



Variations in nutrient composition of oyster nuts (*Telfairia pedata*) across different agro-climatic conditions

Emmanuel Mwakasege, Anna Treydte, Otmar Hoeglinger, Neema Kassim & Edna Makule |

To cite this article: Emmanuel Mwakasege, Anna Treydte, Otmar Hoeglinger, Neema Kassim & Edna Makule | (2021) Variations in nutrient composition of oyster nuts (*Telfairia pedata*) across different agro-climatic conditions, Cogent Food & Agriculture, 7:1, 1913843, DOI: [10.1080/23311932.2021.1913843](https://doi.org/10.1080/23311932.2021.1913843)

To link to this article: <https://doi.org/10.1080/23311932.2021.1913843>



© 2021 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.



Published online: 27 Apr 2021.



Submit your article to this journal [↗](#)



Article views: 34



View related articles [↗](#)



View Crossmark data [↗](#)



Variations in nutrient composition of oyster nuts (*Telfairia pedata*) across different agro-climatic conditions

Emmanuel Mwakasege, Anna Treydte, Otmar Hoeglinger, Neema Kassim and Edna Makule

Cogent Food & Agriculture (2021), 7: 1913843



Received: 22 November 2020
Accepted: 01 April 2021

*Corresponding author: Emmanuel Mwakasege, Department of Food Biotechnology and Nutritional Sciences, School of Life Science and Bio-Engineering, the Nelson Mandela African Institution of Science and Technology (NM-AIST), P.O.Box 447, Arusha, Tanzania
E-mail: mwakasegee@nm-aist.ac.tz

Reviewing editor:
Manuel Tejada Moral, University of Seville, Seville Spain

Additional information is available at the end of the article

FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Variations in nutrient composition of oyster nuts (*Telfairia pedata*) across different agro-climatic conditions

Emmanuel Mwakasege^{1,2*}, Anna Treydte^{3,4}, Otmar Hoeglinger⁵, Neema Kassim¹ and Edna Makule¹

Abstract: In sub-Saharan Africa, nutrient deficiency remains a challenge. The challenge is partly due to the underutilization of available local nutrient sources and failure to optimize nutrients based on agro-climatic conditions. This study investigated the nutrient composition and variations in the underutilized oyster nuts (*Telfairia pedata*) from different sites and elevation levels encompassing different agro-climatic conditions. Fats were the most abundant contents of the nuts with 68%, followed by 25% protein, 5% carbohydrates, and 2% ash. Fatty acid contents were dominated by linoleic acid (47%), while magnesium was 150 mg/100 g, the most abundant mineral element. Protein and fat contents increased significantly with declining elevations, while sites did not show any significant effects, except for oleic acids. These were higher in Tanga compared to Kilimanjaro and Arusha sites. In contrast, linoleic acids and minerals such as magnesium (Mg) and phosphorus (P) decreased significantly in low elevations. Other nutrients such as carbohydrates, potassium (K), calcium (Ca), iron (Fe), palmitic acid, and stearic acid were not significantly affected by site nor elevations. Our results highlight that, particularly in lower elevations associated with high temperature and high precipitation, oyster nuts' quality is optimized and can contribute to reducing micronutrient deficiency and improve local communities' nutritional status in sub-Saharan Africa.

ABOUT THE AUTHORS

Emmanuel Mwakasege; is a researcher at the Nelson Mandela African Institution of Science and Technology, Food Biotechnology, and Nutrition Sciences.

Anna Treydte; a professor at the Nelson Mandela African Institution of Science and Technology, Department of Sustainable Agriculture, Biodiversity Conservation and Ecosystems Management.

Otmar Hoeglinger; a biochemistry professor at the University of Applied Sciences, upper Austria.

Neema Kassim; Senior lecturer at Nelson Mandela African Institution of Science and Technology.

Edna Makule; Senior lecturer at Nelson Mandela African Institution of Science and Technology, School of Life Science and Bio-Engineering.

PUBLIC INTEREST STATEMENT

Oyster nuts (*Telfairia pedata*) are underutilized oilseeds with potential food and industrial applications. These nuts form an important part of traditional and heritage food in sub-Saharan Africa where they are regarded as highly nutritious. For generations, the nuts have been consumed by pregnant and lactating mothers due to their lactogenic properties. The nuts have a similar taste to almond and are consumed while fresh, roasted, or added as thickeners in soup dishes. The oil has been used in soap making and the cosmetic industry. Due to their resistance to drought, low input requirement, and high yield, these nuts have the potential to alleviate existing nutritional deficiency in sub-Saharan Africa. Therefore, this research will enhance the nutritional information database and enable optimization of the nutrient quality of these nuts.

Subjects: Agriculture and Food; Biochemistry; Food Chemistry; Carbohydrates; Food Analysis; Lipids; Nutrition; Equality & Human Rights; Gender & Sexuality; Language & Linguistics

Keywords: fatty acids; minerals; protein; geographical location; under-utilized; nutrient analysis

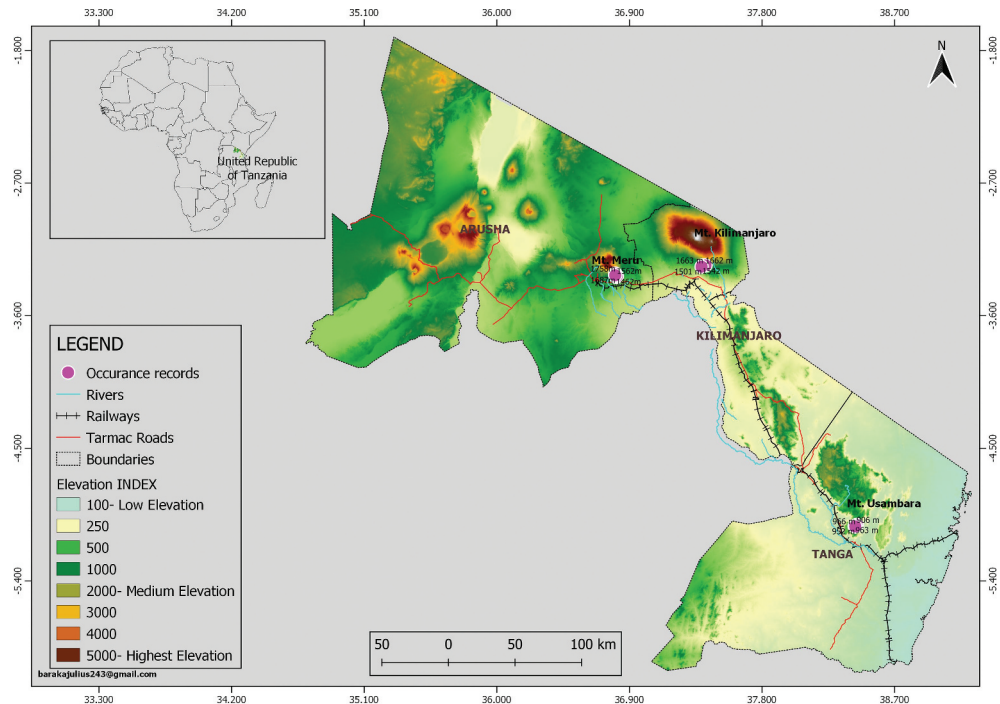
1. Introduction

Nutrient deficiency in sub-Saharan Africa remains a challenge despite local and international institutions' efforts (Bain et al., 2013; Ecker et al., 2010). Although nutrient-rich sources are available, utilization, and nutrient optimization in different climatic conditions is still a challenge (Mbwana et al., 2017). Oyster nuts (*Telfairia pedata* Hook) is one of the under-utilized oilseed plants of the family Cucurbitaceae in sub-Saharan Africa (Ajayi & Dullou, 2015; Asiegbu, 1987). These nuts are grown for their valuable edible nuts, which are consumed fresh, roasted, ground, or added as thickeners in vegetables, soups, or meat dishes (Ajayi & Dullou, 2015; Musalima et al., 2019). The flour made from oyster nut seeds is supplemented in baked products, while its pressed oil is locally used for cooking by local communities (Kazadi et al., 2015; Okoli, Bosa & Nyananyo, 1988). Its vines are drought resistant, have low cultivation input requirements, and high yield per area (Agatemor, 2006; Ajayi & Dullou, 2015; Garrity, 2004; Musila, 2018). Additionally, due to their lactogenic and medicinal properties, the oyster nut is used by local pregnant and lactating mothers to increase milk production and fast healing (Kazadi et al., 2015). Despite these benefits, these nuts' nutritional composition has not been adequately quantified, limiting their utilization and contribution to health among rural communities (Musila, 2018).

Moreover, oilseeds are affected by internal and external factors that result in variations in their nutrient compositions (Ayerza & Coates, 2011; D'Imperio et al., 2007; Vollmann et al., 2007). Under constant agro-ecological conditions, different cultivars show variations in nutrient contents, seed size, weight, and agricultural performances (Borges et al., 2007; Vollmann et al., 2007). Likewise, farming practices and agro-climatic conditions such as temperature, rainfall, precipitations, and geographical sites affect plants' physiological reactions, causing variations in nutrient compositions (D'Imperio et al., 2007; Romero et al., 2016). Due to existing differences in soil composition and agro-climatic conditions in different geographical sites used for cultivation, the same oilseeds cultivars were reported to contain nutrients in different proportions (Borges et al., 2007; D'Imperio et al., 2007; Romero et al., 2016). Additionally, Oyster nuts are mostly grown in agroforests of high hills and mountains at 800 to 2,000 masl elevation ranges (Ajayi & Dullou, 2015; Okoli, 2007). These differences in elevation range cause variations in temperature and precipitations. D'Imperio et al. (2007) and Hemp (2006) reported a decline of temperature with a lapse rate of 0.56°C and 1°C for every 100 m upwards while the precipitations rates were also decreasing from low to high elevation levels. As a result, deviations in temperature and precipitations might affect enzymatic kinetics in plants resulting in variations of nutrient contents such as linoleic acid, oleic acid, protein, and fat saturation in oilseeds (N. G. Izquierdo et al., 2006). Therefore, there is a need to identify and characterize agro-climatic conditions for the production of high-quality nutrient sources.

This study evaluated and quantified the nutrient contents and potential of oyster nuts as the under-utilized source of nutrients. We also assessed the variations in oyster nuts' nutrient contents from different sites and elevation levels to highlight the effects of agro-climatic conditions on nutrient contents. We hypothesized that (a) nutrient contents in oyster nuts will differ across different sites, with oyster nuts grown in the eastern sites with colder temperatures being higher in nutrients than the western sites. We further expected that (b) nutrient contents in oyster nuts will increase in higher elevations, where cooler temperatures and higher precipitations are experienced. Our study highlights oyster nuts' nutritious potential

Figure 1. Map showing study sites in three regions of Arusha (agro-forests of mount Meru), Kilimanjaro (agro-forests of Mount Kilimanjaro), and Tanga (agro-forests of Usambara mountains) in northern Tanzania.



when grown under optimal environmental conditions which can improve local communities' diet and health.

2. Materials and methods

2.1. Study sites

We conducted the study in northern Tanzania, where oyster nuts are mostly grown (Figure 1). We purposefully selected three oyster nut growing sites (Kilimanjaro, Tanga, and Arusha). In Kilimanjaro, samples were collected along agroforests of Mount Kilimanjaro located at 3.0674° S, 37.3556° E from 800 up to 2000 masl. In Tanga, samples were collected along agroforests of the Usambara Mountains located 4.7500° S, 38.5000° E, from 900 up to 2000 masl. Arusha region, samples were collected along edges of agroforests of mount Meru found 3.2393° S, 36.7627° E, from 900 to 2000 masl. These sites were selected along mountain edges from bottom to top because they span different elevations (masl) associated with variations in climatic factors such as temperature and precipitation regimes (Hemp, 2006).

2.2. Sample collection

We collected oyster nut samples in May, June, and July 2019, during harvest season in the sites. Only naturally grown *Telfairia pedata* species were used in this study to prevent nutrient variations due to differences in species or farming practices. At each site, growing areas were allocated into three fields based on elevational ranges categorized into "low elevation" (800–1,200 masl), "medium–elevation" (1,200–1,600 masl), and "high elevation" (1,600–2,000 masl). Six samples were collected from each site (Table 1). Samples were cleaned, sun-dried as described by Musalima et al. (2019), and transported to the University of Applied Sciences, Wels, Upper Austria, for analysis.

Table 1. Description of collection sites and their environmental conditions (i.e., average annual temperature range, average annual rainfall range, and elevational gradient) in the year 2019, in northern Tanzania

Region	# samples	Environmental conditions		
		Temperature (°C)	Rainfall (mm)	Elevation (masl)
Arusha	6	17–20	800–1,200	900–1,600
Kilimanjaro	6	21–27	800–2,300	800–2,400
Tanga	6	30–32	1,100–1,400	700–1,200

Source: TMA (2018).

2.3. Chemical analyses

2.3.1. Proximate analyses

Oysternut samples were prepared from individual plants by removing the fibrous outer shell and splitting the inner shell to obtain the kernels (Figure 2). Each sample was ground to flour using a blender and stored at 4°C before analysis (Nielsen, 2014). Moisture contents were analyzed according to Yerlikaya et al. (2012) by subjecting the samples in a hot-air oven at 105°C over the night. Ash contents were analyzed by burning the samples in a muffle furnace at 500°C for 8 hours (Nielsen, 2014). Crude fat was determined by using petroleum ether in a soxhlet apparatus extraction, according to the AOAC (1990) method (no 934.50). Crude protein was determined by using the Kjeldahl method (AOAC, 1990; no 981.10). Carbohydrates were calculated according to Grosso et al. (2000) as the difference of other contents from 100%. All analyses were done in triplicates.

2.3.2. Mineral analyses

Samples were prepared as described by Saracoglu et al. (2007), and Xie et al. (2013) using the dry ashing digestion procedure with few modifications. All the reagents were prepared from analytical grade chemicals and double-distilled deionized water was employed. All the equipments were washed using 4 mol/l hydrochloric acids and rinsed with deionized water before being used. 2 g of sample material in a porcelain container was burned in a furnace oven set at 500°C for 6 hours. A 5 ml of 4 mol/l hydrochloric acids was added, followed by distilled water and filtered. 1 ml of the

Figure 2. The oyster nut (*Telfairia pedata*) showing (A) closed oyster nut seed, (B) opened shell, (C) fibrous outer shell, (D) inner shell, (E) kernel after being split in half, (F) ground oyster nut kernel.

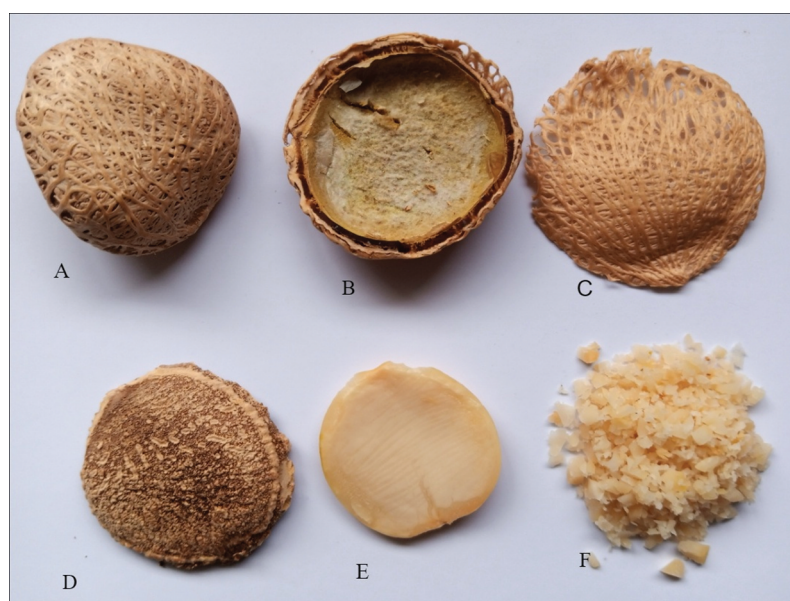
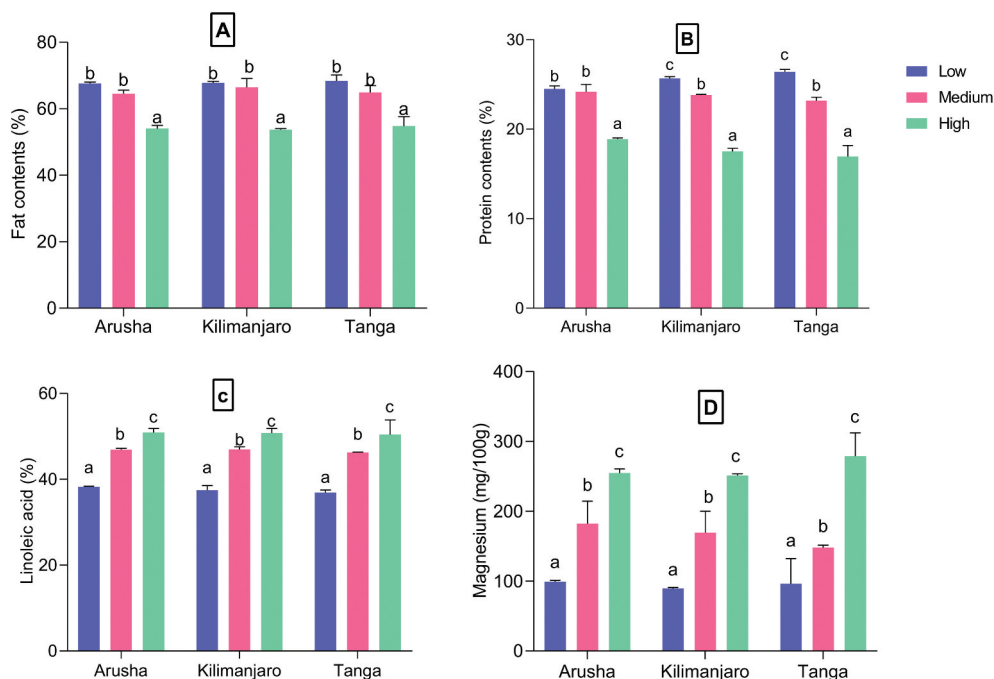


Figure 3. Bar graphs showing average (\pm SD) for variations of nutrient compositions (A) fat, (B) protein, (C) linoleic acid, and (D) magnesium in oyster nuts across different sites and elevation levels collected in northern Tanzania in 2019. Different letters above column groups of three indicate significant difference across elevations. “Low” = low elevation (800–1,200 masl), “medium” = medium elevation (1,200–1,600 masl), and “high” = high elevation (1,600–2,000 masl). N = 18.



sample was added in a tube of 1 ml of 4 mol/l hydrochloric acids and dissolved in 8 ml distilled water to make a 10 ml dilution. The mineral analysis was done using pre-calibrated ICP-OES (model Icap7200 Duo, Thermo Fisher, Waltham, USA), equipped with an auto-sampler (Teledyne ASX-280, Omaha, NE 68,144 USA). We analyzed magnesium (Mg), potassium (K), calcium (Ca), copper (Cu), iron (Fe), zinc (Zn), phosphorus (P), and sodium (Na). All analyses were done in triplicates. For calibration procedures, standard solutions of analytes were prepared by dissolving a stock of 1000 mg/l of all analyzed elements.

2.3.3. Fatty acid analyses

Fatty acid methyl esters (FAME) were prepared as described by Teh and Birch (2013) where 10 mg of dry oyster nut oil sample was methylated and suspended with a 5 ml mixture of acetyl chloride and methanol in the ratio of 1:50. The mixture was left for 4 hours at 60°C. The reaction was stopped by adding 2.5 ml of 0.6 g/ml sodium carbonate. Fatty acid methyl esters were extracted by 2 ml hexane and 1 ml of the upper clear phase transferred to a GC vial. The appropriately diluted hexane extract was inserted in a thermo-trace gas chromatography equipped with an autosampler (AS 2000). The detection was carried out with a flame ionization detector (FID) (Agilent Tech Inc., Wilmington, DE, USA). The chromatographic conditions were composed of an injection volume of 2 μ l, and the injector temperature 240°C. Helium was applied as carrier gas with 120 kPa constant pressure and a flow of 30 ml/min, while the Agilent capillary column DB23 60 m, 0.25 mm ID, and film thickness of 0.25 μ m were used for analytical separation. The oven temperature gradient was set at 0–3 minutes at 130°C, then 6.5°C per minute to 170°C, followed by 2.8°C per minute to 215°C, and then was maintained for 10 minutes. Finally, 3°C per minute to 240°C and maintained for 15 minutes. The FID was set at a temperature of 280°C and an airflow of 450 ml/min with hydrogen flow of 45 ml/min and makeup gas of nitrogen held at 40 ml/min (Gao et al., 2015). Data were analyzed using Chrom card data system version 2.8 from Thermo Finnigan. Each oyster nut oil sample was analyzed in duplicates. For calibration, an external standard method was used where standard solutions with known analyte concentrations and fixed volume were prepared and injected in the column. The calibration plot was prepared and used to determine the concentration of the fatty acids in oyster nut samples.

Table 2. Average (\pm SD) of oyster nut ash, fat, protein, carbohydrate, and energy contents across different sites in northern Tanzania collected in the year 2019

Sites	Ash (%)	Fat (%)	Protein (%)		
Carbohydrates (%)	Energy (kcal)				
Arusha	3.0 \pm 0.1 ^a	63.2 \pm 1.5 ^a	23.1 \pm 1.9 ^a	7.1 \pm 3.6 ^a	690.1 \pm 23.1 ^a
Kilimanjaro	2.8 \pm 0.1 ^a	66.4 \pm 2.6 ^a	22.8 \pm 1.2 ^a	4.8 \pm 3.9 ^a	707.9 \pm 19.2 ^a
Tanga	2.3 \pm 0.3 ^a	68.1 \pm 1.2 ^a	25.3 \pm 1.0 ^a	1.4 \pm 1.6 ^a	719.2 \pm 17.6 ^a

Letter “a” in superscript indicate no significant differences within rows by Turkey’s multiple comparison test at $P=0.05$.

2.4. Statistical analysis

Two-way analysis of variance (ANOVA) was used to compute the effects of elevations, categorized into “low elevation” (800-1,200 masl), “mid-elevation” (1,200–1,600 masl), and “high elevation” (1,600-2,000 masl), the three growing sites, and their interactions on nutrient compositions (proximate, minerals, and fatty acid contents) in oyster nuts (Romero et al., 2016). Data diagnostic tests such as the normality test (using the Shapiro-Wilk normality test) were run before analysis (Angelini, 2018). Post-hoc tests using Turkey’s multiple comparison tests were done to compare means. The criterion for significance was set at $p < 0.05$. All analyses were run using R-software Version 3.3.1

3 Results

3.1. Proximate, minerals, and fatty acid contents of oyster nuts

Descriptive statistics for proximate results for oyster nuts indicated that fat was the most abundant content in oyster nuts, followed by protein, carbohydrates, and ash contents on a dry matter basis (Table 2). Fatty acid content analysis revealed that the polyunsaturated fatty acid (PUFA), made of linoleic acid (C18:2 n-6), was 47% the most abundant component (Table 3). Saturated fatty acids (SFAs) were 43%, mainly composed of palmitic acid and stearic acid (Table 3). Another fatty acid of interest was oleic acid (C18:1 n-9), which constituted low amounts of monounsaturated fatty acids (MUFA). Finally, trace element analysis found that magnesium (Mg) and phosphorus (P) contents were about four times higher than other mineral elements such as potassium (K), Calcium (Ca), and Iron (Fe) (Table 4).

3.2. Variations of nutrient contents across different sites and elevation

There was no significant difference in all proximate contents, including fat ($F_{2, 9} = 3.98, P = 0.072$) and protein contents ($F_{2, 9} = 0.71, P = 0.527$) across sites. Still, there was a slightly higher protein and fat content in the Tanga region than in Kilimanjaro and Arusha (Table 2). Ash and carbohydrates trends were slightly but not significantly higher in Arusha compared to Kilimanjaro and Tanga regions ($F_{2, 9} = 1.72, P = 0.25$ and $F_{2, 9} = 1.34, P = 0.68$, respectively; Table 2).

Furthermore, determination of oil quality across sites showed that oleic acid (C18:1 n-9) was slightly higher in Tanga compared to Kilimanjaro and Arusha ($F_{2, 9} = 5.91, P = 0.035$; Table 3) while linoleic acid (C18:2 n-6) was not significantly different across sites ($F_{2, 9} = 0.47, P = 0.668$). In addition, the most abundant minerals magnesium (Mg) and phosphorus (P) were not significantly different across sites ($F_{2, 9} = 0.16, P = 0.854$ and $F_{2, 9} = 1.54, P = 0.287$, respectively; Table 4)

In contrast, ash, protein, and fat compositions significantly differed across elevations. Both protein ($F_{2, 9} = 69.38, P = 0.001$) and fat ($F_{2, 9} = 24.75, P = 0.002$) contents were significantly lower in higher elevations compared to lower elevation levels while the opposite was true for ash contents ($F_{2, 9} = 28.13, P = 0.001$). Moreover, oil quality based on fatty acid contents differed significantly only for linoleic acid ($F_{2, 9} = 51.31, P < 0.001$) by increasing in high elevation levels

Table 3. Average (\pm SD) of fatty acid contents of oyster nuts across different sites from samples collected in June to August 2019 in northern Tanzania

Fatty acids (%)	Sites		
	Arusha	Kilimanjaro	Tanga
Linoleic acid (C18:2 n-6)	49.8 \pm 2.4 ^a	48.1 \pm 0.5 ^a	45.7 \pm 0.2 ^a
Palmitic acid (C16:0)	32.7 \pm 1.5 ^a	33.5 \pm 0.5 ^a	32.4 \pm 1.3 ^a
Stearic acid (C18:0)	9.8 \pm 1.8 ^a	9.5 \pm 0.6 ^a	11.4 \pm 2.1 ^a
Oleic acid (C18:1 n-9)	7.6 \pm 1.1 ^a	7.8 \pm 0.7 ^a	8.1 \pm 1.1 ^b
Palmitoleic acid (C16:1 n-7)	0.2 \pm 0.0 ^a	0.2 \pm 0.0 ^a	0.2 \pm 0.0 ^a
Myristic acid (C14:0)	0.1 \pm 0.0 ^a	0.1 \pm 0.0 ^a	0.1 \pm 0.0 ^a
Arachidic acid (C20:0)	0.3 \pm 0.0 ^a	0.3 \pm 0.0 ^a	0.3 \pm 0.0 ^a
Saturated fatty acids (SFAs)	43.1 \pm 1.2 ^a	43.4 \pm 0.7 ^a	44.3 \pm 1.1 ^a
Mono-unsaturated fatty acid (MUFAs)	7.7 \pm 1.1 ^a	8.0 \pm 0.7 ^a	8.3 \pm 1.0 ^a
Poly-unsaturated fatty acids (PUFAs)	49.8 \pm 2.4 ^a	48.1 \pm 0.5 ^a	45.7 \pm 0.2 ^b

Letters "a" in superscript indicate no significant different means within columns (sites) by Turkey's multiple comparison test at $P = 0.05$.

Table 4. Average (\pm SD) of mineral contents in oyster nuts across different sites in northern Tanzania collected from June to August 2019

Minerals (mg/100 g)	Sites		
	Arusha	Kilimanjaro	Tanga
Magnesium (Mg)	220.8 \pm 80.1 ^a	210.9 \pm 50.9 ^a	94.7 \pm 21.2 ^a
Phosphorus (P)	205.2 \pm 35.1 ^a	202.5 \pm 26.6 ^a	131.7 \pm 65.2 ^a
Potassium (K)	17.4 \pm 4.8 ^a	18.0 \pm 2.9 ^a	16.2 \pm 3.1 ^a
Calcium (Ca)	19.9 \pm 5.1 ^a	12.3 \pm .3 ^a	9.9 \pm 2.8 ^a
Manganese (Mn)	0.2 \pm 0.05 ^a	0.1 \pm 0.05 ^a	0.1 \pm 0.04 ^a
Iron (Fe)	12.9 \pm 1.0 ^a	12.2 \pm 1.2 ^a	11.1 \pm 1.0 ^a
Copper (Cu)	0.4 \pm 0.0 ^a	0.4 \pm 0.0 ^a	0.5 \pm 0.1 ^a
Zinc (Zn)	1.4 \pm 0.5 ^a	1.2 \pm 0.6 ^a	1.3 \pm 0.4 ^a
Selenium (Se)	0.01 \pm 0.0 ^a	0.01 \pm 0.0 ^a	0.01 \pm 0.0 ^a
Sodium (Na)	4.3 \pm 0.9 ^a	4.2 \pm 2.2 ^a	4.2 \pm 3.6 ^a

(Figure 3). Other fatty acid contents found in oyster nuts were not significantly different across elevations.

Only magnesium (Mg) contents increased from low to high elevations ($F_{2, 9} = 85.50, P < 0.001$; Figure 3) while phosphorus (P) was higher in lower elevations ($F_{2, 9} = 41.29, P < 0.001$). Other mineral contents were not significantly different across different elevations. The interaction between sites and elevation was not significantly different in most cases except for Phosphorus contents ($F_{2, 9} = 11.01, P = 0.009$).

4. Discussion

4.1. Proximate, minerals, and fatty acid contents of oyster nuts

According to our results, oyster nuts can be regarded as a good source of nutrients. Our oyster nut samples contained about 25% proteins (Table 2), which was equal to the amount reported in peanuts (*Arachis hypogaea*) (25%) and even higher than that in cashew nuts (*Anacardium occidentale*) (21%), walnuts (*Juglans* spp.) (17%), and sesame seeds (*Sesamum indicum*) (19%) (USDA, 2015). According to WHO (2010), pregnant and lactating women have a recommended daily allowance (RDA) for the protein of 1.1 g/kg/day. This large proportion can be acquired through oyster nuts' consumption. Additionally, oyster nuts contained high amounts of fat (68%), mostly used by local communities for food, cooking, hair, and skin tonic. We found that this fat in oyster nuts contains high MUFA and PUFA, which are highly beneficial for improving health. These can also negatively affect the oil's stability and shelf life since polyunsaturated fatty acids, including linoleic acids, are unstable when exposed to heat, light, and oxygen (Borges et al., 2007).

The quality of the oil is determined by fatty acid composition (N. G. Izquierdo et al., 2006). Our oyster nuts contained monounsaturated fatty acids (MUFA) composed of 8.1% oleic acids (C18:1 n-9), which contributes to the stability of the oil and reduces the onset of cardiovascular diseases to consumers (Abedi & Sahari, 2014). Additionally, oyster nut oil contained about 47% linoleic acid (C18:2 n-6), an essential polyunsaturated fatty acid. A ratio of 1:2 for alpha-linolenic acid (C18:3 omega-3) and linoleic acid (C18:2 omega-6) contents have been reported to be vital for maintaining good health as they can reduce rates of inflammation and cardiovascular diseases when consumed (Abedi & Sahari, 2014; Gibson et al., 2011; Salter, 2013; Simopoulos, 2011).

Our study showed that oyster nut samples also contained a high amount of magnesium and phosphorus, which are essential for maintaining muscle and bone strength, boosting the immune system, and aiding in energy production (Fender, 2014). The recommended daily intake for magnesium to maintain body health is 310–420 mg (King et al., 2005), which can be attained by consuming about 150 g of oyster nuts per day. According to Ajayi and Dullou (2015), unshelled oyster nuts have a shelf life of up to eight years. They also have rich nutrient composition, simple and low input requirements during cultivation. With these factors, Oyster nuts can be utilized in complementary food formulations. Oyster nuts can, thus, replace other common oilseeds such as peanuts, which are highly susceptible to microbial infestations and aflatoxins, often due to storage difficulty (Blesa et al., 2003).

4.2. Variations of nutrients across different sites and elevations

Generally, genotypes and cultivars have been shown to affect oilseeds' chemical contents (Borges et al., 2007; Vollmann et al., 2007). However, several studies have recently identified that agro-climatic conditions and location can also affect oilseeds' chemical contents (Ayerza & Coates, 2011; D'Imperio et al., 2007). In our study, only oleic acid showed variations based on sites. Oleic acid was higher in samples from western sites (Kilimanjaro and Arusha) compared to eastern sites (Tanga). Existing variations are probably due to differences in growing conditions, with western sites experiencing slightly lower annual temperatures and rainfall conditions (Thornton et al., 2009). Hence, the westernmost sites seemed most beneficial for attaining high oleic acid content, which has more health benefits. Similar observations were reported in the protein and fat composition of chestnuts (*Castanea sativa* L.), where variations in nutrients were found across different sites rather than elevations and seeds origin (Borges et al., 2007).

Furthermore, protein and fat contents declined in higher elevations, which indicates that lower elevations might be preferred for future cultivations. Differences in elevations are associated with changes in environmental conditions such as temperature and precipitation (Hemp, 2006). Due to variations of these environmental factors, different elevation levels have been reported to exhibit different chemical compositions within similar cultivars (Ayerza & Coates, 2011; D'Imperio et al., 2007). Changes in temperature and precipitations were reported in a study conducted on slopes of Mount Kilimanjaro and Usambara by Hemp (2006). The study

intended to investigate climatic conditions' variations due to changes in elevations from the bottom to the mountains' top. The temperature was found to decrease by 0.56°C per 100 masl upwards. These changes were from the bottom 800 masl with 23°C to the top 5000 masl with -7°C. Due to changes in evaporation rates as temperature decreases, precipitation increased from bottom to top. These results reflect on existing variations in nutritional contents in oyster nuts from samples collected at different elevations along the edges of Mount Kilimanjaro, Usambara, and mount Meru. In similar studies, variations of fat contents in chestnuts were associated with differences in elevation, temperature, and soil composition. These factors affect rates of enzyme reactions causing desaturation or saturation of fat contents (Ayerza & Coates, 2011; Borges et al., 2007). Hence, high protein and fat contents in oyster nuts can be achieved in lower elevation levels with comparatively higher temperatures.

In fatty acid contents, the significant increase of linoleic acids from lower to higher elevations agrees with studies by Ayerza and Coates (2011), D'Imperio et al. (2007), and N. G. Izquierdo et al. (2006) who identified temperature as the main factor for the determination of fatty acid compositions. The observed differences might reflect desaturase enzyme activity for oyster nuts, responsible for converting palmitic acid, oleic acid, and stearic acid to linoleic acid. Furthermore, fatty acids are synthesized within plastids containing 16-18 carbon atoms. The fatty acids are then transported to the cytosol, where desaturation occurs. These cause linoleic and linolenic acid formation (Łukaszewicz et al., 2004). This is supported by a study on hybrid sunflowers (*Helianthus annuus* L.) by N. Izquierdo et al. (2002), where enzymatic activity catalyzing oleic acid desaturations were found to be higher in cooler night temperature than in high day temperatures. The same variations were also reported in chia seeds (*Salvia hispanica* L.) by Ayerza and Coates (2011), where linoleic acids were found to increase in higher elevations. Besides, Vollmann et al. (2007) also described temperature as the main factor for fatty acid variations in camelina seeds (*Camelina sativa* L.), pointing out the significance of optimum temperature for enzymatic activity.

Mineral analyses showed variations in magnesium (Mg) and phosphorus (P) contents which increased in high elevations. These variations agree with studies on selenium concentration in Brazilian nuts (*Bertholletia excels*) by Junior et al. (2017). However, plants' uptake of mineral elements also depends on soil mineral concentration and soil acidity levels (Kabata-pendias et al., 2004; Romero et al., 2016). Hence, these variations could be contributed by differences in mineral concentrations in different elevations. High mineral contents in oyster nut samples from high elevations also indicate mineral-rich soil in the top of volcanic mountains such as Kilimanjaro (Hemp, 2006). Hence, additional studies should also focus on the contribution of soil mineral concentrations and pH to oyster nut mineral compositions.

High elevations receive more annual precipitations (You et al., 2010). Hence, high amounts of fatty acid and mineral contents in oyster nut samples from high elevations might also be associated with the generally higher annual precipitation in higher elevations apart from temperature (Hemp, 2006; Winiger, 2017). Similarly, Nenadis et al. (2015) reported reduced phenolic compounds and antioxidant activity on *Arbutus unedo* plants due to reduced precipitation, emphasizing water's importance to plant nutrient contents and physiology. Hence, the optimization of oyster nut oil quality can be achieved by cultivating at high precipitation sites in high elevations or irrigation methods.

5. Conclusion

We conclude that oyster nuts are a rich source of nutrients, contributing to the health and social-economic benefits to communities due to the nut's rich nutritional profile. High protein, fat, linoleic acid, and oleic acid compositions make oyster nuts a potential alternative to common oilseeds used in different food formulations. Furthermore, elevation levels in cultivation areas are an essential factor for improving nutrient compositions in oyster nuts. Therefore, protein contents can be optimized by cultivating on low elevation sites. At the same time, oil quality can be improved through increasing oleic and linoleic acid contents at higher elevation sites with low temperatures and increased precipitation. As oyster nuts are low in maintenance and

management requirements, we highlight that these nuts can easily be incorporated in diversifying the livelihoods and nutrient efficiency in rural communities in sub-Saharan Africa.

Acknowledgements

The Centre for Research, Agricultural advancement, Teaching Excellence and Sustainability in Food and Nutritional Security (CREATES), hosted by the School of Life Sciences and Bioengineering at the Nelson Mandela African Institution of Science and Technology (NM-AIST) and the University of Applied Sciences (Fh wels) where chemical analyses were done.

Funding

The authors received no direct funding for this research.

Author details

Emmanuel Mwakasege^{1,2}

E-mail: mwakasegee@nm-aist.ac.tz

ORCID ID: <http://orcid.org/0000-0002-6255-3239>

Anna Treydte^{3,4}

Otmar Hoeglinger⁵

Neema Kassim¹

Edna Makule¹

¹ Department of Food Biotechnology and Nutritional Sciences. School of Life Science and Bio-Engineering, The Nelson Mandela African Institution of Science and Technology (NM-AIST), P.O.Box 447, Arusha, Tanzania.

² Ecology of Tropical Agricultural Systems, Hans Ruthenberg Institute, University of Hohenheim, Stuttgart 70599, Germany.

³ Department of food science and technology. Mwalimu Julius K. Nyerere University of Agriculture & Technology, P. O. Box 976, Musoma, Tanzania.

⁴ University of Applied Sciences, Wels 4600, Upper Austria, Austria.

⁵ Department of Sustainable Agriculture, Biodiversity Conservation and Ecosystems Management, the Nelson Mandela African Institution of Science and Technology (NM-AIST), P.O.Box 447, Arusha, Tanzania.

Conflicts of Interest

The authors declare no conflict of interest.

Cover Image

Source: Author.

Citation information

Cite this article as: Variations in nutrient composition of oyster nuts (*Telfairia pedata*) across different agro-climatic conditions, Emmanuel Mwakasege, Anna Treydte, Otmar Hoeglinger, Neema Kassim & Edna Makule, *Cogent Food & Agriculture* (2021), 7: 1913843.

References

- Abedi, E., & Sahari, M. A. (2014). Long-chain polyunsaturated fatty acid sources and evaluation of their nutritional and functional properties. *Food Science and Nutrition*, 2(5), 443–463. <https://doi.org/10.1002/fsn3.121>
- Agatemor, C. (2006). Studies of selected physicochemical properties of fluted pumpkin (*Telfairia occidentalis* Hook F.) seed oil and Tropical almond (*Terminalia catappa* L.) seed oil. *Pakistan Journal of Nutrition*, 5(4), 306–307. <https://doi.org/10.3923/pjn.2006.306.307>
- Ajayi, S. A., & Dullou, A. (2015). Conservation status of *Telfairia* spp. in sub-Saharan Africa. *United Nations*, 12. <http://www.un.org/sustainabledevelopment/sustainable-development-goals/>
- Angelini, C. (2018). Regression analysis. *Encyclopedia of Bioinformatics and Computational Biology: ABC of*

- Bioinformatics*, 1–3, 722–730. <https://doi.org/10.1016/B978-0-12-809633-8.20360-9>
- Asiegbu, J. E. (1987). Some biochemical evaluation of fluted pumpkin seed. *Journal of the Science of Food and Agriculture*, 40(2), 151–155. <https://doi.org/10.1002/jsfa.2740400207>
- Ayerza, R., & Coates, W. (2011). Protein content, oil content, and fatty acid profiles as potential criteria to determine the origin of commercially grown chia (*Salvia hispanica* L.). *Industrial crops and products*, 34, 1366–1371.
- Bain, L. E., Awah, P. K., Geraldine, N., Kindong, N. P., Sigal, Y., Bernard, N., & Tanjeko, A. T. (2013). Malnutrition in Sub-Saharan Africa: Burden, causes, and prospects. *Pan African Medical Journal*, 15, 1–9. <https://doi.org/10.11604/pamj.2013.15.120.2535>
- Blesa, J., Soriano, J. M., Moltó, J. C., Marín, R., & Mañes, J. (2003). Determination of aflatoxins in peanuts by matrix solid-phase dispersion and liquid chromatography. *Journal of Chromatography. A*, 1011(1–2), 49–54. [https://doi.org/10.1016/S0021-9673\(03\)01102-6](https://doi.org/10.1016/S0021-9673(03)01102-6)
- Borges, O. P., Soeiro Carvalho, J., Reis Correia, P., & Paula Silva, A. (2007). Lipid and fatty acid profiles of *Castanea sativa* Mill. Chestnuts of 17 native Portuguese cultivars. *Journal of Food Composition and Analysis*, 20(2), 80–89. <https://doi.org/10.1016/j.jfca.2006.07.008>
- D'Imperio, M., Mannina, L., Capitani, D., Bidet, O., Rossi, E., Bucarelli, F. M., Quaglia, G. B., & Segre, A. (2007). NMR and statistical study of olive oils from Lazio: A geographical, ecological, and agronomic characterization. *Food Chemistry*, 105(3), 1256–1267. <https://doi.org/10.1016/j.foodchem.2007.02.045>
- Ecker, O., Weinberger, K., & Qaim, M. (2010, June). Patterns and determinants of dietary micronutrient deficiencies in rural areas of East Africa. *AfJARE*, 4, 175–194.
- Fender, G. (2014). Calcium metabolism and its disorders. *Second, Reproductive Endocrinology for the MRCOG and Beyond*. Vol. 24 189–196.
- Gao, F., Yang, S., Birch, J., Yoon, E. F., Kang, J., & Westrich, B. (2015). Acceptable. *Journal of Food Composition and Analysis*, 43, 7–17. <https://doi.org/10.1016/j.jfca.2015.04.004>
- Garrity, D. P. (2004). *Agroforestry and the achievement of the Millennium Development Goals*. *Agroforestry systems*, 61, 5–17.
- Gibson, R. A., Muhlhausler, B., & Makrides, M. (2011). Conversion of linoleic acid and alpha-linolenic acid to long-chain polyunsaturated fatty acids (LCPUFAs), with a focus on pregnancy, lactation, and the first 2 years of life. *Maternal & Child Nutrition*, 7(SUPPL. 2), 17–26. <https://doi.org/10.1111/j.1740-8709.2011.00299.x>
- Grosso, N. R., Nepote, V., & Guzmán, C. A. (2000). Chemical composition of some wild peanut species (*Arachis* L.) seeds. *Journal of Agricultural and Food Chemistry*, 48(3), 806–809. <https://doi.org/10.1021/jf9901744>
- Hemp, A. (2006). *Continuum or zonation? Altitudinal gradients in the forest vegetation of Mt. Kilimanjaro*. *Plant ecology*, 184, 27–42.
- Izquierdo, N., Aguirrezábal, L., Andrade, F., & Pereyra, V. (2002). Night temperature affects fatty acid composition in sunflower oil depending on the hybrid and the phenological stage. *Field Crops Research*, 77(2–3),

- 115–126. [https://doi.org/10.1016/S0378-4290\(02\)00060-6](https://doi.org/10.1016/S0378-4290(02)00060-6)
- Izquierdo, N. G., Aguirrezábal, L. A. N., Andrade, F. H., & Cantarero, M. G. (2006). Modeling the response of fatty acid composition to temperature in a traditional sunflower hybrid. *Agronomy Journal*, 98(3), 451–461. <https://doi.org/10.2134/agronj2005.0083>
- Junior, E. C. S., Wadt, L. H. O., Silva, K. E., Lima, R. M. B., Batista, K. D., Guedes, M. C., Carvalho, G. S., Carvalho, T. S., Reis, A. R., Lopes, G., & Guilherme, L. R. G. (2017). Chemosphere Natural variation of selenium in Brazil nuts and soils from the Amazon region. *Chemosphere*, 188, 650–658. <https://doi.org/10.1016/j.chemosphere.2017.08.158>
- Kabata-pendias, A., Soubra, W. W., & Dionne, D. (2004). Soil- Plant transfer of trace elements—An environmental issue. *The Journal of Surgical Research*, 122(1), 143–149. <https://doi.org/10.1016/j.jss.2004.10.001>
- Kazadi, M., Pius, T. M., Bashwira Samvura, A. N. K., Kadima, M. B., Bbb, J. N., & Kadima, J. (2015, January). Composition of fatty acids and tocopherols content in oilseeds of six wild selected composition of fatty acids and tocopherols content in oilseeds of six wild selected plants from Kahuzi-Biega National Park/DR. Congo. *European Journal of Medicinal Plants*, 8(3), 157–166. Article No.EJMP. <https://doi.org/10.9734/EJMP/2015/17297>
- King, D. E., Mainous, A. G., Geesey, M. E., & Woolson, R. F. (2005). Dietary magnesium and C-reactive protein levels. *Journal of the American College of Nutrition*, 24(3), 166–171. <https://doi.org/10.1080/07315724.2005.10719461>
- Łukaszewicz, M., Szopa, J., & Krasowska, A. (2004). Susceptibility of lipids from different flax cultivars to peroxidation and its lowering by added antioxidants. *Food Chemistry*, 88(2), 225–231. <https://doi.org/10.1016/j.foodchem.2003.12.042>
- Mbwana, H. A., Kinabo, J., Lambert, C., & Biesalski, H. K. (2017). Factors influencing stunting among children in rural Tanzania: An agro-climatic zone perspective. *Food Security*, 9(6), 1157–1171. <https://doi.org/10.1007/s12571-017-0672-4>
- Musalima, J. H., Ogwok, P., & Mugampoza, D. (2019). Antioxidant vitamins, minerals, and tannins in oil from groundnuts and oyster nuts grown in Uganda. *Food science & nutrition research* 2(2), 1.
- Musila, G. A. East and Central Africa. (2018). *Journal of Commonwealth Literature*, 53(4), 4. Issue. <https://doi.org/10.1177/0021989418801176>
- Nenadis, N., Llorens, L., Koufogianni, A., Díaz, L., Font, J., Abel, J., & Verdaguer, D. (2015). Interactive effects of UV radiation and reduced precipitation on the seasonal leaf phenolic content/composition and the antioxidant activity of naturally growing *Arbutus unedo* plants. *Journal of Photochemistry & Photobiology, B: Biology*, 153, 435–444.
- Nielsen, S. S. (2014). Food Analysis Fourth Edition. In *Food Analysis*. New York: Springer.
- Okoli, B. E. (2007). *Telfairia pedata* (Sm. ex Sims) Hook. Protabase Record. Vegetable Oils/Oleagineux. [CD-Rom]. PROTA, Wageningen. http://database.prota.org/PROTAhtml/Telfairiapedata_En.htm
- Okoli, Bosa, E., & Nyananyo, B. L. (1988). Palynology of *Telfairia* L. (Cucurbitaceae). *Folia Geobotanica et Phytotaxonomica*, 23(3), 281–283. <https://doi.org/10.1007/BF02854822>
- Romero, N., Saavedra, J., Tapia, F., Sepúlveda, B., & Aparicio, R. (2016). Influence of agroclimatic parameters on phenolic and volatile compounds of Chilean virgin olive oils and characterization based on geographical origin, cultivar, and ripening stage. *Journal of the Science of Food and Agriculture*, 96(2), 583–592. <https://doi.org/10.1002/jsfa.7127>
- Salter, A. M. (2013). Dietary fatty acids and cardiovascular disease. *Animal*, 7(SUPPL.1), 163–171. <https://doi.org/10.1017/S1751731111002023>
- Saracoglu, S., Saygi, K. O., Uluozlu, O. D., Tuzen, M., & Soylak, M. (2007). Determination of trace element contents of baby foods from Turkey. *Food Chemistry*, 105(1), 280–285. <https://doi.org/10.1016/j.foodchem.2006.11.022>
- Simopoulos, A. P. (2011). Evolutionary aspects of diet: The omega-6/omega-3 ratio and the brain. *Molecular Neurobiology*, 44(2), 203–215. <https://doi.org/10.1007/s12035-010-8162-0>
- Teh, S., & Birch, J. (2013). Journal of Food Composition and Analysis Physicochemical and quality characteristics of cold-pressed hemp, flax, and canola seed oils. *Journal of Food Composition and Analysis*, 30(1), 26–31. <https://doi.org/10.1016/j.jfca.2013.01.004>
- Thornton, P. K., Jones, P. G., Alagarswamy, G., & Andresen, J. (2009). Spatial variation of crop yield response to climate change in East Africa. *Global environmental change*, 19, 54–65.
- USDA. (2015). National Nutrient Database for Standard ReferenceRelease 28 Nutrients: Selenium, Se (µg). <https://ods.od.nih.gov/pubs/usdandb/VitA-betaCarotene-Content.pdf>
- Vollmann, J., Moritz, T., Kargl, C., Baumgartner, S., & Wagentristl, H. (2007). Agronomic evaluation of camelina genotypes selected for seed quality characteristics. *Industrial Crops and Products*, 26(3), 270–277. <https://doi.org/10.1016/j.indcrop.2007.03.017>
- WHO. (2010). *WHO technical consultation on postpartum and postnatal care*. World Health Organization.
- Winiger, M. (2017). *Karakorum-Hindukush-western Himalaya: Assessing high-altitude water Karakorum – Hindukush- Western Himalaya: Assessing high-altitude water resources abstract:hydrological processes*, 19, 2329–2338.
- Xie, J. H., Shen, M. Y., Nie, S. P., Liu, X., Yin, J. Y., Huang, D. F., Zhang, H., & Xie, M. Y. (2013). Simultaneous analysis of 18 mineral elements in *Cyclocarya paliurus* polysaccharide by ICP-AES. *Carbohydrate Polymers*, 94(1), 216–220. <https://doi.org/10.1016/j.carbpol.2012.12.072>
- Yerlikaya, C., Yucel, S., Erturk, Ü., & Korukluoğlu, M. (2012). Proximate composition, minerals, and fatty acid composition of *Juglans Regia* L. genotypes and cultivars grown in Turkey. *Brazilian Archives of Biology and Technology*, 55(5), 677–683. <https://doi.org/10.1590/S1516-89132012000500006>
- You, Q., Kang, S., Pepin, N., Flügel, W. A., Yan, Y., Behrawan, H., & Huang, J. (2010). Relationship between temperature trend magnitude, elevation and mean temperature in the Tibetan Plateau from homogenized surface stations and reanalysis data. *Global and Planetary Change*, 71(1–2), 124–133. <https://doi.org/10.1016/j.gloplacha.2010.01.020>



© 2021 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

You are free to:

Share — copy and redistribute the material in any medium or format.

Adapt — remix, transform, and build upon the material for any purpose, even commercially.

The licensor cannot revoke these freedoms as long as you follow the license terms.

Under the following terms:

Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made.

You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

No additional restrictions

You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.



***Cogent Food & Agriculture* (ISSN: 2331-1932) is published by Cogent OA, part of Taylor & Francis Group.**

Publishing with Cogent OA ensures:

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

Submit your manuscript to a Cogent OA journal at www.CogentOA.com

