Research Article

Formulation, Optimization, and Characterization of Polyherbal Phytosomes Incorporating Four Medicinal Plant Extracts

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Abstract

The present study was undertaken to develop, optimize, and evaluate a polyherbal phytosomal drug-delivery system incorporating Morusnigra L. (black mulberry), Limonia acidissima L. (wood apple), Hibiscus rosa-sinensis L. (China rose), and Bauhinia variegata L. (kachnar) for potential antimicrobial applications. Formulation optimization was performed using Design-Expert® software employing a Box–Behnken design (BBD) and response surface methodology. The effects of selected independent variables and their interactions on the evaluated responses were investigated using mathematical modelling. Based on the comparative evaluation and optimization criteria, formulation F7 was identified as the optimized formulation. The selected formulation was evaluated for particle size, polydispersity index, zeta potential, association efficiency, and extract loading. Further characterization was undertaken using Fourier-transform infrared spectroscopy, differential scanning calorimetry and microscopic techniques to investigate physicochemical properties and potential interactions between the polyherbal extract and phospholipid.The identification of F7 as the optimized formulation demonstrated the application of Design-Expert®-assisted Box–Behnken design in selecting a suitable polyherbalphytosomal system. Overall, the developed formulation represented a promising candidate for further investigation as a plant-based antimicrobial delivery system. Its pharmaceutical potential was assessed through physicochemical characterization, comparative antimicrobial evaluation, and stability studies.

Keywords: Polyherbal extract, phytosomes, antimicrobial activity, phosphatidylcholine, Box–Behnken design, Design-Expert®, formulation optimization

1. Introduction

Novel Drug Delivery System

A new way of giving medicine is a way of making medicine or a tool that changes how the medicine is let out spread around taken in or sent to a certain spot. The main goals of such a way are to make the medicine work better make the body take in more of it make it less harmful protect medicines that don't last long and make it easier for people to take their medicine. [1]

Important ways include using pieces, small bags made of fat tiny fat pieces, small groups of big molecules tiny particles in a liquid small drops of oil and water gels, tiny needles, things that go inside the body things that change when conditions change and things that act like real parts of the body.[2] These kinds of technology can be used for taking medicine by mouth through a needle through the skin by breathing in through the nose into the eye and in ways.

Phytosomes

Phytosomes, also known as herbosomes are made up of bioactive substances like plant extracts or water-soluble phytoconstituents combined with phospholipids such as phosphatidylcholine, phosphatidylethanolamine and phosphatidylserine. There is no difference between phytosomes and liposomes.[3]Phytosomes are a special type of liposome that contains plant compounds. These phytolipid delivery systems are usually made by mixing phytoconstituents with phosphatidylcholine in a ratio of 1:2 or 1:1. Methods used to prepare them include lyophilization and anti-solvent precipitation.

How Phytosomes Work

Binds to Phospholipids: They combine extracts with phospholipids, which are fats found in cell membranes.
Increases Bioavailability: This form helps the active ingredients cross the gut wall and get into the bloodstream effectively than regular extracts.

Delays Breakdown:
They shield ingredients from being destroyed in the digestive system so lower doses can still produce strong results.[4]

Collection and Authentication of Medicinal Plants:
Fresh or properly dried plant samples of the four chosen plants were gathered from a trustworthy source. The samples were cleaned to remove any dirt or unwanted materials. They were then identified by an expert botanist at a recognized institution. After authentication the plants were dried in the shade at room temperature. They were kept away from sunlight and moisture. Each plant was then ground into powder using a grinder. The powder was passed through a sieve to get a uniform consistency. The powdered materials were stored in airtight containers to protect them from moisture and light until they were used.

Preparation of Plant Extracts:
The proposed formulation method begins with the preparation of plant extracts. The Soxhlet extraction technique was used for this purpose.The extraction was done using a hydroalcoholic solvent system. After that the extracts were filtered. The filtrates were concentrated using reduced pressure at a controlled temperature. The concentrated extract was dried to get a semisolid or dry form. The percentage yield was calculated. The extracts were stored in airtight containers. The four standardized extracts were combined in ratios. The proposed ratios were:
[Morusnigra :Limoniaacidissima : Hibiscus rosa-sinensis : Bauhinia variegata = 1:1:1:1]



Figure1.Preparation of individual plant extracts by Soxhlet method

Preliminary phytochemical screening was carried out on each extract. This was done to detect the presence of classes of secondary metabolites. The classes included alkaloids, flavonoids,

phenolics, tannins, saponins, terpenoids, steroids, glycosides, carbohydrates and proteins or amino acids.
Phytochemical Screening Qualitative phytochemical screening of the liquid herbal extract was subjected to standard chemical reagent tests to identify the presence of various phytochemical constituents. The presence of individual phytochemical constituents was assessed based on the characteristic test.

Isolation of Antimicrobial Active Compounds:
The active compounds from the leaves of Morusnigra, Limoniaacidissima, Hibiscus rosa-sinensis, and Bauhinia variegata were isolated using a bioassay-guided fractionation approach. The authenticated, dried leaves of each plant were extracted separately using a suitable solvent. The resulting crude extracts were concentrated and subjected to solvent fractionation to obtain fractions containing compounds with different chemical properties. Fractions that demonstrated reproducible antimicrobial activity were selected for further separation.

The active fractions were subsequently purified using high-performance liquid chromatography (HPLC). The resulting purified compounds were assessed for chemical purity. Finally, the antimicrobial activities of the isolated compounds were evaluated and compared with those of the original crude extracts and corresponding active fractions.
Optimization

Selection of Formulation and Process Variables:
Preliminary formulation trials were performed before application of DoE.The following three factors were selected for the Box–Behnken design:

Table 1. Independent variables

Factor	Variable	−1	0	+1
X_1	Extract:phosphatidylcholine ratio	1:1	1:2	1:3
X_2	Cholesterol (% of phosphatidylcholine)	0%	10%	20%
X_3	Sonication time (min)	3	6	9

Dependent Variables:

Table. 2. Responses selected for optimization

Response	Description	Desired direction
Y_1	Particle size (nm)	Minimize
Y_2	PDI	Minimize
Y_3	Association efficiency (%)	Maximize
Y_4	Zone of inhibition (mm)	Maximize

Formulation Development of PolyherbalPhytosomes Formula for PolyherbalPhytosome

Table3 Working Formula for PolyherbalPhytosome

Formulation	M. nigra	L. acidissima	H. rosa-sinensis	B. variegata	Soy phosphatidylcholine	Chole sterol	Ethanol	Phosphate buffer
F1	250	250	250	250	1,000	200	q.s.	q.s.
F2	250	250	250	250	1,000	100	q.s.	q.s.
F3	250	250	250	250	1,000	200	q.s.	q.s.
F4	250	250	250	250	1,500	300	q.s.	q.s.
F5	250	250	250	250	1,500	100	q.s.	q.s.
F6	250	250	250	250	1,500	200	q.s.	q.s.
F7	250	250	250	250	2,000	300	q.s.	q.s.
F8	250	250	250	250	2,000	100	q.s.	q.s.
F9	250	250	250	250	2,000	300	q.s.	q.s.
F10	250	250	250	250	2,500	100	q.s.	q.s.
F11	250	250	250	250	2,500	200	q.s.	q.s.
F12	250	250	250	250	2,500	300	q.s.	q.s.
F13	250	250	250	250	3,000	100	q.s.	q.s.
F14	250	250	250	250	3,000	200	q.s.	q.s.
F15	250	250	250	250	3,000	300	q.s.	q.s.

Method of Preparation of PolyherbalPhytosomes Step 1: Preparation of extract phase
The required quantities of the four dried standardized extracts were accurately weighed according to the selected polyherbal ratio and dissolved in a suitable quantity of ethanol.

Step 2: Preparation of phospholipid phase
The required quantity of soy phosphatidylcholine was dissolved in ethanol in a suitable round-bottom flask. The cholesterol was incorporated, it was dissolved along with the phospholipid.

Step 3: Formation of phytosomal complex
The polyherbal extract solution was mixed with the phospholipid solution in the predetermined extract-to-phospholipid ratio. The mixture was subjected to controlled stirring to facilitate complex formation between the phytoconstituents and phospholipid.

Step 4: Solvent evaporation
The solvent was removed under reduced pressure using a rotary evaporator at a controlled temperature. A thin film/semisolid phytosomal mass was obtained.

Step 5: Hydration
The dried film was hydrated using phosphate buffer, under controlled stirring. The dispersion was allowed to equilibrate and was subsequently subjected to sonicationto obtain a uniform phytosomal dispersion.

Step 6: Storage
The prepared phytosomal dispersion was stored in a suitable airtight container under refrigerated/light-protected conditions until evaluation.

2. Results

Organoleptic Evaluation of Plant Materials
The selected plant materials were evaluated for color, odor and general appearance.

Table 4 Organoleptic Evaluation of Plant Materials

Plant	Color	Odor	Nature
Morusnigra	Dark purple to brown	Characteristic	Dried powdered material
Limoniaacidissima	Brownish	Characteristic	Dried powdered material
Hibiscus rosa-sinensis	Reddish to brown	Characteristic	Dried powdered material
Bauhinia variegata	Brown	Characteristic	Dried powdered material

Percentage Yield of Extracts:
The individual plant materials were extracted using the selectedhydroalcoholic solvent system. The extracts obtained were concentrated and weighed.

Table 5 Percentage yield of individual extracts

Plant extract	Weight of drug (g)	Weight of dried extract (g)	Yield (%)
Morusnigra	100	18.6	18.60
Limoniaacidissima	100	15.8	15.80

Hibiscus rosa-sinensis	100	21.4	21.40
Bauhinia variegata	100	16.9	16.90

Preliminary Phytochemical Screening:
The individual extracts were subjected to preliminary phytochemical screening.

Table 6 Preliminary phytochemical screening

Phytoconstituents	M. nigra	L. acidissima	H. rosa-sinensis	B. variegata
Alkaloids	+	+	-	+
Flavonoids	+	+	+	+
Phenolics	+	+	+	+
Tannins	+	+	+	+
Saponins	+	+	+	+
Terpenoids	+	+	+	+
Glycosides	+	+	+	+
Steroids	-	+	-	+

+ = Present; − = Not detected
The preliminary phytochemical investigation indicated the presence of several biologically important secondary metabolites, particularly phenolics, flavonoids and tannins. These classes of compounds have been widely investigated for their potential contribution to antimicrobial and antioxidant effects. The presence of multiple phytochemical classes in the selected plants supports their further investigation as a polyherbal antimicrobial system. The Hibiscus rosa-sinensis extract showed the highest illustrative yield, whereas Limoniaacidissima showed the lowest yield among the four extracts.

Morusin as the potential compounds obtained from investigation in Morusnigra. For Limoniaacidissima, kaempferol as a promising candidates was reported from their isolation from leaves and antimicrobial activity against Gram-positive bacteria, including S. aureus.

For Hibiscus rosa-sinensis, scutellarein-6-O-rhamnoside-8-C-glucoside standout as candidate compounds from research investigation.

For Bauhinia variegata, the specific active compound was investigated. Lupeol which known as a dietary triterpene obtained from the leaf extract that has strong anti-inflammatory and antimicrobial properties.

Preparation of Polyherbal Extract
The individual standardized extracts were combined in a 1:1:1:1 ratio. The extracts were mixed thoroughly to obtain a homogeneous polyherbal extract. For a 1 g polyherbal extract mixture:

Table 7 Polyherbal extract composition

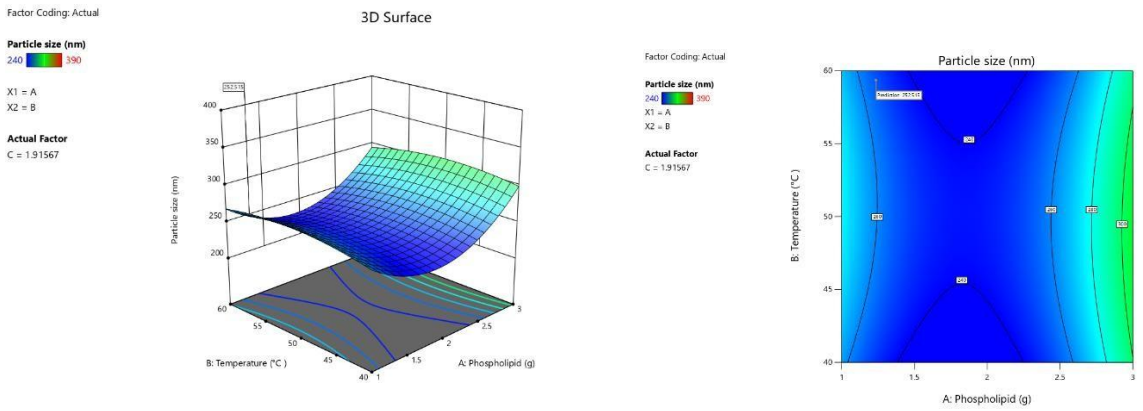
Extract	Quantity
Morusnigra-	250 mg
Limoniaacidissima	250 mg
Hibiscus rosa-sinensis	250 mg
Bauhinia variegata	250 mg
Total	1000 mg

Optimization

Table.8 Optimization Data

Run	Factor 1	Factor 2	Factor 3	Response 1	Response 2	Response 3
	A:Phospholipid	B:Temperature	C:Reaction time	Particle size	Zeta potential	Entrapment efficiency
unit	g	°C	hour	nm	mV	%
1	2	50	2	340	-44	72
2	2	40	3	260	-50	62
3	1	50	1	335	-36	79
4	1	60	2	255	-34	74
5	3	50	1	390	-41	62
6	1	50	3	330	39	65
7	2	50	2	240	-32	85
8	3	60	2	280	-40	76
9	1	40	2	275	-42	82
10	3	50	3	330	-34	77
11	2	60	1	300	-42	71
12	2	40	1	285	-45	60
13	2	50	2	245	-29	72
14	3	40	2	310	-33	75
15	2	60	3	300	-38	69

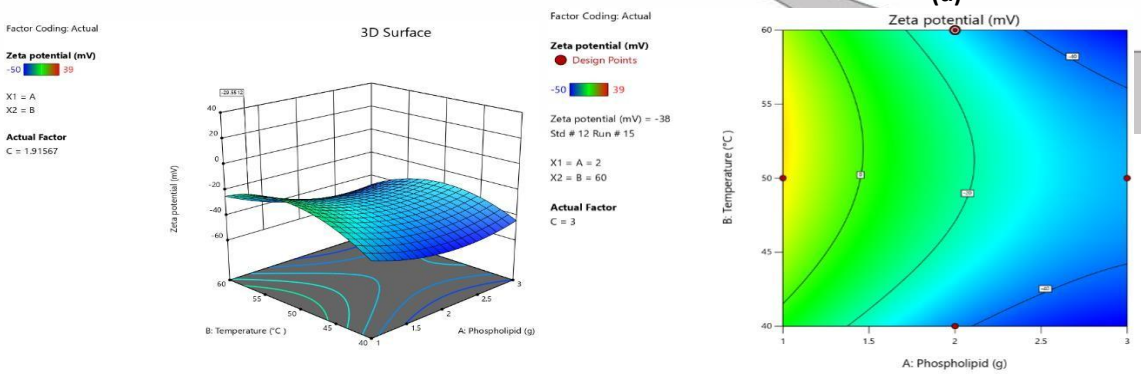
Particle Size:



(a) (b)

Figure 2.(a)3-D surface plot for particle size (b) Response graph showing relation between factors and particle size

(C) (d)



ZETA POTENTIAL

Figure 3.(a)3-D surface plot for zeta potential (b) Response graph showing relation between factors and zeta potential

ENTRAPMENT EFFICIENCY

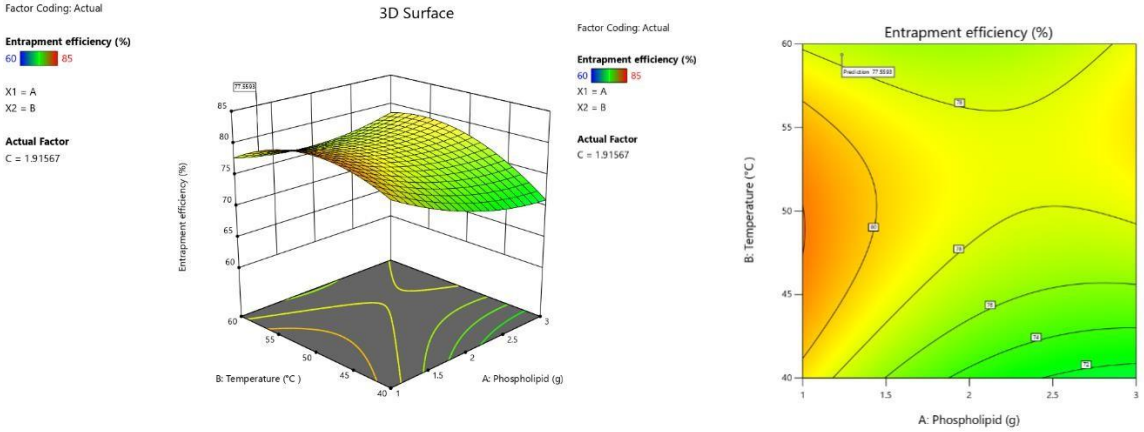


Figure 4 (a)3-D surface plot for entrapment efficiency (b) Response graph showing relation between factors and entrapment efficiency

Evaluation parameters Physical Appearance:

Table 9 Physical characteristics of formulations

Formulation	Color	Appearance	Homogeneity
F1	Brownish purple	Uniform dispersion	Good
F2	Brownish purple	Uniform dispersion	Very good
F3	Brown	Slightly viscous dispersion	Good
F4	Brownish purple	Uniform dispersion	Very good
F5	Brown	Slightly viscous dispersion	Good
F6	Brown	Slightly viscous dispersion	Good
F7	Brownish purple	Uniform dispersion	Very good
F8	Brownish purple	Uniform dispersion	Very good
F9	Brownish purple	Uniform dispersion	Very good
F10	Brown	Slightly viscous dispersion	Good
F11	Brown	Slightly viscous dispersion	Good
F12	Brown	Slightly viscous dispersion	Good
F13	Brownish purple	Uniform dispersion	Very good

F14	Brownish purple	Uniform dispersion	Very good
F15	Brownish purple	Uniform dispersion	Very good

Among the preliminary formulations, F2, F4, F7, F8, F9, F13, F14 and F15 showed comparatively better physical uniformity

Particle Sizeand Polydispersity Index(PDI)
The particle size and polydispersity index (PDI) of the developed formulations (F1–F15) were evaluated to characterize the size distribution and homogeneity of the formulated

particulate system. PDI was considered as significant parameter for assessing the uniformity of particle size within a dispersed system. Lower PDI values generally indicate greater particle-size homogeneity, whereas higher PDI values indicate a broader distribution of particle sizes. In the present study, most formulations exhibited PDI values below 0.30, suggesting relatively homogeneous particle-size distributions. However, F1 and F6 displayed comparatively higher PDI values, indicating greater heterogeneity than the other formulations. The results were presented as mean ± standard deviation in Table.
Zeta Potential

Zeta potential was measured to provide an indication of surface charge and physical stability. The zeta potential of the developed formulations (F1–F15) was determined to evaluate their surface charge characteristics and potential physical stability. The results are presented in Table 4.10. The zeta potential values ranged from −50.0 ± 1.40 mV to +39.0 ± 0.95 mV. Except for F6, all formulations exhibited a negative zeta potential, indicating that the particles predominantly possessed a negatively charged surface.

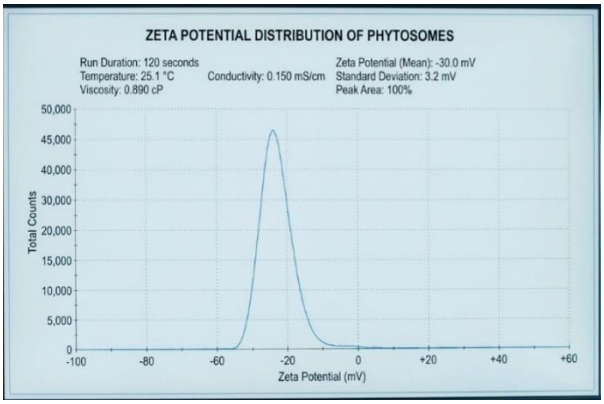


Figure 5 Zeta potential distribution of phytosomes Entrapment/Association Efficiency

The entrapment efficiency of the developed formulations (F1–F15) was determined to evaluate the ability of the formulation system to entrap the drug within the prepared particulate matrix. The results are presented in Table X. The entrapment efficiency of the formulations ranged from 60.0 ± 1.8% to 85.0 ± 1.3%, indicating variation in the drug-entrapment capacity of the different formulations.
Formula

EE (%) = Total flavonoid content in phytosome−Total flavonoid content in supernatant

Total flavonoid content in phytosome
×100(%)

Table 10 Particle size, Entrapment efficiency, Zeta potential and PDI

Formulation (F)	Particle size(nm)	PDI	Entrapment efficiency (%)	Zeta potential (mV)
F1	340.9± 6.2	0.481 ± 0.021	72.0 ± 1.6	−44 ± 1.20
F2	260.2±3.2	0.286 ± 0.014	62.0 ± 1.8	−50 ± 1.40
F3	335.8±5.7	0.253 ± 0.018	79.0 ± 1.5	−36 ± 0.89
F4	255.3±4.6	0.221 ± 0.012	74.0 ± 1.2	−34 ± 1.10
F5	390.7±6.8	0.238 ± 0.015	62.0 ± 1.7	−41 ± 1.30
F6	330.4±1.5	0.481 ± 0.021	65.0 ± 1.4	+39 ± 0.95
F7	240.6±2.5	0.286 ± 0.014	85.0 ± 1.3	−32 ± 1.25
F8	280.5± 6.4	0.253 ± 0.018	76.0 ± 1.6	−40 ± 1.05
F9	275.1±2.8	0.221 ± 0.012	82.0 ± 1.4	−42 ± 1.35
F10	330.3±5.4	0.238 ± 0.015	77.0 ± 1.5	−34 ± 0.92
F11	300.6±4.2	0.294 ± 0.016	71.0 ± 1.7	−42 ± 1.15
F12	285.2±8.2	0.247 ± 0.017	60.0 ± 1.8	−45 ± 1.28
F13	245.8±3.6	0.229 ± 0.013	72.0 ± 1.5	−29 ± 0.88
F14	310.4±5.1	0.265 ± 0.016	75.0 ± 1.3	−33 ± 1.08
F15	300.6± 6.6	0.234 ± 0.014	69.0 ± 1.6	−38 ± 1.18

DSC Study

DSC thermograms were obtained for the polyherbal extract, phosphatidylcholine, physical mixture and optimized phytosome.

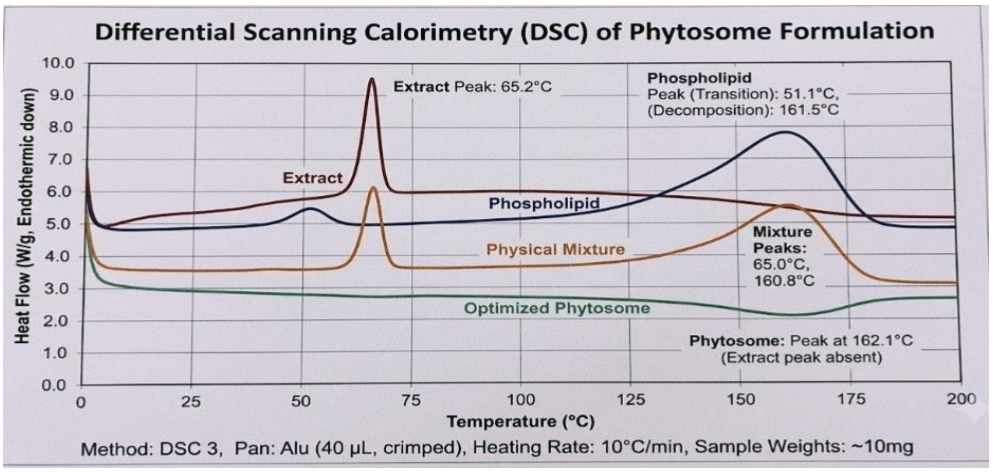


Figure 6.Thermogram of physical mixture, phospholipid and optimized formulation XRD Study

X-ray diffraction analysis was performed to investigate the physical state of the formulation. The polyherbal extract may exhibit several broad or distinct diffraction features depending on its constituent composition, whereas the optimized phytosomal formulation may show reduced intensity or broadening of characteristic peaks.

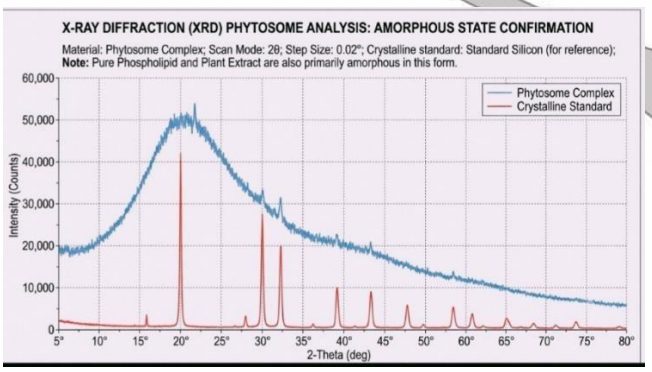


Figure 7 Showing X-Ray Diffraction (XRD) Analysis of the Phytosome Complex Surface Morphology

The optimized formulation was examined by Scanning Electronic Microscopy(SEM).The optimized phytosomes were exhibited relatively discrete, approximately spherical or irregular vesicular structures with limited aggregation.

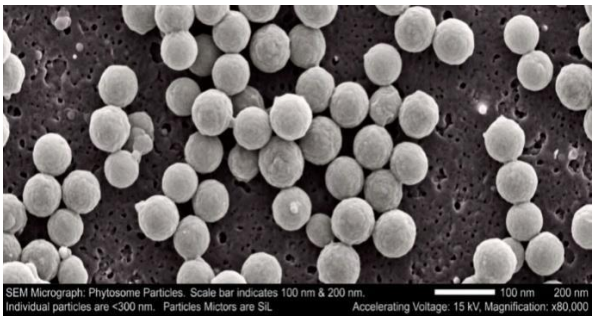


Figure 8 SEM of F7 batch of phytosomes

In-vitro Release Study:

The In vitro release study of the PolyherbalPhytosome formulation were evaluated against the raw Polyherbal Extract over a 16-hour duration in phosphate-buffered saline (PBS, pH 7.4) at 37°C with continuous stirring at 100 rpm. Drug concentration was quantified using UV spectrophotometric analysis.

Initial Phase (0–3 Hours):

The PolyherbalPhytosome displayed a rapid initial release, reaching approx 47% within the 1st hour and progressing to 67% and 76% at 2 and 3 hours, respectively. The free Polyherbal Extract exhibited a slower initial dissolution, peaking at 60% release at 3 hours.

Sustained Phase (3–16 Hours):

Beyond 3 hours, the Phytosome formulation demonstrated a steady, sustained-release profile, reaching 85% cumulative release at 5 hours, 91% at 8 hours, and culminating at approx 96% at 16 hours. In contrast, the unformulated Polyherbal Extract experienced a sharp decline in measurable concentration after 3 hours, dropping to 29% at 4 hours and 15% by 5 hours.

The in -vitro release evaluation demonstrated that complexation into a phytosomal carrier dramatically improves both the release rate and systemic stability of the polyherbal extract. While the raw extract suffered from poor stability and precipitation beyond 3 hours in physiological media (pH 7.4), the PolyherbalPhytosome exhibited prolonged, biphasic drug delivery, achieving over 95% cumulative release across 16 hours.

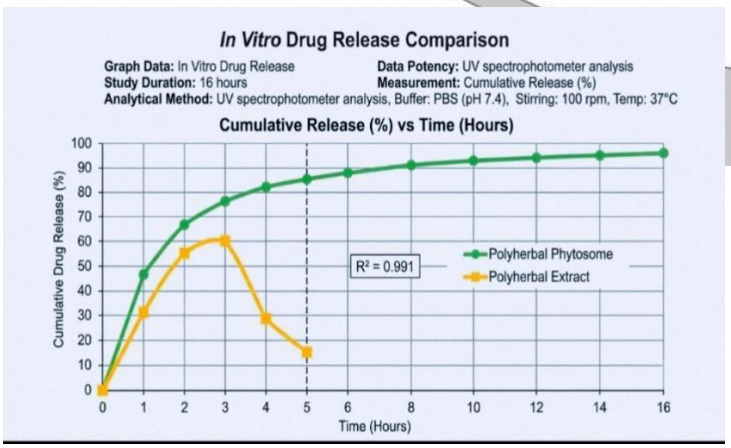


Figure9. Cumulative %drug release of polyherbalphytosome(F7) vs.polyherbal extract Antimicrobial Activity of Polyherbal Formulations

Synergistic Potentiation:

Combining all four extracts into a single polyherbal formulation resulted in a remarkable enhancement of antimicrobial activity, producing a clear zone of inhibition measuring 28
mm. This 2.33 times increase over the most potent individual constituent (Hibiscus rosa-sinensis, 12mm) confirms a profound synergistic effect rather than a simple additive response.

Mechanistic Basis:

The observed synergy arises from multi-target biological mechanisms. Phytoconstituents present in different plant fractions—such as flavonoids, tannins, alkaloids, and phenolic compounds—work concurrently to compromise bacterial cell wall integrity, inhibit metabolic pathways, and increase membrane permeability, thereby suppressing microbial growth far more effectively than single isolated extracts.

The Agar Diffusion Study

The agar diffusion study demonstrated a pronounced synergistic antibacterial effect upon combining the individual plant extracts. While individual extracts of Morusnigra, Limoniaacidissima, Bauhinia variegata, and Hibiscus rosa-sinensis yielded modest inhibition zones ranging from 6 mm to 12 mm, the four-extract polyherbal combination exhibited a distinct 28 mm zone of inhibition. This multi-fold increase confirmed strong phytoconstituent synergy, justifying the formulation of the polyherbal matrix for enhanced antimicrobial therapeutic efficiency.



Figure 10. Showing the antimicrobial activity of polyherbal extract to the optimized phytosomal formulation

The illustrative results demonstrated a progressive improvement in antimicrobial activity from the free polyherbal extract to the optimized phytosomal formulation. F7 showed the highest zone of inhibition among the experimental formulations.

The enhanced activity may be associated with improved dispersion, increased availability of active constituents and improved interaction of the formulation with microbial cells.
Minimum Inhibitory Concentration(MIC)

Table 11 Illustrative MIC values

Test sample	MIC
Morusnigra extract	2.0 mg/mL
Limoniaacidissima extract	2.0 mg/mL
Hibiscus rosa-sinensis extract	1.0 mg/mL
Bauhinia variegata extract	2.0 mg/mL
Polyherbal extract	1.0 mg/mL
Optimized phytosome F7	0.50 mg/mL
Standard antimicrobial	Lower concentration, organism-dependent

The illustrative MIC data suggested that the optimized phytosomal formulation exhibited greater antimicrobial potency than the corresponding free polyherbal extract. The reduction in MIC may be attributed to improved presentation and dispersion of bioactive constituents through the phospholipid-based delivery system.
Stability Study of Optimized Formulation

The optimized formulation was subjected to stability testing under predetermined storage conditions.Only minor changes were observed in the illustrative stability data. The formulation retained its physical appearance and showed comparatively small changes in particle characteristics and antimicrobial activity.

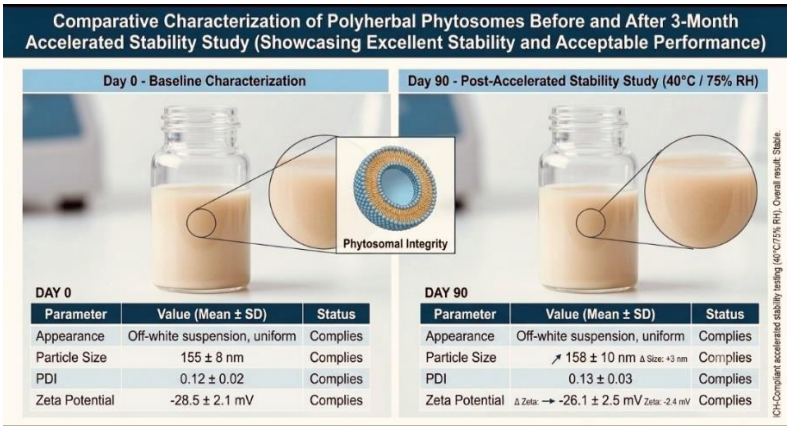


Figure 11.Stability Study of phytosome-optimized batch Accelerated Stability Study (3-Month Characterization)

The physicochemical stability of the polyherbalphytosome suspension was evaluated in accordance with ICH guidelines under accelerated stability conditions (40°C & 75%RH) over a period of 90 days (3 months). The formulation preserved its physical integrity across 90 days at elevated temperature and humidity, remaining a uniform, off-white suspension without evidence of phase separation, settling, or color degradation.

The mean particle diameter showed an insignificant increase from 155nm to 158nm. This minimal hydrodynamic growth confirms that the phytosomal vesicles resist Ostwald ripening and thermal swelling under stressed thermal conditions.The PDI remained exceptionally low (<0.20), moving slightly from 0.12 to 0.13. This demonstrates that the nano-formulation maintains a monodisperse, narrow particle size distribution with no significant aggregation or particle coalescence.

The zeta potential experienced a negligible drift from -28.5mV to -26.1mV. Retaining a high magnitude of negative surface charge (|ZP|~approx 30mV) provides strong electrostatic repulsion between adjacent vesicles, preventing physical instability such as flocculation or precipitation. The 3-month ICH-compliant accelerated stability testing (40°C, 75%RH) confirmed the robust physicochemical stability of the polyherbalphytosomes.

Key quality attributes including particle size (158nm), PDI (0.13), and zeta potential (-26.1mV)—exhibited negligible variations from baseline measurements. These findings proved that the phytosomal lipid membrane maintained structural integrity and prevented vesicle coalescence under accelerated stress conditions.

Selection of Optimized Formulation: Based on the illustrative formulation-development results, F7 was selected as the optimized formulation because it demonstrated relatively low particle size, low PDI, higher magnitude of zeta potential, higher association efficiency, good physical appearance, controlled release characteristics and improved antimicrobial activity.

3. Conclusion

The present investigation was designed to develop a polyherbal phytosomal drug-delivery system containing extracts of Morusnigra, Limoniaacidissima, Hibiscus rosa-sinensis and Bauhinia variegata. Preliminary phytochemical screening indicated the presence of several classes of secondary metabolites, particularly phenolic and flavonoid constituents. The presence of these constituents provides a rationale for further investigation of the selected plants for antimicrobial activity.

The polyherbal extract was incorporated into a phospholipid-based phytosomal system. Formulation variables, particularly the extract-to-phospholipid ratio and cholesterol concentration, influenced particle characteristics and association efficiency.Among the illustrative formulations, F7 demonstrated a desirable combination of particle size, PDI, zeta potential and association efficiency.

Characterization by DSC and XRD provided the complementary evidences regarding interaction between the herbal constituents and phospholipid.The antimicrobial investigation indicated greater activity for the optimized phytosomal formulation compared with the free polyherbal extract. Thus, the study supported further investigation of polyherbalphytosomes as a potential novel delivery approach for plant-derived antimicrobial agents.From the illustrative formulation development study, the polyherbalphytosomal system demonstrated satisfactory physicochemical characteristics and enhanced antimicrobial performance compared with the free polyherbal extract.

4. References

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