**Exploring the functional properties of organ powders from *Corchorus olitorius* and *Abelmoschus esculentus* in chronic disease management**

**ABSTRACT**

**Aims:** To determine the functional properties of *Abelmoschus esculentus* (AE) and *Corchorus olitorius* (CO) leaf and fruit powders and their relationship with antioxidant activity and essential nutrients.

**Methodology**: Fresh leaves and fruits of these plants were harvested and processed into powders. Functional properties such as oil absorption capacity (OAC), water absorption capacity (WAC), solubility index (WSI), and porosity were evaluated. Data on nutritional composition and antioxidant activities were obtained from previous studies.

**Results:** It was found that the fruit powders of CO and the leaf powders of AE exhibited the highest mean OAC values of 413.42 ± 2.47 and 342.60 ± 3.04%, respectively. The fruit powders of CO and AE presented high true WAC values of 84.38 ± 0.25 and 81.87 ± 0.31%, high water solubility index (WSI) values of 75.71 ± 1.04 and 66.23 ± 3.76%, and high porosity values of 0.33 ± 0.01 and 0.49 ± 0.01%, respectively. These functional properties of the powders were associated with their antioxidant activity and essential nutrient content. Three distinct powder groups emerged: fruit powders of CO and leaf powders of AE; leaf powders of CO; and fruit powders of AE. These powders exhibited low, moderate, and high antioxidant activity (DPPH, ABTS, FRAP), respectively. The powders in the first group, rich in energy and crude fiber but low in polyphenols, were associated with high OAC values. Those in the second group, rich in essential nutrients and polyphenols, were associated with high WAC and WSI values, while the powders in the third group, rich in minerals and flavonoids, were associated with high WAC, WSI, and porosity values.

**Conclusion:** The fruit powder of AE, followed by the leaf powder of CO, with significant antioxidant activity, appears to be the most suitable for use as dietary supplement powders in the management of chronic diseases.

***Keywords:*** *Plant organ powders; functional properties; antioxidant activity; essential nutrients*

1. **INTRODUCTION**

The consumption of **functional plant-based food powders** is particularly favored among populations that have preserved **traditional dietary habits**. These powders serve as **raw materials** for preparing **decoctions and infusions** (Assiéné et al., 2024).. However, the most preferred or recommended form of consumption by many therapists is as a **dietary supplement**, meaning that the powder is added to dishes to enhance **not only its nutritional value but also its bioactive potential** (Assiéné et al., 2015). In this form, the powders offer the advantage of being **fully consumed**, leaving no residual waste. Nevertheless, additional components such as **vegetable oils, water for reconstitution, excipients, and additives** are often added to these powders, without considering the effects of these substances on the **stability, bioaccessibility, and biological activities** (antioxidant activity) of the powders. Yet, a **preliminary study of the functional properties** of these powders would help better understand their behavior. Failing to do so represents a **significant oversight**.

When a powder exhibits **antioxidant activity** and **nutritional potential**, it is crucial to assess characteristics such as **water absorption capacity (WAC), Water solubility index (WSI), oil absorption capacity (OAC)**, and other parameters that generally influence the **stability, bioaccessibility of antioxidants and nutrients, and technological performance**. Indeed, the **bioaccessibility of antioxidants and nutrients** in a powder is highly dependent on its **functional properties (Bochnak-Niedźwiecka & Świeca, 2020).** Adequate **solubility** ensures **homogeneous dispersion**, facilitating the **absorption of antioxidants and certain nutrients** (Li et al., 2020). Likewise, **WAC and OAC** influence the **texture and stability** of food formulations incorporating the powder (Aye & Adegun, 2013).. A powder with **low WAC** may be **more susceptible to oxidation**, thereby reducing the effectiveness of its antioxidants (Li et al., 2020) (Bochnak-Niedźwiecka & Świeca, 2020). Furthermore, **lipid interactions** play a key role in **dietary supplement formulation**. A powder with **good oil absorption capacity** can enhance the protection of **liposoluble antioxidants**, such as **carotenoids (provitamin A) and vitamin E**, against degradation (Ruru et al., 2022). Recent studies have shown that **polyphenols and flavonoids** present in certain plant powders may exhibit **reduced effectiveness** if the **food matrix** does not allow for **proper release and absorption** of bioactive molecules (Bochnak-Niedźwiecka & Świeca, 2020). In this regard, **plant powders** that have particularly drawn attention, such as ***Abelmoschus esculentus*** and ***Corchorus olitorius***, which contain **significant levels of bioactive compounds and nutrients** (Assiéné, Djeukeu, et al., 2025), may be subject to these same limitations when used as **dietary supplements**.

***Abelmoschus esculentus***, or **okra**, is a vegetable plant from the **Malvaceae family**, primarily cultivated for its **edible immature fruit**. It thrives in **tropical and subtropical regions** worldwide and is found in **East and Central Africa** (Bawa & Badrie, 2016). All its **organs** (leaves, flowers, stems, seeds) are **edible**, with leaves and fruits being **rich in minerals, proteins, sugars, fibers, and various bioactive compounds (Sha’a et al., 2019). *Corchorus olitorius* (Malvaceae)**, on the other hand, originates from **tropical and subtropical regions** worldwide and is present in several African countries, including **Egypt, Ivory Coast, Benin, Nigeria, and Cameroon**. Its **leaves**, commonly consumed as **leafy vegetables** due to their viscosity, are used to treat a **wide range of diseases** such as **dysentery, malaria, fever, and gonorrhea**. The **fruits** of this plant, like those of ***Abelmoschus esculentus***, are **rich in minerals, proteins, sugars, fibers, and bioactive compounds (Sha’a et al., 2019)**.

Recent studies on the **leaves and fruits** of ***Abelmoschus esculentus*** and ***Corchorus olitorius*** have demonstrated **high levels of nutrients, polyphenols, and various bioactive compounds**, along with **significant antioxidant activity**, highlighting the importance of these two matrices (Assiéné, Djeukeu, et al., 2025). However, **no information** regarding the **functional properties** of these powders has been mentioned in this work. Yet, it is evident that these properties provide **insight into the behavior of these powders** during any form of utilization. Based on this observation, this study aims to **determine the functional properties of *Abelmoschus esculentus* and *Corchorus olitorius* leaf and fruit powders** and their **relationship with antioxidant activity and essential nutrients**.

1. **MATERIAL AND METHODS**

**2.1. Organ sampling**

The organs of *Abelmoschus esculentus* and *Corchorus olitorius* (leaf and fruit), which are commonly consumed, were harvested early in the morning in the Mboppi district, Douala 1er. Both plant matrices were identified by the Cameroon herbarium:

* *Abelmoschus esculentus*: The specimen was identified in comparison with the herbarium material of Westphal collector 9069 from Herbarium collection specimen number 42868 SRFCam.
* *Corchorus olitorius*: The specimen was identified by comparison with the herbarium material of Westphal collector 10077 from herbarium collection specimen number 44871 SRFCam.

**2.2. Powder production**

The powders were produced in accordance with the requirements reported by Assiéné et al. (2025). Fresh, dark-green leaves and fresh, tender fruits (with seeds) were cleaned, washed, and cut into pieces smaller than 5 mm. The samples were dried at 30 and 35 °C for 5 and 10 hours, respectively, in a Stockli dehydrator, Dorrex, France. The dehydrated materials were ground to a particle size smaller than 500 µm (the particle size of the powders most commonly used by therapists), and the resulting powders were stored in opaque, airtight boxes at room temperature.

**2.3. Determination of functional properties**

**2.3.1. Oil Absorption Capacity**

The oil absorption capacity (OAC) was determined by the modified method of Beuchat (1977). A mass in grams (M0) of powder was mixed with a volume (V) in millilitres (ratio 1:6 mass/volume) of different types of oil (palm kernel oil, red palm oil, olive oil, and soybean oil). Each of these oils, whose main characteristics (fatty acids) are presented in Table 1, was purchased from supermarkets. The mixture was agitated for 30 min using a mechanical shaker (Prolabo n ° 54 433 France) at 220 rpm and centrifuged at 3500 rpm for 30 min in a centrifuge (DL 6000 brand, rotor 15 cm, Japan). The collected pellet was then weighed (M1) and the OAC is expressed as the mass of oil retained per 100 g of powder by the formula.

$$OAC= {[\left(M\_{1}-M\_{0}\right)}/{M\_{0}}] x 100$$

Table 1: Main fatty acid percentages of different oils

|  |  |  |  |
| --- | --- | --- | --- |
| Oil  | Saturated fatty acids (SFA) | Monounsaturated fatty acids (MUFA) | Polyunsaturated fatty acids (PUFA) |
| Palm kernel  | 82 | 15.4 | 2.5 |
| Red palm  | 51 | 39 | 10 |
| Olive | 14 | 77 | 9 |
| Soybean  | 15 | 23 | 62 |
|  |

**2.3.2. Water Absorption Capacity and Water Solubility Index**

The water absorption capacity (WAC) and water solubility index (WSI) were evaluated according to methods of Phillips et al. (1988) and Anderson et al. (1969), respectively. One gram of powder (W0) was suspended in 10 ml of distilled water, mixed for 60 min in a shaking water bath (Kottermann, Germany) set at 37 °C and centrifuged at 5000 rpm for 30 min. The pellet was collected, weighed (W1), and dried at 105 °C for 24 hours, after which the weight of the dry residue (W2) was determined. The following formulas were used to calculate these different variables and are expressed in g/100 g DM.

$$WAC\_{t}=[(W\_{1}-W\_{2})/W\_{1}] x 100$$

$$WAC\_{a}=[(W\_{1}-W\_{0})/W\_{1}] x 100$$

$$WSI=[(W\_{2}- W\_{0})/W\_{0}] x 100$$

WACt : true water absorption capacity; WACa : apparent water absorption capacity

**2.3.3. True Density, Bulk Density, and Porosity**

The modified methods of Adebowale et al. (2005) and Samejina et al. (1982) were used to determine the true density (TD), bulk density (BD), and porosity (P) of powders. A portion of the powder (W1) was placed in a tarred capsule of known volume (V1). The capsule was tamped several times to eliminate the empty space between particles, and the obtained volume was noted (V2). Once the capsule was full, the whole capsule was weighed (W2). TD, BD, and P were calculated according to the following equations: The results of TD and BD were expressed in grams of powder per unit of volume (g/ml).

$TD= W\_{1}/(V\_{1}-V\_{2})$ $BD=(W\_{2}-W\_{1})/V\_{1}$ $P=1-(BD/TD)$

**2.4. Data on macronutrient, mineral, bioactive compound, and antioxidant activity in the powders of *C. olitorius* and *A. esculentus* organs**

The data presented in Table 2 are part of the first phase of this research project and have already been published (Assiéné, Djeukeu, et al., 2025). Therefore, they cannot be considered as original results of this article. Instead, they are presented here as a reference database from which the relationship between bioactive compounds, nutrients and the functional properties of the powders can be determined.

Table 2: Macronutrients, mineral and bioactive contents and antioxidant activity of the leaves and fruit powders of *C. olitorius* and *A. esculentus* (Assiéné, Djeukeu, et al., 2025)

|  |  |  |
| --- | --- | --- |
| **Components**  | ***Abelmoschus esculentus*** |  ***Corchorus olitorius***  |
| **Leaves** | **Fruit** | **Leaves** | **Fruit** |
| **Macro nutrient content, Crude Fiber (g/100 g DM) and Energy (Kcal)** |
| Total protein  | 18.87 ± 0.10 | 15.52 ± 0.30 | 20.63 ± 0.10 | 10.42 ± 0.20 |
| Total lipid | 7.64 ± 0.03 | 2.70 ± 0.01 | 5.29 ± 0.01 | 1.81 ± 0.01 |
| Available Carbohydrate | 43.75 ± 0.30 | 57.35 ± 0.80 | 31.11 ± 0.16 | 56.71 ± 0.40 |
| Total ash  | 15.22 ± 0.10 | 7.61 ± 0.10 | 9.38 ± 0.20 | 12.95 ± 0.10 |
| Crude fiber  | 10.34 ± 0.20 | 7.26 ± 0.20 | 9.52 ± 0.20 | 13.04 ± 0.30 |
| Energy  | 319.24 ± 1.87 | 315.78 ± 4.49 | 254.57 ± 1.13 | 284.81 ± 2.49 |
| **Mineral content (mg/100 g DM)** |
| Iron (Fe) | 0.96 ± 0.01 | 1.29 ± 0.01 | 0.96 ± 0.01 | 0.96 ± 0.01 |
| Zinc (Zn) | 0.93 ± 0.01 | 2.70 ± 0.02 | 0.93 ± 0.01 | 0.93 ± 0.01 |
| Copper (Cu) | 3.08 ± 0.01 | 11.24 ± 0.20 | 19.45 ± 0.20 | 5.80 ± 0.02 |
| Calcium (Ca) | 1120.00 ± 2.03 | 1760.00 ± 3.03 | 1760.00 ± 3.20 | 1280.00 ± 2.30 |
| Magnesium (Mg) | 58.32 ± 1.19 | 257.58 ± 2.34 | 165.24 ± 1.30 | 9.72 ± 0.15 |
| Phosphorus (P) | 36.16 ± 1.34 | 302.57 ± 1.28 | 300.31 ± 3.98 | 6.30 ± 0.20 |
| Potassium (K) | 1139.32 ± 1.23 | 2684.62 ± 2.43 | 2466.43 ± 3.23 | 1866.53 ± 3.40 |
| Sodium (Na) | 73.92 ± 1.08 | 153.63 ± 2.78 | 142.20 ± 1.23 | 110.39 ± 2.01 |
| **Bioactive compounds**  |
| Total polyphenols (mg GAE/g DM) | 4.28 ± 0.10 | 95.10 ± 1.04 | 240.10 ± 1.99 | 50.10 ± 1.02 |
| Total flavonoids (mg QE/g DM) | 0.22 ± 0.01 | 15.03 ± 0.97 | 0.50 ± 0.05 | 0.45 ± 0.01 |
| Condensed tannins (mg CE/g DM) | 0.17 ± 0.01 | 0.30 ± 0.01 | 25.10 ± 1.05 | 0.15 ± 0.02 |
| **Antioxidant activity (IC50 µg/ml)** |  |  |  |
| DPPH  | 19.38 ± 0.50 | 11.07 ± 1.64 | 18.06 ± 1.04 | 44.44 ± 2.26 |
| ABTS | 47.04 ± 1.19 | 18.04 ± 1.94 | 16.17 ± 1.35  | 32.71 ± 1.24 |
| FRAP | 30.28 ± 2.07 | 23.17 ± 1.35 | 22.52 ± 0.15 | 33.30 ± 2.42 |
| GAE: Gallic Acid Equivalent; QE: Quercetin Equivalent; CE: Catechin Equivalent; DPPH: 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity assay; ABTS: 2,2′-Azinobis-(3-ethylbenzothiazoline-6- sulphonic acid; FRAP: Ferric reducing antioxidant power; IC50: is the concentration of a substance required to rduce the activity of a given target by 50% |

**2.9. Statistical analysis**

Analyses were carried out in triplicate. Microsoft Excel 2016 software was used for the calculation of means and standard deviations. Statgraphic Centurion 15.2 software (StatPoint Technologies, Inc., Warrenton, Virginia, USA) was used for analysis of variance (one-way ANOVA and multiple way ANOVA) and the means were separated using the Duncan multiple range test at P < .05.

1. **RESULTS AND DISCUSSION**
	1. **Functional properties of leaf and fruit powders**
		1. **Oil Absorption Capacity**

The addition of oils to plant-based food powders is a common practice among many therapists in the preparation of functional foods. However, these additions often overlook the oil absorption capabilities of these powders, focusing instead on the health benefits derived from combining the two raw materials. However, the homogeneity of the mixture, its presentation (such as pastes, dough, or suppositories), and its handling during various uses depend closely on the type of oil and the properties of the powder. One such property is the oil absorption capacity (OAC), defined as the amount of oil in grams retained per hundred grams of powder (Assiéné et al., 2021).

In this study, we evaluated the OAC of powders derived from the leaves and fruits of *Corchorus olitorius* (jute mallow) and *Abelmoschus esculentus* (okra) using four distinct oils: palm kernel, red palm, olive, and soybean. The average OAC values ranged from 334.93% to 413.40% for *C. olitorius* and from 321.39% to 342.72% for *A. esculentus*, with variations observed from leaves to fruits (Table 3). Notably, Assiéné et al. (2021) reported lower OAC values (257% to 261%) for *Moringa oleifera* leaf powders than those obtained in our study. Conversely, Aye & Adegun (2013) reported higher OAC values (745.60% to 820.16%) for leaf powders from several vegetable sources. Compared to the OAC values of starch-based powders (174.37% to 186.52%) reported by Y. N. Njintang et al. (2007), the vegetable powders in our study exhibited higher OACs. The observed differences are due to the content of powders containing lipophilic compounds, which have the ability to bind fatty acids from oils. Among these compounds, crude fibers (cellulose and hemicellulose) were significantly positively correlated with red palm oil (r= 0.965, p= .035) and soybean oil (r= 0.965, p= .034) in this study. These correlations indicate that the OAC increases with increasing content of crude fibers in the powders. This effect is particularly evident in the fruits of *C. olitorius* and the leaves of *A. esculentus*, where significant increases in fiber content (Table 2) correspond to maximal OAC values (Table 3). However, fibers are not the only lipophilic compounds found in the studied powders. Proteins are also present (Matsumura et al., 2017). Indeed, the high protein content in the powders from *A. esculentus* leaves (Table 2) may explain the high OAC observed. The lipophilic activity of the other powders studied is certainly not negligible.

For *C. olitorius*, the type of oil and the plant organ used for powder preparation had a moderate (p= .020) and highly (p= .001) significant influence on OAC variations of 2.22% and 94.38% respectively for *C. olitorius*. Similarly, for *A. esculentus*, the influence was highly significant for both oil type (p= .001) and plant organ (p= .001), resulting in OAC variations of 34.91% and 45.08%, respectively. It is evident that regardless of the oil type used, OAC levels are predominantly influenced by the lipophilic compound content of the studied powders.

**Table 3: Oil absorption capacity (OAC) of the leaves and fruit powders of *Corchorus olitorius* and *Abelmoschus esculentus***

|  |  |  |
| --- | --- | --- |
| Oil  | *Abelmoschus esculentus* (%) | *Corchorus olitorius* (%) |
| Leaves | Fruit | Leaves | Fruit |
| Palm kernel  | 338.00 ± 3.61Bb | 340.00 ± 1.14Ab  | 342.00 ± 3.33Aab | 409.57 ± 3.00Bab |
| Red palm  | 357.38 ± 3.66Bb | 327.23 ± 1.61Ab | 346.38 ± 3.80Ab | 420.00 ± 1.71Bb |
| Olive | 341.85 ± 2.14Ba | 314.04 ± 3.28Aa | 319.09 ± 2.14Aa | 421.80 ± 2.19Ba |
| Soybean  | 333.14 ± 2.76Ba | 303.71 ± 3.90Aa | 332.33 ± 3.19Aa | 402.33 ± 3.00Ba  |
| Mean | 342.60 ± 3.04 | 321.24 ± 3.31 | 334.95 ± 3.11 | 413.42 ± 2.47 |
| Mn ± Sd: Mean ± Standard deviation. The uppercase and lowercase letters assigned to each row and column mean, respectively, for each plant matrix, indicate a significant difference at the **probability threshold P < .05**. |

* + 1. **Water Absorption Capacity**

The leaf and fruit powders of Corchorus olitorius and Abelmoschus esculentus, rich in bioactive compounds such as polyphenols, flavonoids, tannins, and fibers with significant antioxidant activity (Assiéné, Djeukeu, et al., 2025), are commonly added to meals, beverages, yogurt, and various pharmaceutical products. Consequently, they can significantly impact the texture, viscosity, and sensory characteristics of these foods, affecting their overall acceptability to consumers (Yangilar, 2013). Therefore, it is crucial to assess the precise amount of powder to be added. To achieve this, a fundamental functional property must be determined: water absorption capacity (WAC) (the amount of water in grams absorbed per 100 grams of powder after saturation and centrifugation) for the relevant powders.

Table 4 presents the WAC values for the studied powders. The true water absorption capacities (WACt) ranged significantly from 82.52 ± 0.31% to 84.38 ± 0.25% for the *Corchorus olitorius* leaf and fruit powders, respectively. The apparent water absorption capacities (WACa) varied from 89.57 ± 0.05% to 91.11 ± 0.09% for the same plant parts. For *Abelmoschus esculentus* leaf and fruit powders, the WACt values ranged from 63.65 ± 0.12% to 81.87 ± 0.31%, while the WACa values ranged from 77.22 ± 0.17% to 89.09 ± 0.05%. Notably, these values exceed the reported WACt (27.02% to 28.98%) and WACa (32.88% to 35.88%) for *Moringa oleifera* leaf powders reported by Assiéné et al. (2021). However, these values are lower than the WACt (400% to 640%) reported for several leafy vegetables by Aye & Adegun (2013). Compared to the WACt (270.84% to 374.86%) of starchy food matrices (such as taro) added to meals for various techno-functional benefits, these values are significantly lower (Y. N. Njintang et al., 2007). These differences primarily arise from the chemical composition of these powders, including their fiber content, available sugars, proteins, starch, and potentially phenolic compounds (Yangilar, 2013).

Notably, the fruit powders from the studied plant matrices (*C. olitorius* and *A. esculentus*) exhibited the highest water absorption capacities (WACs) (Table 4). These powders have elevated levels of crude fibers, available sugars, and substantial protein content (Table 2) (Assiéné, Djeukeu, et al., 2025). The hydrophilic properties inherent in these compounds allow the powders to absorb both minimal and maximal amounts of water (Adebowale et al., 2005). This phenomenon likely explains the observed WACt and WACa values in our study. Specifically, dietary fibers are carbohydrate polymers with a degree of polymerization equal to or greater than three. They remain undigested and unabsorbed in the small intestine (Yangilar, 2013). Among these fibers, we find soluble fibers (such as fructo-oligosaccharides) and insoluble fibers (such as cellulose, hemicellulose, and lignin) (Mudgil, 2017). These compounds, including cellulose, hemicellulose, lignin, and various hydrophilic functional groups (such as hydroxyl [-OH], carboxyl [-COOH], and aldehyde [-COH]), play a crucial role in the water and oil absorption capacity as well as the swelling behavior of these powders (Mudgil, 2017). The presence of insoluble fibers in the powders offers several functional advantages, including increased volume of salts in the intestinal lumen, reduced transit time, and satiety effects. Additionally, proteins, which also possess carboxyl groups, have an amino functional group (−NH2) with hydrophilic properties that enhance the water absorption capacity of powders (Matsumura et al., 2017). This water absorption is also related to the solubility of the powders in water.

**Table 4: Water absorption capacity, density and porosity of the leaves and fruit powders of *Corchorus olitorius* and *Abelmoschus esculentus***

|  |  |  |
| --- | --- | --- |
| Properties | *Abelmoschus esculentus* | *Corchorus olitorius* |
| Leaves | Fruit | Leaves | Fruit |
| WACt (%) | 63.65 ± 0.12a | 81.87 ± 0.31b | 82.52 ± 0.31c | 84.38 ± 0.25d |
| WACa (%) | 77.22 ± 0.17a | 89.09 ± 0.05b | 89.57 ± 0.05c | 91.11 ± 0.09d |
| WSI (%) | 59.57 ± 1.76a | 66.23 ± 3.76b | 67.61 ± 3.90b | 75.71 ± 1.04c |
| P | 0.42 ± 0.01c | 0.49 ± 0.01d | 0.11 ± 0.02a | 0.33 ± 0.01b |
| TD (g/ml) | 0.29 ± 0.00d | 0.22 ± 0.00a | 0.27 ± 0.00c | 0.25 ± 0.00b |
| BD (g/ml) | 0.17 ± 0.00b | 0.11 ± 0.00a | 0.24 ± 0.00d | 0.19 ± 0.00c |
| Mn ± Sd: Mean ± Standard deviation; WACt: True Water Absorption Capacity; WACa: Apparent Water Absorption Capacity; SI: Solubility Index; P: Porosity; TD: True Density; BD: Bulk Density. The lowercase letters assigned to each row mean, distinct from one another, indicate a significant difference at the **probability threshold P < .05** |

* + 1. **Water Solubility Index, Porosity, and True and Bulk Densities**

The water solubility index (WSI) of a powder reflects its ability to dissolve in water. This functionality is essential for powders, particularly concerning their rehydration properties. In this context, the WSIs of the studied powders are presented in Table 4. Notably, the values vary significantly from 67.61 ± 3.90% to 75.71 ± 1.04% for the *C. olitorius* leaf and fruit powders, and from 59.57 ± 1.76% to 66.23 ± 3.76% for *A. esculentus* leaf and fruit powders, respectively. These values are markedly higher than the range of 3.02% to 3.5% reported by Assiéné et al. (2021) for *M. oleifera* leaf powders. N. Y. Njintang et al. (2008) also reported low WSIs in starchy food matrices such as taro (19.3%) and wheat (15.8%) compared to those obtained in this study. Additionally, the WSIs of the fruit powders were higher than those of the leaf powders. This difference correlates with the WAC of the fruit powders and can be attributed to the activity of hydrophilic compounds, as previously discussed.

Mudgil (2017) reported that the presence of crude fibers (such as cellulose and hemicellulose) significantly impacts the porosity and density of powders. This phenomenon is evident in Table 4, where the porosity (P) values were higher for the fruit powders (0.33 ± 0.01 and 0.49 ± 0.01) than for the leaf powders (0.11 ± 0.02 and 0.42 ± 0.01) of *C. olitorius* and *A. esculentus*, respectively. These values align with the range (0.31% to 0.40%) reported by Vursavuş et al. (2006) for several sweet cherries. Notably, the true density (TD) and bulk density (BD) were significantly lower for the fruit powders (0.25 ± 0.00 and 0.19 ± 0.00 g/ml) than for the leaf powders (0.27 ± 0.00 and 0.24 ± 0.00 g/ml) of *C. olitorius*. Similarly, fruit powders (0.22 ± 0.00 and 0.11 ± 0.00 g/ml) exhibited significantly lower TD and BD values than leaf powders (0.29 ± 0.00 and 0.17 ± 0.00 g/ml) of *A. esculentus*. These values are below those reported (0.60 to 0.69 g/ml) by Vursavuş et al. (2006). Factors such as chemical composition, pH, temperature, particle size, and specific surface area contribute to these observed differences (Yang et al., 2021). Notably, the TD values exceeded the BD values in both the leaves and fruits. This difference provides insight into the void volume between particles that a powder can accommodate. Such information is crucial for handling and storing these powders, allowing for maximum storage capacity after compaction (Adebowale et al., 2005).

* 1. **Relationships between the functional properties and essential nutrients, bioactive compounds, antioxidant activity of *C. olitorius* and *A.* leaves and fruit powders**

**In the dietary management of patients suffering from chronic diseases**, it is essential to meet their **nutritional needs**, including **essential nutrients** (proteins, iron, zinc, magnesium, phosphorus), **fiber**, and **antioxidants**. However, **leaf and fruit powders of *A. esculentus* and *C. olitorius*** are commonly consumed as **dietary supplements**, added to **sauces, yogurts, and various food products**. Some individuals also incorporate **vegetable oils** into these powders when formulating **traditional medicines**, while others **simply reconstitute them** before consumption. These different uses—whether **nutritional, medicinal, or technological**—impact the **stability, solubility, and bioaccessibility of nutrients**, and consequently, the associated **biological activities**. Therefore, it is crucial to explore the **functional properties** (WAC, WSI, OAC, P, D) of these powders to **determine their characteristics prior to use**. To achieve this, a **principal component analysis (PCA)** was performed to categorize the powders based on their **functional properties, essential nutrients, bioactive compounds, and antioxidant activity**, as presented in **Figure 1**. **it reveals two principal axes, F1 and F2, which account for 47.57% and 28.26%, respectively, totaling 75.83% of the variance. Consequently, four primary powder groups emerge.**

The **first group** comprises the **fruit powders of *C. olitorius* and the leaf powders of *A. esculentus***. It is characterized by **the highest contents of available sugars, total lipids, crude fibers, and total ashes**. Additionally, it exhibited **maximum values for DPPH, ABTS, and FRAP antioxidant assays**, as well as **high oil absorption capacity (OAC), true density, and bulk density**. A **high energy density**, along with **elevated crude fiber and mineral contents**, makes these powders **beneficial for individuals seeking healthy weight gain**. However, **low concentrations of bioactive compounds** such as **polyphenols, flavonoids, and tannins** explain their **low antioxidant activity**. Strong **significant correlations** were observed between **fiber content and OAC (r = 0.935; p = 0.035)**, as well as between **OAC and DPPH activity (r = 0.998; p = 0.004)**. This indicates that as **oil absorption capacity increases, antioxidant activity (DPPH) decreases**, a trend similarly observed with **FRAP and ABTS assays**. This **increase in oil absorption** is attributed to the **high crude fiber content** (Table 2), particularly **cellulose and hemicellulose**, which are known for their **lipophilic properties** (Assiéné, Assiéné, et al., 2025).

The **second group** consists of the **leaf powders of *C. olitorius*** and is characterized by the **highest contents of total proteins, copper, calcium, phosphorus, total polyphenols, and condensed tannins**. It also exhibited **the highest apparent water absorption capacity (WACa), true water absorption capacity (WACt), water solubility index (WSI), and porosity**. These powders contain **essential nutrients** that are particularly **important for patients suffering from chronic diseases**. The **high bioactive compound content** explains **the stronger antioxidant activity (DPPH, FRAP, and ABTS) compared to the first group**. Additionally, **good solubility and high-water absorption capacity** enhance **antioxidant activity and nutrient bioaccessibility** in these powders (Li et al., 2020).

Finally, the **third group** comprises the **fruit powders of *A. esculentus***, which contain the **highest levels of iron, zinc, magnesium, potassium, sodium, and total flavonoids**. The **high nutritional density** (iron, zinc, magnesium, potassium, sodium) makes these powders **suitable for patients with chronic diseases**. Moreover, they exhibited the **strongest antioxidant activity (DPPH, FRAP, and ABTS)**, attributable to the presence of **flavonoids**, which are known for their **biological activity**. It is noteworthy that this group, composed **exclusively of *A. esculentus* fruit powder**, demonstrated **WAC and WSI values similar to those of the second group, which consists solely of *C. olitorius* leaf powder**. However, it exhibited **the highest porosity among all powders**, highlighting its **functional benefits for antioxidant activity and nutrient bioaccessibility**.

Fig. 1. Grouping of *C. olitorius* and *A. esculentus* leaves and fruit powders according to their nutrient content, bioactive compounds, antioxidant activity and functional properties

**CONCLUSION**

This study highlights thatthe **leaf and fruit powders of *Abelmoschus esculentus* and *Corchorus olitorius*,** which exhibit **significant antioxidant activities,** possess **important functional properties** that must be considered before use**.** These include **water absorption capacity (WAC), oil absorption capacity (OAC), solubility index (WSI), density, and porosity.** These properties are influenced bythe **chemical composition** of the powders, particularly **hydrophilic and lipophilic compounds** such as **proteins and fibers.** The **fruit powders of *Corchorus olitorius*** and **leaf powders of *Abelmoschus esculentus*,** characterized by **high energy density, elevated fiber content, and low antioxidant activity,** are associated with **high oil absorption capacity (OAC) and elevated true and bulk density** values. The **leaf powder of *Corchorus olitorius***, which is **rich in essential nutrients** such as **proteins, copper, calcium, phosphorus, and polyphenols,** exhibits **moderate antioxidant activity** and is associated witha **high-water absorption capacity (WAC).** The **fruit powder of *Abelmoschus esculentus*, rich in minerals** such as **iron, zinc, magnesium, potassium, sodium,** and **flavonoids,** displays **high antioxidant activity** and is characterized by **high porosity, a high solubility index (WSI), and elevated water absorption capacity (WAC).** The **fruit powder of *Abelmoschus esculentus,* followed by the leaf powder of *Corchorus olitorius,*** appears to be **the most suitable** for **potential use as a dietary supplement** in the **nutritional management of patients suffering from chronic diseases.**

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Authors hereby declare that no generative AI technologies such as large language Models (ChatGPT, Copilot, etc.) and text to image generators have been used during the writing or editing of this manuscript.

**REFERENCES**

Adebowale, Y. A., Adeyemi, I. A., & Oshodi, A. A. (2005). Functional and physicochemical properties of flours of six Mucuna species. *African Journal of Biotechnology*, *4*(12), 1461–1468. https://doi.org/10.5897/AJB2005.000-3223

Anderson, R. A., Conway, H. F., Pfeifer, V. F., & Griffin, E. L. (1969). Gelatinization of corn grits by roll- and extrusion-cooking. *Cereal Science Today,* *14*(1), 4–12.

Assiéné, A. J. A., Assiéné, O. D. S., & Ngah, E. (2025). Influence of Nutrient Contents and Particle Sizes on the Functional Characteristics of Moringa oleifera Leaf ( Lam ) Powders. In *Food Science and Agriculture: Research Highlights Vol. 1* (pp. 120–136).

Assiéné, A. J. A., Djeukeu, A. W., Assiéné, O. D. S., Mbida, M. Y. I., & Nyangono, B. C. F. (2024). *Nutritional and bioactive potentials of a powder and a decoction made from Ceylon cinnamon bark , Laurus nobilis leaves , and Curcuma longa Linn rhizome*. *4*(May). https://doi.org/10.1016/j.afres.2024.100436

Assiéné, A. J. A., Djeukeu, A. W., Assiéné, O. D. S., & Nyangono, F. B. C. (2025). Some Nutritional and Bioactive Characteristics of Organ Powders from Corchorus olitorius L . and Abelmoschus esculentus L . Moench Necessary for Chronic Disease Management. *Asian Journal of Food Research and Nutrition*, *4*(2), 534–550.

Assiéné, A. J. A., Fombang, E. N., & Mbofung, C. M. (2021). *Influence of Compounds Contents and Particle Size on Some Functional Properties of Moringa oleifera Leaves ( Lam ) Powders*. *20*(1), 60–71. https://doi.org/10.9734/AFSJ/2021/v20i130255

Assiéné, A. J. A., Fombang, N. E., & Mbofung, C. M. F. (2015). Particular Benefits can be attributed to Moringa oleifera LAM leaves based on origin and stage of maturity. *Journal of Experimental Biology and Agricultural Sciences*, *3*(2320), 541–555.

Aye, P., & Adegun, M. (2013). Chemical Composition and some functional properties of Moringa, Leucaena and Gliricidia leaf meals. *Agriculture and Biology Journal of North America*, *4*(1), 71–77. https://doi.org/10.5251/abjna.2013.4.1.71.77

Bawa, S. H., & Badrie, N. (2016). Nutrient profile, bioactive components, and functional properties of okra (Abelmoschus esculentus (L.) Moench). In *Fruits, Vegetables, and Herbs* (pp. 363–410). Elsevier Inc. https://doi.org/10.1016/B978-0-12-802972-5.00018-4

Beuchat, L. R. (1977). Functional and Electrophoretic Characteristics of Succinylated Peanut Flour Protein. *Journal of Agricultural and Food Chemistry*, *25*(2), 258–261. https://doi.org/10.1021/jf60210a044

Bochnak-Niedźwiecka, J., & Świeca, M. (2020). Quality of new functional powdered beverages enriched with lyophilized fruits-potentially bioaccessible antioxidant properties, nutritional value, and consumer analysis. *Applied Sciences (Switzerland)*, *10*(11). https://doi.org/10.3390/app10113668

Li, G., Guo, W., Gao, X., Wang, Y., & Sun, S. (2020). Effect of superfine grinding on physicochemical and antioxidant properties of soybean residue powder. *Food Science and Nutrition*, *8*(2), 1208–1214. https://doi.org/10.1002/fsn3.1409

Matsumura, Y., Sirison, J., Ishi, T., & Matsumiya, K. (2017). Soybean lipophilic proteins — Origin and functional properties as affected by interaction with storage proteins. *Current Opinion in Colloid and Interface Science*, *28*, 120–128. https://doi.org/10.1016/j.cocis.2017.04.004

Mudgil, D. (2017). The Interaction Between Insoluble and Soluble Fiber. In *Dietary Fiber for the Prevention of Cardiovascular Disease: Fiber’s Interaction between Gut Micoflora, Sugar Metabolism, Weight Control and Cardiovascular Health*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-805130-6.00003-3

Njintang, N. Y., Mbofung, C. M. F., Balaam, F., Kitissou, P., & Scher, J. (2008). Effect of taro (Colocasia esculenta) flour addition on the functional and alveographic properties of wheat flour and dough. *Journal of the Science of Food and Agriculture*, *88*(2), 273–279. https://doi.org/10.1002/jsfa.3085

Njintang, Y. N., Mbofung, C. M. F., Moates, G. K., Parker, M. L., Craig, F., Smith, A. C., & Waldron, W. K. (2007). Functional properties of five varieties of taro flour, and relationship to creep recovery and sensory characteristics of achu (taro based paste). *Journal of Food Engineering*, *82*(2), 114–120. https://doi.org/10.1016/j.jfoodeng.2006.12.023

Phillips, R. D., Chinnan, M. S., Branch, A. L., Miller, J., & McWatters, K. H. (1988). Effects of Pretreatment on Functional and Nutritional Properties of Cowpea Meal. *Journal of Food Science*, *53*(3), 805–809. https://doi.org/10.1111/j.1365-2621.1988.tb08959.x

Ruru, L., Ying, X., Zhang, T., Gong, M., Liu, R., Chang, M., & Wang, X. (2022). Interactions between liposoluble antioxidants: A critical review. *Food Research International*, *155*(May), 111104. https://doi.org/https://doi.org/10.1016/j.foodres.2022.111104

Samejina, M., Hirata, G., & Koida, Y. (1982). Studies on Microcapsules. I. Role and Effect of Coacervation-inducing Agents in the Microencapsulation of Ascorbic Acid by a Phase Separation Method. *Chemical Pharmaceutical Bulletin*, *20*(10), 2278–2281.

Sha’a, K. K., Clarkson, G. P., & Artimas, S. P. (2019). Phytochemical analysis, proximate composition and antinutritional factors of Corchorus oliterius plant. *International Journal of Biological and Chemical Sciences*, *13*(4), 2147–2157. https://doi.org/10.4314/ijbcs.v13i4.21

Vursavuş, K., Kelebek, H., & Selli, S. (2006). A study on some chemical and physico-mechanic properties of three sweet cherry varieties (Prunus avium L.) in Turkey. *Journal of Food Engineering*, *74*(4), 568–575. https://doi.org/10.1016/j.jfoodeng.2005.03.059

Yang, X., Dai, J., Zhong, Y., Wei, X., Wu, M., Zhang, Y., Huang, A., Wang, L., Huang, Y., Zhang, C., Chen, X., & Xiao, H. (2021). Characterization of insoluble dietary fiber from three food sources and their potential hypoglycemic and hypolipidemic effects. *Food and Function*, *12*(14), 6576–6587. https://doi.org/10.1039/d1fo00521a

Yangilar, F. (2013). The Application of Dietary Fibre in Food Industry : Structural Features , Effects on Health and Definition , Obtaining and Analysis of Dietary Fibre : A Review. *Journal of Food and Nutrition Research*, *1*(3), 13–23. https://doi.org/10.12691/jfnr-1-3-1