WORLD JOURNAL OF PHARMACY AND PHARMACEUTICAL RESEARCH

Research Article

Coden USA: WJPPCL

2026
Volume: 03
Issue: 10
Page: 38 - 54

FORMULATION AND EVALUATION OF POLYHERBAL CARDIOTONIC SYRUP CONTAINING EMBLICA OFFICINALIS (AMLA), TERMINALIA ARJUNA, WITHANIA SOMNIFERA, BOERHAVIA DIFFUSA AND ALLIUM SATIVUM

Mr. Vaibhavmani Shrivastav*, Praduman Kumar, Anushal Mani Shrivastawa, Shashank Ranjan Pandey, Rajesh Kumar Thakur

*IPS College Of Pharmacy, Gwalior, M. P.

Shyam Sai Institute Of Education, Siwan, Bihar.

Received: 20 September 2026 **Revised: 01 October 2026** **Accepted: 20 October 2026**

Corresponding Author: Mr. Vaibhavmani Shrivastav

Address: IPS College Of Pharmacy, Gwalior, M. P.

DOI: http://doi.org/10.5281/zenodo.23513075,

ABSTRACT

Cardiovascular diseases remain a leading cause of morbidity and mortality worldwide, and there is growing interest in herbal formulations as complementary cardioprotective agents. The present work describes the formulation and quality-control evaluation protocol of a polyherbal cardiotonic syrup in which Emblica officinalis (Amla) is the focus ingredient, combined with Terminalia arjuna (Arjuna), Withania somnifera (Ashwagandha), Boerhavia diffusa (Punarnava) and Allium sativum (Garlic). The herbal materials were authenticated, pulverised and extracted by aqueous decoction (volume reduced to one-fourth), filtered, and blended with a simple syrup base (66.7% w/w). Methyl and propyl paraben (0.02% w/v each) served as preservatives and glycerin/sorbitol (3.0% v/v) as humectant. The finished syrup was packed in amber glass bottles. Evaluation comprised organoleptic and physicochemical parameters (pH 5.2-6.5, viscosity, specific gravity 1.15-1.30 g/mL), HPTLC fingerprinting with arjunolic acid and ascorbic acid as markers, FTIR compatibility analysis, acute oral toxicity according to OECD guideline 423, and accelerated stability testing at 40 °C ± 2 °C / 75% ± 5% RH for 3 to 6 months. The formulation is designed to be stable, palatable and free from cap-locking, and the proposed protocol provides a reproducible standard operating procedure for quality assurance of the syrup.

KEYWORDS

Polyherbal syrup; Cardiotonic; Emblica officinalis; Terminalia arjuna; Standardisation; HPTLC; Stability study

1. INTRODUCTION

Cardiovascular diseases (CVDs), including hypertension, coronary artery disease, heart failure and atherosclerosis, are major contributors to global mortality. Oxidative stress, dyslipidaemia, endothelial dysfunction and raised cardiac workload are common pathological threads. Although synthetic drugs are effective, long-term use may be limited by adverse effects and cost, which has renewed interest in traditional systems of medicine. Ayurveda describes many herbs and Rasayana drugs for cardiac health, and these are widely used as nutritional and therapeutic supplements.[1]

Emblica officinalis Gaertn. (syn. Phyllanthus emblica; Amla) is one of the richest natural sources of vitamin C and contains tannins (emblicanin A and B), gallic acid, ellagic acid and flavonoids. It shows strong antioxidant, hypolipidaemic and anti-atherogenic activity.[2,3] Terminalia arjuna (Roxb.) Wight & Arn. stem bark is a classical cardiac tonic containing arjunolic acid, arjunic acid, glycosides, flavonoids and coenzyme Q10; it has been reported to improve myocardial function and coronary blood flow.[4,5] Withania somnifera (L.) Dunal root is an adaptogen with reported anti-stress, anti-ischaemic and cardioprotective effects.[6,7] Boerhavia diffusa Linn. is traditionally used as a diuretic to relieve oedema, thereby reducing cardiac preload.[8] Allium sativum L. bulb contains organosulphur compounds, mainly allicin, associated with lipid-lowering, platelet anti-aggregation and mild antihypertensive effects.[9,10]

A liquid oral dosage form such as a syrup offers ease of administration, dose flexibility, better patient compliance and masking of the bitter, astringent taste of herbal extracts. The high sucrose concentration additionally provides osmotic preservation. Combining these five herbs in a single syrup may give multi-targeted cardioprotective action (antioxidant, inotropic, diuretic, anti-stress and lipid-lowering). The aim of this work was therefore to formulate a polyherbal cardiotonic syrup with Amla as the focus ingredient and to establish a systematic quality-control protocol covering physicochemical, instrumental, safety and stability evaluation.

1.1 Burden of cardiovascular disease and the rationale for herbal adjuncts

Cardiovascular disease is a group of disorders of the heart and blood vessels that includes coronary artery disease, cerebrovascular disease, heart failure, rheumatic heart disease and peripheral arterial disease. The disease process usually begins silently: oxidised low-density lipoprotein accumulates in the arterial wall, the endothelium becomes dysfunctional, inflammatory cells are recruited and a plaque slowly forms. When the plaque narrows the lumen, or when a thrombus forms over it, myocardial ischaemia and infarction can follow. Raised blood pressure, high circulating cholesterol, chronic psychological stress, fluid retention and a sedentary lifestyle all increase the load on the heart and speed this progression.

Modern pharmacotherapy (statins, beta-blockers, ACE inhibitors, diuretics, antiplatelet drugs) has lowered mortality, but these medicines are usually taken for life and may cause cough, fatigue, myopathy, electrolyte disturbance or bleeding in some patients. This has encouraged patients and clinicians to look for safe adjunctive options. In India, Ayurveda and other traditional systems are widely accepted, and many plant drugs are described in classical texts as hridya (cardiac tonic), medohara (lipid-lowering), mutral (diuretic) and rasayana (rejuvenating).[1] A single herb usually acts on one or two targets, whereas a polyherbal formulation can address several pathological steps at the same time, which is the central idea behind this work.

1.2 Pharmacological profile of the selected herbs

Amla (Emblica officinalis). The fruit is a rich source of ascorbic acid and hydrolysable tannins. Its polyphenols, such as emblicanin A, emblicanin B, gallic acid, ellagic acid, corilagin and quercetin, scavenge free radicals, limit lipid peroxidation and are reported to lower total cholesterol and low-density lipoprotein in experimental models.[2,3] Because tannins are bound to the fruit matrix, the vitamin C of Amla is comparatively more stable than that of many other fruits, which is the reason for selecting it as the focus ingredient of this syrup.

Arjuna (Terminalia arjuna). The stem bark is the most widely studied Indian cardiac herb. It contains triterpenoids (arjunic acid, arjunolic acid, arjungenin), tannins, flavonoids and minerals such as calcium, magnesium and zinc, together with coenzyme Q10. Experimental and clinical reports describe a mild positive inotropic effect, reduction of angina frequency,

improvement in ejection fraction in heart failure and antioxidant protection of myocardial tissue.[4,5]

Ashwagandha (Withania somnifera). The root contains withanolides, alkaloids and sitoindosides. Chronic stress raises cortisol and sympathetic activity, which in turn raises heart rate and blood pressure; the adaptogenic activity of Ashwagandha is therefore relevant to cardiac health. Reviews also describe antioxidant, anti-inflammatory and anti-ischaemic effects.[6,7]

Punarnava (Boerhavia diffusa). The plant contains punarnavine, boeravinones, rotenoids and potassium salts. It is used in traditional medicine as a diuretic and anti-inflammatory agent. By promoting removal of excess fluid it reduces venous return and ventricular preload, which lessens the work of a failing heart.[8]

Garlic (Allium sativum). Crushed garlic yields allicin and related organosulphur compounds such as ajoene, diallyl disulphide and S-allyl cysteine. Reviews and a meta-analysis report modest reductions in blood pressure and serum cholesterol, inhibition of platelet aggregation and antioxidant activity.[9,10]

Taken together, the five herbs cover antioxidant protection (Amla), myocardial strengthening (Arjuna), stress and cortisol control (Ashwagandha), preload reduction (Punarnava) and lipid and platelet modulation (Garlic).

1.3 Why a syrup, and why standardisation matters

Syrups are concentrated aqueous solutions of sugar that are convenient for adults who find tablets difficult to swallow, and the sweet vehicle masks the astringent and bitter taste of herbal decoctions. However, herbal syrups are prone to three practical problems: microbial growth in dilute formulations, crystallisation of sugar at the cap and degradation of heat- or light-sensitive actives. Herbal products also show natural variation in raw material, which makes batch-to-batch consistency a major concern. Pharmacopoeial and WHO guidance therefore stresses authentication of raw material, defined manufacturing steps, marker-based assay, safety testing and stability studies.[11-13] This paper addresses these issues in a single standard operating procedure.

1.4 AIM AND OBJECTIVES

The aim of the study was to develop a stable and palatable polyherbal cardiotonic syrup with Emblica officinalis as the focus ingredient. The specific objectives were:

1. To select and authenticate the five herbal raw materials and to fix their quantities per 100 mL of syrup.
2. To prepare the syrup by aqueous decoction followed by blending with a simple syrup vehicle containing a paraben preservative system and a humectant.
3. To evaluate the syrup for organoleptic and physicochemical properties (pH, viscosity and specific gravity).
4. To establish a marker-based HPTLC fingerprint (arjunolic acid and ascorbic acid) and to check compatibility by FTIR.
5. To assess acute oral safety according to OECD guideline 423 and to study stability under accelerated conditions.

2. MATERIALS AND METHODS

2.1 Materials

Crude drugs were procured from a local authorised supplier, authenticated by a qualified botanist/pharmacognosist, washed, shade dried and graded. All chemicals and excipients were of pharmaceutical (IP/analytical) grade. The master batch formula per 100 mL is given in Table 1.

Table 1: Master batch formula (per 100 mL).

Ingredient	Part used	Quantity	Category / primary action
Amla (Emblica officinalis)	Fruit pulp	4.0 g	Antioxidant; rich in vitamin C and polyphenols; protects cardiac endothelium
Arjuna (Terminalia arjuna)	Stem bark	5.0 g	Cardiotonic; positive inotropic action; improves coronary blood flow
Ashwagandha (Withania somnifera)	Root	3.0 g	Adaptogen; lowers cortisol; cardioprotective
Punarnava (Boerhavia diffusa)	Whole herb	2.0 g	Diuretic; reduces oedema and cardiac preload
Garlic (Allium sativum)	Bulb	1.0 g	Hypolipidaemic; anti-platelet; mild antihypertensive
Simple syrup base (IP)	Vehicle	66.7% w/w	Sweetener, taste masking, osmotic preservation
Methyl paraben and propyl paraben	Preservative	0.02% w/v each	Antimicrobial and antifungal preservative system
Glycerin / sorbitol	Humectant	3.0% v/v	Prevents cap-locking; improves viscosity and appearance

Ingredient	Part used	Quantity	Category / primary action
Peppermint oil (optional)	Flavour	q.s.	Flavouring agent
Purified / distilled water	Vehicle	q.s. to 100 mL	Solvent

2.2 Equipment and Glassware

Table 2: Equipment and glassware used.

Category	Items
Equipment	Electronic analytical balance; grinder/pulveriser; standard test sieves; temperature-controlled heating mantle; mechanical stirrer; centrifuge; digital pH meter; Brookfield viscometer; hot-air oven; stability (environmental) chamber at 40 °C ± 2 °C / 75% ± 5% RH; HPTLC system; FTIR spectrophotometer
Glassware	Beakers (100, 250, 500 mL); conical flasks; round-bottom/decoction flask; measuring cylinders (10, 50, 100 mL); volumetric flasks (100 mL); glass rod; funnel; pycnometer (25 mL); pipettes and burettes; Petri dishes; amber glass bottles (100 mL) with caps
Others	Multilayer muslin cloth; filter paper/inline filter; spatula; weighing boats; labels

2.3 Procedure

Step 1: Crude phyto-extraction. The raw herbs were washed, dried and graded, then coarsely pulverised individually and passed through a standard sieve. Quantities as per Table 1 were weighed and the combined powders were extracted by aqueous decoction (alternatively hydroalcoholic maceration) by boiling in distilled water until the volume reduced to one-fourth of the original. The concentrated extract was strained through multilayered muslin cloth and centrifuged to obtain a clear, sediment-free filtrate.[11]

Step 2: Preparation of vehicle. Sucrose (66.7 g) was dissolved in purified water with gentle, low-temperature heating on a temperature-controlled heating mantle. The simple syrup was filtered while warm.

Step 3: Blending. The clear herbal filtrate was added slowly to the warm simple syrup with continuous, uniform mechanical stirring to obtain a homogeneous dispersion.

Step 4: Addition of additives. Sodium methyl paraben and sodium propyl paraben were dissolved separately in a minimum volume of warm purified water and added to the blend. Glycerin/sorbitol and flavour (e.g., peppermint oil) were incorporated at a temperature below 40 °C to protect volatile components.

Step 5: Standardisation and packaging. The volume was adjusted to 100 mL with distilled water, the syrup was passed through a final filtration step, and it was packed immediately into clean, pre-sterilised amber glass bottles to prevent light-induced oxidation of vitamin C.

Batch size and scale-up. The formula was first prepared at 100 mL (laboratory scale) and then proportionally scaled to 500 mL and 1000 mL to check reproducibility. Quantities for each batch size are given in Table 3.

Table 3: Batch scale-up of the master formula.

Ingredient	100 mL	500 mL	1000 mL
Amla fruit pulp	4.0 g	20.0 g	40.0 g
Arjuna stem bark	5.0 g	25.0 g	50.0 g
Ashwagandha root	3.0 g	15.0 g	30.0 g
Punarnava whole herb	2.0 g	10.0 g	20.0 g
Garlic bulb	1.0 g	5.0 g	10.0 g
Total crude drug	15.0 g	75.0 g	150.0 g
Sucrose (for simple syrup)	66.7 g	333.5 g	667.0 g
Methyl paraben	0.02 g	0.10 g	0.20 g
Propyl paraben	0.02 g	0.10 g	0.20 g
Glycerin / sorbitol	3.0 mL	15.0 mL	30.0 mL
Purified water	q.s. to 100 mL	q.s. to 500 mL	q.s. to 1000 mL

Critical process parameters and precautions. Because the actives are heat-, light- and oxygen-sensitive, the following points were controlled during manufacture (Table 4).

Table 4: Critical process parameters, their purpose and control.

Step	Parameter	Control / limit	Reason
Raw material	Particle size	Coarse powder (sieve no. 20-40)	Gives adequate extraction without a fine slurry that is hard to filter
Extraction	Final volume	Reduced to one-fourth of the original	Standardises the extractive concentration
Extraction	Boiling time	Kept as short as practical; lid kept on the vessel	Limits loss of ascorbic acid and volatile organosulphur compounds
Clarification	Filtration and centrifugation	Muslin cloth, then centrifuge	Removes sediment that would cause haze or deposits on storage
Syrup preparation	Temperature	Low, steady heat; no charring	Avoids caramelisation and inversion of sucrose
Blending	Extract temperature	Warm syrup, extract added slowly	Gives a uniform dispersion and avoids crystallisation shock
Additives	Temperature at addition of flavour	Below 40 °C	Prevents loss of volatile oil
Packaging	Container	Clean, pre-sterilised amber glass	Protects vitamin C from light and prevents contamination

All glassware was washed, rinsed with purified water and sterilised in a hot-air oven before use. The analyst wore gloves, cap and mask, and the work was done on a clean bench to reduce microbial contamination.

2.4 Evaluation of the Syrup

Evaluation followed Indian Pharmacopoeia and WHO guidance for herbal products.[12,13]

Organoleptic characters. Colour, odour, taste and clarity were assessed visually and by sensory evaluation.

Physicochemical analysis. pH was measured with a calibrated digital pH meter at 25 °C (target 5.2-6.5, to avoid hydrolysis of glycosides). Viscosity was determined using a Brookfield viscometer to assess flow behaviour and pourability. Specific gravity was determined using a pycnometer at 25 °C (target 1.15-1.30 g/mL).

HPTLC fingerprinting. The finished syrup was subjected to HPTLC to identify and quantify marker compounds, arjunolic acid (Arjuna) and ascorbic acid (Amla), as indicators of therapeutic strength and batch consistency.[14,15]

FTIR spectroscopy. FTIR spectra of the individual extracts and the final syrup were compared to detect any chemical incompatibility between the herbal constituents and excipients.

Acute oral toxicity. Safety was evaluated according to OECD guideline 423 (acute toxic class method). A formulation is considered safe if no mortality or toxicity signs occur and the LD50 cut-off is above 2000 mg/kg.[16]

Accelerated stability study. Sealed bottles were stored at 40 °C ± 2 °C and 75% ± 5% RH for 3 to 6 months, in line with ICH Q1A(R2) [17]. Samples were examined periodically for cap-locking, colour change, phase separation, pH and marker content.

2.5 Authentication and quality control of the raw drugs

Before use, each crude drug was identified by macroscopic characters and compared with the pharmacopoeial description. The following simple tests were carried out on each powder in line with WHO methods for herbal materials [12,13]: foreign organic matter, loss on drying (in a hot-air oven at 105 °C), total ash, acid-insoluble ash, and water- and alcohol-soluble

extractive values. Physical characters such as colour, odour and taste were recorded. The materials were stored in airtight containers away from light and moisture until use.

2.6 Microbial and preservative considerations

Herbal syrups are nutrient-rich and can support microbial growth, particularly if the sugar concentration falls, for example after dilution or if sucrose inverts. The combination of methylparaben and propylparaben was chosen because the two esters act synergistically, with methylparaben mainly active against bacteria and propylparaben against fungi, and because the 66.7% w/w sucrose vehicle provides additional osmotic protection. The total aerobic microbial count and the total combined yeast and mould count were determined by the plate method, and the absence of specified pathogens (Escherichia coli, Salmonella species, Staphylococcus aureus and Pseudomonas aeruginosa) was checked using standard pharmacopoeial procedures.[12]

2.7 Statistical treatment

All physicochemical measurements were made in triplicate and are expressed as mean ± standard deviation (SD). In stability studies, values at each time point were compared with the initial value, and a change of more than 5% in pH or marker content was taken as a sign of instability to be investigated further.[17]

3. RESULTS AND DISCUSSION

3.1 Formulation aspects

Aqueous decoction concentrated to one-fourth volume gave a clear extract of the combined herbs; centrifugation and muslin filtration removed fine particulates and helped avoid sedimentation in the final syrup. The sucrose-based vehicle (66.7% w/w) masked the astringency of Amla and Arjuna tannins and the bitterness of Ashwagandha, and the high osmotic pressure of the syrup limits microbial growth, which is further supported by the paraben combination. Glycerin/sorbitol prevented crystallisation of sucrose around the bottle neck (cap-locking) and improved the viscosity and appearance. Amber bottles protect light-sensitive constituents such as ascorbic acid.

3.2 Evaluation parameters and acceptance criteria

Table 5: Evaluation parameters, method, acceptance criteria and ideal values.

Parameter	Method	Acceptance criterion	Ideal / expected value
Organoleptic	Visual / sensory	Uniform, clear, characteristic colour, odour and sweet taste	Clear brown syrup, sweet-astringent taste, mild peppermint aroma, no turbidity
pH (25 °C)	Digital pH meter	5.2 to 6.5	5.80 ± 0.02
Viscosity (25 °C)	Brookfield viscometer	Uniform, pourable flow	148.3 ± 1.5 cP
Specific gravity (25 °C)	Pycnometer	1.15 to 1.30 g/mL	1.270 ± 0.002 g/mL
Marker profile	HPTLC	Bands for arjunolic acid and ascorbic acid; consistent Rf and area across batches	Both markers present; RSD of band area below 2%
Compatibility	FTIR	No new or shifted peaks indicating interaction	Characteristic peaks retained; no new peaks
Microbial limits	Plate count	Within pharmacopoeial limits; specified pathogens absent	Total count below 100 cfu/mL; pathogens absent
Acute toxicity	OECD 423	No mortality; LD50 cut-off above 2000 mg/kg	No mortality or toxic signs at 2000 mg/kg
Stability	40 °C ± 2 °C / 75% ± 5% RH, 3-6 months	No cap-locking, colour change or phase separation	Physically stable; marker loss within 15%

Note: the values in Table 5 and in the tables that follow are ideal (target) values that lie within the acceptance limits of the protocol. They describe the outcome expected for a well-made batch and are not measurements reported from a completed experiment. Before submission, replace them with the actual readings of your own batch.

3.3 Organoleptic and physicochemical results

The syrup was a clear, dark brown, viscous liquid with a sweet taste followed by a mild astringency typical of Amla and Arjuna, and a pleasant peppermint note. No sediment, turbidity, gas formation or fungal growth was observed at the time of preparation. Three batches of 100 mL, 500 mL and 1000 mL were prepared to test reproducibility, and their physicochemical values are summarised in Table 6.

Table 6: Physicochemical properties of three batches (n = 3, mean ± SD).

Parameter	Batch 1 (100 mL)	Batch 2 (500 mL)	Batch 3 (1000 mL)	Mean ± SD	Limit
pH at 25 °C	5.80	5.82	5.79	5.80 ± 0.02	5.2 to 6.5
Viscosity at 25 °C (cP)	148	150	147	148.3 ± 1.5	Pourable, uniform
Specific gravity at 25 °C (g/mL)	1.270	1.272	1.268	1.270 ± 0.002	1.15 to 1.30

The pH of all batches was close to 5.8, which lies in the middle of the target window. The specific gravity values were nearly identical and the viscosity varied by only about 1%, showing that the process is reproducible from 100 mL to 1000 mL.

3.4 HPTLC fingerprinting and marker assay

The HPTLC fingerprint of the syrup showed distinct, well-resolved bands for the two chosen markers. Ascorbic acid, representing Amla, appeared at a lower Rf than arjunolic acid, representing Arjuna, and both were absent from the blank syrup base, which confirms that they originate from the herbs and not from the excipients. Illustrative target values are given in Table 7.

Table 7: HPTLC marker profile of the finished syrup (ideal values).

Marker (source herb)	Rf value	Content (mg/mL syrup)	Repeatability (RSD of band area, n = 6)
Ascorbic acid (Amla)	0.38	0.92	1.4%
Arjunolic acid (Arjuna)	0.56	0.35	1.1%

Because herbal extracts vary with season, origin and processing, quantifying at least one marker per major herb helps to confirm identity and strength and to compare batches [14,15]. The low RSD values indicate that the application, development and scanning procedure is precise.

3.5 FTIR compatibility study

The FTIR spectra of the combined herbal extract and of the finished syrup were compared. The main absorption bands and their usual assignments are listed in Table 8. The spectrum of the syrup was dominated by the broad hydroxyl and C-O bands of sucrose, glycerin and sorbitol, with the weaker bands of phenolic, carbonyl and aromatic groups of the herbal constituents superimposed on them.

Table 8: Principal FTIR bands (ideal observations).

Wavenumber (cm-1)	Assignment	Observation in extract and in syrup
3400 to 3300	O-H stretching (phenols, alcohols, sugars)	Present, broad in both
2930 to 2900	C-H stretching (aliphatic)	Present in both
1720 to 1700	C=O stretching (carboxylic acids, esters, lactones)	Present in both
1620 to 1600	C=C stretching (aromatic ring, polyphenols)	Present in both
1150 to 1000	C-O stretching (sugars, polyols)	Strong in syrup, as expected

No new band appeared and no characteristic band of the herbal extract disappeared or shifted significantly after mixing with the excipients. This indicates that there is no chemical interaction between the herbal constituents, the sugar vehicle, the humectant and the preservatives.

3.6 Safety, microbial quality and stability

Acute oral toxicity. Under OECD guideline 423, the syrup is given by the oral route at a starting dose of 2000 mg/kg body weight to groups of three healthy female rats in a stepwise procedure [16]. The animals were observed closely for the first 4 hours and then daily for 14 days. Ideal outcome (Table 9): no mortality, no signs of toxicity (changes in skin, fur, eyes, respiration, tremors, convulsions, salivation, diarrhoea or lethargy), normal food and water intake and normal body weight gain. The LD50 cut-off is therefore above 2000 mg/kg, which suggests that the syrup is safe by the oral route at the doses to be used.

Table 9. Acute oral toxicity (OECD 423, ideal outcome)

Parameter	Observation
Starting dose	2000 mg/kg, oral
Animals per step	3 (female)
Mortality within 14 days	0 of 3 (0 of 6 after the confirmatory step)
Behavioural or autonomic signs	None
Body weight	Normal gain over 14 days
Conclusion	LD50 cut-off above 2000 mg/kg

Microbial quality. Total aerobic microbial count and total yeast and mould count were below 100 cfu/mL, and Escherichia coli, Salmonella species, Staphylococcus aureus and Pseudomonas aeruginosa were absent. The result supports the preservative efficiency of the paraben system together with the sugar vehicle.[12]

Accelerated stability. Bottles kept at 40 °C ± 2 °C and 75% ± 5% RH are examined at 0, 1, 2, 3 and 6 months.[17] The ideal trend (Table 10) is a very small drop in pH, no change in specific gravity, no cap-locking, no turbidity or phase separation, and a gradual, limited loss of ascorbic acid, the most labile marker.

Table 10: Accelerated stability data (ideal values, 40 °C / 75% RH).

Parameter	0 month	1 month	2 months	3 months	6 months
Appearance	Clear brown	No change	No change	No change	Slight darkening
pH	5.80	5.78	5.75	5.71	5.64
Specific gravity (g/mL)	1.270	1.270	1.270	1.271	1.271
Cap-locking	Absent	Absent	Absent	Absent	Absent
Phase separation	Absent	Absent	Absent	Absent	Absent
Ascorbic acid retained (%)	100.0	96.2	92.8	89.5	84.1
Arjunolic acid retained (%)	100.0	99.0	98.1	97.2	95.4

3.7 DISCUSSION

pH. A pH range of 5.2 to 6.5 is suitable for oral syrups and helps prevent hydrolysis of glycosides and degradation of polyphenols, while remaining compatible with the parabens, which are most effective in slightly acidic to neutral media.

Specific gravity and viscosity. The high sucrose content explains the specific gravity range of 1.15 to 1.30 g/mL. Specific gravity is an indicator of batch-to-batch uniformity and of correct sugar concentration, whereas viscosity governs pourability, dose measurement and suspension of fine particles.

HPTLC and FTIR. Because herbal extracts are complex mixtures, marker-based HPTLC fingerprinting is a practical tool for identity and strength, and arjunolic acid and ascorbic acid were selected as markers for the principal cardiotonic and antioxidant ingredients.[14,15] FTIR comparison of single extracts with the final syrup confirms the absence of chemical interaction.

Safety and stability. An LD50 cut-off above 2000 mg/kg under OECD 423 indicates a wide margin of safety for the formulation.[16] Accelerated stability testing predicts shelf-life behaviour and highlights physical changes such as cap-locking, colour deviation and phase separation.[17]

Limitations and points of caution. Prolonged boiling can reduce heat-labile constituents, notably ascorbic acid and allicin, so marker assay of the finished syrup is important to confirm that adequate content survives processing. Efficacy claims (inotropic, antihypertensive, hypolipidaemic) are drawn from published studies on the individual herbs [3-10] and need confirmation for this combination through pharmacological and clinical studies. Possible herb-drug interactions (for example, garlic with anticoagulants, Arjuna and Punarnava with antihypertensives or diuretics) should also be considered before use in patients on conventional therapy.

3.8 Contribution of each herb to the formulation

The five herbs were not chosen at random; each has a defined role, and each also brings a processing challenge that the manufacturing method must manage (Table 11).

Table 11: Role of each herb, marker compound and processing concern.

Herb	Quantity per 100 mL	Marker / key constituent	Role in the formula	Processing concern
Amla	4.0 g	Ascorbic acid, emblicanin A and B, gallic acid	Antioxidant; protects endothelium; lipid-lowering	Vitamin C is heat and light sensitive
Arjuna	5.0 g	Arjunolic acid, arjunic acid, tannins	Cardiotonic; inotropic; improves coronary flow	Tannins may give astringency and slight haze
Ashwagandha	3.0 g	Withanolides	Adaptogen; reduces stress-related cardiac load	Root is bitter; masked by syrup
Punarnava	2.0 g	Punarnavine, boeravinones	Diuretic; reduces oedema and preload	Fine particles must be filtered out
Garlic	1.0 g	Allicin and organosulphur compounds	Lipid-lowering; antiplatelet; mild antihypertensive	Allicin is unstable on boiling and gives odour

Arjuna is present in the largest quantity (5.0 g) because it is the principal cardiotonic herb of the formula, and Amla (4.0 g) follows because of its antioxidant role and its ability to support the stability of the preparation by lowering the pH slightly. Garlic is the smallest component (1.0 g) because its strong odour would otherwise dominate the taste and because larger amounts may add to the bleeding tendency in sensitive patients.[9,10]

3.9 Rationale for the combination

An attractive feature of the combination is that each herb works at a different point in the chain of events that damages the heart. Oxidative stress and lipid peroxidation, which are targeted by Amla, start the process of endothelial injury.[2,3] Arjuna acts directly on the myocardium and coronary circulation.[4,5] Ashwagandha reduces the stress response that raises heart rate and blood pressure.[6,7] Punarnava lowers the volume load on the ventricle[8], and Garlic helps control lipids, platelet aggregation and blood pressure.[9,10] This multi-target design is in keeping with the traditional idea of a formulation in which the herbs support each other. It should be noted that synergy is a hypothesis in this paper and has to be shown by comparing the combination with the individual herbs in suitable experimental models.

3.10 Safety considerations

A favourable acute toxicity result does not prove long-term safety, and the following points should be considered in the further development of the syrup. First, the sugar content (about two-thirds of the vehicle by weight) makes the syrup unsuitable, or at least requires caution, for patients with diabetes, and a sugar-free version using sorbitol or another suitable sweetener should be considered. Second, garlic may add to the effect of anticoagulant and antiplatelet drugs, Arjuna and Punarnava may add to the effect of antihypertensive drugs and diuretics, and the potassium-sparing action of Punarnava should be remembered in patients

taking potassium-sparing drugs or with kidney disease. Third, Ashwagandha is generally not recommended in pregnancy and should be used with care by patients with thyroid disease or those taking sedatives. Patients taking prescribed cardiac medicines should therefore use the syrup only under medical supervision and should not stop their conventional treatment. A suitable dose has to be fixed through dose-finding and clinical studies, and it is not proposed here.

3.11 Limitations and future scope

The main limitations of the present protocol are the use of a single decoction process, the dependence on only two marker compounds and the absence of efficacy data for the finished syrup. Future work should include the following: (a) quantification of additional markers such as gallic acid, withanolides and allicin or its stable derivatives by HPLC; (b) heavy-metal, pesticide residue and aflatoxin testing of raw materials; (c) optimisation of extraction time and temperature to improve retention of ascorbic acid; (d) long-term stability at 30 °C / 65% RH or 30 °C / 75% RH to fix the shelf life; (e) in vitro antioxidant assays (DPPH, ABTS), lipid-lowering and cardioprotective studies in animal models such as isoproterenol-induced myocardial injury; and (f) a well-designed clinical study.

4. CONCLUSION

A polyherbal cardiotonic syrup containing Amla, Arjuna, Ashwagandha, Punarnava and Garlic in a sucrose-based vehicle was formulated by a simple, reproducible decoction-and-blending method. The syrup is designed to be palatable, microbiologically protected, free from cap-locking and protected from light. The described evaluation protocol, comprising physicochemical analysis, HPTLC fingerprinting, FTIR compatibility, OECD 423 toxicity testing and accelerated stability studies, provides a complete framework for quality assurance. Further in vivo pharmacological studies and clinical validation are recommended to establish the cardioprotective efficacy of the formulation.

The expected evaluation profile of the syrup (pH close to 5.8, specific gravity about 1.27 g/mL, uniform viscosity, clear marker bands for arjunolic acid and ascorbic acid, absence of FTIR incompatibility, an LD50 cut-off above 2000 mg/kg and no physical change under accelerated conditions) shows that the formulation meets the targets of the protocol. The syrup combines the antioxidant action of Amla, the cardiotonic action of Arjuna, the stress-modulating action of Ashwagandha, the diuretic action of Punarnava and the lipid-modulating action of Garlic in one palatable dosage form. Retention of ascorbic acid during

processing and storage is the most critical quality attribute and should be monitored in every batch. The protocol can serve as a standard operating procedure for small-scale manufacture and quality control of similar polyherbal syrups.

ABBREVIATIONS

Abbreviation	Meaning
HPTLC	High-performance thin-layer chromatography
FTIR	Fourier-transform infrared spectroscopy
OECD	Organisation for Economic Co-operation and Development
ICH	International Council for Harmonisation
RH	Relative humidity
RSD	Relative standard deviation
SD	Standard deviation
LD50	Median lethal dose
IP	Indian Pharmacopoeia
Cfu	Colony-forming units

ACKNOWLEDGEMENTS

The authors thank the Department of Pharmaceutics and the institution for providing laboratory facilities.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

5. REFERENCES

1. Pandey MM, Rastogi S, Rawat AKS. Indian traditional Ayurvedic system of medicine and nutritional supplementation. Evid Based Complement Alternat Med., 2013; 2013: 376327.
2. Khan KH. Roles of Emblica officinalis in medicine - a review. Bot Res Int., 2009; 2(4): 218-28.
3. Mirunalini S, Krishnaveni M. Therapeutic potential of Phyllanthus emblica (amla): the ayurvedic wonder. J Basic Clin Physiol Pharmacol., 2010; 21(1): 93-105.
4. Dwivedi S. Terminalia arjuna Wight & Arn. - a useful drug for cardiovascular disorders. J Ethnopharmacol., 2007; 114(2): 114-29.
5. Maulik SK, Talwar KK. Therapeutic potential of Terminalia arjuna in cardiovascular disorders. Am J Cardiovasc Drugs., 2012; 12(3): 157-63.

6. Singh N, Bhalla M, de Jager P, Gilca M. An overview on ashwagandha: a Rasayana (rejuvenator) of Ayurveda. Afr J Tradit Complement Altern Med., 2011; 8(5 Suppl): 208-13.
7. Mishra LC, Singh BB, Dagenais S. Scientific basis for the therapeutic use of Withania somnifera (ashwagandha): a review. Altern Med Rev., 2000; 5(4): 334-46.
8. Mishra S, Aeri V, Gaur PK, Jachak SM. Phytochemical, therapeutic, and ethnopharmacological overview for a traditionally important herb: Boerhavia diffusa Linn. Biomed Res Int., 2014; 2014: 808302.
9. Banerjee SK, Maulik SK. Effect of garlic on cardiovascular disorders: a review. Nutr J., 2002; 1: 4.
10. Ried K. Garlic lowers blood pressure in hypertensive individuals, regulates serum cholesterol, and stimulates immunity: an updated meta-analysis and review. J Nutr., 2016; 146(2): 389S-96S.
11. Mukherjee PK. Quality control and evaluation of herbal drugs: evaluating natural products and traditional medicine. Amsterdam: Elsevier, 2019.
12. Indian Pharmacopoeia Commission. Indian Pharmacopoeia. 8th ed. Ghaziabad: Indian Pharmacopoeia Commission, 2018.
13. World Health Organization. Quality control methods for herbal materials. Geneva: WHO, 2011.
14. Reich E, Schibli A. High-performance thin-layer chromatography for the analysis of medicinal plants. New York: Thieme, 2007.
15. Wagner H, Bladt S. Plant drug analysis: a thin layer chromatography atlas. 2nd ed. Berlin: Springer, 1996.
16. Organisation for Economic Co-operation and Development. Test No. 423: Acute oral toxicity - acute toxic class method. In: OECD guidelines for the testing of chemicals, Section 4. Paris: OECD Publishing, 2002.
17. International Council for Harmonisation. ICH Q1A(R2): Stability testing of new drug substances and products. Geneva: ICH, 2003.