oil or fat sample (g).

28.2 = Conversion factor derived from the molecular weight of oleic acid (282) divided by 10.

3. Statistical Analysis

Locational variability in kernel and seed oil chemical characteristics was assessed at two spatial scales, community and individual tree, following the approach of [10]. Descriptive statistics were computed using untransformed data, after which normality was assessed and transformations applied where necessary. Relationships between oil stability parameters and explanatory variables, including tree and fruit morphology, ecological zone, soil properties, and oil yield, were examined using correlation analysis. To minimise multicollinearity, highly correlated variables were screened and redundant variables excluded.

Differences between kernel and seed oils were evaluated using independent t -tests. Variation in oil chemical properties across communities was analysed using one-way analysis of variance (ANOVA), with both within- and between-community effects tested. Where significant differences were detected, Tukey's Honestly Significant Difference (HSD) post hoc test was applied to identify pairwise differences among group means while controlling for family-wise Type I error. All statistical analyses were performed using SPSS (version 23), with significance evaluated at $p < 0.05$.

4. Results and Discussion

4.1. Physical Characteristics of *Allanblackia parviflora* Oil

The physical properties of fats and oils affect the function of lipids in foods and their processing. They can be used for assessing the purity and quality of lipids with desired characteristics (Nichols & Sanderson, 2003). Kernel (dehulled seeds) and seed (entire seeds with seed coat) oils were liquid during pressing with heat application but solidified at room temperature. In their liquid state, both oils are golden, with the kernel oil lighter in colour. Both oils in their solid state are white.

4.2. Oil Stability Properties of *Allanblackia parviflora*

4.2.1. Free fatty Acid

The Codex Alimentarius Commission has established an international scale or standard for edible fats and oils that must be achieved before they are permitted on the international market. One criterion is the concentration of free fatty acids, expressed as %FFA, as it provides an estimate of the extent of alteration of triglyceride in oils [9]. The permissible limit of free fatty acid in refined and virgin vegetable oils according to the Codex Alimentarius Commission (CODEX STAN 210-1999) is $\leq 0.3\%$ for refined and $\leq 2.0\%$ for virgin edible vegetable oils [22].

In this study, the percentage kernel oil free fatty acid (KOFFA) and seed oil free fatty acid (SOFFA) ranged between 0.12% - 0.50% with a mean of 0.37% and 0.12% - 0.69% with a mean of 0.53%, respectively, across all 157 trees sampled (see **Table 1**). Although this study did not consider chemically refining our kernel and seed oils, some trees had excellent %FFA, which allows the kernel and seed oils from those trees to be used without going through any refining processes. In all, 37 trees had kernel oil %FFA $\leq 0.3\%$ and were within the permissible limit recommended by Codex Alimentarius for refined edible oils, while 120 trees had kernel oil %FFA above 0.3% but far below 2.0%. Concerning seed oil %FFA, 10 trees had their seed oil %FFA $\leq 0.3\%$, and 147 trees had seed oil %FFA above 0.3% but below 2.0%. There was a significant ($r = 0.830$, $p = 0.000$) difference between the KOFFA and SOFFA.

Previous studies by Noumi *et al.* [9] on a different species of *Allanblackia* (*A. floribunda*), the best fruits for seed extraction as part of the process of sample preparation. Although Noumi *et al.* [9] study collected the best fruits, but how long the fruits had been under the trees was not accounted for. Our present study extracted seeds from fruits already fallen from the trees but were kept enhancing maceration. The differences between %KOFFA and %SOFFA may be attributed to properties of the hulls/husks (brewing conditions), which may have resulted in relatively higher %SOFFA. Based on our findings, dehulling or removal of the seed coat is preferred over using entire seeds, because kernel oils had lower free fatty acid content compared to seed oils. To determine the cause of the differences in %KOFFA and %SOFFA, further studies need to be carried out and should focus on investigating the conditions of harvested fruits' pulps before seed extraction and their impact on the free fatty acid content.

The mean %FFA for trees within communities are presented in **Table 1**. Three communities (SD-AA, SD-F and SD-NE) had their mean %KOFFA within the Codex Alimentarius permissible limit for refined oils ($\leq 0.3\%$). The KOFFA results from these three communities, and in particular, the results reported for SD-NE are consistent with the %FFA concentration reported by Sefah *et al.* (2010) for a bulked *Allanblackia parviflora* kernel oil sample (0.25%) collected from the SD-NE community. These three communities are within the moist semi-deciduous forest zone with relatively low rainfall. A previous report by Noumi *et al.* [9] also reported *Allanblackia floribunda* to have a free fatty acid of $\leq 0.3\%$ limit imposed

by Codex. Again, this was a bulk sample from Cameroon. The current work, which presents a comprehensive analysis of individual trees across 16 communities and three ecological zones, provides a clearer picture of the variation in %FFA.

None of the communities' mean seed oil %FFA was below or equal to 0.3%. The highest mean (0.61%) SOFFA was recorded in the community ME-SB and differed significantly between SD-NE (0.42%) and SD-AA (0.43%) communities, which recorded low mean SOFFA. The tree-to-tree variation (expressed as standard deviation) for both kernel and seed are high, particularly for communities SD-AA, SD-AK, SD-AN, SD-AT, SD-F, and SD-NE in the moist semi-deciduous forest zone. The SD-AA community, which recorded the lowest KOFFA, was significantly different from communities SD-AF ($p = 0.044$), ME-S ($p = 0.035$) and ME-SB ($p = 0.007$). KOFFA differed significantly between ecological zones. Significant difference was observed between SD and ME ($p = 0.022$), while SOFFA in the SD ecological zone differed significantly from ME ($p = 0.022$) and W ($p = 0.014$) ecological zones. In the various ecological zones, there were proportionately more trees that had kernel oil free fatty acid contents $\leq 0.3\%$ in the SD zone (25 trees) compared to ME (6 trees) and W (6 trees) ecological zones. A similar trend was observed for %SOFFA, with 8 trees in the SD ecological zone compared to ME and W ecological zones, with 1 tree each falling within the limit. Although no literature has been cited concerning the effect of climatic conditions on FFA of *Allanblackia* oils, based on this work, it appears that *A. parviflora* trees located in the SD ecological zones (relatively low rainfall areas) produce oils with lower oil free fatty acid content compared to other trees in ME and W (relatively high rainfall areas). In comparing our findings with other oilseed crops, a study conducted on olive seeds from different locations in Tunisia indicated that olives grown in the three different locations, characterised by their temperature and rainfall, showed slight differences in free fatty acid contents [23].

For the relationship between KOFFA, SOFFA and climatic, morphological, and soil parameters, there was only one significant (but negative) correlation ($r = -0.206$, $p = 0.010$) between SOFFA and altitude (and no such correlation was observed for KOFFA).

Data on free fatty acid content of vegetable oils and their relationships with tree size (DBH) and age are difficult to come by. However, both %KOFFA and %SOFFA were found to be tree age related, and this is demonstrated in significant positive correlations between their %FFA in relation to both tree age and DBH. Afoakwa & Sakyi-Dawson [24] work on palm oil showed a significant difference between free fatty acid and the ages of oil palm trees, where mature trees (15 - 20 years) seemed to have lower oil FFA than younger trees (5 - 10 years). Previous study on oil palm tree indicated that free fatty acid (FFA) content of oil in a fresh ripe, unbruised fruit is below 0.3%. However, as fruits ripen, the exocarp becomes susceptible to lipolytic enzyme attack, especially at the base of the palm fruit. The enzymic attack results in an increase in the FFA of the oil through hydrolysis. The variation in the composition and quality of the oil depends on the extent of dete-

rioration or damage caused to the fruits (seeds) due to other factors. Field factors that affect the composition and final quality of palm oil are genetic, age of the tree, agronomic, environmental, harvesting technique, handling and transport [25]. It is possible that the same effect is found in *A. parviflora* fruits, and that this study collected fruits of varying ripeness or seed conditions, hence the high rates of variability described.

There were no significant correlations between the following quality parameters: KOFFA and KOY; SOFFA and KOY; SOFFA and SOY, except KOFFA and SOY, which showed a significant negative correlation ($r = -0.164$, $p = 0.040$). No significant correlations were observed between KOFFA, SOFFA and other morphological characteristics of the trees, nor between KOFFA, SOFFA and soil properties.

By Codex Alimentarius Commission definition, the vegetable oils generated by our extraction method, which involved pressing with heat, are classed as virgin oils. All 157 samples analysed met this 2% criterion; the oils (either sourced from kernel and seed) are considered suitable for consumption and use in the food industry due to their low %FFA. Some kernel and seed oils from individual trees had their free fatty acid content equal to or below 0.3%. This property puts the oils in a category of quality vegetable oil that needs no chemical refining before its application in the food industry. The total number of trees included in these categories of low oil FFA were 37 for KOFFA and 10 for SOFFA. Out of the 37 trees with low %KOFFA, 25 came from the SD ecological zone and 6 each from the ME and W ecological zones. Regarding %SOFFA, 8 trees of low %SOFFA came from the SD area and 1 each from the remaining ecological zones. These findings suggest that the moist semi-deciduous forest zone (SD) with lower rainfall compared to the moist (ME) and wet (W) evergreen forest zones support low %FFA of *Allanblackia* oil.

Table 1. Percentage kernel oil and seed oil ranges and mean free fatty acids of *Allanblackia parviflora* in different communities. The communities are grouped according to their ecological zones (Std. Dev. = Standard deviation).

| Community (Code) | Oil chemical property | | | |
|-------------------------|---------------------------|---|-------------------------|---|
| | Kernel oil tree range (%) | Mean kernel oil free fatty acid (%) \pm Std. Dev. | Seed oil tree range (%) | Mean seed oil free fatty acid (%) \pm Std. Dev. |
| Adansi Akrofuom (SD-AA) | 0.12 - 0.47 | 0.29 \pm 0.14 | 0.12 - 0.62 | 0.43 \pm 0.16 |
| Afosu (SD-AF) | 0.36 - 0.48 | 0.42 \pm 0.03 | 0.52 - 0.57 | 0.55 \pm 0.02 |
| Akoase (SD-AK) | 0.20 - 0.50 | 0.36 \pm 0.10 | 0.20 - 0.60 | 0.47 \pm 0.15 |
| Anwona (SD-AN) | 0.12 - 0.48 | 0.36 \pm 0.13 | 0.12 - 0.59 | 0.49 \pm 0.16 |
| Atwereboana (SD-AT) | 0.20 - 0.43 | 0.36 \pm 0.08 | 0.39 - 0.58 | 0.51 \pm 0.05 |
| Fenaso (SD-F) | 0.20 - 0.41 | 0.30 \pm 0.09 | 0.40 - 0.63 | 0.48 \pm 0.09 |
| New Edubease (SD-NE) | 0.19 - 0.40 | 0.31 \pm 0.10 | 0.20 - 0.59 | 0.42 \pm 0.14 |
| Wassa Akropong (SD-WA) | 0.34 - 0.44 | 0.40 \pm 0.04 | 0.51 - 0.64 | 0.60 \pm 0.05 |

Continued

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|-----------------------|-------------|-------------|-------------|-------------|
| Benso (ME-B) | 0.20 - 0.43 | 0.36 ± 0.09 | 0.40 - 0.68 | 0.60 ± 0.09 |
| Daboase (ME-D) | 0.12 - 0.45 | 0.36 ± 0.11 | 0.25 - 0.65 | 0.49 ± 0.12 |
| Samreboi (ME-S) | 0.38 - 0.48 | 0.43 ± 0.03 | 0.53 - 0.69 | 0.60 ± 0.05 |
| Sefwi Bodi (ME-SB) | 0.40 - 0.48 | 0.46 ± 0.02 | 0.54 - 0.67 | 0.61 ± 0.04 |
| Asonti (W-AS) | 0.20 - 0.42 | 0.34 ± 0.10 | 0.45 - 0.63 | 0.49 ± 0.11 |
| Banso (W-BA) | 0.32 - 0.45 | 0.40 ± 0.04 | 0.43 - 0.63 | 0.55 ± 0.06 |
| Kwansima (W-KS) | 0.20 - 0.46 | 0.39 ± 0.07 | 0.35 - 0.69 | 0.60 ± 0.10 |
| Nzema Akropong (W-NA) | 0.38 - 0.46 | 0.42 ± 0.03 | 0.48 - 0.69 | 0.60 ± 0.07 |
| All Trees (n = 157) | 0.12 - 0.50 | 0.37 ± 0.09 | 0.12 - 0.69 | 0.53 ± 0.12 |

Codex Alimentarius Commission, 2009 Standard: Refined oils: %FFA ≤ 0.3% (as oleic acid). Virgin oils: %FFA ≤ 2.0% (as oleic acid) (CAC, 2009).

4.2.2. Peroxide Value

The usefulness of a particular fat or oil in the food, cosmetic and pharmaceutical industry is ultimately determined by its peroxide value [26]. Peroxide value (PV) is used to determine the stability of fats and oils. A peroxide value greater than zero suggests the beginning of the oxidation process, which is associated with the development of rancidity in oils and fats.

Kernel and seed oil peroxide values (PV) from this study are presented in **Table 2**. The percentage kernel oil peroxide value (KOPV) ranged from 1.59 to 4.00 meq/kg for all 157 samples, with a mean of 2.11 meq/kg. Seed oil peroxide values (SOPV) ranged from 2.00 to 6.00 meq/kg, with a mean of 3.84 meq/kg. The peroxide values (PV) for both kernel and seed oils for all the individual trees sampled were lower than the 10.0 meq/kg value recommended by Codex Alimentarius for refined edible fats and oils [22]; both oils do not need to go through refining processes. The low PVs make *A. parviflora* more stable and resistant to lipid oxidation. Fats and oils with this property are less susceptible to rancidity and are therefore suitable in both food and non-food industries. The mean KOPV (2.11 meq/kg) and SOPV (3.84 meq/kg) obtained for all trees sampled for this study were also consistent with values obtained in previous research on kernel oil PV (3.0 meq/kg) reported by Sefah *et al.* [27] for a bulked *A. parviflora* kernel oil from one community in Ghana.

Similar to %FFA, seed oil PV was higher and varied significantly ($r = 0.393$, $p = 0.000$) from kernel oil PV. The dehulling of seeds has been recommended for some oils to reduce the PV, as high peroxide values lead to the development of off flavours (rancidity) in oils [28]. Dehulling is not necessary for *A. parviflora* as the PV for seeds is well below 10.

Peroxide values of kernel and seed oils were analysed for differences between trees, communities, and ecological zones. As shown in **Table 2**, there was little tree to tree differences in communities SD-AF, SD-AN, SD-F, ME-B, ME-S, W-

BA, W-KS, W-NA and ME-D regarding kernel oil PV. The least standard deviation (0.00) recorded suggests that trees in the ME-D community were less variable. Community ME-SB had the highest mean KOPV (3.64 meq/kg) and differed significantly from some communities. Trees in other communities also showed some level of variation in their KOPV. There were no significant differences between KOPV and ecological zones.

Regarding SOPV, tree-to-tree differences were higher than KOPV in the communities. Community ME-SB was less variable (std. dev., ± 0.01) and differed significantly from some communities. Similar to KOPV, community ME-SB recorded the highest mean SOPV (5.19 meq/kg). There was considerable variation between communities. The communities within the SD ecological zone were more variable than those in the ME and W ecological zones. There was no significant variation between ecological zones regarding KOPV ($r = -0.148$, $p = 0.064$) and SOPV ($r = -0.071$, $p = 0.380$). Similar findings were reported by Arslan *et al.* [29] in their work, which studied the variation in the quality characteristics of olive oil as induced by growing conditions (characterised by altitude, temperature, and rainfall). From their study, there was no significant relationship between the peroxide values of the olive oil samples and their different locations.

The number of seeds per fruit (S#), seed width (SW) and fruit shape (FL/FW) had significant correlation with KOPV. Meanwhile, there was no correlation between KOPV and tree characteristics (tree age, DBH, Frtwt, FrtPwt, SL, SL/SW, ShT, and Shwt). Although there were significant correlations between tree age and TDBH with respect to SOPV, no similar correlation was observed between tree ages and TDBH regarding KOPV. A study by Afoakwa & Sakyi-Dawson [24] on palm oil suggested that older oil palm trees (15 - 20 years) had higher oil PV values than palm trees younger than 10 years old. In our study, the evidence of an SOPV relationship with tree age suggests that there is something in the shell that accumulates with age and elevates PV; this needs to be investigated. Apart from TDBH, no tree morphological characteristics showed a significant correlation with SOPV. Like KOPV, there was no significant correlation ($p > 0.05$) between KOY, SOY and SOPV, but significant differences were observed between altitude and SOPV.

Among the soil properties considered (pH, N, P, K, clay and silt), significant correlations were observed between K ($r = 0.209$, $p = 0.009$) and % silt ($r = -0.244$, $p = 0.002$) regarding KOPV and between silt and SOPV ($r = -0.160$, $p = 0.045$).

4.3. Variation and Correlates of Kernel and Seed Oil Stability Properties

The chemical properties considered in the multivariate and correlation analyses were limited to oil stability indices, namely free fatty acids (FFA) and peroxide values (PV), for both kernel oil (KO) and seed oil (SO). Principal component analysis (PCA) was used to explore the combined influence of ecological zone, tree habitat, and kernel oil yield (KOY) categories on these stability parameters.

Table 2. Kernel oil and seed oil ranges and mean peroxide values (PV) of *Allanblackia parviflora* in different communities. The communities are grouped according to their ecological zones (Std. Dev. = Standard deviation).

| Community (Code) | Oil chemical property | | | |
|-------------------------|------------------------------------|---|----------------------------------|---|
| | Kernel oil tree range (meq/kg oil) | Mean kernel oil PV (meq/kg oil) \pm Std. Dev. | Seed oil tree range (meq/kg-oil) | Mean seed oil PV (meq/kg oil) \pm Std. Dev. |
| Adansi Akrofuom (SD-AA) | 1.60 - 4.00 | 2.16 \pm 0.66 | 3.19 - 5.20 | 3.76 \pm 0.83 |
| Afosu (SD-AF) | 1.59 - 2.40 | 1.84 \pm 0.28 | 2.39 - 4.00 | 3.43 \pm 0.76 |
| Akoase (SD-AK) | 1.59 - 3.20 | 2.24 \pm 0.69 | 3.20 - 5.20 | 4.15 \pm 0.60 |
| Anwona (SD-AN) | 1.59 - 2.00 | 1.72 \pm 0.20 | 2.40 - 4.00 | 3.60 \pm 0.56 |
| Atwereboana (SD-AT) | 1.99 - 4.00 | 2.76 \pm 0.85 | 2.00 - 6.00 | 4.27 \pm 1.17 |
| Fenaso (SD-F) | 1.59 - 2.39 | 1.84 \pm 0.30 | 3.19 - 4.00 | 3.59 \pm 0.42 |
| New Edubease (SD-NE) | 1.99 - 4.00 | 2.71 \pm 0.96 | 3.97 - 5.20 | 4.59 \pm 0.63 |
| Wassa Akropong (SD-WA) | 1.60 - 2.40 | 2.00 \pm 0.38 | 2.40 - 5.20 | 3.83 \pm 0.89 |
| Benso (ME-B) | 1.59 - 2.00 | 1.72 \pm 0.19 | 2.39 - 4.00 | 3.03 \pm 0.73 |
| Daboase (ME-D) | 1.59 - 1.60 | 1.60 \pm 0.00 | 2.39 - 4.00 | 3.60 \pm 0.68 |
| Samreboi (ME-S) | 1.60 - 2.40 | 1.76 \pm 0.34 | 2.39 - 4.00 | 3.43 \pm 0.76 |
| Sefwi Bodi (ME-SB) | 1.99 - 4.00 | 3.64 \pm 0.67 | 5.16 - 5.20 | 5.19 \pm 0.01 |
| Asonti (W-AS) | 1.60 - 4.00 | 2.68 \pm 0.94 | 3.20 - 5.20 | 4.19 \pm 0.76 |
| Banso (W-BA) | 1.59 - 2.00 | 1.72 \pm 0.20 | 2.40 - 4.00 | 3.59 \pm 0.56 |
| Kwansima (W-KS) | 1.59 - 2.00 | 1.68 \pm 0.17 | 3.19 - 4.00 | 3.67 \pm 0.41 |
| Nzema Akropong (W-NA) | 1.59 - 2.00 | 1.64 \pm 0.14 | 3.17 - 4.00 | 3.37 \pm 0.35 |
| All Trees (n = 157) | 1.59 - 4.00 | 2.11 \pm 0.75 | 2.00 - 6.00 | 3.84 \pm 0.83 |

Codex Alimentarius Commission, 2009 Standard: Refined oils: ≤ 10 meq/kg oil. Virgin oils: ≤ 15 meq/kg oil (CAC, 2009).

For kernel oils, the first two principal components accounted for a cumulative variation of 59.8%. The separation observed among trees was largely associated with variations in FFA and PV, rather than clear distinctions based on ecological zones or tree habitat variables. Although some clustering of trees from the semi-deciduous (SD) and wet evergreen (W) zones was observed, considerable overlap occurred across all zones, indicating weak ecological structuring of kernel oil stability properties. Trees from the SD zone exhibited greater variability, while those from the moist evergreen (ME) zone were more moderately distributed. Generally, the PCA results suggest that kernel oil stability is not strongly influenced by ecological zone or habitat.

Similarly, for seed oils, the first two principal components explained 59.8% of the total variation, with FFA and PV contributing to sample dispersion. However, no distinct grouping or consistent separation of samples by ecological zone, community, or tree habitat was evident. The wide overlap among samples across zones indicates that seed oil stability properties are largely independent of geographic location and environmental conditions within the studied range.

Correlation analysis further supported these observations. Location-related variables, including ecological zone and community, as well as age-related traits such as tree diameter at breast height (DBH) and estimated tree age, showed partial influence on free fatty acid contents of both kernel and seed oils. In contrast, soil characteristics, particularly silty soil fractions and altitude, exerted a significant influence on peroxide values, suggesting that oxidative stability may be more sensitive to site-specific edaphic and topographic conditions than to tree morphology.

Kernel oil yield (KOY) and several morphological and soil parameters, including fruit weight, fruit pulp weight, seed length, seed shape indices, shell proportion, soil pH, nitrogen, phosphorus, and clay content, did not show significant correlations with either FFA or PV. These findings indicate that oil stability properties are largely decoupled from yield-related traits and most morphological attributes.

Substantial tree-to-tree variation in oil stability properties was observed; however, this variation was not systematically associated with ecological zone, tree habitat, or most morphological characteristics. The results are consistent with findings from other tree oil species, such as shea butter and *Madhuca longifolia*, where chemical stability indices showed limited dependence on climatic or geographic factors [30] [31]. Collectively, these results suggest that *Allanblackia parviflora* oil exhibits relatively stable chemical quality across its natural distribution, supporting its suitability for large-scale sourcing and commercial utilisation without the need for location-specific quality segregation (see Table 3).

Table 3. A summary of oil chemical characteristics and significant relationships with location, oil yields, tree morphology and soil properties variation: the correlation coefficient, r and p (in bold parentheses) values are shown.

| | Ecozone | Comm. | Alt. | SOY | T.age | TDBH | FL/FW | S# | SW | ShT | K | Silt |
|-------|-----------------------|------------------------|------------------------|------------------------|------------------------|-----------------------|-----------------------|-----------------------|------------------------|-----|-----------------------|------------------------|
| KOFFA | 0.19 (0.02) | 0.28 (0.00) | - | -0.16 (0.04) | 0.23 (0.00) | 0.22 (0.01) | - | - | - | - | - | - |
| SOFFA | 0.24 (0.00) | 0.34 (0.00) | -0.21 (0.01) | - | 0.27 (0.00) | 0.22 (0.01) | - | - | - | - | - | - |
| KOPV | - | -0.17 (0.04) | 0.23 (0.00) | - | - | - | 0.26 (0.00) | 0.18 (0.03) | -0.21 (0.01) | - | 0.21 (0.01) | -0.24 (0.00) |
| SOPV | - | - | 0.16 (0.05) | - | -0.17 (0.04) | 0.18 (0.02) | - | - | - | - | - | -0.16 (0.05) |

Note: - = No significant, **Ecozone**= ecological zone, **Comm.** = communities, **Alt.** = altitude, **SOY** = seed oil yield, **T.age** = tree age, **TDBH** = tree diameter at breast height, **FL/FW** = fruit length/fruit width, **S#** = number of seeds per fruit, **SW** = seed width, **ShT** = shell thickness and **K** = potassium; **KOFFA** = kernel oil free fatty acid, **SOFFA** = seed oil free fatty acid, **KOPV** = kernel oil peroxide value, **SOPV** = seed oil peroxide value.

5. Conclusion

This study has revealed the physicochemical properties of both kernel and seed oils. The relationships between location, oil yields, tree morphology, soil properties and these oil chemical characteristics were also demonstrated. Although our

extraction method did not involve any chemical refining process, % free fatty acids levels for some tree kernels and seed oils were within the Codex Alimentarius Commission specification limit for refined vegetable oils. All the trees had the kernel and seed oils within the acceptable limit for virgin oils. This property places a premium on the oils and can be applied widely in the food industry without further chemical refining. Both seeds and kernel peroxide values were all below the Codex permissible limits, in industries where peroxide value is the issue of concern; the oil can be used without further refining. Considering the overall means, the fatty acid composition for both seeds and kernel oils sample can safely be used in both food and non-food industries. Generally, the chemical properties of the kernel oils were higher compared to seed oil, particularly FFA and PV, which are also stability/quality determinants of fats/oils. However, more trees were identified having their seed oil fatty acid compositions within the EFSA acceptable limit for refined *Allanblackia* oil compared to the kernel oils.

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Conflicts of Interest

The authors declare no conflicts of interest.

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