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Preparation and Pharmaceutical Application of Palmyra Palm Sprout Powder

Naresh Babu Rekha*[1], G. Nirmala Jyothi [1], Alapati Mohana Lakshmi Suvarna [1], Vemuri Vamsi [1] Uddanti Laxmi Sivani [1] Kadimi Jae Sree Varshini [1] Mallika Harika [1] Reddy Velangini Akasah [1] Ravuri Rakesh Kumar [1] Rodda Phanindra [1] Ganna Anitha [2]

1) Department of Pharmaceutics, Nirmala College of Pharmacy, Atmakuru, Mangalagiri, Guntur, A.P, India.

2) Department of Pharmaceutical Chemistry, Shri Venkateshwara College of Pharmacy, Pondicherry.

[1*]**Corresponding Author Details**: Naresh Babu Rekha

Nirmala College of Pharmacy, Atmakuru, Mangalagiri, Guntur, A.P, India. Contact No. 9949096910 Email Id: nareshbaburekha@gmail.com

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Abstract

This study explored Palmyra palm sprout powder (PPSP) as an excipient in Pioglitazone hydrochloride (HCl) tablets, comparing it with Microcrystalline Cellulose (MCC). Evaluated tablet properties included hardness, friability, disintegration time, dissolution profiles, flowability, compressibility, and stability. PPSP's biochemical analysis revealed reducing sugars, pentose sugars, hexose sugars, non-reducing polysaccharides, alkaloids, and mucilage, but no proteins or flavonoids. PPSP improved flowability and compressibility, indicated by a lower angle of repose and favourable Carr's Index and Hausner's Ratio. Seven tablet formulations (PG 1 to PG 7) with varying PPSP to MCC ratios were prepared. PG 3, with a 2:1 PPSP to MCC ratio, exhibited optimal characteristics: hardness of 4 kg, friability of 0.72%, and a disintegration time of 2 minutes. Dissolution studies confirmed PG 3 provided the highest drug release rates across all time points. FTIR analysis indicated no interactions between Pioglitazone HCl and the excipients, confirming the compatibility of the formulations. This comprehensive evaluation demonstrated that PPSP is a viable and effective alternative excipient, potentially enhancing the performance, manufacturability, and therapeutic efficacy of Pioglitazone tablets, thus offering improved patient compliance.

Keywords: Palmyra Palm Sprout Powder, Pioglitazone HCl, MCC, dissolution, FTIR.

1. Introduction

In the ongoing quest to enhance the management of type 2 diabetes mellitus, Pioglitazone hydrochloride (HCl) serves as a pivotal oral ant-diabetic medication. Nissen, S. According to the literature activating the peroxisome proliferator-activated receptor gamma

(PPAR-γ), Pioglitazone enhances insulin sensitivity, facilitating improved glucose uptake in peripheral tissues while reducing hepatic glucose productionE., &Wolski, K. (2007); Nissen, S. E., &Wolski, K.(2007). This dual mechanism helps to effectively lower blood glucose levels, making Pioglitazone an essential component in the therapeutic arsenal against diabetes(1) (2).

PubChem (2004) gives an overview of pioglitazone and described its pharmacological effects, highlighting its role as a thiazolidinedione with hypoglycemic activity, insulin-sensitizing properties, and potential benefits such as ferroptosis inhibition and cardioprotection(3). Wikipedia, an another source detailed how pioglitazone hydrochloride treats type 2 diabetes by enhancing insulin sensitivity and activating PPARγ to regulate glucose and lipid metabolism, though it can cause side effects like weight gain and oedema(4). Pai SA and Kshirsagar NA (2016) gave a systematic review assessed pioglitazone's safety, efficacy, and utilization in Indian patients with type 2 diabetes, comparing findings with European data. It found that pioglitazone's efficacy was similar to that observed in European trials, and no significant link to bladder cancer was found in Indian studies(5). (Ph, Al et al., 2011) their research aimed at improving the dissolution rate of pioglitazone HCl using solid dispersion techniques with β-cyclodextrin and PEG 6000 found that formulation F6 showed the highest dissolution rate, demonstrating significant improvement over pure pioglitazone(6).

Katdare, A., &Chaubal, M. V. (2006)Zhang, Y., & Law, Y. M. (2003) Formulated Pioglitazone into tablet form requires meticulous attention to excipients-non-active substances that significantly influence the tablet's physical and chemical properties. Traditional excipients like Microcrystalline Cellulose (MCC) are commonly used to achieve desired characteristics such as hardness (mechanical strength), friability (resistance to crumbling), disintegration time (speed at which the tablet breaks down), and dissolution profile (rate and completeness of drug release)(7) (8).Mahapatra, A. K., & Reddy, B. P. K. (2017)However, the search for novel excipients that can further enhance these characteristics is ongoing, aiming to improve the efficacy and patient compliance of Pioglitazone tablets(9).

Gupta, R. K., & Dutta, A. (2013)Prasad, A.R. Basava, et al. (2021)In this context, the use of Palmyra palm sprout powder (PPSP) is investigated as a novel excipient for Pioglitazone tablet formulation. PPSP, derived from the Palmyra palm, is proposed for its potential to enhance tablet characteristics due to its unique physicochemical properties. The

investigation involves a detailed comparison of PPSP with conventional excipients like MCC, evaluating its impact on key parameters essential for tablet formulation(10)(11).(Bhosale et al., 2016) their study developed pioglitazone hydrochloride-loaded lipospheres using the melt dispersion technique and a 32 full factorial design, showing effective sustained drug release and stability (12).

(Pandit, V. et al., 2012)The study focuses on the effects of PPSP on various critical aspects, including the tablet's hardness, which determines its ability to withstand physical stress; friability, which assesses its resistance to crumbling and breaking; disintegration time, which measures how quickly the tablet disintegrates in the gastrointestinal tract; and the dissolution profile, which examines the rate at which Pioglitazone is released and becomes available for absorption. Additionally, the study assesses the flow properties of the powder blend, which are crucial for consistent tablet production, by measuring parameters such as the angle of repose, Carr’s Index, and Hausner’s Ratio(12)(13).

Gupta, R. K., & Dutta, A. (2013); Prasad, A.R. Basava, et al. (2021)Exploring PPSP's role as an excipient aims to uncover whether it can offer improvements over MCC, thereby enhancing the overall performance and reliability of Pioglitazone tablets. Potential applications extend beyond immediate formulation benefits, encompassing broader pharmaceutical contexts where PPSP might be utilized to optimize other medications' properties. The promising results observed in the flow properties and compressibility profile of PPSP suggest that it could be a valuable addition to pharmaceutical excipient libraries(14)(15).

Sandhiyadevi, P., et al. (2021); Rahman, Shaikh, et al. (2021) Future research directions include investigating the scalability of PPSP for commercial production, assessing its compatibility with various active ingredients, and evaluating its long-term stability under different storage conditions. Furthermore, clinical trials could be conducted to evaluate the bioavailability and therapeutic efficacy of Pioglitazone tablets formulated with PPSP compared to those with traditional excipients. Through this comprehensive investigation, the study seeks to contribute to more effective Pioglitazone tablet formulations, ultimately leading to better therapeutic outcomes and patient adherence. The introduction of PPSP as an excipient not only enhances the physical properties of the formulation but also introduces the added benefits of its nutritional and pharmacological properties, making it a valuable and innovative component in the field of pharmaceutical sciences(16)(17).

2. Methodology

2.1 Preparation of Palmyra Palm Sprout Powder (PPSP)

2.2 Powder Analysis

2.3 Tablet Formulation

2.4 Post-Formulation Studies

2.5 Characterization (FTIR)

2.1 Preparation of Palmyra Palm sprout Powder:-

Preparation and Cleaning: (Korese, Joseph Kudadam et al., 2021)

1. **Peeling and Cleaning**: Peel the palm sprouts to remove the outer layers and expose the inner core, eliminating dirt, debris, or husk.
2. **Washing**: Wash the peeled sprouts under running water to remove any remaining impurities, ensuring a clean final product.

Drying Process:

3. **Cutting into Small Pieces**: Cut the cleaned sprouts into small, uniform pieces to increase surface area for efficient drying.
4. **Drying in Hot Air Oven**: Spread the pieces on trays and dry them in a hot air oven at 60-70°C. This temperature range dehydrates the sprouts without damaging their nutrients.
5. **Duration of Drying**: Dry the sprout pieces for 3 to 4 days, monitoring temperature and moisture levels to ensure consistent quality.

Grinding and Sieving:

6. **Grinding into Powder**: Transfer the dried pieces to a hand mill and mixer, grinding them into a fine powder with uniform particle size.
7. **Sieving**: Sieve the ground powder to achieve the desired texture and consistency using sieve sizes no. 85 and no. 120.

Final Product:

8. **Packaging**: Collect the sieved powder and pack it into suitable containers, ensuring it remains uncontaminated.

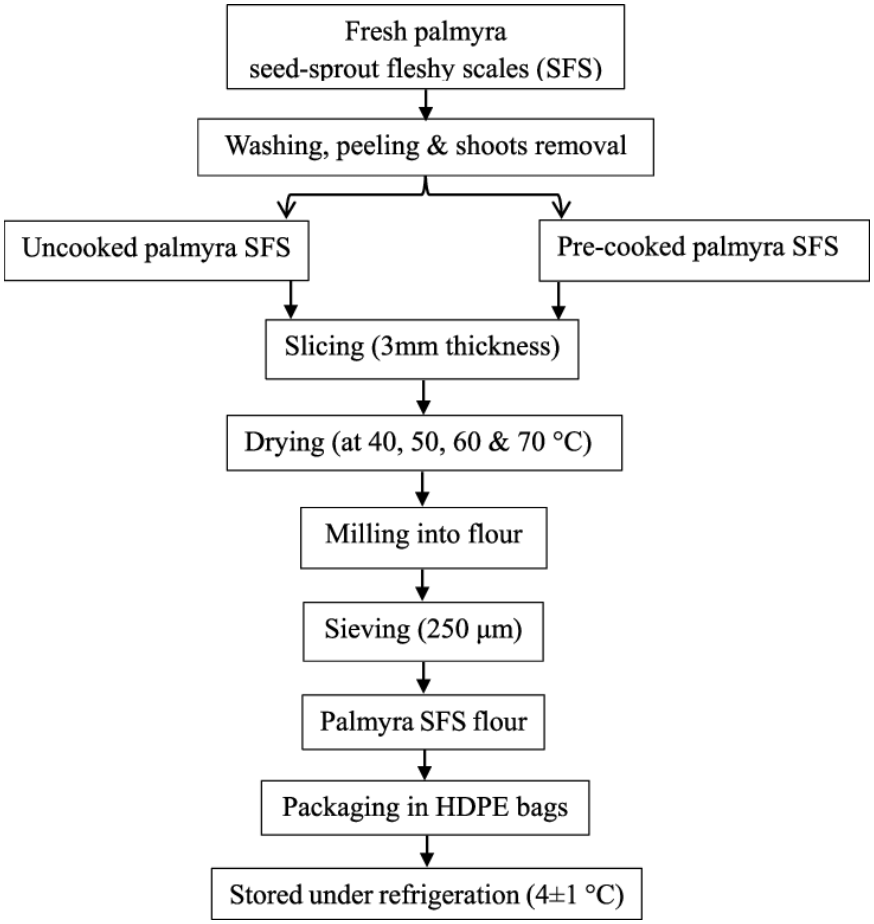


Figure 1. ***Flow chart for the Preparation of Palmyra Palm Sprout Powder (PPSP)***(18)

a) ***Palmyra Palm Sprouts (PPS)*** **b)** ***Cleaned and washed***

c) ***Sliced PPS*** **d)** ***Dried PPS Pieces***

e) ***Milling*** **f)** ***Sieving***

Palmyra Palm Sprout Powder (PPSP)

Figure 2.*Processing of Palmyra Palm Sprout Powder (PPSP)*

2.2 Powder Analysis

2.2.1 Biochemical tests: - D.K. R. Khandelwal and Dr.VrundaSethi (2018)

2.2.1.1 Tests for Carbohydrates:

a) Reducing Sugars:

- **Fehling's Test:** Mix 1 ml each of Fehling's A and B, boil for one minute, add the test solution, heat in a boiling water bath for 5-10 minutes. Yellow to brick-red precipitate forms.
- **Benedict's Test:** Mix equal volumes of Benedict's reagent and the test solution, heat in a boiling water bath for 5 minutes. Solution turns green, yellow, or red.

b) Monosaccharides:

- **Barfoed's Test:** Mix equal volumes of Barfoed's reagent and the test solution, heat for 1-2 minutes, cool. Red precipitate forms.

c) Pentose Sugars:

- Mix equal amounts of the test solution and HCl, heat, add a crystal of phloroglucinol. Red color appears.

d) Hexose Sugars:

- **Selwinoff's Test:** Heat 3 ml of Selwinoff's reagent and 1 ml of the test solution in a boiling water bath for 1-2 minutes. Red color forms.

e) Non-Reducing Polysaccharides (Starch):

- **Iodine Test:** Mix 3 ml of the test solution with a few drops of dilute iodine solution. Blue color appears, disappears on boilingand reappears on cooling.

2.2.1.2 Tests for Proteins:

- **Biuret Test:** Add 4% NaOH and a few drops of 1% CuSO4 solution to 3 ml of the test solution. Violet or pink color appears.
- **Millon's Test:** Mix 3 ml of the test solution with 5 ml of Millon's reagent. White precipitate turns brick red upon warming.

2.2.1.3 Test for Flavonoids:

- **Shinoda Test:** Add 5 ml of 95% ethanol/t-butyl alcohol, a few drops of concentrated HCl, and 0.5 g of magnesium turnings to the dry powder or extract. Orange, pink, red, or purple color appears.

2.2.1.4 Test for Alkaloids:

- **Dragendorff's Test:** Add a few drops ofDragendorff's reagent to 2-3 ml of the filtrate. Orange-brown precipitate forms.
- **Mayer's Test:** Add a few drops of Mayer's reagent to 2-3 ml of the filtrate. Precipitate forms.

2.2.1.5 Test for Mucilage:

- **Swelling Test:** The powdered drug swells in water or aqueous KOH(19).

2.2.2 Flow Properties:

(Schlick-Hasper et al., 2022) **Micromeritics** studies small particles' properties for optimal powder performance in applications. Key properties include particle size, shape, surface area and bulkand tapped densities, angle of repose, Carr's index, and Hausner's ratio, impacting flowability, compressibility, and packing.

Flow Characteristics:

- **Bulk Volume:**It refers to the volume occupied by a given mass of powder after it has been subjected to a standardized mechanical tapping process. This process involves mechanically tapping or jolting the powder in a graduated cylinder or similar container until minimal volume reduction is observed, indicating that the particles have settled into a more compact arrangement.
- **Tapped volume:** It refers to the volume occupied by a given mass of powder after it has been subjected to a standardized mechanical tapping process. This process involves mechanically tapping or jolting the powder in a graduated cylinder or similar container until minimal volume reduction is observed, indicating that the particles have settled into a more compact arrangement.

- **Bulk Density:** Mass of powder divided by its bulk volume, calculated by noting the volume of a known mass in a graduated cylinder:

$$\boldsymbol{Bulk\ density = \frac{Mass\ of\ powder}{Bulk\ volume}}$$

- **Tapped density**: Tapped density is the mass of a powder divided by its tapped volume after mechanical tapping. It measures how densely the powder can be packed under external forces.

  To determine tapped density, place a known mass of powder in a graduated cylinder, tap it mechanically until the volume no longer changes, then use the formula:

$$\boldsymbol{Tapped\ density = \frac{Mass\ of\ powder}{Tapped\ volume}}$$

- **Angle of Repose:** The angle of repose is the maximum angle at which a powder can be piled without slumping. It reflects the internal friction and cohesiveness of the powder particles.

  It is performed by allowing the powder to flow freely through a cylinder or funnel to form a pile. It is calculated by using following formula;

$$\boldsymbol{Angle\ of\ Repose\ (\theta) = tan^{-1}\frac{h}{r}}$$

- **Hausner Ratio:** It is the ratio of tapped density to bulk density. It reflects the compressibility and cohesiveness of a powder.

$$\boldsymbol{Hausner\ ratio = \frac{Tapped\ density}{bulk\ density}}$$

- **Carr's index (Compressibility index):** It measures the relative difference between tapped and bulk denisities, expressed as a percentage. It indicates the powder's ability to decrease in volume under pressure.

$$\boldsymbol{Carr's\ index = \frac{Tapped\ density - Bulk\ density}{Tapped\ density} \times 100}$$

- **Flowability:** It refers to the ability of a powder to flow under specified conditions. It is a general measure influenced by particle size, shape, moisture content, and the

cohesive forces between particles. The flow properties of the palm sprout powder is performed and compared with talc taken as standard samples (20) (21).

Preparation of Samples for the Evaluation of Flow Properties:

The below Table 2 describes about the samples preparation for the evaluation of the flow properties.

Table 2: Preparation of Samples for Evaluation of Flow Properties

S.NO	Type of Sample	Microcrystalline Cellulose (MCC)	Talc	Palmyra Palm Sprout Powder (PPSP)
1.	**Standard sample**	50gm	2%	-
2.	**Test sample**	50gm	-	2%

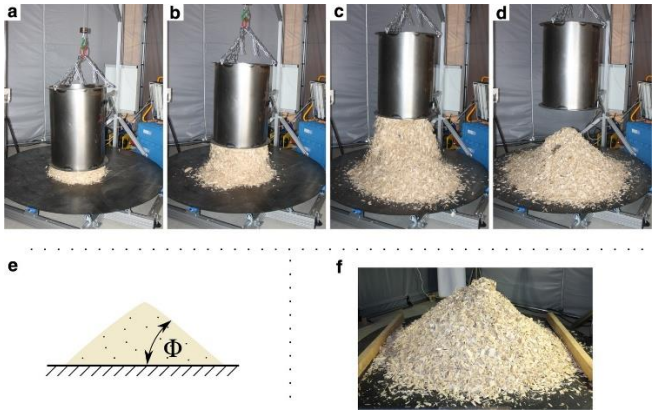
2.2.3 Disintegration Activity:

The disintegrating activity of PPSP is checked by comparing with the standard disintegrating agent SSG. The tablets were prepared and disintegration is performed and compared by following the below formulation Table 3.

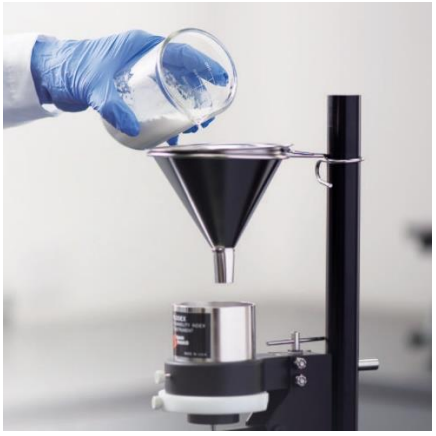
Table 3: Preparation of Samples for Evaluation of Disintegration Activity

S.NO	Type of Sample	Microcrystalline Cellulose (MCC)	Sodium Starch Glycolate (SSG)	Palmyra Palm Sprout Powder (PPSP)
1.	**Standard Sample**	50gm	2%	-
2.	**Test Sample**	50gm	-	2%

Bulk Density Apparatus



Angle of Repose (Hollow Cylinder Method)



Flowability (Funnel Method)

Figure 3: ***Instrumentation for Flow Studies***

2.3 Tablet Formulation

In this study, a factorial design was employed to assess the formulation of Pioglitazone hydrochloride (HCl) tablets using Palmyra palm sprout powder (PPSP) as an excipient. Seven different tablet formulations (PG 1 to PG 7) were prepared as given in Table 4, using the direct compression method as shown in Figure 4. Each formulation contained a consistent dose of Pioglitazone (15 mg) and varying amounts of PPSP and Microcrystalline Cellulose (MCC), with magnesium stearate (6 mg) and talc (6 mg) as common components across all formulations. The PPSP content ranged from 300 mg to 0 mg, inversely balanced by increasing MCC content from 0 mg to 300 mg across the formulations.

These tablets were then subjected to post-formulation tests to evaluate their characteristics, such as hardness, friability, disintegration time, and dissolution profiles, aiming to optimize the formulation by identifying the ideal combination of PPSP and MCC for enhanced tablet performance.

Table 4: Formulations of Pioglitazone HCl

Composition	**Formulations**						
	PG 1	**PG 2**	**PG 3**	**PG 4**	**PG 5**	**PG 6**	**PG 7**
Ratio of MCC : PPSP	Pure PPSP	(5:1)	(2:1)	(1:1)	(1:2)	(1:5)	Pure MCC
Pioglitazone HCl	15mg	15mg	15mg	15mg	15mg	15mg	15mg
PPSP	300mg	250mg	200mg	150mg	100mg	50mg	-
MCC	-	50mg	100mg	150mg	200mg	250mg	300mg
Magnesium stearate (2%)	6mg	6mg	6mg	6mg	6mg	6mg	6mg
Talc (2%)	6mg	6mg	6mg	6mg	6mg	6mg	6mg

Preparation of Formulation

Tablet Punching Machine

Tablets

Figure 4: ***Tablet Preparation***

2.4 Post-formulation Studies

Post formulation parameters are specific tests conducted on a finished pharmaceutical product to ensure its quality, efficacy, safety, and stability. Here are the key parameters explained:

2.4.1 Hardness: Measures the tablet's resistance to crushing. This ensures tablets can withstand handling, packaging, and transportation without breaking, and helps control the release of the active ingredient during ingestion.

2.4.2 Friability: Tests tablet durability by tumbling them in a friabilator to check for weight loss. Low friability means tablets are less likely to crumble, ensuring consistent dosing and stability during shipping and handling.

2.4.3 Disintegration Time: Determines how quickly tablets or capsules break down into smaller particles in a specified liquid medium. A shorter disintegration time enhances the medication's onset of action, crucial for immediate-release formulations.

2.4.4 Calibration Curve:

- **Stock Solution**: Dissolve 50 mg of Pioglitazone HCl in 0.1M HCl to get a concentration of 1 mg/mL.
- **Calibration Solutions**: Prepare dilutions from the stock solution to obtain concentrations of 5, 10, 15, 20, and 25 µg/mL using 0.1M HCl.
- **Absorbance Measurement**: Measure the absorbance of each solution with 0.01M HCl as a blank using a UV-visible spectrophotometer at 270 nm.

2.4.5 Dissolution Profile: Hazarika, J. N. R., & Deb, P. (2017)Assesses the rate and extent of the active ingredient's dissolution from the dosage form under standardized conditions. This predicts how the drug will behave in the body and ensures therapeutic efficacy and batch-to-batch consistency.The dissolution of all the formulations is performed according to IP standards and procedures (22).

2.5 Fourier Transform Infrared Spectroscopy (FTIR): Identifies chemical bonds and functional groups in the active ingredient and excipients. FTIR ensures the integrity and compatibility of the formulation and detects any potential interactions that could affect

stability and efficacy. These tests ensure the pharmaceutical product meets the required standards before it is released for distribution and use.

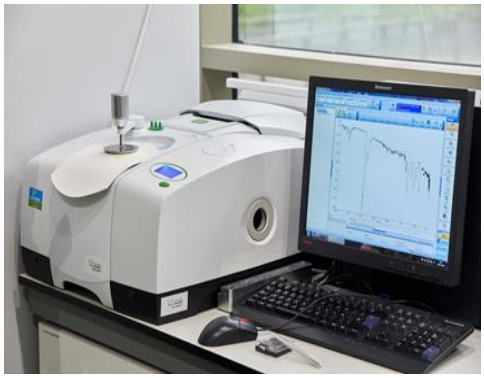
Monsanto Hardness Tester

Single Drum Roche Friabilator

Double Basket Disintegration Apparatus

Dissolution Test Apparatus

UV-Visible Spectrophotometer



FTIR Spectroscopy

Figure 5: ***Instrumentation for Post-Formulation Studies***

3. Results and Discussions

3.1 Powder Analysis

3.1.1 Biochemical studies

From the Table 5; biochemical analysis of the sample revealed a diverse composition of carbohydrates, including reducing sugars (positive results with Fehling's and Benedict's tests), pentose sugars (positive with HCl and phloroglucinol test), hexose sugars (positive with Selwinoff's test), and non-reducing polysaccharides (positive with iodine test). In contrast, the sample tested positive for alkaloids with Dragondroff's and Mayer's reagents, confirming their presence. Additionally, the sample contained mucilage. These results align with literature findings on reducing sugars, pentose sugars, hexose sugars, non-reducing polysaccharides, and alkaloids in plant extracts. The presence of mucilage is consistent with existing studies, highlighting its common occurrence in plant materials. This analysis underscores the variability in phytochemical composition influenced by factors such as extraction methods and plant species, emphasizing the importance of comprehensive analysis in botanical studies.

Table 5: Biochemical Tests of PPSP

S.NO	Name of the Test	Result	Test image
1.	**Test for Carbohydrates**		
	a) Test for reducing sugars		
	Fehlings Test	+	
	Benedicts Test	+	
	b) Test for monosacharrides		
	Barfoed Test	–	

	c) Test for pentose sugars		
	HCl + Phloroglucinol crystal	+	
	d) Test for hexose sugars		
	Selwinoff's Test	+	
	e) Test for non-reducing polysacharrides		
	Iodine Test	+	
2.	**Test for Proteins**		
	a) Millon's Test	–	
	b) Biuret Test	–	
3.	**Test for Flavonoids**		
	a) Shinoda test	–	
4.	**Test for Alkaloids**		
	a) Dragondroff's Test	+	
	b) Mayer's Test	+	
5.	**Test for Mucilage**	+	

3.1.2 Evaluation of Flow Properties

A comparison between a standard sample and a test sample with PPSP as an excipient in Pioglitazone HCl tablets reveals several key differences and advantages. From Table 6;both samples have the same bulk volume (50 ml) and bulk density (0.5). The test sample has a slightly higher tapped volume (34.5 ml) compared to the standard (32 ml), resulting in a lower tapped density for the test sample (0.72) versus the standard (0.78). The test sample exhibits a significantly lower angle of repose (29.24) compared to the standard (34.99), indicating superior flow properties crucial for achieving uniform and consistent tablets.Carr's Index and Hausner's Ratio further highlight the improved performance of the test sample, with Carr's Index at 30.5% compared to the standard's 35.8%, and Hausner's Ratio at 1.44 compared to the standard's 1.56. These metrics suggest that PPSP enhances the compressibility and flowability of the tablet formulation. However, the test sample has a slightly longer flow time (4 minutes 43 seconds) compared to the standard (3 minutes 44 seconds), indicating potential consistency issues that may require further refinement or blending with other excipients.

Table 6: Flow Properties

S.NO	Parameter	Standard Sample	Test sample
1.	**Bulk volume**	50 ml	50ml
2.	**Tapped volume**	32ml	34.5ml
3.	**Bulk density**	0.5	0.5
4.	**Tapped density**	0.78	0.72
5.	**Angle of repose**	34.99	29.24
6.	**Carr's index (%C)**	35.8%	30.5%
7.	**Hausner's ratio**	1.56	1.44
8.	**Flow ability**	3 min 44 sec	4 min 43 sec

3.1.3 Evaluation of Disintegration Activity

The below Table 7 compares disintegration times for standard and test samples across three trials. The standard sample shows consistently faster disintegration times, with an average of 55.33 seconds across trials (56 sec, 50 sec and 60 sec). In contrast, the test sample with PPSP as anexcipient takes longer to disintegrate, averaging 2 minutes and 27 seconds (2 min 44 sec, 2 min 39 sec, 2 min). This indicates that while PPSP improves other tablet properties, it may slow down disintegration. These results suggest that although PPSP enhances flowability, compressibility, and packing ability, it significantly increases disintegration time.

Table 7: Disintegration Activity

S.NO	Trials	Standard Sample	Test Sample
1.	**Trial – 1**	56 sec	2 min 44 sec
2.	**Trial – 2**	50 sec	2 min 39 sec
3.	**Trial - 3**	60 sec	2 min
4.	**Average**	55.33 sec	2 min 27 sec

3.2 FTIR Spectroscopy

3.2.1 Compatibility Studies:

Dr. S. Ravi Sankar (2010) the compatibility of Pioglitazone HCl and its excipients (MCC & PPSP) was evaluated by FTIR spectral studies (Table 8). It was found that there are no interactions between the drug and the excipients from the FTIR Spectrophotometer(23) (24).

Table 8: FTIR Range for Pure Drug and Excipients mixture.

S. NO	Functional Group	Absorption Range (cm^{-1})	Pioglitazone HCl	Pioglitazone HCl + PPSP	Pioglitazone HCl + MCC

1.	**O-H Stretching**	3500-3200	3321	3325	3322
2.	**N-H Stretching**	3400-3500	3445	3440	3447
3.	**C=O Stretching (Ketone)**	1700-1725	1715	1712	1714
4.	**C=O Stretching (Amide)**	1650-1700	1653	1656	1655
5.	**N-H Bending**	1500-1650	1543	1544	1542
6.	**C=C Stretching (Aromatic)**	1450-1600	1575	1576	1575
7.	**C-H Stretching (Aromatic)**	3030	3031	3032	3030
8.	**C-H Bending (Aromatic)**	700-850	740	738	739
9.	**O-H Bending (Alcohols)**	1050-1150	1082	1083	1084
10.	**C-H Streching (Alkane)**	2960-2850	2925	2923	2924
11.	**C-H Bending (Alkane)**	1340	1342	1341	1340

3.2.2 Characterization by FTIR Spectroscopy

The FTIR spectra from Figure 10, 11, 12; comparison shows that the characteristic peaks of pioglitazone HCl are consistently observed in its formulations with Palmyra palm powder and MCC. Minor shifts in peak positions (1 to 4 cm^{-1}) indicate only slight interactions with the excipients, suggesting that the chemical structure and functional groups of pioglitazone HCl remain unchanged.

Key peaks for O-H stretching, N-H stretching, C=O stretching (ketone and amide), N-H bending, C=C stretching (aromatic), C-H stretching and bending (aromatic and alkane), and O-H bending (alcohols) are all present and consistent with the known structure of pioglitazone HCl. For example, the O-H stretching peak around 3321 - 3325 cm^{-1}, N-H

stretching around 3440 - 3447 cm^{-1}, and C=O stretching (ketone) around 1712 - 1715 cm^{-1} confirm the stability of these functional groups.

These results indicate that Palmyra palm powder and MCC do not significantly alter the chemical environment of pioglitazone HCl, maintaining its integrity, efficacy, and stability in the formulated products. This is important for ensuring the active drug remains effective when combined with different excipients.

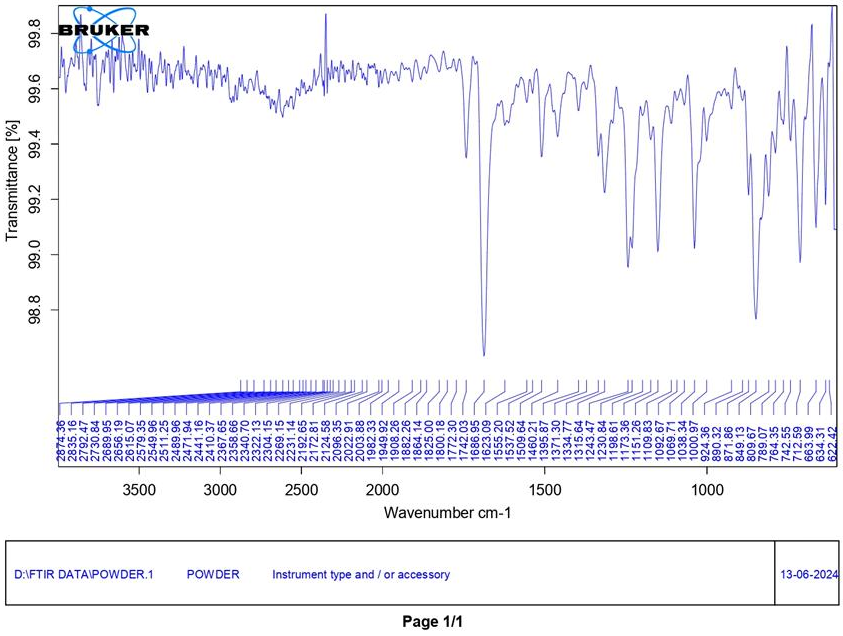


Figure 10: ***FTIR Spectra of Pioglitazone HCl***

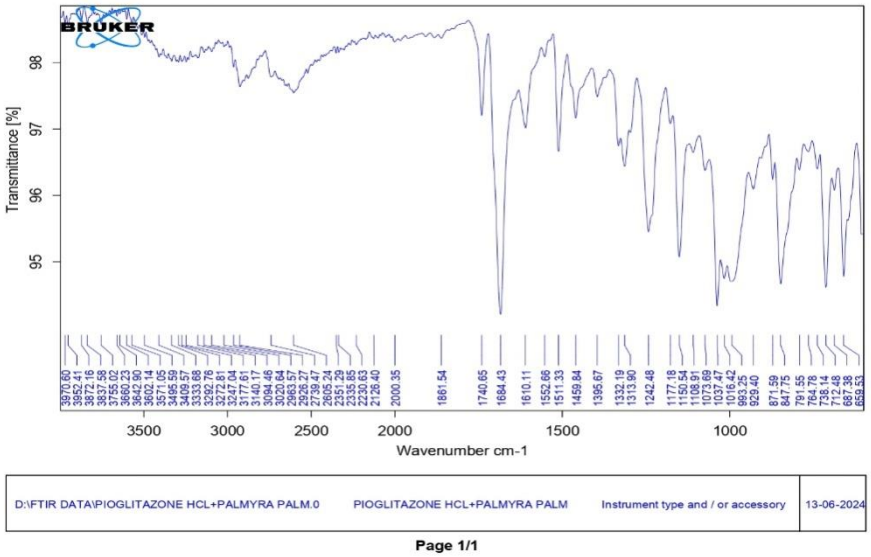


Figure 11: ***FTIR Spectra of Pioglitazone HCl + PPSP***

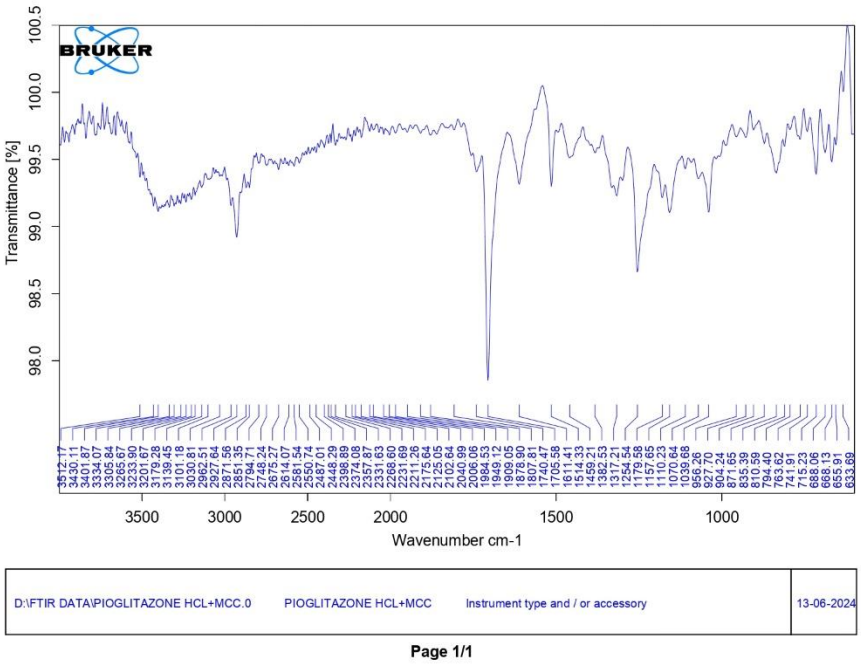


Figure 12 : ***FTIR Spectra of Pioglitazone HCl + MCC***

3.3 Analytical Studies:

Calibration of Pioglitazone HCl:

Table 9: Absorbance values of Pioglitazone HCl

S.NO	Concentration (µg / ml)	Absorbance				Standard Deviation (SD)	Average (±)SD
		Trial-1	Trial-2	Trial-3	Average		
1.	**5**	0.219	0.217	0.221	0.219	0.002	0.219±0.002
2.	**10**	0.410	0.409	0.411	0.410	0.001	0.410±0.001
3.	**15**	0.575	0.574	0.576	0.575	0.001	0.575±0.001
4.	**20**	0.765	0.764	0.766	0.765	0.001	0.765±0.001
5.	**25**	0.925	0.924	0.926	0.925	0.001	0.925±0.001

The above Table 9 shows the absorbance values for each concentration of pioglitazone HCl are consistent across three trials, showing very low standard deviations and indicating reliable measurements. The absorbance increases proportionally with concentration, suggesting a linear relationship. This linearity is essential for creating a calibration curve to determine unknown drug concentrations in future samples.

The calibration curve (Absorbance vs. Concentration) shows a linear relationship within the 5 – 25 µg/ml range, confirmed by a straight line as seen in the Figure 6. The R^2 value of 0.9992 indicates an excellent fit, meaning almost all variability in absorbance is explained by the concentration.

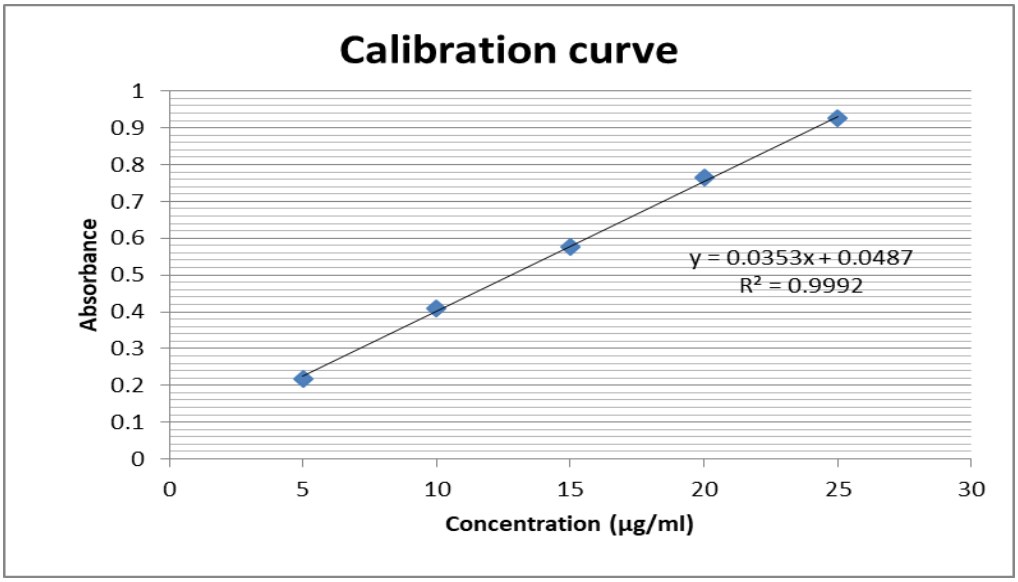


Figure 6: ***Calibration Curve of Pioglitazone HCl***

Figure 7: ***Cuvette with sample in UV-Visible Spectroscopy***

3.4 Post-formulation Studies:

In the present experimental studies, the results of the all the formulations i.e. PG 1 to PG 7 ranges from, hardness 3 – 12.5 kg; friability 0.89% - 0.18%; disintegration 1.10 minutes – 30 minutes are shown in the Table 10. Evaluating the formulations provided, PG3 stands out with its hardness of 4 kg, friability of 0.72%, and disintegration time of 2 minutes, meeting IP standards effectively. This suggests that PG3 demonstrates favourable characteristics suitable for tablet formulation according to IP guidelines.

Table 10: Post-formulation Studies of Formulations of Pioglitazone HCl

S.NO	Formulation	Hardness	Friability	Disintegration
1.	**PG 1**	3kg	0.89%	1.10 min
2.	**PG 2**	3.5kg	0.79%	1.45 min
3.	**PG3**	**4kg**	**0.72%**	**2 min**
4.	**PG 4**	5kg	0.69%	2min 30 sec
5.	**PG 5**	6kg	0.31%	3min 30 sec
6.	**PG 6**	7.6kg	0.29%	8min 13sec
7.	**PG 7**	12.5kg	0.18%	30min

3.5 Dissolution Studies:

The dissolution study data indicate that PG3 is the best performing formulation, consistently showing the highest drug release rates across all time points. At 5 minutes, PG 3 released 19.9% of the drug, significantly higher than other formulations and the market formulation (22.4%). By 10 minutes, PG 3 reached 41.6%, and at 15 minutes, it achieved 56.4%. By 30 minutes, PG 3 had released 84.6% of the drug, and it reached nearly complete drug release (99.89%) by 45 minutes, surpassing the market formulation's 87.2% at the same time. PG 2 and PG 4 also demonstrated strong performance, particularly in the mid to later stages of the study, with drug release rates close to PG 3 and the market formulation. The market formulation had the highest initial release, but PG 3 outperformed it in the later stages, making PG 3 a promising candidate for further development. The following Table 11 and Figure 8, 9 provides the dissolution results of all the formulations (PG 1 to PG 7) and marketed formulation.

Table 11: Dissolution Studies

S.NO	Time (min)	% Cumulative Drug Release							
		PG 1	**PG 2**	**PG 3**	**PG 4**	**PG 5**	**PG 6**	**PG 7**	**Marketed**

1.	**5**	11.21	16.9	**19.9**	12.3	11.7	13.2	8.4	22.4
2.	**10**	22.4	35.2	**41.6**	33.9	33.1	30.4	26.3	40.2
3.	**15**	38.9	49.4	**56.4**	53.4	47.7	41.2	42.2	53.6
4.	**30**	70	73.7	**84.6**	78.4	70.9	65.8	63.9	75.8
5.	**45**	92	94.9	**99.89**	94	84.2	81.6	72.7	87.2

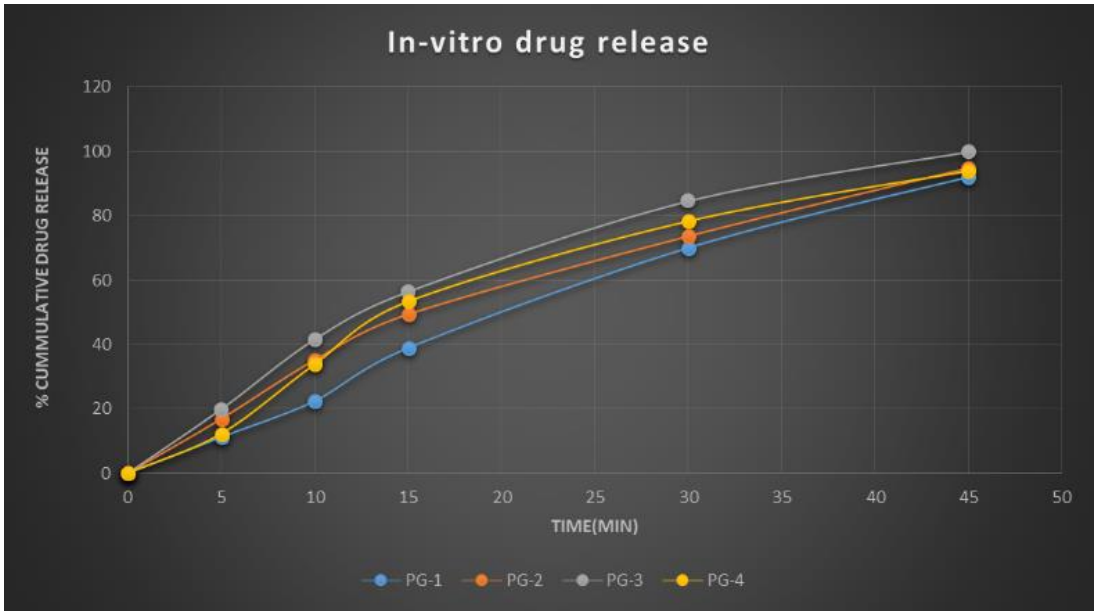


Figure 8: ***In-vitro Drug Release Profile for PG 1 to PG 4***

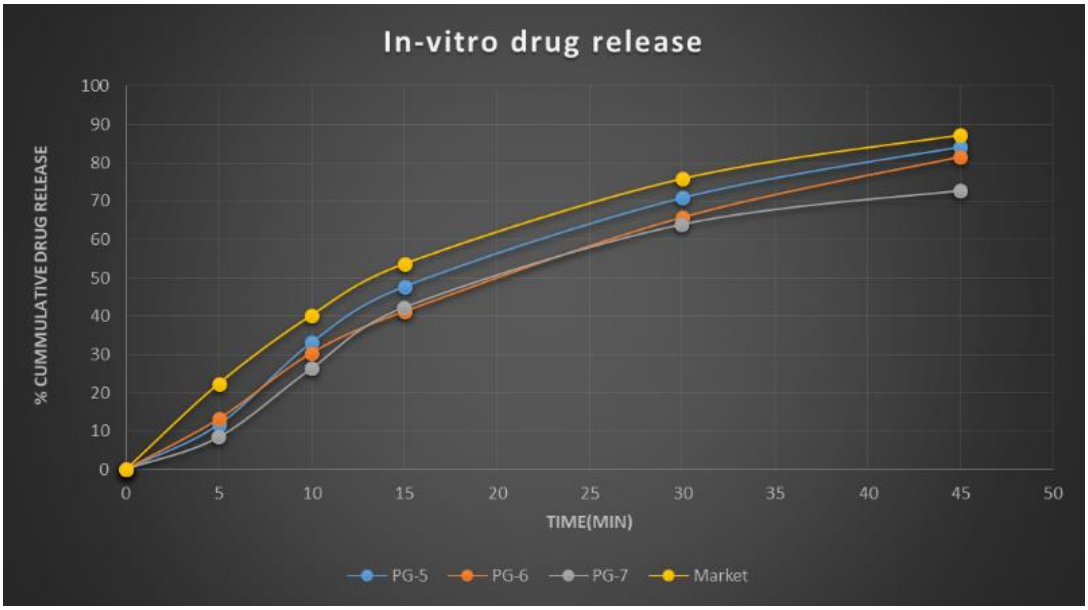


Figure 9*: In-vitro Drug Release Profile for PG 5 to Marketed formulation*

4. Summary

The study evaluated Palmyra palm sprout powder (PPSP) as an alternative excipient for Pioglitazone HCl tablets, comparing it to Microcrystalline Cellulose (MCC). PPSP, rich in carbohydrates and alkaloids, showed promising pharmaceutical properties. Flow analysis of PPSP revealed good flowability, superior compressibility, and favorable Carr's Index and Hausner's Ratio, although with slightly longer flow times.

Using a factorial design approach, various concentrations of PPSP in Pioglitazone tablets were assessed for properties like hardness, friability, disintegration time, and dissolution profiles. The PG 3 formulation met Indian Pharmacopoeia (IP) standards with a hardness of 4 kg, friability of 0.72%, and a disintegration time of 2 minutes. Dissolution studies showed PG 3 had rapid and consistent drug release, outperforming the market standard by releasing 84.6% of the drug in 30 minutes and nearly 100% in 45 minutes.

FTIR spectroscopy confirmed the compatibility of PPSP with Pioglitazone HCl, showing minimal shifts in characteristic peaks, indicating that PPSP does not significantly alter the drug's chemical environment. This study highlights PG 3 as a promising candidate for further development, offering enhanced therapeutic efficacy and patient compliance.

5. Conclusion

The findings from this study underscore Palmyra palm sprout powder (PPSP) as a promising natural excipient for Pioglitazone HCl tablet formulations. PPSP exhibited favorable Flowproperties, including good flowability and compressibility, which are critical for ensuring uniform tablet quality and efficient manufacturing processes. Its composition rich in carbohydrates and alkaloids, aligns well with pharmaceutical requirements, potentially enhancing the stability and bioavailability of Pioglitazone tablets.

In formulation development, PPSP demonstrated its capability to meet and even exceed Indian Pharmacopoeia (IP) standards for tablet characteristics. Notably, formulation PG 3 showed optimal hardness, minimal friability, and rapid disintegration time, meeting the criteria for immediate-release tablets effectively. The dissolution studies further highlighted PG 3's superior performance, achieving significant drug release within a short time frame and surpassing the market formulation's efficacy.

FTIR spectroscopy confirmed the compatibility of PPSP with Pioglitazone HCl, showing minimal interaction between the drug and the excipient. This ensures the stability of Pioglitazone HCl in the formulated tablets, preserving its therapeutic efficacy without compromising its chemical integrity.

In conclusion, Palmyra palm sprout powder emerges as not only a viable alternative to traditional excipients like Microcrystalline Cellulose but also as a natural option that could potentially enhance the quality, stability, and therapeutic outcomes of Pioglitazone tablets. Its promising attributes warrant further exploration and development in pharmaceutical sciences, offering new avenues for improving drug delivery systems and patient care in the treatment of diabetes and other related conditions.

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