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Study of the Physicochemical Parameters of Peanut Seeds from Three Regions of Chad: Implications for Food Security

Mahamat Seïd Ali Malloum[1,2,*], Mbai-Yelkom Fidel Karnot[1,2,*], Abdoulaye Ibrahim Djabar[1,2], Ahmat Al Tidjani Hissein[1,2]

[1]University of N'Djamena, CHAD.
[2]Water and Environment Laboratory (LABEEN)
*Corresponding authors: seidaligarga@gmail.com, yelkomfk96@gmail.com

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Abstract This study focused on evaluating the physicochemical parameters of peanut seeds and oilcake extracted from these seeds, sourced from three regions of Chad (South, Center, and East). The seeds were analyzed for their protein, fat, ash, and moisture content, revealing high protein levels of 23.22% to 27.85% and fat levels of 44.13 g/100gDM to 55.55 g/100gDM, with moderate moisture content ranging from 4.82% to 9.55% and ash content around 2.24–2.85%, reflecting their nutritional value. Fresh oilseed meal had high protein levels of 33.88% to 44.75%, significant residual fat levels of 26.75 g/100gDM to 31.15 g/100gDM, and high moisture levels of 24.95% to 30.50%, which limits its shelf life. After drying, dry oilseed meal had low moisture content (2.57% to 3.92%), preserved protein (42.17% to 46.75%), and fat (22.55% to 30.56%), ensuring better stability and interesting nutritional potential. The differences observed between areas reflect the initial quality of the seeds and the processing conditions. These results suggest that dry meal is a suitable source of protein and energy for animal feed and that drying is essential to extend the shelf life of peanut by-products.

Keywords: *Arachis hypogaea, peanut seeds, oilcake, food security, Chad*

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1. Introduction

The peanut (*Arachis hypogaea L.*), whose fruit is called a peanut, is a plant of the legume family (Fabaceae) native to northwestern Argentina and southeastern Bolivia and cultivated in tropical, subtropical, and temperate regions for its oilseeds [1], high nutritional value, and industrial applications [2]. It is an essential source of protein and lipids, with seeds generally containing 20–42.1% protein, 41.5–50% lipids, and 3.7–8.5% fiber [3,4,5]. Global peanut production in 2023 is estimated at 45.5 million tons, with China, India, and Nigeria as the main producers [6,7]. The global average yield is 1.66 t/ha, reflecting the importance of this crop for food security and the overall agricultural economy. These bioactive compounds give peanut seeds interesting nutritional and functional properties, particularly due to their amino acid and unsaturated fatty acid profile [8].

In Africa, peanuts occupy a strategic position, particularly in Senegal, Nigeria, Sudan, and Ghana, where they are a source of income and a staple food. In 2018, Senegal produced 1.68 million tons, and Nigeria 4.61 million tons [7,9]. The oils extracted have varying physicochemical properties depending on the variety and extraction methods, with iodine, saponification, and peroxide values reflecting their nutritional quality and oxidative stability [2,10,11]. Peanut meal, a by-product of oil extraction, is used as animal feed due to its high protein content, but its shelf life is limited by high moisture content and the risk of microbial degradation [12,13].

In Chad, agriculture accounts for approximately 52.3% of GDP, employing nearly 80% of the working population [14,15]. Chad is the world's eleventh largest peanut producer, with a cultivated area of 0.48 million hectares and an annual production of 0.45 million tons. Yields vary between 600 kg/ha in low-fertility basins and 900 kg/ha in fertile areas [16]. National peanut production is estimated at 893,000 tons over an area of 754,252 ha, with an average yield of 1.06 t/ha [6]. Locally produced seeds, oils, and oilcakes are used for human and animal consumption, but their industrial value remains low, and the preservation of oilcakes is a major challenge due to their high moisture content. In this context, this study aims to investigate the physicochemical properties of peanut seeds from three regions (South, Center, and East) in Chad. The results will enable the nutritional and industrial quality of these products to be assessed in order to propose strategies for optimizing their use in food.

2. Materials and Methods

1. Study area and period

This study was conducted in N'Djamena on peanut samples collected in three agroecological regions of Chad: the Center (GAC), the South (GAS), and the East (GAE). These three areas represent the country's main peanut production basins. The samples were collected during the 2024 agricultural season, in collaboration with local producers, in order to obtain samples representative of regional production.

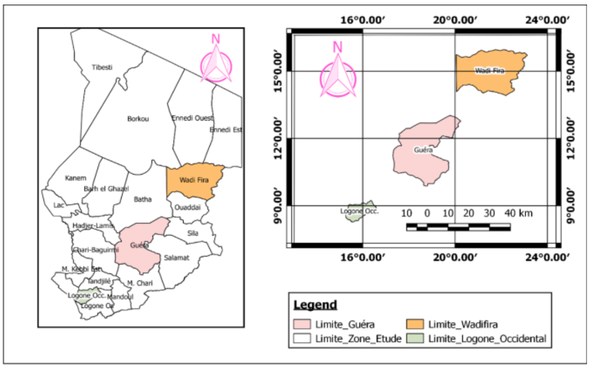

Figure 1. Map of study areas

2. Biological material

The biological material used in this study consists mainly of peanut seeds from three (3) regions of Chad (South, Center, and East).

3. Sampling

A total of eighteen (18) peanut seed samples were collected, with six (6) samples of 2 kilograms of peanut seeds per region, sorted manually to remove impurities, then packaged in labeled, airtight bags. They were stored for forty-five days in the laboratory at 4°C before being analyzed. The seeds were ground using an electric grinder (hammer mill type) to obtain a homogeneous flour for physico-chemical analysis and oil extraction.

(a) Guéra peanut (Center)

(b) Wadi-Fira peanut (East)

(c) Moundou peanut (South)

Figure 2. Different types of peanuts from three regions: (a) Central, (b) Eastern, and (c) Southern

4. Analysis of physicochemical parameters

a. Determination of fat content (Soxhlet method)

Fats are organic substances that can be extracted from fruits and plants using nonpolar organic solvents with a Soxhlet apparatus. The fat content of the seeds is extracted from 30g of powder using the Soxhlet method; the solvent used is hexane. After distillation, the percentage of lipids is expressed as a percentage of dry matter [17]. The fat content is calculated [18,19] using the following formula: **MG % = $((P_2-P_1)/(P_3))$ x100** (Eq. 1)

Where: P_1: Weight of empty flask (g).

P_2: Weight of flask with extracted oil (g).

P_3: Weight of test sample (g)

b. Determination of protein content

The protein content of the samples is calculated from the total nitrogen content. Crude protein was measured using the BIBPEA method based on the Kjeldahl method [20]. This is a three-step method: mineralization of organic nitrogen, distillation of ammonia displaced from its salt by soda, and acid-base titration. The protein content is determined using the following formula:

$TP = W_N \times Fc$ where **$W_N = (1.4007) \times (V-V_0) \times 0.1\ M_E$** (Eq. 2)

TP: protein content;

Fc: conversion factor;

M_E: test mass;

W_N: nitrogen content;

V: titration volume of the sample;

V_0: blank titration volume.

c. Determination of moisture content

Twenty grams of each sample to be analyzed were placed in a weighed container and dried in an oven at 104°C. The samples were removed at regular intervals and weighed until a constant mass was obtained [21,23]. The moisture content was calculated using the following equation: **H % = $((M_0-M)/(M_0))$ x100 (Eq. 3)**

Where M_0: initial mass of the sample

M: mass of the sample after drying

d. Determination of ash content

The ash content of peanut seeds is determined by calcination in a muffle furnace: a pre-dried and ground sample is incinerated at a high temperature (650°C) until a constant weight is reached, then the mineral residue is weighed. The percentage of this residue in relation to the initial mass gives the ash content, a measure of the inorganic matter content. The result is expressed as a percentage of ash content on a dry basis [24,18,19]:

Ash Mass (Mc) = Final mass (capsule + ash) – Mass of the tared capsule (Eq. 4)

Ash Content (%) = $(M_C/(M_0))$ x100 (Eq. 5)

Where Mc: Ash Mass

M_0: Initial Mass of the Sample

e. Oil Extraction

The oil was extracted using the Soxhlet method with hexane solvent (≥ 95% purity). For each test, 50 g of dehydrated flour was placed in a cellulose cartridge and subjected to extraction for 4 hours and 30 minutes. After extraction, the solvent was removed by evaporation under reduced pressure using a rotary evaporator, and the oils obtained were weighed to calculate the extraction yield according to formula [19]:

Yield (%) = (Mass of oil extracted (g))/(Mass of initial sample (g))×100 (Eq. 6)

f. Preparation and characterization of oilseed meal

The solid residues after extraction (oilseed meal) were recovered, dried at 60°C for 24 hours, then finely ground. Two types of oilseed meal were analyzed:

- Fresh oilseed meal: collected immediately after extraction.
- Dry oilseed meal: fresh oilseed meal subjected to additional drying in an oven.

Composition analyses (moisture, protein, ash, residual fat) were performed according to methods [18,19].

g. Extraction steps

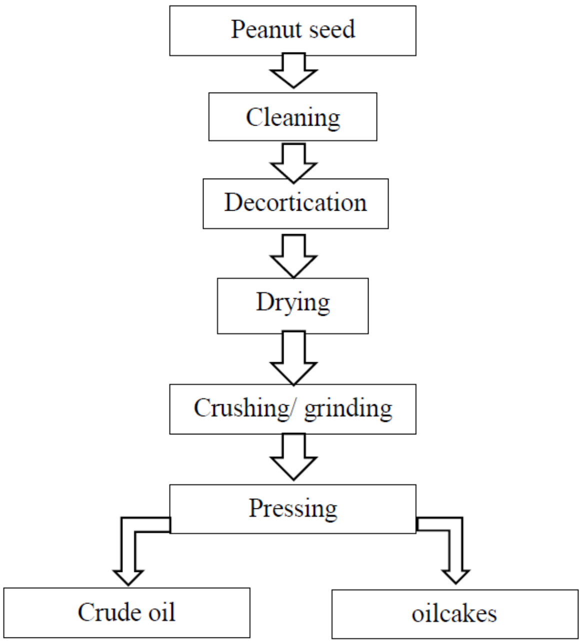

Figure 3. Steps of oil extraction and peanut cake

3. Results and Discussion

The fat content of the samples varies between 44.13 and 55.55 g/100 g DM, with the highest average in the eastern region (50.79 g/100 g DM) and the lowest in the southern region (45.40 g/100 g DM). These values are consistent with international standards (47–50%) reported by the FAO [25] and corroborated by Singh et al [26], who describe peanuts as an oilseed rich in unsaturated fatty acids. The higher lipid content observed in the eastern region could be due to specific varietal or agroecological factors.

Moisture content ranges from 4.82% to 9.55%, with a higher average in the East (7.76%). This result exceeds the standard set by the Codex Alimentarius [18,19], which recommends a maximum moisture content of 7% for peanuts in order to limit microbial growth. Excessive moisture is a risk factor for contamination by fungi of the genus Aspergillus, which are responsible for the production of aflatoxins, whose toxic and carcinogenic effects are widely documented [27,28]. This finding reflects inadequate drying or storage conditions, particularly in the eastern region.

The ash values obtained range from 2.24 to 2.85%, reflecting a satisfactory mineral content. They fall within the range reported by Anyasor et al [29], i.e., 2–3%. The differences observed between regions could be attributed to the mineralogical composition of the cultivated soils and the farming techniques adopted by producers.

The protein content of the samples varies between 22.75 and 27.85%, with the highest average in the Guéra region in the center (26.52%) and the lowest in the Wadi Fira region in the east (23.88%). These results corroborate data from the FAO [25] and Anyasor et al [29], which place the protein content of peanuts between 22 and 30%. The high protein content in Guéra, in the center, highlights its nutritional potential, particularly in a context where peanuts are an accessible source of vegetable protein in Chad.

Oil extraction from peanuts from the Southern (GAS), Central (GAC), and Eastern (GAE) regions was carried out using hexane solvent, with extraction times ranging from 4.5 to 5 hours. The yields obtained ranged from 42.50% to 45.50%, with an average of 44.15% in the Eastern region, 43.20% in the Southern region, and

42.75% in the Central region. These results reflect the natural lipid content of the seeds, which varies according to the production area and variety [29,25,26]. These yields suggest that peanut seeds from all three regions are suitable for edible oil production, but that varietal selection or optimization of pre-treatment (cleaning, grinding, drying) could further improve yields in the South and Central regions.

Table 1. Physicochemical analyses of peanut seeds from three (3) regions

Samples	Fat (g/100gMS)	Moisture (%)	Ash (%)	Protein (%)
GAC1	46.90	4.82	2.31	26.45
GAC2	45.43	6.76	2.45	**27.85**
GAC3	45.26	5.55	**2.24**	24.54
GAC4	49.37	6.16	2.36	27.25
Mean ± SD	**46.74 ±1.87**	**5.82 ±0.89**	**2.34 ±0.09**	**26.52 ±1.46**
GAS1	44.13	5.96	2.45	27.15
GAS2	45.43	5.32	2.75	24.34
GAS3	47.50	7.55	2.56	26.45
GAS4	44.55	5.25	2.55	23.55
Mean ± SD	**45.40 ±1.49**	**6.02 ±1.07**	**2.58 ±0.13**	**25.37 ±1.73**
GAE1	48.55	6.38	2.57	25.23
GAE2	53.54	9.55	2.75	22.75
GAE3	55.55	5.57	2.85	24.32
GAE4	45.50	7.56	2.58	23.20
Mean ± SD	**50.79 ±4.49**	**7.27 ±1.72**	**2.69 ±0.13**	**23.88 ±1.05**

GAC: peanut seeds from the Center; GAS: peanut seeds from the South; GAE: peanut seeds from the East; SD: Standard deviation

Table 2. Extraction of oils from peanut seeds using hexane

Samples	Areas of Origin	Extraction Time	Percentage	Yield (%)
GAS1	Southern Region	4:30 a.m. to 5 a.m.	42.50%	43.20%
GAS2			43.05%	
GAS3			44.50%	
GAS4			42.75%	
GAC1	Central Region	4:30 a.m. to 5 a.m.	43.50%	42.75%
GAC2			41.75%	
GAC3			42.50%	
GAC4			43.25%	
GAE1	Eastern Region	4:30 a.m. to 5 a.m.	45.50%	44.15%
GAE2			43.75%	
GAE3			44.85%	
GAE4			42.50%	

GAS: Southern peanut seeds; GAC: Central peanut seeds; GAE: Eastern peanut seeds

Table 3. Physicochemical composition of fresh peanut seed meal from the three regions

Samples	Fat (g/100gMS)	Moisture (%)	Ash (%)	Protein (%)
TFGAS1	31.150	30.505	3.570	44.750
TFGAS2	29.970	28.693	3.060	37.710
Mean ± SD	30.56 ± 0.59	29.60 ± 0.91	3.32 ± 0.26	41.23 ± 3.52
TFGAC1	23.980	24.950	3.160	33.875
TFGAC2	29.850	29.450	3.543	36.37
Mean ± SD	26.92 ± 2.93	27.20 ± 2.25	3.35 ± 0.19	35.12 ± 1.25
TFGAE1	26.755	26.750	3.580	43.150
TFGAE2	28.360	27.259	3.250	41.165
Mean ± SD	27.56 ± 0.80	27.00 ± 0.25	3.42 ± 0.17	42.16 ± 0.99

TFGAS: fresh peanut meal from the South; TFGC: fresh peanut meal from the Center; TFGAE: fresh peanut meal from the East; SD: standard deviation

The results of the physicochemical analysis of fresh peanut meal from the three agro-ecological regions of Chad reveal significant variability between regions, reflecting both the initial composition of the seeds and the extraction conditions.

The residual fat content varies between 26.92 g/100 g DM (Center) and 30.56 g/100 g DM (South). These relatively high levels reflect incomplete extraction by hexane, confirming that the method used leaves a significant lipid fraction in the meal. However, such residues are common and give the product a significant energy value for animal feed [29]. Southern oilseed meal has the highest lipid content, which can improve its caloric density.

The values observed (24.95–30.51%) are higher than the storage standards (<12%) recommended by the FAO [25]. High moisture content promotes mold growth and oxidative degradation of lipids, thereby reducing the stability of oilseed meal. This highlights the need for post-extraction drying to extend shelf life and limit the risk of microbial contamination.

Ash content ranges from 3.06% to 3.58%, which is close to the values reported in the literature (3–5%) for peanut meal [22]. This mineral fraction reflects the presence of essential nutrients (calcium, magnesium, phosphorus, potassium), contributing to the nutritional value of the meal.

Protein content varies greatly between regions: 33.87% (Center) to 44.75% (South), with high levels in the South and East (>40%). These levels are close to international standards for peanut meal used in animal and aquaculture feed [26]. The meal from the Center has a lower content, which could be related to the quality of the initial seeds or to agro-ecological variability. Nevertheless, all samples confirm that peanut meal is an excellent source of vegetable protein.

Table 4. Physicochemical composition of dry peanut meal from the three provinces

Samples	Fat (g/100gMS)	Moisture (%)	Ash (%)	Protein (%)
TSGAS1	30.56	3.790	3.500	46.75
TSGAS2	2949	3.923	3.173	45.65
Mean ± SD	30.03 ±0.53	3.86 ±0.09	3.34 ±0.23	46.20 ±0.78
TSGAC1	22.55	2.570	3.463	44.500
TSGAC2	23.54	3.200	3.033	44.243
Mean ± SD	23.05 ±0.70	2.89 ±0.45	3.25 ±0.30	44.37 ±0.18
TSGAE1	25.14	3.513	3.24	42.17
TSGAE2	27.35	3.250	3.35	45.50
Mean ± SD	26.25 ±1.56	3.38 ± 0.19	3.30 ±0.08	43.84 ±2.36

TSGAS: dry peanut meal from the South; TSGAC: dry peanut meal from the center; TSGAE: dry peanut meal from the East, SD: standard deviation

Physicochemical analysis of dry peanut meal shows greater stability than fresh meal, particularly in terms of moisture content and shelf life.

The fat content varies from 22.55 g/100 g DM in the central region to 30.02 g/100 g DM in the southern region. Although slightly lower than those of fresh cake, these values still indicate a significant presence of residual lipids. This energy fraction may be an advantage for animal feed [30], but it also suggests moderate extraction efficiency. Cake from the South has the highest lipid content, reinforcing its energy value.

The levels observed (2.57–3.92%) are in line with the storage standards (<12%) recommended by the FAO [25]. Unlike fresh oilseed meal (nearly 30%), dry oilseed meal has increased stability and a reduced risk of microbial and fungal growth. This result confirms that drying is essential for the preservation and safety of this co-product.

Ash values range from 3.03% to 3.50%, comparable to those of fresh oilseed meal. They reflect the essential mineral fraction, mainly consisting of calcium, magnesium, potassium, and phosphorus, which are useful elements in animal nutrition [22]. Differences between regions remain small, indicating relative mineral homogeneity in the oilseed meal.

The protein content remains high, ranging from 42.17% in the east to 46.75% in the south, which makes these oilseed meals excellent sources of vegetable protein. The values observed are higher than those reported for certain peanut meal in West Africa (40–45%) by Anyasor et al [29]. Southern meal has the highest protein content, reinforcing its value in the formulation of rations for ruminants, poultry, and fish.

4. Conclusion

Ultimately, physicochemical analysis of peanut seeds, oils, and oilcake produced in the southern, central, and eastern regions of Chad showed relatively low but significant variability between regions. Oil yields (42.75–44.15%) reveal good extraction potential, while the cake still has appreciable fat content and high protein levels (up to 46.75%), confirming its nutritional value and usefulness as a feed supplement for livestock. Moisture and ash content are generally in line with storage and quality standards, demonstrating the stability and safety of the products. These results highlight the strategic importance of Chadian peanuts not only as a source of vegetable oil but also as a sustainable protein resource. They open up prospects for better agro-industrial development, strengthening food security, and contributing to the local economy through improved processing methods and optimized use of by-products.

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CONFLICTS OF INTEREST: The authors declare no conflict of interest

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