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Research Article

Formulation Strategy and Excipient Selection for *Tribulus terrestris L.* Tablets: A Quality-Based Approach

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ABSTRACT

Background: To develop and evaluate a tablet formulation containing standardized dry extract of *Tribulus terrestris* L.—a plant traditionally used in Mongolian medicine—by focusing on excipient optimization and pharmaceutical quality assessment. **Methods:** Tablets were manufactured using the wet granulation method, incorporating an extract standardized to 54.45% dioscin. Various excipient ratios were investigated to determine the optimal formulation. Dioscin content was quantified using UV-visible spectrophotometry. **Results:** The optimized formulation comprised 25% dry extract, 34% lactose, 34% microcrystalline cellulose, 6% PVPP, 0.5% magnesium stearate, 0.5% talc, and 4.5% HPMC. The tablets demonstrated acceptable pharmaceutical characteristics, including an average weight of 0.113 ± 0.001 g, hardness of 0.83 ± 0.23 MPa, friability of 98.17 ± 0.65%, and disintegration time of 7.30 minutes. The dioscin content was 13.50 ± 0.50 mg/g, with an assay recovery of 95.51%. Dissolution exceeded 83% in both media within 45 minutes. The similarity factor (f_2) confirmed equivalent dissolution profiles. **Conclusion:** The developed *T. terrestris* tablet formulation met pharmacopoeial standards and exhibited consistent physical, chemical, and biopharmaceutical performance, supporting its potential as a standardized herbal medicinal product for clinical and commercial application.

Key words: *Tribulus Terrestre's L.*; tablet; excipients; saponins; spectrophotometer.

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INTRODUCTION

Tribulus terrestris L. (TT) is an annual herbaceous plant of the Zygophyllaceae family, widely distributed across arid and semi-arid regions globally, including desert and steppe ecosystems.[1] In traditional Mongolian medicine, TT has been employed for centuries as a diuretic, neuroprotective agent, circulatory stimulant, immune enhancer, and general tonic to promote physical stamina.[2]

Contemporary pharmacological research has validated several of these traditional applications, revealing that TT possesses a wide range of biological activities. These include immunomodulatory, antiurolithiatic, antidiabetic, cardioprotective, anti-inflammatory, hypolipidemic, neuroprotective, anticancer, and analgesic effects.[3,4]

These pharmacological properties are largely attributed to the rich composition of bioactive compounds in the plant. To date, more than 108 steroidal saponins, primarily of the furostanol and spirostanol types, have been identified in TT. In addition, it contains various secondary metabolites such as flavonoids, tannins, terpenoids, alkaloids, and phenolic acids.[3]However, the chemical composition of TT can vary significantly depending on factors such as geographical origin,[5] growth stage, and the extraction[6–8] and purification methods used.[9]Therefore, standardization of both the raw material and processing techniques is essential to ensure consistent pharmacological efficacy.[10]

Tablets are generally considered a suitable dosage form for herbal preparations due to advantages such as cost-effective manufacturing, accurate dosing, and superior storage stability. Nevertheless, dry herbal extracts typically possess poor physicochemical and mechanical characteristics—including hygroscopicity, stickiness, and low bulk density—which adversely affect powder flowability and compressibility during the tableting process. To overcome these formulation challenges, the extraction procedure must first be optimized to yield a dry extract with high bioactive content and suitable technological properties. Subsequently, the development of a pharmaceutical formulation that ensures proper disintegration, mechanical strength, content uniformity, and compliance with regulatory quality standards is essential. [11]

Despite the growing popularity of herbal medicines, many commercial products still rely on crude or semi-purified extracts. Comprehensive studies using fully standardized extracts with validated pharmaceutical properties remain limited, highlighting the need for further research to support their therapeutic efficacy and formulation stability. [12]

The development of an effective oral dosage form, particularly a tablet, from a standardized TT dry extract requires careful selection of pharmaceutical excipients. Excipients play a critical role in tablet manufacturability and mechanical strength and influence disintegration time, dissolution rate, bioavailability, and storage stability. Therefore, formulation design must adopt a scientifically rational approach that ensures both functional performance and preservation of bioactivity.[13,14] While research on TT-based tablet formulations remains limited, existing studies have shown that the choice of excipients and manufacturing methods significantly affects tablet performance. For instance,

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fast-disintegrating tablets prepared via direct compression using TT fruit and seed extracts with superdisintegrants, such as sodium starch glycolate and crospovidone, achieved disintegration within 29–69 s and dissolution rates above 99% within five minutes. Another study developed floating tablets combining TT with *Pedalium murex* extract, which provided sustained gastric retention and complete drug release over 15 h.[15]

This study aimed to develop a pharmaceutical tablet formulation containing a standardized dry extract of *Tribulus terrestris* (TT) to address the key formulation challenges associated with herbal dosage forms. The extract was prepared from the aerial parts of the plant, purified using a macroporous adsorption resin, concentrated under vacuum, and freeze-dried to obtain a stable dry extract.

A series of pharmaceutical excipients were evaluated to assess their effects on essential tablet quality parameters, such as flowability, compressibility, disintegration time, and dissolution behavior. Based on these assessments, an optimized formulation was developed.

The primary objective of this study was to formulate a standardized TT extract tablet that meets pharmaceutical quality standards, maintains biological efficacy, exhibits physicochemical and formulation stability, and is suitable for clinical use and scalable industrial production.

MATERIALS AND METHODS

This study was designed using a factorial experimental approach to investigate the effects of different diluent and disintegrant types and their ratios on the formulation quality of tablets containing standardized *Tribulus terrestris* dry extract.

Plant Material Collection and Preparation of Dry Extract

The aerial parts of *Tribulus terrestris* were collected from Dundgovi Province, Mongolia. To prepare the dry extract, the plant material was extracted using 70% ethanol under reflux conditions at a solid-to-liquid ratio of 1:6. The extraction was carried out for 6 hours with continuous stirring and heating. The resulting solution was purified using HPD-100 macroporous resin to eliminate unwanted impurities. The purified extract was then freeze-dried to obtain a dry powder suitable for formulation and further analysis.

Preformulation Study

Excipients were screened based on their performance in wet granulation-based formulations. For the diluent selection study, four formulations were prepared using lactose, microcrystalline cellulose (MCC), starch, and dextrin as the sole diluent in each. For disintegrant screening, individual formulations were prepared containing one of the following: DST, polyvinylpolypyrrolidone (PVPP), croscarmellose sodium (cCMC-Na), or low-substituted hydroxypropyl cellulose (L-HPC). Each excipient's effect on tablet performance was evaluated in terms of disintegration time, hardness, friability, and visual appearance.

Tablet Preparation via Wet Granulation

All formulations were produced using a standardized wet granulation process. Each tablet contained 25 mg of standardized dry extract, 6.5 mg of PVPP as the disintegrant, and 0.5 mg of magnesium stearate as a lubricant. The steps were as follows:

1. The dry extract was blended with the selected excipients.
2. A 4.5% hydroxypropyl methylcellulose (HPMC) gel solution was added to the mixture to produce a uniform wet mass.
3. The wet mass was passed through a No. 20 mesh sieve to generate granules.
4. The granules were dried at 50 °C for 29 minutes to reach optimal moisture content.
5. Dried granules were sieved, lubricated, and mixed thoroughly.
6. The final granules were compressed into tablets using a ZP-7 rotary tablet press.

Evaluation of Tablet Quality Attributes

The physical and chemical characteristics of the manufactured tablets were evaluated in accordance with the **Mongolian National Pharmacopoeia**. All assessments strictly followed the requirements outlined in the official monograph titled *"Tablets."* The primary objective of this evaluation was to verify the pharmaceutical quality, therapeutic consistency, safety, and manufacturing reliability of the developed formulation.

The following critical quality parameters were assessed:

- Visual appearance
- Average weight and weight uniformity
- Mechanical strength (tablet hardness)
- Friability
- Disintegration time
- Content of active ingredient (dioscin assay)
- Dissolution behavior

Preparation of dioscin standard solution for quantitative analysis

Dioscin, the principal bioactive marker in *Tribulus terrestris*, was selected as the analytical reference for evaluating extraction yield, content uniformity, and dissolution performance of the formulated tablets.

To prepare the standard solution, 9.2 mg of dioscin (purity: 96.1%) was accurately weighed and dissolved in a small volume of methanol in a 50 mL volumetric flask. The solution was diluted to volume with methanol to achieve a final concentration of 0.184 mg/mL. From this stock solution, 0.20–1.20 mL aliquots were transferred into separate test tubes. Following methanol evaporation, 5 mL of perchloric acid ($HClO_4$) was added to each tube. The samples were incubated in a water bath at 25 °C for 30 minutes, then rapidly cooled in an ice bath for 5 minutes. Absorbance was measured at 409 nm using a UV-Visible spectrophotometer. The dioscin reference standard was obtained from Jinjin Tianjilian Biotechnology Co., Ltd.

Quantification of dioscin in tablets

For dioscin quantification, twenty tablets were accurately weighed, finely powdered, and 0.100 g of the homogenized powder was transferred into a 100 mL volumetric flask. Methanol was added, and the mixture was subjected to ultrasonic treatment for 30 minutes to ensure complete extraction of the active ingredient. The volume was adjusted to 100 mL with methanol, then centrifuged and filtered to obtain Solution A.

A 2 mL aliquot of Solution A was transferred into a test tube, and 4 mL of perchloric acid ($HClO_4$) was added. The tube was sealed and incubated in a water bath at 25 °C for 30 minutes, followed by rapid cooling in an ice bath. The absorbance of the resulting solution was measured at 409 nm using a UV-Visible spectrophotometer. The dioscin content was calculated based on a previously established standard calibration curve.

Dissolution study in distilled water

Dissolution testing was carried out using an RC 806 dissolution apparatus at 37 ± 0.5 °C and 100 rpm, with 250 mL of distilled water

as the dissolution medium. At predetermined time intervals (5, 10, 15, 20, 30, 45, 60, and 90 minutes), 3 mL samples were withdrawn, filtered through a 0.8 µm membrane filter, and analyzed.

From each filtrate, a 1 mL aliquot was transferred to a test tube, followed by the addition of 4 mL of perchloric acid. The mixture was vortexed, incubated at 25 °C for 25 minutes, and then cooled in an ice bath. Absorbance was recorded at 409 nm using a UV-Vis spectrophotometer. A blank solution was prepared by treating 1 mL of distilled water with 4 mL of perchloric acid under identical conditions.

Dissolution study in 0.1 M hydrochloric acid

The same procedure was repeated using 0.1 M hydrochloric acid as the dissolution medium under identical operating conditions (37 ± 0.5 °C, 100 rpm, 250 mL). At each designated time point, 3 mL samples were withdrawn and filtered. A 1 mL aliquot of each filtrate was then mixed with 4 mL of perchloric acid, incubated at 25 °C for 25 minutes, cooled in an ice bath, and analyzed spectrophotometrically at 409 nm.

Statistical analysis

Statistical analysis was performed using SPSS version 25.0 (SPSS Inc., Chicago, IL, USA). One-way analysis of variance (ANOVA) was applied to assess differences among groups. Pearson's chi-squared (χ^2) test was used for analyzing categorical variables. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Evaluation of dry extract quality

Following the preparation of the *Tribulus terrestris* (TT) dry extract, its dioscin content was quantified to ensure standardization. The extract contained 544.47 ± 1.66 mg/g of dioscin, representing approximately 54.45% of the total composition. A representative image of the dry extract is shown in Figure 1.

Assessment of flow properties of the powdered extract

The powdered TT extract was assessed to determine its suitability for tablet formulation, focusing on flow and compressibility characteristics. Flowability was evaluated using Carr's Compressibility Index, which was calculated to be 21.70 ± 0.88%, falling within the acceptable range indicative of good flow properties. The Hausner Ratio was measured at 1.28 ± 0.01, suggesting satisfactory compressibility. These values confirm the extract's appropriateness for solid dosage formulation.

However, due to the limitations associated with direct compression—primarily the poor compactibility and cohesion of the powdered extract—the wet granulation method was selected for tablet manufacturing. This technique enabled more effective incorporation of excipients and better control over process parameters, ultimately enhancing the quality of the final tablets.

Selection of diluent excipients for tablet formulation

Tablet formulation was performed using the wet granulation method, which involved blending, wet massing, drying, and compression. Each formulation consistently included 25 mg of dry extract, 6.5 mg of PVPP as the disintegrant, and 0.5 mg of magnesium stearate as the lubricant. The detailed composition of each formulation is provided in Table 1. The objective of this study was to evaluate the influence of various diluent excipients on the technological and physicochemical characteristics of the tablets, with the goal of identifying the most suitable diluent for further formulation development.

As shown in Table 2, tablets formulated with microcrystalline cellulose (MCC) exhibited the shortest disintegration time (8.54 ± 0.44 minutes), which was significantly faster than those containing starch (15.15 ± 0.34 minutes) or dextrin (23.43 ± 0.79 minutes) ($p < 0.0001$; $p < 0.05$). In addition, MCC-based tablets demonstrated the highest resistance to mechanical stress (97.6%) ($p < 0.0001$) and achieved the highest appearance rating (4.0 ± 0.00), indicating superior physical integrity and overall acceptability.

Although lactose-containing tablets showed a slightly longer disintegration time (11.66 ± 0.34 minutes), they exhibited the highest hardness value (0.64 ± 0.09 MPa), which was significantly greater than that of MCC tablets (0.23 ± 0.06 MPa) ($p = 0.04$; $p < 0.05$). This finding suggests that lactose contributed to enhanced compressibility and resistance to breakage.

In contrast, starch- and dextrin-based tablets exhibited prolonged disintegration times and inferior mechanical properties, rendering them unsuitable for further development.

Based on these findings, MCC was selected for its rapid disintegration, mechanical resilience, and excellent visual quality, whereas lactose was chosen for its superior compressibility and hardness—supporting its use as a co-diluent in the optimized formulation.

Optimization of lactose-to-MCC ratio in tablet formulation

To optimize the diluent combination, a series of formulations with varying lactose-to-MCC ratios were prepared. Five formulations were evaluated using the following ratios: 57:11, 46:22, 34:34, 22:46, and 11:57 (Table 3). This systematic approach aimed to identify the optimal balance of flowability, compressibility, and disintegration behavior to enhance overall tablet performance.

As presented in Table 4, modifying the lactose-to-MCC ratio had a statistically significant influence on tablet performance. Among the five tested formulations, the 34:34 ratio exhibited the most balanced and favorable results across all evaluated parameters.

- Disintegration Time: Tablets with a 34:34 ratio disintegrated most rapidly (10.59 ± 0.79 minutes), significantly faster than those with a 11:57 ratio (16.23 ± 0.45 minutes) ($p = 0.0001$; $p < 0.05$).
- Tablet Hardness: The 34:34 formulation also demonstrated superior mechanical strength (1.7 ± 0.26 MPa), outperforming the 57:11 and 46:22 ratios (1.37 ± 0.22 MPa and 1.38 ± 0.43 MPa, respectively) ($p = 0.0001$; $p < 0.05$).
- Friability: Although the 46:22 formulation showed slightly higher friability resistance (97.6%), the 34:34 formulation also remained within acceptable limits at 96.2% ($p = 0.006$; $p < 0.05$).
- Visual Appearance: The 34:34 formulation received the highest visual evaluation score (3.9 ± 0.32), indicating excellent uniformity, smooth surface, and consistent shape, significantly outperforming the 57:11 formulation (2.9 ± 0.32) ($p = 0.0001$; $p < 0.05$).

Taken together, the 34:34 ratio formulation provided the most optimal combination of rapid disintegration, strong mechanical properties, acceptable friability, and superior appearance. These findings support its selection as the lead candidate for further formulation refinement and scale-up.

Disintegrant type and ratio optimization

A screening study was subsequently performed to evaluate the effect of disintegrant type on tablet disintegration behavior. All formulations were prepared with the same base composition, varying only in the type of disintegrant incorporated (Table 5).

According to the disintegration test results, the formulation containing polyvinylpolypyrrolidone (PVPP) showed the fastest disintegration time, averaging 7.1 ± 0.07 minutes. In comparison, formulations

Table 1. Formulation composition of TT tablets for evaluation of individual diluent excipients

Formulation No.	Dry Extract (mg)	PVPP (mg)	Lactose (mg)	MCC (mg)	Starch (mg)	Dextrin (mg)	Magnesium Stearate (mg)
1	25	6.5	68.0				0.5
2	25	6.5		68.0			0.5
3	25	6.5			68.0		0.5
4	25	6.5				68.0	0.5

Table 2. Results: Outcomes of the study on diluent selection

Characteristic	Groups				P value
	Lactose	MCC	Starch	Dextrin	
Disintegration time (min)ǂ	11.66 ± 0.34	8.54 ± 0.44	15.15 ± 0.34	23.43 ± 0.79	0.0001†
Disintegration time <15 min§	6 (100)	6 (100)	1 (16.7)	0 (0)	0.0001[f]
Hardness (MPa)ǂ	0.64 ± 0.09	0.23 ± 0.06	2.9 ± 0.59	2.44 ± 0.3	0.0001†
Hardness 0.45 - 1.2 Mpa§	10 (100)	0 (0)	0 (0)	0 (0)	0.0001[f]
Abrasiveness (%)	87.5	97.6	96.2	94.8	
Appearance of the tabletsǂ	2.8 ± 0.42	4 ± 0	3.1 ± 0.32	2.9 ± 0.32	0.0001†

ǂ - calculated for mean ± standard deviation
§ - calculated for case number (percent)
† - P value for One-Way ANOVA test
[f] - P value for Fisher's exact test

Table 3. Formulation designs with adjusted lactose-to-MCC ratios

Formulation No.	Dry Extract (mg)	PVPP (mg)	Magnesium Stearate (mg)	Lactose (mg)	MCC (mg)
1	25	6.5	0.5	57	11
2	25	6.5	0.5	46	22
3	25	6.5	0.5	34	34
4	25	6.5	0.5	22	46
5	25	6.5	0.5	11	57

Table 4. The results of the determination of suitable ratio of lactose and MCC

Characteristic	Groups					P value
	Ratio 57:11	Ratio 46:22	Ratio 34:34	Ratio 22:46	Ratio 11:57	
Disintegration time (min)ǂ	11.71 ± 0.43	11.51 ± 0.45	10.59 ± 0.79	14.03 ± 0.37	16.23 ± 0.45	0.0001†
Disintegration time <15 min§	6 (100)	6 (100)	6 (100)	6 (100)	0 (0)	0.0001[f]
Hardness (MPa)ǂ	1.37 ± 0.22	1.38 ± 0.43	1.7 ± 0.26	2.03 ± 0.21	2.26 ± 0.23	0.0001†
Hardness 0.45 - 1.2 Mpa§	2 (20)	4 (40)	0 (0)	0 (0)	0 (0)	0.0001[f]
Abrasiveness (%)	87.5	97.6	96.2	94.8	96.2	
Appearance of the tabletsǂ	2.9 ± 0.32	3.2 ± 0.42	3.9 ± 0.32	3 ± 0.47	3.1 ± 0.57	0.0001†

ǂ - calculated for mean ± standard deviation
§ - calculated for case number (percent)
† - P value for One-Way ANOVA test
f - P value for Fisher's exact test

Table 5. Formulation variants of tablets containing different disintegrants

Formulation No.	Dry Extract (mg)	Lactose (mg)	MCC (mg)	Magnesium Stearate (mg)	PVPP	DST	cCMC-Na	L-HPC
1	25	34	34	0.5	6.5			
2	25	34	34	0.5		6.5		
3	25	34	34	0.5			6.5	
4	25	34	34	0.5				6.5

Table 6. Results of selection of the disintegrants for a tablet containing TT dry extract

Characteristic	DST	PVPP	cCMC-Na	L-HPC	P value
Disintegration time (min)ǂ	12.24 ± 0.17	7.1 ± 0.07	13.06 ± 0.03	14.16 ± 0.07	0.0001
Disintegration time <15 min§	6 (100)	6 (100)	6 (100)	6 (100)	

ǂ - calculated for mean ± standard deviation
§ - calculated for case number (percent)
P value for One-Way ANOVA test

Table 7. Variants of tablet formulations with different PVPP levels

Formulation No.	Dry Extract (mg)	Lactose (mg)	MCC (mg)	Magnesium Stearate (mg)	PVPP (mg)
1	25	34	34	0.5	8
2	25	34	34	0.5	6
3	25	34	34	0.5	5
4	25	34	34	0.5	4

Table 8.

Characteristic	PVPP 8 mg	PVPP 6 mg	PVPP 4 mg	PVPP 2 mg	P value
Disintegration time (min)ǂ	8.35 ± 0.17	7.34 ± 0.13	12.46 ± 0.07	13.39 ± 0.13	0.0001
Disintegration time <15 min§	6 (100)	6 (100)	6 (100)	6 (100)	

ǂ - calculated for mean ± standard deviation
§ - calculated for case number (percent)
P value for One-Way ANOVA test

incorporating DST, cCMC-Na, and L-HPC demonstrated progressively longer disintegration times of 12.24, 13.06, and 14.16 minutes, respectively. These results indicate that PVPP is the most effective disintegrant among those evaluated (Table 6).

In the subsequent optimization phase, the concentration of PVPP was systematically varied between 2 and 8 mg to investigate its dose-dependent effect on disintegration performance. The findings from this evaluation are presented in Table 7. Table 8. Results of the study on the selection of ratios for disintegrants

Quality assessment of *Tribulus terrestris* tablets

The pharmaceutical quality of the *Tribulus terrestris* (TT) tablet formulation was assessed in compliance with the Mongolian National Pharmacopoeia (MNP), focusing on organoleptic attributes, physical and mechanical properties, disintegration and dissolution behavior, and active ingredient content.

The tablets were round, biconvex, brown in color, with a smooth surface and a characteristic herbal odor, all in accordance with pharmacopoeial standards.

- **Weight uniformity**: Mean tablet weight was 0.113 ± 0.01 g, with a deviation of ±9.28%, within the MNP limit of ±10% for tablets under 0.1 g.
- **Mechanical strength**: Tablet hardness measured 0.83 ± 0.23 MPa, within the accepted 0.45–1.2 MPa range. Friability was 98.17 ± 0.65%, exceeding the minimum threshold of 97%, indicating robustness and low risk of abrasion.
- **Assay and uniformity**: The average dioscin content was 12.07 ± 0.30 mg/g (RSD 2.5%), meeting the ±7.5% pharmacopoeial tolerance. Content uniformity was confirmed at 13.50 ± 0.50 mg/g (RSD 3.7%), within the regulatory limit of ±15%.
- **Disintegration**: The tablets disintegrated in 7.30 ± 0.28 minutes, well below the 15-minute limit for uncoated tablets.
- **Dissolution**: Dioscin release reached 84.30 ± 0.11% in distilled water and 83.27 ± 1.03% in 0.1 M HCl within 45 minutes, exceeding the minimum 75% threshold.

These findings demonstrate that the developed TT tablet formulation fulfills all critical quality specifications, supporting its pharmaceutical acceptability and potential for clinical and commercial development.

Quantification of dioscin content

Standard dioscin solutions were analyzed using a UV-Vis spectrophotometer over a wavelength range of 190–450 nm, with maximum absorbance detected at 409 nm. A calibration curve was established across the concentration range of 7.36–44.16 µg/mL, yielding a linear regression equation of $\mathbf{y = 0.0245x + 0.025}$ and a Pearson correlation coefficient of $\mathbf{r = 0.99}$ ($p < 0.0001$), confirming excellent linearity. This calibration model was subsequently applied for the quantitative determination of dioscin in the tablet samples.

Based on the formulation composition, the theoretical dioscin content per tablet was calculated to be 13.61 mg/g, assuming the dry extract contained 54.45% dioscin and each tablet included 0.025 g of dry extract. In contrast, the actual assay determined a content of 13.50 ± 0.50 mg/g, corresponding to a yield of 95.51%. This indicates minimal loss of the active compound during manufacturing and demonstrates high retention efficiency.

Dissolution profile of tablets

The dissolution behavior of the formulated tablets was assessed in two media—distilled water and 0.1 M hydrochloric acid—over a 90-minute period to evaluate drug release under both neutral and acidic conditions.

Dissolution in distilled water

At 5 minutes, the tablets released 2.16 µg/mL of dioscin, corresponding to 46.88% dissolution. This increased to 3.31 µg/mL (71.78%) at 15 minutes, peaking at 3.81 µg/mL (82.68%) at 20 minutes. The release rate then plateaued, reaching 83.27% at 90 minutes (Figure 4).

Dissolution in 0.1 M Hydrochloric Acid

In acidic medium, initial dioscin release was lower, with 1.22 µg/mL (26.41%) dissolved at 5 minutes. However, dissolution progressed steadily, reaching 3.24 µg/mL (70.31%) at 15 minutes and peaking at 3.81 µg/mL (82.68%) thereafter.

Dissolution in acidic medium (0.1 M HCl)

In a 0.1 M hydrochloric acid medium, the initial dissolution of dioscin was relatively low, with 1.22 µg/mL released at 5 minutes, corresponding to 26.41% dissolution. However, the release progressively increased over time, reaching 3.24 µg/mL (70.31%) at 15 minutes and 3.81 µg/mL (82.68%) at 30 minutes. By 90 minutes, the dissolution profile had plateaued, with a final concentration of 3.89 µg/mL, corresponding to a cumulative release of 84.45% (Figure 4).

To better characterize the time-dependent dissolution behavior, linear regression analysis was applied to the release data obtained in both media.

In distilled water, the dissolution trend followed the equation:

Figure 1. *Tribulus terrestris* L. dry extract.

Figure 2: Tablets prepared from *Tribulus Terrestris L.*dry extract.

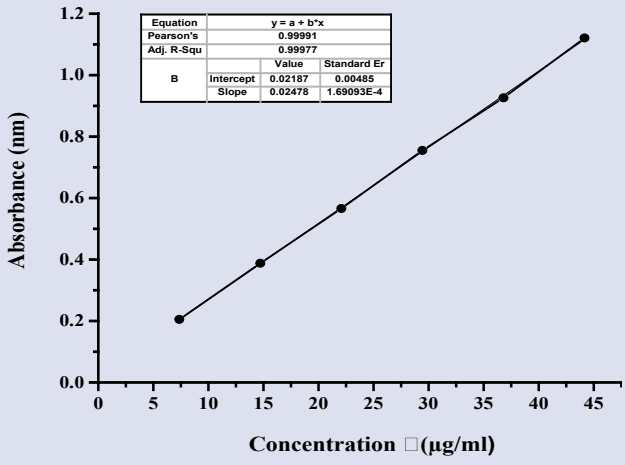

Figure 3: Standard calibration curve used for dioscin quantification.

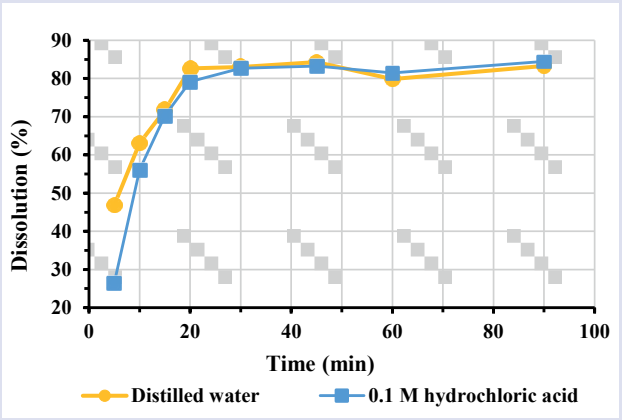

Figure 4: Dissolution behavior of the tablets in two media: distilled water and 0.1 M hydrochloric acid.

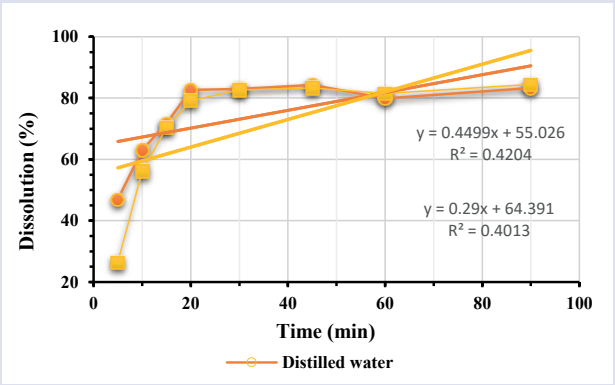

Figure 5: Dissolution profile with linear regression analysis.

Dissolution (%) = 0.29x + 64.39, with a coefficient of determination **R^2 = 0.40** and a *p*-value of 0.092, indicating a moderate, but statistically non-significant, correlation between time and drug release.

In 0.1 M hydrochloric acid, the dissolution profile was described by the equation:

Dissolution (%) = 0.45x + 55.03, with **R^2 = 0.42** and $p = 0.082$, similarly reflecting a moderate but non-significant relationship. These trends are illustrated in Figure 5.

While the statistical significance thresholds were not met in either case, the progressive increase in dissolution percentage over time in both media highlights the formulation's consistent release characteristics. These results suggest that the tablets offer reliable and predictable drug release profiles under both neutral and acidic gastrointestinal conditions.

DISCUSSION

Microcrystalline cellulose (MCC) and lactose are among the most frequently used excipients in tablet formulation, owing to their essential roles in ensuring manufacturability, physical stability, and in vivo performance. Together, these excipients can comprise 70–80% of a typical tablet formulation.[16]

MCC, a purified α-cellulose derivative, is widely valued for its excellent compressibility, fast disintegration, and moderate hardness.[17] It is a multifunctional excipient, often employed as a diluent, disintegrant, and binder, with recommended usage levels ranging from 20% to 90%. Lactose, on the other hand, is primarily used to enhance blend compressibility and also functions as both a diluent and binder. Early selection and compatibility testing of these excipients are crucial, as

they can profoundly influence drug stability and the overall success of a formulation.[18,19]

When developing formulations that include moisture-sensitive active pharmaceutical ingredients (APIs), careful optimization of the MCC-to-lactose ratio is essential.[20]A 34:34 ratio of MCC to lactose has been shown to provide optimal performance by balancing the plastic deformation characteristics of MCC with the brittle fracturing behavior of lactose, resulting in tablets with superior hardness and compaction properties.[18] Similarly, a 50:50 mixture of anhydrous lactose and Pharmacel® 112 has demonstrated a favorable balance between mechanical strength and rapid disintegration, making it particularly effective for fast-dissolving formulations.[21]

Recent advances in co-processing technologies have further improved the functional performance of excipients, enhancing properties such as flowability, compressibility, disintegration, and dissolution.[22] Co-processed excipients combine the individual strengths of their components, offering synergistic performance advantages. Notably, a co-processed MCC:lactose blend in a 34:34 ratio has proven to be highly suitable for immediate-release formulations, delivering optimal mechanical strength, fast disintegration, and efficient drug release—features that clearly distinguish it from modified-release systems.[23]

At a concentration of 6%, polyvinylpolypyrrolidone (PVPP) significantly reduced tablet disintegration time to 7.34 ± 0.13 minutes. This improvement is primarily attributed to PVPP's high swelling capacity and strong capillary action. Although this concentration slightly exceeds the typical usage range of 2–5%, it remains within acceptable pharmaceutical limits and effectively satisfies pharmacopoeial disintegration standards.[24]

Hydroxypropyl methylcellulose (HPMC), used at a concentration of 4.5%, contributed to enhanced mechanical strength and modulated disintegration behavior. HPMC is generally employed at levels between 2% and 5%, particularly in pellet formulations of moisture-sensitive drugs, especially when organic solvents are utilized.[25]

Fundamental technological attributes of tablet dosage forms—such as mechanical strength (e.g., hardness), disintegration time, and dissolution rate—are critical factors that directly affect the bioavailability and therapeutic performance of orally administered drugs. Among these, disintegration time plays a particularly vital role, as it governs the rate of drug release and the onset of pharmacological action.[26]

Recent research has emphasized the importance of disintegration mechanisms, including water penetration into the tablet matrix, polymer swelling, and disruption of interparticulate bonding, as key drivers of tablet disintegration dynamics.

The growing incidence of poorly water-soluble active pharmaceutical ingredients (APIs) has underscored the need for advanced drug delivery systems that enhance solubility, improve gastrointestinal absorption, and ensure optimal therapeutic efficacy.[27]

The dissolution profiles of the tested formulations showed strong consistency across both distilled water and 0.1 M hydrochloric acid, indicating the formulation's robustness and its ability to maintain performance under varying physiological conditions. A distinct burst release phase was observed within the first 15 minutes, followed by a stable, sustained-release phase—suggesting that drug release is primarily governed by diffusion mechanisms.[28]

In both media, over 80% of the active ingredient was released within 30 minutes, reflecting the efficiency of the formulation and the reliability of the manufacturing process.[29] This rapid dissolution is particularly beneficial for immediate-release dosage forms, facilitating quick drug absorption and a prompt onset of therapeutic action.[30]

Furthermore, the similar dissolution behavior observed in both neutral and acidic environments suggests that the formulation is pH-independent—a desirable property for oral solid dosage forms subjected to the fluctuating pH conditions of the gastrointestinal tract. These findings were corroborated by the similarity factor (f_2), confirming the equivalence of dissolution profiles across the two media.

In summary, the *Tribulus terrestris* tablet formulation demonstrated efficient in vitro performance, consistent release characteristics, and compliance with pharmaceutical quality standards. Collectively, these results support its potential as a standardized phytopharmaceutical product suitable for clinical use.[31]

CONCLUSION

This study successfully established a robust tablet formulation containing 25% standardized dry extract of *Tribulus terrestris*. The optimization of excipient composition—specifically, the incorporation of microcrystalline cellulose (MCC) and lactose in a 34:34 ratio, 6% polyvinylpolypyrrolidone (PVPP), and 4.5% hydroxypropyl methylcellulose (HPMC)—resulted in a formulation with desirable technological and biopharmaceutical characteristics.

The final tablets exhibited consistent physical properties, with an average weight of 0.113 ± 0.001 g, hardness of 0.83 ± 0.03 MPa, friability of 98.17 ± 0.65%, and a disintegration time of 7.30 ± 0.28 minutes. Dioscin content was determined to be 13.50 ± 0.50 mg/g, ensuring the formulation met active ingredient specifications.

Dissolution studies demonstrated that more than 84% of the active compound was released within 45 minutes in both distilled water and 0.1 M hydrochloric acid, confirming a pH-independent release profile. The similarity factor (f_2) supported the equivalence of dissolution behavior across media.

An assay recovery rate of 95.51% verified the accuracy, reproducibility, and reliability of the formulation and manufacturing processes. The final product complied with all critical quality attributes as defined by the Mongolian National Pharmacopoeia, confirming its suitability for pharmaceutical application.

These results emphasize the importance of excipient selection and precise ratio optimization in the development of standardized herbal formulations, providing a strong foundation for clinical use and future regulatory approval.

CONFLICT OF INTEREST

The authors declare no conflicts of interest associated with this study.

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DATA AVAILABILITY STATEMENT

The data supporting this study are available from the NN repository at www.NNN.org/download.

ETHICAL APPROVAL

Decision of the Ethics Review Committee of the Health Sciences University of Mongolia, dated February 17, 2023, under the reference number 2023/3-02.

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REFERENCE

1. Tkachenko K, Avramov L, Vasilev A, Shi L, Frontasyeva M. Major and trace element content of *Tribulus terrestris* L. wildlife plants. *Plants.* 2020;9. doi:10.3390/plants9121764
2. Tserendagva D, trans. Essence of spring water, root of the eight-part secret: fundamental principles of doctrine (Tibetan, Mongolian, and English). Ulaanbaatar: Bit Press LLC; 2017
3. Zhu W, Du Y, Meng H, Dong Y, Li L. A review of traditional pharmacological uses, phytochemistry, and pharmacological activities of *Tribulus terrestris*. *Chem Cent J.* 2017;11(1):60. doi:10.1186/s13065-017-0289-x
4. Saeed M, Munawar M, Bi JB, et al. Promising phytopharmacology, nutritional potential, health benefits, and traditional usage of *Tribulus terrestris* L. herb. *Heliyon.* 2024;10: e25549. doi: 10.1016/j.heliyon. 2024.e25549
5. Dinchev D, Janda B, Evstatieva L, Oleszek W, Aslani MR, Kostova I. Distribution of steroidal saponins in *Tribulus terrestris* from different geographical regions. *Phytochemistry.* 2008;69(1):176-186. doi: 10.1016/j.phytochem.2007.07.003
6. Kaushik J, Tandon S, Gupta V, Nayyar J, Singla SK, Tandon C. Response surface methodology-based extraction of *Tribulus terrestris* leads to an upsurge of antilithiatic potential by inhibition of calcium oxalate crystallization processes. *PLoS One.* 2017;12(8): e0183218. doi: 10.1371/journal.pone.0183218
7. Simeonov E, Yaneva Z, Chilev C. Extraction of protodioscin from *Tribulus terrestris*–optimisation of kinetics and modeling. *Rev Chim.* 2021;71(12):56-66. doi:10.37358/RC.20.12.8386
8. Tian C, Chang Y, Zhang Z, et al. Extraction technology, component analysis, antioxidant, antibacterial, analgesic and anti-inflammatory activities of flavonoids fraction from *Tribulus terrestris* L. leaves. *Heliyon.* 2019;5: e02234. doi: 10.1016/j.heliyon. 2019.e02234
9. Yin L, Xu Y, Qi Y, et al. A green and efficient protocol for industrial-scale preparation of dioscin from *Dioscorea nipponica* Makino by two-step macroporous resin column chromatography. *Chem Eng J.* 2010;165(1):281-289. doi: 10.1016/j.cej.2010.09.045
10. Mulinacci N, Vignolini P, la Marca G, Pieraccini G, Innocenti M, Vincieri FF. Food supplements of *Tribulus terrestris* L.: An HPLC-ESI-MS method for an estimation of the saponin content. *Chromatographia.* 2003;57(9):581-592. doi:10.1007/BF02491733
11. Mudrić J, Arsenijević J, Maksimović Z, et al. Tablet and capsule formulations incorporating high doses of a dry optimized herbal extract: The case of *Satureja kitaibelii*. *J Drug Deliv Sci Technol.* 2021; 66:102776. doi: 10.1016/j.jddst.2021.102776
12. Janssen PHM, Fathollahi S, Bekaert B, et al. Impact of material properties and process parameters on tablet quality in a continuous direct compression line. *Powder Technol.* 2023; 424:118520. doi: 10.1016/j.powtec.2023.118520
13. Pifferi G, Santoro P, Pedrani M. Quality and functionality of excipients. *Il Farmaco.* 1999;54(1):1-14. doi:10.1016/S0014-827X(98)00101-3
14. Gazi AS, Begum A, Begum S. An overview on pharmaceutical excipients—their roles and applications. *Int J Pharm Sci Med.* 2022;7(12):84-96. doi:10.47760/ijpsm. 2022.v07i12.005
15. Venkatachalam CD, Sengottian M, Sengodan T. Formulation and evaluation of polyherbal floating effervescence tablet containing *Pedalium murex* and *Tribulus terrestris* fruit extracts. *Int J Appl Pharm.* 2017;9(2):10. doi:10.22159/ijap.2017v9i2.16319
16. Wang D, Cheow WS, Amalina N, Faiezin M, Hadinoto K. Selecting optimal pharmaceutical excipient formulation from life cycle assessment perspectives: A case study on ibuprofen tablet formulations. *J Clean Prod.* 2021; 292:126074. doi: 10.1016/j.jclepro.2021.126074
17. Raval M, Patel J, Parikh RK, Sheth N. Dissolution enhancement of chlorzoxazone using cogrinding technique. *Int J Pharm Investig.* 2015;5(4):247. doi:10.4103/2230-973x.167689
18. Wang J, Wen H, Desai D. Lubrication in tablet formulations. *Eur J Pharm Biopharm.* 2010;75(1):1-15. doi: 10.1016/j.ejpb.2010.01.007
19. Tablets: A brief overview. *Pharma Pharm Process Sci.* 2019;2019(1). doi:10.33513/ppps/1901-10
20. Franc A, Vetchý D, Fülöpová N. Commercially available enteric empty hard capsules, production technology and application. *Pharmaceuticals (Basel).* 2022;15(11):1398. doi:10.3390/ph15111398
21. Castro SG, Dib A, Suárez G, et al. Comparative plasma exposure of albendazole after administration of rapidly disintegrating tablets in dogs. *Biomed Res Int.* 2013; 2013:920305. doi:10.1155/2013/920305
22. Veronica N, Liew CV, Heng PWS. Insights on the role of excipients and tablet matrix porosity on aspirin stability. *Int J Pharm.* 2020; 580:119218. doi: 10.1016/j.ijpharm.2020.119218
23. Garnero C, Aiassa V, Longhi MR. Innovative technological systems to optimize the delivery and therapeutic activity of antimicrobial drugs. In: *Elsevier eBooks.* Elsevier BV; 2020:105-139. doi:10.1016/b978-0-12-819666-3.00004-3
24. Mahmoudi ZN, Upadhye SB, Ferrizzi D, Rajabi-Siahboomi AR. In vitro characterization of a novel polymeric system for preparation of amorphous solid drug dispersions. *AAPS J.* 2014;16(4):685-697. doi:10.1208/s12248-014-9590-y
25. Chatlapalli R, Rohera BD. Physical characterization of HPMC and HEC and investigation of their use as pelletization aids. *Int J Pharm.* 1998;161(2):179-193. doi:10.1016/S0378-5173(97)00350-5
26. Hart LM. Brief overview of various approaches to enhance drug solubility. *J Dev Drugs.* 2013;2(3). doi:10.4172/2329-6631.1000115
27. Zhang X, Xing H, Zhao Y, Ma Z. Pharmaceutical dispersion techniques for dissolution and bioavailability enhancement of poorly water-soluble drugs. *Pharmaceutics.* 2018;10(3):74. doi:10.3390/pharmaceutics10030074
28. Lu JX, Tupper C, Murray J. Biochemistry, dissolution and solubility. *StatPearls.* Published online September 2021. https://europepmc.org/article/MED/28613752
29. Shashank N, AS R, Shwetha S, Kamath K. Study of post compression parameters of various marketed paracetamol tablets in India. *Pharmatutor.* 2019;7(2):35. doi:10.29161/pt. v7.i2.2019.35
30. Gupta A, Hunt RL, Shah RB, Sayeed VA, Khan MA. Disintegration of highly soluble immediate release tablets: A surrogate for dissolution. *AAPS PharmSciTech.* 2009;10(2):495-499. doi:10.1208/s12249-009-9227-0
31. Markl D, Zeitler JA. A review of disintegration mechanisms and measurement techniques. *Pharm Res.* 2017;34(5):890-917. doi:10.1007/s11095-017-2129-z

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