Evaluation of formulated suspension with varying concentrations of pectin derived from Mango (*Mangifera indica* Linn.) peel and acacia (*Acacia Senegal* L.) as suspending agents

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| Nature has provided us a wide variety of materials to help improve and sustain the health of all living things either directly or indirectly.Pharmaceutical excipients used as suspending agents from natural sources are preferable due to their biocompatibility, abundance, and positive impact on the environment. *Mangifera indica* peel is excessively produced as a by-product of local food processing plants in Cebu. The objective of the study is to characterize the formulated suspensions with varying concentration of pectin from mango peel and acacia (*Acacia Senegal L*) as a suspending agent.**Objective:** Determine the characteristics of the formulated suspensions with varying concentrations of pectin from mango peel and acacia as suspending agents **Method:** Paracetamol suspensions were prepared with mango pectin at concentrations of 2, 3 and 4 % and acacia (3%) as standard. The prepared suspensions were characterized based on sedimentation volume, degree of flocculation, flow rate, pH, viscosity and redispersibility.**Results and discussions**: Mango pectin exhibited good sedimentation volume and viscosity-enhancing property, qualities which are important as a suspending agent in pharmaceutical suspensions. **Conclusion:** The present review provided an overview of various aspects of natural suspending agent like general extraction method, physicochemical properties which supported the possible utility of mango peel derived pectin as a potential biomaterial in formulating pharmaceutical suspensions. |

*Keywords: Suspending agent,Acacia ,Suspension,Mango peel, pectin*

1. INTRODUCTION

A pharmaceutical suspension is defined as a coarse dispersion in which the internal phase is dispersed uniformly throughout the external phase. Suspension is thermodynamically unstable, so it is necessary to add suspending agents which reduces the rate of settling and permits easy redispersion of any settled particulate matter both by protective colloidal action and by increasing the consistency of the suspending medium. Suspensions can be classified as coarse or colloidal dispersion based on the size of the particles. Suspensions with a particle size greater than 1 µm are termed as coarse suspension whereas those below 1 µm are known as colloidal suspensions. The term pharmaceutical suspensions apply to those suspensions when the solid particles of the disperse phase are therapeutically active. The reasons for formulating pharmaceutical suspensions is to mask the bitter taste of drug, increase drug stability, achieve controlled or sustained release and when the drug is insoluble in the delivery vehicle (Friedrick William Akuffo, 2024)

 (). Pharmaceutical suspensions have greater use in the pharmaceutical industry since they are the only choice if the drug is not soluble or poorly soluble, drugs incorporated in suspensions exhibit a higher rate of bioavailability due to its large surface area, leading to higher dissolution rate, (Barker, 2013).

Physical stability, sedimentation, and compaction of pharmaceutical suspension can cause problems like difficulty to formulate a suspension, uniformity, and accuracy of dose which are hardly achieved unless suspensions are packed in unit dosage form are part of the disadvantages of suspensions. To avoid all these disadvantages encountered during the formulation of pharmaceutical formulation, a well-studied excipient both synthetic, semi-synthetic (eg. Methylcellose) or natural (eg. Acacia, tragacath and pectin) has to be used as a suspending agent (Santosh Kumar and Naga Satya Yagnesh, 2016).

Suspending agents are classified into the following: (i) inorganic materials, (ii) synthetic compounds, or polysaccharide, natural agents also known as polysaccharides/pectin consists of a) Animal source e.g. gelatin, b) Plant source e.g. acacia, tragacanth, starch, seaweed (Alginates), c) mineral sources e.g. bentonite, kaolin. Semisynthetic agents consist of substituted cellulose (mineral) e.g. hydroxyethylcellulose, sodium carboxymethylcellulose, microcrystalline cellulose while synthetic agents consist of carboxypolymethylene (Carbopol), polyvinyl alcohol, polyvinyl pyrrolidone iodine complex (PVC). Suspending agents act by preventing sedimentation and aggregation or caking of particles in suspension (Lloyd and Ansel, 2015). The advantages of using syntentic and semi-synthetic suspending agents include stability, solubility in water, do not form a gel on heating, and have good developed thixotropy (Goswami and Naik, 2014). But in general synthetic and semi-synthetic suspending agents are; expensive to acquire, toxic, produce environmental pollution during synthesis and non-renewable sources (Naga Vamsi Krishna et al., 2011). Current studies are now focusing on natural agents due to their biocompatibility, safety, environmental friendly and less cost (Naga Vamsi Krishna et al., 2011). There are different natural agents that are now being explored for its use as a pharmaceutical excipient. Pectin is one of the natural agents that possess swelling activity that is of greater importance in the formulation of pharmaceutical suspension.

 Pectin, a multifunctional constituent of cell wall, is a high-value functional food ingredient. It is produced commercially as a white to light brown powder, mainly extracted from fruits. Because of its ability to form a thick gel-like solution, pectin is used commercially in the preparation of jellies, jams, and marmalades. Its thickening properties also make it useful in the confectionery, pharmaceutical, and textile industries.

Acacia gum or gum Arabic is the dried gummy exudate from the stems and branches of *Acacia Senegal* (Fam. Leguminosae) and other related African species of acacia. Gum arabic is a branched molecule of 1, 3-linked β-D galactopyranosyl units. It consists of monosaccharide sugars such as arabinose, glucuronic acid, and rhamnose (Ogaji, 2011). The most utilized gum type is gum arabic (GA) obtained from *Acacia senegal var. senegal* trees. The wide use of GA is due to its high solubility and low viscosity compared to other polysaccharides, its good emulsifying characteristics and its non-toxic nature (Taha *et al*., 2012). Acacia gums are unique hydrocolloids in that they are water-soluble. They are, notably, used in the food industry to control and modify the rheological properties of aqueous food systems. Acacia gums act as stabilizers, film formers, thickeners, flocculants, suspending agents and emulsifiers. *Acacia senegal var. senegal* gum is a superior choice over *Acacia seyal var. seyal* gum although both are considered GA in the international market (Elmanan *et al*., 2008).

Mango possesses pharmacological properties of anti-diabetic, anti-oxidant, antiviral, anti-inflammatory properties. Various effects like antibacterial, anti-fungal, anthelmintic, anti-parasitic, anticancer, anti-HIV, anti-bone resorption, antispasmodic, antipyretic, antidiarrheal, immunomodulation, hypolipidemic, anti-microbial, hepatoprotective, and gastro protective (Parvez, 2016). Mango peels consist of approximately 20−40% of the total mango processing waste (by weight) generated in industries (Asif, 2016). Major components in mango peels are as follows: cellulose, 15−18%; hemicellulose, 5−11%; lignin, 9− 12%; pectin, 20−35%; proteins, 6−10%; ash, 2%; extractives 5−10%. The majority of the carbohydrates are soluble dietary fiber such as pectin (Ajila, 2013). Compared to other commercial sources such as apple pomace (10−15% pectin), citrus peel (25−35% pectin), sugar beet (10−20% pectin) and sunflower (15−25% pectin), the quantity of pectin in mango peels varies from 20 to 30% of total peel weight (Maran, 2015).



## Figure 1. Structure of pectin (Hassan *et al*., 2018)

**B**

B

A

C

**Figure 2. *Mangifera indica* Linn**

A: Habit of growth (https://[www.google.com/search/](http://www.google.com/search/) mangifera+indica+plant.com) B: Fruits (https://[www.philstar.com/business/2019/06/07/1924212/japan-firm-buying-](http://www.philstar.com/business/2019/06/07/1924212/japan-firm-buying-) philippine-mangoes)

C: Roots (Saavedra, 2011)

Physico-chemical stability of suspensions is important for maintaining the quality of the product. Physical stability of suspensions may be defined as the condition in which the particles do not aggregate in which they remain uniformly distributed throughout the dispersion (Sinko *et al*, 2007). The following are the common parameters used to determine suspending ability.

**Sedimentation volume (F**). This is the ratio of the ultimate height (Hu) of the sediment as suspension settles in a cylinder under standard conditions to the initial height (Ho) of the total suspension. F has values ranging from less than one to greater than one. When F<1 or F=1, the system is in flocculated equilibrium and show no clear supernatant on standing. When F>1, the sedimentation volume is greater than the original volume due to the network of flocs formed in the suspension and so loose and fluffy sediment. Thus, sedimentation volume gives only a qualitative account of flocculation (Manoj, 2013).

**Viscosity.** It can modify the sedimentation rate and maintain proper viscosity of the suspension to ensure the accuracy of dosing. If the particles in a suspension settles quickly, it may not be possible to withdraw the appropriate volume of the preparation from the container (Nutan *et al*, 2010).

**Degree of flocculation**. Degree of flocculation (β) is a parameter to compare flocculated systems relating the sedimentation volume of the flocculated suspension (F) to the sedimentation volume of the suspension when deflocculated (F∞). The degree of flocculation is determined by dividing the sedimentation volume of flocculated suspension

(F) to the sedimentation volume of the suspension when deflocculated (F∞) (Remington, 2006).

**Flow rate**. It is an estimate of the ease with which the suspension will be poured from the container. The flow rate of the suspension decreases with an increase in concentration of suspending agent (Yohannes Mengesha, 2021)

**Redispersibility.** It is estimated by manual shaking of the container holding the suspension. When the drug material is in the dispersed state, the dispersed material will have an equilibrium solubility that varies relative to its particle size. Small particles will have higher equilibrium solubility than the larger particles (Yohannes Mengesha, 2021).

Researchers have studied pectin extensively for their applications in product development, specifically as pharmaceutical excipients.Tamarind seed polysaccharide, tragacanth, acacia and gelatin at concentration range of 1 - 4.5%w/v were used to prepare paracetamol suspension. Characterization tests were carried out on each of polysaccharide. Sedimentation volume (%), rheology and particle size analysis were employed as evaluation parameters. The values obtained were used as basis for comparison of the suspending agents studied. Compound tragacanth gum had the highest suspending ability relative to the other materials (Malviya *et al*., 2010).

Suspensions of paracetamol were prepared and compared with different concentrations (1%, 2%, 3% and 4% w/v) of *Abelmoschus esculentus* mucilage, sodium CMC and tragacanth gum. Their sedimentation profile, redispersibility, degree of flocculation and rheological behavior were compared. The mucilage was found to be a superior suspending agent than tragacanth and is comparable to sodium CMC (Kumar, 2009).

Isolation and characterization of mucilage from five species of *Abelmoschus*; two cultivated (*A. esculentus, A. caillei*) and three wild (*A. manihot, A. angulosus* and *A. moschatus*) were conducted. The study also includes an assessment of the efficacy of mucilage of two species, *A. esculentus* and *A. moschatus* in paracetamol suspension preparation (Nair, 2012). Using a new technique, the yield of extracted pectin increased to 25.26%. (Malviya *et al*., 2011).

Acetaminophen tablets containing starch as a binding agent was used as standard for comparison with the acetaminophen tablets with pectin as binding agent. Mango pectin and starch were compared individually as tablet binder in paracetamol tablet formulation. The study revealed that mango pectin is comparable to starch as binding agent (Bersabal *et al*., 2014).

2. material and methods

Collection and preparation of plant sample

Mango (*Mangifera indica* Linn) peel, other parts of the plant and fruit samples were submitted to the Department of Agriculture, Field Office Region VII for authentication (Appendix A). Ripe mango peels were obtained as a waste from a fruit processing plant, Profood International Corporation. Peels were carefully washed and dried in an oven for 24 h at 50-55 ºC (Berardini, 2005).

Extraction of pectin from mango peel

One kilogram (Figure 1) of dried fruit peel was weighed, cut into pieces, and powdered using an electric blender. Powdered peel were further passed through sieve # 20 and stored in air tight container until used. A total of 400 g mango peel powder was mixed with 2200 mL distilled water and acidified with hydrochloric acid to meet the designed pH of 2.0. The mixture was then stirred using a stirrer until all the mango peel powder was evenly wetted by acidified water in homogenous form. The pectin extraction procedure was continued by heating the acidified samples at 90 ± 5°C in a stirring hot plate for 4 h. The solution was then cooled and filtered using a two-layer cheesecloth. The filtrate was collected then added with twice its volume of absolute ethanol. Pectin isolate was obtained, and then recovered by centrifuge at 5000 rpm for 10 minutes (Figure 2). The resulted pectin substance was dried in an oven at 65°C until a constant weight was reached (Kamble *et al*., 2017). The percentage yield was computed using the formula:

%𝑦𝑖𝑒𝑙𝑑 = 𝑤𝑒𝑖𝑔ℎ𝑡 𝑜𝑓 𝑑𝑟𝑖𝑒𝑑 𝑝𝑒𝑐𝑡𝑖𝑛 × 100

𝑤𝑒𝑖𝑔ℎ𝑡 𝑜𝑓 𝑑𝑟𝑖𝑒𝑑 𝑚𝑎𝑛𝑔𝑜 𝑝𝑒𝑒𝑙

## Preparation of paracetamol suspensions

To prepare paracetamol suspension, mango peel pectin or acacia was separately triturated with 5 g of paracetamol, benzoic acid, and added with 50 mL of water to form a smooth paste. The mixture was then transferred into a graduated cylinder and sufficient amount of water was added to reach the desired volume (100 mL). The resulting preparation was shaken vigorously for 2 minutes using an automatic shaker (Figure 3). Three different concentrations (2, 3 and 4%) of mango peel pectin were used in preparing the formulations (Table 1).

**Table 1. Formulation of paracetamol suspensions**

**Formulations**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Ingredients** | F0(no suspending agent) | F1 | F2 | F3 | F4(standard, 3%w/v) |
| Paracetamol | 5 g | 5 g | 5 g | 5 g | 5 g |
| Benzoic acid | 0.1 g | 0.1 g | 0.1 g | 0.1 g | 0.1 g |
| Mango pectin | 0 g | 2 g | 3 g | 4 g | - |
| Acacia gum | - | - | - | - | 3 g |
| Distilled water | 100 mL | 100 mL | 100 mL | 100 mL | 100 mL |

Paracetamol, USP

Added with either mango peel pectin or acacia and benzoic acid

Added with water and triturated using mortar and pestle

Smooth paste-like mass

Added with sufficient amount of water to reach desired volume

Shaken for 2 min using automatic shaker

Paracetamol suspension

**Figure 3. Preparation of paracetamol suspension**

## Characterization and evaluation of paracetamol suspension (Rajendra *et al*., 2011; Malviya, 2011)

Characterization of the different formulation were performed in 3 trials with 3 replicates.

**Sedimentation volume.** Each suspension (25 mL) was stored in graduated cylinder for 4 days at 30°C. Observations will be made every 24 h for 4 days. The sedimentation volume, F (%), was calculated using the following equation;

𝐹 = 𝐻𝑢 × 100

𝐻𝑜

Where: 𝐻𝑢= The final volume of the sediment,

𝐻𝑜= The original volume of sediment.

**Viscosity**. Different concentrations of the prepared suspension were made separately in a 600 mL beaker, appropriate enough to immerse the spindle groove in the fluid. Viscosity values at rotational speed of 10, 20, 50 and 100 rpm were determined at room temperature. All determinations were made in at least triplicate and obtained the results. The results were obtained and expressed as mean values. Viscosity was measured in millipascal-second (mPa.s).

**pH**. Paracetamol suspension (10 mL) and other formulations were measured using digital pH meter.

**Degree of flocculation.** Degree of flocculation was determined using the following equation:

𝛽 = (𝑉𝑢)𝑓𝑙𝑜𝑐

(𝑉𝑢)𝑑𝑒𝑓𝑙𝑜𝑐

Where (Vu) floc is ultimate sedimentation volume of flocculated suspension and (Vu) defloc is ultimate sedimentation volume of deflocculated suspension.

**Flow rate.** The time taken for 10 mL sample of suspension to flow through a 10 mL pipette was determined and the flow was calculated using the following equation:

𝐹 = 𝑉𝑜𝑙𝑢𝑚𝑒 𝑜𝑓 𝑝𝑖𝑝𝑒𝑡𝑡𝑒 (𝑚𝐿)

𝐹𝑙𝑜𝑤 𝑡𝑖𝑚𝑒 (𝑚𝐿)

**Redispersibility**. Each suspension (25 mL) was poured into bottles, stoppered and kept on a vibration free platform. The suspensions were shaken manually by hand for various time intervals (2, 5, 7 days). At regular interval one tube was removed and shaken vigorously to redistribute the sediment and the presence of deposit (if any) were recorded

***In vitro* dissolution study.** Calibration solutions containing varying concentration of paracetamol (2µg/mL, 4µg/mL, 6µg/mL, 8µg/mL and 10µg/mL) were prepared. Absorbance of each prepared solution was measured at 273 nm using double beam UV visible spectrophotometer and recorded. A plot of absorbance versus concentration (standard curve) was plotted using Microsoft Excel. Dissolution study of formulated suspensions was carried out in USP type II dissolution test apparatus in 500 mL of 0.1N HCl for 20 min maintained at 37ºC ± 0.50ºC, with stirring speed of 25 rpm. Prepared suspensions (10 mL) was introduced carefully into the bottom of the apparatus. Aliquots (5 mL) were withdrawn at interval of 5 min for analysis and replenished by equivalent amount of blank. The aliquots were filtered through Whatman® filter paper and paracetamol was quantified at 273 nm by double beam UV- Visible spectrophotometer and the absorbance was measured.

## Statistical analyses

All statistical analyses was performed using the Statistical Packages for Social Sciences (SPSS). All results were expressed as mean ± standard deviation.

The results were evaluated using the analysis of variance (One -Way ANOVA) and Tukey HSD to determine the difference in the means of the activities of the extracts and controls in each activity investigated.

3. results:

## Characterization and evaluation of formulated suspensions

Five different suspensions were formulated and designated with codes F0 to F4, where F0 is the formulation without any suspending agent, F4 is the standard formulation containing acacia gum, and F1 to F3 are formulations containing varying concentrations of pectin extracted from mango peel (Figure 4). These formulations were then evaluated for the parameters listed below.



**Figure 4 Formulated suspensions**

**Sedimentation volume.**The sedimentation volume of the different formulations are shown in Figure 5. Sedimentation volume increased proportionally with the concentration of the suspending agent, mango pectin. The sedimentation volume was observed for 4 days from the day the suspensions were prepared. At the end of the observation period, the sedimentation volume for all formulations did not change significantly. Starting day 1 to day 4, the highest sedimentation volume (100%) was observed in F3 compared with the controls (F1, F4). The greater the sedimentation volume, the lower the sedimentation rate suggesting greater stability of the suspensions. Sedimentation volume increased with increasing concentration of mango pectin in the formulation.

\* # \* # \* # \* #

100

80

**Percentage of sedimentation**

60

40

20

0

1 2 3 4

**Observation day**

## Figure 5. Sedimentation volume of the formulations. F0 ( ), F1 (), F2 (), F3 () F4 (). Each value represent the mean ± standard deviation (n = 9). \*Significant difference (*p* < 0.05) between F0 and F1, F2, or F3; #*p* < 0.05 F4 and F1, F2 or F3.

**Degree of flocculation.** The degree of flocculation of the formulations are presented in Figure 6. Formulation without pectin (F0) was used as a control. The degree of flocculation for all the formulations decreased with time. The high degree of flocculation was observed in F3 with a value of 83.33 while F4, the standard suspension, exhibited the lowest degree of flocculation. The degree of flocculation was observed for 4 days. There was no difference observed in the 4 days.

100

\*

\*

\*

\*

80

**Degree of flocculation**

60

40

20

0

1 2 3 4

**Observation day**

## Figure 6. Degree of flocculation of the formulations. F0 (), F1 (), F2 (), F3 () F4 (). Each value represent the mean ± standard deviation (n = 9). \*Significant difference (*p* < 0.05) between F4 and F1, F2, or F3.

**Redispersibility.** The redispersibility of formulations was performed at day 2, 5, and 7 days (Fig. 7). The highest number of shakes were observed in F0 which means greater number of shakes is required to redisperse the formulation. The required number of shakes increased with the observation day suggesting that aggregation of the particles may have occurred and thus requires more number of shakes to redisperse. Throughout the observation period, F3 remained in its dispersed state while F1, F2 and F4 had an average number of shakes, 4, 6, and 3, respectively required to redisperse the suspension.

15

\*

10

**Number of shakes**

5

0

2 5 7

**Observation day**

## Figure 7. Redispersibility of the formulations. F0 (), F1 (), F2 (), F3 ( ) F4 (). Each value represent the mean ± standard deviation (n = 9). \*Significant difference (*p* < 0.05) between F0 and F1, F2, F3 or F4.

**pH of formulations.** The pH values of the formulations ranged in between the average of 1.07-3.84 (Figure 8). F3 formulation had the highest pH 3.84 which corresponded to a 4-fold higher pH compared to F4.

4.5 \* #

3.0

1.5

**pH**

0.0 F0 F1 F2 F3 F4

**Formulations**

## Figure 8. pH of the formulations. F0 (), F1 ( ), F2 (), F3 () F4 (). Each value represent the mean ± standard deviation (n = 9). \*Significant difference (*p* < 0.05) between F0 and F1, F2, or F3; #*p* < 0.05 F4 and F1, F2 or F3.

**Flow rate.** Flow rate of the formulations are shown in Figure 9. The highest average flow rate of 1.17 m/s was observed in F0 while F3 had the lowest average flow rate of 0.13 m/s. An 8-fold lower flow rate was observed with F3 when compared with F4. The flow rate of the suspension decreased with an increase in concentration of suspending agent. This indicates that it will take more time for the suspensions containing higher proportion of mango pectin to flow.

1.6

\*

#

1.2

0.8

**Flow rate (m/s)**

0.4

0.0

F0 F1 F2 F3 F4

**Formulations**

## Figure 9. Flow rate of the formulations. F0 (), F1 (), F2 ( ), F3 () F4 (). Each value represent the mean ± standard deviation (n = 9). \*Significant difference (*p* < 0.05) between F0 and F1, F2, or F3; #*p* < 0.05 F4 and F1, F2 or F3.

**Viscosity.**The viscosity of the formulations are presented in Figure 10. The viscosities of F0 and F4 are 11.34 and 19.43 millipascal seconds (mPa.s), respectively while F1, F2, and F3 had viscosities of 11.46, 72.0 and 83.4 mPa.s, respectively. It was observed that F2 and F3 exhibited 4-fold higher viscosities when compared with F4.

100

80

60

**Visocisty (mPa.s)**

40

20

0

F0 F1 F2 F3 F4

**Formulations**

## Figure 10. Viscosity of the formulations. F0 (), F1 (), F2 (), F3 () F4 (). Each value represent the mean ± standard deviation (n = 9).

***In vitro* dissolution test.** Calibration curve of paracetamol solution are shown in Figure 11. A good correlation was observed between concentration of paracetamol and its absorbance (*r2* = 0.99). Drug release data of paracetamol suspensions are shown in Figure 11. *In vitro* dissolution study showed that 70.24% of drug released within 20 minutes in the case of formulation F3 (4% pectin). Whereas, formulation F2 released 50.71% within 20 minutes, while formulation F0, F1 and F4 released 29.14%, 42.93% and 35.26% respectively after 20 minutes. There is no official specification as a minimum limit for dissolution of paracetamol suspensions.

0.8

y = 0.0692x + 0.0281 R² = 0.99

0.6

0.4

**Absorbance**

0.2

0

0 2 4 6 8 10

## Concentration (ug/mL)

**Figure 11. Calibration curve of paracetamol solution**

100

F0

F1

F2

F3

F4

80

60

**Drug release (%)**

40

20

0

0 5 10 15 20

**Time (min)**

**Figure 12. Drug release profile of the formulations. Each value represent the mean ± standard deviation (n = 9).**

discussions:

This study investigated the use of mango pectin as a suspending agent in a pharmaceutical suspension. The method employed in the present study yielded a sufficient amount of mango pectin for characterization and preparation of various paracetamol formulations.

The prepared pectin did not meet the physical attribute (yellow-white) of standard pectin preparations presumably due to the unintended extraction of the pigments from the dried peel. An acceptable suspension must possess desirable appearance and palatability especially for the intended population subgroups (i.e., pediatric).

The ideal pharmaceutical suspension should be uniformly dispersed, possesses high sedimentation volume which indicates particles settle more gradually, hence, better physical stability. An acidic pH allows maximum stability of the suspension in that the suspension has electrostatic stability due to repulsive force between charged particles. At a lower pH (acidic condition), the particles create high surface charge that result in higher zeta potential values. The condition provides enough electrostatic repulsion force between particles to prevent attraction and collision caused by Brownian motion (Irwan *et al*., 2016) Faster dissolution with a higher percentage of drug release and a higher degree of flocculation which prevents the suspension from forming sediments.

Pharmaceutical suspensions containing paracetamol as a model drug were prepared in five different formulations containing either mango peel-derived pectin or acacia gum

as a suspending agent. The prepared pharmaceutical suspensions contain no metal ions or other viscosity-inducing agent. Hence, the effect of pectin in formulation can be easily observed. Mango peel-derived pectin used as a suspending agent in the prepared suspension was evaluated for sedimentation volume, degree of flocculation, flow rate, viscosity, redispersibility, and *in vitro* dissolution rate. F4 suspension, containing acacia gum as the suspending agent, had fulfilled some of the characteristics, it had a good flow rate, acidic pH that would provide the suspension with good stability, good redispersion which is shown through less number of shakes. Among the prepared formulations containing mango peel-derived pectin, F3 had characteristics close to an ideal pharmaceutical suspension. Pectin-containing formulations exhibited a higher degree of flocculation which may be attributed to a relatively low degree of esterification found in mango peel-derived pectin. A low degree of esterification in pectin possess a higher amount of negatively charged carboxyl group providing more effective sites to form bridge binding formulation components cohesively (Salehizadeh and Shokaosadati, 2001). In addition, a low degree of esterification tends to form gels electrostatically stabilized by metal ions (Ciriminna *et al*., 2017).

Formulation F3 showed the highest drug release profiles (70%) at 20 minutes despite having the highest viscosity suggesting that drug could be freely released from the formulation. The use of a larger amount of pectin (4%) in the formulation would denote the presence of higher methoxyl content, an important component in the gel-forming capacity of pectin in pharmaceutical suspensions. Hence, F3 had high viscosity, low flow rate, and high sedimentation volume. The amount of pectin (4%) used in the formulation was correlated with the increase in viscosity, flow rate, and sedimentation volume. Suspensions with very high viscosity pose some disadvantages as a pharmaceutical product associated with poor pourability of the suspension and may affect dose accuracy. Overall, the stability of all the formulations using mango peel-derived pectin as a suspending agent was better with higher sedimentation volume compared to acacia gum (F4). Findings in the present study corroborated with a previous work where acacia gum (5%) was unable to disperse drug particles in paracetamol formulation (Piriyaprasarth and Sriamornsak, 2011).

The feasibility of preparing pectin from mango peels for use as a suspending agent in pharmaceutical suspensions has been established. Mango pectin exhibited good

sedimentation volume and viscosity-enhancing property, qualities which are important as a suspending agent in pharmaceutical suspensions. These parameters support the possible utility of mango peel-derived pectin as a new biomaterial in formulating pharmaceutical suspensions.

4. Conclusion

In the present study, Mango pectin exhibited good sedimentation volume and viscosity-enhancing property, characteristics which are important for a suspending agent in pharmaceutical suspensions. These parameters support the possible utility of mango peel-derived pectin as a potential biomaterial and excipient in formulating pharmaceutical suspensions.

**RECOMMENDATIONS**

The researcher recommends the conduct of stability studies of mango pectin-derived pharmaceutical suspensions. Palatability tests, morphological tests, and similar tests must be conducted to advance the applications of mango pectin as pharmaceutical excipients.

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**APPENDIX A**

# AUTHENTICATION CERTIFICATE



**APPENDIX B**

RAW DATA

**Sedimentation volume (%)**

|  |  |
| --- | --- |
|  | Day 1 |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Ave | SD |
| F0 | 3 | 6 | 3 |  |  |  | 2 | 6 | 3 | 3.83 | 1.72 |
| F1 | 20 | 10.4 | 20.8 | 24.8 | 23.2 | 25.6 | 20.8 | 23.2 | 24.8 | 21.51 | 4.62 |
| F2 | 97.6 | 99.6 | 97.6 |  |  |  | 28 | 27.2 | 30.4 | 63.40 | 38.22 |
| F3 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.00 | 0.00 |
| F4 | 2 | 2 | 4 | 3 | 6 | 3 | 2 | 6 | 3 | 3.44 | 1.59 |

|  |  |
| --- | --- |
|  | Day 2 |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | AVE | SD |
| F0 | 3 | 6 | 3 |  |  |  | 2 | 6 | 3 | 3.83 | 1.72 |
| F1 | 16 | 12 | 20 | 22.4 | 21.6 | 24 | 19.2 | 21.6 | 23.2 | 20.00 | 3.84 |
| F2 | 89.6 | 84.4 | 84 |  |  |  | 25.6 | 26.4 | 26.4 | 56.07 | 32.85 |
| F3 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.00 | 0.00 |
| F4 | 2 | 2 | 4 | 3 | 6 | 3 | 2 | 6 | 3 | 3.44 | 1.59 |

|  |  |
| --- | --- |
|  | Day 3 |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | AVE | SD |
| F0 | 3 | 6 | 3 |  |  |  | 2 | 6 | 3 | 3.83 | 1.72 |
| F1 | 14.4 | 12 | 19.2 | 22.4 | 21.6 | 24 | 19.2 | 21.6 | 23.2 | 19.73 | 4.08 |
| F2 | 72 | 67.2 | 69.6 |  |  |  | 24 | 25.6 | 25.6 | 47.33 | 24.45 |
| F3 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.00 | 0.00 |
| F4 | 2 | 2 | 4 | 3 | 6 | 3 | 2 | 6 | 3 | 3.44 | 1.59 |

|  |  |
| --- | --- |
|  | Day 4 |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | AVE | SD |
| F0 | 3 | 6 | 3 |  |  |  | 2 | 6 | 3 | 3.83 | 1.72 |
| F1 | 14.4 | 12 | 19.2 | 22.4 | 21.6 | 24 | 19.2 | 21.6 | 23.2 | 19.73 | 4.08 |
| F2 | 59.2 | 59.2 | 65.6 |  |  |  | 24 | 25.6 | 25.6 | 43.20 | 20.01 |
| F3 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.00 | 0.00 |
| F4 | 2 | 2 | 4 | 3 | 6 | 3 | 2 | 6 | 3 | 3.44 | 1.59 |

**pH of suspension**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | AVE | SD |
| F0 | 3.04 | 3.04 | 3.04 | 2.93 | 2.93 | 2.92 | 2.93 | 2.93 | 2.93 | 2.97 | 0.06 |
| F1 | 3.51 | 3.51 | 3.49 | 3.51 | 3.53 | 3.53 | 3.6 | 3.65 | 3.6 | 3.55 | 0.05 |
| F2 | 3.75 | 3.7 | 3.7 | 3.72 | 3.72 | 3.72 | 3.72 | 3.72 | 3.72 | 3.72 | 0.01 |
| F3 | 3.78 | 3.78 | 3.78 | 3.83 | 3.83 | 3.8 | 3.89 | 3.93 | 3.93 | 3.84 | 0.06 |
| F4 | 1 | 1.17 | 1.01 | 1.09 | 1.05 | 1.14 | 1.08 | 1.05 | 1.12 | 1.08 | 0.06 |

**Flow rate (mL/s) of suspension**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | AVE | SD |
| F0 | 1.2 | 1.04 | 1.04 | 1.24 | 1.27 | 1.1 | 1.26 | 1.23 | 1.2 | 1.18 | 0.09 |
| F1 | 0.65 | 0.72 | 0.62 | 0.54 | 0.5 | 0.54 | 0.65 | 0.63 | 0.59 | 0.60 | 0.07 |
| F2 | 0.67 | 0.49 | 0.61 | 0.36 | 0.33 | 0.35 | 0.36 | 0.35 | 0.3 | 0.42 | 0.13 |
| F3 | 0.16 | 0.15 | 0.17 | 0.11 | 0.11 | 0.1 | 0.15 | 0.1 | 0.16 | 0.13 | 0.03 |
| F4 | 1 | 1.17 | 1.01 | 1.09 | 1.05 | 1.14 | 1.08 | 1.05 | 1.12 | 1.08 | 0.06 |

**Degree of flocculation**

|  |  |
| --- | --- |
|  | Day 1 |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Ave | SD |
| F1 | 1.5 | 8.67 | 8.67 | 20.6 | 9.67 | 21.3 | 17.3 | 9.67 | 20.7 | 13.13 | 7.05 |
| F2 | 81.3 | 81.3 | 40.7 | 25.3 | 12.3 | 26 | 23.3 | 11.3 | 25.3 | 36.33 | 26.90 |
| F3 | 83.3 | 83.3 | 41.7 | 83.3 | 83.3 | 83.3 | 83.3 | 41.6 | 83.3 | 74.06 | 18.39 |
| F4 | 0.67 | 2 | 0.5 | 1 | 0.5 | 1.33 | 0.67 | 1 | 1 | 0.96 | 0.48 |

|  |  |
| --- | --- |
|  | Day 2 |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | AVE | SD |
| F1 | 13.3 | 10 | 8.33 | 18.7 | 9 | 20 | 16 | 9 | 19.3 | 13.74 | 4.85 |
| F2 | 74.7 | 70 | 35 | 22.7 | 11.3 | 22 | 21.3 | 11 | 22 | 32.22 | 23.83 |
| F3 | 83.3 | 83.3 | 41.7 | 83.3 | 83.3 | 83.3 | 83.3 | 41.6 | 83.3 | 74.06 | 18.39 |
| F4 | 0.67 | 2 | 0.5 | 1 | 0.5 | 1.33 | 0.67 | 1 | 1 | 0.96 | 0.48 |

|  |  |
| --- | --- |
|  | Day 3 |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | AVE | SD |
| F1 | 12 | 10 | 8 | 18.7 | 9 | 20 | 16 | 9 | 19.3 | 13.56 | 4.93 |
| F2 | 60 | 59 | 29 | 22 | 11 | 21.3 | 21.3 | 11 | 22 | 28.52 | 18.45 |
| F3 | 83.3 | 83.3 | 41.7 | 83.3 | 83.3 | 83.3 | 83.3 | 41.6 | 83.3 | 74.06 | 18.39 |
| F4 | 0.67 | 2 | 0.5 | 1 | 0.5 | 1.33 | 0.67 | 1 | 1 | 0.96 | 0.48 |

|  |  |
| --- | --- |
|  | Day 4 |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | AVE | SD |
| F1 | 12 | 10 | 8 | 18.7 | 9 | 20 | 16 | 9 | 19.3 | 13.55 | 4.93 |
| F2 | 49.3 | 49.3 | 27.3 | 22 | 11 | 21.3 | 21.3 | 11 | 22 | 26.07 | 14.21 |
| F3 | 83.3 | 83.3 | 41.7 | 83.3 | 83.3 | 83.3 | 83.3 | 41.6 | 83.3 | 74.06 | 18.39 |
| F4 | 0.67 | 2 | 0.5 | 1 | 0.5 | 1.33 | 0.67 | 1 | 1 | 0.96 | 0.48 |

**Redispersibility test**

|  |  |
| --- | --- |
|  | Day 2 |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Ave | SD |
| F0 | 5 | 4 | 5 | 5 | 6 | 7 | 6 | 5 | 4 | 5.22 | 0.97 |
| F1 | 3 | 3 | 4 | 3 | 4 | 5 | 3 | 5 | 4 | 3.78 | 0.83 |
| F2 | 6 | 5 | 6 | 6 | 5 | 6 | 5 | 5 | 6 | 5.56 | 0.53 |
| F3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| F4 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 3 | 3 | 3.22 | 0.44 |

|  |  |
| --- | --- |
|  | Day 5 |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | AVE | SD |
| F0 | 7 | 6 | 7 | 7 | 8 | 9 | 7 | 7 | 9 | 7.44 | 1.01 |
| F1 | 3 | 3 | 4 | 3 | 5 | 5 | 4 | 5 | 5 | 4.11 | 0.93 |
| F2 | 6 | 5 | 6 | 6 | 5 | 7 | 6 | 6 | 6 | 5.89 | 0.60 |
| F3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| F4 | 4 | 3 | 3 | 3 | 5 | 3 | 4 | 3 | 3 | 3.44 | 0.73 |

|  |  |
| --- | --- |
|  | Day 7 |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | AVE | SD |
| F0 | 12 | 10 | 9 | 10 | 11 | 8 | 10 | 12 | 9 | 10.11 | 1.36 |
| F1 | 4 | 6 | 7 | 4 | 6 | 5 | 4 | 4 | 5 | 5.00 | 1.12 |
| F2 | 6 | 6 | 7 | 7 | 6 | 7 | 6 | 6 | 7 | 6.44 | 0.53 |
| F3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| F4 | 4 | 5 | 3 | 3 | 4 | 4 | 3 | 4 | 4 | 3.78 | 0.67 |

**Viscosity**

|  |  |  |  |
| --- | --- | --- | --- |
| Formulation | Spindle # | Speed | Viscosity (mPa.s) |
| F0 | #1 | 100 | 11.34 |
| F1 | #2 | 100 | 11.46 |
| F2 | #2 | 100 | 72.0 |
| F3 | #2 | 100 | 83.4 |
| F4 | #1 | 100 | 19.43 |

APPENDIX C

STATISTICAL ANALYSIS

Table C-1: One-way ANOVA for sedimentation volume.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *Source of**Variation* | *SS* | *Df* | *MS* | *F* | *P-**value* | *F crit* |
| BetweenGroups | 58386.76 |  | 4 14596.69 | 104.4058 1.3-20 2.605975 |
| Within Groups | 5592.289 |  | 40 139.8072 |  |
| Total | 63979.05 | 44 |  |  |

Table C-2: Tukey’s Honestly Significant Difference Test for sedimentation volume

|  |  |  |
| --- | --- | --- |
| **Formulations** | Sig. | Interpretation |
| F0 | F1 | 5.90542-09 | Significant |
| F2 | 2.78377-04 | Significant |
| F3 | 7.95601-28 | Significant |
| F4 | 0.564627747 | Insignificant |
| F1 | F2 | 0.015158244 | Insignificant |
| F3 | 4.36795-20 | Significant |
| F4 | 3.90028-09 | Significant |
| F2 | F3 | 8.14139-06 | Significant |
| F4 | 2.50479-04 | Significant |
| F3 | F4 | 5.7018-28 | Significant |

Table C-3: One- way ANOVA for degree of flocculation

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *Source of**Variation* | *SS* | *Df* | *MS* | *F* | *P-**value F crit* |
| BetweenGroups | 27517.91 | 3 9172.635 | 46.28963 9.6-12 2.90112 |
| Within Groups | 6341.039 | 32 198.1575 |  |
| Total | 33858.95 | 35 |  |

Table C-4: Tukey’s Honestly Significant Difference Test for degree of flocculation.

|  |  |  |
| --- | --- | --- |
| **Formulations** | Sig. | Interpretation |
| F1 | F2 | 0.02768849 | Insignificant |
| F1 | F3 | 5.53374-08 | Significant |
| F1 | F4 | 2.27278-06 | Significant |
| F2 | F3 | 2.39358-04 | Significant |
| F3 | F4 | 5.32092-04 | Significant |
| F2 | F4 | 2.25604-09 | Significant |

Table C-5: One-way ANOVA for redispersibility test

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *Source of Variation* | *SS* | *Df* | *MS* | *F* | *P-**value* | *F crit* |
| Between Groups | 295.9183 |  | 4 73.97957 | 243.844 | 1.64-27 | 2.605975 |
| Within Groups | 12.13556 |  | 40 0.303389 |  |  |  |
| Total | 308.0538 | 44 |  |  |  |  |

Table C-6: Tukey’s Honestly Significant Difference Test for redispersibility test

|  |  |  |
| --- | --- | --- |
| **Formulations** | Sig. | Interpretation |
| F0 | F1 | 4.92081-08 | Significant |
| F2 | 1.23909-06 | Significant |
| F3 | 7.24385-19 | Significant |
| F4 | 3.18898-12 | Significant |
| F1 | F2 | 1.71539-04 | Significant |
| F3 | 2.15626-10 | Significant |
| F4 | 0.02125491 | Insignificant |
| F2 | F3 | 2.44911-17 | Significant |
| F4 | 4.32041-09 | Significant |
| F3 | F4 | 5.92808-13 | Significant |

Table C-7: One- way ANOVA for pH

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *Source of**Variation* | *SS* | *Df* |  | *MS* | *F* | *P-**value* | *F crit* |
| BetweenGroups | 46.93641 | 4 |  | 11.7341 | 4111.618 | 1.05-51 | 2.605975 |
| Within Groups | 0.114156 |  | 40 | 0.002854 |  |  |  |
| Total | 47.05056 |  | 44 |  |  |  |  |

Table C-8: Tukey’s Honestly Significant Difference Test for pH

|  |  |  |
| --- | --- | --- |
| **Formulations** | Sig. | Interpretation |
| F0 | F1 | 1.80303-13 | Significant |
| F0 | F2 | 2.60013-17 | Significant |
| F3 | 1.75552-15 | Significant |
| F4 | 2.19254-21 | Significant |
| F1 | F2 | 1.11136-07 | Significant |
| F1 | F3 | 2.20825-08 | Significant |
| F4 | 2.61562-23 | Significant |
| F2 | F3 | 6.10442-05 | Significant |
| F2 | F4 | 8.28024-26 | Significant |
| F3 | F4 | 2.54835-23 | Significant |

Table C-9: One- way ANOVA for flow rate

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *Source of**Variation* | *SS* | *Df* | *MS* | *F* | *P-value* | *F crit* |
| Between |  |  |  | 248.040 |  | 2.60597 |
| Groups | 6.959453 | 4 | 1.739863 | 1 | 1.18-27 | 5 |
| Within |  |  |  |  |
| Groups | 0.280578 | 40 | 0.007014 |
| Total | 7.240031 | 44 |  |

Table C-10: Tukey’s Honestly Significant Difference Test for flow rate.

|  |  |  |
| --- | --- | --- |
| **Formulations** | Sig. | Interpretation |
| F0 | F1 | 7.79064-11 | Significant |
| F2 | 2.33122-10 | Significant |
| F3 | 4.63526-16 | Significant |
| F4 | 0.016257186 | Insignificant |
| F1 | F2 | 0.002432012 | Insignificant |
| F3 | 2.25336-12 | Significant |
| F4 | 3.25613-11 | Significant |
| F2 | F3 | 9.3697-06 | Significant |
| F4 | 3.69-10 | Significant |
| F3 | F4 | 3.95738-18 | Significant |