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A Formulation and Evaluation of Citicoline Oral Disintegrating Tablet using Co-Processed Isabgol Mucilage-Crospovidone Super-disintegrant

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ABSTRACT

This research focused on the development and assessment of Citicoline orally disintegrating. tablets (ODTs) utilizing a co-processed superdisintegrant composed of Isabgol mucilage and Crospovidone to facilitate swift tablet disintegration and drug dissolution. Isabgol mucilage was isolated from Isabgol husk and analyzed for its physicochemical properties. The isolated mucilage was co-processed with Crospovidone and evaluated for micrometric characteristics. Five distinct Citicoline ODT formulations (designated F1 through F5) were manufactured via direct compression using varying proportions of the co-processed superdisintegrant. These formulations underwent comprehensive evaluation, including pre-compression and post compression assessments, FTIR analysis for drug-excipient compatibility, wetting and disintegration time measurements, drug content determination, content uniformity testing, and in vitro dissolution profiles The isolated Isabgol mucilage yielded a recovery rate of 33% and demonstrated a swelling index of 310%. The micrometric evaluation of the co-processed superdisintegrant revealed an angle of repose of 26.42°, a Carr's Index of 14.28%, and a Hausner ratio of 1.16. Among the tested formulations, F5 displayed superior overall characteristics, featuring a mean weight of 399 mg, a hardness of 4 kg/cm', friability of 0.12%, a wetting time of 16 seconds, a disintegration time of 17 seconds, and a drug content of 99.8%. Furthermore, formulation F5 achieved complete (100%) drug release within 30 minutes, with content uniformity maintained between 98.98% and 100.17%. This investigation confirms that the co-processed Isabgol mucilage—Crospovidone system serves as an efficient superdisintegrant for Citicoline ODTs. The optimized F5 formulation demonstrated rapid wetting and disintegration, adequate mechanical integrity, consistent drug distribution, and full drug release, highlighting its viability for the production of Citicoline orally disintegrating tablets.

Introduction

Oral delivery is the most widely favored and convenient method for administering pharmaceutical therapies, owing to its ease of use, high patient compliance, and suitability for self-administration. [1] However, traditional tablets can pose challenges for patients who struggle with swallowing solid dosage forms. Orally disintegrating tablets (ODTs) have become a leading alternative formulation, engineered to dissolve swiftly in the mouth to enable drug release without requiring water [2].

Citicoline, a neuroprotective and neurocognitive agent, is employed in managing neurological disorders to enhance neuronal function. [3] Developing Citicoline in an ODT format offers a highly convenient administration option, potentially improving patient compliance and acceptability [4] The performance of ODTs is highly dependent on the choice and concentration of superdisintegrants. [5] Co-processed excipients are increasingly utilized because combining materials can yield enhanced functional properties compared to their separate components. Isabgol mucilage, a natural polysaccharide extracted from Plantago ovata, exhibits excellent swelling and water-absorption capabilities.

Crospovidone is a synthetic superdisintegrant recognized for its rapid hydration and disintegration kinetics.[6] Synergizing Isabgol mucilage and crospovidone as a co-processed superdisintegrant represents a promising, strategy to optimize the disintegration behavior of Citicoline ODTs.

Consequently, this study focuses on formulating and evaluating Citicoline ODTs utilizing a co - processed Isabgol mucilage-crospovidone superdisintegrant system.

'The resulting formulations are assessed through comprehensive pre-compression and post- compression evaluations to determine their physical attributes and disintegration performance, leading to the selection of an optimal formulation.

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Materials and Methods

Materials

For the development of citicoline orally disintegrating tablets (ODT), citicoline was utilized as the active pharmaceutical ingredient. Natural mucilage was extracted from Isabgol husk, while crospovidone was selected as the synthetic superdisintegrant to prepare the co-processed superdisintegrant. [7] The formulation also incorporated mannitol to serve as a diluent and improve mouthfeel, alongside microcrystalline cellulose, which functioned as a diluent and compressibility-enhancing agent. Aspartame was included as a sweetener for taste-masking purposes. Talc and magnesium stearate were employed as the glidant and lubricant, respectively. Acetone acted as the precipitating solvent for mucilage isolation, with distilled water serving as the medium for extraction and processing.

Citicoline was supplied by Kimia Bioscience Limited (Haryana), and Isabgol husk was obtained from Sidhipur Isabgol Factory Private Ltd. Crospovidone and aspartame were sourced from Pharmafabrikon, while mannitol was purchased from Hi Media Laboratories. Microcrystalline cellulose was obtained from SD Fine Chemicals Limited. Talc, magnesium stearate, and acetone were acquired from Modern Scientific, and distilled water was supplied by Exide.

Isolation of Isabgol Mucilage and Preparation of the Co-Processed Superdisintegrant. Isolation of Isabgol Mucilage:

Isabgol mucilage was isolated from Isabgol husk via aqueous extraction followed by acetone precipitation[8]. Specifically, 75 g of Isabgol husk was accurately weighed and soaked in 750 mL of distilled water at room temperature for 12 to 24 hours to facilitate hydration and release the mucilaginous components. The hydrated mixture was then heated at 60-70°C for approximately 45-60 minutes under continuous stirring to maximize the extraction of mucilage into the aqueous phase. After cooling slightly, the mixture was filtered through a muslin cloth to remove insoluble fibrous residues, and the filtrate containing the extracted mucilage was collected. After measuring the volume of the filtrate, acetone was added slowly at a 1:3 ratio (filtrate to acetone) with constant stirring to precipitate the mucilage. The resulting white-to-cream precipitated mass was isolated by filtration and washed with a small amount of acetone to remove residual impurities. The recovered mucilage 2.3 Characterization of Isolated Mucilage and Co-Processed Superdisintegrant was transferred to a tray or silica crucible and dried in a hot-air oven at 50-60°C for 4-6 hours until a constant weight was achieved. The dry material was then pulverized using a mortar and pestle and passed through Sieve No. 40 or No. 60 to obtain a uniform powder. The final isolated mucilage was stored in an airtight, moisture-protected container.

Preparation of Co-Processed Isabgol Mucilage-Crospovidone Superdisintegrant:

To prepare the co-processed superdisintegrant, the isolated Isabgol mucilage was combined with Crospovidone in a 1:1 ratio.

Precise quantities of each component were weighed and dry-mixed in a mortar for 10-15 minutes to ensure uniform distribution.

Distilled water was added gradually with continuous mixing to form a cohesive wet mass, which was then passed through Sieve No. 16 to produce wet granules.

These wet granules were dried in a hot-air oven at 50-60°C for 4-6 hours until completely dry.

The dried granules were then gently ground in a mortar and pestle and passed through Sieve No. 40 to achieve a uniform particle size.

The resulting co-processed superdisintegrant was stored in an airtight container for future characterization and formulation of Citicoline ODTs.

Characterization of Isolated Mucilage and Co-Processed Superdisintegrant

To evaluate its suitability as a natural superdisintegrant, the isolated Isabgol mucilage was assessed for its physical properties, percentage yield, and swelling index. Subsequently, the co-processed Isabgolmucilage—Crospovidone material was analyzed for its micromeritic and flow properties, including the angle of repose, bulk density, tapped density, Carr's compressibility index, and Hausner ratio. These parameters were studied to establish the handling, packing, and flow characteristics of the material prior to its use in tablet formulations.

Physical characteristics and percentage yield

The isolated mucilage was visually inspected for color, texture, and overall appearance, presenting as a creamish-white, smooth, and free-flowing powder. The percentage yield of the isolated mucilage was determined by comparing the actual weight of the recovered dry mucilage to the theoretical yield.

Percentage Yield=Theoretical Yield /Actual Yield x100%

In this study, 25 g of mucilage was recovered from 75 g of Isabgol husk, representing a 33% yield.

Swelling index

The swelling characteristics of the isolated mucilage were evaluated by measuring its volumetric expansion upon hydration. One gram of the dry mucilage powder was precisely weighed and placed into a 25 mL graduated cylinder, where the initial volume (V1) was noted. Distilled water was added to reach the 25 mL mark, and the cylinder was agitated gently every 10 minutes during the first hour to promote uniform hydration, After standing undisturbed for 24 hours at roomtemperature, the final swollen volume (V2) was recorded. The swelling index was calculated accordingly.

$$\text{Swelling Index} = W/V1$$

The isolated Isabgol mucilage demonstrated a swelling index of 310%, indicating significant water absorption and volume expansion when hydrated. [9]

Micrometric characterization of the co-processed superdisintegrant

The co-processed Isabgolmucilage Crospovidone superdisintegrant was characterized by measuring its angle of repose, bulk density, tapped density, Carr's compressibility index, and Hausner ratio. The angle of repose was measured to determine powder flow, while bulk and tapped densities were analyzed to assess packing behavior. Carr's index and the Hausner ratio were derived from these densities to evaluate compressibility and flowability.

The co-processed superdisintegrant displayed an angle of repose of 26.42°, a bulk density of 0.42 glcm', a tapped density of0.49 g/em*, a Carr's index of 14.28%, and a Hausner ratio of 1.16, confirming favorable flow and packing properties for direct-compression manufacturing.

Bulk Density (g/mL) = W / Vo

Where:

W = Weight of powder (g)

Vo = Bulk volume of powder (mL)

Tapped Density (g/mL) = W / Ve

Where:

W = Weight of powder (g)

Vi = Tapped volume of powder (mL)

Carr's Index (%) = [(Tapped Density — Bulk Density) / Tapped Density] X 100

Hausner's Ratio = Tapped Density / Bulk Density

Angle of repose - tan θ = h / r

Where:

θ = Angle of repose

h = Height of powder heap (cm)

r = Radius of powder heap (cm)

Drug—Excipient Compatibility Evaluation:

The compatibility of Citicoline with the formulation excipients was evaluated using Fourier- transform infrared (FTIR) spectroscopy. Spectra for pure Citicoline and the optimized formulation (F5) were recorded across the range of 4000-400 cm^{-1}, These spectra were compared to monitor the presence and preservation of the characteristic absorption bands associated with Citicoline's functional groups. To assess potential drug—excipient interactions, the spectra were analyzed for any significant alterations, including the appearance of new peaks or major shifts in the primary absorption bands. The retention of Citicoline's spectral features in the optimized formulation, without notable changes, indicated compatibility between the drug and the excipients.

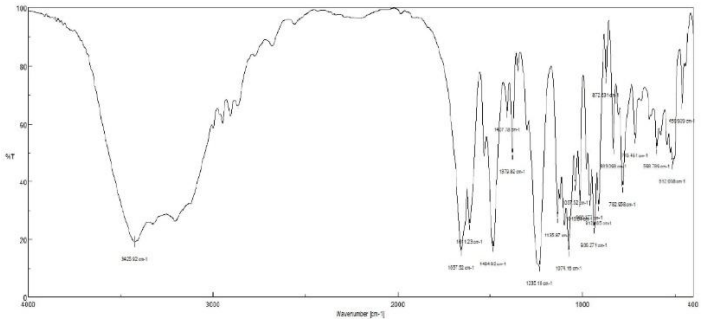

Figure 1: This Image represents the FTIR Spectra of Pure Citicoline

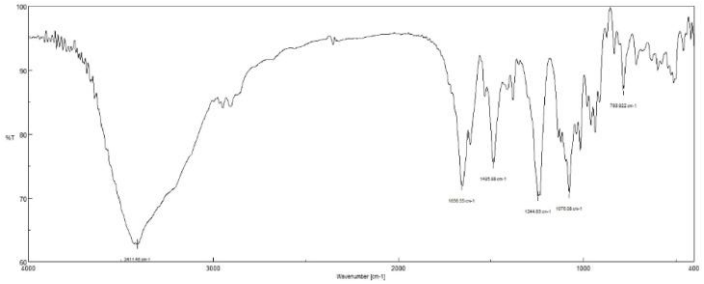

Figure 2 : This Image represents the FTIR Spectra of optimized Formulation [F5]

UV Spectrophotometric Quantification of Citicoline

To determine the concentration of Citicoline within the prepared formulations, a UV spectrophotometric method was utilized. Initially, 100 mg of Citicoline sodium was precisely weighed and dissolved in distilled water inside a 100 mL volumetric flask. The volume was adjusted to 100 mL to yield a primary stock solution with a concentration of 1000 µg/mL Subsequently, a 10 mL aliquot of this solution was transferred to a 100 mL volumetric flask and diluted with distilled water to produce a 100 µg/mL working stock solution.

To identify the wavelength of maximum absorption, a 10 µg/mL test solution was prepared by diluting 1 mL of the working stock solution to 10 mL. After allowing the UV—visible spectrophotometer to warm up for 15-20 minutes, the baseline was set using distilled water as a blank. The Citicoline solution was scanned within the wavelength range of 200—400 nm to determine the peak absorbance wavelength. The resulting λmax for Citicoline was identified at 271

For the calibration curve, standard Citicoline solutions were prepared spanning a concentration range of 2-14 µg/mL. Specific aliquots of the 100 µg/mL working stock solution were transferred into individual 10 mL volumetric flasks and diluted to volume with distilled water to yield final concentrations of 2, 4, 6, 8, 10, 12, and 14 µg/mL. The absorbance of each standard was measured at 271 nm using a quartz cuvette with a 1 cm path length, against a distilled water blank. The calibration curve was generated by plotting absorbance against

Citicoline concentration, from which the regression equation and correlation coefficient (R2) were calculated to verify the linearity of the relationship.

Formulation of Citicoline ODTs by Direct Compression.

Formulation Design: Average weight of the Tablet = 400 mg

Table 2: Control Formulations

Ingredients	F1	F2
Citicoline	250mg	250mg
Isabgol Mucilage	20mg	
Crospovidone		20mg
Mannitol	80mg	80mg
Micro Crystalline Cellulose	40mg	40mg
Aspartame	5mg	5mg
Talc	3mg	3mg
Magnesium Stearate	2mg	2mg

Table 3: Formulation Variants

Ingredients (mg)	F3	F4	F5
Citicoline	250mg	250mg	250mg
Co-processed SD	15mg	20mg	25mg
Mannitol	85mg	80mg	75mg
Micro Crystalline Cellulose	40mg	40mg	40mg
Aspartame	5mg	5mg	5mg
Talc	3mg	3mg	3mg
Magnesium Stearate	2mg	2mg	2mg

Preparation of Citicoline Orally Disintegrating Tablets (ODTs) via Direct Compression.

Citicoline ODTs were manufactured using a direct compression approach incorporating isolated Isabgol mucilage, Crospovidone, and a co-processed combination of Isabgol mucilage and Crospovidone as superdisintegrants. To evaluate how the type and concentration of the superdisintegrant affect tablet performance, five distinct formulations (FI to F5) were prepared. Each tablet had a target weight of 400 mg and included 250 mg of Citicoline, Control formulations F1 and F2 utilized Isabgol mucilage and Crospovidone individually, whereas formulations F3, F4, and FS contained the co -processed superdisintegrant at dosages of 15, 20, and 25 mg, respectively. The quantity of mannitol was adjusted accordingly in each formulation to ensure a consistent final tablet weight. All raw materials were precisely weighed and screened through a No. 40 sieve to break up agglomerates and ensure uniform particle size, while magnesium stearate was sieved independently through a No. 60 mesh. Citicoline, mannitol, microcrystalline cellulose, and the selected superdisintegrant were combined in a mortar and blended thoroughly for 15 minutes to achieve a homogeneous powder mixture. Following this, aspartame was added, and the mixture was blended for another 5 minutes. Finally, talc and magnesium stearate were introduced and gently mixed for 2 to 3 minutes to facilitate proper lubrication without over-blending. The prepared powder blend was then fed into the hopper of a rotary tablet press and compressed under appropriate pressure to yield the orally disintegrating tablets. The finished tablets were collected and preserved in airtight containers at room temperature, shielded from moisture, pending subsequent evaluation.

Characterization of Powder Mixtures and Formulated ODTs

Before tableting, the flowability and packing properties of the prepared powder mixtures were assessed. The suitability of these blends for direct compression was analyzed by measuring the angle of repose, bulk density, tapped density, Carr's compressibility index, and Hausner ratio. [10] The angle of repose was determined based on the dimensions of the formed powder cone using the equation tan 6 = hr. Bulk density was calculated as the ratio of the powder mass to its untapped volume, whereas tapped density was derived from the mass and volume measured after mechanical tapping, Standard equations were applied to calculate the Car's index and Hausner ratio from these bulk and tapped density measurements.

The compressed ODTs underwent evaluation for weight uniformity, thickness, hardness, friability, wetting duration, disintegration time, and active ingredient content. [11] To test weight variation, 20 randomly selected tablets were weighed individually to calculate the average weight and the percentage deviation from this average. A Vernier caliper was utilized to measuretablet thickness, and a Monsanto hardness tester was used to determine mechanical strength. Friability testing was performed using a Roche friabilator at 25 rpm for 4 minutes (totaling 100 revolutions), with the percentage weight loss calculated by comparing initial and final tablet weights.

Wetting time was assessed via the tissue-paper technique. A tablet was positioned on a folded tissue paper saturated with 6 mL of distilled water containing eosin dye inside a Petri dish. The duration for complete wetting was recorded0, with the average calculated across three replicates, Disintegration testing was conducted using an IP disintegration tester filled with distilled water maintained at 25 + 2°C. The time required for the tablets to break down completely was monitored, targeting a disintegration time of under 30 seconds for the ODTs.

To evaluate the uniformity of Citicoline distribution within the formulations, drug content was analyzed spectrophotometrically. The assay followed a standard UV

spectrophotometric procedure, measuring the absorbance of the sample solution at the predetermined Amax. The drug concentration was then quantified using a standard calibration curve. Finally, the various formulations were compared based on their physical, chemical, and performance parameters to identify the candidate with the most optimal overall profile

In-Vitro Dissolution Study

The *in-vitro* dissolution profiles of the prepared Citicoline ODT formulations were assessed using a USP Type II (paddle) apparatus. The dissolution medium consisted of 900 mL of distilled water, maintained at a temperature of 37 + 2°C with a paddle speed of 50 rpm. Individual tablets from each formulation were placed in the dissolution vessel, and 5 mL samples were extracted at scheduled intervals of 5, 10, 15, 20, and 30 minutes. To maintain a constant volume, an equal amount of fresh, temperature - equilibrated dissolution medium was introduced after each withdrawal. The collected samples were filtered through Whatman filter paper, and their absorbance was measured with a UV-visible spectrophotometer at the established Amax of Citicoline. Using a previously developed calibration curve, the concentration of Citicoline was determined to calculate the cumulative percentage of drug release at each interval. The dissolution profiles of formulations F1—F5 were then compared to assess the impact of different superdisintegrant systems on the rate and extent of Citicoline release. The formulation that demonstrated the most favorable dissolution behavior, combined with optimal disintegration and tablet characteristics, was selected as the optimized formulation.

Content Uniformity and Selection of the Optimized Formulation

To ensure consistent Citicoline distribution among individual tablets, the content uniformity of the optimized formulation (F5) was evaluated. Ten F5 tablets were individually analyzed to determine their Citicoline content, and the resulting values were compared to assess tablet-to- (ablet variability. The formulation was deemed satisfactory if the individual assay results fell within the specified pharmacopoeialacceptance limits.

Selection of the optimized formulation was based on the comprehensive evaluation of both pre- compression flow properties and post-compression characteristics, including weight, thickness, hardness, friability, wetting time, disintegration time, drug content, dissolution behavior, and content uniformity. Formulation F5 was selected as the optimal formulation due to its favorable balance of rapid wetting and disintegration, robust mechanical properties, high drug content, complete dissolution within 30 minutes, and acceptable content uniformity.

Results and Discussion

Characterization of Isabgol Mucilage and Co-Processed Superdisintegrant.

Following extraction, precipitation, drying, and sieving, the isolated Isabgol mucilage was obtained as an off-white, odorless, and free-flowing powder. This mucilage demonstrated excellent swelling capacity and rapid hydration, confirming its suitability as a natural superdisintegrant in orally disintegrating tablet (ODT) formulations. The co-processed Isabgol mucilage—Crospovidone superdisintegrant was successfully prepared using a solvent-assisted co- processing technique. The resulting composite displayed superior flowability and reduced cohesiveness compared to the isolated mucilage alone. The incorporation of Crospovidone optimized the powder's dispersion and handling properties, which are essential for direct compression processing. The combination of the swelling action of Isabgol mucilage and the capillary nicking of Crospovidone was expected to produce a synergistic effect, accelerating ‘water penetration into the tablet core to facilitate rapid disintegration and enhanced dissolution. The successful development and favorable physicochemical properties of this co-processed superdisintegrant validated its applicability for Citicoline ODT formulations

Table 4 : Characterization of Isabgol Mucilage and Co-Processed Superdisintegrant.

PARAMETER	OBSERVATION
Color	Creamish-white
Texture	Smooth powder
Appearance	Free flowing
Swelling index	310

Drug—Excipient Compatibility and UV Spectrophotometric Characterization. FTIR Compatibility Study:

Fourier Transform Infrared (FTIR) spectroscopy was used to evaluate the compatibility of Citicoline with Isabgol mucilage and Crospovidone. FTIR spectra of pure Citicoline, isolated Isabgol mucilage, Crospovidone, and the optimized formulation were recorded and compared. [12] The characteristic absorption peaks of Citicoline's functional groups were preserved in the optimized formulation without significant shifts, disappearance, or the emergence of new peaks. This indicated that no chemical interactions occurred between Citicoline and the selected excipients during formulation. The FTIR analysis confirmed the stability of the drug in the presence of these excipients, supporting their use in the ODT formulations.

UV Spectrophotometric Characterization:

Citicoline exhibited a maximumabsorbance wavelength (lambda max) of 272 nm in a pH 6.8 phosphate buffer. Standard Citicoline solutions were analyzed to construct a calibration curve plotting concentration against

absorbance. A linear relationship between absorbance and concentration was observed within the designated analytical range, demonstrating that the UV spectrophotometric method is suitable for quantifying Citicoline in tablet assays, dissolution studies, and content uniformity tests. This analytical method showed satisfactory linearity, reproducibility, and reliability for routine pharmaceutical analysis of Citicoline ODTs

IR spectrum of Citicoline Sodium

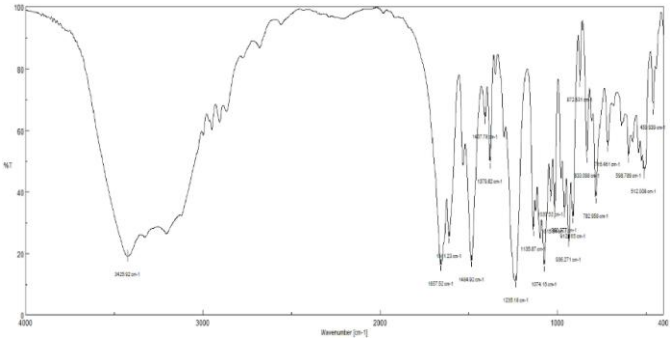

Figure 3: This image represents the IR Spectrum of citicoline sodium

IR spectrum of F5 Formulation

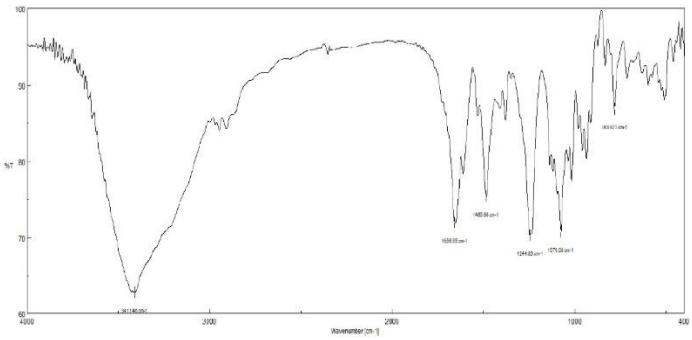

Figure: 4 This image represents the IR spectrum of F5 Formulation

Table: 5 The below table represents the interpretation of Major FTIR peaks of citicoline and optimized Formulation(F5).

Pure Citicoline (cm)	F5 Formulation (cm	Observation
3425.92	3411.46	0—H stretching (minor shift) (Broad Peak retained)
1657.52	1656.55	C=0 stretching retained
1484.92	1485.88	CH2 bending retained
1235.18	1236.15	Phosphate (P=O) stretching retained
1074.16	1076.08	P—0 / C—0 stretching retained

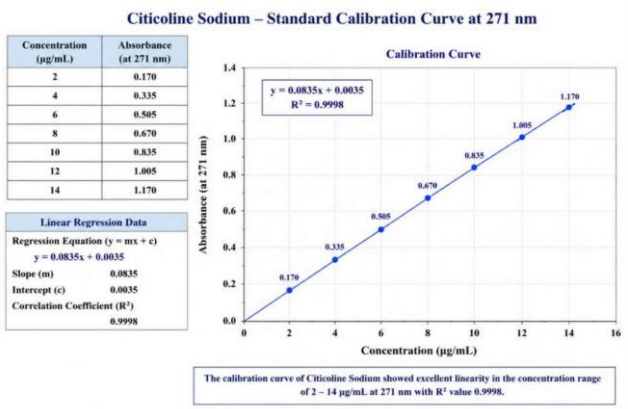

Figure: 5 This Image represents The Standard Calibration Curve of Citicoline sodium

Precompression and Postcompression Characteristics of Citicoline ODT s.

Precompression Evaluation:

Prior to tableting, the powder blends for formulations FI—F5 were assessed for bulk density, tapped density, angle of repose, Carr's index, and Hausner ratio. The recorded angle of repose values indicated good flowability across all formulations. Both Carr's index and Hausner ratio values were within acceptable limits, confirming satisfactory compressibility and suitability for direct compression.[13] The enhanced flow characteristics of the formulations containing the co-processed superdisintegrant can be attributed to the improved particle properties achieved during co-processing. Overall, the precompression analysis confirmed that all powder blends met the flow and compression requirements necessary for uniform die filling and successful tab1eting.[14]

Table: 6 This Table represents Pre Compression evaluvation parameters of Formulations Fl- F5

Formulation	Angle of Repose (°)	Carr's Index (%)	Hausner Ratio
F1	31.5	18.3	1.22
F2	29.1	16.8	1.20
F3	27.4	14.7	1.17
F4	26.5	13.9	1.15
F5	26.2	13.5	1.15

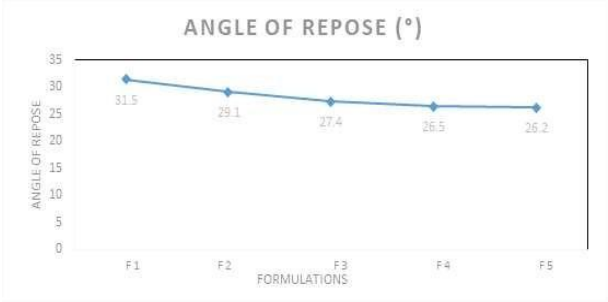

Figure: 6 This Graph represents Angle of Repose of Formulations FI- F5

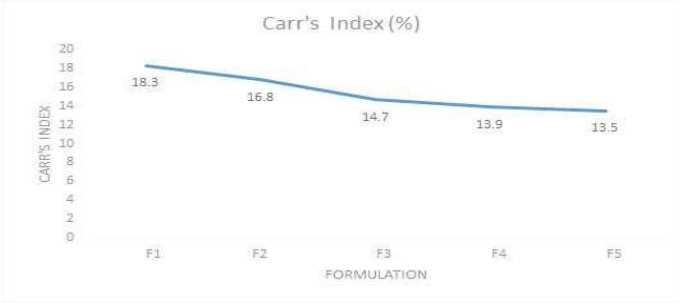

Figure: 7 This Graph represents Carr's Índex of Formulations Fl- F5

Table: 7 This Table represents Drug Content (%) of Formulations Fl- F5

Formulation	Drug Content (%)
F1	96.9
F2	98.2
F3	98.8
F4	99.4
F5	99.8

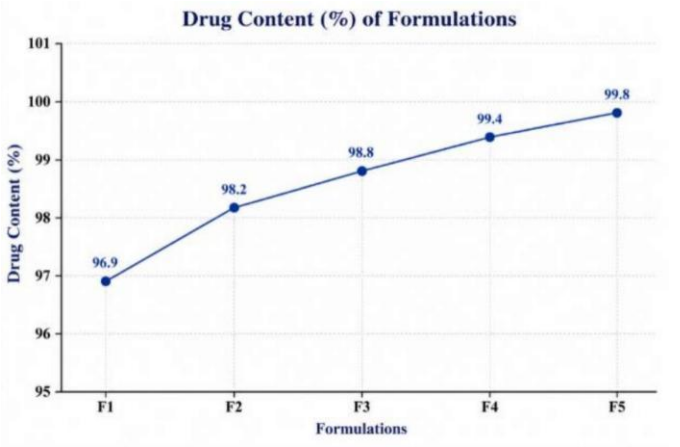

Figure: 8 This Graph represents Drug Content (%) of Formulations FI- F5

Post compression Evaluation:

The compressed Citicoline ODTs were evaluated for weight variation, thickness, hardness, friability, wetting time, water absorption ratio, disintegration time, and drug content. [15] All formulations complied with pharmacopoeia standards for weight variation, demonstrating uniform powder distribution during compression, The tablet hardness was sufficient to withstand handling and transport while still allowing rapid disintegration, and friability values remained within acceptable limits, indicating adequate mechanical strength. Furthermore, the drug content in all batches fell within the acceptable range, confirming uniform distribution of Citicoline. 'Among the developed formulations, F5 offered the best balance of mechanical strength and rapid disintegration, indicating that its concentration of the co-processed Isabgol mucilage—Crospovidone system was optimal for Citicoline ODT formulation.

Table : 8 Average weight of the Tablet

Formulation	Average Weight (mg)
F1	399 mg
F2	400 mg
F3	400 mg
F4	401 mg
F5	399 mg

Table : 9 Thickness of the tablet

Formulation	Thickness (mm)
F1	3.3
F2	3.4
F3	3.3
F4	3.3
F5	3.4

Table 10: Hardness of the tablet

Formulation	Hardness (kg/cm^Z)
F1	3
F2	3
F3	4
F4	3
F5	4

Table: 11 Evaluation of friability of the tablet

Formulation	Friability (%)
F1	0.14
F2	0.12
F3	0.11
F4	0.11
F5	0.12

Effect of Co-Processed Superdisintegrant on Wetting and Disintegration.

Wetting and disintegration times are critical quality attributes for ODTs, as they directly govern. the ease of administration and the onset of drug release. The integration of the co-processed Isabgol mucilage—Crospovidone superdisintegrant led to a marked reduction in both wetting and disintegration times [1 5] compared to formulations with lower concentrations of the superdisintegrant. This performance improvement is attributed to the complementary mechanisms of the two excipients: Isabgol mucilage rapidly absorbs water and swells [16], while Crospovidone promotes rapid capillary wicking [17] of the dissolution medium into the porous tablet structure. This simultancous swelling and nicking generates internal pressure within the tablet matrix, accelerating its breakup. Formulation FS displayed the shortest wetting and disintegration times, confirming that this concentration of the co-processed superdisintegrant achieved the highest disintegration efficiency. These results demonstrate that co-processing a natural superdisintegrant with a synthetic counterpart can significantly enhance the functional performance of Citicoline ODTs.

Table : 12 Disintegration time of the tablet

Formulation	Disintegration Time (sec)
FI	50
F2	24
F3	27
F4	25
F5	17

Table :13 Wetting time of the tablet

Formulation	Wetting Time (sec)
F1	42
F2	28
F3	24
F4	18
F5	16

In-Vitro Drug Release and Dissolution Behaviour.

In vitro dissolution studies were conducted using a USP Type II apparatus with a pH 6.8 phosphate buffer as the medium. All formulations showed rapid Citicoline release, though variations in the rate and extent of release were observed depending on the concentration of the co-processed superdisintegrant. [19] Formulations with higher concentrationsof the Isabgol mucilage-Crospovidone system demonstrated faster dissolution profiles. This improved dissolution behavior is likely due to rapid tablet disintegration, which increases the surface area for dissolution, enhances medium penetration into the tablet core, and facilitates efficient drug particle dispersion. Among the formulations, F5 exhibited the highest cumulative drug release within 30 minutes, showing superior dissolution performance compared to the other batches.

This enhanced dissolution profile confirmed that the co-processed superdisintegrant successfully improved tablet disintegration and subsequent drug release, both of which are critical for ODTs designed to provide rapid therapeutic action, [20]

Table:14 *in vitro* Dissolution studies

Time (min)	F1	F2	F3	F4	F5
5	60	70	68	75	78
10	72	81	88	94	96
15	83	94	96	98	99
20	87	96	98	99	99.5
30	92	99	99	99.8	100

Comparative Evaluation and Optimization of F5.

A comparative assessment of formulations F1-F5 was conducted, evaluating critical quality attributes such as flow properties, compressibility, hardness, friability, wetting time, disintegration time, drug content, and cumulative drug release. While all formulations produced acceptable tablets, F5 consistently showed superior performance across all parameters. This formulation exhibited excellent precompression flow, adequate post compression mechanical strength, minimal wetting time, rapid disintegration, uniform drug content, and the highest cumulative drug release. This outstanding performance is attributed to the synergistic interaction between the swelling of Isabgol mucilage and the wicking of Crospovidone, which collectively enhanced water uptake, tablet breakup, and dissolution efficiency. Based on these evaluations, F5 was selected as the optimized Citicoline ODT formulation containing the co-processed Isabgol mucilage-Crospovidone superdisintegrant system. The optimized formulation demonstrated excellent pharmaceutical characteristics, making it suitable for subsequent stability evaluations and future development studies.

Summary and Conclusion

In this study, Citicoline orally disintegrating tablets (ODTs) were successfully developed and evaluated by direct compression using a co-processed

superdisintegrant composed of Isabgol mucilage and Crospovidone.

[21] The Isabgol mucilage, isolated from Plantago ovata husk, demonstrated excellent swelling and hydration properties, confirming its effectiveness as a natural superdisintegrant. Co-processing this mucilage with Crospovidone yielded a multifunctional superdisintegrant system with improved flow, compressibility, and disintegration efficiency. All prepared formulations (F1-F5) displayed acceptable pre-compression and post-compression characteristics, including favorable flow properties, adequate hardness, low friability, consistent weight variation, and satisfactory dnig content. [22] The integration of the co- processed superdisintegrant significantly enhanced the wetting time, disintegration rate, and dissolution behavior of the Citicoline ODTs, driven by the synergistic swelling action of the Isabgol mucilage and the nicking action of the Crospovidone. Among the evaluated formulations, F5 showed the most optimal overall performance, characterized by excellent powder flow, appropriate mechanical strength, minimal wetting time, rapid disintegration, uniform drug content, and maximum cumulative drug release within 30 minutes. FTIR analyses verified the compatibility between Citicoline and the chosen excipients, indicating no significant drug-excipient interactions, while the developed UV spectrophotometric method proved suitable for routine pharmaceutical analysis. Overall, this research demonstrates that the co-processed Isabgol mucilage-Crospovidone system serves as an efficient superdisintegrant for Citicoline ODTs. The optimized formulation F5 represents a promising, patient-friendly dosage form that can enhance compliance, convenience, and rapid drug release, especially for geriatric, dysphagic, and neurologically impaired populations.

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Reference

1. Seager H. Drug-delivery products and the Zydis fast-dissolving dosage form. J Pharm Pharmacol. 1998;50(4):375-382. doi:10.1111/j.2042-7158.1998.tb06876.x.
2. Fu Y, Yang S, Jeong SH, Kimura S, Park K. Orally fast disintegrating tablets: developments, technologies, taste masking and clinical studies. Crit Rev Ther Drug Carrier Syst. 2004;21(6):433 -476.
3. Adibhatla RM, Hatcher JF. Citicoline mechanisms and clinical efficacy in cerebral ischemia and neurodegenerative diseases. J Neurosci Res. 2002;70(2):133 -139. doi:10.1002/jnr.10403.
4. Secades JJ, Lorenzo JL. Citicoline: pharmacological and clinical review, 2006 update. Methods Find Exp Clin Pharmacol. 2006;28(Suppl B):1-56.
5. Shirsand SB, Sarasija S, Swamy PV, Kumar DN, Rampure MV. Plantago ovata mucilage as a natural superdisintegrant in fast disintegrating tablets. Indian Drugs. 2009;46(7):49-52.
6. Gohel MC, Parikh RK, Brahmbhatt BK, Shah AR. Preparation and assessment of novel co -processed superdisintegrant consisting of crospovidone and sodium starch glycolate: a technical note. AAPS PharmSciTech. 2007;8(1):E63-E69. doi:10.1208/pt0801009.
7. Rowe RC, Sheskey PJ, Quinn ME, editors. Handbook of pharmaceutical excipients. 8th ed. London: Pharmaceutical Press; 2017.
8. Kulkarni RL, Bhosale PB, Patil SR. Isolation and characterization of Plantago ovata mucilage for pharmaceutical applications. Int J Pharm Sci Rev Res. 2013;18(2):45 -50.
9. Malviya A, Sharma P, Dubey S. Extraction and evaluation of natural mucilage as tablet disintegrant. Int J Pharm Res Dev. 2012;4(8):60-67.
10. Indian Pharmacopoeia Commission. Indian pharmacopoeia. Ghaziabad: Indian Pharmacopoeia Commission; 2022.
11. United States Pharmacopeial Convention. United States pharmacopeia and national formulary (USP-NF). Rockville (MD): United States Pharmacopeial Convention; 2023.
12. Silverstein RM, Webster FX, Kiemle DJ. Spectrometric identification of organic compounds. 8th ed. New York: Wiley; 2014.
13. Aulton ME, Taylor KMG. Aulton's pharmaceutics: the design and manufacture of medicines. 6th ed. Edinburgh: Elsevier; 2022.
14. Lachman L, Lieberman HA, Kanig JL. The theory and practice of industrial pharmacy. 3rd ed. Philadelphia: Lea & Febiger; 1986.
15. Skoog DA, Holler FJ, Crouch SR. Principles of instrumentalanalysis.7th ed Boston: Cengage Learning 2018.
16. Maheswari KR, Kumar MR. Evaluation of swelling characteristics of natural polymers used in tablet formulations. Asian J Pharm Res. 2015;5(1):25 -30.
17. Gohel M, Jogani P. Co-processed superdisintegrants for orally disintegrating tablets. Pharm Technol. 2005;29(10):52-62.
18. Allen LV, Popovich NG, Ansel HC. Ansel's pharmaceutical dosage forms and drug delivery systems. 10th ed. Philadelphia: Wolters Kluwer Health; 2014.
19. Kibbe AH, editor. Handbook of phamiaceutical excipients. 8th ed. London: Pharmaceutical Press; 2017.
20. Kuchekar BS, Arumugam AC. Fast dissolving tablets: a novel approach to drug delivery. Indian J Pharm Educ Res. 2001;35(4):150-152.
21. Brunton LL, Hilal-Dandan R, Knollmann BC, editors. Goodman and Gilman's the pharmacological basis of therapeutics. l3th ed. New York: McGraw-Hill Education; 2018.
22. Indian Pharmacopoeia Commission. Indian pharmacopoeia. Vol II. Ghaziabad: Indian Pharmacopoeia Commission; 2022.
23. Banker GS, Rhodes CT. Modem pharmaceutics. 4th ed. New York: Marcel Dekker; 2002.
24. Sweetman SC, editor. Martindale: the complete drug reference. 39th ed. London: Pharmaceutical Press; 2017.
25. Tripathi KD. Essentials of medical pharmacology. 9th ed. New Delhi: Jaypee Brothers Medical Publishers; 2021.