EUROPEAN JOURNAL OF BIOMEDICAL AND PHARMACEUTICAL SCIENCES
http://www.ejbps.com

ISSN 2349-8870
Volume: 10
Issue: 5
01-09
Year: 2023

# PREPARATION AND EVALUATION OF ECO-FRIENDLY WASTE PRODUCT FROM *COCOS NUCIFERA* PULP MARC AS EXCIPIENT FOR DRUG DELIVERY

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**Article Received on 22/02/2023** **Article Revised on 14/03/2023** **Article Accepted on 03/04/2023**

## ABSTRACT
This study was directed towards preparing, evaluating and recycling eco-friendly ***Cocos nucifera*** (coconut) pulp marc as pharmaceutical excipient for drug delivery. The *Cocos nucifera* pulp powder was obtained by dehusking the *Cocos nucifera* fruit, pulverizing, dewatering the pulverized pulp and finally defatted, re-pulverized, dried and stored. The powder was subjected to organoleptic, phytochemical, physicochemical, physicotechnical and microscopic analyses. The powder had a pleasant odour, white colour, sweet taste, and a fine fluffy texture but some crystalline particles were present. The physicotechnical properties of the powder showed a poor flow. The microscopic view revealed a high percentage of fibre. The phytochemical screening confirmed the presence of carbohydrate, protein, saponins, reducing sugars and alkaloids. Furthermore, proximate chemical composition analysis showed that *Cocos nucifera* pulp powder contains some carbohydrate (23.41%), protein (7.44%), lipids (3.65%), ash (4.4%), moisture (7%) and fibre (54.1%). The results of swelling studies revealed swelling capacity of 242% and hydration capacity of 5.42%. The Results obtained show that *Cocos nucifera* (coconut) pulp marc has great potential as a disintegrant and could be further explored as a pharmaceutical excipient in drug delivery.

**KEYWORDS:** *Cocos nucifera*, pulp marc, evaluation, pharmaceutical excipient, drug delivery, disintegrant.

## INTRODUCTION
The pharmaceutical excipient industry to date has been an extension of the food industry which has helped in maintaining a good safety profile and assuring faster regulatory clearance. Almost all therapeutic products, for human and veterinary use, contain excipients. The total amount of excipients frequently used is usually greater than the amount of the active drug substance(s) in a dosage form.[1,2] Even though in recent years, a number of modified and co-processed excipients come to the market, almost all manufacturers refrain from the development of novel excipients due to cost. The development of a new excipient takes time, requires resources and is associated with high failure risk.[3] However, with the increasing number of new drug moieties of varying physicochemical and stability properties, formulation scientists have to search for newer excipients to achieve the desired set of functionalities.[1]

The coconut palm (*Cocos nucifera*), a member of the family, *arecaceae* (palm family) has a fruit (botanically classified as drupe) commonly seen in the tropics. The *Cocos nucifera* palm is grown throughout the tropics for decoration, as well as for its many culinary and non-culinary uses. Every part of the *Cocos nucifera* palm is used by humans in some manner and has significant economic value. Traditionally, in Nigeria, the milk extracted from *Cocos nucifera* pulp is used as flavour in making coconut rice and the marc (or residue) is usually thrown away. Nothing has been done on the characterization and possible application of this residue in drug delivery. So, there is need to recycle this *Cocos nucifera* pulp marc The aim of this work is to recycle that eco-friendly waste product (the *Cocos nucifera* pulp marc) by preparing and characterizing the *Cocos nucifera* pulp powder (marc) for use as an excipient in drug delivery.

## MATERIALS AND METHODS
### Materials
The materials used are *Cocos nucifera* fruits from the local market in Elele, Rivers State of Nigeria, acetone Molisch reagent, concentrated sulphuric acid, test tube, ferric chloride, lead acetate solution, Fehling's solution I and II, Millon's reagent, concentrated nitric acid, dilute sodium hydroxide, ethanol, Mayer's reagent, Dragendorff's reagent, Wagner's reagent, boric acid, hydrochloric acid, perchloric acid, Anthrone reagent, glucose solution, picric acid solution, xylene , n-hexane

and distilled water. The above reagents are everyday analytical laboratory chemicals used in our laboratories.

## METHODS

### Preparation of *Cocos nucifera* Pulp Marc Powder

The mesocarps of the *Cocos nucifera* fruits were removed (dehusking) and the brown coloured part of the endocarp was scrapped to recover the white pulps. The weight of the wet white pulp was noted. The white pulp was grated and dewatered by cold maceration in acetone for about 10 minutes twice. The dewatered pulp was dried in hot air oven at a temperature of 60$^{o}$C.[4] The dried pulp was defatted in N-hexane by soxhlet extraction at a temperature of 60$^{o}$C using the method outlined by Mepba and Achinewhu[5] and redried.

### Determination of Percentage (%) Yield

The weight of the *Cocos nucifera* pulp was determined before grating (initial weight) and after isolation (final weight). The percentage yield was computed as.

$$\%\ yield\ = \frac{final\ weight\ (g)}{Initial\ weight\ (g)}\ \times 100$$

### Organoleptic Properties

The taste, odour, colour, shape and texture of the defatted *Cocos nucifera* pulp marc powder were noted and evaluated.

### Microscopic View

The *Cocos nucifera* pulp marc powder was mounted on a glass slide and viewed under the microscope at a magnification of x40.

### Phytochemical Analysis

The phytochemical tests carried out were based on procedures outlined by Yadav and Agarwala.[6] The *Cocos nucifera* pulp marc powder was screened for the following; carbohydrate, saponins, tannins, reducing sugars, protein and alkaloids.

### Test for Carbohydrates (Molisch's test)

A 0.5g quantity of the *Cocos nucifera* pulp marc powder was boiled with 2ml of distilled water and filtered. To the filtrate, few drops of α- naphthol solution in ethanol (Molisch reagent) was added and concentrated sulphuric acid was then gently poured down the side of the test tube to form a lower layer. A purple interfacial ring indicates the presence of carbohydrates.

### Test for Saponins (Frothing test)

A 20ml volume of distilled water was added to 0.5g of the *Cocos nucifera* pulp marc powder and boiled on a hot water bath for 2 minutes, filtered and allowed to cool. A 5ml volume of the filtrate was diluted with 15ml of distilled water and shaken vigorously. Formation of stable froth indicates the presence of saponins.

### Test for Tannins

A 0.5g quantity of the *Cocos nucifera* pulp marc powder was boiled with 20ml of distilled water, filtered and the filtrate used to check for the presence of tannins through ferric chloride and lead acetate tests.

#### *Ferric chloride test*

Few drops of ferric chloride solution were added to 3ml of the filtrate. Formation of a greenish black precipitate indicates the presence of tannins.

#### *Lead acetate test*

Lead acetate solution was added to 3ml of the filtrate. Formation of precipitate indicates the presence of tannins.

### Test for Reducing Sugars

A 5ml volume of a mixture of equal volume of Fehling's solution I and II were added to 5ml of the *Cocos nucifera* aqueous extract and then heated over a water bath for 5 minutes. A brick red precipitate showed the presence of reducing sugars.

### Test for Proteins

A 0.5g quantity of the *Cocos nucifera* pulp marc was macerated in 20ml of distilled water, filtered and the filtrate was used for Millon's and Xanthoproteic tests in order to test for the presence of protein.

#### *Millon's test*

Two drops of Millon's reagent were added to a little portion of the filtrate in a test tube. A white precipitate indicates the presence of proteins.

#### *Xanthoproteic test*

A 5ml volume of the filtrate was heated with few drops of concentrated nitric acid. A yellow colour which changes to orange on addition of an alkali (dilute sodium hydroxide) indicates the presence of protein.

### Test for Alkaloids

A 20ml volume of 3% sulphuric acid in 50% ethanol was added to 2g of the *Cocos nucifera* pulp marc powder and heated on a boiling water bath for 10 minutes, cooled and filtered. A 2ml volume of the filtrate was tested with a few drops of Mayer's reagent (Potassium mercuric iodide solution), Dragendorff's reagent (Bismuth potassium iodide solution), Wagner's reagent (iodo-potassium iodide solution) and picric acid solution (1%). Alkaloids give milky precipitate with Mayer's reagent; reddish brown precipitate with Wagner's reagent; yellowish precipitate with picric acid and brick red precipitate with Dragendorff's reagent.

### Physicochemical Properties

#### Determination of pH

One gram (1.0g) of the *Cocos nucifera* powder was made into mucilage with 100mls of distilled water and the pH was determined with an electronic pH meter (Mettler-

Toledo International Incorporation, USA).This was done in triplicate.[7]

**Swelling Capacity (SC)**

The swelling of the *Cocos nucifera* pulp marc powder was determined by the method of Iwuagwu and Okoli (1992). The tapped volume occupied by 5g of the powders (Vx) was noted. The powders were then dispersed in 85ml of distilled water and the volume made up to 100ml with more water. After 24 hours of standing, the volume of sediment (Vv) was estimated and the swelling capacity computed as.

$$SC = \frac{Vv - Vx}{Vx} * 100$$

This was done in triplicate.

**Hydration Capacity**

Modified methods of Kornblum and Stoopak[8] and Giger-Reverdin[9] were used. One gram (1.0g) of the *Cocos nucifera* pulp marc powder (Y) was placed into each of three 13ml plastic centrifuge each and covered with 10ml of distilled water. The tube was shaken intermittently for 2 hours and left to stand for 30 minutes before centrifuging at 3000rpm for 10 minutes. The supernatant was carefully decanted and the weight of the powder after water uptake and centrifugation (X) was determined. The hydration capacity was calculated as.

$$Hydration\ capacity = \frac{X}{Y}$$

This was done in triplicate.

**True Density**

The true density of the *Cocos nucifera* pulp marc were determined by the liquid displacement method using xylene as the immersion fluid.[10] The weight of an empty 25ml pycnometer (Marienfield, Germany), was determined, then filled with xylene (Soma- Aldrish, Germany), stoppered and excess fluid wiped off from the body when weighed (a). A 1g quantity of the powdered *Cocos nucifera* pulp marc sample was weighed (W) and carefully transferred into the pycnometer, stoppered and excess fluid wiped off again (b). The true density ($D_{tr}$) was determined by using the formula below.

$$Dtr = \frac{W}{(a+W)-b} X\ SG$$

Where W = the weight of powder
SG = specific gravity of solvent
a = weight of bottle + solvent
b = weight of bottle + solvent + powder.
This was done in triplicate.

**Packing Fraction**

Packing fraction ($P_f$) was expressed as the ratio between the bulk density ($D_b$) and the true density ($D_{tr}$).

$$P_f = D_b / D_{tr}$$

**Powder Porosity**

The powder porosity (E) was calculated using the formula stated below.[10]

$$E = \frac{(1 - D_b)}{D_{tr}} x\ 100$$

Where $D_b$ is the bulk density, $D_{tr}$ is the true density and E is the porosity.

**Moisture Sorption Capacity**

The method of Ohwoavworhua, Kunle[7] was used. Two grams (2.0g) each of the *Cocos nucifera* pulp marc powder (W) were accurately weighed and evenly distributed over the surface of a tarred petri dish. The samples were then placed in a large dessicator containing distilled water in its reservoir. The weight gained by the exposed samples after a 5-day period was recorded (Wg) and the amount of water absorbed (Wa) was calculated from the weight differences as follows;

$$W_a = W_g - W$$

**Proximate Chemical Analysis**

The proximate chemical compositions for protein, carbohydrate, lipid, ash, fibre and moisture in the *Cocos nucifera* pulp marc powder were determined as outlined below.

***Moisture Content Determination***

A 5g quantity of the *Cocos nucifera* pulp marc powder was weighed into a clean dry porcelain evaporating dish. This was then dried in an oven (Gallenkamp, England) at a temperature of 105 °C for 5 hours. The evaporating dish was cooled in a desiccator at room temperature and then reweighed. The percentage moisture content was determined as the ratio of weight of moisture loss to weight of samples expressed as percentages by using the formula.

$$\%\ moisture = \frac{weight\ of\ fresh\ sample - weight\ of\ dried\ sample}{Weight\ of\ sample\ used} \times 100$$

The method above is a modified procedure outlined by Jaafar, Rahman.[11]

***Determination of Protein Content (Kjeldahl Method)***

A 100mg of the *Cocos nucifera* pulp marc sample was weighed into a clean conical flask of 250ml capacity; where upon a 3g of digested catalyst was added into the flask followed by 20ml concentrated sulphuric acid. The sample was digested by heating until it formed black to sky-blue colouration. The digest was cooled to room temperature and was diluted to 100ml with distilled water.

A 20ml diluted digest was measured into a distillation flask and the flask was held in place in a heating mantle. The distillation flask was attached to a Liebig's condenser connected to a receiver containing 10ml of 2% boric acid indicator. A 40ml volume of 40% sodium hydroxide solution was injected into the digest via a syringe attached to the mono- arm steelhead until the digest was strongly alkaline. The mixture was heated to boiling point and the distilled ammonia gas moved via the condenser into the receiving beaker. The colour of

boric acid changed from purple to greenish as ammonia distillate was introduced into boric acid.

The distillate was titrated with standard 0.1N Hydrochloric acid solution back to purple from greenish. The volume of hydrochloric acid added to effect this change was recorded as titre value.[11]

***Determination of Carbohydrate Content (Clegg Anthrone Method)***

A 100mg of the *Cocos nucifera* sample was weighed into a 25ml volumetric flask, 1ml distilled water and 1.3ml of 62% perchloric acid was added and shaken for a period of 20 minutes and homogeneous mixture was obtained. The flask was made up to 25 ml mark with distilled water and stoppered. The solution formed was filtered through a filter paper. A 1 ml volume of the filtrate was collected and transferred into a 10 ml test tube; this was diluted to volume with distilled water. A 1 ml volume of working solution was pipetted into a clean test tube to which 5ml Anthrone reagent was added. A 1 ml volume of distilled water and 5ml Anthrone reagent were thoroughly mixed. The absorbance of this mixture was read at 630nm wavelength using 1ml distilled water mixed with the 5ml Anthrone reagent as blank. A 0.1 ml volume of glucose solution was also prepared and treated as the sample with Anthrone regent. Absorbance of the standard glucose was read and the value of carbohydrate as glucose was calculated using the formula below.[12, 13]

$$\%\ \text{Carbohydrate Content as glucose} = \frac{25\ X\ Absorbance\ of\ sample}{Absorbance\ of\ standard\ glucose\ X\ 1}$$

***Determination of Lipid Content (Using Soxhlet Extraction Method)***

A 2g of *Cocos nucifera* pulp marc powder sample contained in a thimble was placed in an extractor chamber. The extractor was placed into a pre-weighed dried distillation flask. Then the solvent (Acetone) was introduced into the distillation flask via the condenser end attached to the soxhlet extractor. The set-up was held in place with a retort stand clamp. Cooled water jet was allowed to flow into the condenser and the heated solvent was refluxed as a result. The lipid in the solvent chamber was extracted in the process of continuous refluxing. When the lipid was extracted completely (after about six hours) from the sample under test, the condenser and the extractor were disconnected and the solvent was evaporated to concentrate the lipid. The flask was then dried in the air oven to constant weight and reweighed to obtain the weight of the lipid. (A modified procedure from Jaafar, Rahman[11])

$$\%\ \text{Lipid Content} = \frac{(Weight\ of\ flask\ and\ extract) - (Weight\ of\ empty\ flask)}{Weight\ of\ sample\ extracted}\ X\ 100\%$$

***Determination of Ash Content (Furnace Method)***

A 1g of the dried *Cocos nucifera* sample was weighed into a porcelain crucible which was previously preheated and weighed. The crucible was placed in a muffle furnace (Sheffield, Germany), set at a temperature of 630 ºC, heated for three hours and switched off. It was allowed to cool to room temperature and reweighed. (A modified procedure from Jaafar, Rahman[11])

$$\%\ \text{Ash Content} = \frac{(Weight\ of\ crucible + Ash\ sample) - Weight\ of\ crucible}{Weight\ of\ Sample}\ X\ 100\%$$

***Determination of Fibre (Crude Fibre Method)***

A 2g quantity of *Cocos nucifera* sample (C) was put into a 250 ml conical flask and 1.25% sulfuric acid solution was added. The sample was heated for about 30 minutes and was filtered using a vacuum filter and washed until traces of acid was undetected using pH paper. Whatman paper 5B of pore size 125 micrometer was placed in the Buchner flask. After that the acid extract was transferred into another 250 ml conical flask and 1.25% NaOH solution was added. The sample was heated again for 30 minutes, filtered using the vacuum filter and washed with water until base was undetected. The whole material was transferred into crucible and dried for 12 h at 120°C. The crucible with the residue inside was quickly weighed (A) before being placed inside a muffle oven at 550°C for 12 h, after which they (crucible +residue) were weighed again and the weight, recorded (B). The formula stated below was used to calculate for percentage weight of the fibre in the *Cocos nucifera* powder pulp marc.[11]

$$\%\ \text{Crude Fiber} = \frac{A-B}{C}\ X\ 100$$

Where A = weight of crucible with dry residue (g)
B = weight of crucible with ash (g)
C = weight of sample (g)

**Physicotechnical Properties**

***Flow Rate/Angle of Repose***

Flow under gravity using a funnel of known orifice diameter of 1.1cm fitted on a retort stand clamp assembly was adopted in the flow rate determination. An 8.5g of the *Cocos nucifera* pulp marc was allowed to flow through the orifice of the funnel from a height of 2cm on a plain sheet of paper. The time taken for the powder to fall from the funnel onto the sheet of paper to form a conical heap was recorded.[10]

The height of the conical heap formed in the flow rate experiment was measured by means of a graduated rule and a pin while the diameter/ radius of the powder heap was determined from circular outlines of the base of the granule heaps. The angle of repose (Ø) was calculated from the equation below;

$$Tan\ \emptyset = \frac{2[Height\ of\ heap]}{Diameter\ of\ heap}$$

***Bulk and Tapped Densities***

A 30g quantity of the powder was poured into a 100ml measuring cylinder, the volume occupied by the granules was recorded. The measuring cylinder was dropped on a wooden surface three times from a height of 3 inches at an interval of 30 seconds and the tapped volume was recorded. The bulk density ($D_b$) and the tapped density

($D_t$) of the powder were thus obtained using the formula.[10]

$$Db = \frac{Mass\ of\ granules}{Bulk\ volume}$$

$$Dt = \frac{Mass\ of\ granules}{Tapped\ volume\ (T_{120})}$$

***Hausner's Quotient***

This is another derived property of powder that is expressed as the ratio between the tapped density and bulk density of the granules. The Hausner's quotient is thus determined using the formula below.[10]

$$Hausner's\ quotient = \frac{Tapped\ density}{Bulk\ density}$$

**Carr's Compressibility Index (C.I.)**

This derived property of powder can be calculated using the formula stated below.[10]

$$Carr's\ Index = \frac{Dt - Db}{Dt} \times 100\%$$

Where $D_t$ = Tapped density, Db = Bulk density

**Analysis of Result**

Statistical analysis of the result was conducted to generate the standard deviation, standard error of mean and f-value.

## RESULT

**Percentage Yield of *Cocos nucifera* Pulp Marc**

Total weight before grating = 2974.4g
Total weight after extraction = 301.4g
Percentage yield =10%

**Table 1: Organoleptic properties of *Cocos nucifera* pulp marc.**

| Organoleptic Test | Observation |
|---|---|
| Odour | Fruity and pleasant |
| Colour | White |
| Taste | Sweet |
| Texture | Fine |

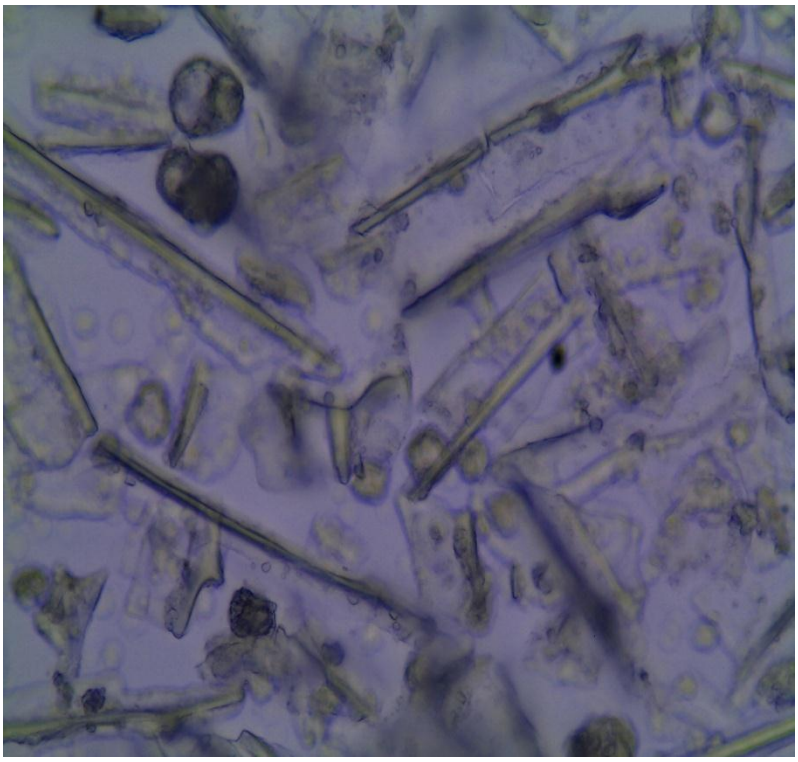

**Figure 1: Microscopic view of *Cocos nucifera* pulp marc (Magnification= x40)**

**Table 2: Phytochemical properties of *Cocos nucifera* (coconut) pulp marc.**

| S/no | Test | Observation | Inference |
|---|---|---|---|
| 1. | Test for Carbohydrate | Purple interfacial ring | Positive |
| 2. | Test for Saponin | Persistent froth | Positive |
| 3. | Test for Tannin | Absence of precipitates | Positive |
| 4. | Test for reducing sugars | Presence of brick red precipitates | Positive |
| 5. | Test for Protein | White precipitate present with Millon's reagent | Positive |
| 6. | Test for Alkaloid | Milky precipitate with Mayer' reagent | Positive |

**Table 3: Physicochemical properties of *Cocos nucifera* pulp marc.**

| Test | Results |
|---|---|
| pH | 6.79 ± 0.11 |
| Swelling Capacity (%) | 242 ± 10.5 |
| Hydration Capacity | 5.42 ± 0.78 |
| True Density (g/ml) | 0.90 ± 0.005 |
| Powder Porosity (%) | 80.0 ± 1.5 |
| Packing Fraction | 0.18 ± 0.005 |
| Moisture Sorption Capacity | 0.45 ± 0.09 |

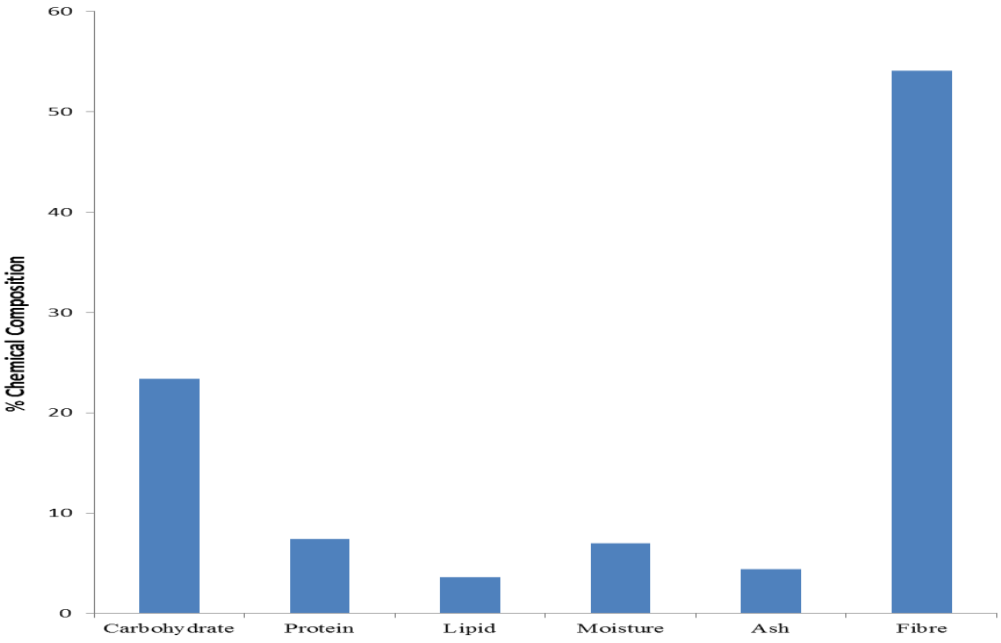


**Figure 2: Proximate chemical composition of *cocos nucifera* pulp marc**

**Table 4: Physico-technical properties of *Cocos nucifera* pulp marc.**

| Physico-technical property | Value |
|---|---|
| Bulk density (g/ml) | 0.17±0.00 |
| Tapped density (g/ml) | 0.27±0.008 |
| Bulkiness | 5.88±0.00 |
| Carr's index (%) | 39.9±1.92 |
| Hausner's quotient | 1.59±0.05 |

## DISCUSSION

### Percentage Yield

Given that more than 50% of untreated *Cocos nucifera* pulp may have watery content, a 10% yield was pretty impressive. As a result, recovering and recycling 10% of raw material that would have been wasted for use as a drug delivery agent is a worthwhile endeavour, as waste management is an unaffordable problem in developing countries due to irreversible trash generation, underlying disposal costs, and inadequate handling infrastructure.[14,15]

### Organoleptic Properties of the *Cocos nucifera* Pulp Marc

The organoleptic qualities of the *Cocos nucifera* pulp marc were good and agreeable as the powder was white, sweet to taste, had a pleasant odour and fine in texture. Medicines historically have been notorious for bad sensory attributes. However, in the present day, a dosage form's sensory acceptability or its organoleptic features are thought to be highly significant product attributes, and the formulator cannot afford to ignore this fact.[16] Such agreeable powder qualities as has *Cocos nucifera* pulp marc will lead to improved patients' compliance when used as an excipient for drug formulation.[17,18]

### Microscopical View of Pulp Marc of *Cocos nucifera*

Figure 1 which shows the microscopical view of the *Cocos nucifera* pulp marc indicates that it contains a good quantity of fibres (>50%) which were seen in the form of strands and Figure 2 confirmed that the fibre content is 54.1%. Though the presence of these fibres resulted to the poor flow of the *Cocos nucifera* pulp marc when subjected to micromeritic analysis of powders for drug production but, it is also an indication that the marc sample (which is of plant origin) is a cellulose material and it could be a good raw material (disintegrant or wicking agent) for drug delivery devices as many studies have shown fibrous materials to be good or potential disintegrants.[18]

**Phytochemical Properties of *Cocos nucifera* Pulp Marc**

Table 3 shows the result of the phytochemical screening which indicates that the *Cocos nucifera* pulp marc contains a good number of phytochemicals in appreciable amounts. The phytochemicals include; saponins, tannins, alkaloids etc. The presence of these secondary metabolites accounts for the use of *Cocos nucifera* pulp marc in medicines and in drug delivery. Some of these phytochemicals possess antimicrobial properties, act as astringents in the gastrointestinal tracts (GIT) and skin abrasions, also as antidotes for poisons and as bronchiodilators.[6,19]

The presence of carbohydrate, protein and reducing sugars is of great importance due to their nutritive value. The content of carbohydrate and reducing sugars seen in the *Cocos nucifera* pulp marc confirms that most plants store carbohydrates as starch.[20,21] Naturally, carbohydrates have high water sorption capacities with good swelling indices[22, 23] which explains the reasons for the good swelling properties of the excipient undergoing development.

**Physicochemical Properties of *Cocos nucifera* Pulp Marc**

***pH***

The Table 4 above shows that the pH of the *Cocos nucifera* pulp marc is 6.79 (≈ 7.0, neutral pH) which implies reduced toxicity. This encourages its use in drug formulation because the product tolerance will be enhanced especially for patients suffering from hyperacidity conditions and general wellbeing.[24]

***Swelling Capacity, Hydration Capacity and Moisture Sorption Profile***

Swelling which is generally accepted as an indication of tablet disintegration ability can be accessed through the determination of hydration capacity, swelling capacity and moisture sorption profile. The hydration capacity value (=5.42 ± 0.78) obtained for *Cocos nucifera* pulp marc indicates that the powder is capable of absorbing about five times its own weight of water. This means that the sample could serve as a good wicking agent and disintegrant.

The swelling capacity which reflects the increase in volume of *Cocos nucifera* pulp marc following water absorption was 242%. The common feature of all theories of disintegration is that penetration of water must precede disintegration. Thus, if the marc sample is incorporated in tablet formulation as a disintegrant, it would probably produce tablet disintegration by two mechanisms; capillary or wicking. From the values above, it is seen that the *Cocos nucifera* pulp marc would make a good disintegrant as indicated by its high swelling capacity.

In order to reflect the relative physical stability of tablets made from this powdered marc when stored under humid conditions, the moisture sorption capacity must be understood. The moisture sorption capacity is a measure of the powder's moisture sensitivity. The results from Table 4 above show that *Cocos nucifera* pulp marc has a moisture sorption capacity of 0.45, which is of medium capacity and so, it could absorb a significant amount of moisture (22.5%). As a result, the tablets may not have good stability, but if the marc is used as a disintegrant, this is a good feature as it will most likely absorb water, swell, and cause tablet disintegration by bursting the tablet. Therefore, in considering the percentage of its moisture sorption capacity on storage factors, it should be stored in an airtight amber container with a dessicant because *Cocos nucifera* pulp marc is sensitive to atmospheric moisture.[25]

***True Density and Powder Porosity***

Powder porosity is a physical test which is the ratio of the space or void between particles of a powder to the volume of the powder. Its value in percentage indicates how highly porous or poorly porous a powder can be and it is directly correlated to the powder's permeability to fluids or liquids respectively.

The result in table 4 above shows that the porosity of *Cocos nucifera* pulp marc is 80%. The value of its porosity indicates that it has a high tendency to absorb moisture which also confirms its high moisture content and moisture sorption capacity.[25]

**Proximate Chemical Composition**

Proximate analysis is a type of scientific enquiry done to determine the approximate amounts of substances (moisture, ash, carbohydrate, protein, lipid and fibre) within a material. This information can be used to create quality controls for various materials.

***Carbohydrates and Protein components***

*Cocos nucifera* pulp marc in Figure 5 above can be seen to have carbohydrate as its second highest chemical content (= 23.4%) since the marc has been defatted already. The test procedure indicates that this carbohydrate is present as glucose. We can recall that the fibre content of the marc is 54.1% and plant fibre has cellulose as its major constituent which can undergo multistage enzymatic hydrolysis to yield glucose.[26] High content of Carbohydrates help in the swelling and wicking properties of the *Cocos nucifera* pulp marc.[22,23]

***Ash Content***

Ash is the inorganic residue remaining after water and organic matter have been removed by heating which provides a measure of total amount of minerals/heavy metals within the tested samples. The ash content is of importance and indicates to some extent, the amount of care in the preparation of the sample. It determines the authenticity and purity of the sample and is equally important in quantitative standards.[27, 28]

From the results shown on the graph in figure 2 above, it can be seen that the ash content of *Cocos nucifera* pulp powder (= 4.4%) is a bit high; and this may be due to the fact that the pulp powder is an unrefined crude product.

***Moisture Content***

Moisture content influences the physical properties of a substance such as weight, density, viscosity, refractive index, electrical conductivity and other such properties.[29-32]

From the results in Figure 2 above, we can see the high value observed for the *Cocos nucifera* pulp marc and this could be as result of the large pore size that may trap water which could result in high moisture content. Since the moisture content value is low[31,32], we can say that the *Cocos nucifera* pulp marc would be physically stable to a reasonable extent and would not deteriorate easily as a result of microbial contamination on storage.

***Lipid Content***

Lipids are a group of esters which are widely distributed in the plant kingdom. In plants, they are abundant in fruits and seeds; this could explain the high lipid content of the *Cocos nucifera* pulp powder. Figure 5 shows that even after defatting, the pulp marc still contains approximately 3.7% lipids. It will be worthy to note that controlling the lipid content of excipients of this kind could be of importance in the pharmaceutical industry since it could help to check the rate at which such products could go rancid on storage.[33]

***Fibre Content***

The Figure 2 above shows that the *Cocos nucifera* pulp powder has fibre content of 54.1%. The high fibre content seen in the *Cocos nucifera* pulp powder is an indication that the pulp powder is a cellulose material (carbohydrates) sourced from plants.[26] This could go a long way to suggest the very excellent swelling indices of the pulp powder as seen in results previously displayed and discussed.

**Physico-technical Properties of the *Cocos nucifera* Pulp Powder**

***Bulk Density, Tapped Density, Carr's Compressibility Index and Hausner's Quotient***

The flow properties of a powder are essential in determining its suitability for use in the pharmaceutical industry. Table 2 presents the values of micromeritic properties of *Cocos nucifera* pulp marc. It can be seen that *Cocos nucifera* pulp powder has bulk density and tapped density values of 0.17g/ml and 0.27g/ml respectively. This translates to a 58.82% difference between the two densities which is quite large. In a free flowing material, the bulk and tapped densities will be closer in values. For poor flowing materials, there are frequently greater inter-particulate interactions (U.S Pharmacopoeia, 2009). An increase in consolidated bulk density is advantageous in tableting. This is because the fill volume of the die would be reduced. Also, good flow rate and fill ensures uniformity of weight and content. The *Cocos nucifera* pulp powder also had Carr's index of 39.9% and Hausner's ratio of 1.59. These values showed that the powder had very poor flow. Carr's index and Hausner's ratio are considered as indirect measurements of flowability of a powder.[24] They are measures of the relative importance of inter-particulate interactions. While the Hausner's quotient is indicative of inter-particle friction, the Carr's index shows the ability of a material to diminish in volume. The Hausner's quotient also gives an insight to the degree of densification of powder which occurs during tabletting. The lower the ratio, the lesser the propensity of the powder to densify.[34]

***Flow Rate and Angle of Repose***

The *Cocos nucifera* pulp powder was observed to have very poor flow characteristics. When the powder was poured through a funnel, it did not flow even when the efflux tube of the funnel was tapped. Therefore angle of repose could not be determined as a result of poor flow.[24]

## CONCLUSION

Though the *Cocos nucifera* pulp marc had very poor flow properties, but the swelling, hydration and moisture sorption capacities suggest that it could be applied as disintegrant and wicking agent in drug delivery.

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