

Comparative evaluation of Packaging materials Used in Ayurvedic Formulations, Stability, Safety, Compatibility and Regulatory Perspective A Review

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Abstract

Ayurvedic formulations are gaining popularity because of their holistic approach. The physicochemical properties of the dosage form, together with its stability, safety, and compatibility, are highly dependent on the packaging material used, which should ensure preservation of the active principle, protection from microorganisms and physical damages during transportation and storage. At the same time, an inappropriate packaging material may compromise the quality of the formulation by degrading its active ingredients or interacting with them. This review discusses the physicochemical properties of the packaging materials (glass, HDPE, PET, PP, aluminium, laminates) used for Ayurvedic medicines. The present review focuses on the benefits and limitations of the use of different packaging materials for Ayurvedic formulations, including issues of stability and compatibility, extractables and leachables, analytical methods, and regulatory aspects. Additionally, this review highlights the recent advances and future perspectives in Ayurvedic formulations.

Keywords: Ayurvedic formulation; pharmaceutical packaging; stability; compatibility; safety; extractables and leachables; HDPE; Glass; Aluminium.

1. INTRODUCTION

Ayurveda is one of the world's oldest medical systems that is using naturally-derived formulations for healing and maintaining health. Herbal drugs play a far-reaching role in Ayurvedic formulations which include churna, vati, kwatha, asava, arista, taila, ghrita, syrup, and capsules. Ayurvedic medicines and formulations are witnessing a tremendous rise in demand in the global market. Hence, special attention should be paid to choosing appropriate packaging materials for Ayurvedic formulations to ensure the quality of the drug.[1,2]

The selected packaging should protect the formulation from mechanical damage and the destructive effects of light, oxygen, temperature, and microorganisms. At the same time, improper packaging may negatively affect the formulation, for example, by adsorbing or desorbing some of its components or introducing foreign substances. This review will focus on the physicochemical properties of pharmaceutical packaging materials used in Ayurvedic formulations, including glass, HDPE, PET, PP, alumin

ium, and laminates. Particular attention will be paid to compatibility and stability. The current review will highlight the analytical methods used to evaluate Ayurvedic formulations and their regulatory aspects. Moreover, this review will identify the research gaps in the field, which, if filled, will allow developing new pharmaceutical packaging materials and improve the understanding of the stability and safety of Ayurvedic formulations.[1,2]

2. Ayurvedic Formulation

Ayurvedic drugs are traditional medicine preparations produced according to the rules and regulations specified by Ayurveda. Hence, Ayurveda medicines and preparations are predominantly derived from herbal, mineral, and animal sources. Preparations are produced in various forms, including churna or Vati/Gutika or tablets, Kwatha liquid extract, Asava/Arishta or fermented liquids, Taila or medicated oil, Ghrita or medicated ghee, Syrup, and capsules. The choice of packaging material is dictated by the properties of the preparation itself since most of the aforementioned forms are hygroscopic. This is why the formulation should be protected from moisture, air, and light. Moreover, some forms of Ayurvedic preparations contain volatile components or may require special storage conditions to avoid microbial contamination. For these reasons, it is vitally important to assess the stability and compatibility of potential packaging materials with each of the Ayurveda formulations.[1,2]

3. Importance Of Packaging in Ayurvedic Medicines

Packaging is an important consideration for Ayurvedic medicinal products as it helps in protecting, preserving, and transporting the product while ensuring convenience to the consumer.

The most appropriate packaging material is the one that is chemically inert, nontoxic, mechanically strong, economical, and can provide protection against light, moisture, oxygen, and other environmental factors. [1,2,16]

4. Packaging Materials Used in Ayurvedic Formulations

4.1 Glass

Glass is a preferred material for Ayurvedic liquid formulations due to its inertness and excellent barrier properties.

Advantages Disadvantages Indications

- Moisture and oxygen barrier
- Chemically inert
- Does not allow migration of plasticizers
- Recyclable and reusable
- High density and brittle
- Expensive to transport

Eg. Asava, Arishta, Kwatha, herbal syrups, medicated oil, Ghrita, and extracts [5, 11]

4.2 High-density polyethylene (HDPE)

HDPE is a cost-effective and tough material suitable for Ayurvedic solid dosage forms.

Advantages

- Light in weight
- Offers good resistance to moisture
- Inert to most chemicals

- Cost-effective

Disadvantages

- Moderate oxygen permeability
- Migration of additives
- Limited protection from light

Eg. Churna, tablets, capsules, and dry extracts [6]

4.3 Polyethylene terephthalate (PET)

PET is a thermoplastic polyester polymer with good oxygen barrier properties.

Advantages

- Light in weight
- Offer transparency and good oxygen barrier
- Easy to recycle

Disadvantages

- Poor heat and moisture resistance

E.g. Herbal syrups, oral liquids, and tonics

4.4 Polypropylene (PP)

PP is a thermoplastic polymer known for its thermal stability and chemical resistance. [14,15,17]

Advantages

- Resistant to heat
- Light in weight
- Sterilizable

Disadvantages

- Poor UV resistance
- Moderate oxygen permeability

E.g. Tablet containers, powder containers, and closures

4.5 Aluminium

Aluminium is a strong metal with good moisture, oxygen, and light barrier properties. [1,16,18]

Advantages

- Excellent barrier to light, oxygen, and moisture
- Long shelf life
- Recyclable

Disadvantages

- Costly
- Requires coating to prevent acid attack

Eg. Blister packs, tubes, sachets, foil pouches, creams, and ointments

4.6 Laminated Packaging

Laminated packaging offers mechanical strength and excellent barrier properties. [9,18]

Advantages

- Excellent moisture and oxygen barrier
- Good flexibility and lightweight

Disadvantages

- Difficult to recycle
- High cost

Eg. Herbal powders, granules, instant products, and single-dose sachets

5. Comparison and Evaluation of Different Packaging Materials

Glass: Inert, good barrier properties. Heavier and more expensive. Liquids, oils, syrups [1,12,14,16,17]

HDPE: Relatively inexpensive, moderately resistant to moisture ; moderate moisture permeability Powders and tablets

PET: Transparent, good barrier to gases Moderate resistance to heat Syrups, oral liquids

PP: Resistant to high temperatures Poor resistance to UV light Containers, closures

Aluminium: Excellent barrier to moisture, oxygen, and light Higher cost compared to other materials Blister packs, tubes, sachets

Laminated packaging: Excellent overall protection Cannot be easily recycled ; sachets, single-dose packing

6. Conclusion

Based on the comparison and evaluation of different packaging materials provided in the table above, the following recommendations can be made. Glass is the most suitable material for packaging liquid medication due to its inertness. HDPE is the most appropriate material for powders and tablets because of its relatively low cost. Oral liquids and syrups are best packaged in PET due to its transparency and good barrier properties. PET is recommended for applications that require resistance to high temperatures. Foils and sachets are the most suitable packaging for medication exposed to moisture, oxygen, and light. Lastly, laminated packaging should be used for sachets due to its excellent protection and good barrier properties.

7. Comparative Evaluation of Packaging Materials

Selection of the most appropriate packaging material is of particularly important for ayurvedic formulations to ensure the quality, stability, and safety of the final product. It is therefore necessary to consider the materials' chemical inertness, barrier properties, mechanical properties, cost, and compatibility with the formulation. The choice of packaging material is critical in Ayurveda to preserve the quality of formulations. The following factors must be considered while selecting a suitable packaging material. [1,12,14,16,17]

Material Properties

- **Glass**

It offers excellent chemical inertness and has good barrier properties.

Advantages, Limitations & Application

- Excellent moisture and oxygen barriers
- Chemically inert
- Recyclable
- Heavy
- Brittle
- Higher transportation cost

Used for packaging asava, arishta, herbal syrups, medicated oils, and herbal extracts.

- **HDPE**

It has good mechanical properties and is economical.

Advantages, Limitations & Application

- Lightweight
- Economical
- Moisture-proof
- Poor oxygen barrier
- Migration of additives

Used for packaging churna, tablets, capsules, and herbal extracts [6].

- **PET**

It has good transparency and offers improved gas barrier.

Advantages, Limitations & Application

- Lightweight
- Transparent
- Recyclable
- Moderate heat and moisture resistance

Used for herbal syrups, oral liquids, and liquid extracts.

- **Polypropylene**

It has good thermal and chemical resistance.

Advantages, Limitations & Application

- Good heat resistance
- Lightweight
- Chemically stable
- Poor UV resistance

Used for ointment, cream, and tablet containers and closures [7].

- **Aluminium**

It offers excellent moisture, light, and oxygen barriers.

Advantages, Limitations & Application

- Excellent moisture and oxygen barriers
- Long shelf life
- Costly
- Corrosive

Used for tablets, capsules, ointments, blisters, and sachets [11].

- **Laminated film**

It offers good moisture and oxygen barriers.

Advantages, Limitations & Application

- Excellent moisture and oxygen barriers
- Lightweight

Difficult to recycle . Used for packing herbal powders, granules, sachets, and instant preparations.

8. Stability

The stability of Ayurvedic formulation is influenced by the type of packaging material. The following parameters are considered while determining the stability of Ayurvedic formulation:[1,12,13,16]

1. Physical stability: It includes the change in physical appearance, color, odor, texture, and moisture content.
2. Chemical stability: It includes the degradation of active phytoconstituents, oxidation, hydrolysis, and changes in pH.
3. Microbiological stability: It includes the contamination and growth of microorganisms.
4. Photochemical stability: It includes the photo-degradation of phytochemicals like curcumin and essential oils. The most common packaging material that offers protection against UV light are amber glass and aluminium [3].

9. Safety Consideration:

The packaging material should not contain harmful substances that could be transferred to the formulation. The following toxicological parameters must be considered while selecting the packaging material:

1. Migration of harmful plasticizers such as diethyl phthalate (DEP), dibutyl phthalate (DBP), and diethylhexyl phthalate (DEHP).
2. Contamination of heavy metals.
3. Presence of monomers.
4. Migration of printing inks and adhesives.
5. Corrosion products.

10. Compatibility

The compatibility study determines the physicochemical interactions between the formulation and the packaging material.

following parameters are considered while performing the compatibility study: [1,7,12,13]

1. Adsorption or absorption of active constituents.
2. Migration of additives.
3. Moisture and oxygen permeability.
4. Change in color and odour.
5. Loss of potency.
6. Formation of toxic degradation products.

Compatibility study helps in selecting the most appropriate packaging material for a given formulation. It also ensures the quality and stability of the formulation during storage.

11. Extractables and Leachable (E&L)

Extractables and leachables (E&L) studies are performed to assess the compatibility of packaging material with the Ayurvedic formulation. Extractables are those compounds that are extracted from the packaging material by using aggressive solvents, whereas leachables are those compounds that get leached out in the drug product during storage. Examples of such compounds are phthalates (DEHP, DBP, DEP), bisphenol A (BPA), antioxidants, residual monomers, and heavy metals. The E&L studies help in ensuring the safety, stability, and regulatory compliance of the final drug product [8,9,11].[1,7-9,12,13]

12. Analytical Techniques

The compatibility of the packaging material is assessed by employing various analytical techniques like: Analytical Technique Purpose

- HPLC : For the identification of marker compounds and degradation products.
- GC–MS : For the identification of plasticizers and volatile contaminants.
- LC–MS/MS for the identification of trace-level leachable and unknowns.
- FTIR & Raman Spectroscopy for the identification of polymer and its compatibility.
- ICP–MS/ICP–OES : For the identification of heavy metals and trace elements.
- UV–Visible Spectroscopy as a routine analytical technique.[11]

13. Regulatory Aspects

The packaging material used for Ayurvedic formulations should be compatible with the formulation and should meet the regulatory guidelines.

The regulatory agencies like AYUSH, WHO, ICH, USP, and FDA have laid down certain guidelines for the packaging of Ayurvedic formulations. The details are furnished below.

Regulatory Agency Guidelines

- AYUSH GMP and stability guidelines.
- WHO Guidelines for packaging, labeling, and quality control.
- ICH Q1A(R2), Q3D, Q8, and Q9 guidelines.
- USP USP <1663>, <1664>, and <661> chapters.
- FDA Guidance on container–closure systems and migration studies.

The guidelines mentioned above help in selecting the suitable packaging material and assessing the compatibility of the packaging material with the formulation in order to ensure the stability of the formulation during the shelf life.[1-10]

14. Research Gap

While some studies have focused on pharmaceutical packaging materials, there is a need for further research comparing the compatibility of different packaging materials with Ayurvedic formulations. Additional studies are needed to evaluate the long-term stability, extractables and leachables, and migration of contaminants specific to Ayurvedic preparations.[1,7,12,13]

15. Future Perspective

Future research endeavors should prioritize the development of sustainable packaging materials, innovative smart packaging solutions, advanced analytical techniques, and standardized compatibility protocols to enhance the quality and safety of Ayurvedic formulations.

16. Conclusion

The choice of packaging material is of utmost importance for the stability, safety, and quality of Ayurvedic formulations. Glass, HDPE, PET, PP, aluminium, and laminated packaging can be considered as suitable options depending on the dosage form of the formulation. The

compatibility studies, along with modern analytical techniques and adherence to regulatory guidelines, play a crucial role in ensuring the selection of appropriate packaging material for Ayurvedic formulations.[1,12-17]

REFERENCE

1. Jenke D. Evaluation of the chemical compatibility of plastic contact materials and pharmaceutical products; safety considerations related to extractables and leachable. *J Pharm Sci.* 2007;96(10):2566-2581. doi:10.1002/jps.20984.
2. Al Salloum H, Saunier J, Tfayli A, Yagoubi N. Studying DEHP migration in plasticized PVC used for blood bags by coupling Raman confocal microscopy to UV spectroscopy. *Mater Sci Eng C Mater Biol Appl.* 2016; 61:56-62. doi: 10.1016/j.msec.2015.12.008.
3. Andjelković T, Bogdanović D, Kostić I, Kocić G, Nikolić G, Pavlović R. Phthalates leaching from plastic food and pharmaceutical contact materials by FTIR and GC-MS. *Environ Sci Pollut Res Int.* 2021;28:31380-31390. doi:10.1007/s11356-021-12724-0.
4. Huang J, Nkrumah PN, Li Y, Appiah-Sefah G. Chemical behavior of phthalates under abiotic conditions in landfills. *Rev Environ Contam Toxicol.* 2013; 224:39-52. doi:10.1007/978-1-4614-5882-1_2.
5. Cao XL, Zhao W, Dabeka R. Di-(2-ethylhexyl) adipate and 20 phthalates in composite food samples from the 2013 Canadian Total Diet Study. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess.* 2015;32(11):1893-1901. doi:10.1080/19440049.2015.1079742.
6. Saad M, Bujok S, Kruczała K. Non-destructive detection and identification of plasticizers in PVC objects by means of machine learning-assisted Raman spectroscopy. *Spectrochim Acta Mol Biomol Spectrosc.* 2024;322:124769. doi:10.1016/j.saa.2024.124769.
7. Kushwah V, Münzer J, Feenstra V, Mohr S, Paudel A. Impact of extractables/leachables from filter materials on the stability of protein-based pharmaceutical products. *AAPS PharmSciTech.* 2022;23(7):233. doi:10.1208/s12249-022-02374-x.
8. Gökekin Y, Bulut M, Çetin Ersen B, Güleli M, Çalışkan C. Evaluation and characterization of different extraction methods for obtaining extractable and leachable materials from rubber stopper systems used in pharmaceutical products. *Eur J Pharm Biopharm.* 2025; 216:114844. doi: 10.1016/j.ejpb.2025.114844.
9. Kurmi M, Prasad S, Panduranga NS, Jayaraman K, Bhutani H. Identification of extractables by liquid chromatography-high resolution mass spectrometry: a case study to understand the extraction profile of different disposable syringes. *J Pharm Biomed Anal.* 2020;191:113602. doi:10.1016/j.jpba.2020.113602.
10. Biedermann M, Grob K. Advantages of comprehensive two-dimensional gas chromatography for comprehensive analysis of potential migrants from food contact materials. *Anal Chim Acta.* 2019;1057:11-17. doi: 10.1016/j.aca.2018.10.046.
11. United States Pharmacopeia. General Chapter <1663>: Assessment of Extractables Associated with Pharmaceutical Packaging/Delivery Systems. USP-NF. Rockville, MD: United States Pharmacopeia; 2020. doi:10.31003/USPNF_M7126_03_01.
12. United States Pharmacopeia. General Chapter <1664>: Assessment of Drug Product Leachables Associated with Pharmaceutical Packaging/Delivery Systems. USP-NF. Rockville, MD: United States Pharmacopeia; 2022. doi:10.31003/USPNF_M7127_02_01.

13. United States Pharmacopeia. General Chapter (661): Plastic Packaging Systems and Their Materials of Construction. USP-NF. Rockville, MD: United States Pharmacopeia; 2026 for the currently indexed version. doi:10.31003/USPNF_M99420_07_01.
14. United States Pharmacopeia. General Chapter <665>: Plastic Components and Systems Used to Manufacture Pharmaceutical Drug Products and Biopharmaceutical Drug Substances and Products. USP-NF. Rockville (MD): United States Pharmacopeia; 2022. doi:10.31003/USPNF_M11135_02_01.
15. U.S. Food and Drug Administration. Container closure systems for packaging human drugs and biologics: guidance for industry. Rockville (MD): U.S. Food and Drug Administration; 1999.
16. Fifiield FW, Kealey D. Principles and Practice of Analytical Chemistry. 5th ed. Chichester: Wiley; 2010. ISBN 978-0-632-05384-1.
17. Ball DJ, Norwood DL, Stults CLM, Nagao LM, editors. Leachables and Extractables Handbook: Safety Evaluation, Qualification, and Best Practices Applied to Inhalation Drug Products. Hoboken, NJ: John Wiley & Sons; 2012. ISBN 978-0-470-17365-7. doi:10.1002/9781118147672.
18. Fifiield FW, Kealey D. Principles and Practice of Analytical Chemistry. 5th ed. Chichester: Wiley; 2010. ISBN 978-0-632-05384-1.
19. Norwood DL, Stults CLM, Nagao LM. Analytical best practices for the evaluation and management of extractables and leachables in orally inhaled and nasal drug products. In: Ball DJ, Norwood DL, Stults CLM, Nagao LM, editors. Leachables and Extractables Handbook. Hoboken, NJ: John Wiley & Sons; 2012. doi:10.1002/9781118147672.ch10.