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Antihypertensive Efficacy Of Fagopyrum Esculentum Monech Stem Extract: Pharmacogenetic, Phytochemical, And In-Vivo Evaluation

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Abstract
The present study evaluates the antihypertensive potential of Fagopyrum esculentum (common buckwheat) stem through an integrative approach encompassing pharmacognostic characterization, phytochemical profiling, and in vivo efficacy tests. Key phytochemical constituents, especially flavonoids (quercetin, rutin), were confirmed via qualitative screening and HPTLC fingerprinting. Two hypertensive rat models – renovascular (2K1C) and glucose-induced – were employed to assess blood pressure and heart rate modulation by the buckwheat stem extract. Treatment with the extract caused systolic blood pressure and heart rate's significant reduction in comparison to hypertensive controls, in both models. The extract also exhibited strong in vitro angiotensin-converting enzyme (ACE) inhibitory activity (IC_{50} ~ 12 µg/mL), surpassing the reference drug captopril. These findings give scientific validation for usingF. esculentumtraditionally in managing hypertension and suggest its potential as a natural antihypertensive agent [1-5].

1.0 INTRODUCTION

Globally, hypertension is a major contributor to cardiovascular disease and early death [1,2]. Despite synthetic antihypertensive drugs availability, uncontrolled hypertension remains prevalent, partly due to side effects and cost barriers [3,4]. There is a growing interest in plant-based therapeutics for hypertension management, as medicinal plants may offer multi-target benefits with lower side effects [5,6]. Fagopyrum esculentum Moench (common buckwheat) is traditionally reputed for its health benefits, including use in managing high blood pressure [7,8]. Buckwheat is filled with bioactive phytochemicals like flavonoids (e.g., quercetin as well as rutin) and other antioxidants [9,10]. These compounds are known to exert vascular protective effects and have been associated with blood pressure-lowering and cardioprotective activities [11,12]. Previous studies have noted buckwheat's antihypertensive potential; for instance, fermented buckwheat products yielded peptides and polyphenols with blood pressure-lowering effects [13-14]. However, comprehensive scientific evaluation of buckwheat stem for antihypertensive activity is limited [15]. In this context, the present study was designed to (a) establish pharmacognostic standards for F. esculentum stem, (b) profile its phytochemical constituents and chromatographic fingerprint, and (c) evaluate its antihypertensive efficacy in experimental models. The working hypothesis is that the flavonoid-rich stem extract can attenuate hypertension via mechanisms such as ACE inhibition and cardio-protection [16-17]. This work aims to give a scientific basis for buckwheat's traditional usage in hypertension as well as compare its efficacy with standard antihypertensive interventions.

2.0 Materials and Methods

2.1 Plant Material and Pharmacognostic Evaluation

- **Collection and Authentication:** Aerial parts (stems and leaves) of F. esculentum were collected from a suitable habitat and authenticated by a botanist. Herbarium specimen was deposited for reference [18].
- **Macroscopic and Microscopic Analysis:**Pharmacognostic characterization of the stem was performed. Macroscopic features (color, texture, fracture, taste) were recorded. Microscopic examination of stem cross-sections and powdered stem was done using standard techniques [19].

- **Physicochemical Parameters:** Standard physicochemical constants were determined for the dried stem powder: water, total ash, acid-insoluble ash as well as alcohol extractive values, moisture content, etc [20].
- **Fluorescence Analysis:** Powdered stem drug had been treated with many reagents as well as observed under UV (254 nm, 365 nm) and visible light [21].

2.2 Preparation of Extracts and Phytochemical Screening

- **Extraction Procedure:** The dried stems were powdered and successively extracted with increasing polaritysolventslikewater, petroleum ether, methanol and chloroform, acetoneusing Soxhlet extraction and maceration for the aqueous extract [22].
- **Qualitative Phytochemical Tests:** Standard chemical tests were performed on various extracts to detect major phytochemical classes. Tests indicated the presence of flavonoids (Shinoda test positive), phenolics/tannins (ferric chloride test yielding dark blue-green), alkaloids (Mayer's and Dragendorff's tests mild positive), carbohydrates (Benedict's test positive), and proteins (Biuret test positive), especially in the polar (methanol, water) extracts. Saponins were absent (no froth in foam test). These findings qualitatively confirmed a broad spectrum of phytoconstituents in F. esculentum stem, aligning with its reputed medicinal properties [23,24].
- **Total Phenolic Content (TPC)**: Using the Folin–Ciocalteu reagent, the TPC was measured and expressed as gallic acid equivalents [25].
- **Total Flavonoid Content (TFC):**Using quercetin as a reference, the aluminium chloride colorimetric technique was used to quantify the flavonoid concentration, expressed as quercetin equivalents [26].
- **HPTLC Fingerprint Analysis**: High-performance thin-layer chromatography was performed on the methanolic stem extract to profile its constituents. Quercetin had been used as a reference marker compound. Extract and standard were applied on a silica gel plate and developed in an appropriate solvent system. The plate was scanned at 366 nm. The HPTLC chromatogram of the extract revealed multiple peaks; importantly, a prominent peak with Rf matching that of standard quercetin was observed (confirming quercetin presence in the extract) [27].

2.3 In Vivo Antihypertensive Activity

- **Experimental Animals:**We utilised adult Wistar albino rats (200–250 g, any sex). The animals had unrestricted access to food and water and were kept in normal housing circumstances. Every experimental method followed with CPCSEA criteria and was authorised by the Institutional Animal Ethics Committee [28].
- **Induction of Renovascular Hypertension (2K1C model):** The two-kidney one-clip (2K1C) Goldblatt model was used to induce renovascular hypertension. Rats had beensplit into groups (n=6 per group): Group I – normotensive normal control; Group II – sham-operated control (surgery without renal artery clipping); Group III – hypertensive control (2K1C, with no treatment); Group IV – 2K1C + F. esculentum extract treatment. For Groups III–IV, hypertension was induced by placing a clip on the left renal artery causing partial occlusion, leading to elevated blood pressure via renin-angiotensin activation. Starting one week post-surgery, Group IV rats received the stem extract (e.g., 200 mg/kg body weight per day, oral) for four weeks, while Group III received vehicle only. Every week, heart rate and systolic blood pressure (SBP) were recorded. A non-invasive tail-cuff technique was used to take the rats' BP after they had been trained and kept slightly warmor via direct carotid cannulation in anesthetized rats (at baseline and study end, as appropriate). Heart rates were derived from pulse recordings [29].
- **Induction of Glucose-Induced Hypertension:** A separate set of rats was used to model hyperglycemia-induced hypertension. They were divided into: Group I – control (normal diet, no treatment); Group II – treated (oral F. esculentum extract, 200 mg/kg). For three weeks, all rats were given an ad libitum 10% glucose solution to cause metabolic alterations that raised BP. Group II additionally received the extract daily during this period. SBP and heart rate were recorded weekly as above. This model simulates hypertension associated with metabolic

syndrome/diabetes, providing a complementary paradigm to the renin-dependent 2K1C model [30].

- **Data Analysis:** Blood pressure and heart rate data are presented as mean ± SEM. Statistical comparisons between groups (extract-treated vs. controls) were made using ANOVA and then post-hoc tests, with $p<0.05$ considered important [31].

2.4 ACE Inhibition Assay (In Vitro)

- **ACE Inhibitory Activity:**Ability of stem extracts to inhibit angiotensin-converting enzyme (ACE) was evaluated in vitro using a colorimetric assay. Various solvent extracts (e.g., petroleum ether, chloroform, acetone, methanol, ethanol, aqueous) were tested at different concentrations. Hippuryl-histidyl-leucine (HHL) was used as a substrate; upon ACE action, it releases hippuric acid, which was quantified (e.g., by reaction with cyanuric chloride or by HPLC). The percentage inhibition of ACE was calculated for each extract concentration. The IC_{50} (concentration required to inhibit 50% of ACE activity) had beendetermined from inhibition curves. Captopril, a standard ACE inhibitor, was tested in parallel as a positive control [32].
- **Phytochemical Component Analysis:** To relate ACE inhibitory activity to extract composition, the most active extract was further analyzed. Given the high flavonoid content in the methanol/ethanol extracts, these were suspected to contribute to ACE inhibition. (Any bioactive-guided fractionation or isolation attempts can be mentioned here if performed, e.g., isolation of rutin/quercetin and testing their ACE inhibition, although in this study the focus remained on the crude extract efficacy [33].

3.0 RESULTS AND DISCUSSION

3.1 Pharmacognostical study

3.1.1 Biological source

Plant collected form Mainpat region in surguja district of Chhattisgarh.It consists of aerial parts of Fagopyrumesculentumbelonging to family Polygonaceae [18].

3.1.2 Macroscopy

With paired opposing leaves and bulged nodes, the stem displays thin twigs of aerial branches that range in thickness from 2 to 2.5 mm(Figure 3.1). Its bark is delicate, exhibiting a dark brown hue interspersed with lighter brown lenticels that are uniformly distributed. The surface of the stem feels slightly textured, while its fracture is irregular and fibrous, imparting an astringent taste devoid of any notable scent. Leaves exhibit a dorsiventral structure, characterized by distinct upper and lower epidermal layers, with lower epidermis cells often presenting a papillose configuration. The hypodermis is located beneath the upper epidermis of midrib region. Palisade tissue of lamina region is notably prominent, organized into two distinct layers. The epidermal hairs are unicellular and densely packed in the midrib area, situated beneath the palisade tissue. The spongy parenchyma is present, encompassing intercellular spaces. Both the palisade and spongy parenchyma are rich in chloroplasts, thereby making the mesophyll tissue capable of photosynthesis [19,20].

Figure 3.1: Fagopyrumesculentum

3.1.3 Microscopy

The cross-sectional view in figure 3.2 of the stem presents a circular configuration. While the inner cork is made up of a few layers of lignified parenchymatous cells orientated radially in regular rows, the outer cork is made up of many layers of dark brown, irregular parenchymatous cells. A noticeable strip of sclereids, grouped in clusters of two to four, is scattered throughout the cortex's many layers of tangentially elongated and rounded cells. Many of the cortex's cells, especially those in the outermost layers, are tannin-rich and vary in colour from yellow and orange to dark brown. Furthermore, a few of thin patches around the well-developed xylem show groupings of pericyclic fibres located outside the phloem.One to four sets of radially elongated lignified medullary ray cells are regularly scattered throughout the xylem, which makes up about one-third of the transverse section. It is made up of tracheids, xylem fibres, well-formed vessels, and xylem parenchyma. Small clusters of sclereids are scattered throughout the medullary ray cells, while thin-walled, rounded or polygonal lignified parenchymatous cells make up the pith, which is located near the centre of the stem. Prismmatic crystals linked to both sclereids and medullary ray cells are also seen in this region, along with tiny clusters of sclereids.[19,20].

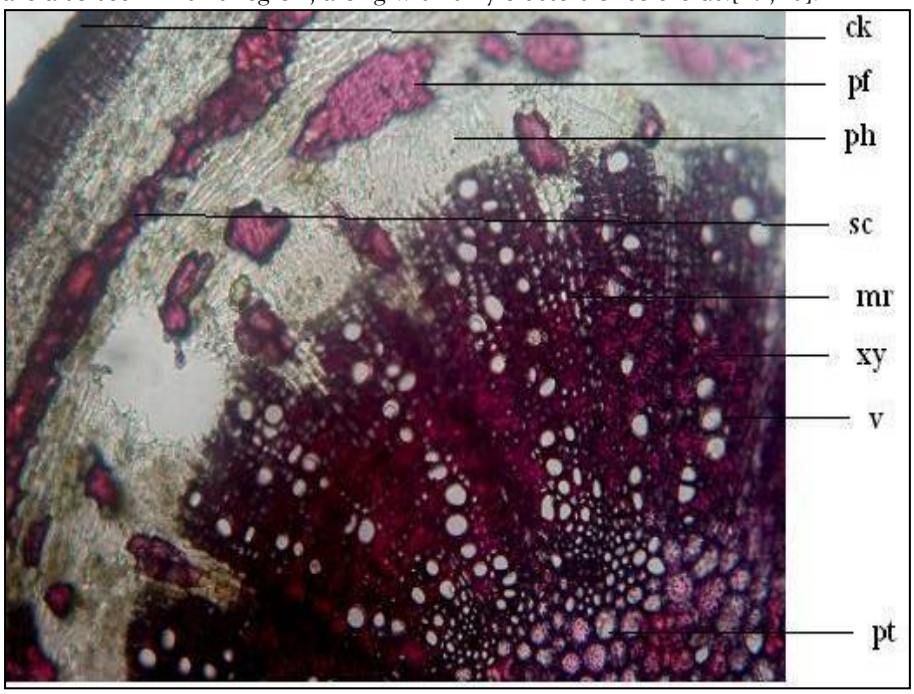

Figure 3.2: Transverse section of stem

ck- cork, **pf**- pericyclic fibres, **ph**- phloem, **sc**- stone cells,**mr**- medullary rays, **xy**- xylem, **v**- vessels, **pt**- pith

3.1.4 Powder analysis

The analysis of the powder derived from the stem unveiled the existence of vessels exhibiting simple pitted thickenings, sclereids clusters harboring prismatic crystals, and remnants of parenchyma cells enriched with tannins. The analysis revealed the existence of tracheids, fibers, and cork cells.(Figure 3.3)

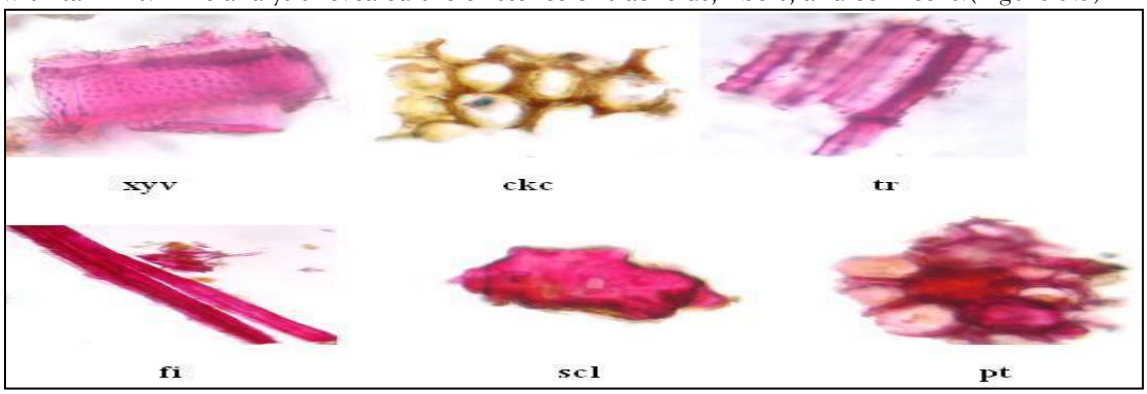

Figure 3.3: Powder characteristics of stem

xyv- xylem vessels, **ckc**- cork cells, **tr**- tracheids, **fi**- fibres, **scl**- sclereids, **pt**- pith

The powder microscopy of leaves(Figure 3.4) doesn't show much detail expect the occurrence of the mesophyll cells, in general. On special staining with iodine, the presence of starch is noted as starch content develops below colorations. Stomata on the surface view of the lower epidermis

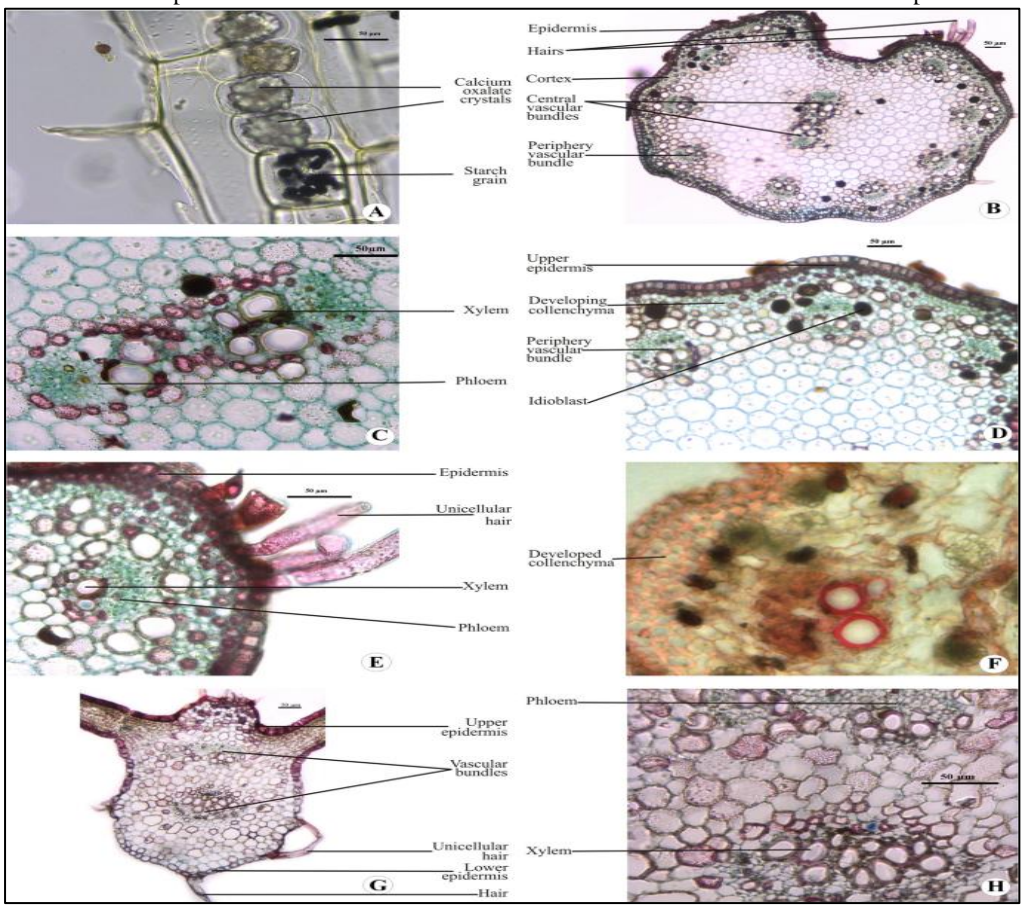

Figure 3.4: Powder microscopy of leaves

3.2 Physicochemical constants of stem of Fagopyrumesculentum

3.2.1 Ash values

Stem powder's total ash contenthad been found to be 3.7% w/w, which represents total amount of inorganic material (mineral content) present(Table 3.1). This is within the acceptable range for crude plant drugs, suggesting a moderate presence of mineral matter and no excessive contamination [20,21].The acid-insoluble ash value was 0.65% w/w, indicating minimal contamination with siliceous materials such as sand or soil. This low value confirms the purity of the raw material and its proper handling during collection and processing.The water-soluble ash was 2.37% w/w, suggesting that a substantial portion of the total ash consists of water-soluble minerals, possibly potassium, calcium, or magnesium salts. This is significant as it gives an idea of the physiological availability of minerals.The sulphated ash, measured at 2.80% w/w, reflects the total content of inorganic residues after complete oxidation of organic matter, further confirming the consistency of total ash findings.

Table 3.1: Ash values

Parameters (ash)	**Value (w/w)**
Total	3.7 %
Acid insoluble	0.65 %
Water soluble	2.37 %
Sulphated	2.80 %

3.2.2 Extractive values

The water-soluble extractive value was 16.7% w/w, indicating a rich content of polar constituents such as sugars, tannins, glycosides, and flavonoids. This high value suggests that water is an effective solvent for extracting active phytochemicals from the stem.The ethanol-soluble extractive value was 5.6% w/w, showing occurence of moderately polar compounds like phenolics, alkaloids, as well as resins.The ether-soluble extractive value was 3.2% w/w, showing the occurence of non-polar constituents such as lipids, waxes, and essential oils, although in lower amounts compared to the polar constituents [21].(Table 3.2)

Table3.2: Extractive values

Parameters (extractive)	Value (w/w)
Water soluble	16.7 %
Ethanol soluble	5.6 %
Ether soluble	3.2 %

3.2.3 Moisture content

Moisture content that is loss on drying at 105 °Cwas 13.45% w/w, which is slightly above the ideal threshold (~10–12%) and could influence the storage stability of the raw drug. Higher moisture content may lead to microbial growth or degradation during storage [20].

3.2.4 Foaming index

The foaming index was recorded as NIL, indicating the absence of saponins or other foaming agents, which are often used as markers for certain pharmacologically active groups.

3.2.5 Tannin content

Tannin content was found to be 9.0% w/w, suggesting a significant amount of astringent polyphenolic compounds. Tannins contribute to antioxidant, antimicrobial, and wound-healing properties, making the stem pharmaceutically valuable [21].

3.2.6 Swelling index

The swelling index was 3, which provides information about the mucilage or hydrophilic fibre content. A moderate swelling index indicates some potential for gastrointestinal health or water retention.

3.3 Phytochemical study of stem of Fagopyrumesculentum

3.3.1 Preliminary phytochemical extraction:

The preliminary phytochemical extraction through successive solvent extraction revealed varying yields and colors of the plant extracts, indicating the differential solubility of phytoconstituents in solvents of increasing polarity(Table 3.3). Petroleum ether (60–80 °C), being a non-polar solvent, extracted a small amount of dull yellowish-green residue (1.17 g), suggesting the limited presence of non-polar compounds such as fats, oils, or waxes. Benzene, another non-polar solvent, yielded a slightly higher amount (1.24 g) with a dark greenish-brown coloration, possibly indicating the presence of certain lipophilic pigments or low-polarity compounds.

Chloroform and acetone, which are moderately polar solvents, resulted in increased yields of 1.73 g and 1.64 g, respectively, with dark green and dirty brown colors. This suggests the occurence of medium-polarity constituents like alkaloids, terpenoids, as well as certain phenolics. Ethanol (95%), a highly polar solvent, produced a substantial blackish-brown extract weighing 4.23 g, reflecting the extraction of a broad range of polar compounds, including flavonoids, tannins, saponins, as well as polyphenolic compounds. The highest yield was obtained using a chloroform:water mixture (1:99), which produced 5.60 g of a brown-colored extract. This result indicates a dominant presence of highly polar, water-soluble phytoconstituents in the plant material [23,24].

Table 3.3: Successive solvent extraction

S. No.	Solvent	Color	Weight of the extract(g)
1.	Petroleum ether (60-80 °C)	Dull yellowish green	1.17
2.	Benzene	Dark greenish brown	1.24
3.	Chloroform	Dark green	1.73

4.	Acetone	Dirty brown	1.64
5.	Ethanol (95%)	Blackish brown	4.23
6.	Chloroform:Water (1:99)	Brown	5.60

3.3.2 Phytochemical analysis of different extracts (Qualitative chemical tests)

The qualitative phytochemical analysis of successive solvent extracts in table 3.4 reveals significant variation in the solubility and presence of bioactive compounds depending on the polarity of the solvents used. Petroleum ether, being non-polar, extracted limited phytochemicals like phytosterols, carbohydrates, as well as fixed oils & fats, indicating the presence of lipophilic and slightly polar compounds. Benzene also showed a limited profile, yielding only fixed oils and fats and proteins, which suggests its relatively poor extraction capability for most phytochemicals. Chloroform, a solvent of intermediate polarity, was positive only for alkaloids, reflecting its moderate ability to dissolve specific bioactive compounds, particularly alkaloids. Acetone showed the presence of flavonoids and proteins, indicating its ability to extract certain moderately polar constituents. Methanol, a highly polar solvent, was far more effective, giving positive results for phenolic compounds, alkaloids, carbohydrates, phytosterols and tannins, as well as flavonoids, demonstrating its broad-spectrum solubility for various polar phytochemicals. Water, the most polar solvent in the study, was found to extract the widest range of compounds. It tested positive for fixed oils, alkaloids, carbohydrates, phytosterolsas well as fats, phenolic compounds & tannins, proteins, & flavonoids, indicating that a large proportion of the plant's bioactive constituents are highly polar and water-soluble. Notably, saponins and gums and mucilages were absent in all extracts, suggesting either their absence in the plant material or the ineffectiveness of the employed solvents in extracting them. Overall, methanol and water emerged as the most efficient solvents for a broad range of phytochemicals, which is valuable for guiding future extraction and bioactivity studies.

Table 3.4: Qualitative chemical tests of successive extracts

Test	Petroleum ether	Benzene	Chloroform	Acetone	Methanol	Water
Alkaloids	-	-	+	-	+	+
Carbohydrates	+	-	-	-	+	+
Phytosterols	+	-	-		+	+
Fixed oils and fats	+	+	-	-	-	+
Saponins	-	-	-	-	-	-
Phenolic compounds and tannins	-	-	-	-	+	+
Proteins	-	+	-	+	-	+
Gums and mucilage's	-	-	-	-	-	-
Flavonoids	-	-	-	+	+	+

(+ Present, - Absent)

3.3.3 Total Phenolic content

It was assessed with the use of gallic acid as the standard, as well as results are shown in mg of gallic acid equivalent (GAE) per gram of extract shown figure 3.5. The methanolic extract exhibited a phenolic content of 1.522 mg/g, while the aqueous extract showed a slightly lower value of 1.1 mg/g. This suggests that methanol is a solvent that extracts phenolic chemicals more effectively than water, likely due to its intermediate polarity which facilitates better solubility of various polyphenolic structures [9].

The antibacterial, anti-inflammatory, and antioxidant properties of phenolic compounds are well recognised, and moderate levels observed here suggest the F. esculentum stem may have beneficial pharmacological potential, especially when extracted with methanol.

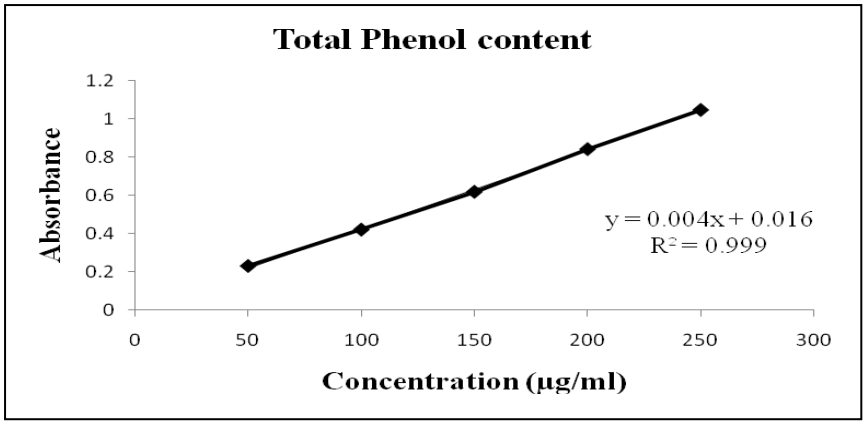

Figure 3.5: Standard plot of Gallic acid

3.3.4 Total Flavonoid content

It is expressed as quercetin equivalents, was determined to be 0.140 mg/g for methanolic extract, as well as 0.029 mg/g for aqueous extract. These results shown in figure 3.6, highlight a marked difference in flavonoid solubility, with methanol again proving to be a more effective solvent than water.Flavonoids are a subclass of polyphenols with potent antioxidant and anti-carcinogenic properties, often contributing to vascular health, immune modulation, and UV protection. Although the absolute flavonoid content is relatively low, the higher yield in the methanolic extract supports its preferential use for isolating such bioactives from the plant material [25,26].

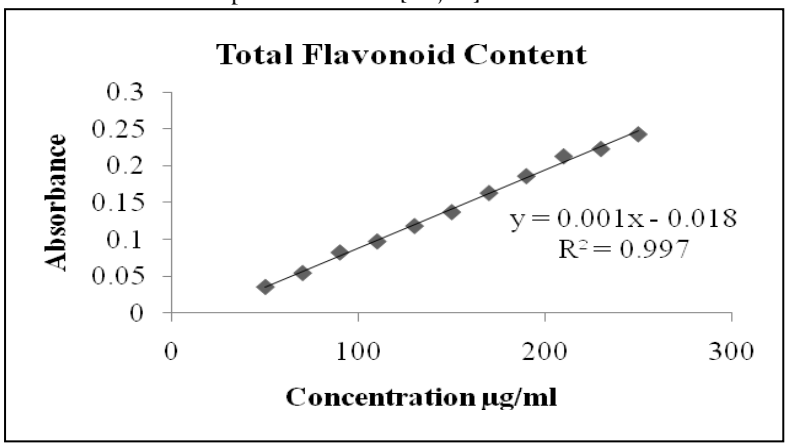

Figure 3.6: Standard plot of quercetin

3.3.5Fluorescence Analysis

The fluorescence analysis of the powdered stem of Fagopyrum esculentum provided valuable insights into the presence of various phytochemicals through color changes observed under short UV light, long UV light, and daylight after treatment with different chemical reagents(Table 3.5). The untreated powder exhibited a yellowish-brown color under short UV, light brown under long UV, and dark brown in daylight, establishing the base characteristics of the sample. Upon treatment with 1N hydrochloric acid (HCl), the powder changed to brown, pale black, and brown respectively, suggesting the occurence of acid-reactive compounds like alkaloids or tannins. Treatment with 1N sulfuric acid (H_2SO_4) produced light lemon yellow under short UV, light violet under long UV, and no color in daylight, possibly indicating the presence of acid-sensitive compounds like flavonoids or phenolics. When treated with 1N nitric acid (HNO_3), the powder showed light blue under short UV, violet under long UV, and dark blue in daylight, hinting at oxidative transformations of phenolic structures.

Alkaline treatments also revealed distinct reactions. The sample treated with 1N aqueous sodium hydroxide (NaOH) exhibited blackish green under short UV, black under long UV, and orange brown in daylight, while alcoholic NaOH treatment resulted in light greenish yellow, light brown, and light yellow respectively. These results are consistent with occurence of flavonoids, coumarins, as well as other phenolic compounds that are known to fluoresce under alkaline conditions. Additional treatments with picric acid and ferric chloride ($FeCl_3$) resulted in greenish yellow to blackish green under UV light and

yellow to bright yellow in daylight, further supporting the presence of phenolic groups. Iodine treatment produced brownish green, reddish brown, and brown, possibly indicating the presence of terpenoids or starch-like compounds. Overall, the fluorescence behavior of the powdered drug in various chemical environments suggests a complex phytochemical profile rich in flavonoids, phenolics, and possibly alkaloids.

Table 3.5: fluorescence analysis of the powdered stem of Fagopyrum esculentum

S. No.	Treatment	Short UV light	Long UV light	Day light
1.	Powder as such	Yellowish Brown	Light brown	Dark brown
2.	Powder + 1N HCl	Brown	Pale black	Brown
3.	Powder + 1N H_2SO_4	Light lemon yellow	Light violet	No colour
4.	Powder + 1N HNO_3	Light blue	Violet	Dark blue
5.	Powder + 1N Aq. NaOH	Blackish green	Black	Orange brown
6.	Powder + 1N AlcNaOH	Light greenish yellow	Light brown	Light yellow
7.	Powder + Picric acid	Greenish yellow	Blackish green	Bright yellow
8.	Powder + 5% $FeCl_3$	Greenish yellow	Blackish green	Yellow
9.	Powder + Iodine	Brownish green	Reddish brown	Brown

3.3.6 HPTLC fingerprint profile of Fagopyrumesculentum

The HPTLC fingerprinting of the methanolic extract of Fagopyrum esculentum stem further confirmed the phytochemical composition, particularly the presence of flavonoids. The extract was analyzed using quercetin, a known flavonoid, as the reference standard. The 3D chromatogram (Figure 3.7) of the extract scanned at 366 nm revealed multiple peaks, indicating the presence of several phytoconstituents. When compared with the HPTLC chromatogram of standard quercetin shown in figure 3.8, the chromatogram of the extract showed matching peaks at similar Rf values, confirming the presence of quercetin or structurally related flavonoids within the sample. This correlation validates the extract's flavonoid content and aligns with the results observed in fluorescence analysis. The presence of quercetin in the methanolic extract in figure 3.9, supports the traditional use of Fagopyrum esculentum for its antioxidant and pharmacological properties and provides a reliable chromatographic fingerprint for quality control and standardization [8,11,12].

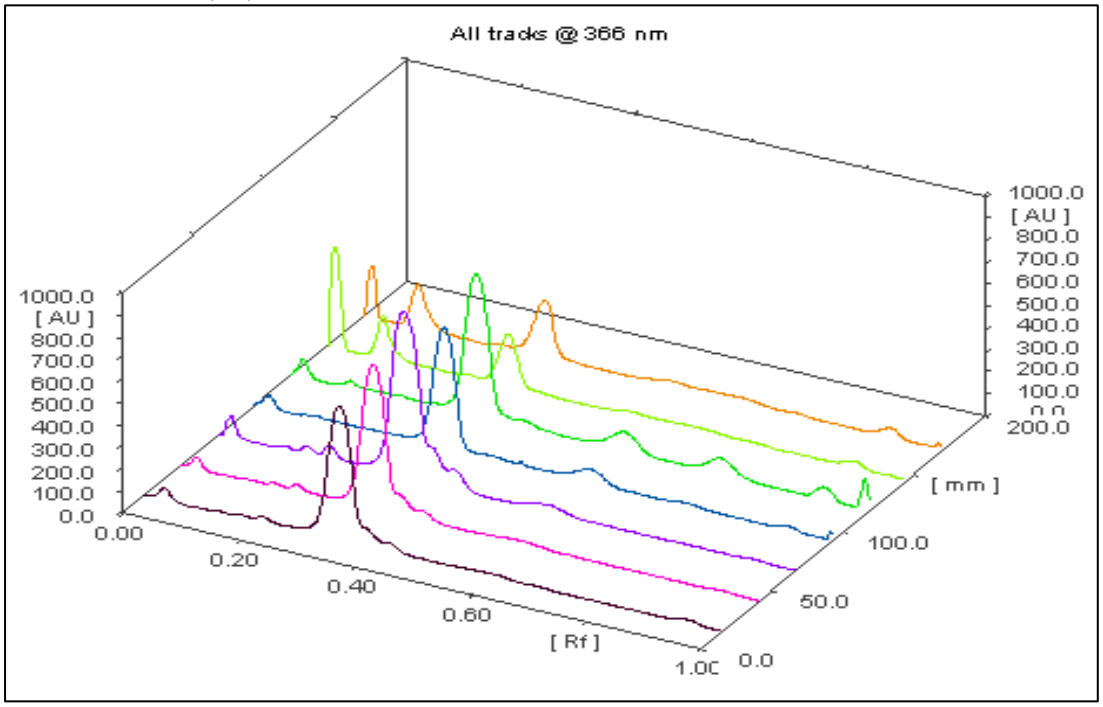

Figure 3.7: 3D chromatogram of quercetin and methanolicextract of Fagopyrumesculentum scanned at 366 nm

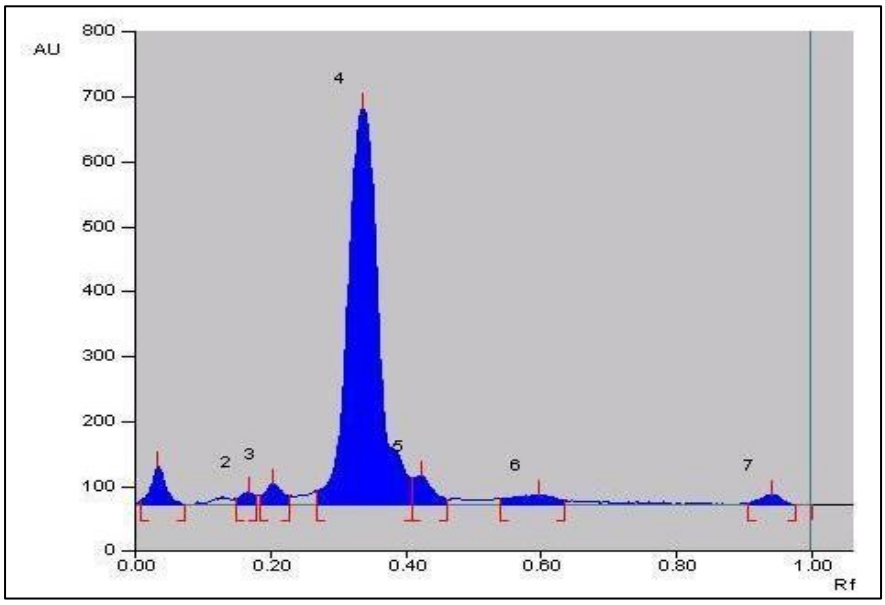

Figure 3.8 HPTLC chromatogram of quercetin

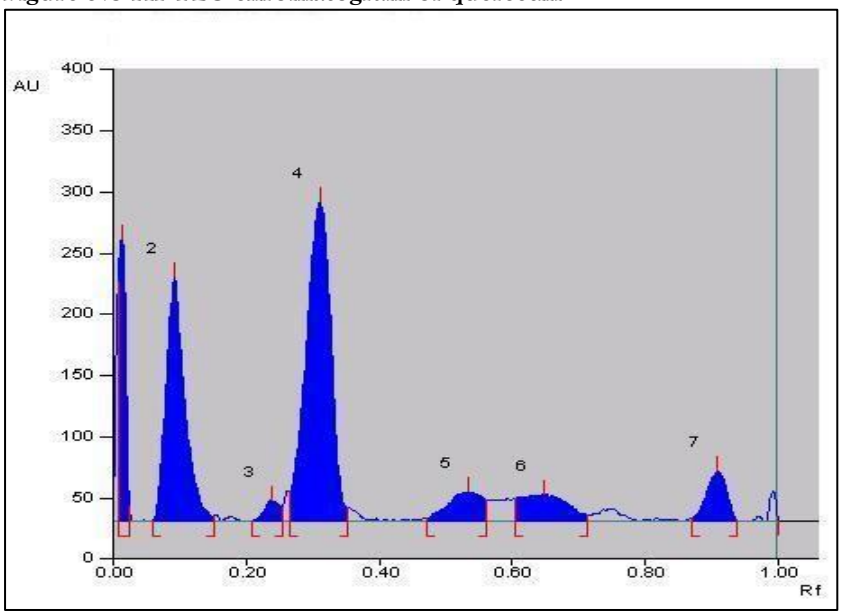

Figure3.9: HPTLC chromatogram of quercetin in methanolic extract of F. esculentum

3.4In vitroAnti-hypertensive activity

3.4.1 Renovascular hypertensive model. (2K1C hypertension)

Fagopyrum esculentum stem extract's antihypertensive activityhad beendetermined using two experimental models: the renovascular hypertension (2K1C) model and the glucose-induced hypertension model. In the renovascular hypertensive model denoted in table 3.6, the normal control (Group I) and sham control (Group II) groups maintained stable systolic blood pressure throughout the four-week period, indicating no significant physiological disturbance. In contrast, the hypertensive group (Group III) showed a consistent rise in systolic blood pressure from 156 mm Hg in Week 0 to 168 mm Hg by Week 4, confirming the successful induction of hypertension. However, the extract-treated group (Group IV) showed a gradual and marked decrease in systolic pressure from 157 mm Hg to 142 mm Hg over the same period, demonstrating the potential blood pressure-lowering effect of the extract. Heart rate measurements supported these findings, with Group III exhibiting a rise from 328 to 350 beats per minute, characteristic of hypertensive stress, whereas the extract-treated group showed a moderate decline from 330 to 314 beats per minute, suggesting a stabilizing effect on cardiovascular function [9,10].

Table 3.6: Effect of Fagopyrum esculentum Stem Extract on Systolic BPand Heart Ratein the 2K1C Renovascular Hypertensive Rat Model.

Group	Systolic Blood pressure (mm Hg)				
	Week 0	Week 1	Week 2	Week 3	Week 4
Group-I (normal control)	121±3.54	120±2.334	121±3.62	121±1.54	120±3.67
Group-II (Sham control)	123±0.84	122±1.56	120±2.54	121±0.82	121±1.58
Group-III(hypertensive group)	156±1.62	159±1.38	162±1.82	165±0.68	168±1.57
Group-IV (extract treated)	157±1.43	154±1.201	150±2.03	145±0.47	142±1.43
Group	**Heart Rate (beats per minute)**				
	Week 0	**Week 1**	**Week 2**	**Week 3**	**Week 4**
Group-I (normal control)	298±1.40	300±0.32	295±1.52	297±1.84	298±0.78
Group-II (Sham control)	320±1.40	300±2.24	298±0.66	296±2.31	297±1.08
Group-III (hypertensive group)	328±1.23	339±1.25	345±1.04	348±1.81	350±0.56
Group-IV (extract treated)	330±1.11	329±0.55	328±1.30	319±1.36	314±1.23

3.4.2 Glucose induced hypertension

In the glucose-induced hypertension model (table 3.7), the control group exhibited a progressive increase in systolic BP from 141 mm Hg to 161 mm Hg over three weeks, while the extract-treated group showed a significant reduction from 143 mm Hg to 128 mm Hg, suggesting effective blood pressure regulation. Similarly, the heart rate in the control group rose from 318 to 328 beats per minute, while a gradual decrease was observed in the extract-treated group from 320 to 307 beats per minute. These results indicate that the stem extract of Fagopyrum esculentum possesses notable antihypertensive properties, capable of counteracting both renovascular and glucose-induced hypertension [7,15,16].

Table 3.7. Effect of Fagopyrum esculentum Stem Extract on Systolic BP and Heart rate in Glucose-Induced Hypertensive Rats

Group	Systolic Blood pressure			
	Week 0	Week 1	Week 2	Week 3
Group-I (control)	141±1.62	150±1.11	156±0.83	161±1.48
Group-II (extract treated)	143±1.43	139±1.201	131±1.83	128±1.38
Group	**Heart Rate (beats per minute)**			
	Week 0	**Week 1**	**Week 2**	**Week 3**
Group-I (control)	318±1.43	321±1.58	325±1.02	328±1.22
Group-II (extract treated)	320±1.55	315±1.04	311±1.23	307±1.32

3.4.3 ACE inhibition activity

The IC_{50} values (µg/mL), which represent the concentration needed to block 50% of ACE activity, were used to assess and express the angiotensin-converting enzyme (ACE) inhibitory activity of several extracts of Fagopyrum esculentum stem. These results are shown in table 3.8 and figure 3.10. With an IC_{50} value of 12 ± 0.011 µg/mL, the ethanol extract showed the most ACE inhibition among the studied extracts, suggesting significant activity. This was followed by the acetone extract (20 ± 0.002 µg/mL) and chloroform extract (23 ± 0.004 µg/mL), which also exhibited notable inhibitory effects [29,32,33].

Table 3.8: Angiotensin-converting enzyme (ACE) inhibitory activity of various extracts of Fagopyrum esculentum stem

Extract	ACE-inhibitory activity (IC50 ug/mL)
Captopril	27 ± 0.121
Petroleum ether	68 ± 0.034
Benzene	38 ± 0.001
Chloroform	23 ± 0.004
Acetone	20 ± 0.002
Ethanol	12 ± 0.011
Chloroform: Water	36 ± 0.011

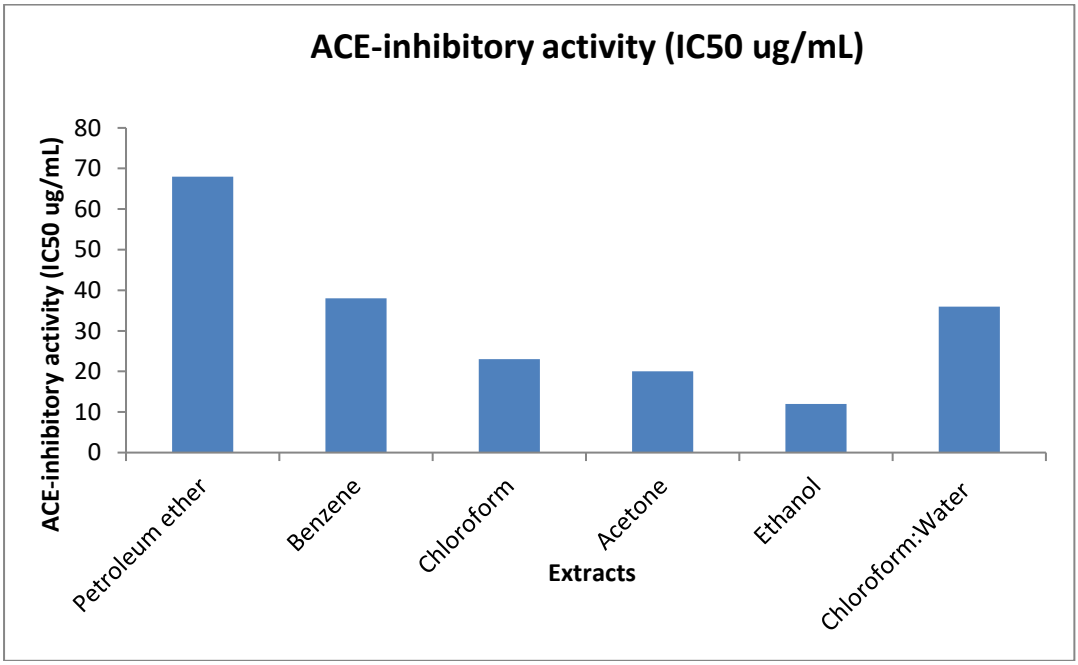

Figure 3.10: Percentage of angiotensin-converting enzyme (ACE) inhibitory activity of various extracts of Fagopyrum esculentum stem

In comparison, standard drug captopril, a known ACE inhibitor, showed an IC_{50} of 27 ± 0.121 µg/mL, indicating that the ethanol, acetone, and chloroform extracts of the plant were more effective in inhibiting ACE than the reference compound. Other extracts, including benzene (38 ± 0.001 µg/mL), chloroform:water mixture (36 ± 0.011 µg/mL), and petroleum ether (68 ± 0.034 µg/mL), exhibited moderate to lower inhibitory activity [11,12,33].

CONCLUSION

The present study comprehensively evaluated the stem of Fagopyrum esculentum for its pharmacognostic, phytochemical, and antihypertensive properties. Pharmacognostic investigations confirmed characteristic anatomical and physicochemical features of the stem, including moderate ash content, high water-soluble extractives, and significant tannin presence. Phytochemical screening showed occurence of flavonoids, phenolics, alkaloids, as well as proteinsprimarily concentrated in methanolic and aqueous extracts. HPTLC analysis confirmed quercetin, a bioactive flavonoid's occurence.In vivo studies using two hypertensive rat models (renovascular and glucose-induced) demonstrated that stem extract significantly

reduced systolic blood pressure and heart rate, validating its antihypertensive potential. The extract also exhibited strong in vitro ACE inhibitory activity, with the ethanol extract showing an IC_{50} of 12 µg/mL—surpassing even the standard drug, captopril [1,7,10,12,13,15].

Together, these findings scientifically substantiate the traditional use of F. esculentum stem in managing hypertension. The extract's rich polyphenolic profile and potent ACE inhibition suggest its promise as a natural, plant-based antihypertensive agent. Further studies, including isolation of active compounds and clinical validation, are warranted to support its development as a therapeutic candidate.

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