# Standardization of Medicinal Plant Raw Materials: Calendulae flos in the State Pharmacopoeia of Ukraine and Český Lékopis

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**Abstract.** The article presents a comparative analysis of the quality indicators of medicinal plant raw materials Calendulae flos according to the monographs of the State Pharmacopeia of Ukraine and Český Lékopis. Macroscopic and microscopic characteristics, methods for identifying biologically active compounds, approaches to the quantitative determination of flavonoids, as well as regulatory requirements for moisture, ash content and impurities are considered. Found that both pharmacopoeias have a high level of consistency in key parameters, but differ in the detail of the description and the severity of control standards: State Pharmacopeia of Ukraine is focused on the accessibility and practicality of methods, while Český Lékopis is focused on accuracy and unification in accordance with European standards. The importance of harmonizing pharmacopoeial requirements for international pharmaceutical practice and increasing the competitiveness of herbal medicines on the global market is emphasized. A promising direction for further research is the use of standardized preparations of calendula officinalis as adjuvants in the therapy of tuberculosis, given their anti-inflammatory, antioxidant, and immunomodulatory properties.

**Keywords:** Calendula officinalis L., Calendulae flos, State Pharmacopoeia of Ukraine, Český Lékopis, standardization, quality control, flavonoids, tuberculosis.

**Introduction.** Standardization of medicinal plant raw materials in modern pharmaceutical practice is one of the key areas of ensuring the effectiveness and safety of herbal medicines. In the context of growing interest in natural remedies for the treatment and prevention of diseases, particularly against the background of the spread of chronic pathologies and post-infectious complications, the unification of quality indicators of herbal raw materials is of particular importance [1, 2].

Monitoring the compliance of medicinal plants with pharmacopoeial requirements allows to guarantee the stability of the chemical composition, reduce the risk of falsification, increase the trust of doctors and patients in herbal medicines and promotes their inclusion in official treatment protocols [3, 4, 5].

Calendula officinalis L. belongs to plants that have a long history of medical use and are the subject of modern research. Its flowers (Calendulae flos) contain a wide range of biologically active substances: flavonoids, carotenoids, triterpene saponins, essential oils, phenolic acids and mucilages, which provide anti-inflammatory, antioxidant, reparative, bactericidal, and immunomodulatory properties [6, 7]. Due to this, calendula is a component of many medicines and cosmetics, used in dermatology (treatment of burns, eczema, inflammatory dermatoses), dentistry (inflammatory diseases of the oral mucosa), gastroenterology (ulcer disease, gastritis), gynecology and other areas [8, 9]. In recent decades, the potential of Calendula officinalis in adjuvant therapy regimens for severe infectious diseases, in particular tuberculosis, has been actively studied. Its anti-inflammatory and antioxidant properties may contribute to reducing the damaging effects of free radicals resulting from prolonged anti-tuberculosis chemotherapy, and its immunomodulatory effect may increase the resistance of patients [10, 11]. The use of standardized calendula preparations may be a promising direction for integration into anti-tuberculosis pharmacotherapy to improve diagnostics according to ICD-11 criteria, reduce side effects, and improve the quality of life of patients [12, 13, 14]. In this context, the harmonization of pharmacopoeial standards for Calendulae flos is of particular importance. National pharmacopoeias, such as the State Pharmacopeia of Ukraine (SPhU), and European counterparts, particularly the Czech Pharmacopeia (Český Lékopis), set requirements for macroscopic and microscopic characteristics of raw materials, impurities, moisture, ash content, as well as methods for identification and quantification of flavonoids [15, 16]. However, each

pharmacopoeia focuses differently: the Ukrainian one is focused on the practical accessibility of quality control for a wide range of laboratories, while the Český Lékopis is focused on detail and accuracy, in accordance with the requirements of the European Union.

The problem of harmonizing pharmacopoeial standards is of not only national but also international importance. It contributes to the unification of the quality of medicinal plant raw materials, facilitates the circulation of medicines on the global pharmaceutical market, and ensures that drugs comply with modern criteria of evidence-based medicine and evidence-based pharmacy [17, 18].

The consistency of requirements between the SPhU and Český Lékopis allows creating a single base for manufacturers, regulatory authorities, and scientists, which is a prerequisite for the development of new medicines and their further integration into international practice.

Thus, conducting a comparative analysis of the quality indicators of Calendulae flos according to the monographs of the SPhU and Český Lékopis is an urgent task that has scientific and practical significance. The results obtained may become the basis for harmonizing pharmacopoeial requirements, increasing the level of quality control, and expanding the possibilities of using standardized calendula preparations, in the adjuvant therapy of tuberculosis.

**The purpose of the study** was to analyze the quality indicators of Calendulae flos according to the monographs of SPhU and Český Lékopis, considering pharmacopoeial approaches to the standardization of medicinal plant raw materials.

To achieve this goal, the following tasks were defined:

- to identify similarities and differences in macroscopic and microscopic features of Calendulae flos;
- to carry out a comparative analysis of methods for identifying biologically active compounds in calendula flowers;
- to investigate approaches to the quantitative determination of flavonoids and assess their significance in standardization;
- to compare regulatory requirements for impurities, ash content, and moisture;
- to assess the significance of harmonizing national and European pharmacopoeial standards for the development of modern pharmaceutical practice and the integration of Ukraine into the European pharmaceutical space.

**Materials and methods.** The materials of the study were official pharmacopoeial sources, in particular the monographs of SPhU and Český Lékopis, which regulate the quality indicators of medicinal plant raw materials Calendulae flos. Additional sources of information were publications devoted to modern approaches to pharmacopoeial standardization and harmonization of requirements in the field of quality control of plant raw materials [1, 2, 15, 19- 30].

To achieve the set goal, the following research methods were used:

- comparative analysis, which allowed comparing the regulatory requirements of SPhU and ČESKÝ LÉKOPIS regarding macroscopic, microscopic, chemical characteristics and quality indicators of Calendulae flos;
- regulatory and documentary method, which provided a systematic study of the provisions of pharmacopoeial articles, their structure and content;
- bibliographic review, which included an analysis of scientific publications and literary sources devoted to pharmacognostic studies and the use of Calendula officinalis L. in medical practice [30-32].

The study of the article is a fragment of research works of Private Scientific Institution "Scientific and Research University of Medical Pharmaceutical Law" on the topic "Multidisciplinary research of post-traumatic stress disorders during war among patients (primarily combatants)" (state registration number 0124U002540, implementation period 2024-2029); Private Scientific Institution “Scientific and Research University of Medical and Pharmaceutical Law” and European Wellness Biomedical Group on the topic “Multimodal innovative research of digital medical technologies by using approaches and methods of evidence-based medicine, quantum medicine, bioquantum medicine, bioquantum therapy, artificial intelligence, bioresonance, proton-plasma, frequency wave,

electronic-pulse, bioregenerative, information mathematical methods of diagnostics, therapy, evidence-based pharmacy, pharmacotherapy of health disorders according to ICD-11 (oncological, allergic, immunological, infectious, addictive, cardiological, comorbid, covid, post-covid, long-covid, etc.) based on medical and pharmaceutical law" (state registration number 0125U002484, implementation period 2025-2033); Private Scientific Institution "Scientific and Research University of Medical and Pharmaceutical Law" and Scientific Research Establishment of Innovations for Future LLC USA on the topic "Multimodal research on innovative legal, medical and pharmaceutical, clinical and pharmacological, behavioral-cognitive, psychological, socio-economic, medical and technological, forensic and pharmaceutical, and digital strategies for patient-centered pharmacotherapy of PTSD and associated diseases in war and conflict settings" (state registration number 0125U003297, implementation period 2025-2029).

## Results and discussion.

### 1. Macroscopic features of Calendulae flos

Macroscopic examination is the basic stage of pharmacopoeial standardization of medicinal plant raw materials, since it allows you to quickly identify the object, confirm its compliance with the botanical species and assess the overall quality of the material. For Calendula officinalis L. (marigold), the determination of the morphological characteristics of flower baskets (Calendulae flos) takes a leading place in standardization.

According to the SPhU, medicinal raw materials include dried whole or partially crushed flower baskets, the diameter of which can reach 4-5 cm. The text of the monograph provides detailed morphological characteristics: the shape of the wrapper, the presence of 2-3 rows of green lanceolate leaves covering the base of the basket, the presence of reed flowers of bright orange or yellow color, as well as smaller tubular flowers located in the center of the basket. Particular attention is paid to the structure of the calendula receptacle, which is flat in marigolds, and its surface is covered with small serrated bracts. The SPhU also requires consideration of the number of ligulate flowers: there should be from 1 to 3 rows, they are elongated-ligulate, with a rounded or slightly notched apex.

In the Český Lékopis, the description of Calendulae flos has a slightly different emphasis. In the Český Lékopis, the color of the flower baskets is emphasized, which should be from light yellow to intense orange, and the requirement for uniformity of the raw material in color is also given. The diameter of the baskets in the Český Lékopis corresponds to the SPhU indicators, but the document pays less attention to the number of rows of ligulate flowers and a detailed description of the tubular elements. At the same time, the Český Lékopis contains stricter requirements for the cleanliness of the surface of the flower baskets: they must be free from foreign parts of stems, leaves or fruits.

Comparative analysis shows that both pharmacopoeias provide a similar description of the main macroscopic features of Calendulae flos. However, the SPhU regulates the morphology of the ligulate and tubular flowers in more detail, which facilitates the identification of plant raw materials even in a crushed state. In contrast, the Český Lékopis focuses on the visual characteristics of whole baskets, on the intensity of color and purity, which reflects the orientation towards practical control over the appearance of batches of raw materials when they are supplied to pharmaceutical companies. Thus, the macroscopic descriptions of Calendulae flos in the SPhU and the Český Lékopis are generally consistent with each other, but differ in the level of detail and priorities of description. The Ukrainian pharmacopoeia is characterized by a more thorough approach to botanical details, while the Český Lékopis is aimed at unifying characteristics for the needs of industrial control. This distribution of emphasis indicates different traditions in pharmacopoeial practice, but at the same time confirms the possibility of harmonizing standards within the European pharmaceutical space.

Macroscopic features are the first stage of identification of medicinal plant raw materials and allow a quick assessment of its authenticity. In SPhU and Český Lékopis, the description of external characteristics of Calendulae flos covers the size, shape, color of flower baskets and individual elements, however, the detail and emphasis in different pharmacopoeias have certain differences. To systematize the data, a comparison of macroscopic features was made in the form of a table.

**Table 1.** Comparison of macroscopic characteristics of Calendulae flos according to SPhU and Český Lékopis.

| Indicator | SPhU | Český Lékopis |
|---|---|---|
| Size of flower baskets | 3-5 cm in diameter | 2-4 cm in diameter |
| Marginal reed flowers | Orange or yellow, up to 2.5 cm long, flat | Yellow or orange, narrower, often slightly curved at the end |
| Tubular flowers | Yellow, numerous, located in the center of the basket | Yellow or orange, tubular shape described in more detail |
| Wrap | Consists of many green bracts arranged in several rows | Number and arrangement of bracts detailed |
| Foreign parts | Minor inclusions of leaves and stems are allowed | Strictly limited number of impurities of uncharacteristic organs |

As can be seen from Table 1, both pharmacopoeias present similar macroscopic characteristics of Calendulae flos, but differ in the degree of detail. In the SPhU, the description is focused on the main morphological features that allow for a quick distinction of the raw material from possible substitutes. In the Český Lékopis, attention is paid to a more precise description of the size and morphological details, in particular the shape of the ligulate and tubular flowers and the number of bracts, which ensures higher specificity of identification. The requirements of the Český Lékopis for the purity of the raw material are more stringent, which corresponds to the general European trends in improving the quality of medicinal plant raw materials.

**2. Microscopic features.**

Microscopic examination is an important stage of pharmacognostic standardization, as it allows the identification of specific anatomical and diagnostic structures of plant raw materials. This is especially relevant in cases where the raw material is crushed or has a heterogeneous composition, which makes it difficult to carry out identification only by macroscopic features.

**Main diagnostic characteristics in the SPhU.** The SPhU monograph states that the most important microscopic diagnostic features of Calendulae flos are:

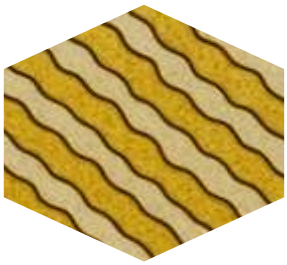
The SPhU pays special attention to the diagnostic value of glandular hairs and pollen grains, which are considered markers for the identification of Calendula officinalis.

**The Český Lékopis approach to the identification of microscopic structures.** In Český Lékopis, the description of microscopic features of Calendulae flos has a different specificity. In Český Lékopis, the emphasis is on:

- the presence of capitate-type glandular hairs with a multicellular head that secrete essential oils;
- characteristic integumentary hairs, mainly multicellular, long, with weakly sinuous sheaths;
- the presence of calcium oxalate crystals in the form of druses, which play a diagnostic role and are a typical feature of the genus Calendula;
- the epidermis of floral elements with wavy anticlinal walls and a pronounced cuticular layer.

The structure of pollen grains is described in less detail in the Český Lékopis, but more attention is paid to the presence of calcium druses, which are considered a key identification feature.

Microscopic analysis is one of the key stages in the identification of Calendulae flos. It allows confirming the presence of characteristic structural elements that serve as diagnostic features. For clarity, the figure shows a comparison of the microscopic features described in the SPhU and the Český Lékopis.

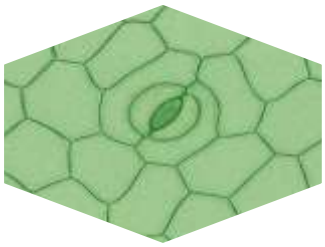


epidermis of reed flowers

cells have an elongated shape with slightly wavy membranes

anomocytic type, located mainly on the lower epidermis of floral elements

breathing apparatus



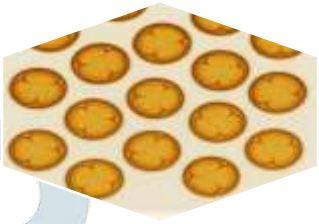


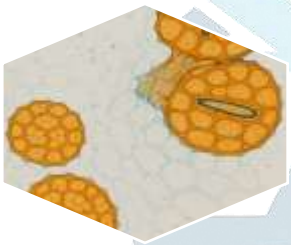
hairs

unicellular integumentary, multicellular simple and glandular with a two-celled stalk and a head consisting of 4-8 cells

spherical, with three pores, up to 40 microns in diameter, with a characteristic exine

pollen grains





fragments of inflorescence

represented by cells with thickened membranes and secretory ducts

**Fig. 1.** Microscopic diagnostic features of Calendulae flos (illustrations created using the AI service).

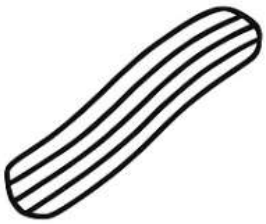
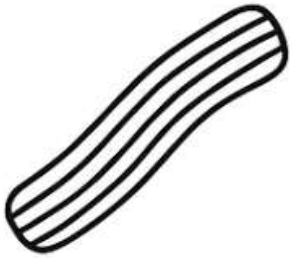
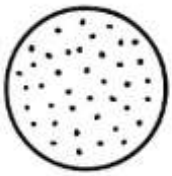
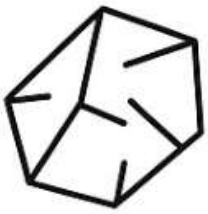
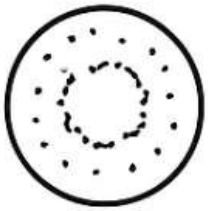
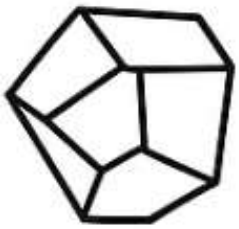
| SPhU | | Český Lékopis | |
|---|---|---|---|
|  |  |  |  |
| Glandular hairs | Mechanical fibers | Glandular hairs | Mechanical fibers |
|  |  |  |  |
| Pollen grains | Calcium crystals | Pollen grains | Calcium crystals |

**Fig. 2.** Characteristic microscopic features of Calendulae flos according to SPhU and Český Lékopis.

As shown in Fig. 1, both pharmacopoeias pay considerable attention to the presence of hairs on the surface of floral elements. In the SPhU, both glandular and multicellular hairs are described in detail, which is a characteristic feature for the identification of Calendula officinalis L. In the Český Lékopis, in addition to these structures, the diagnostic value of calcium crystals in the cells, as well as the shape of pollen grains, is emphasized. Thus, the approach of the Český Lékopis is more detailed and aimed at increasing the specificity of microscopic analysis. This reflects different levels of regulation: the Ukrainian Pharmacopoeia is focused on basic features, while the Český Lékopis emphasizes additional diagnostic criteria, which is important in international standardization practice.

**Comparative analysis.**

The comparison shows that the SPhU and the Český Lékopis provide a consistent list of basic microscopic structures characteristic of Calendulae flos. Both pharmacopoeias emphasize the importance of hairs (integumentary and glandular) and the structure of the epidermis of floral elements. At the same time, the differences lie in the details:

- SPhU provides a more complete description of pollen grains and the structure of the receptacle, which makes the method convenient for pharmacognostic identification in educational and research laboratories.
- Český Lékopis focuses on the presence of calcium crystals and the features of glandular hairs, emphasizing these features as key for diagnosis.

Thus, SPhU is focused on a comprehensive description of anatomical-diagnostic characteristics, while Český Lékopis is focused on the selection of a narrow spectrum of highly specific structures. This reflects different traditions in standardization, but at the same time complements each other, allowing for a more complete and reliable identification of Calendulae flos in different laboratory conditions.

**3. Identification methods.**

Identification methods play a key role in the pharmacopoeial standardization of medicinal plant raw materials, as they allow to confirm the presence of specific biologically active compounds and distinguish genuine raw materials from impurities or counterfeits. For Calendulae flos, the main marker substances are flavonoids, phenolic acid derivatives, and triterpene saponins, which determine its pharmacological activity.

**SPhU.** In SPhU, the method for identifying Calendulae flos is based on thin-layer chromatography. For analysis, alcohol extracts of flowers are used, which are applied to a sorbent (silica gel). Rutin, caffeic acid and chlorogenic acid are used as standard substances. After developing the chromatograms in ultraviolet light or using appropriate reagents, the Rf and color of the extract zones are compared with the zones of standard samples. This approach allows to confirm the presence of flavonoids and phenolic acids in the raw materials, which are the main quality markers.

**Český Lékopis.** In Český Lékopis, thin-layer chromatography is also used as the basic method for the identification of Calendulae flos. However, in Český Lékopis, the emphasis is on flavonoid compounds, in particular quercetin and isorhamnetin derivatives, as well as phenolic acids, among which chlorogenic acid derivatives occupy a leading place. In the Český Lékopis method, the use of several development systems is important, which increases the reliability of the analysis. In addition, in Český Lékopis, the requirements for mobile phases and reagents for visualization are more clearly specified, which contributes to better reproducibility of results in different laboratories.

**Differences in identification methods.** The comparison shows that both pharmacopoeias recognize TLC as the main method for identifying Calendulae flos, however, there are certain differences:

- in SPhU, rutin, caffeic and chlorogenic acids are used as marker substances, which ensures simplicity of analysis and accessibility of the method for routine laboratories;
- in Český Lékopis, the marker spectrum is broader, including quercetin and isorhamnetin derivatives, which allows for a more accurate characterization of the flavonoid profile;
- SPhU is focused on practical and rapid analysis, while Český Lékopis sets more stringent conditions for mobile phases and developers, which contributes to increased reproducibility of results.

Thus, the methods for identifying Calendulae flos in SPhU and Český Lékopis are generally consistent, but differ in the level of detail and emphasis. The Ukrainian Pharmacopoeia emphasizes the accessibility and universality of TLC analysis, while Český Lékopis emphasizes standardization and accuracy, which meets modern requirements of the European Union. Both approaches can be considered complementary, and their harmonization will contribute to the unification of pharmacopoeial standards and facilitate international quality control of Calendulae flos.

Identification methods are a key element of pharmacopoeial control, as they allow to confirm the authenticity of the raw material and the presence of biologically active substances in it. In SPhU and Český Lékopis, thin-layer chromatography is used for Calendulae flos, but there are certain differences in the approaches regarding the standards used and the conditions of the analysis. A table was compiled to compare the identification methods.

**Table 2.** Identification methods for Calendulae flos according to SPhU and Český Lékopis.

| Parameter | SPhU | Český Lékopis |
|---|---|---|
| Method | TLC | TLC |
| Solvents | Mixture of toluene, ethyl acetate and formic acid | Mixture of butanol, acetic acid and water |
| Comparison Standards | Rutin, caffeic acid, chlorogenic acid | Isorhamnetin-3-O-rutinoside, hyperoside, phenolic acid derivatives |
| Detection | Treatment with diazotizing reagent, viewing under UV light | Use of specific reagents for flavonoids, viewing under UV light |
| Result | Characteristic spots for rutin, caffeic and chlorogenic acids | Characteristic spots for isorhamnetin, hyperoside and other flavonoids |

Table 2 shows that both pharmacopoeias use thin-layer chromatography as the basic method for the identification of Calendulae flos, but differ in the choice of marker compounds and the composition of the mobile phases. SPhU focuses on rutin and hydroxycinnamic acid derivatives, while Český Lékopis uses a wider range of flavonoids, including isorhamnetin and hyperoside. This increases the specificity of the analysis and allows for the characterization of a more complete flavonoid profile. Thus, the SPhU method is simpler and more accessible for routine practice, while Český Lékopis is more detailed and scientifically sound, reflecting the pan-European pharmacopoeial control standards.

**4. Quantitative determination of flavonoids**

Flavonoids are the leading group of biologically active substances of Calendula officinalis L., which determine the anti-inflammatory, antioxidant, and immunomodulatory properties of the flowers of this plant. That is why in pharmacopoeial monographs, the quantitative determination of flavonoids is considered one of the key quality indicators of Calendulae flos.

**Spectrophotometric methods in SPhU.** The SPhU regulates the use of the spectrophotometric method in the visible part of the spectrum. The sample is prepared by extracting the dry raw material with 70% ethanol, after which the optical density of the resulting solution is measured at a wavelength of about 410 nm. For quantitative determination, a standard sample of rutin is used, which is used to calculate the flavonoid content in terms of hyperoside. The method is adapted to the conditions of routine laboratories and does not require complex equipment, which makes it accessible for wide practice.

**Český Lékopis approaches to quantitative analysis.** The Český Lékopis also uses the spectrophotometric method, but with some peculiarities. In Český Lékopis, more attention is paid to the conditions for extract preparation: the exact ratio of raw materials and extractant, infusion time, temperature control, and purity of solvents. For the quantitative determination of flavonoids, Český Lékopis focuses on the use of isorhamnetin-3-O-rutinoside and hyperoside as standard compounds. This approach allows for a broader characterization of the flavonoid profile and ensures increased accuracy and reproducibility of the analysis.

**Standards for the minimum content of flavonoids.** Despite certain methodological differences, both pharmacopoeias – SPhU and Český Lékopis both set the same standard for the minimum content of flavonoids: not less than 0.4% in terms of hyperoside. This indicates the consistency of approaches to assessing the quality of Calendulae flos in national and European pharmacopoeial practice. At the same time, Český Lékopis regulates stricter control of the purity of reagents and conducting parallel measurements to increase the reliability of the results.

Thus, the spectrophotometric methods established in the SPhU and Český Lékopis have a high degree of similarity, but differ in details. The Ukrainian Pharmacopoeia is focused on simplicity and accessibility of the analysis, while the Český Lékopis is focused on the rigor of the procedures and reproducibility of the results. Harmonization of these approaches provides a single quality standard, which is important for the international pharmaceutical market and the creation of standardized medicinal products based on Calendula officinalis L.

Quantitative determination of the flavonoid content in Calendulae flos is important, since it is these compounds that determine the pharmacological activity of the raw material. The SPhU and Český Lékopis use spectrophotometric methods, but there are differences in the details of sample preparation and the choice of standard substances. For clarity, the data are summarized in the table.

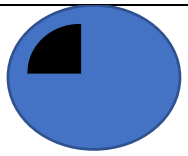
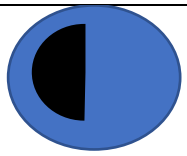
**Table 3.** Comparison of methods for the quantitative determination of flavonoids in Calendulae flos according to the SPhU and Český Lékopis.

| Parameter | SPhU | Český Lékopis |
|---|---|---|
| Method | Visible spectrophotometry | Visible spectrophotometry |
| Extractant | 70% ethanol | Ethanol with strictly regulated ratio of raw material to solvent |
| Wavelength | ~410 nm | ~410 nm |
| Standard substance | Rutin, calculated as hyperoside | Isorhamnetin-3-O-rutinoside and hyperoside |
| Minimum flavonoid content | Not less than 0.4% calculated as hyperoside | Not less than 0.4% in terms of hyperoside |
| Features of the method | Simplicity and accessibility for routine laboratories | Strict control of extraction conditions, mandatory parallel measurements |

Table 3 shows that both pharmacopoeias regulate the same minimum content of flavonoids (0.4% in terms of hyperoside), which indicates the consistency of the approaches. At the same time, the methods have certain differences: in SPhU, rutin is the main standard substance, while in Český Lékopis, isorhamnetin-3-O-rutinoside and hyperoside are additionally used, which allows for a more detailed assessment of the flavonoid profile. In addition, Český Lékopis provides for stricter control of extraction conditions and mandatory parallel measurements, which increases the accuracy and reproducibility of the results. While the SPhU approach ensures accessibility and convenience in practical activities, the Český Lékopis approach is focused on accuracy and harmonization with European standards.

**5. Quality indicators of Calendulae flos.**

Quality indicators of medicinal plant raw materials determine its suitability for further use in the production of medicinal products. These parameters include moisture, ash content, and the number of foreign impurities, which are common standardization parameters for most pharmacopoeial monographs. They ensure the stability of the raw material, prevent the development of microbiological contamination, and guarantee the preservation of biologically active substances.

| | |
|---|---|
|  **loss in mass upon drying (moisture)** |  **total ash content** |
| not more than 14% | not more than 11% |

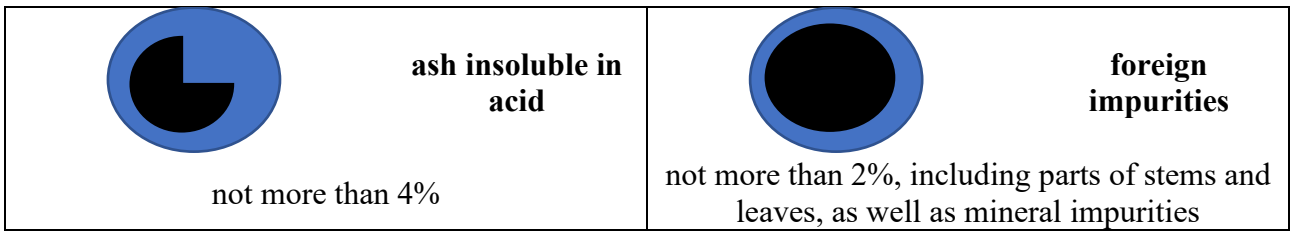



**Fig. 3.** Regulatory requirements for Calendulae flos are established by the State Pharmacopoeia of Ukraine.

Thus, the Ukrainian Pharmacopoeia pays attention to both physicochemical parameters and morphological impurities, which ensures comprehensive quality control.

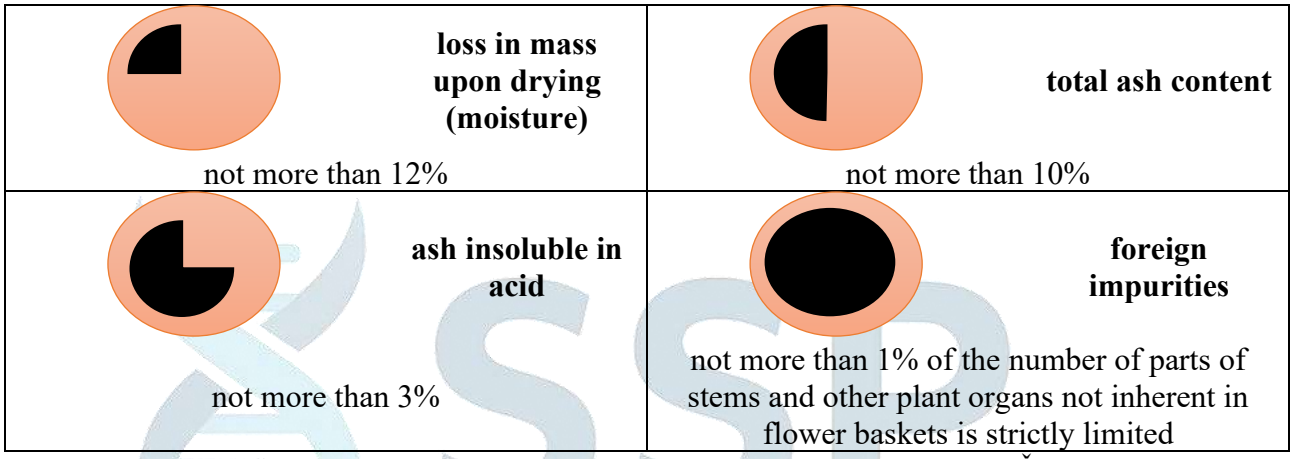



**Fig. 4.** Requirements for the main quality indicators for Calendulae flos set by Český Lékopis

Thus, Český Lékopis sets lower limit values for moisture and ash content, and puts forward stricter requirements for the purity of raw materials.

Determination of physicochemical quality indicators, such as moisture, ash content and the content of foreign impurities, is of key importance for establishing the suitability of Calendulae flos for medical use. The SPhU and Český Lékopis regulate similar parameters, but their regulatory values differ. A table has been compiled to compare the requirements.

**Table 4.** Comparison of physicochemical indicators of Calendulae flos according to SPhU 2.0 and Český Lékopis

| Indicator | SPhU | Český Lékopis |
|---|---|---|
| Loss on drying | Not more than 14% | Not more than 12% |
| Total ash | Not more than 11% | Not more than 10% |
| Acid insoluble ash | Not more than 4% | Not more than 3% |
| Foreign impurities | Not more than 2% | Not more than 1% |

Table 4 shows that both pharmacopoeias establish the same range of control parameters, but the Český Lékopis standards are more stringent. In particular, the permissible level of moisture and ash content in Český Lékopis is lower than in SPhU, and the maximum permissible content of foreign impurities is only 1% (versus 2% in SPhU). This indicates the increased requirements of Český Lékopis for the purity and stability of medicinal plant raw materials, which is consistent with European quality standards. In contrast, the Ukrainian standards are more flexible and practically oriented, which facilitates their use in routine pharmaceutical practice. Harmonization of these approaches can contribute to the creation of a single international standard for the control of Calendulae flos, necessary for integration into the global pharmaceutical market.

**Comparison and analysis.**

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Comparative analysis shows that SPhU and Český Lékopis regulate a similar range of quality parameters for Calendulae flos, but their values differ somewhat. The Ukrainian Pharmacopoeia allows higher limits for moisture and ash content, which makes the standards more adaptable to the conditions of procurement and storage in production practice. Český Lékopis, on the contrary, sets stricter criteria aimed at increasing the purity and stability of raw materials, focusing on the standards of the European Union.

Such differences are explained by different approaches: SPhU is focused on the accessibility and practicality of control, while Český Lékopis is focused on strict regulation and minimizing the risk of foreign components. Harmonization of these standards in the future will contribute to the creation of unified standards for the international pharmaceutical market, which is of particular importance to produce herbal medicines based on Calendula officinalis L.

| **SPhU** | **Český Lékopis** |
|---|---|
|  |  |
| Rutin<br>Caffeic acid<br>Chlorogenic acid | Isorhamnetin<br>Hyperoside<br>Phenolic acid derivatives |

**Fig. 5.** Thin-layer chromatography of flavonoids in Calendulae flos according to SPhU and Český Lékopis

To confirm the identity of Calendulae flos in SPhU and Český Lékopis, the method of thin-layer chromatography is used. It allows determining the presence of characteristic flavonoids and phenolic acid derivatives, which act as marker compounds. The figure shows a comparative TLC profile of Calendulae flos according to the requirements of SPhU and Český Lékopis.

As shown in Figure 4, both pharmacopoeias use thin-layer chromatography as the main method for the identification of Calendulae flos, but the marker compounds differ. In SPhU, the main standards are rutin, caffeic and chlorogenic acids, which allow for rapid confirmation of the

authenticity of the raw material. In Český Lékopis, the spectrum of markers is broader and includes isorhamnetin-3-O-rutinoside, hyperoside and phenolic acid derivatives, which provides a more complete characterization of the flavonoid profile. This difference emphasizes the desire of Český Lékopis to a higher level of specificity and unification of the analysis, while the Ukrainian standard is focused on the accessibility and practicality of routine control.

The results obtained indicate the relevance of harmonizing the requirements for the identification, quantification, and standardization of medicinal plant raw materials Calendula officinalis L. in accordance with the provisions of SPhU and Český Lékopis. It has been established that the main attention of both pharmacopoeias is focused on determining the content of biologically active substances, primarily flavonoids, which have pronounced antioxidant, anti-inflammatory, and reparative activity [33-35].

Studies of modern approaches to standardization show that methods for quantitative determination of flavonoids, particularly spectrophotometric and chromatographic, are basic in both national and European standards. Analyzing the results of studies by domestic and foreign authors, we can note the gradual introduction of innovative analytical technologies, in particular fluorescent probes, and visualization methods, which expand the possibilities of biochemical control of medicinal raw materials [36-37].

Publications of recent years emphasize the need for unification of approaches to pharmacopoeial analysis of Calendula officinalis L. raw materials, since different countries use different marker substances for quantitative determination - from rutin to isorhamnetin glycosides [38-40]. Such a difference in assessment criteria may affect the results of quality control, which necessitates the creation of harmonized methods considering the European Union pharmacopoeias.

A comparative analysis showed that the SPhU provisions comply with the basic principles of the European Pharmacopoeia, but require further elaboration regarding the definition of individual groups of biologically active compounds and the use of reference standards [41-42]. In Ukrainian practice, it is important to expand the analytical arsenal using high-resolution chromatographic systems, LC–MS methods, and spectrophotometry with differential analysis.

In addition, when developing standardized dosage forms based on Calendula officinalis L., it is necessary to consider not only the chemical composition, but also the pharmacological properties and stability of bioactive components during storage and technological processing. Studies confirm that the combination of chemical and pharmacotechnological methods allows to increase the accuracy of quality control of raw materials and finished products.

In summary, it can be noted that the harmonization of requirements between SPhU and Český Lékopis is of strategic importance for ensuring uniform standards for quality control of herbal medicines, increasing the level of pharmaceutical safety, and expanding the export potential of Ukrainian medicinal plant raw materials.

Further research should be directed to a multidisciplinary context: the creation of an integrated database of pharmacopoeial standards for use in pharmacotherapy regimens for health disorders, the search for new drugs, the testing of harmonized identification methods, the development of new generation monographs [43-61].

**Conclusions.** The comparative analysis of the quality indicators of Calendulae flos according to the monographs of SPhU and Český Lékopis showed both the presence of a significant number of common provisions and certain differences in the standardization of this medicinal plant raw material. Common features are the use of macroscopic and microscopic characteristics for identification, the use of thin-layer chromatography to confirm the presence of marker compounds, as well as the establishment of a minimum flavonoid content of at least 0.4% in terms of hyperoside.

The differences lie in the detail of the description and the strictness of the regulatory requirements. SPhU is characterized by a more practical orientation, with a detailed description of the structure of floral elements and the possibility of applying the methods in routine laboratory conditions. Český Lékopis, on the other hand, sets stricter standards for moisture, ash content, and impurities, and pays special attention to highly specific diagnostic signs, such as the presence of calcium crystals and the characteristics of glandular hairs.

Harmonization of pharmacopoeial standards between SPhU and Český Lékopis is of great importance for international pharmaceutical practice. It ensures the unification of quality control of medicinal plant raw materials, promotes the integration of Ukraine into the European pharmaceutical space and increases the competitiveness of herbal medicines on the world market.

A promising direction for further research is the use of standardized preparations of calendula officinalis as adjuvants in tuberculosis therapy regimens. Due to its anti-inflammatory, antioxidant and immunomodulatory properties, Calendula officinalis L. can reduce the intensity of inflammatory processes, improve the state of the immune system, and potentially reduce the risk of side effects from long-term anti-tuberculosis chemotherapy. This opens up new prospects for the integration of plant raw materials into modern approaches to the treatment of socially significant infectious diseases.

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