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Evaluation of Okra Pectin from Different Genotypes as Effective Suspending Agents in Pharmaceutical Formulations

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ABSTRACT

Introduction: Natural suspending agents are increasingly being investigated because of their relative non-toxicity, lesser cost, availability and biocompatibility compared to the currently utilised synthetic and semi-synthetic suspending agents. Pectin, a biopolymer found naturally in plants is gaining increased application in the pharmaceutical and biotechnology industry following its successful functional application as gelling agents, emulsifying agents and fat substitutes in the food industry. This study aimed at evaluating the suspending properties of pectin obtained from five okra (*Abelmoschus esculentus* L.) genotypes; PL1 (Penkrumah), PL2 (Agbagoma), PL3 (Asha), PL4 (Sengavi) and PL5 (Balabi).

Materials and methods: The pectin was extracted using standard protocols and characterised by investigating properties such as degree of esterification. A 5% $^{w}/_{v}$ paracetamol suspension was formulated utilising okra pectin as a suspending agent at concentrations of 0.5%, 1% and 2%$^{w}/_{v}$ and compared to Tragacanth gum suspensions at the same concentrations (0.5%, 1% and 2%$^{w}/_{v}$).

Results: All the extracted pectins had low degrees of esterification (<50 %). The pH, redispersibility, apparent viscosity, sedimentation rate and sedimentation volume of the formulated suspensions were investigated over a 4-week period. The suspensions were stable as evidenced by no significant ($p \geq 0.05$) fluctuations in pH during the period of study. Compared to when tragacanth was used as a suspending agent, the sedimentation rates, the flow rates of suspensions and redispersibility of the paracetamol suspensions utilising okra pectin were lower while the sedimentation volumes were higher at all the concentrations utilized and met standard requirements.

Conclusion: The evidence suggests that all five okra genotypes exhibit better suspending properties when compared to tragacanth gum and thus may be used as an alternative suspending agent.

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Introduction

Suspension as a pharmaceutical liquid dosage form is a coarse dispersion in which the internal phase is uniformly dispersed throughout the external phase (Alalor & Obunezie, 2020). Suspensions are thermodynamically unstable and thus require the addition of suspending agents to mitigate caking, sedimentation, and permit resuspension which are the major challenges facing suspension formulations (Owusu et al., 2022; Woldu et al., 2021a). Suspending agents can be categorised into three; natural suspending agents such as acacia, tragacanth, and pectin; semi-synthetic agents such as methylcellulose; and synthetic suspending agents such as carbopol (Doye et al., 2017; Woldu et al., 2021a). Nevertheless, the cost, availability, sustainability and compatibility issues of synthetic and inorganic suspending agents, render the natural agents preferable alternatives. Natural suspending agents have the attribute of being non-toxic, biodegradable, less expensive, and readily available (Kaushik et al., 2022; Onyishi et al., 2014).

Pectin, a biopolymer found naturally in plants is gaining increased application in the pharmaceutical and biotechnology industry as binders, disintegrants and carriers of drugs purposed for controlled release particularly following its successful functional application as gelling agents, emulsifying agents and fat substitutes in the food industry (Boakye-Gyasi et al., 2021; Malviya & Kulkarni, 2012; Owusu et al., 2021). Presently, the commercially available pectin is predominantly obtained from citrus peels or apple pomace. However, despite both being by-products of the juice or cider manufacturing industry, their long maturation periods and increased susceptibility to diseases pose a major challenge (Boakye-Gyasi et al., 2021; Chen et al., 2014; Malviya & Kulkarni, 2012; Owusu et al., 2021). Therefore, efforts are being made to obtain pectin from plants with relatively shorter maturity periods, which can also produce a substantial yield. One of the promising plant leads is okra (*Abelmoschus esculentus* L.).

Okra (*Abelmoschus esculentus* L.) is an essential vegetable crop which is primarily cultivated worldwide for its immature pods (Boakye-Gyasi et al., 2021; FAO et al., 2013; Kpodo et al., 2017a). There are over 50 species of okra that have been investigated as possible excipients in pharmaceutical formulations (Al-Shawi et al., 2021; Chen et al., 2014; Elkhalifa et al., 2021; Naveen et al., 2017; Prajapati et al., 2013; Srivastava & Malviya, 2011) Nevertheless, compared to other natural polymers, like alginate and gums, translation into routine pharmaceutical industrial application is limited. Several reported literature reveals the potential of okra as a binder, disintegrant and other excipients in pharmaceutical formulations (Al-Shawi et al., 2021; Elkhalifa et al., 2021; Sonawane et al., 2021).

Rhamnogalacturonan-I (RG-I) segments with varying molecular weights (10-767 × 10^3g/mol) and compositions of side chains have been reported to be abundant in isolated okra pectins (Kpodo et al., 2017a). Alba & Kontogiorgos posit that, several factors particularly the genotype of the okra plants can cause extracted pectins to exhibit heterogeneity in macromolecular characteristics such as the degree of esterification, chemical composition and molecular weight, which can subsequently affect their functional properties (Alba & Kontogiorgos, 2017).

Previous works have established that the genotypes; Penkrumah, Agbagoma, Asha, Sengavi, and Balabi are commonly cultivated and consumed in Ghana while preliminary characterisation also highlights the potential for pharmaceutical application (Afotey et al., 2023; Agbenorhevi et al., 2020; Kpodo et al., 2017b). Moreover, the high burden of Ghana's drug importation (70-90%) contributes significantly to Ghana's annual healthcare expenditure resulting in the high cost of medicines and impeding the attainment of the World Health Organisation (WHO) Universal Health Coverage (WHC) (Adebisi et al., 2022; Conway et al., 2019).

Consequently, this study aims to investigate the potential and comparative suspending properties of pectin obtained from five okra genotypes cultivated in Ghana using paracetamol suspensions. Understanding the effects genetic variations have on the quality of pectin produced will impact the commercialization of cultivated okra pectin as a pharmaceutical excipient (suspending agent) while providing the needed literature to address its potential as a pharmaceutical suspending agent. Moreover, the utilization of locally sourced pectin has the potential to reduce the country's healthcare expenditure and attain Universal Health Coverage.

Materials and methods

Materials

Paracetamol BP (Biotech Co., China), tragacanth (Sigma Aldrich, Damsta Germany), 0.1%w/v benzoic acid (BDH England), and laboratory grades of concentrated hydrochloric acid and ethanol (96%) (Department of Pharmaceutics, Kwame Nkrumah University of Science and Technology (KNUST), Ghana). Okra (*Abelmoschus esculentus* L.) genotypes: PL1 (Penkrumah), PL2 (Agbagoma), PL3 (Asha), PL4 (Sengavi), and PL5 (Balabi) were obtained from several markets in Ghana and authenticated at the department of Herbal Medicine by Mr. Clifford Asare. The specimen voucher numbers KNUST/HMI/2023/F002-F006 were assigned to the okra pods respectively after they were deposited at the herbarium. All reagents employed were of analytical grade.

Method

Extraction of Pectin

Okra pectin was extracted and isolated using reported protocols (Alba et al., 2015; Kpodo et al., 2017a). The seeds were removed after the pods were cut open and then sun-dried and milled into powder. An amount of 20 g of the dried okra powder was subsequently defatted for 4 hours with petroleum ether (1 g:10 mL). Employing the extraction conditions of pH 6.0 and 80°C, an aqueous extraction of the defatted okra powder was carried out using 0.1 M phosphate buffer (1 g powder:30 mL buffer solution) for 1 hour. Subsequently, the soluble polymer was isolated from the insoluble polymer using centrifugation (3000 rpm for 10 min at 25 °C). The solubilized pectin in the supernatant was then concentrated using evaporation at 80 °C for 30 min and then precipitated with 96% ($^{v}/_{v}$) aqueous ethanol and then washed in isopropanol and freeze-dried. To prevent absorption of moisture while pending further analysis, the freeze-dried pectins were stored in airtight containers in desiccators.

Characterization of Pectin

Pectin yield

The pectin yield was determined using reported protocols (Kpodo et al., 2017; Samavati, 2013).

Determination of the degree of esterification of extracted pectin using Fourier Transformed Infrared (FTIR) Spectroscopy

FTIR analysis of okra pectin from the different genotypes was performed with the aid of a Bruker Alpha II FTIR spectrophotometer (400 to 2000 cm^{-1}). The degree of esterification (DE) of the samples was subsequently calculated by determining the peak area values of the free carboxyl groups and the esterified groups by following the equation (Pappas et al., 2004).

$$DE = 124.7 \times R + 2.2013 \quad (1)$$

$$R = \frac{A_{1722.24}}{A_{1722.24} + A_{1606.75}} \times 100 \quad (2)$$

Where DE is the degree of esterification and $A_{1722.24}$ and $A_{1606.75}$ are the absorbance densities at 1722.24 and 1606.75 cm^{-1} respectively (Güzel & Akpınar, 2019).

Formulation of Paracetamol Suspension

The paracetamol suspensions (5.0 % $^{w}/_{v}$) were prepared using okra pectin concentrations of 0.5, 1.0 and 2.0 $\%^{w}/_{v}$. Benzoic acid (0.1 $\%^{w}/_{v}$) was employed as a preservative in each formulation. The direct incorporation and levigation techniques as described by (Owusu et al., 2022) were used. Table 1 depicts the formula used in formulating the paracetamol suspensions using tragacanth as the suspending agent. The same formula was used for the pectin suspensions. The concentrations of tragacanth and okra pectin (suspending agent) were the only variables altered in the formula (Oppong et al., 2016).

Table 1. Composition of paracetamol suspensions using tragacanth as a suspending agent

Ingredient	Quantities
Paracetamol powder	5.0 g
Tragacanth (0.5,1,2 % $^{w}/_{v}$)	0.5,1.0,2.0 g
Benzoic acid (0.1 % $^{w}/_{v}$)	0.1 g
Distilled water to	100.0 mL

Quality Control Evaluations on Formulated Suspensions

pH

The pH of the formulated suspensions was determined after they were freshly prepared and then at weekly intervals using the Hanna pH meter (HI 2215). The measurements were carried out in triplicates and the means and standard deviations were noted after ensuring the electrodes were fully immersed (Mahmud et al., 2010; Nep & Conway, 2011; Oppong et al., 2016).

Flow Rate

The flow rate was determined by measuring the time it took for the formulated suspensions to flow through a 20 mL pipette with a stopwatch. The mean values and standard deviations were calculated after the triplicate readings were recorded (Mahmud et al., 2010; Nep & Conway, 2011; Oppong et al., 2016).

Redispersibility

The redispersibility was measured by recording the number of strokes (inversions) needed to resuspend the formulations completely. This was carried out by turning 50 mL of the formulated suspensions in a measuring cylinder through a 180° cycle. This determination was done at weekly intervals for 4 weeks (Mahmud et al., 2010; Nep & Conway, 2011; Oppong et al., 2016).

Sedimentation Rate and Volume

The sedimentation rates of the formulated suspensions were measured by determining the sediment level in the measuring cylinder at intervals of 10, 20, 30, 40, 50 and 60 minutes. During 4 weeks, the sedimentation volume of the suspension was determined by measuring the sediment volume in 50 mL of the formulated suspensions, weekly. The sedimentation volume (*F*) was calculated using Equation 3. Triplicate measurements were recorded and the mean value was calculated (Mahmud et al., 2010; Nep & Conway, 2011; Oppong et al., 2016).

$$F = \frac{Vu}{Vo} \quad (3)$$

Where Vu is the ultimate volume of sediment in mL and Vo is the original volume of sediment in mL before settling occurred.

Results

Characterization of Extracted Okra Pectin of Different Genotypes

Percentage yield and physicochemical evaluation of okra pectin

The percentage yields from all the five different okra (*Abelmoschus esculentus* L.) genotypes ranged from 6 to 19 $\%^{w}/_{w}$ in the following order PL2 > PL5 > PL3 > PL4 > PL1 as shown in Figure 1.

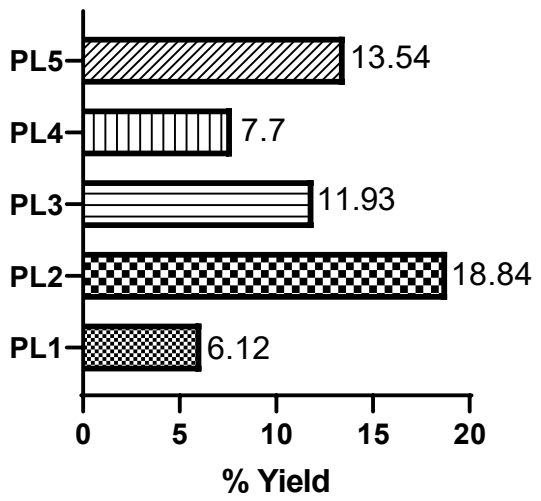

Figure 1: Percentage of pectin yields from different okra genotypes

FTIR Spectroscopy

The FTIR spectra of pectin from all the different genotypes depicted a high level of similarity when peak positions were compared (Table 2 and Figure 2)). Prominent absorption bands were observed between 1730 and 1700 cm^{-1} and 1600-1630 cm^{-1}. The carbohydrate fingerprint regions (1000-1200 cm^{-1}) were also similar which could be assigned to the stretching vibrations of glycosidic bonds (C-O) and pyranoid rings (C-C). The absorption bands between 1730 and 1700 cm^{-1} could be assigned to the C=0 stretching vibrations of the esterified methyl and free carboxylic acid groups. In the region of 1600-1630, the stretching vibration of the carboxylate anion (COO^{-}) was assigned (Manrique & Lajolo, 2002).

Figure 3 shows the degree of esterification (DE) of all the okra genotypes using the two critical peaks of the free carboxyl groups and the esterified groups. The DE of all the genotypes were between 43.56 and 49.00% with PL5 recording the highest DE.

Quality Control Evaluations of Formulated Suspensions

pH, Redispersibility and Flow Rate of Formulated Suspensions

Table 3 shows the pH of the formulated suspensions during the 4-week observation period. The pH of all the formulated suspensions was weakly acidic during the evaluation period and showed no visible signs of incompatibility such as caking, aggregation and crystal growth. When compared to the initial pH of the freshly prepared suspensions, a non-significant difference ($p \geq 0.05$) was observed for all suspensions during the 4-week study period.

The redispersibility of suspensions, an essential qualitative test which assures uniformity of doses is presented in Figure 5 (a-c) (in Appendix). The results indicate that the okra pectin (PL) irrespective of the concentrations or genotype employed was readily re-dispersible when compared to tragacanth (ST).

When the flow rates or apparent viscosities of the suspensions were investigated, it was observed from the time course curves that at all concentrations, when tragacanth was used as a suspending agent, the flowrates were significantly ($p < 0.0001$) higher than when PL was used. The area under the time course curves which highlight cumulative effect also supported this by highlighting a significant difference in flow rates ($p < 0.0001$) as shown in figures 6 (a-c) (in appendix).

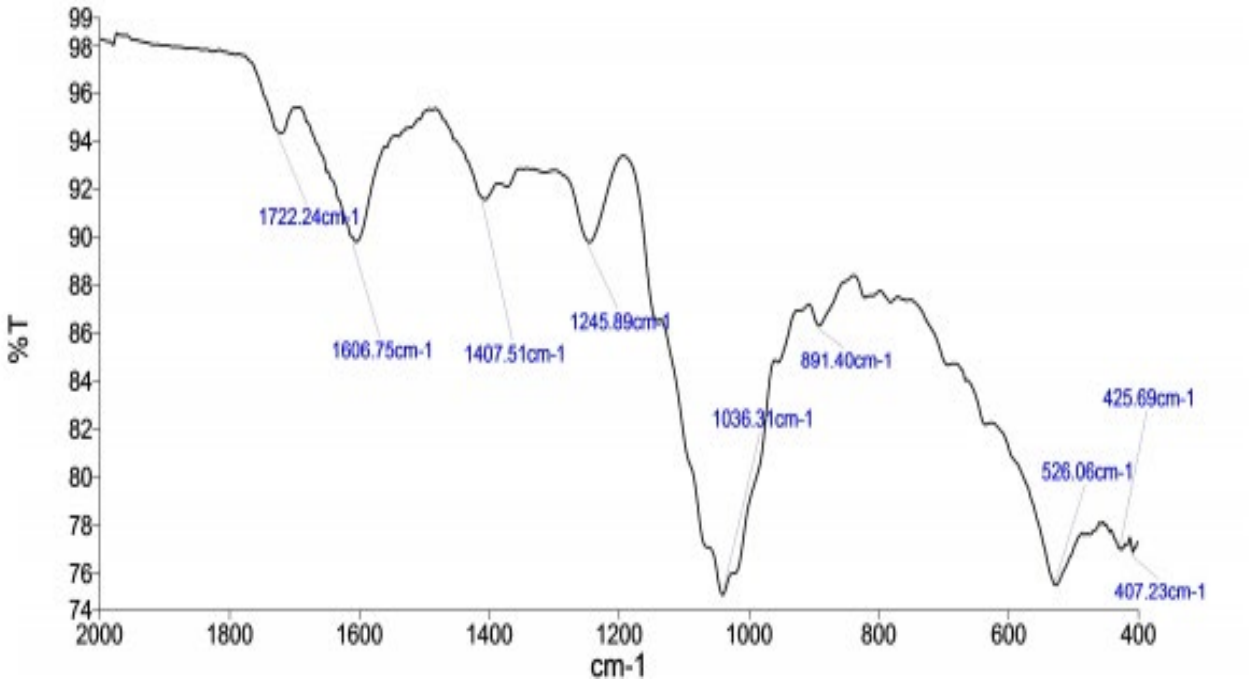

Figure 2: FTIR spectra of different okra genotypes PL1

Sedimentation Rate and Volume

The sedimentation rates of the different concentrations of suspending agents are presented in Figure 7 (a-c) (in the appendix). An increase in concentration from 0.5 to 2% resulted in a decrease in sedimentation rate for all suspensions. Moreover, when compared to tragacanth, PL recorded lower sedimentation rates over the study period at all concentrations which were proportional to the concentrations of PL used.

Figures 8 (a-c) (in the appendix) show the sedimentation volumes (SV) of suspension during the 4-week evaluation period. At 0.5%, SV values were very close to 0 when compared to the higher concentrations (1% and 2%) and were non-significantly different ($p > 0.05$) compared to tragacanth. At 2%, significant differences ($p < 0.0001$) were observed for all PL genotypes when compared to tragacanth while only PL1, PL4 and PL5 were significantly different ($p < 0.0001$) at 1%. PL4 comparatively had the highest SV however, cumulatively, the SV of tragacanth was lower than all PL genotypes at all concentrations.

Discussion

The study aimed to investigate the potential and comparative suspending properties of pectin obtained from five okra genotypes cultivated in Ghana using paracetamol suspensions. The yields obtained were comparable to those reported by Alba and colleagues who reported values between 13 and 15.9% (Alba et al., 2015). The differences in pectin yields attest to the fact that the source of pectin (genetic variations) has a significant impact on the amount of pectin extracted (Chan & Choo, 2013). The results were consistent with results reported by Owusu *et al.* (6-19%) who also discussed extensively the physicochemical properties of pectin from different okra genotypes (Owusu et al., 2021). The knowledge from their background informed the investigation into the suitability of okra pectin as a pharmaceutical suspending agent.

Suspending agents are increasingly utilized to enhance the viscosity and slow sedimentation rates of suspensions to ensure the administration of accurate doses (Ayesu Djakari et al., 2022). One of the essential determinants of suspension stability is the pH which is usually impacted by the nature of polymeric chains in suspending agents used (Reyes-Ortega, 2014). The slightly acidic pH values obtained were comparable with other published literature (The Lubrizol Corporation, 2020; Vázquez-Blanco et al., 2018). Slightly acidic pH (<5.0) is reported to enhance the adsorption of pectin and decrease sedimentation (Lam et al., 2007; Maroziene & De Kruif, 2000; Nakamura et al., 2006). Lower pH ranges tend to decrease the dissociation of carboxyl residues in the galacturonic acid chains of pectin. This culminates in reduced electrostatic repulsion, increased hydrogen bonds and hydrophobic interactions, all of which are essential in the stabilization of pectin gels (Gawkowska et al., 2018). Furthermore, the slightly acidic pH can prevent microbial degradation of suspensions upon storage which was evidenced by the lack of stability issues throughout the study period.

The redispersibility of suspensions is an essential quality which assures accuracy in dosing by ensuring that suspended particle do not aggregate but are uniformly distributed (Nutan & Reddy, 2010; Piriyaprasarth & Sriamornsak, 2011) Higher number of cycles represent poor redispersibility and this could be accounted for by the tighter packing of particles which can be resolved by the addition of a deflocculating agent (Allen & Ansel, 2013; Nutan & Reddy, 2010). The results indicate that the okra pectin irrespective of the concentrations or genotype employed was readily redispersible when compared to the standard (tragacanth) indicating loose aggregates which are easily redispersed by small agitation (Alalor & Obunezie, 2020).

The formulated okra suspensions were pourable from their containers with minimal agitation and thus exhibited pseudoplastic flow, a desired property of suspensions (Allen & Ansel, 2013; Nutan & Reddy, 2010). Higher concentrations of the suspending agent result in decreased viscosity and increased pourability, a key attribute for maintaining pseudoplastic flow (Bamigbola et al., 2017). An increase in concentration is associated with overlapping of coils and an increase in entanglements which increases viscosity but reduces the flow rate (Piriyaprasarth & Sriamornsak, 2011). This property also ensures increased stability and pourability of suspensions (Bamigbola et al., 2017; Larsson et al., 2012; Nutan & Reddy, 2010; Woldu et al., 2021b). At all concentrations, PL demonstrated a significant ($p < 0.0001$) difference in flow rate which suggests better suspending properties compared to tragacanth. The molecules in tragacanth are highly branched compared to pectin and this affects its ability to form gels (Vaclavik & Christian, 2003). Furthermore, both carbohydrates contain different monosaccharide compositions and molecular weights which have been reported to impact their gelling properties in addition to other physicochemical properties such as hydrogen bonding and Van der Waal forces(Mikušová et al., 2022).

An ideal property of a good suspension is the ability of suspended particles to settle slowly for an accurate dose to be administered. A high sedimentation volume (closer to 1) and a slow sedimentation rate are therefore recommended. PL possess good stability indexes and though the dispersed phase settled, the inter-particulate attraction and bonding were not strong enough to form a hard cake during

Table 2. Relevant peaks and assigned groups of other okra genotypes

Okra genotype	Relevant peaks (cm^{-1})	Assigned functional groups
PL2	1037.83	C-O stretching of alcohol (-OH) group
	1407.32	O-H bending of carboxylic acid (-COOH) group
	1603.30	the stretching vibration of the carboxylate anion (COO^-)
	1721.12	C=O stretching vibrations of the esterified methyl and free carboxylic acid groups
PL3	1032.36	C-O stretching of alcohol (-OH) group
	1408.17	O-H bending of carboxylic acid (-COOH) group
	1602.18	the stretching vibration of the carboxylate anion (COO^-)
	1723.62	C=O stretching vibrations of the esterified methyl and free carboxylic acid groups
PL4	1032.29	C-O stretching of alcohol (-OH) group
	1400.22	O-H bending of carboxylic acid (-COOH) group
	1604.32	the stretching vibration of the carboxylate anion (COO^-)
	1719.52	C=O stretching vibrations of the esterified methyl and free carboxylic acid groups
PL5	1037.40	C-O stretching of alcohol (-OH) group
	1407.07	O-H bending of carboxylic acid (-COOH) group
	1606.67	the stretching vibration of the carboxylate anion (COO^-)
	1720.12	C=O stretching vibrations of the esterified methyl and free carboxylic acid groups

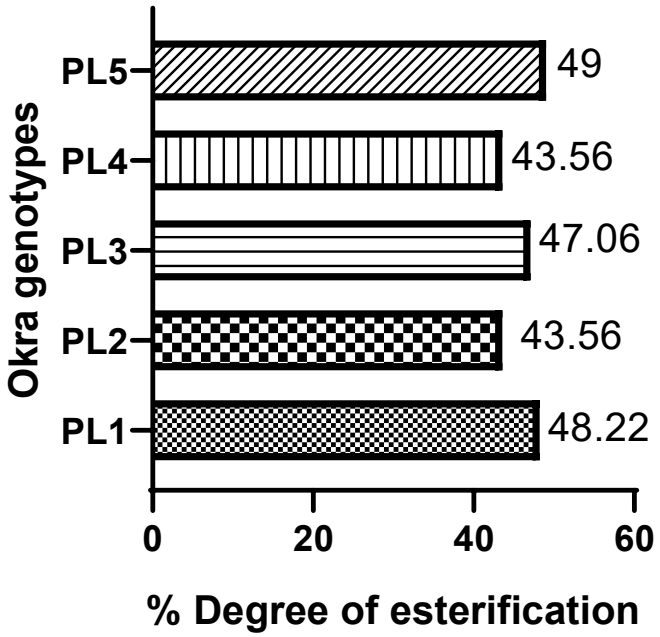

Figure 3. The Degree of Esterification of Pectin from Different Okra Genotypes

Table 3. pH of the Formulated Suspensions over a 4-Week Period

Formulation	pH				
	Freshly prepared	Week 1	Week 2	Week 3	Week 4
ST 0.5 %	4.60±0.04	4.60±0.03 [a]	4.61±0.06 [a]	4.61±0.04 [a]	4.62±0.02 [a]
ST 1.0 %	4.80±0.05	4.80±0.06 [a]	4.81±0.03 [a]	4.81±0.08 [a]	4.81±0.02 [a]
ST 2.0 %	4.81±0.03	4.81±0.01 [a]	4.82±0.04 [a]	4.82±0.08 [a]	4.82±0.06 [a]
PL1 0.5 %	4.82±0.06	4.83±0.06 [a]	4.83±0.09 [a]	4.83±0.03 [a]	4.83±0.08
PL1 1.0 %	4.83±0.04	4.82±0.04 [a]	4.82±0.09 [a]	4.83±0.06 [a]	4.83±0.07 [a]
PL1 2.0 %	4.83±0.07	4.82±0.03 [a]	4.82±0.08 [a]	4.82±0.03 [a]	4.82±0.05 [a]
PL2 0.5 %	4.81±0.04	4.81±0.06 [a]	4.83±0.02 [a]	4.83±0.02 [a]	4.83±0.02 [a]
PL2 1.0 %	4.82±0.02	4.83±0.09 [a]	4.83±0.06 [a]	4.83±0.05 [a]	4.83±0.06 [a]
PL2 2.0 %	4.84±0.03	4.84±0.03 [a]	4.83±0.05 [a]	4.84±0.07 [a]	4.84±0.07 [a]
PL3 0.5 %	4.77±0.07	4.77±0.01 [a]	4.83±0.02 [a]	4.83±0.02 [a]	4.83±0.02 [a]
PL3 1.0%	4.78±0.08	4.78±0.04 [a]	4.79±0.06 [a]	4.78±0.03 [a]	4.78±0.05 [a]
PL3 2.0 %	4.79±0.04	4.79±0.04 [a]	4.79±0.08 [a]	4.79±0.06 [a]	4.79±0.06 [a]
PL4 0.5 %	4.79±0.04	4.78±0.05 [a]	4.78±0.04 [a]	4.78±0.05 [a]	4.79±0.06 [a]
PL4 1.0 %	4.79±0.06	4.79±0.03 [a]	4.79±0.05 [a]	4.79±0.04 [a]	4.79±0.05 [a]
PL4 2.0 %	4.80±0.08	4.79±0.03 [a]	4.79±0.05 [a]	4.80±0.02 [a]	4.80±0.04 [a]
PL5 0.5 %	4.88±0.03	4.88±0.04 [a]	4.88±0.04 [a]	4.88±0.05 [a]	4.88±0.02 [a]
PL5 1.0 %	4.90±0.05	4.90±0.06 [a]	4.89±0.05 [a]	4.89±0.06 [a]	4.89±0.04 [a]
PL5 2.0 %	4.91±0.07	4.91±0.06 [a]	4.91±0.03 [a]	4.90±0.04 [a]	4.91±0.06 [a]

Values are means ± SD (n = 3). [a] $p \geq 0.05$ non-significant difference in pH between freshly prepared suspensions and during the evaluation period using one-way ANOVA. (ST, standard).

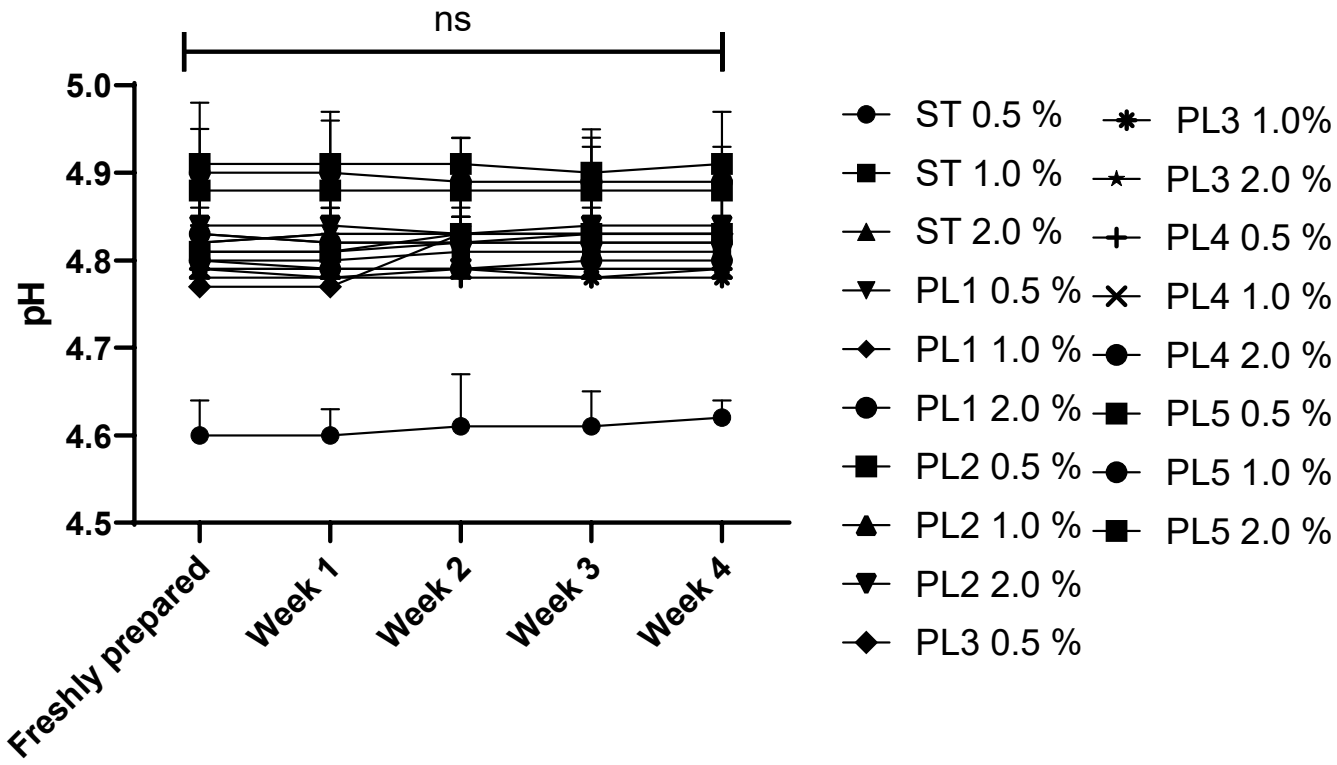

Figure 4. pH of the Formulated Suspensions over a 4-Week Period.

the evaluation period. The sedimentation rates of the suspensions were inversely proportional to the concentrations of PL used in the formulation which indicates that, as the concentration increases, the suspending ability of pectin also increases and supports the findings in the flow rate.

Conclusion

Okra pectin demonstrated good suspending properties when compared to routinely used natural suspending agent, tragacanth. At all concentrations, okra pectin exhibited superior pH, flow rate, and redispersibility, as well as sedimentation volume and rate. The abundance, cost-effectiveness and non-toxicity of okra pectin positions it as a good raw material for the pharmaceutical industry in Ghana with the potential to reduce overhead costs in formulating oral dosage forms.

Authors Contributions

Conceptualization, MEBG, MTB, KOK. And FWAO.; methodology, FWAO, PGJA, JA, EAQ and BAA.; data curation, PGJA, PKT; writing—original draft preparation, FWAO, PJGA, MEBG; writing—review and editing, KOK, MTB. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare no conflicts of interest.

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APPENDIX

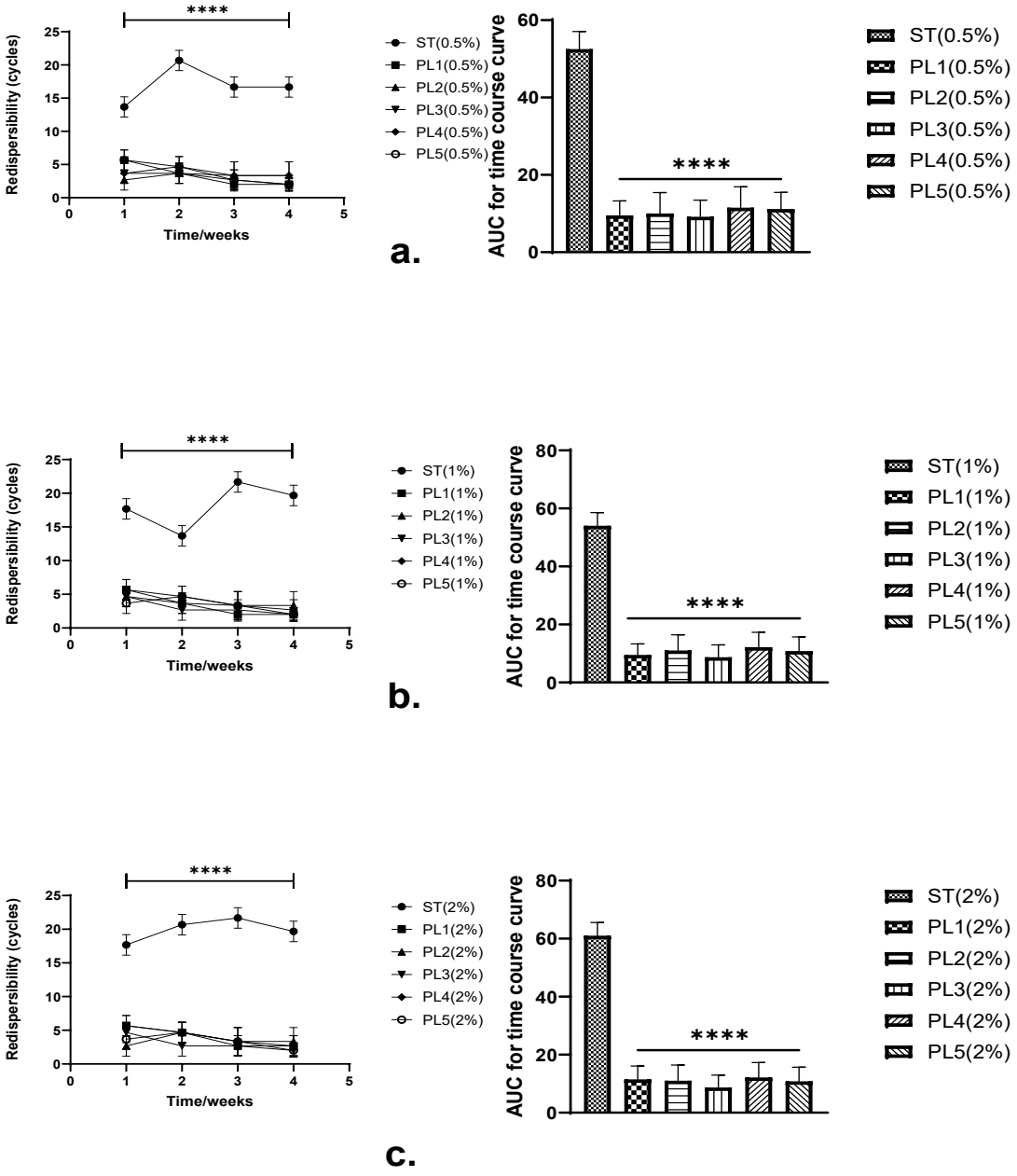

*Figure 5: Redispersibility (cycles) of suspensions formulated with different suspending agents (a) PL (0.5%w/v) and ST (0.5%w/v), (b) PL (1%w/v) and ST (1%w/v) and (c) PL (2%w/v) and ST (2%w/v). **** $p < 0.0001$ significance difference between (ST) Tragacanth and PL.*

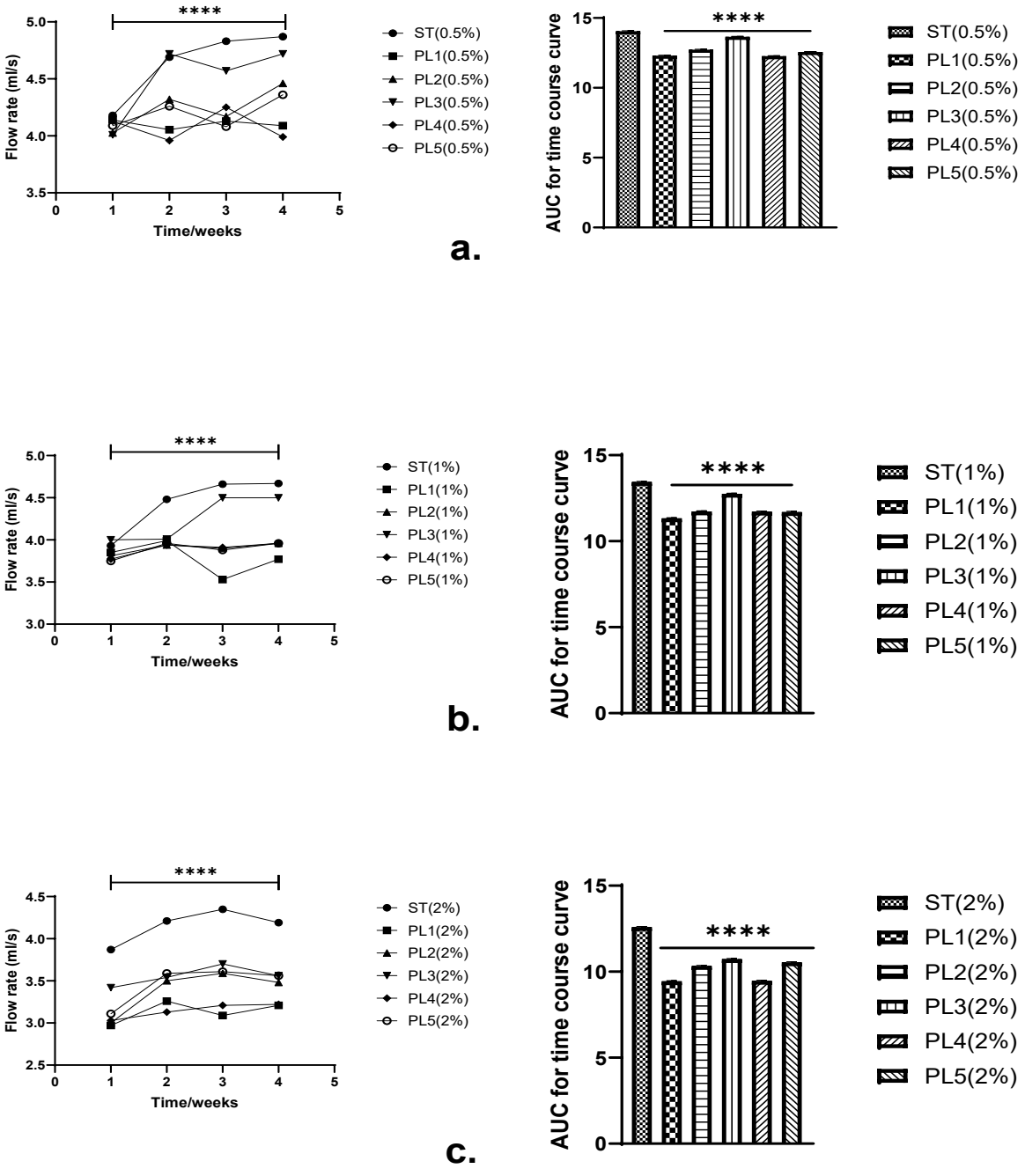

*Figure 6: Flow rate of suspensions (ml/s) of suspensions formulated with different suspending agents (a) PL (0.5%w/v) and ST (0.5%w/v), (b) PL (1%w/v) and ST (1%w/v) and (c) PL (2%w/v) and ST (2%w/v). **** $p < 0.0001$ significance difference between (ST) Tragacanth and PL.*

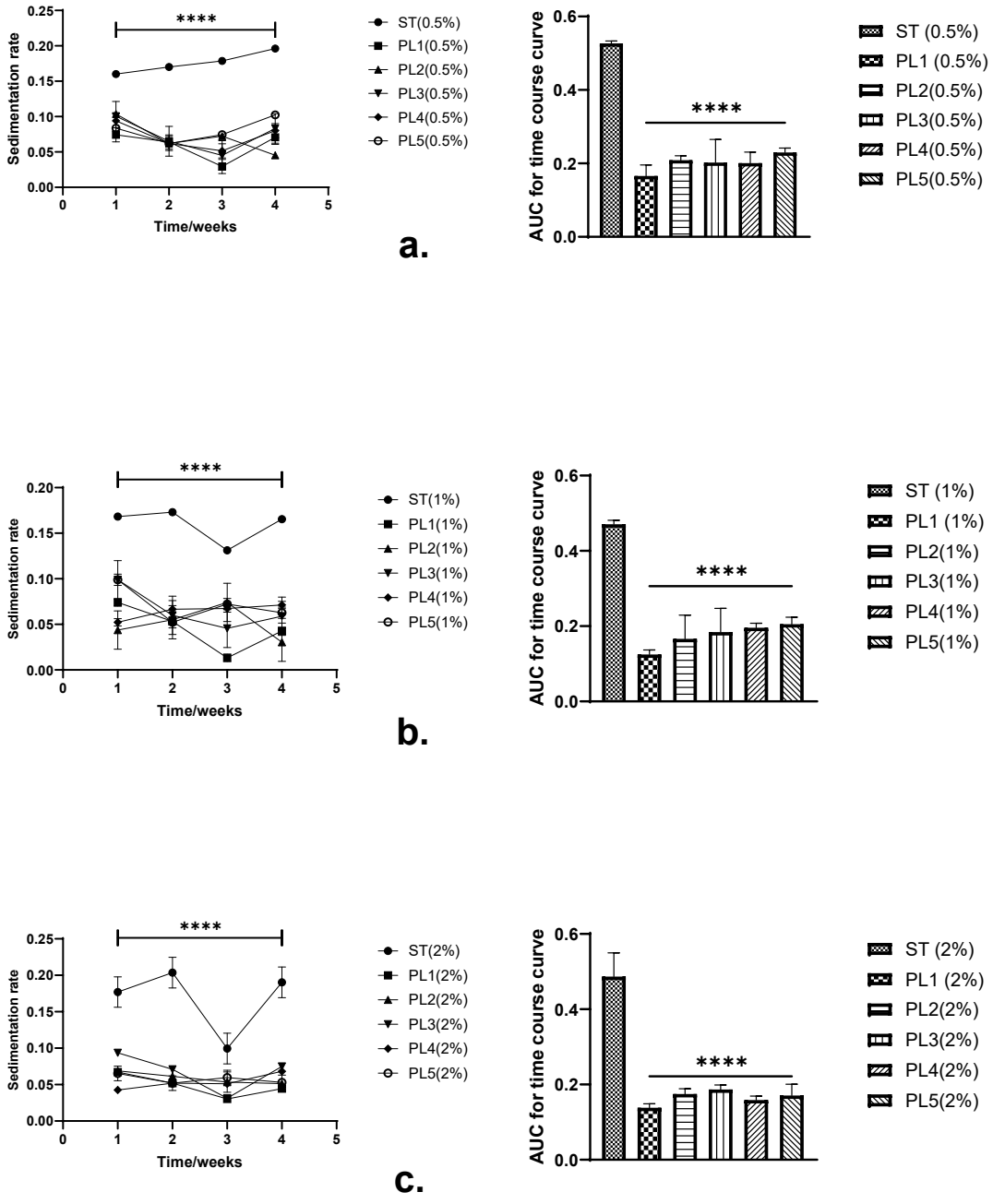

*Figure 7: Sedimentation rate of suspensions formulated with different suspending agents (a) PL (0.5%w/v) and ST (0.5%w/v), (b) PL (1%w/v) and ST (1%w/v) and (c) PL (2%w/v) and ST (2%w/v).). **** $p < 0.0001$ significance difference between (ST) Tragacanth and PL.*

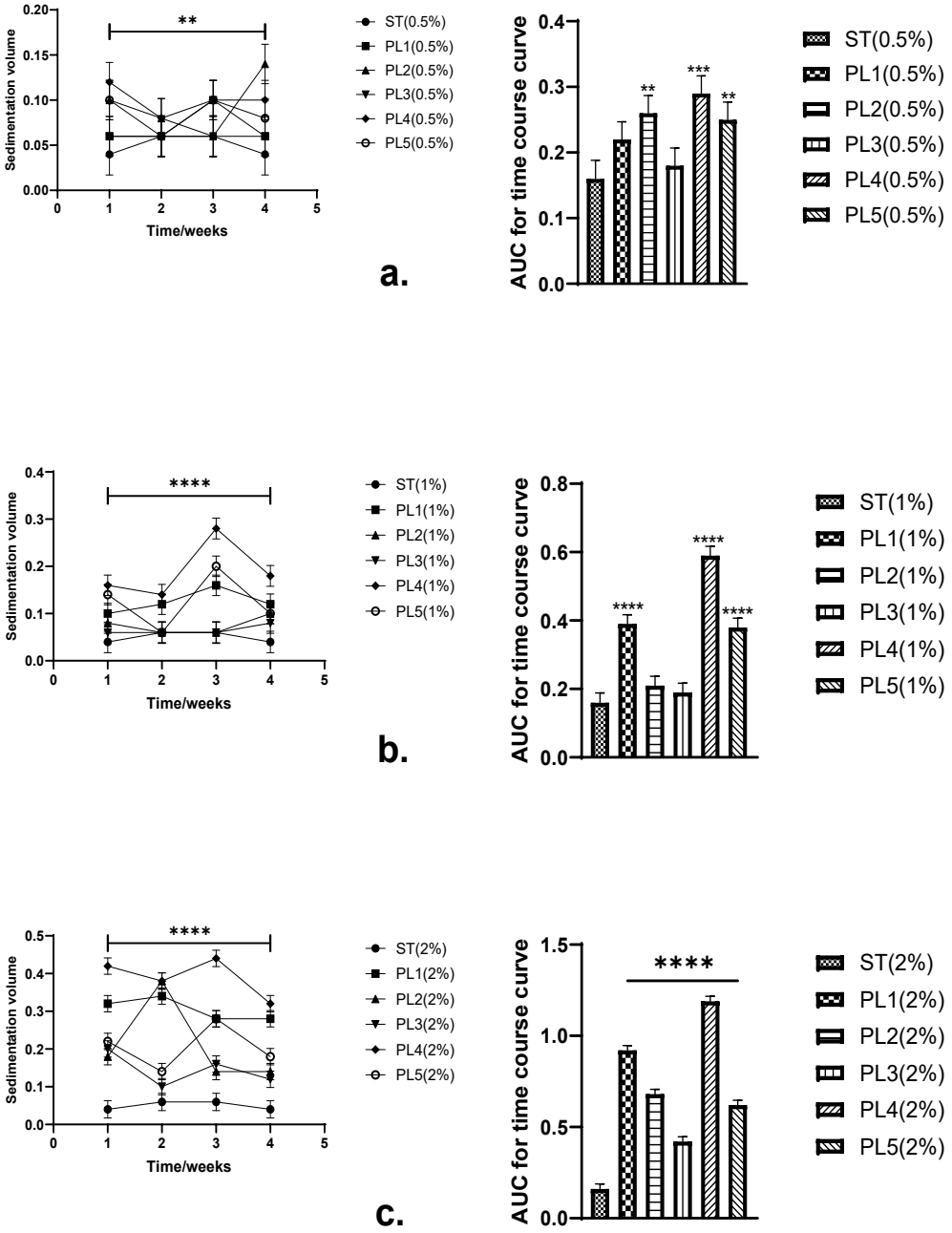

*Figure 8: Sedimentation volume of suspensions formulated with different suspending agents (a) PL (0.5%w/v) and ST (0.5%w/v), (b) PL (1%w/v) and ST (1%w/v) and (c) PL (2%w/v) and ST (2%w/v).). **p <0.01, ***p<0.001,**** p<0.0001 significance difference between (ST) Tragacanth and PL.*