Proximate Composition of Tiger Nut, Maca Powder, Ashwagandha and Moringa Leaf Powder and their Binary Blends

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ABSTRACT

Tiger nut, moringa leaf powder, maca powder and ashwagandha are recognised functional food ingredients, but empirical proximate data on their binary blends are scarce, so blends cannot be formulated or compared on a scientific basis. This study therefore evaluated the proximate composition of the four ingredients and their six binary blends. Tiger nut from Nkawkaw was oven-dried at 60 °C for 72 h and milled, and commercial moringa, maca and ashwagandha powders were sourced in Kumasi, Ghana. Six 50:50 (w/w) blends were prepared by geometric dilution. Ten treatments were analysed in a Completely Randomized Design with three analytical replicates. Moisture, crude protein, crude fat, crude fibre, total ash and nitrogen-free extract carbohydrate were determined by AOAC (1990) methods, and data were analysed by ANOVA with Tukey's HSD test at $P<0.01$. Treatments differed significantly ($P<0.01$) for all parameters. Moringa leaf powder had the highest protein (46.06%) and crude fibre (28.05%), tiger nut the highest fat (21.80%) and lowest moisture (2.18%), maca powder the highest carbohydrate (69.98%), and ashwagandha the highest ash (9.08%). Among the binary blends, Moringa + Ashwagandha had the highest crude fibre (26.38%) and ash (8.02%) with the lowest moisture (3.39%), and Moringa + Maca had the highest carbohydrate (63.64%). Moringa leaf powder was the richest single ingredient in protein and fibre, and Moringa + Ashwagandha was the strongest blend for fibre, ash and low moisture.

Keywords: Functional foods, proximate composition, moringa leaf powder, tiger nut, binary blends

INTRODUCTION

The global demand for functional foods continues to rise, driven by increasing healthcare costs, extended life expectancy, and the growing consumer preference for diets that address nutritional needs beyond mere satiety (Siró et al., 2008; Bigliardi and Galati, 2013). Functional foods, first formally recognized in Japan in the 1980s, are defined as natural or processed foods that contain biologically active compounds capable of promoting optimal health and reducing the risk of chronic disease when consumed in defined, non-toxic amounts (Martirosyan, 2025). Plant-based ingredients occupy a central place in this shift, as their macronutrient composition can be incorporated into food matrices with minimal processing infrastructure, making them especially relevant in resource-limited settings where the double burden of undernutrition and diet-related non-communicable disease persists (Omokpariola et al., 2026).

Tiger nut (Cyperus esculentus), moringa leaf powder (Moringa oleifera), maca powder (Lepidium meyenii), and ashwagandha (Withania somnifera) are four such plant-based ingredients that have each attracted independent attention for their proximate quality. Tiger nut is notable for its high starch and unsaturated fat content, though its protein content remains comparatively low (Pelegrín et al., 2022; Yu et al., 2022). Moringa leaf powder is consistently reported as one of the most protein- and fibre-dense plant materials available, with proximate values that routinely exceed those of conventional leafy vegetables (Gopalakrishnan et al., 2016; Leone et al., 2015). Maca powder is valued for its relatively high protein content among root crops, alongside a low fat and moderate fibre profile (Gonzales, 2012; Chen et al., 2017). Ashwagandha, though primarily consumed for its bioactive

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withanolide content, also carries a distinct proximate profile characterized by high crude fibre and comparatively low macronutrient density (Gulati et al., 2017; Kumari and Gupta, 2016; Veer et al., 2019). Despite the individual recognition of each of these ingredients, none possesses a complete proximate profile on its own. Blending, as a simple, low-cost, and adaptive food technology, offers a practical route to compositional complementarity, allowing the limitations of one ingredient to be offset by the strengths of another (Bigliardi and Galati, 2013). Binary blending, in particular, provides the simplest framework for evaluating pairwise ingredient interactions before more complex multi-ingredient formulations are attempted, and it allows compositional changes to be directly attributed to specific ingredient combinations (Kaur and Das, 2011). Despite the growing body of literature on tiger nut, moringa leaf powder, maca powder, and ashwagandha individually, empirical data on the proximate composition of their binary blends remain scarce. Without such baseline compositional data, the potential of these blends as functional food ingredients cannot be scientifically substantiated or used to guide product development. Characterizing the proximate composition of these four ingredients, both individually and as binary blends, therefore provides the necessary scientific foundation for their consideration as functional food components.

The objective of this study was to evaluate the effect of tiger nut, moringa leaf powder, maca powder, and ashwagandha, individually and as their binary blends, on proximate composition (moisture, crude protein, crude fat, crude fibre, ash, and carbohydrate).

METHODOLOGY THE STUDY AREA

Research Location and Duration

This study was conducted at Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. Raw material processing, blend formulation, and sample preparation were carried out at the Department of Horticulture Laboratory. All proximate analytical procedures were performed at the Department of Crop and Soil Science Laboratory, KNUST.

Sample Collection and Preparation

Commercial dried powders of moringa leaf (Moringa oleifera), maca (Lepidium meyenii), and ashwagandha (Withania somnifera) were purchased from local suppliers in Kumasi, Ghana. Dehydrated moringa leaf powder was obtained from Food and Beverages Therapy Limited (KNUST Commercial Area). Maca powder and ashwagandha root powder were sourced from Premium Nutritionals Center (Dr. K. Addo Kuffour Avenue, Kumasi). Fresh tiger nut tubers (Cyperus esculentus, 7.0 kg) were purchased from a local farmer in Nkawkaw, Eastern Region, Ghana.

Upon arrival, tiger nut tubers were thoroughly washed under running tap water, rinsed with distilled water to remove surface debris and particulate matter, and blotted dry with tissue paper. The cleaned tubers were dried in a Magtech oven, preheated for one hour before the samples were introduced, at 60 °C for 72 h. The dried tubers were ground into a fine powder using a seed grinder. To ensure particle size uniformity across all treatments, the ground tiger nut powder and the three commercial powders were individually passed through a standard 1.00 mm laboratory sieve mesh.

Six binary (50:50 w/w) blends were prepared from the standardized individual ingredient powders to a total mass of 200 g per blend:

1. Tigernut + Maca Powder
2. Tigernut + Moringa Leaf Powder
3. Tigernut + Ashwagandha Powder
4. Moringa Leaf Powder + Maca Powder
5. Moringa Leaf Powder + Ashwagandha Powder

6. Maca Powder + Ashwagandha Powder

To ensure homogeneity and prevent wall-adherence or density-driven stratification, each 50:50 blend was mixed using the geometric dilution technique, starting with equal 5 g increments of each constituent ingredient. Following initial blending, each formulation was passed through three sequential sifting cycles using the 1.00 mm mesh sieve to eliminate agglomerates and achieve complete dispersion. The four individual powders and six binary blends were packed in labeled mini resealable bags prior to chemical analysis.

Experimental Design and Treatment Formulations

The study was conducted using a Completely Randomized Design (CRD) comprising ten treatments (four raw ingredients and six binary blends) with three independent replications, yielding thirty experimental units ($N = 30$). The detailed treatment structure is presented in Table 1.

Table 1: Treatment formulations of tiger nut, maca powder, ashwagandha powder, and moringa leaf powder.

Treatment	Combinations
Tigernut	100%
Moringa Leaf Powder	100%
Maca Powder	100%
Ashwagandha Powder	100%
Tigernut +Maca Powder	50%+50%
Tigernut +Moringa leaf Powder	50%+50%
Tigernut +Ashwagandha Powder	50%+50%
Moringa Leaf Powder + Maca Powder	50%+50%
Moringa Leaf Powder + Ashwagandha Powder	50%+50%
Maca Powder + Ashwagandha Powder	50%+50%

Proximate Analysis

The proximate parameters moisture, crude protein, crude fat, crude fibre, total ash, and nitrogen-free extract (NFE) carbohydrate were determined in triplicate using standardized procedures of the Association of Official Analytical Chemists (AOAC, 1990).

Crude Fibre Content

Two grams of each sample were weighed, put in a digestion flask with 200 cc of 1.25% sulfuric acid, and boiled slowly for half an hour. The residue was promptly filtered through linen and then rinsed with distilled water until it was acid-free. After re-transferring the residue to the digestion flask, 200 ml of 1.25% sodium hydroxide (NaOH) was added, and 30 minutes of heating were spent on the combination. After filtering the leftover material, it was repeatedly washed in distilled water to eliminate any remaining alkali. The residue was placed in a porous crucible, washed with 15 mL of 95% ethanol and dried at 105 °C to constant weight.

Crude fibre percentage was determined.

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$$\% \text{ Crude fiber} = \frac{(\text{Mass of fiber})}{(\text{Dry mass of sample used})} \text{x}100$$

Crude Protein Content

Crude protein was determined via the Micro-Kjeldahl digestion, distillation, and titration protocol (AOAC Method 984.13) using a protein conversion factor of 6.25.

Digestion

A 2 g sample was transferred into a clean 500 mL long-necked Kjeldahl digestion flask. Ten milliliters (10 mL) of distilled water was added, followed by a full spatula of Kjeldahl catalyst (a mixture of 100 parts sodium sulfate (Na_2SO_4), 10 parts copper sulfate ($CuSO_4$), and 1 part selenium). Concentrated sulfuric acid (H_2SO_4; 20 mL) was added. The mixture was digested until the mixture was clear and colorless. The flask was allowed to cool to ambient temperature, transferred quantitatively into a 100 mL volumetric flask, and diluted to volume with distilled water.

Distillation

A 10 mL aliquot of the diluted digest was transferred into a Kjeldahl distillation apparatus. Forty percent sodium hydroxide (NaOH, 20 mL) and 70 mL of distilled water were added to liberate ammonia gas. The liberated ammonia was steam-distilled into an receiving flask containing 10 mL of 4% (w/v) boric acid (H_3BO_3) solution with 3 drops of mixed indicator (methyl red and methylene blue). Distillation was continued until approximately 100 mL of distillate was collected.

Titration

The distillate was titrated against standardized 0.1 N hydrochloric acid (HCl) until the blue-green solution changed to a permanent light pink endpoint. A reagent blank containing no sample was digested and titrated under identical conditions.

The percentage nitrogen and crude protein contents were calculated using the following equations:

$$\text{Nitrogen (\%)} = \left[\frac{(V_s - V_b) \times N \times 0.014007 \times D}{W \times A}\right] \times 100$$

$$\text{Crude Protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$

Where:

- V_s = volume of standardized HCl used for sample titration (mL)
- V_b = volume of standardized HCl used for blank titration (mL)
- N = normality of standardized HCl (0.1 N)
- 0.014007 = milliequivalent weight of nitrogen (g/meq)
- D = total volume of digest (100 mL)
- A = volume of digest aliquot distilled (10 mL)
- W = mass of sample weighed (1.000 g)

Total Ash Content

One gram of each sample was placed in a crucible and weighed. The crucible was then placed in a furnace that was continuously set at 550 °C for five to six hours, or until the sample turned white ash. Its weight was then recorded after it had some time to cool in a desiccator.

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The amount of ash in % was determined as

(A+B)-A=B

(A+C)-A=C

%Ash=(C/B) x 100

Where A=weight of crucible, B=weight of sample, C=weight of Ash

Moisture Content Determination

Moisture content was determined using the oven drying method (AOAC, 1990). A 5 g portion (W_1) of each sample was weighed into a previously weighed dish. The dishes were placed in an oven maintained at 100 °C for 24 h. Samples were removed, transferred to a desiccator and cooled for 30 min before re-weighing. The procedure was repeated until a constant weight (W_2) was attained.

The moisture percentage was calculated as follows:

$$\text{Moisture (\%)} = \left(\frac{W_1 - W_2}{W_1}\right) \times 100$$

Where:

- W_1 = initial sample weight before drying (g)
- W_2 = final constant sample weight after oven drying (g)

Crude Lipids Content

Crude fat was determined by Soxhlet extraction with petroleum ether (AOAC, 1990). One gram of finely ground sample (W_s) was weighed into a folded filter paper, dried at 100 °C for 30 min to remove moisture and cooled in a desiccator. The filter paper was placed in the Soxhlet extractor, which sat on a pre-weighed round-bottom flask (W_2) containing 250 mL of petroleum ether on a hot plate, with cooling water circulating through the condenser. Extraction was carried out continuously for 4 to 6 hours until complete, after which the heat was reduced. The flask was dried, cooled in a desiccator and weighed (W_1).

Crude fat percentage was calculated as:

$$\text{Crude Fat (\%)} = \left(\frac{W_1 - W_2}{W_s}\right) \times 100$$

Where:

- W_1 = mass of flask + ether extract (g)
- W_2 = mass of empty flask (g)
- W_s = initial sample mass (g)

Carbohydrate Content

Total available carbohydrate was determined by difference (nitrogen-free extract, NFE) according to FAO guidelines:

$$\text{Carbohydrate (\%)} = 100 - (\%\text{Moisture} + \%\text{Crude Protein} + \%\text{Crude Fat} + \%\text{Crude Fibre} + \%\text{Total Ash})$$

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Statistical Analysis

Each treatment was analysed in triplicate (n = 3). The four ingredient powders were single lots, and each blend was prepared in replicates. Treatment means were compared by one-way ANOVA and separated by Tukey's HSD where F-tests were significant ($P<0.01$). Results are presented as means ± standard deviation.

RESULTS AND DISCUSSION

Moisture Content of Tiger Nut, Maca Powder, Ashwagandha, and Moringa Leaf Powder Composite Blends

Tiger nut recorded the lowest moisture content among the individual ingredients (2.18%), significantly lower ($P<0.01$) than maca powder, moringa leaf powder, and ashwagandha, which recorded no significant difference among themselves at 4.37%, 4.73%, and 4.53% respectively. Among the binary blends, Moringa + Ashwagandha recorded the lowest moisture content (3.39%), significantly different ($P<0.01$) from all other blends, while Tigernut + Moringa recorded the highest moisture content (6.71%). No significant difference was recorded between Moringa + Maca (4.56%) and Maca + Ashwagandha (4.37%), between Tigernut + Maca (5.67%) and Tigernut + Ashwagandha (5.32%). All values recorded across the ten treatments fell below the 10% threshold recommended for dry food powders (Mardiana et al., 2025), indicating favourable shelf stability for all individual ingredients and blends.

The moisture content recorded for tiger nut was considerably lower than values reported in the literature. Emurotu (2017) reported a moisture content of 10.5% for the yellow variety of tiger nut, while Ibrahim et al. (2016) reported moisture contents of 8.93% and 9.20% for yellow and black tiger nut varieties respectively. Aduwamai et al. (2018) similarly reported a moisture content of 10.69% in soaked tiger nut samples. Imafidon and Emumejakpo (2026) likewise reported 7.50% for sun-dried tiger nut tubers from Benin City, Nigeria. The lower value recorded in this study may be attributed to the extensive oven-drying process applied during sample preparation, in which fresh tiger nuts were dried at 60°C for 72 hours, effectively removing the majority of free water from the tuber matrix prior to milling (Anyene et al., 2026). The moisture content recorded for moringa leaf powder (4.73%) was lower than values reported in comparable studies. Khan et al. (2023) reported 6.38% for commercially dehydrated moringa leaf powder, Handayani et al. (2022) reported 7.80%, and Ahmed et al. (2023) reported 7.94%. This difference may be attributed to the commercial drying process applied to the powder prior to acquisition, as it had already undergone standardised moisture reduction (Handayani et al., 2022). The moisture content recorded for maca powder (4.37%) was consistent with the general moisture range reported for commercially processed maca powders. Chen et al. (2017) noted that moisture content in maca varied significantly by cultivation region and post-harvest drying conditions, while Wang and Zhu (2019) reported that fresh maca hypocotyls contain more than 80% water, with the dried form yielding considerably lower moisture contents depending on the drying regime applied. The moisture content recorded for ashwagandha (4.53%) was substantially lower than values reported in the literature for fresh and dried Withania somnifera plant parts. Veer et al. (2019) reported a moisture content of 7.2% and Kumari and Gupta (2016) reported 7.45% for ashwagandha root powder, both higher than the value recorded in this study, while Krishnamurthy and Sarala (2010) reported a fresh leaf moisture content of 24.64%. These differences likely reflect the part of the plant analysed, the drying conditions applied, and whether the product was fresh, oven-dried, or commercially processed.

Among the binary blends, the elevated moisture content recorded for Tigernut + Moringa may be attributed to the hygroscopic nature of moringa leaf powder, which is known to readily absorb moisture due to its high protein and dietary fibre content (Sultana, 2020; Handayani et al., 2022). The lower moisture content recorded for Moringa + Ashwagandha, by contrast, fell below both parents (4.73% and 4.53%), which simple mixing cannot produce and which may reflect moisture loss during blending, sieving or storage.

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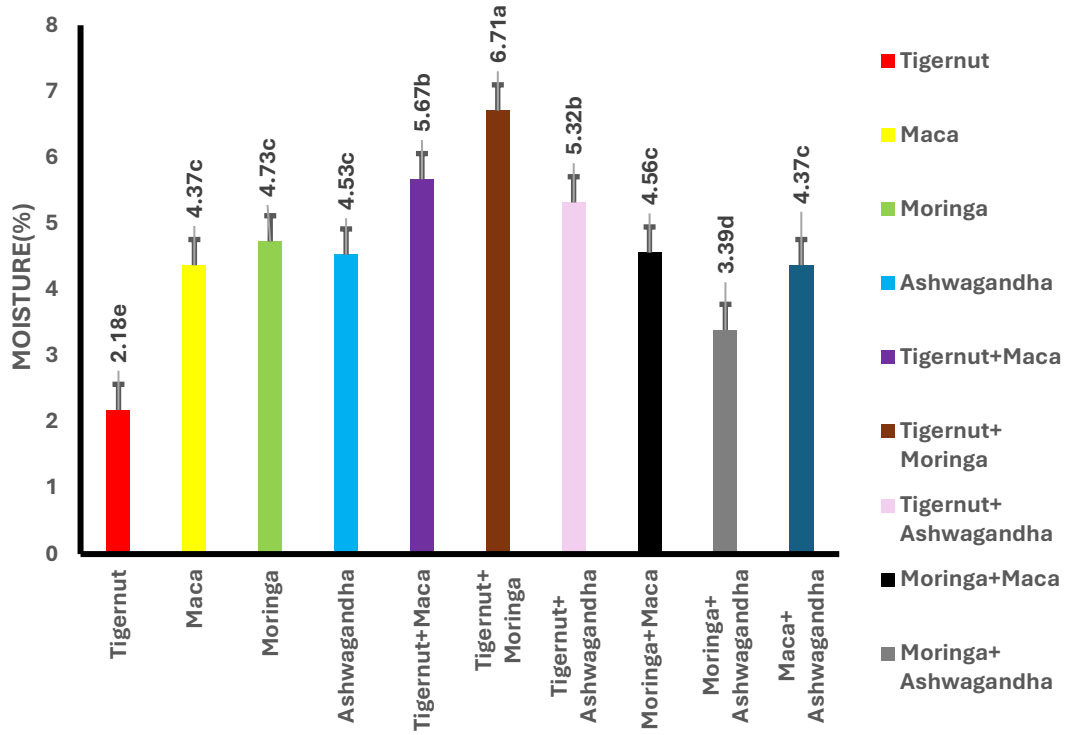

Figure 1: Moisture Content of Tiger Nut, Maca Powder, Ashwagandha and Moringa Leaf Powder Composite Blends.

Protein Content of Tiger Nut, Maca Powder, Ashwagandha, and Moringa Leaf Powder Composite Blends

Moringa leaf powder recorded the highest protein content among the individual ingredients (46.06%), significantly different ($P<0.01$) from all other treatments, followed by maca powder (13.40%), ashwagandha (7.27%), and tiger nut (5.46%). Among the binary blends, protein content ranged from 10.71% in Tigernut + Ashwagandha to 16.96% in Maca + Ashwagandha, with no significant difference recorded between Maca + Ashwagandha (16.96%) and Moringa + Ashwagandha (16.9%). Moringa + Maca (13.84%) recorded no significant difference from maca powder alone.

The protein content recorded for moringa leaf powder in this study was considerably higher than values reported in the literature. Masitlha et al. (2024) reported a mean crude protein content of 27.22% for moringa leaves collected from Gaborone, Botswana, while Singh and Prasad (2013) reported values between 19.77% and 20.06% for dried moringa leaves, and Cao et al. (2023) reported that Moringa oleifera leaf protein is generally 20% or higher. The value exceeds the published ranges. It may reflect the composition of the commercial product, including leaf-to-stem ratio, cultivar, growing conditions and processing, which this study did not verify (Masitlha et al., 2024). The conversion factor of 6.25 also counts non-protein nitrogen as protein. The protein content recorded for maca powder (13.40%) fell within the range reported in the literature. Chen et al. (2017) reported a range of 9.31% to 21.02% for maca cultivated in different regions of China, which compares closely with the value obtained in this study, while Peres et al. (2020) reported a narrower range of 8.9% to 11.6%, slightly below the present finding. The protein content recorded for ashwagandha (7.27%) was higher than several previously reported values. Kumari and Gupta (2016) reported 3.9 g/100 g, Veer et al. (2019) reported 3.3% protein, and Singirala et al. (2025) reported 3.9 g protein per 100 g of ashwagandha. This difference may be attributed to the part of the plant used, the drying method applied, and the soil and cultivation conditions, all of which are known to influence the proximate composition of Withania somnifera (Singirala et al., 2025). The protein content recorded for tiger nut (5.46%) was higher than reported in several previous studies. Suleiman et al. (2018) reported 2.83%, while Abdulrasheed et al. (2023) reported a range of 2.83% to 3.34%. Imafidon and Emumejakpo (2026) reported 4.57% for tubers from Benin City, which is also lower than the present value. Yu et al. (2022) reported a slightly wider range of 3.28% to 8.45%, which encompasses the present finding. As a starchy, lipid-rich tuber, tiger nut typically records low protein content relative to other proximate fractions.

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Among the binary blends, Maca + Ashwagandha and Moringa + Ashwagandha recorded the highest protein content, reflecting the relatively high individual protein contribution of ashwagandha, maca, and moringa leaf powder. Tigernut + Ashwagandha recorded the lowest protein content among the blends, consistent with the principle that combining two comparatively low-protein ingredients in a 50:50 ratio dilutes the protein content of the resulting mixture (Peres et al., 2020; Dimina et al., 2022).

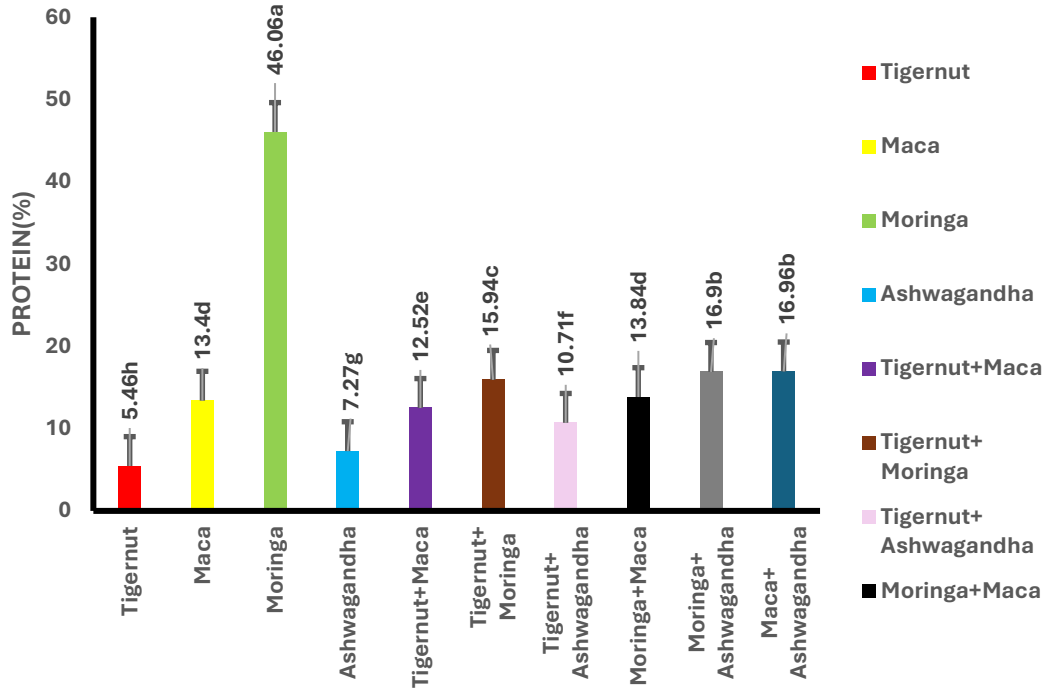

Figure 2: Protein Content of Tiger Nut, Maca Powder, Ashwagandha and Moringa Leaf Powder Composite Blends.

Crude Fat Content of Tiger Nut, Maca Powder, Ashwagandha, and Moringa Leaf Powder Composite Blends

Tiger nut recorded the highest fat content among the individual ingredients (21.8%), significantly different ($P<0.01$) from all other treatments, followed by maca powder (6.66%), moringa leaf powder (5.6%), and ashwagandha (4.57%), with each ingredient differing significantly from the other. Among the binary blends, fat content ranged from 5.65% in Moringa + Ashwagandha to 15.66% in Tigernut + Ashwagandha, with no significant difference recorded between Tigernut + Ashwagandha (15.66%) and Tigernut + Maca (15.34%). Blends containing tiger nut recorded the highest fat values overall, ranging from 14.56% to 15.66%, while blends without tiger nut fell within a markedly lower range of 5.65% to 8.22%.

The fat content recorded for tiger nut in this study was lower than several previously reported values. Knazicka et al. (2026) cited fat contents of 20% to 38% for tiger nut tubers, while Coşkuner et al. (2002) reported a crude lipid content of 24.5% for chufa lines grown in Çukurova, Turkey. Wang et al. (2021) similarly reported a crude oil content range of 24.9% to 28.9%. Imafidon and Emumejakpo (2026) reported 26.53% for tubers from Benin City, which is also above the present value. The difference may be attributed to variation in tuber maturity at harvest, drying conditions, and cultivar differences, all of which are known to affect fat accumulation in tiger nut tubers (Wang et al., 2021). The fat content recorded for moringa leaf powder (5.6%) was higher than values reported in comparable studies. Ogbe and Affiku (2011) reported a crude fat content of 2.11% for moringa leaves harvested from Lafia, Nigeria, while Khalid et al. (2023) reported 2.82%. Karim et al. (2013), however, reported a comparable value of 6.49% for moringa leaf powder used as a fortificant in yam flour. The relatively higher value recorded in this study may be attributed to varietal differences, leaf maturity at harvest, and the commercial drying and milling process applied before the powder was purchased (Ogbe and Affiku, 2011). The fat content recorded for maca powder (6.66%) was considerably higher than values reported in the literature. Chen et al. (2017) reported a crude lipid content of only 0.59% to 1.00% for maca cultivated in different regions of China,

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while Wang and Zhu (2019) reported approximately 2.2% for maca hypocotyls. This difference may reflect a different ecotype, area of cultivation, or a less refined commercial powder retaining a higher proportion of the native lipid fraction than the samples used in the cited studies. The fat content recorded for ashwagandha (4.57%) was substantially higher than reported values for Withania somnifera root powder. Veer et al. (2019) reported a fat content of 0.9% and Kumari and Gupta (2016) reported 0.3 g per 100 g. Krishnamurthy and Sarala (2010), however, reported that ashwagandha seeds recorded a fat content as high as 13.86%, considerably higher than the value obtained in this study, while the leaves recorded a comparatively low fat content. The relatively higher fat content observed for ashwagandha in this study may therefore be attributed to possible incorporation of seed fraction during processing, or to differences in the plant part used, drying method, and geographical origin (Krishnamurthy and Sarala, 2010). Among the binary blends, Tigernut + Ashwagandha and Tigernut + Maca recorded the highest fat content, followed by Tigernut + Moringa, consistent with the high individual fat content of tiger nut. The lowest fat content was recorded in Moringa + Ashwagandha, which was not significantly different from moringa leaf powder alone, reflecting the comparatively low fat content of both ingredients individually. Maca + Ashwagandha recorded a fat content not significantly different from maca powder alone. This pattern is consistent with the principle that the fat content of a composite blend is a function of the proportional fat contribution of its constituent ingredients (Chen et al., 2017).

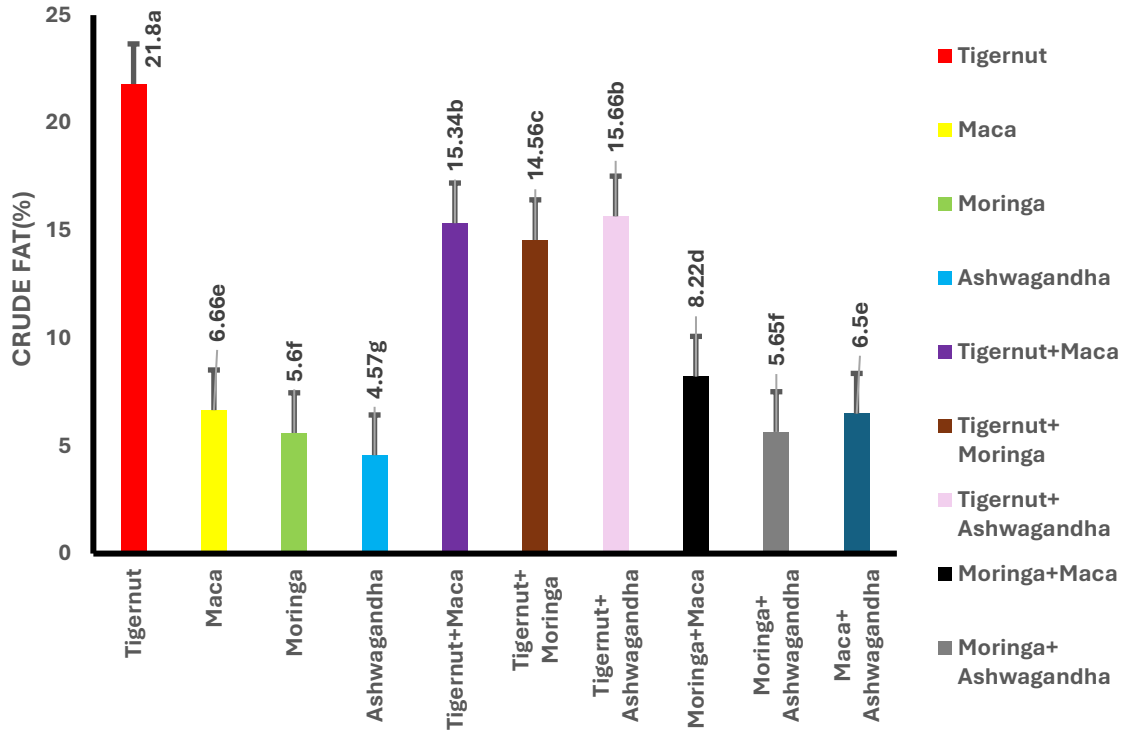

Figure 3: Fat Content of Tiger Nut, Maca Powder, Ashwagandha and Moringa Leaf Powder Composite Blends.

Crude Fibre Content of Tiger Nut, Maca Powder, Ashwagandha, and Moringa Leaf Powder Composite Blends

Moringa leaf powder recorded the highest crude fibre content among the individual ingredients (28.05%), significantly different ($P<0.01$) from all other treatments, followed by ashwagandha (16.12%), tiger nut (5.06%), and maca powder (3.42%), with each ingredient differing significantly from the other. Among the binary blends, crude fibre content ranged from 5.04% in Tigernut + Maca to 26.38% in Moringa + Ashwagandha. Moringa + Ashwagandha recorded the highest crude fibre content among the blends and differed significantly from moringa leaf powder alone ($P<0.01$). No significant difference was recorded between Tigernut + Ashwagandha (18.97%) and Maca + Ashwagandha (18.47%), among tiger nut (5.06%), Tigernut + Maca (5.04%), and Moringa + Maca (5.27%).

The crude fibre content recorded for tiger nut (5.06%) was lower than values reported in several previous studies. Imafidon and Emumejakpo (2026) reported a crude fibre content of 7.50% for tiger nut tubers, while Coşkuner

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et al. (2002) reported 8.91% for chufa lines cultivated in Çukurova, Turkey, and Yu et al. (2022) reported 7.48% and 13.97% for raw and processed tiger nuts respectively. This difference may be attributed to the milling and sieving process used in sample preparation, which involved passing the dried tubers through a 1.00 mm mesh screen, potentially reducing the proportion of larger, fibre-rich particle fractions retained in the resulting powder (Cheng et al., 2023; Chikpah et al., 2020).

The crude fibre content recorded for moringa leaf powder (28.05%) was considerably higher than values reported in similar studies. Ogbe and Affiku (2011) reported crude fibre content ranging from 6.00% to 9.60% for moringa leaves collected from Lafia, Nigeria. This difference may be attributed to cultivar differences, leaf maturity at harvest, and the processing methods used in preparing the commercial powder (Ogbe and Affiku, 2011; Krah et al., 2022). The crude fibre content recorded for maca powder (3.42%) was significantly lower than that reported in the literature. Peres et al. (2020) reported a fibre content ranging from 8.2% to 9.1% for the dry maca hypocotyl. The lower fibre content observed in this study may be explained by the use of a different ecotype, growing area, or a more refined commercial processing method that retains less fibrous hypocotyl material (Peres et al., 2020). The crude fibre content recorded for ashwagandha (16.12%) was lower than some previously reported values. Singirala et al. (2025) reported that ashwagandha leaves and roots contain 28.8% dietary fibre, considerably higher than the value obtained in this study. This difference may be attributed to the part of the plant used, drying conditions, and the geographical source of the material, all of which have been found to significantly affect the proximate composition of Withania somnifera powders (Singirala et al., 2025). Among the binary blends, Moringa + Ashwagandha recorded the highest crude fibre content, reflecting the substantial individual contribution of moringa leaf powder, the highest-fibre ingredient in the study. Tigernut + Ashwagandha and Maca + Ashwagandha recorded comparable, intermediate fibre content, reflecting the contribution of ashwagandha as the second-highest fibre ingredient. Tigernut + Maca recorded the lowest fibre content among the blends, consistent with the comparatively low individual fibre contributions of both tiger nut and maca powder. Proportional contribution of the parent ingredients explained the fibre content of some blends but not others: Tigernut + Ashwagandha (18.97%) and Maca + Ashwagandha (18.47%) exceeded both parents, and Moringa + Maca (5.27%) fell far below the 15.7% expected from its parents.

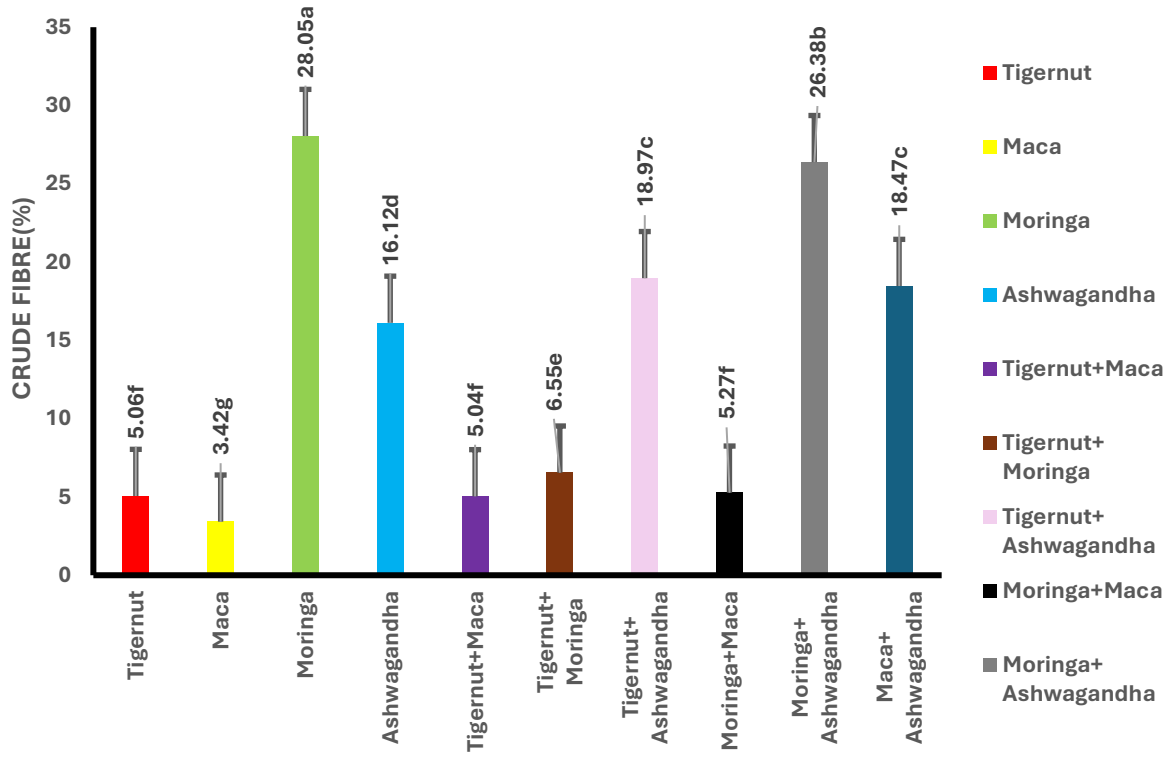

Figure 4: Crude Fibre Content of Tiger Nut, Maca Powder, Ashwagandha and Moringa Leaf Powder Composite Blends.

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NFE Carbohydrate Content of Tiger Nut, Maca Powder, Ashwagandha, and Moringa Leaf Powder Composite Blends

Maca powder recorded the highest carbohydrate content among the individual ingredients (69.98%), significantly different ($P<0.01$) from all other treatments, followed by tiger nut (63.17%), ashwagandha (58.43%), and moringa leaf powder (7.39%), with each ingredient differing significantly from the other. Among the binary blends, carbohydrate content ranged from 39.66% in Moringa + Ashwagandha to 63.64% in Moringa + Maca. No significant difference was recorded between tiger nut (63.17%) and Moringa + Maca (63.64%), or between ashwagandha (58.43%) and Tigernut + Maca (59.35%). Tigernut + Moringa (53.2%), Maca + Ashwagandha (49.53%), Tigernut + Ashwagandha (45.12%), and Moringa + Ashwagandha (39.66%) each differed significantly from all other treatments.

The carbohydrate content recorded for tiger nut (63.17%) was higher than the values reported in previous studies. Knazicka et al. (2026) cited a carbohydrate content of about 47% for tiger nut tubers, lower than the value obtained in this study, while Olapade et al. (2021) reported 29.98% to 53.08% for tiger nut flours processed by roasting, fermentation or germination (30.93% and 31.28% for fresh and dried untreated flours), and Ogunka-Nnoka et al. (2020) reported 46.88% to 49.01% for air-dried, blanched, fermented and dehydrated tiger nut, all lower than the present finding. Imafidon and Emumejakpo (2026) also reported a lower value of 50.89% for tubers from Benin City. The lower carbohydrate values of the untreated flours in Olapade et al. (2021) coincide with their higher crude fibre (28.06% to 40.98%), since carbohydrate is calculated by difference. The differences observed relative to the literature may be attributed to tuber maturity, drying method, and processing conditions applied prior to milling (Olapade et al., 2021). The carbohydrate content recorded for moringa leaf powder (7.39%) was considerably lower than values reported in similar studies. Ogbe and Affiku (2011) reported a carbohydrate content of 63.11% for moringa leaves grown in Lafia, Nigeria, Sultana (2020) reported a range of 47.25% to 56.25% across five local cultivars, and Khan et al. (2023) reported 40.98% for dehydrated moringa leaf powder fortified in bread. The low carbohydrate content recorded in this study is consistent with the unusually high crude fibre (28.05%) and crude protein (46.06%) content recorded for the same ingredient, since carbohydrate content is calculated by difference (Onwuka, 2005). The carbohydrate content recorded for maca powder (69.98%) was higher than values reported in the literature. Peres et al. (2020) reported that dry maca is composed of 54.6% to 60% carbohydrates, lower than the value obtained in this study. The higher value recorded for maca powder may be attributed to the comparatively low crude fibre content (3.42%) recorded for the same ingredient, which would proportionately raise the calculated carbohydrate value, alongside possible differences in ecotype, cultivation zone, and the extent of commercial processing (Peres et al., 2020). The carbohydrate content recorded for ashwagandha (58.43%) falls within a reasonable range given the relatively low crude fibre (16.12%) and crude fat (4.57%) content recorded for the same ingredient, which would proportionately raise the calculated carbohydrate fraction (Onwuka, 2005). Among the binary blends, Moringa + Maca recorded the highest carbohydrate content, not significantly different from tiger nut alone, indicating that maca powder contributes substantially to the carbohydrate content of the blend despite the very low carbohydrate content of moringa leaf powder. Tigernut + Maca recorded a carbohydrate content not significantly different from ashwagandha alone, reflecting the substantial individual contribution of both tiger nut and maca powder. Tigernut + Moringa recorded a comparatively lower value, reflecting the diluting effect of moringa leaf powder's low carbohydrate content on the blend. Moringa + Ashwagandha recorded the lowest carbohydrate content among the blends, consistent with the relatively high crude fibre and fat content contributed by ashwagandha, while Maca + Ashwagandha and Tigernut + Ashwagandha recorded intermediate values, still significantly lower than their non-ashwagandha counterpart blends. This pattern supports the principle that carbohydrate content, being calculated by difference, is inversely related to the combined proximate profile of protein, fat, fibre, and ash in a given blend (Onwuka, 2005).

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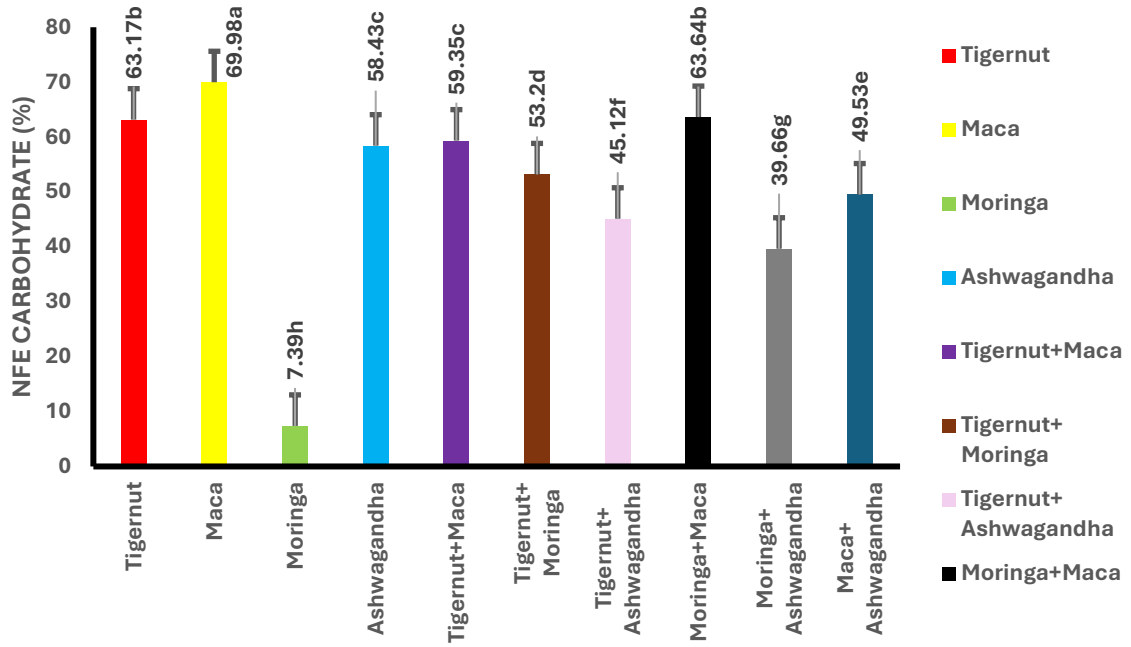

Figure 5: NFE Carbohydrate Content of Tiger Nut, Maca Powder, Ashwagandha and Moringa Leaf Powder Composite Blends.

Total Ash Content of Tiger Nut, Maca Powder, Ashwagandha, and Moringa Leaf Powder Composite Blends

Ashwagandha recorded the highest total ash content among the individual ingredients (9.08%), significantly different ($P<0.01$) from all other treatments, followed by moringa leaf powder (8.16%), tiger nut (2.33%), and maca powder (2.17%), with no significant difference recorded between tiger nut and maca powder. Among the binary blends, total ash content ranged from 2.08% in Tigernut + Maca to 8.02% in Moringa + Ashwagandha. Moringa + Ashwagandha recorded the highest total ash content among the blends and was not significantly different from moringa leaf powder alone. No significant difference was recorded between Tigernut + Ashwagandha (4.22%), Moringa + Maca (4.48%), and Maca + Ashwagandha (4.16%), or among tiger nut (2.33%), maca powder (2.17%) and Tigernut + Moringa (3.05%), or among tiger nut, maca powder and Tigernut + Maca (2.08%), although Tigernut + Moringa and Tigernut + Maca differed from each other.

The total ash content recorded for tiger nut (2.33%) was lower than the values reported in some studies and close to those in others. Ogunka-Nnoka et al. (2020) reported ash contents of 4.97% to 6.20% for air-dried, blanched, fermented and dehydrated tiger nut, higher than the value obtained in this study, while Nwosu et al. (2022) reported ash contents of 2.27% and 2.70% for n-hexane and ethanol extracts respectively, closely matching the present finding. Imafidon and Emumejakpo (2026) reported a higher value of 3.00% for tubers from Benin City, while Olapade et al. (2021) reported 1.50% to 2.03% for untreated tiger nut flours, slightly below the present value. Aduwamai et al. (2018), however, reported a lower value of 1.47% for fried tiger nut samples.

The total ash content recorded for moringa leaf powder (8.16%) fell within the range reported in similar studies. Ogbe and Affiku (2011) reported an ash content range of 8.05% to 10.38% for moringa leaves collected from Lafia, Nigeria, which encompasses the value obtained in this study, further corroborating the characterisation of Moringa oleifera leaves as a mineral-rich plant material. The total ash content recorded for maca powder (2.17%) was lower than the value reported in the literature. Peres et al. (2020) reported an ash content of 5.0% for dry maca, considerably higher than the value obtained in this study. This difference may be attributed to variation in ecotype, cultivation area, and processing methods, since more extensively processed maca powders may undergo procedures that reduce mineral matter content relative to less refined ones (Peres et al., 2020). The total ash content recorded for ashwagandha (9.08%) was the highest among all four ingredients studied, consistent with its recognised mineral density. This elevated value reflects the substantial mineral matter content documented for Withania somnifera root powder in the literature (Singirala et al., 2025). Among the binary blends, Moringa + Ashwagandha recorded the highest total ash content, reflecting the combined contribution of the two highest

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ash-containing ingredients in the study. Moringa + Maca, Tigernut + Ashwagandha, and Maca + Ashwagandha recorded intermediate, statistically indistinguishable values, indicating a diluting effect when an ash-rich ingredient is combined with one of relatively low ash content. Tigernut + Moringa recorded an intermediate value not significantly different from tiger nut or maca powder alone, reflecting the relatively small contribution of moringa leaf powder to this particular blend despite its high individual ash content. Tigernut + Maca recorded the lowest total ash content among the blends, consistent with the comparatively low individual ash content of both tiger nut and maca powder. This pattern confirms that the ash content of a composite blend is largely dependent on the ash contribution of its constituent ingredients (Ogbe and Affiku, 2011).

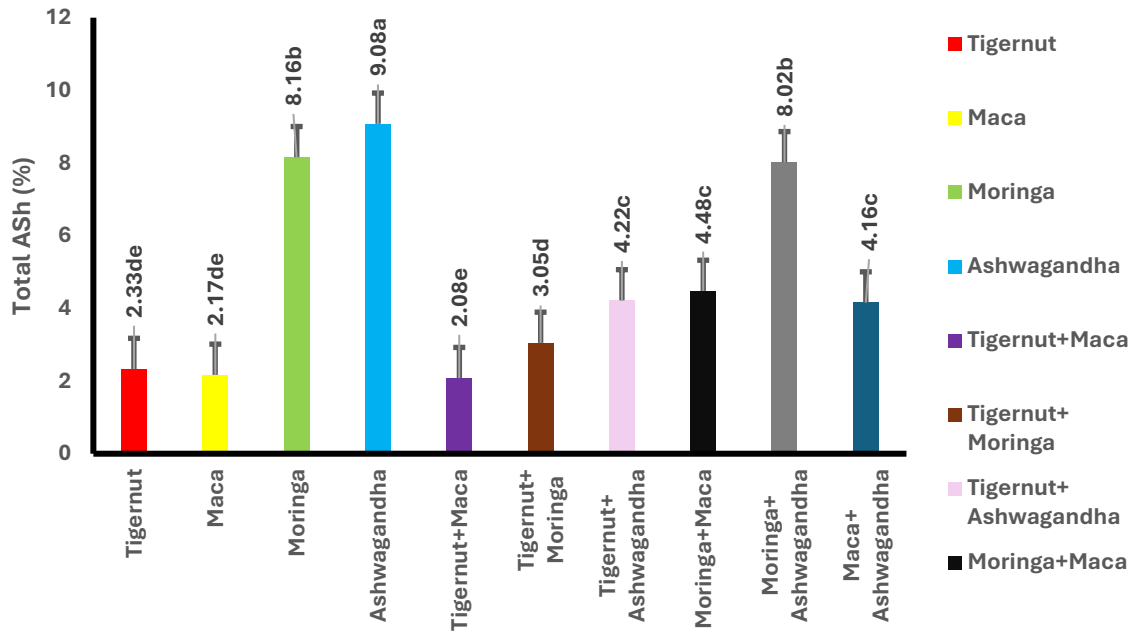

Figure 6: Total Ash Content of Tiger Nut, Maca Powder, Ashwagandha and Moringa Leaf Powder Composite Blends.

Deviation of Blends from Additive Expectations

For a 50:50 blend, the expected value of each parameter is the mean of the two parent values, and the measured value should lie between them. Moisture fell outside the parent range in four of the six blends (Tigernut + Maca, Tigernut + Moringa, Tigernut + Ashwagandha and Moringa + Ashwagandha). Protein in Moringa + Maca (13.84%) matched maca powder alone and fell below the expected 29.73%, and protein in Moringa + Ashwagandha (16.9%) fell below the expected 26.7%. Protein in Maca + Ashwagandha (16.96%) and crude fibre in Maca + Ashwagandha (18.47%) and Tigernut + Ashwagandha (18.97%) exceeded both parents, while crude fibre in Moringa + Maca (5.27%) fell below the expected 15.7%.

Fine moringa powder differs from the other powders in particle size and density, so analytical portions of 1 to 2 g may not represent a 50:50 mixture evenly. The rankings among blends are therefore indicative, and the deviations from additive expectations need confirmation in further trials.

The moringa leaf powder (46.06% protein, 28.05% crude fibre), maca powder (6.66% fat) and ashwagandha (4.57% fat) were single commercial lots of unverified composition, and their values exceed published ranges. Plant part, cultivar, growing conditions and processing differ among suppliers, so the values apply to these lots only.

CONCLUSION

In conclusion, the proximate composition of tiger nut, maca powder, ashwagandha, and moringa leaf powder, individually and as binary blends, was assessed, and Moringa + Ashwagandha recorded the highest crude fibre (26.38%) and total ash (8.02%) content and the lowest moisture (3.39%) among the binary blends, making it the

strongest blend for fibre, ash and low moisture. Moringa leaf powder alone was most effective for protein (46.06%) and crude fibre (28.05%) enrichment, while tiger nut recorded the highest fat content (21.8%) among the individual ingredients. Binary blending did not consistently follow the proportional contribution of the parent ingredients: protein, crude fibre and moisture in several blends fell outside the range of their parents, and these deviations need confirmation with independent blend batches.

I. Recommendations

The following recommendations were made.

1. Sensory evaluation of the binary blends, particularly Moringa + Ashwagandha, is recommended to assess consumer acceptability in terms of taste, aroma, colour, and texture before commercial product development.
2. Further studies should assess the mineral, antinutrient, and antioxidant properties of these blends to provide a more complete understanding of their nutritional and functional value.
3. Future work should repeat the study with additional independent blend batches and confirm the composition of commercial powders (plant part, cultivar and supplier certificate) to resolve the deviations from additive expectations.

Author Contributions

Paul Atambire Amaliya contributed to the conceptualisation, methodology, data curation, formal analysis, and writing of the original draft. Newton Kweku Amaglo contributed to the supervision and review and editing of the manuscript. Ebenezer Kwasi Ntiri contributed to the planning, co-supervision, review and editing of the draft.

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Conflicts of Interest

The authors declare that they have no conflict of interest.

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