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RESEARCH ARTICLE

CHARACTERIZATION AND PHARMACEUTICAL EVALUATION OF *DAUCUS CAROTA* PECTIN AS A SUSPENDING AGENT IN ORAL DOSAGE FORMS

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ABSTRACT

Background: Suspensions are equilibrated two-phased thermodynamically unstable systems increasingly used in the stability and bioavailability enhancement of a myriad of drug substances. Biodegradable, biocompatible and cost-effective biopolymers such as pectin are becoming popular alternative suspending agents to decrease sedimentation and ensure uniformity and accuracy in drug dosing. Nevertheless, limited commercial pectin sources with ideal gelling properties necessitate the search for novel sources, such as carrots, a versatile vegetable. **Objectives:** The study therefore centred on the characterization and pharmaceutical evaluation of the suspending qualities of *Daucus carota* (carrot) pectin acquired from the conventional acid extraction procedure. **Methodology:** Fresh carrots were acquired, authenticated and processed before pectin extraction. The pectin extracted was characterized and evaluated for phytochemical properties such as proximate composition and degree of esterification. Different concentrations (1% and 2%) of carrot pectin and acacia gum (as a standard) were utilized in formulating paracetamol suspensions as suspending agents. **Results:** The pectin yield was 11.6% and contained glycosides, tannins, saponins, and phenols. FTIR analysis identified all the essential pectin functional groups, while other characterization parameters showed quality-high methoxyl pectin. Carrot pectin suspensions demonstrated significantly ($P < 0.01$) lower re-dispersibility and sedimentation rate when compared to acacia. The flow rate and sedimentation volumes were however, not significantly different. **Conclusion:** The characterization and suspending properties of carrot pectin have been successfully evaluated. Ultimately, acacia gum can be substituted with carrot pectin as a suspending agent.

Keywords: *Daucus carota* pectin, Suspending agent, Pharmaceutical suspension, Excipients

INTRODUCTION

Suspension dosage forms are equilibrated two-phased systems increasingly utilized in the stability and bioavailability enhancement of a myriad of drug substances. Suspending agents (stabilizers) are incorporated to circumvent the thermodynamic instability of suspensions by enhancing viscosity and slowing sedimentation while ensuring easy re-dispersibility upon mild agitation (1, 2). Biodegradable, biocompatible and cost-effective biopolymers such as pectin are becoming increasingly popular as alternative suspending agents (1, 3).

Pectin, an essential plant cell wall component containing approximately 17 different monosaccharides with over 20 different linkages has vital uses in the food and beverage industries as well as the pharmaceutical sector. Structurally, homogalacturonan (HG) represents the principal pectic polysaccharide. Homogalacturonan is a linear homopolymer consisting of galacturonic acid (GalA) linked via α-(1-4)-bonds. GalA has varying degrees of carboxyl moieties partially esterified at the Carbon on position 6 (3–5). The global pectin value (USD 958 million in 2015) is projected to grow by 7.3% in 2023 due to increased demand (5, 6). The current pectin sources, notably apple pomace, sugar beet pulp and citrus peels, are disadvantaged mainly by long maturity periods and increased susceptibility to diseases. This impedes the global supply chain highlighting the need for novel sources. A promising lead in this regard is the carrot, a biennial versatile vegetable crop, which is rated sixth among 22 of the most popularly consumed vegetables (7).

Carrots are good sources of carotenoids, essential minerals and vitamins, dietary fibre (like pectin), and other vital nutrients such as antioxidants (7, 8). However, despite being considerably rich in pectin, industrially processed carrot is discarded as waste (30-50%) or as animal feed which contributes significantly to environmental pollution (8, 9). The successful valorization of carrot waste as a pectin source can therefore represent a significant transformation from waste to wealth.

The acid extraction technique (pH 1.5), particularly using citric acid, has been extensively employed in commercial pectin production by applying conventional heat (90^{o}C). Furthermore, the citric acid extraction technique is reported to be the least depolymerizing and de-esterifying of all acidic solvents (10, 11).

There is currently limited literature on the extraction of pectin from carrot (*Daucus carota*) using the eco-friendly citric acid extraction technique as well as its pharmaceutical application as a suspending agent. The study therefore aimed at examining the suitability of the acid extraction process and the quality of extracted pectin in the pharmaceutical excipient industry. Moreover, the success of this project holds huge potential for generating enormous profits through the diversification and transformation of carrot wastes into a commercialized pharmaceutical excipient, all while reducing significant health care costs precipitated by the importation of excipients.

METHODOLOGY

Materials

Vegetables of *Daucus carota* L. were obtained from the market of Ayigya, Kumasi-Ghana. Acacia gum powder (from Sigma-Aldrich, Darmstadt, Germany) and paracetamol powder of purity 99% were acquired from the Xi'an Henrikang Biotech Co., China. UK chemicals in Kumasi provided analytical grades of NaCl, 95% Isopropyl alcohol, citric acid, benzoic acid, ammoniacal alcohol, 0.1 N NaOH, and 95% ethanol. The Department of Pharmaceutics laboratory, KNUST, Kumasi supplied the distilled water used in the project.

Methods

Carrot (*Daucus carota*) pectin extraction procedure

The method used by Udonne and colleagues was used to extract the pectin with minor modifications (12). Fresh carrots were thoroughly washed, grated, sun-dried and finally pulverized into a fine powder using a countertop blender. A mixture of 200 g of the pulverized carrot, and 250 mL of distilled water (pH adjusted to 1.5 with citric acid) was heated at 40 °C for 1 hour and passed through a cheesecloth for filtration. The precipitation of the extracted pectin was carried out by adding 250 mL of ethanol (95%) to the filtrate. After thoroughly

stirring the mixture, it was left to rest for a period of 30 minutes. The precipitates were subsequently skimmed off, filtered and dried in the oven at a stable temperature of 30 °C for a 24-hour period. The carrot acid-extracted pectin (CAP) was subsequently kept in an airtight ziplock bag until use (12). The percentage yield of CAP was determined on dry bases in the equation below

$$Percentage\ Yield = \frac{Weight\ of\ CAP}{Weight\ of\ dried\ powdered\ carrot} \times 100 \quad (1)$$

Physicochemical analysis and characterization of CAP

Proximate composition and phytochemical screening

The ash content, moisture contents and crude proteins were determined using standard reported methods (13, 14). The presence of the secondary metabolites namely, glycosides, saponins, tannins and phenols were also determined (15).

Characterization of CAP

The titrimetric methods described by (16) were utilized in establishing the equivalent weight, methoxyl content, anhydrouronic acid and degree of esterification of CAP. Equations, 2-6 were used in calculating the parameters respectively.

$$Equivalent\ weight = \frac{weight\ of\ pectin\ sample\ (g) \times 1000mg}{vol.\ of\ alkali\ (ml) \times Normality\ of\ Alkali} \quad (2)$$

$$Methoxyl\ content\ (\%) = \frac{vol.of\ alkali\ (ml) \times Normality\ of\ Alkali \times 31 \times 100}{weight\ of\ pectin\ sample\ (mg)} \quad (3)$$

Where 31 represents the methoxyl group molecular weight.

$$\%\ AUA = \frac{176 \times 100}{Z} \quad (4)$$

The molecular weight of AUA is represented by 176.

Z is evaluated as presented in Equation 4:

$$Z = \frac{Pectin\ weight\ (mg)}{\mu eq\ (Equivalent\ weight + \%\ MeO)} \quad (5)$$

$$\%\ DE = \frac{\%MeO \times 176 \times 100}{\%\ AUA \times 31} \quad (6)$$

Fourier Transformed Infrared (FTIR) spectroscopy analysis

A solid powdered CAP sample was used for the FTIR analysis without dispersing in D_2O. The Bruker FTIR spectrophotometer operating on Platinum ATR at 4 cm^{-1} resolution (Jos Hansen & Soehne GmbH, Hamburg, Germany) was used to obtain the spectrum of CAP. The range of wavelength was 4000–400 cm^{-1} was analysed.

Formulation of paracetamol suspension

The paracetamol suspensions were made utilizing the direct incorporation or dispersion method and levigation procedures. CAP at concentration levels of 2% $^{w}/_{v}$ and 1% $^{w}/_{v}$ served as the test-suspending agent while the standard was acacia gum. The suspensions were kept in amber bottles, appropriately labelled, and stored at room temperature far away from light (1,17).

Table 1. **Paracetamol suspension master formula**

Ingredient	Quantities
Paracetamol powder (99%)	5.0 g
Acacia/CAP (1% w/v or 2% w/v)	1.0 g or 2.0 g
Benzoic acid (0.1% $^{w}/_{v}$)	0.1 g
Distilled water to	100.0 mL

Quality control tests on suspensions

Sedimentation volume (F)

A quantity of 50 mL of the suspensions formulated was quantitatively transferred into separate 100 mL measuring cylinders. The ultimate volumes were read the day after day 1 and then weekly for 3 weeks (17). The volume of sedimentation (F) was determined using Equation 7:

$$F = \frac{Ultimate\ Volume}{Initial\ volume} \times 100\% \quad (7)$$

Flow rate (f) and viscosity

An RV spindle No.2 fitted Drawell digital viscometer (HBDV-I) was used to measure the viscosity of the suspensions. Subsequently, the required time for 10 mL paracetamol suspension to move through the full length of a pipette was ascertained as the flow rate (f) (17,18). The equation 8 was used to compute the flow rate:

$$f = \frac{volume\ of\ pipette\ in\ ml}{time\ in\ seconds} \quad (8)$$

pH of suspensions

The formulations were quantitatively transferred into beakers (100 mL) and thoroughly mixed to ensure homogeneity before submerging the electrodes of the pH meter. Triplicate values were recorded (1,18).

Ease of re-dispersibility

A qualitative assessment of the suspension's re-dispersibility was made. Separate portions of the suspension were transferred into measuring cylinders (100 mL) and allowed to stand on the bench for 24 hours. The amount of cycles needed to redistribute the sediment was noted. Triplicate determinations were obtained (17, 18).

Sedimentation rate

Separate portions of the suspensions were quantitatively transferred into measuring cylinders (100 mL) and left to stand undisturbed. For an hour, the sediment volume was measured for each formulation at intervals of 10 minutes starting with the initial volume (50 mL). The sedimentation rate of the suspensions was obtained by calculating the gradient of the sediment volume against the time plots (17, 18).

Statistical analysis

The p-values were calculated using two-way and one-way analysis of variance (ANOVA) where applicable, followed by the appropriate multiple comparison tests. The level of significance was set at ≤ 0.05 and GraphPad Prism (version 8.0.1) was used for all the analyses.

RESULTS AND DISCUSSION

Yield, phytochemical analysis and identification of CAP

The percentage yield of pectin was 11.6% and this was comparable to values reported in literature (8, 19). The yield of pectin is affected by the extraction method, source of pectin, pH of extracting medium and extraction time. Acidic pH, in particular, causes the loosening of the cell wall matrix and hydrolyses insoluble pectin substances to soluble pectin (8, 20).

Secondary metabolites; phenols, tannins, saponins and glycosides were identified in CAP (Table 2). Secondary metabolites are low molecular weight compounds with a myriad of ecological functions in plants. They are particularly implicated in the antioxidant, nootropic, antineoplastic and antimicrobial activities of plants in man (21,22). Moreover, saponins have also been reported to exhibit stabilizing properties in dispersed systems (23,24).

Table 2. Phytochemical profile of *Daucus carota* pectin

Phytochemicals	Observation	Inference
Phenols	The bluish-black colour	+
Saponins	Five minutes of persistent froth	+
Glycosides	Appearance of precipitate (brick-red)	+
Tannins	After the addition of 5 drops of 1% ferric chloride solution, a light brown precipitate was formed, which persisted	+

Key: + means "is present"

Proximate content and characterization of CAP

The proximate composition of CAP (Table 3) was essential to ascertain purity and give credence to its pharmaceutical application (Ismail *et al.*, 2012). The moisture content, ash content and protein content were 8.93±1.37; 1.10±1.06 and 2.64±1.49 respectively. The moisture content is an indication of stability during shelf life as high moisture (water) impacts microbial oxidation and hydrolysis of pectin (25). The British Pharmacopoeia recommends a < 15% $^{w}/_{w}$ moisture content while the IPPA also accepts < 12% therefore, the pectin was of the required moisture content. Nevertheless, CAP should still be stored in an air-tight container during long-term storage since it is hygroscopic (1, 25).

The ash content which is influenced by the presence of inorganic residues, extraction methodology and insulation of pectin is an indication of pectin purity. The IPPA recommends a maximum limit of 10% therefore, the CAP was high-quality pectin (25).

The proteinaceous components in pectic polymers influence their activating and stabilizing properties in formulations. Crude protein contents are affected by extraction methods and time, ethanol precipitation, and pH (26–28).

The equivalent weight is a measure of the amount of free galacturonic acid (GalA), the main pectic polysaccharide present in the pectin. The type of plant, method of extraction, and quality of source materials have all been established to impact the equivalent weight. High equivalent weights have been reported to indicate high gelling abilities of pectin as well as quality (16, 29). The equivalent weight was 436.69±2.70 mg/mol. The results obtained were comparable to those reported by Houben and colleagues and within the limit of ≤ 800 mg set by the International Pectin Producers Association (IPPA) (30–33).

The gel-forming properties of pectin in addition to other functional properties, such as setting time, texture and structure are determined by the methoxyl contents (30, 34). Pectins with values ≥ 7.12% are considered to have high amounts of methyl alcohol in moles per 100 mol of galacturonic acids (30,31). The methoxyl content of CAP was 8.96±0.04 therefore, it can be postulated that CAP can disperse in aqueous media to yield high sugar gels. The high methoxyl content is also suggestive that CAP can be used as a pharmaceutical excipient (e.g., suspending agents) (16, 29, 31).

The structure and texture of pectin, as well as the quality, are affected by the anhydrouronic acid (AUA) content. The recommended levels are > 65% which authenticates that pectin contains low concentrations of proteins, starch and sugars (16, 26, 29, 35). The AUA content of CAP was 91.17±0.00 which is indicative of very pure pectin with reduced cell wall constituent adulterations.

The degree of esterification (DE) calculated for CAP was 55.79±0.27 and could be described as high methoxyl pectin. A high DE (> 50%) reflects good thickening and gelling properties of CAP supporting the proposed claim that CAP could be used as a suspending agent (36). Nevertheless, there is conflicting literature on the DE of carrot pectin. Several authors described high values (>50%) while other studies reported low values (<50%) demonstrating the effect of extraction conditions such as methodology, time, temperature, and pH on the DE of pectin (8, 33, 36, 37).

The FTIR was also utilized in characterizing CAP by assigning functional groups corresponding to peaks in the spectra (Figure 1). The principal bands observed at 3263.97, and 2918.02-2473.57 cm^{-1} were assigned to the O-H stretching vibrations, and the C-H stretching vibrations of the CH, CH_2 and CH_3 respectively (8). The stretching vibrations of the carbonyl group (C=O) in the carboxylic acid ester groups were assigned 1709.57 cm^{-1} while the carbonyl groups in the free carboxylic acid moieties (COO^-) were assigned to 1618.29 cm^{-1}. The pyranose and furanose groups as well as the rhamnogalacturonan were assigned at the peaks between 1000-1200 cm^{-1} (8,38). The assigned wavenumbers were comparable to commercial pectin (8, 39).

Table 3. Characterization of *Daucus carota* pectin

Parameter	CAP
Equivalent Weight (mg/mol)	436.69±2.70
Methoxyl Content (%)	8.96±0.04
Anhydrouronic Acid Content, AUA (%)	91.17±0.00
Degree of Esterification, DE (%)	55.79±0.27
Moisture Content (%)	8.93±1.37
Ash Content (%)	1.10±1.06
Crude Protein (%)	25.64±1.49

Data is presented as mean ± SD (n=3)

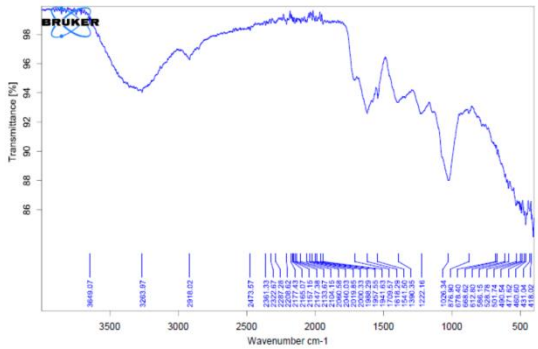


Figure 1. FTIR spectra of *Daucus carota* pectin

Quality control analysis of formulated suspensions

pH of suspensions

The assessment of the pH of suspensions constitutes an integral stability analytical metric (1,17). Acidic pH (<5.0) enhances pectin adsorption through electrostatic and steric stabilization, which reduces sedimentation and particle aggregation (40–42). A reasonably constant weakly acidic pH was observed for all the suspensions during the 4 week evaluation period (Table 4). When acacia was compared to CAP at all concentrations, a significant difference ($P < 0.01$) was observed, which could be accounted for by the acidic extraction procedure. Furthermore, the pH stability and lack of undesired physical modifications over the evaluation period may suggest a lack of instability issues as the acidic pH discourages microbial growth during the shelf-life (17, 18).

Table 4. The pH of acacia and *Daucus carota* pectin suspensions

Week	ACACIA 1%	CAP 1%	ACACIA 2%	CAP 2%
Week 1	3.58±0.03	3.22±0.01[a]	3.70±0.03	3.30±0.02[a]
Week 2	2.91±0.01	2.77±0.02[a]	2.67±0.03	2.72±0.01[b]
Week 3	3.06±0.01	2.66±0.03[a]	3.22±0.01	2.81±0.02[a]
Week 4	3.14±0.01	2.76±0.01[a]	3.39±0.01	2.84±0.02[a]

Data is presented as mean ± SD (n=3). ****P < 0.0001 (a), *P < 0.01 (b), P > 0.05 non-significant (ns)

Ease of redispersibility of suspension

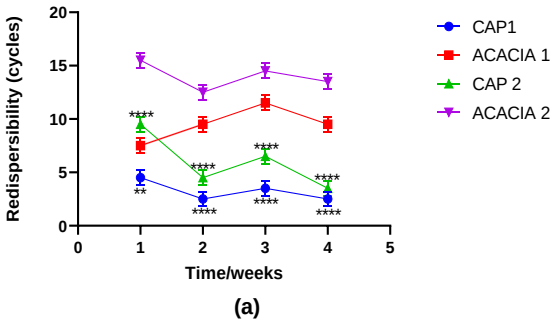
The quality of a suspension is indicated by the fewer cycles required to rotate the sediment through 180 degrees and obtain a homogeneous suspension (17). During the 4 week evaluation period, CAP suspensions recorded significantly lower re-dispersibility values ($p \leq 0.01$) at all concentrations when compared to acacia while the areas under the curves corroborated this by demonstrating significantly lower re-dispersibility cycles for CAP when compared to acacia at all concentrations (Figure 2). This implies that mild agitations are required to ensure uniform distribution and by extension, uniform dosing when CAP is utilized as suspending agent. Furthermore, it could be observed that higher concentrations resulted in higher cycles of re-dispersibility for all suspensions which could be accounted for by the increase in apparent viscosity by an increase in concentration (43–45). Nevertheless, since caking or other physical instabilities were not observed throughout the study period, the increase in viscosity did not affect the stability of suspensions.

Flow rate and viscosity of suspensions

A pseudoplastic flow was demonstrated by all formulated suspensions which is an ideal quality (Figure 3) (46, 47). CAP recorded higher viscosities when compared to Acacia gum at all concentrations (Figure 3). When compared with less viscous suspensions, it is reported that suspensions with higher viscosities tend to exhibit better stability (46–48).

The apparent viscosity or flow rate of the suspending medium is attributed principally to the random Brownian motion of the polymer chains. This results in entangled structures which entrap water molecules within the lattice. However, upon application of minimal sheer stress, these polymeric structures disentangle into parallel orientation (shear thinning). This phenomenon impacts stability during storage (prevents caking) and facilitates re-dispersibility ensuring accurate and uniform dosing (1,17,49–54). The apparent viscosity was observed to be inversely correlated with the flow rate and

directly correlated with the concentration during the evaluation period (Figures 3 and 4). An increase in viscosity resulted in a decrease in terminal settling velocity ensuring that dispersed particles settled slowly (43,55,56). However, there was no significant difference between CAP and acacia apart from week 1 suggesting comparable flow rates. Another characteristic observation made was the decrease in flow rates of all formulations over the study period. This according to Ngwuluka and colleagues may be described as autocatalytic hydrolysis, a natural characteristic of gums and pectins (57). Moreover, the absence of untoward physical changes at the end of the study may indicate this phenomenon did not impact the suspension stability.



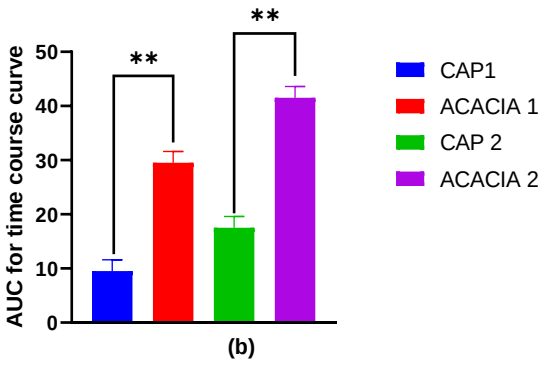


Figure 2. Effect of different concentrations of acacia and *Daucus carota* pectin (CAP) on (a) the redispersibilty and (b) the cumulative effect of suspending agents on the redispersibility of suspensions. Values are means ± SD (n=2). **** p ≤ 0.0001, ** p ≤ 0.01, p ≤ 0.01; significance between Acacia and CAP; area under curve (a),(AUC)

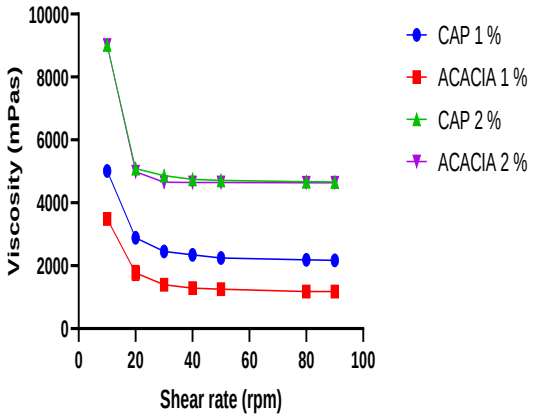
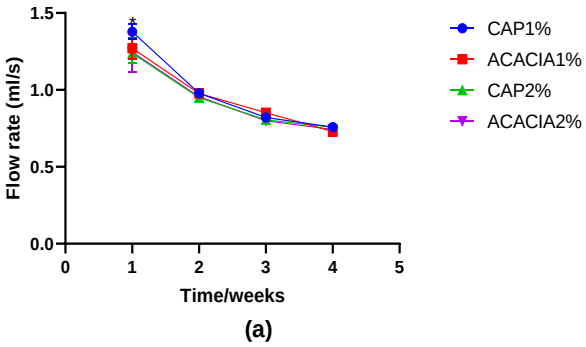


Figure 3. The impact of different concentrations of acacia and *Daucus carota* pectin (CAP) on the viscosity of formulated suspensions.



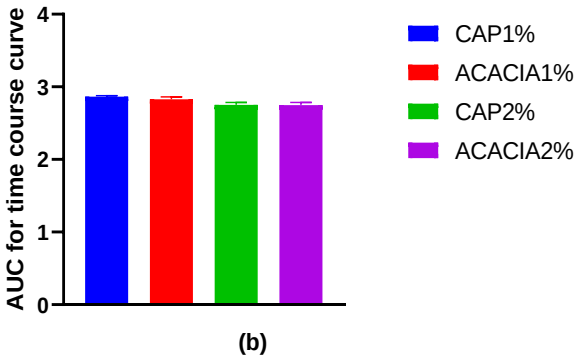


Figure 4. Effect of different concentrations of acacia and *Daucus carota* pectin (CAP) on (a) the flow rate and (b) the cumulative effect of suspending agents on the flow rate of suspensions. Values are means ± SD (n=3). * p ≤ 0.05; significance between Acacia and CAP; area under curve (a), (AUC)

Sedimentation rate and volume

The rate of sedimentation is an essential quality control parameter. Slower sedimentation rates are a good indication of suspending properties and are inversely related to the viscosity as dictated by the Stokes equation (53). Figure 5 shows that generally, a higher concentration was associated with a lower sedimentation rate which corroborated the assessments in flow rate above. Furthermore, CAP demonstrated significantly lower sedimentation rates ($p < 0.001$) when compared to acacia at all concentration levels which attests to the fact that it ensures the continued dispersion of suspended particles to ensure accurate and uniform doses are dispensed (45).

The sedimentation volume of suspensions typically ranges between 0 and 1. Values closer to 1 are considered better suspensions as they have a decreased tendency of caking and ensure accurate doses are unforming dispensed (17). Generally, except for the 3rd week, there was no significant difference between the CAP and acacia which was also supported by the area under the curves (Figure 6). This shows that the sedimentation volumes were comparable.

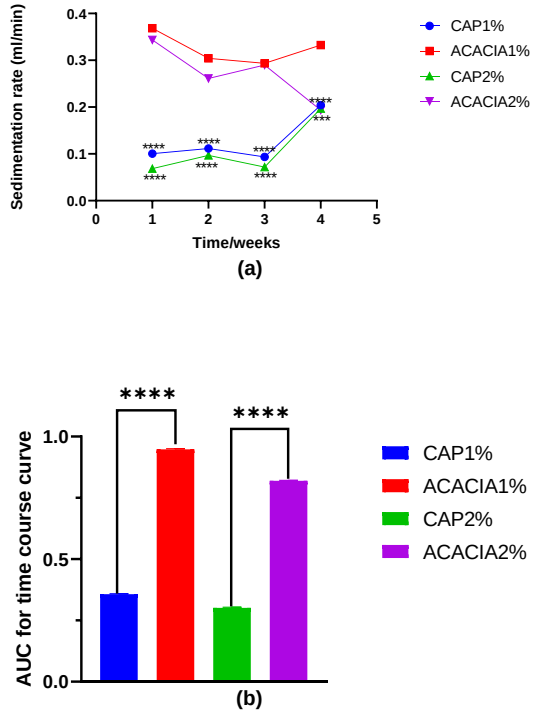


Figure 5. Effect of different concentrations of acacia and *Daucus carota* pectin (CAP) on (a) sedimentation rate and (b) the cumulative effect of suspending agents on the sedimentation rate of suspensions. Values are means ± SD (n=3). **** $p \leq 0.0001$, *** $p \leq 0.001$; significance between Acacia and CAP; area under curve (a), (AUC)

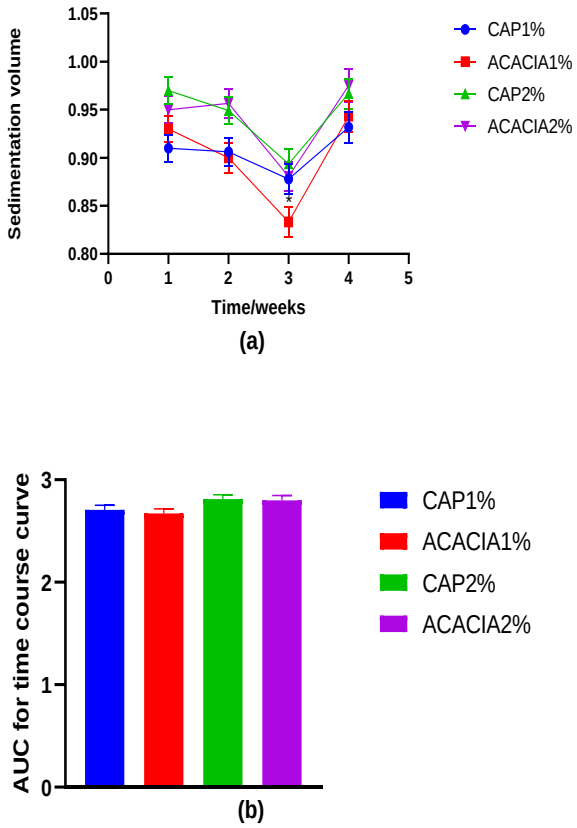


Figure 6. Effect of different concentrations of acacia and *Daucus carota* pectin (CAP) on (a) sedimentation volume and (b) the cumulative effect of suspending agents on the sedimentation volume of suspensions. Values are means ± SD (n=3). * $p \leq 0.01$; significance between acacia and CAP, area under curve (a), (AUC)

CONCLUSION

In conclusion, the study has demonstrated that carrot (*Daucus carota)* yields a high-quality that can be used as a suitable alternative to current pectin sources. Furthermore, at concentration levels of 1% and 2%, acid-extracted carrot (*Daucus carota*) pectin is comparable to acacia gum as a suitable pharmaceutical suspending agent.

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DECLARATIONS

Authors' Contributions
FWAO supervised and designed the study concept; FWAO, PGJA and MEBG contributed to the study design, data collection, and manuscript write-up. MTB, DABO, SAM, and AMAB contributed to data analysis, and interpretation and critically reviewed the manuscript. All authors reviewed the results and approved the final version of the manuscript.

Ethical Approval
Not applicable

Conflict of Interest
The authors declared no conflict of interest among them.

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Data availability
The data used to support the study's findings is provided in the publication and can also be obtained upon request from the corresponding author.

REFERENCES

1. Henry AD, Noble K, Michael S, Raphael J, Akuffo OF, Philomena E, Francis A, Kwabena OK. Investigation of the physicochemical properties of freeze-dried fruit pulp of Telfairia occidentalis and its potential use as suspending agent.Heliyon.2022. https://doi.org/10.1016/j.heliyon.2022.e09997
2. Owusu FW, Acquah PG, Boakye-Gyasi ME, Johnson R, Yeboah GN, Archer MA, Antwi MB, Asare SO. Pharmaceutical Assessment of the Impact of the Method of Extraction on the Suitability of Pectin from Plantain (Musa paradisiaca) Peels as a Suspending Agent in Oral Liquid Formulations. The Scientific World Journal. 2023. https://doi.org/10.1155/2023/8898045
3. Boakye-Gyasi ME, Owusu FW, Entsie P, Agbenorhevi JK, Banful BK, Bayor MT. Pectin from okra (Abelmoschus esculentus L.) has potential as a drug release modifier in matrix tablets. The Scientific World Journal. 2021. | https://doi.org/10.1155/2021/6672277
4. Picot-Allain MC, Neergheen VS. Pectin a multifaceted biopolymer in the management of cancer: A review. Heliyon. 2023. https://doi.org/10.1016/j.jtocrr.2023.100571
5. Picot-Allain MC, Ramasawmy B, Emmambux MN. Extraction, characterisation, and application of pectin from tropical and sub-tropical fruits: a review. Food Reviews International.2022 https://doi.org/10.1080/87559129.2020.1733008
6. Mamiru D, Gonfa G. Extraction and characterization of pectin from watermelon rind using acetic acid. Heliyon. 2023. https://doi.org/10.1016/j.heliyon.2023.e13525
7. Kaur GJ, Orsat V, Singh A. Sustainable usage of carrot discards in food processing. International Journal of Sustainable Development & World Ecology. 2022 . https://doi.org/10.1080/13504509.2021.1896589
8. Jafari F, Khodaiyan F, Kiani H, Hosseini SS. Pectin from carrot pomace: Optimization of extraction and physicochemical properties. Carbohydrate polymers. 2017 http://dx.doi.org/10.1016/j.carbpol.2016.11.013
9. Šeregelj V, Vulić J, Ćetković G, Čanadanovć-Brunet J, Šaponjac VT, Stajčić S. Natural bioactive compounds in carrot waste for food applications and health benefits. Studies in natural products chemistry. 2020 . https://doi.org/10.1016/B978-0-12-819483-6.00009-6
10. Wandee Y, Uttapap D, Mischnick P. Yield and structural composition of pomelo peel pectins extracted under acidic and alkaline conditions. Food Hydrocolloids. 2019.https://doi.org/10.1016/j.foodhyd.2018.08.017
11. Kliemann E, De Simas KN, Amante ER, Prudêncio ES, Teófilo RF, Ferreira MM, Amboni RD. Optimisation of pectin acid extraction from passion fruit peel (Passiflora edulis flavicarpa) using response surface methodology. International journal of food science & technology. 2009. https://doi.org/10.1111/j.13652621.2008.01753.x
12. Udonne JD, Ajani OO, Akinyemi OP. A comparative study of extraction of pectin from wet and dried peels using water based and

microwave method. International Journal of Scientific and Engineering Research. 2016.
13. Shaari N, Shamsudin R, Nor MZ, Hashim N. Quality attributes of Malaysia purple-fleshed sweet potato at different peel condition. Agronomy. 2021 . https://doi.org/10.3390/agronomy11050872
14. Goyal K, Singh N, Jindal S, Kaur R, Goyal A, Awasthi R. Kjeldahl method. Adv. Tech. Anal. Chem. 2022.
15. Evans WC. Trease and Evans' pharmacognosy. Elsevier Health Sciences; 2009
16. Twinomuhwezi H, Godswill AC, Kahunde D. Extraction and characterization of pectin from orange (Citrus sinensis), lemon (Citrus limon) and tangerine (Citrus tangerina). American Journal of Physical Sciences. 2023. https://doi.org/10.47604/ajps.1049
17. Owusu FW, Boakye-Gyasi E, Bayor MT, Osei-Asare C, Johnson R, Osei YA, Asare VA, Mensah KA, Acquah PG, Otu DA, Asante R. Pharmaceutical Assessment of Watermelon Rind Pectin as a Suspending Agent in Oral Liquid Dosage Forms. BioMed Research International.2022. https://doi.org/10.1155/2022/9526404
18. Oppong EE, Osei-Asare CH, Klu MW. Evaluation of the suspending properties of shea tree gum. International Journal of Pharmacy and Pharmaceutical Sciences. 2016.
19. Artikova R, Khuzhanazarova M, Azimova D, Temirova M. Isolation of pectin from vegetable waste and study of its physical and chemical properties. InE3S Web of Conferences2023. https://doi.org/10.1051/e3sconf/202338903104
20. Zaidel DN, Zainudin NN, Jusoh YM, Muhamad II. Extraction and characterisation of pectin from sweet potato (Ipomoea batatas) pulp. Journal of Engineering Science and Technology. 2015 .
21. Wink M. Introduction: biochemistry, physiology and ecological functions of secondary metabolites. Annual plant reviews volume 40: Biochemistry of plant secondary metabolism. 2010 . https://doi.org/10.1002/9781444320503.ch1
22. Kennedy DO, Wightman EL. Herbal extracts and phytochemicals: plant secondary metabolites and the enhancement of human brain function. Advances in Nutrition. 2011 .
23. Kharat M, McClements DJ. Fabrication and characterization of nanostructured lipid carriers (NLC) using a plant-based emulsifier: Quillaja saponin. Food Res Int. 2019.
24. Weigel F, Weiss J, Decker EA, McClements DJ. Lutein-enriched emulsion-based delivery systems: Influence of emulsifiers and antioxidants on physical and chemical stability. Food chemistry. 2018 . https://doi.org/10.1016/j.foodchem.2017.09.060
25. Sarah M, Hisham MF, Rizki M, Erwinda R. Effect of Power and Time in Pectin Production from Cocoa Pod Husk Using Microwave-Assisted Extraction Technique. International Journal of Renewable Energy Development. 2020 . http://ejournal.undip.ac.id/index.php/ijred
26. Mada T, Duraisamy R, Guesh F. Optimization and characterization of pectin extracted from banana and papaya mixed peels using response surface methodology. Food Science & Nutrition. 2022. https://doi.org/10.1002/fsn3.2754
27. Li DQ, Du GM, Jing WW, Li JF, Yan JY, Liu ZY. Combined effects of independent variables on yield and protein content of pectin extracted from sugar beet pulp by citric acid. Carbohydrate polymers. 2015 . https://doi.org/10.1016/j.carbpol.2015.04.058
28. Yapo BM, Robert C, Etienne I, Wathelet B, Paquot M. Effect of extraction conditions on the yield, purity and surface properties of sugar beet pulp pectin extracts. Food chemistry. 2007 . https://doi.org/10.1016/j.foodchem.2005.12.012
29. Ismail NS, Ramli N, Hani NM, Meon ZJ. Extraction and characterization of pectin from dragon fruit (Hylocereus polyrhizus) using various extraction conditions. Sains Malaysiana. 2012 .
30. Siddiqui A, Chand K, Shahi NC. Effect of process parameters on extraction of pectin from sweet lime peels. Journal of The Institution of Engineers (India): Series A. 2021. https://doi.org/10.1007/s40030-021-00514-3
31. Susanti S. Comparing the chemical characteristics of pectin isolated from various Indonesian fruit peels.2021. https://doi.org10.22146/ijc.59799

32. Indriani R, Legowo Am, Susanti S. Karakteristik Pektin yang Diisolasi dari Kulit Mangga (Mangifera indica) dan Kulit Semangka (Citrullus vulgaris). Characteristics of Pectin Isolated from Mango (Mangifera indica) and Watermelon (Citrullus vulgaris) Peel (Doctoral dissertation, Fakultas Peternakan Dan Pertanian Undip).2017.
33. Houben K, Jolie RP, Fraeye I, Van Loey AM, Hendrickx ME. Comparative study of the cell wall composition of broccoli, carrot, and tomato: Structural characterization of the extractable pectins and hemicelluloses. Carbohydrate Research. 2011. https://doi.org/10.1016/j.carres.2011.04.014
34. Azad AK, Ali MA, Akter MS, Rahman MJ, Ahmed M. Isolation and characterization of pectin extracted from lemon pomace during ripening. Journal of Food and Nutrition Sciences. 2014.
doi: 10.11648/j.jfns.20140202.12
35. Joel JM, Barminas JT, Riki EY, Yelwa JM, Edeh F. Extraction and characterization of hydrocolloid pectin from goron tula (Azanza garckeana) fruit. world scientific news. 2018.
36. Misra NN, Yadav SK. Extraction of pectin from black carrot pomace using intermittent microwave, ultrasound and conventional heating: Kinetics, characterization and process economics. Food Hydrocolloids. 2020. https://doi.org/10.1016/j.foodhyd.2019.105592
37. Kyomugasho C, Willemsen KL, Christiaens S, Van Loey AM, Hendrickx ME. Microscopic evidence for Ca2+ mediated pectin–pectin interactions in carrot-based suspensions. Food chemistry. 2015. https://doi.org/10.1016/j.foodchem.2015.04.135
38. Chen Y, Zhang JG, Sun HJ, Wei ZJ. Pectin from Abelmoschus esculentus: Optimization of extraction and rheological properties. International journal of biological macromolecules.2014. . https://doi.org/10.1016/j.ijbiomac.2014.07.024
39. Pérez J, Gómez K, Vega L. Optimization and preliminary physicochemical characterization of pectin extraction from watermelon rind (Citrullus lanatus) with citric acid. International journal of food science. 2022 https://doi.org/10.1155/2022/3068829
40. Lam M, Shen R, Paulsen P, Corredig M. Pectin stabilization of soy protein isolates at low pH. Food Research International. 2007 . https://doi.org/10.1016/j.foodres.2006.08.004
41. Nakamura A, Yoshida R, Maeda H, Corredig M. The stabilizing behaviour of soybean soluble polysaccharide and pectin in acidified milk beverages. International Dairy Journal.2006. https://doi.org/10.1016/j.idairyj.2005.01.014
42. Maroziene A, De Kruif CG. Interaction of pectin and casein micelles. Food hydrocolloids. 2000 . https://doi.org/10.1016/S0268-005X(00)00019-9
43. Deshmukh SS, Katare YS, Shyale SS, Bhujbal SS, Kadam SD, Landge DA, Shah DV, Pawar JB. Isolation and evaluation of mucilage of Adansonia digitata Linn as a suspending agent. Journal of Pharmaceutics. 2013. http://dx.doi.org/10.1155/2013/379750
44. Nayak AK, Pal D, Pradhan J, Ghorai T. The potential of Trigonella foenum-graecum L. seed mucilage as suspending agent. Indian J Pharm Educ Res. 2012 .
45. Piriyaprasarth S, Sriamornsak P. Flocculating and suspending properties of commercial citrus pectin and pectin extracted from pomelo (Citrus maxima) peel. Carbohydrate polymers. 2011 . https://doi.org/10.1016/j.carbpol.2010.08.018
46. Nutan MT, Reddy IK. General principles of suspensions. Pharmaceutical suspensions: from formulation development to Manufacturing. 2010.
47. Allen L, Ansel HC. Ansel's pharmaceutical dosage forms and drug delivery systems. Lippincott Williams & Wilkins; 2013.
48. Larsson M, Hill A, Duffy J. Suspension stability; why particle size, zeta potential and rheology are important. Annu. Trans. Nord. Rheol. Soc. 2012 .
49. Azubuike CP, Alfa MA, Oseni BA. Characterization and evaluation of the suspending potentials of Corchorus olitorius mucilage in pharmaceutical suspensions.2017.
50. Ajala TO, Silva BO. The effect of pharmaceutical properties on the acid neutralizing capacity of antacid oral suspensions. Journal of Pharmaceutical Investigation. 2015.

51. Odeku OA. The pharmaceutical equivalence and stability of multisource metronidazole suspensions. African Journal of Medicine and Medical Sciences. 2014.
52. Gbenga BL, Oluwabunmi A. Suspending properties of natural gums extracted from Abelmuscus esculentus pod and Chrysophyllum albidium fruit. African Journal of Pharmacy and Pharmacology. 2015. https://doi.org/10.5897/AJPP2014.%204170
53. Manoharan C, Basarkar A, Singh J. Various pharmaceutical disperse systems. InPharmaceutical suspensions: from formulation development to manufacturing 2009 .
54. Asantewaa Y, Ofori-Kwakye KW, Kipo SL, Boamah VE, Johnson RA. Investigation of the emulsifying and suspending potential of cashew tree gum in pharmaceutical formulations. International journal of Pharmacy and Pharmaceutical sciences. 2011.
55. Manoharan C, Basarkar A, Singh J. Various pharmaceutical disperse systems. InPharmaceutical suspensions: from formulation development to manufacturing 2009.
56. Bamigbola EA, Olorode OA, Uzim DA. Evaluation of the suspending properties of Cola acuminata gum on calamine suspension. Journal of Phytomedicine and Therapeutics. 2017.
57. Ngwuluka NC, Akanbi M, Agboyo I, Uwaezuoke OJ. Characterization of gum from Sesamum indicum leaves as a suspending agent in a pediatric pharmaceutical suspension. WJPR. 2012 .