



Research article

Investigation of the physicochemical properties of freeze-dried fruit pulp of *Telfairia occidentalis* and its potential use as suspending agent

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ABSTRACT

Plant-based (natural) excipients can reduce the over reliance on synthetic ones. They have advantages such as low toxicity, biodegradability and low-cost relative to the synthetic ones. *Telfairia occidentalis* is a creeping plant that is cultivated for food in some African countries. The leaves, stem and root of the plant have been investigated as potential sources of medicine. This study aimed at evaluating the fruit pulp as a potential suspending agent. The ripe fruits of the plant were harvested and authenticated at the Department of Herbal Medicine, KNUST. The fruit pulp was extracted, freeze-dried and evaluated for its anti-microbial, phytochemical, physicochemical and anti-oxidant properties. Different concentrations of the dried pulp were used as a suspending agent in calamine lotion formulations, using bentonite as reference. The extract contained alkaloids, tannins, saponins, coumarins, glycosides, terpenoids magnesium and potassium. No antimicrobial and antioxidant activities were detected. The extract at all tested concentrations produced some level of suspendability. The test suspensions have good flow rates, high sedimentation volumes, high degree of flocculation, and relative ease of re-dispersion. However, these parameters were significantly ($P < 0.05$) lower (except flow rate) compared to those of bentonite as a suspending agent.

1. Introduction

Pharmaceutical suspensions are liquid dosage forms composed of insoluble or poorly soluble solid particles dispersed in an aqueous medium or a liquid. Suspensions for oral administration are convenient for children and elderly patients who may find it difficult to take drugs in tablets and capsule dosage forms. Suspensions make their active ingredients more bioavailable than solid dosage forms (Adikwu et al., 2003; Ali et al., 2010). However, a primary drawback in suspension formulation is that, they are thermodynamically unstable (Eraga et al., 2014). When stored, the insoluble active pharmaceutical ingredients sediment at the base of the storage medium. It is advantageous that formulations of this nature easily disperse when shaken (Ansel et al., 2005). That is why it is important to incorporate suspending agents into pharmaceutical suspensions. Suspending agents have been categorized as: Inorganic materials, synthetic compounds and polysaccharides. Acacia, Tragacanth, Karaya, Abelmoschus and Khaya which are natural

gums belong to the polysaccharide category according to Trease and Evans (2009). Gums are commonly used as suspending agents, emulsifiers, thickening agents, binding agents and film formers in the pharmaceutical industry.

The plant kingdom is being thoroughly studied in recent years for the development of advanced active pharmaceutical ingredients and excipients to use in drug manufacturing. Many individuals are now resorting to plants and some alternative medicine sources for the treatment of different illnesses. Pharmaceutical manufacturers and pharmaceutical scientists are increasingly interested in plants as sources of excipients due to their availability, relatively non-toxicity, stability and renewability (Beneke et al., 2009). It is therefore important to explore newer plant sources to meet the demands of the pharmaceutical industry.

Telfairia occidentalis, popularly called fluted pumpkin is found in several African countries and known in the Ghanaian language as Krobbonko. The leaves, stem, seeds and roots have been studied extensively and established to possess nutritional (Arkordda, 1990),

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anti-inflammatory (Oluwole et al., 2003), antibacterial (Odoemena and Essien, 1995), erythropoietic (Ajayi et al., 2000), anticholesterol (Eseyin et al., 2005), anticancer (Okokon et al., 2012; Ejike and Ezeanyika, 2011) and antidiabetic (Eseyin et al., 2000, 2005) activities. However, very little is published on the fruit case and the pulp which according to McGrath et al. (1989) represents 70 % of the weight of the whole fresh fruit. This study therefore sought to investigate the fruit pulp for its potential value as a pharmaceutical suspending agent in pharmaceutical suspensions which can potentially lead to its industrial use.

2. Materials and methods

2.1. Materials

The materials used were Calamine powder, zinc oxide powder, sodium citrate, glycerol, liquefied phenol, purified water (Pharmaceuticals Department, KNUST), Concentrated Ammonia, 1 % Lead Acetate, 10 % Sulphuric acid, Concentrated Sulphuric acid, Sodium hydroxide, Fehling's Solution A and B, Chloroform, Acetic acid, Hydrochloric acid (10 %) (Department of Pharmacognosy, KNUST), Perchloric acid (70%), 1, 1-diphenyl-2-picrylhydrazyl and 1, 1-diphenyl-2-picrylhydrazyl (DPPH) (Department of Food Science and Biotechnology, KNUST). The agar employed for microbial analysis were Mannitol salt agar, Nutrient agar, Nutrient broth, Bismuth sulfite agar, MacConkey agar and Sabouraud dextrose agar (OXOID Laboratories, England).

2.2. Methods

2.2.1. Collection, extraction and purification of fluted pumpkin (*Telfairia occidentalis*) fruit pulp

The fluted pumpkin fruit (*Telfairia occidentalis*), was harvested at Jacobu in the Amansie Central District of the Ashanti Region of Ghana and verified by the Department of Herbal Medicine, Faculty of Pharmacy and Pharmaceutical Sciences, Kwame Nkrumah University of Science and Technology (KNUST). The colour and rims of fruits were observed, countered and recorded. The fruits were weighed using an electronic balance (ac Adum equipment Ltd, model: ADP 2100). The length and diameters were measured with the aid of a rule. They were washed and split open. The pulp was separated from the seeds and pods using a kitchen knife. The wet *Telfairia occidentalis* fruit pulp was frozen in a deep freezer -8 °C for 4 days. The frozen sample was subsequently freeze-dried (YK- 118 vacuum freeze-dryer) in vacuo (0.00–5.4 torr) within the temperature range of -47 °C to -53 °C. The dried sample was powdered and kept in a desiccator until used.

2.2.2. Organoleptic properties of freeze-dried extract

The colour, odour, nature and taste of the powdered freeze-dried *Telfairia occidentalis* were determined by using appropriate senses. The colour was also determined by the colour wheel prescribed by Allam and colleague (Allam and Kumar, 2011).

2.2.3. Phytochemical screening of constituents of extract

2.2.3.1. Test for tannins. The test was carried out by adding 1 % lead acetate drops to water extract of the freeze-dried fruit pulp in a test tube and observed for the formation of a precipitate (Goldbeater's skin test). The appearance of precipitate indicated the presence of tannins (Trease and Evans, 2009).

2.2.3.2. Test for flavonoids. A piece of filter paper was lowered into a test tube containing the water extract of the sample and allowed to dry. The dried paper was then dipped into concentrated Ammonia. An observation of an intense yellow colour confirms the presence of flavonoids (Trease and Evans, 2009).

2.2.3.3. Test for saponins. The powdered sample of the freeze-dried fruit pulp was boiled with distilled water on a water bath. It was filtered while hot and the filtrate was diluted with distilled water and shaken intensively for 2 min. The appearance of a stable froth indicated the presence of Saponins (Trease and Evans, 2009).

2.2.3.4. Test for glycosides. Filtered water extract of the sample was warmed with dilute sulphuric acid (10%) and filtered a second time. Two drops of sodium hydroxide were added to the filtrate to make it alkaline. Fehling's solution A and Fehling's solution B were then added and heated using water bath. The resultant mixture was observed for a red precipitate (Trease and Evans, 2009).

2.2.3.5. Test for triterpenoids. The presence of triterpenoids was tested by employing the Salkowski test. Three millilitres (3 ml) of concentrated sulphuric acid were added down the sides of the test tube containing 2 ml of the chloroform extract of the sample. An observation of a reddish-brown ring at the interface is an indication of the presence of triterpenoids (Sofowara, 1993).

2.2.3.6. Test for sterols. Acetic anhydride and concentrated Sulphuric acid were added to chloroform extract of the sample. The formation of a precipitate is an indication of the presence of sterols (Trease and Evans, 2009).

2.2.3.7. Test for coumarins. Ammonia (10%, 0.5 ml) was added to two millilitres (2 ml) chloroform extract of the sample and boiled on a water bath. The mixture was allowed to cool and observed under Ultra-violet (UV) light for the occurrence of bluish green fluorescence (Trease and Evans, 2009).

2.2.4. Microbial analysis

2.2.4.1. Microbial screening. A 10 ml solution of 1.0 g of the freeze-dried pulp powder was prepared with sterile water. This solution was serially diluted (10² folds) using the same solvent and incubated at 37 °C for 24 h. Half a millilitre (0.5 ml) was then transferred aseptically into a sterilized Petri dish. Then 20 ml of the already prepared agars (culture media) was poured over it, swirled, covered and allowed to solidify. The Petri dish was inverted and incubated at 37 °C for 72 h.

2.2.4.2. Antimicrobial assay. Agar diffusion procedure as proposed by Mills-Robertson et al. (2014 and 2015) was employed in analysing the effect of the freeze-dried fruit pulp extract on specific strains of bacteria.

2.2.5. Physicochemical analysis

2.2.5.1. pH of the freeze-dried fruit pulp. An amount of 0.1g of freeze-dried fruit pulp powder of *Telfairia Occidentalis* was weighed into a beaker and dissolved with ten millilitres (10 ml) of distilled water (1 % w/v). The pH was measured using the pH meter (Mettler Toledo). The test was carried out at room temperature and in triplicates (British Pharmacopoeia, 2013). The determination was carried out in triplicates. The same procedure was used for the freshly prepared and stored suspensions (39 days) of both bentonite and freeze-dried pulp extract suspensions.

2.2.5.2. Moisture content of the freeze-dried fruit pulp. Two (2 g) of the pulp powder was transferred into a previously dried and weighed Petri dish. The Petri dish was put in a 105 °C thermostatically operated oven for 4 h. It was then withdrawn with a tong and put in a desiccator to cool and weighed (British Pharmacopoeia, 2013). This was repeated three times. Percentage moisture was determined using Eq. (1).

$$\% \text{ Moisture} = [(W_d - W_p) / (W_w - W_p)] \times 100 \quad (1)$$

Where W_w , W_d , and W_p is the weight of Petri dish with wet sample, weight of Petri dish with dried sample and weight of empty Petri dish respectively.

2.2.5.3. Ash value of sample. Two grams (2 g) of the pulp powder was weighed and transferred into a crucible. The crucible was put in a thermostatically controlled muffle furnace at 600 °C for 2 h. The temperature of the furnace was allowed to drop to 250 °C, before samples were removed and placed in a desiccator to cool and weighed (*British Pharmacopoeia, 2013*). The procedure was carried out in triplicates. Percentage ash was determined by Eq. (2) given below.

$$\% \text{ Ash} = [(W_a - W_c) / (W_s - W_c)] \times 100 \quad (2)$$

Where W_a , W_c and W_s is weight of crucible with ash, weight of empty crucible and weight of crucible with sample respectively.

2.2.5.4. Acid insoluble ash of the sample. Test was conducted using ash from the ash content determination. Twenty-five millilitres (25 ml) of dilute hydrochloric acid (10 % of density 1.05) was added to 0.21 g ash. The insoluble residue was filtered out and quantitatively transferred into a previously weighed Fisher crucible. The crucible containing the residue was put in an oven maintained at 105 °C for drying. It was then placed in a desiccator to cool and weighed (*British Pharmacopoeia, 2013*). The experiment was repeated two more times. Acid insoluble ash was determined using Eq. (3).

$$\% \text{ Acid Insoluble Ash} = [(W_{ia} - W_c) / W_{sa}] \times 100 \quad (3)$$

Where W_{ia} and W_{sa} is weight of crucible with insoluble ash, W_{sa} is weight of sample ash used and W_c is as defined above.

2.2.5.5. Swelling index of the sample. The swelling index test was done by using a modified form of the procedure described by *Bonsu et al. (2016)*. Two (2.0) grams of the powdered pulp was weighed into a 25 ml measuring cylinder and the initial volume recorded. Twenty (20) millilitres of distilled water was measured and added to the sample and the setup was left undisturbed for 24 h. The final volume was recorded and the swelling index calculated using Eq. (4).

$$\text{Swelling index} = [(V_f - V_o) / V_o] \times 100 \quad (4)$$

where; V_o is the initial volume and V_f is the final volume of the pulp powder.

This procedure was repeated two more times.

2.2.5.6. Flow properties of powdered freeze-dried fruit pulp

2.2.5.6.1. Hausner ratio and Carr's index. Twenty (20) grams of the freeze-dried pulp sample was accurately transferred through a funnel into a 50 ml measuring cylinder and the volume recorded as initial volume (V_o). The cylinder and its content were tapped to obtain a constant final volume (V_f) of the content. The test was repeated three times. The initial (D_o) and final (D_f) densities were calculated as the ratio of the weight of the material to the initial and final volume respectively. Hausner's ratio and Carr's index were then calculated using Eqs. (5) and (6) below;

$$\text{Carr's Index} = [(D_f - D_o) / D_f] \times 100\% \quad (5)$$

$$\text{Hausner's Ratio} = D_f / D_o \quad (6)$$

where D_f is final density and D_o is initial density (*Aulton, 2007*).

2.2.5.6.2. Angle of repose. The angle of repose was evaluated by the fixed base method. The sample was gently discharged a funnel into the center of a circular Petri dish of internal diameter 4.5 cm to form a cone. The height of the funnel was spontaneously adjusted to avoid contact with the apex of the developing cone. The discharge was stopped when particle lying on the slope of the cone began to roll over the edge of the

Petri dish. The effective height of the cone (from the edge of the Petri dish to the apex) formed by the sample was measured and used to calculate the angle of repose as given in Eq. (7).

$$\Theta = \tan^{-1} h/0.5d \quad (7)$$

where Θ = angle of repose (*Aulton, 2007*). The experiment was repeated three times.

2.2.6. Mineral content determination

Elemental content determination was performed using methods described by *Alagic and Huremovic., (2015)*; *Baronowska et al., (2002)* with adjustments to the procedures. The freeze-dried pulp powder was digested by weighing 0.2 g into a test tube. Four millilitres (4 ml) of concentrated sulphuric acid, one millilitre (1ml) of nitric acid and one millilitre (1 ml) of perchloric acid (70 % v/v) were added to the sample. The sample was kept in a burning fume chamber at a temperature of 450 °C for 2 h until solution was colourless. The colourless solution was further diluted with distilled water to 50 ml and labelled for metal analysis using the Atomic Absorption Spectrophotometer (ASS Model Nov AA 400P). A 50 ml blank was also prepared and labelled appropriately using distilled water and the same amount of concentrated sulphuric acid, nitric acid and perchloric acid. Calcium, Iron, Potassium, Sodium, Copper, Zinc, Magnesium and Manganese were tested for.

2.2.7. Anti-oxidant test using 1,1-diphenyl-2-picrylhydrazyl (DPPH)

An amount (0.5 g) of the freeze-dried pulp was weighed into a 15 ml centrifuge tube and dissolved with 10 ml distilled water. It was centrifuged for 15 min at a speed of 10, 000 rpm to obtain a relatively clear sample solution (0.05%w/v). The reaction mixture for analysis was obtained by measuring 0.2 ml of the prepared sample solution, 0.2 ml of distilled water and 6 ml of a 0.004% DPPH (1,1-diphenyl-2-picrylhydrazyl) into a test tube, shaken and left in the dark for 30 min. Absorbance of the mixtures and blank (distilled water) were measured using Ultraviolet (UV) spectroscopy (UV5, Mettler Toledo) at 517 nm wavelength. The experiment was repeated on Ascorbic acid which is a standard anti-oxidant. Percentage inhibition was calculated using Eq. (8).

$$\text{DPPH radical scavenging activity (\% Inhibition)} = [1 - (A_s/A_o)] \times 100\% \quad (8)$$

Where A_o is absorbance of DPPH solution diluted to same volume with distilled water and A_s is absorbance of sample (*Braca et al., 2001*).

2.2.8. Analysis of freeze-dried Telfairia occidentalis fruit pulp by fourier transform infrared spectrophotometer (FTIR)

The freeze-dried fruit pulp samples were analyzed for functional group identification and possible interactions using a Bruker alpha FTIR over a wavenumber range of 4000 to 400 cm^{-1} . The Bruker alpha FTIR uses attenuated total reflectance (ART) with a diamond crystal. The diamond crystal was wiped with isopropanol to ensure its cleanliness and the background scan was taken. An amount (0.2 g) of the sample was placed on the crystal directly and the pressure gauge applied to ensure strong contact. Samples were then scanned to generate the desired spectra (*Boakye-Gyasi et al., 2021*).

2.2.9. Preparation of calamine suspensions using different suspending agents

Calamine suspension was prepared by triturating Calamine powder (15 g), Zinc Oxide powder (5 g), bentonite powder (0.1 %w/v) and 0.5 g sodium citrate (dissolved in 70 ml purified water) in a ceramic mortar. Liquefied phenol (0.5 ml) and glycerol (5 ml) were added and the preparation was quantitatively transferred into a 100 ml measuring cylinder and topped up to volume with sufficient purified water. The procedure was repeated using 0.2 %, 0.3 %, 0.4 %, 0.5 %, 1 %, 2 % and 3 %w/v of bentonite as the suspending agent to complete the series of reference products (*British Pharmacopoeia, 2013*). Test products were prepared using the freeze-dried pulp as the suspending agent at the same concentration levels as bentonite used in the reference products.

2.2.10. Evaluation of calamine suspensions

The calamine suspensions prepared with different concentrations of the freeze-dried pulp and bentonite as suspending agents were analyzed for the following parameters: sedimentation profile, pH, and rheological behaviour, degree of flocculation and ease of re-dispersing. The freshly prepared suspensions were monitored hourly for 7 h and then every 3 days for 39 days.

2.2.10.1. Determination of sedimentation volume. The sedimentation volumes were determined by comparing the sediment volume (V_u) at each time point to the initial volume (V_o) of suspension.

Sedimentation volume, F (%) of the suspension was obtained using Eq. (9).

$$F = (V_u/V_o) \times 100 \quad (9)$$

V_u = volume of sediment at a time point, V_o = the original volume of suspension (Banker and Rhodes., 1998).

2.2.10.2. Determination of flow rate. The flow rate was determined by measuring the time (in seconds) taken for a suspension to flow through a 10 ml stable pipette. The flow rate (ml/s) was obtained using Eq. (10).

$$\text{Flow rate } (\eta\alpha) = \text{volume of pipette (ml)} / \text{flow time (sec)} \quad (10)$$

2.2.10.3. Re-dispersibility. Re-dispersibility was analyzed after 39 days, using the approach by Okoye et al. (2014) with slight modification. The measuring cylinder containing the suspension was sealed to prevent leakage; the cylinder was then turned upside down repeatedly until complete dispersion of the suspension was achieved. The number of turns required to effect complete dispersion was taken as a measure of re-dispersibility.

2.2.10.4. Degree of flocculation. Fresh calamine suspensions were prepared without sodium citrate (deflocculating agent). The degree of flocculation (β) was determined as the ratio of the sedimentation volume of the flocculated suspensions (formulations without sodium citrate) to the sedimentation volume of the deflocculated suspensions (formulation with sodium citrate). The degree of flocculation was determined by using Eq. (11).

$$\beta = F/F\alpha \quad (11)$$

F = ultimate sedimentation volume in flocculated suspension

$F\alpha$ = ultimate sedimentation volume in deflocculated suspension (Martin et al., 1991)

2.2.10.5. pH determination of suspensions. The pH of freshly prepared and stored (39 days) suspensions of both bentonite and freeze-dried pulp were measured using a calibrated Mettler Toledo pH meter.

2.2.11. Statistical evaluation

GraphPad Prism (version 5) and Microsoft excel were employed for statistical analysis. Mean and standard deviations for all data were computed. P values were obtained using the unpaired t-test. P-values equal to or less than 0.05 were considered significant while values greater than 0.05 were not significant.

3. Results and discussion

3.1. Organoleptic and phytochemical properties of freeze-dried fruit pulp of *Telfairia occidentalis*

Telfairia occidentalis fruits used in the study were green in colour, with yellow fibrous pulp and dark red heart-shaped seeds averaging eighty-

three (83) per fruit. Other characteristics of the fruit are summarized in Table 1. These characteristics confirmed the observation by Arkordda (1990).

Organoleptic study showed the freeze-dried pulp to have yellowish-orange colour with mildly sweet taste. The dried powder was odourless and free flowing. Phytochemical screening showed the presence of alkaloids, saponins, tannins, coumarins, glycosides and terpenoids and the absence of flavonoids and sterols This slightly differs from a study by Anthony and Ojeifo. (2016) which reported the presence of flavonoids and sterols in the leaves of the plant. This may be as a result of the accumulation of slightly different phytochemicals in different parts of the plants (roots, leaves, stem, fruits and seeds).

3.2. Microbial quality and antimicrobial properties of freeze-dried fruit pulp of *Telfairia occidentalis*

Microbial analysis showed the absence of fungi, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Salmonella species*, *Escherichia coli* and presence of acceptable limits of aerobic counts (2.30×10^2 cfu). The results are in line with the British Pharmacopeia., (2013) standards for microbial analysis for active pharmaceutical ingredients, excipients, drug products and sterile products. The freeze-dried fruit pulp of *Telfairia occidentalis* when tested against some specific microorganisms showed no antimicrobial activity.

3.3. Physicochemical properties of freeze-dried fruit pulp of *Telfairia occidentalis*

The pH of 1 %w/v concentration of the freeze-dried pulp employed in the analysis as presented in Table 2, is weakly acidic (6.01 ± 0.03) and would be a suitable choice of excipient for pharmaceutical formulation since pH affects the stability of most pharmaceutical preparations (Saraf, 2010).

Swelling index as presented in Table 2 was 200 %w/v. This means the freeze-dried pulp can be adopted as a tablet binder, a disintegrant and a suspending agent since a polymer's swelling capacity demonstrates its ability to hold water, swell into a gel and release embedded drugs (Mahmud et al., 2010; Kipo et al., 2014). According to Leon et al. (1987), the important characteristics that pharmaceutical excipients or materials must possess are flowability and compressibility. Values obtained (Table 2) for Hausner ratio, Carr index and angle of repose show the freeze-dried pulp is less cohesive and has good flow characteristics.

Moisture content is one of the most commonly measured properties of food and pharmaceutical raw materials and finished products. It is an important tool in the pharmaceutical industry for microbial stability, drug quality and drug processing operations. The moisture content of 10.04 %w/w obtained for the freeze-dried fruit pulp was within pharmacopeia standard for pharmaceutical excipients. Moisture content according to the British Pharmacopeia (2013), must not exceed 15 %w/w. The total ash and acid-insoluble as values (Table 2) clearly indicated that the freeze-dried pulp contained insignificant amount of earthly matter

Table 1. Profile of *Telfairia occidentalis* fruit and fruit pulp.

Parameter	Results
Colour of fruit	Green
Colour of fruit pulp	Yellowish-orange
Nature of fruit pulp	Fibrous
Circumference of the widest section of the fruit (cm)	36.44 ± 2.74
Weight of fruit (g)	1713.22 ± 290.36
Number of rims on fruit	10 ± 0.1
Length of fruit (cm)	29.2 ± 1.32
Number of seeds per fruit	83 ± 3
Shape and colour of seeds	Heart-shaped and reddish-brown

Table 2. PH, proximate, swelling index and flow analysis of freeze-dried *Telfairia occidentalis* fruit pulp.

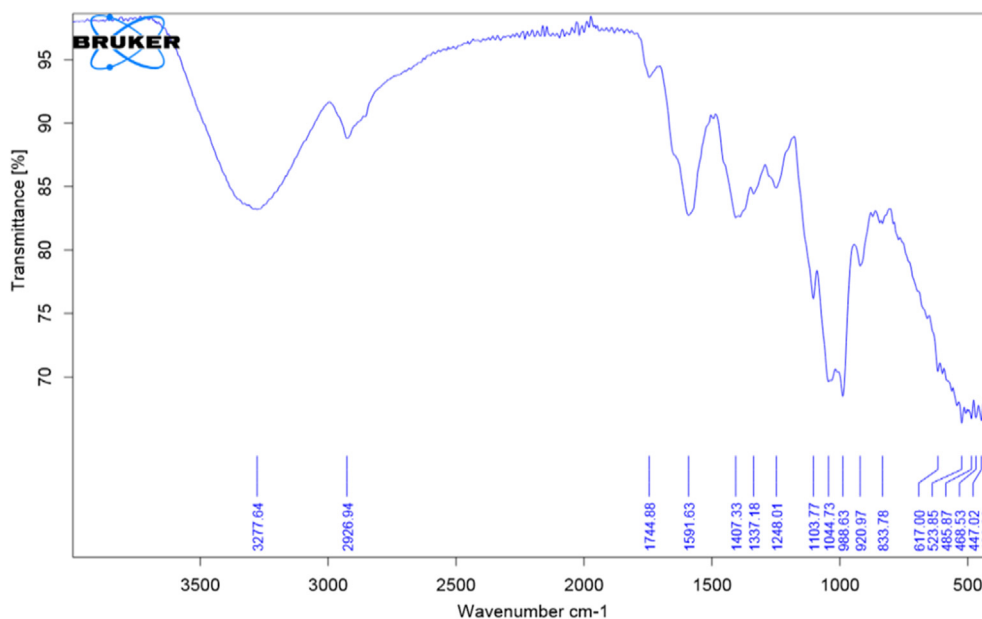
Parameter	Results
pH	6.01 ± 0.03
Moisture (%)	10.04 ± 0.37
Total Ash (%)	10.35 ± 0.40
Acid insoluble ash (%)	0.01 ± 0.00
Swelling Index (%)	200.00 ± 0.00
Hausner's ratio	1.12 ± 0.00
Carr's index	10.53 ± 0.00
Angle of repose (°)	43.43 ± 0.00

due to proper cleaning and processing of the *Telfairia occidentalis* fruit and the freeze-dried pulp.

The freeze-dried fruit pulp had high levels of elemental content made up of magnesium (50455.26 mg), Potassium (13312.69 mg), calcium (211.47 mg), Iron (124.16 mg) and Sodium (122.89 mg) per kilogram sample. These values were in line with a study by Essien et al. (1992), where they concluded that *Telfairia occidentalis* fruit pulp contained relatively high amounts of potassium, calcium, magnesium, sodium, zinc and iron but very small amount of manganese (0.06 mg/100 mg) and copper (1.13 mg/100 mg). For this study manganese and copper were not detected per the amount of sample used for the experiment. This may also be due to differences in the geographical location of plant material used as well as the method of processing.

Anti-oxidant activity of freeze-dried pulp was tested and compared with the anti-oxidant activity of ascorbic acid (standard anti-oxidant). The freeze-dried pulp recorded a significantly ($P < 0.001$) lower inhibition ($9.73 \pm 0.28\%$) as against $96.82 \pm 0.28\%$ inhibition by Ascorbic acid.

The FTIR fingerprint (Figure 1) characterized and identified the inorganic and organic components of the freeze-dried fruit pulp of *Telfairia occidentalis*. Principal bands for the freeze-dried pulp were shown at 3277.64 cm^{-1} , 2926.94 cm^{-1} , 1744.88 cm^{-1} and 1591.63 cm^{-1} which is an indication of the presence of O–H stretch bonds, C–H single bonds, C=O (carbonyl group) and C=N stretch respectively. Possible components may include alcohol/phenol, alkane, aldehyde and an imine.

**Figure 1.** FTIR spectrum of freeze-dried *Telfairia occidentalis* fruit pulp.

3.4. Quality assessment of formulated suspensions

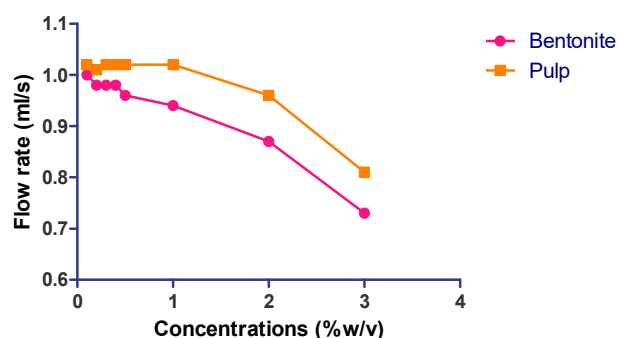
The suspending ability of the freeze-dried pulp and bentonite in the calamine suspensions formulated were evaluated by analyzing the flow rate through a pipette, sedimentation volume, re-dispersibility, pH and degree of flocculation.

Flow rate (Figure 2) of the freshly prepared suspensions for all concentrations of Bentonite was within the range of 0.73–1 ml/s which did not differ significantly ($P > 0.05$) from that (0.81–1.02 ml/s) of freeze-dried pulp-containing suspensions.

This observation indicates that the flow rate of the suspensions was not affected differently by the two suspending agents. Generally however, an increased in concentration of bentonite and freeze-dried pulp resulted in a decrease in the flow rate, as a direct result of an increase in apparent viscosity of the suspensions. On day 39 of storage, the products retained their flow characteristics (Figure 3). This may be due to the absence of significant coagulation and or caking within the products.

The apparent viscosities of the bentonite formulated suspensions were generally higher than those of the freeze-dried pulp formulated suspensions.

At day one and at the end of the 39th day the sedimentation volumes (F) were generally lower for the freeze-dried pulp formulated suspensions compared to that of the bentonite formulated suspensions for all

**Figure 2.** Flow rate of freshly prepared bentonite and freeze-dried pulp calamine suspensions at all concentration (0.1 %–3%).

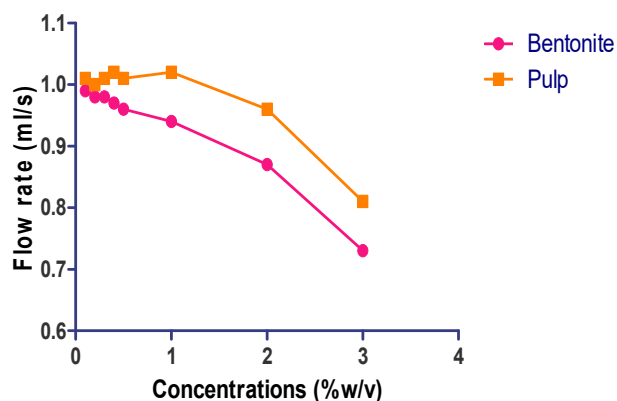


Figure 3. Flow rate of bentonite and freeze-dried pulp calamine suspensions (stored for 39 days) at all concentration (0.1 %–3%).

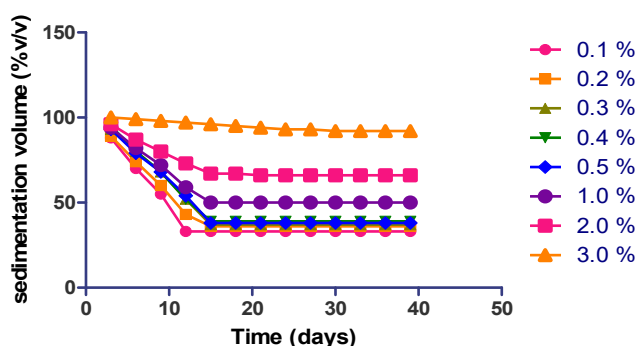


Figure 4. Sedimentation volume of calamine suspensions prepared with bentonite against time (days) for all concentrations (0.1 %–3.0 %).

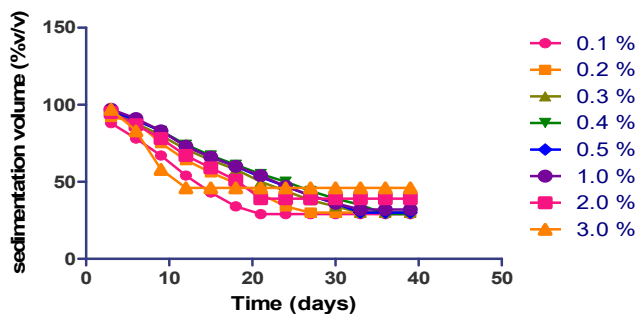


Figure 5. Sedimentation volume of calamine suspensions prepared with freeze-dried pulp against time (days) for all concentrations (0.1 %–3.0 %).

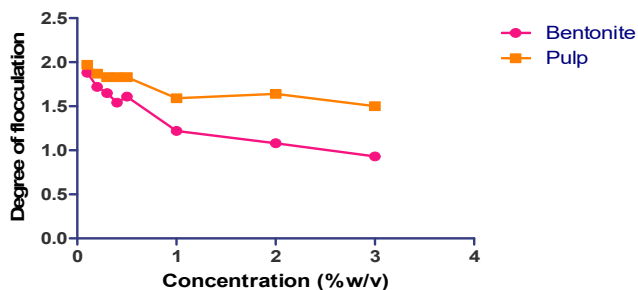


Figure 6. Degree of flocculation of bentonite and freeze-dried pulp formulated calamine suspensions at all concentration (0.1 %–3%).

concentrations employed (Figures 4 and 5). This may be due to a higher sedimentation rate of the freeze-dried pulp formulated suspensions.

According to Asantewaa et al. (2011), one of the important characteristics of a suspension is viscosity. The increase in the apparent viscosity of a suspension has a positive effect in slowing settling and improving stability. A well-formulated suspension must have the dispersed phase particles suspended on agitation of the containers and remain so for a reasonable period to ensure accurate dosing. This happens following breakdown of the flocculated structure which for a good suspension (thixotropic suspensions) must be re-established to prevent caking of the product in the long term.

A well-formulated suspension must be readily re-dispersed upon agitation to ensure uniformity of administered doses (Bhurat et al., 2012). Both bentonite and freeze-dried pulp formulated suspensions re-dispersed upon turning the container upside down but generally the freeze-dried fruit pulp formulated suspensions were less readily re-dispersed compared to the bentonite formulated suspensions.

The pH of freshly prepared and stored suspensions for both suspending agents bentonite and freeze-dried pulp, were alkaline (pH 9.34–9.89). There were no changes in the pH during the storage period (39 days) for all the concentrations employed for both bentonite and freeze-dried pulp formulations. This is an indication that the freeze-dried fruit pulp and bentonite did not hinder the stability of the active ingredient in the suspensions. Generally, the formulated suspensions containing bentonite showed an increase in sedimentation volume with increasing concentrations (Figure 4). However, there was no correlation between concentrations of freeze-dried pulp and the sedimentation volume (Figure 5). Since sedimentation volume has no practical reference point and only provides a qualitative understanding of a suspension's sedimentation, the degree of flocculation, β , which compares sedimentation volumes of flocculated to deflocculated suspensions is a more significant parameter to analyse (Hiestand, 1964). The degree of flocculation as presented on Figure 6, generally decreased consistently as the concentration of the bentonite and freeze-dried pulp increased. The degree of flocculation was higher in the freeze-dried fruit pulp formulated suspensions than the bentonite formulated suspensions for all the concentrations employed in the study. This confirms the fact that the sedimentation volumes of the freeze dried pulp formulations are lower than those of corresponding concentrations of bentonite suspensions.

4. Conclusion

This study has shown that freeze-dried fruit pulp from *Telfairia occidentalis* possess some level of suspending ability in pharmaceutical preparations which is lesser than that of bentonite, when used at 0.1 %w/v, 0.2 %w/v, 0.5 %w/v, 1.0 %w/v and 2.0 %w/v concentrations. The freeze-dried pulp of *Telfairia occidentalis* can also be investigated as a tablet binder, a disintegrant and emulsifying agent due to its good swelling capacity.

Declarations

Author contribution statement

Noble Kuntworbe: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Ayensu Djakari Henry; Sekyere Michael: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Johnson Raphael; Owusu Frederick; Ofori-Kwakye Kwabena: Analyzed and interpreted the data; Wrote the paper.

Entsie Philomena: Analyzed and interpreted the data.

Amankwah Francis: Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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