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Assessment of packaging, labelling, and physicochemical quality of herbal medicines marketed for typhoid in the Kumasi Metropolis

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ABSTRACT

Many Ghanaians depend on herbal remedies to treat typhoid, a serious infection caused by *Salmonella typhi*, which remains highly prevalent in Ghana. This study aimed to assess the labelling, packaging and some physicochemical characteristics of herbal medicines marketed for typhoid in Kumasi Metropolis. A market survey of the products was carried out at purposively selected pharmacies, OTC outlets, and herbal shops in the Kumasi Metropolis (Adum and Oforikrom). Ten liquid products (P1–P10) were selected according to strict inclusion and exclusion criteria and visually inspected. For brands present at multiple locations, outlets were selected using simple random sampling. Additionally, the pH, extract weight per dose (EWD), and relative density of each sample were measured and analysed using principal component analysis. Individual products contained between two herbs (P-2, P-3, P-6) and up to twelve different herbs (P-9). A significant proportion of the products (n = 7) lacked package inserts and secondary packaging. Eight (8) products lacked accompanying dosing devices, while all the products included the manufacturer's address on the primary packaging. Other indications noted on packaging included abdominal pains (18.18%), appetite loss (9.10%), malaria (45%), jaundice (18.18%), and peptic ulcer (9.10%). The products exhibited a relative density range of 0.9998 to 1.006, with pH values between 5.0 and 7.02. The EWD varied from 0.05 g (P-3) to 0.96 g (P7). Most products had intact primary packaging and contained basic identification and traceability information; however, important deficiencies were identified in dosing information, patient-use information, and packaging-related requirements. Nevertheless, regulatory authorities should conduct routine inspections of marketed products to ensure herbal products remain safe for consumption.

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1. Introduction

Typhoid is a serious infection caused by *Salmonella typhi*, usually transmitted via contaminated food and water (Popa & Popa, 2021). Once ingested, *Salmonella typhi* multiply and spreads into the bloodstream. Ghana is a country endemic for typhoid (Acosta-Alonzo *et al*., 2020). The Global Burden of Disease (GBD) study estimates that in 2019, there were at least 65,856 cases of typhoid and 1,150 deaths caused by it. Moreover, typhoid resulted in the loss of 88,249 disability-adjusted life years (Mahmoud *et al*., 2023).

Herbal medicines encompass finished products, herbal preparations, herbs, and herbal materials that contain active ingredients, plant parts, or other plant components, or combinations of these (Alamgir, 2017). Increased awareness of the benefits of herbal medicines as alternatives to allopathic drugs, along with concerns over the adverse effects of conventional pharmaceuticals, has driven demand for herbal medicinal products (Ahmad Khan & Ahmad, 2019; Ekor, 2014).

Many consumers mistakenly believe herbal remedies are inherently safe; however, the diverse composition of herbs and their extracts, combined with regional regulations, presents significant challenges for quality control, standardisation, and classification (Govindaraghavan & Sucher, 2015; Kumari & Kotecha, 2016). Additionally, some herbal remedies contain pollutants and adulterants, further exacerbating these issues (Zhang *et al*., 2012). However, as the market continues to grow, the clinical, financial, health, and pharmaceutical value of these products has also increased, emphasising the importance of monitoring their quality and safety (Muyumba *et al*., 2021).

In Ghana, around 65% of people depend solely on herbal medicine for their basic healthcare needs. Most of these herbal products, licensed by the Food and Drugs Authority (FDA) of Ghana for sale in the country, are primarily available in liquid form (Agyeman-Duah *et al*., 2017; Asase, 2023).

In 2021, approximately 50% of the 615 herbal products analysed at the Centre for Plant Medicine Research (CPMR) failed to meet quality control standards (Asase, 2023). However, literature on the quality of herbal dosage forms remains limited. This study aims to address this gap by systematically examining the packaging, labelling accuracy, and physicochemical properties of herbal medicines marketed for typhoid, providing valuable insights for regulators, manufacturers, and consumers.

2. Materials and methods

2.1. Market survey and collection of samples

A market survey of herbal medicines marketed for typhoid was conducted at purposively sampled pharmacies, over-the-counter (OTC) medication outlets, and herbal shops in the Kumasi Metropolis (specifically, Adum and Oforikrom) from May to July 2024, based on product availability.

Products were included in the study if they were registered by the Food and Drugs Authority, in liquid herbal forms and explicitly labelled as “anti-typhoid" or verbally marketed by vendors for typhoid treatment or management. Included products were polyherbal or single-herb liquid formulations derived from plant material, sold in their original sealed, unopened containers. The study excluded non-liquid dosage forms, orthodox anti-typhoid liquid dosage forms, products that were opened, expired, or visibly expired, and duplicate samples of the same brand or batch from the same vendor. Ten (10) products met the inclusion criteria, and all were included in the study. When a brand was available at multiple outlets, simple random sampling was used to select the outlet for sample collection. Each outlet received a unique number, and a random number generator (random.org) selected the outlet from which the sample was obtained. Three bottles from the same batch were purchased to enable triplicate analysis during physicochemical testing, ensuring reliable and reproducible results for each product.

2.2. Packaging evaluation and visual inspection

Details such as the product name, batch numbers, FDA registration numbers, manufacturing and expiry dates, and active ingredients with their dosages were recorded. Additionally, the visual inspection tool previously developed by Amekyeh *et al*. (2024) was used to check specific details such as visible defects, damage, or irregularities in the packaging materials and design, the product presentation, and whether the product is stored under appropriate conditions for consumption. The product labels were cross-referenced with the Food and Drugs Authority Guideline on Labelling of Drugs (FDA/DNC/GDL – 12/02) and the World Health Organisation’s BE AWARE Tools for Visual Inspection of Medicines to ensure compliance with mandatory labelling requirements (FDA, 2024; Schiavetti *et al*., 2020; WHO, 2023)

2.3. Physicochemical properties

2.3.1. Seal integrity test

The method described by Osei-Asare *et al*. (2023) was adopted for the study. Briefly, a glass beaker was filled with water mixed with a dye. After inverting each herbal product and securing it on a retort stand, the caps were fully submerged. The setup was then monitored for bubbles over 30 minutes.

2.3.2. pH

A digital pH meter (Hanna HI2215, Italy) with a suitable electrode for liquid samples was used to measure pH. The device was calibrated with standard buffer solutions that cover the expected pH range of the samples. Each sample was thoroughly shaken, then 10 mL was transferred into a clean, dry 25 mL beaker. The pH electrode was carefully immersed in the sample, ensuring it was well suspended and free of air bubbles. The pH reading was allowed to stabilise before recording. Triplicate readings were carried out.

2.3.3. Relative density

The relative density of each herbal mixture was determined using a liquid pycnometer. Initially, the weight of the stopper and pycnometer was recorded. Then, the weights of each sample and equal volumes of water were measured separately. The relative density was determined by dividing a sample's weight by the weight of the corresponding reference mass of water. All measurements were performed in triplicate at 30±2 °C.

2.3.4. Extract weight per dose determination

The previously validated protocol described by Amekyeh and colleagues was adapted. Briefly, 50 mL of each product was transferred into previously weighed, labelled, and dried dishes and subsequently dried in a hot-air oven at 60°C for 72 hours to constant weight. After drying, dishes were cooled in a desiccator and reweighed to determine the weight of the dried extract (Amekyeh *et al*., 2024). The Extract weight per dose (EWD) was calculated using Eq. (1). Triplicate determinations were carried out for each product.

$$EWD = \frac{\text{Weight of dried residue}}{\text{Volume dried}} \times \text{Dose volume} \quad (1)$$

2.4. Data analysis

Data were analysed using GraphPad Prism (version 10.4.2) and Microsoft Excel (Office LTSC). Descriptive statistics summarised key findings, and normality and homogeneity of variance were assessed before conducting inferential tests. A one-way ANOVA was performed to identify significant differences between the samples. The Brown–Forsythe test confirmed equal variances across groups for pH ($F_{9,20}$ = 1.039, P = 0.4450), relative density ($F_{9,20}$ = 0.7725, P = 0.6429), and extract weight per dose ($F_{9,20}$ = 0.4266, P = 0.9052). When significant differences were found, Tukey's post hoc test was employed for pairwise comparisons. Each product was analysed in triplicate using three separate bottles from the same batch (not repeated measures from a single bottle) to ensure reliable, reproducible results. Additionally, Principal Component Analysis (PCA) was conducted with OriginPro 2024 (OriginLab Corporation, Northampton, MA, USA) to examine variability in the physicochemical and cost-related parameters (cost, relative density, weight/dose, child dose/bottle, adult dose/bottle, and pH) measured across the ten herbal products. Before analysis, each variable was standardised, and PCA was performed on the correlation matrix. The dataset contained no missing values. Product groupings were initially qualitatively identified by analysing the distribution of sample scores in the PCA biplot. To statistically support these groupings, hierarchical cluster analysis (HCA) was subsequently performed on the same standardised dataset using Euclidean distance and Ward's linkage method.

3. Results and Discussion

3.1. Packaging and physical appearance

Packaging, particularly in pharmaceutical products, is ubiquitous and fundamentally linked to drug stability, efficacy, and patient safety. Packaging acts as a primary barrier that preserves drug quality by protecting it from environmental hazards, such as microbial contamination, and maintaining the product's physicochemical integrity. Packaging also facilitates identification, ensures dose compliance, and security through features like serialisation and child-resistant closures (Chaliha *et al*., 2013; Kumar, 2023; Thakur, 2025). The results (Table 1) showed that a substantial proportion of products (n = 7, 70%) lacked package inserts because they lacked secondary packaging materials. Similar studies on herbal products have highlighted this issue. Indeed, as revealed by Amekyeh and colleagues, 82.35% of sampled liquid antimalarial herbal preparations on Ghanaian markets lacked packaging inserts (Amekyeh *et al*., 2024). Package inserts contain valuable information such as dosage, contraindications and other essential details that ensure positive therapeutic outcomes (Shruti *et al*., 2016). Moreover, despite the prevailing dogma that patients rarely read them because of low literacy rates, studies have shown that well-designed patient information leaflets can improve patient knowledge, increase medication adherence, and reduce medication errors (Guzenda *et al*., 2025; Wrench *et al*., 2019). Additionally, it is also a regulatory requirement (Young *et al*., 2018).

Most products (80%, n=8) did not include dosing devices. This absence of dosing aids could lead patients to use household devices for administration, increasing the risk of severe toxicity (Bayor *et al*., 2010). Furthermore, many products lacked side-effect labels, with only 20% (P-7 and P-9) providing information on adverse effects, making it difficult for patients to notice or report side effects. Regulators should require all products to display potential side effects clearly on the packaging.

All sample labels, except for P-3, P-8, and P-9, were legible and permanent; however, the primary and secondary packaging labels matched in all cases. The legibility and indelibility of labels serve as security features that prevent products from being easily tampered with or counterfeited, making them more traceable and identifiable (Spink *et al*., 2011). Notwithstanding this, the products were readily recognisable and traceable through the primary packaging, as they contained all the necessary information. The specific herbs and amounts used in preparation were listed on all the products (either primary or secondary packaging or both).

Notably, each product exhibited a uniform and consistent texture, free from lumps, clots, and foreign matter particles. This may indicate good physical quality and stability, likely due to an effective production process and good primary packaging (amber plastic) (Amekyeh *et al*., 2024). However, these potential internal quality benefits may be seriously compromised by the dosing and safety information deficiencies discussed earlier.

Table 1
Results of product visual inspections

Parameter	Yes, n (%)	No, n (%)
Packaging		
Is there a Secondary packaging?	3 (30)	7 (70)
Is the secondary packaging intact?	3 (30)	7 (70)
Is the bottle intact?	10 (100)	0 (0)
Is the closure of the bottle intact and airtight?	9 (90)	1 (10)
Does the primary packaging clearly specify the storage conditions of the medicine?	7 (70)	3 (30)
Does the product come with a package insert?	3 (30)	7 (70)
A dosing device is provided with the product.	2 (20)	8 (80)
Does the label on the carton match the label on the bottle?	3 (30)	7 (70)
Are all the details on the labels legible and indelible?	7 (70)	3 (30)
Symbol (®) follows the trade name.	3 (30)	7 (70)
Side effects stated.	2 (20)	8 (80)
Identification		
Secondary packaging contains the following information on the outer side.		
Amount(s) of active ingredient(s)	3 (30)	7 (70)
Expiry date in uncoded form	3 (30)	7 (70)
Primary packaging displays the following information on the outer side.		
Amount(s) of active ingredient(s)	10 (100)	0 (0)
Active ingredient(s) name(s)	10 (100)	0 (0)
Dosage		
Dosage clearly indicated on primary packaging	10 (100)	0 (0)
Dosage clearly indicated on secondary packaging	3 (30)	7 (70)
Traceability		
Secondary packaging carries the following information on the outer side.		
Name and address of manufacturer OR company/person responsible for placing the product on the market	3 (30)	7 (70)
Batch number	3 (30)	7 (70)
Primary packaging bears the following information on the outer surface side.		
Name and address of the manufacturer or company/person responsible for placing the product on the market	10 (100)	0 (0)
Batch number	10 (100)	0 (0)
Approval/registration number	10 (100)	0 (0)
Physical Appearance		
The colour of the product is homogeneous	10 (100)	0 (0)
The product has a uniform texture, without lumps, clots, or foreign particles	10 (100)	0 (0)

Table 2
Details about packaging specifics and sample costs

Code	Manufacturing date	Expiry date	Primary packaging	Secondary packaging	Volume (mL)	Cost of bottle (GHS)
P-1	03/24	03/24	Amber Plastic	Paper	750	30
P-2	01/23	01/26	Amber Plastic	–	1000	20
P-3	08/23	08/26	Amber Plastic	–	800	20
P-4	06/23	06/26	Amber Plastic	–	500	20
P-5	01/24	01/26	Amber Plastic	–	750	25
P-6	07/23	07/25	Amber Plastic	–	1000	25
P-7	01/24	01/26	Amber Plastic	Paper	330	18
P-8	12/23	12/26	Amber Plastic	–	500	20
P-9	02/24	02/26	Amber Plastic	–	330	20
P-10	10/23	10/25	Amber Plastic	Paper	500	20

–, not applicable.

3.2. Dose and cost of products

The study found that all bottles listed daily dosages, but 70% (n = 7) did not specify a treatment duration on their labels (see Table 3). This omission is clinically significant. Treatment duration is a key therapeutic parameter for anti-infectives. In fact, typhoid management guidelines recommend 7–14 days or 5 days after fever ends (CDC, 2024). Insufficient treatment risks about a 10% relapse rate (CDC, 2024; Masuet-Aumatell & Atouguia, 2021; Veeraraghavan *et al*., 2018). Products missing duration information may lead to premature termination of drug therapy, which can cause antimicrobial resistance and relapse, or to unsupervised extended use. This also highlights a labelling compliance issue. Indeed, the WHO guidelines require duration of use as a label element for products with therapeutic claims (WHO, 2018). Since these products are used for serious bacterial infections, the 70% omission rate needs regulatory scrutiny.

P-2 did not specify an age category for children, while P-10 did not mention a dosage for children. The labels for P-1, P-5, P-7, and P-8 specified an adult age of ≥ 18 years, while most product labels listed a children's age range of 12–17 years (see Table 3). The variations, and sometimes the complete absence, of paediatric dosing regimens across products raise significant concerns about how paediatric dosing for these complex herbal formulations is determined beyond meeting regulatory requirements. Typically, paediatric doses of single-ingredient medicines are mostly based on pharmacokinetic studies or known weight/age calculations (Batchelor & Marriott, 2015; Khan *et al*., 2022). However, for several polyherbal products, it is often unclear, with some practitioners treating the age group as "small adults" by simple extrapolation from adult doses (Ferro, 2015). This approach is problematic because children differ from adults in several pharmacological processes, and simple extrapolations may cause adverse outcomes. The lack of a clear, evidence-based rationale for paediatric dosing is a significant gap that manufacturers and regulators must address through increased transparency and more precise paediatric-specific dosing guidelines.

Numerous factors influence the final product cost, including materials used, their quality (grade), production expenses, and other excipients. The amount of active ingredients and the volume of primary packaging directly affect the finished product price (Mubarak, 2020). Bottle volumes ranged from 330 to 1000 mL, and prices ranged from GHS 18 to 30 (Table 2). Fig. 1 illustrates how the number of daily doses for adults and children affects bottle cost. Products with larger volumes, such as P-6 and P-1, which provide more daily doses, tend to be priced higher than those with smaller volumes.

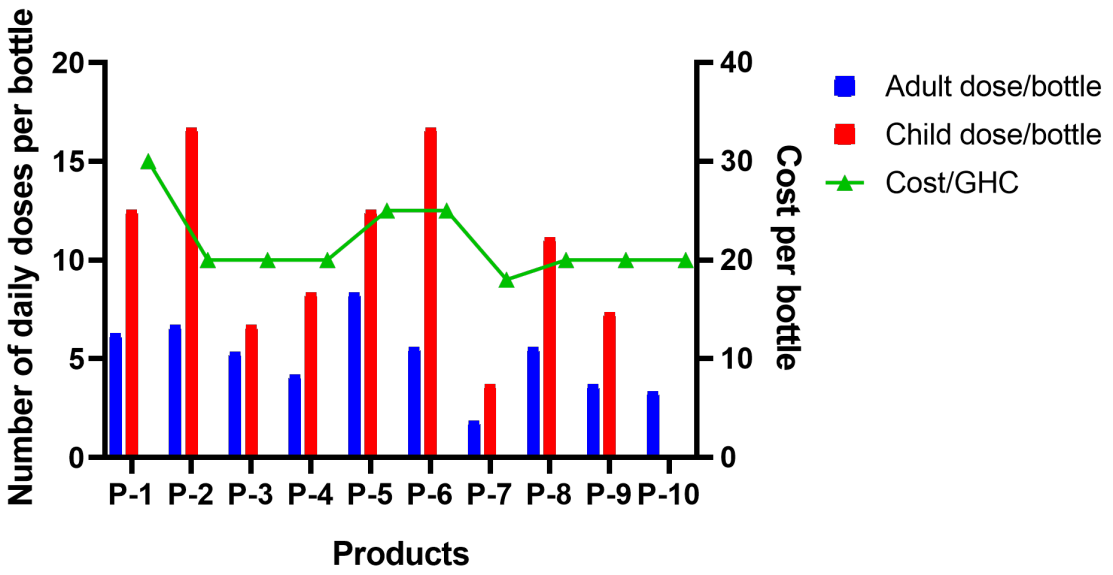


Fig. 1. Number of daily doses per bottle and the associated cost.

3.3. Product indications

Most herbal medicines have multiple indications because different phytoconstituents in the varied plants used to prepare a single product (Amekyeh *et al*., 2024). This explains why most of these products have many indicated conditions. The study revealed that three products were designated solely for typhoid. Product P-8 had four additional indications, the most among the samples (see Table 4). Fig. 2 illustrates that, besides typhoid, the listed indications included abdominal pains (18.18%), appetite loss (9.10%), malaria (45%), jaundice (18.18%), and peptic ulcer (9.10%).

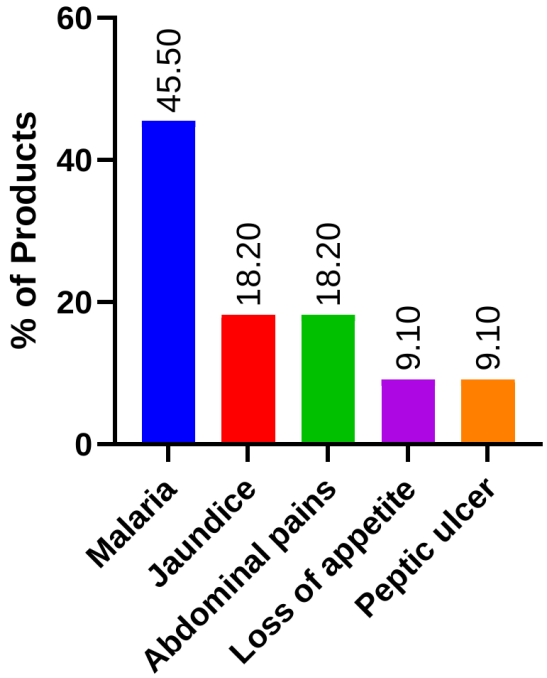


Fig. 2. Indications beyond typhoid listed on labels.

3.4. Herbs featured in the herbal products

Each product contained at least two herbs (P-2, P-3, P-6) and up to twelve different herbs (P-9) (see Table 3). Overall, the 10 products included 43 plant entries, representing 31 unique constituent plants. The commonest herbs were *Vernonia amygdalina* (n=3), *Citrus aurantifolia* (n=2), *Persea americana* (n=2), *Spondias mombin* (n=2), *Carica papaya* (n=2) and *Paullinia pinnata* (n=3) (Table 3). The remaining plants were used once in each product (Table 3). Plants such as *Vernonia amygdalina*, *Paullinia pinnata, and Persea americana* have been reported to show strong activity against *Salmonella typhi and S. paratyphi* and are mainly used folklorically to treat and manage typhoid fever (Bekoe *et al*., 2017; Iroha *et al*., 2010; Koffuor *et al*., 2016). However, the literature did not explicitly cite scientific evidence for the use of certain plants, such as *Gentiana lutea* and

Centella asiatica, emphasising the need to verify their folkloric uses. None of the products listed the specific plant part used on their labels, which could hinder reproducibility.

Table 3
Indications, constituents and dosages of products

Code	Indication(s)	Listed plant(s)	Adult dosage	Children dosage
P-1	Typhoid, Malaria	*Gentiana lutea, Centella asiatica, Allium sativum, Crataegus oxyacantha*	≥ 18 years, 60 mL twice daily for 7 days before meals.	12-17 years, 30 mL twice daily for 7 days before meals.
P-2	Typhoid	*Azadirachta indica, Momordica charantia*	No age specified; 75 mL twice daily before meals.	No age specified, 30 mL twice daily before meals.
P-3	Typhoid, Jaundice	*Nauclea latifolia, Morinda lucida*	No age specified; 50 mL three times daily before meals.	6-12 years old: 40 mL three times daily before meals.
P-4	Typhoid	*Jatropha curcas, Nauclea latifolia, Hoslundia opposita*	No age specified, 60mL three times daily.	For ages 6-12 years, administer 30 mL three times daily. For ages 11-17 years, give 45 mL twice daily.
P-5	Typhoid, Malaria, Jaundice	*Alchornea cordifolia, Xylopia aethiopica, Zingiber officinale, Anthocleista nobilis, Paullinia pinnata*	Adults aged 18 years and over, 45 mL twice daily after meals.	For ages 12 to 17 years, take 30 mL twice daily after meals.
P-6	Typhoid, Malaria	*Carica papaya, Cassia alata*	No age specified. Take 60 mL three times daily after meals.	≥12 years: 30 mL twice daily after meals.
P-7	Typhoid, Abdominal pains, Peptic ulcer	*Spondias mombin, Persea americana, Paullinia pinnata, Citrus aurantifolia*	Adults aged 18 or over: 60 mL three times daily, before or after meals.	For ages 12-17 years, administer 30 mL three times a day, either before or after meals.
P-8	Typhoid, Pains, Malaria, Loss of appetite	*Rauwolfia vomitoria, Vernonia amygdalina, Moringa oleifera*	Adults aged 18 or over: 30 mL three times daily for 7 days after meals.	For individuals aged 12-17 years, administer 15 mL three times daily for 7 days, preferably before meals.
P-9	Typhoid	*Spondias mombin, Persea americana, Paullinia pinnata, Citrus aurantifolia, Psidium guajava, Trema orientalis, Cnestis ferruginea, Momordica charantia, Vernonia amygdalina, Lantana camara, Morinda lucida, Bidens pilosa*	No age specified, 30 mL three times daily after meals for 21 days	≥12 years: 15 mL three times daily for 21 days after meals.
P-10	Typhoid, Malaria	*Ocimum viride, Vernonia amygdalina, Morinda lucida, Alstonia boonei, Carica papaya, Zea mays*	No age specified; 50 mL three times daily after meals	–

–, not applicable.

3.5. Seal integrity test

A fundamental role of primary packages is to provide a barrier that guards against microbial contamination from the natural environment and atmosphere (Osei-Asare *et al*., 2023). Only P-9 failed the seal integrity test (Table 4), indicating a potential weakness in this product's packaging barrier that could compromise its ability to prevent ingress of environmental contaminants, including microorganisms.

Table 4
Seal integrity test of sampled herbal products

Product	Observation
P-1	No bubbles observed
P-2	No bubbles observed
P-3	No bubbles observed
P-4	No bubbles observed
P-5	No bubbles observed
P-6	No bubbles observed
P-7	No bubbles observed
P-8	No bubbles observed
P-9	Bubbles observed
P-10	No bubbles observed

3.6. pH

The pH of a formulation indicates its level of acidity or alkalinity. This is crucial because it influences drug solubility, activity, absorption, stability, and patient comfort (Kumadoh *et al*., 2024). Additionally, the pH can affect physical properties like viscosity, especially in polymeric materials or formulations containing them (Sa *et al*., 2019). The rate of hydrolysis may also depend on the pH. Therefore, measuring pH helps optimise the formulation and may require excipients to enhance stability and tolerability upon administration. In this study, pH ranged from 5.0 to 7.02 ($F_{9,20}$ = 477.8, P < 0.0001), indicating slightly acidic to neutral conditions. Pairwise comparisons indicated significant differences ($p < 0.05$), except for P-2 vs P-10, P-4 vs P-7, P-4 vs P-9, P-5 vs P-8, P-6 vs P-9, and P-7 vs P-9, which showed no statistically significant difference ($p > 0.05$). As reported by Amekyeh *et al*. (2024), highly acidic liquids intended for oral use may harm dental health by causing erosion. However, because all products have a pH of ≥5, they are less likely to cause dental erosion than more acidic options. However, rinsing the mouth with water after use is still recommended as a precaution.

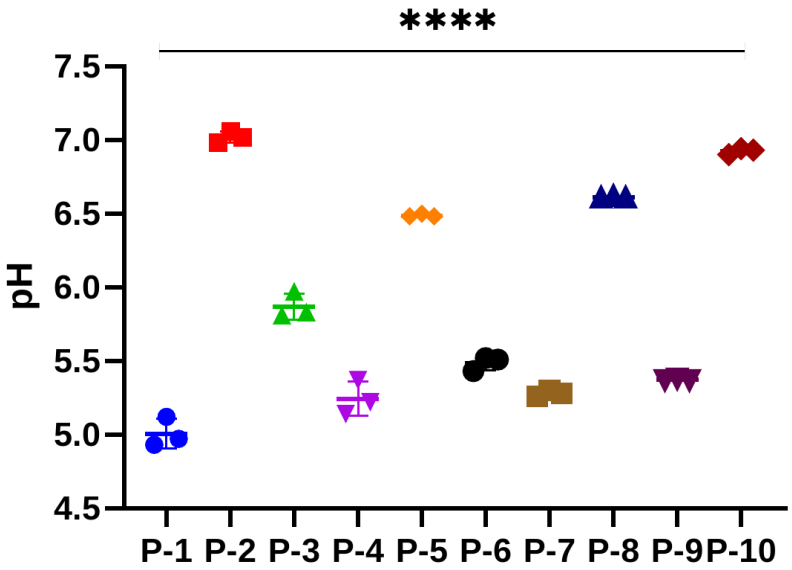


Fig. 3. pH of the sampled herbal products. ****P < 0.001, significant difference using ordinary one-way ANOVA.

3.7. Relative density and extract weight per dose (EWD)

Relative density is an essential parameter in liquid dosage forms, indicating the mass-to-volume relationship compared to water. Along with factors like formulation composition (e.g., excipients), viscosity, and particle size distribution, it can influence the product's sedimentation behaviour, affecting stability and dosing accuracy (Sharif, 2024). The measured relative densities ranged from 0.9998 to 1.006 ($F_{9,20}$ = 351089, P < 0.0001), with pairwise comparisons across all products indicating significant differences ($p < 0.05$). This narrow range reflects consistency in the mass-to-volume relationship across products.

The EWD ranged from 0.05 g (P-3) to 0.96 g (P7) ($F_{9,20}$ = 274.5, P < 0.0001) and represents the amount of non-volatile material after evaporation of a defined volume of formulation. Pairwise comparisons revealed significant differences ($p < 0.05$), notably with product P6, which differed significantly from all other products. This may not necessarily represent the amount of API present, as it may comprise herbal solids, sugars, gums, excipients, and other non-volatile components. Nevertheless, EWD may help mask the taste of some bitter herbal products and facilitate the transport of bulky liquid preparations. Furthermore, as demonstrated by Osei-Asare and colleagues, EWD may help determine the amounts required to prepare unit-dose tablets or capsules (Osei-Asare *et al*., 2021). The amounts obtained were consistent with previous studies on herbal preparations (Amekyeh *et al*., 2024; Osei-Asare *et al*., 2021)

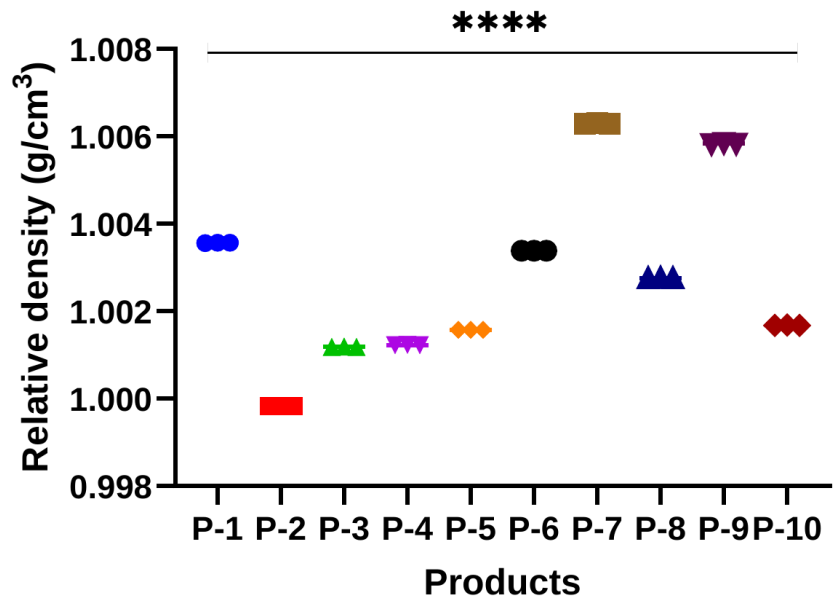


Fig. 4. Relative density of the sampled herbal products. ****P < 0.001, significant difference using ordinary one-way ANOVA.

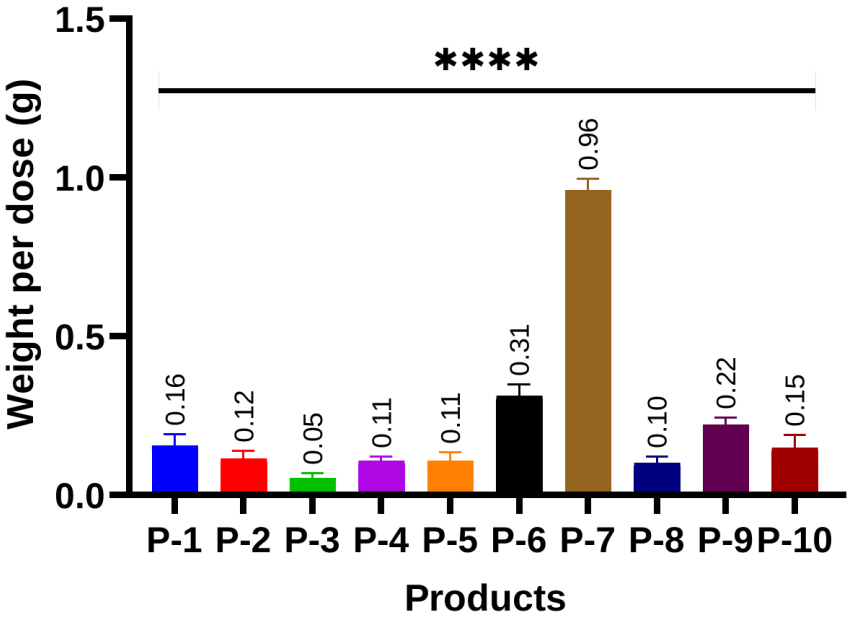


Fig. 5. Weight per dose of the sampled herbal products. ****P < 0.001, significant difference using ordinary one-way ANOVA.

3.8. Comparison of parameters using principal component analysis

Analysis of the properties revealed distinct groups among the products (Figs. 6 and 7). In the PCA biplot, PC1 and PC2 explained 49.88% and 28.27% of the total variance, respectively (78.15% combined). Products on the positive side of PC1 (P-1, P-6, P-5, P-2, P-3, and P-8) were linked to higher cost and dose-related variables (child dose/bottle, adult dose/bottle), while those on the negative side (P-7, P-9, and P-10) correlated with greater relative density and weight per dose. Hierarchical cluster analysis confirmed this separation, identifying two main clusters at the highest level of dissimilarity: Cluster 1 (P-1, P-2, P-3, P-4, P-5, P-6, and P-8) and Cluster 2 (P-7, P-9, and P-10), aligning with the PC1-based division seen in the biplot. In Cluster 1, P-1 stood out as the most distinct, separating early from P-2 through P-8, which formed two closely related subgroups. Within Cluster 2, P-7 and P-9 grouped more tightly with each other than with P-10.

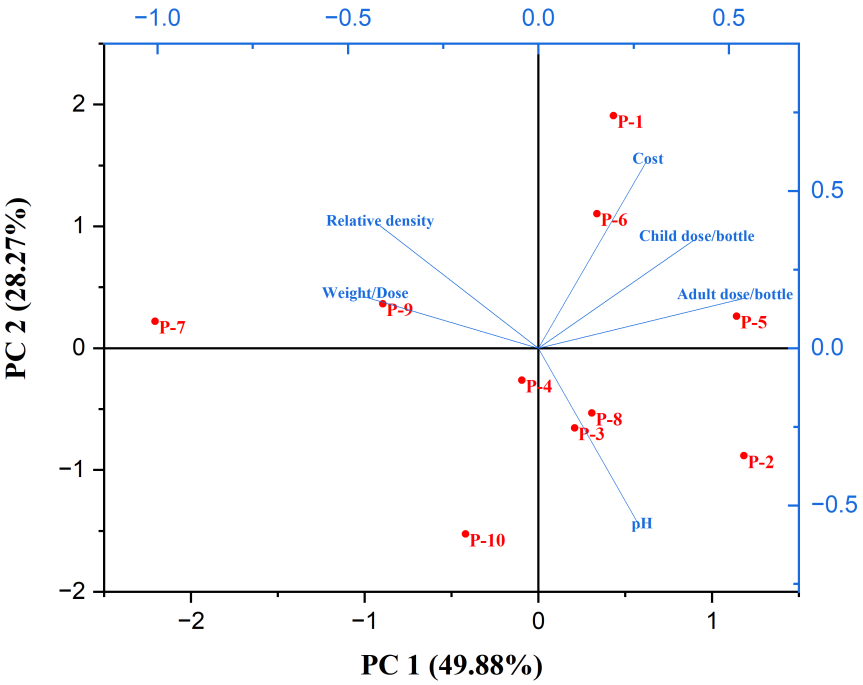


Fig. 6. Biplot illustrating the principal component analysis of the parameters.

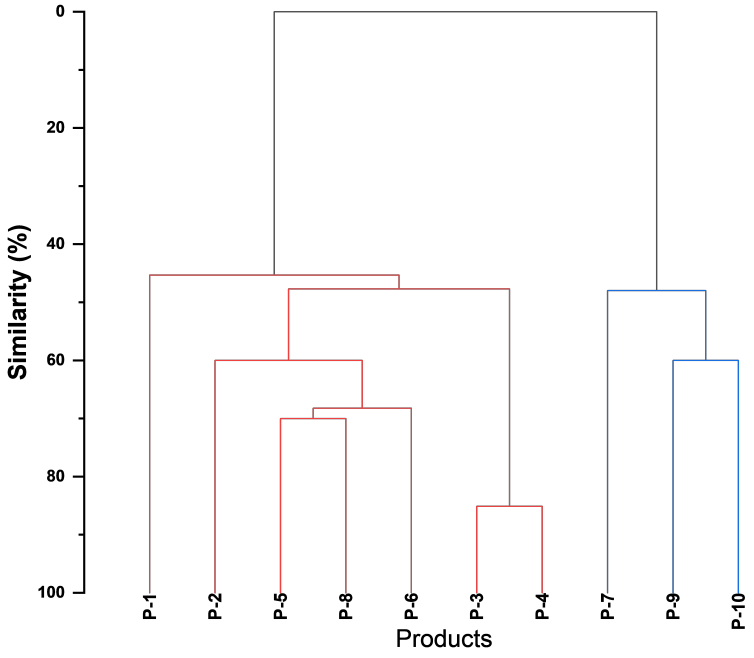


Fig. 7. Hierarchical cluster analysis of the parameters.

4. Limitations

This study's limitations include sampling only one batch per product and a small number of distinct products, which means batch-to-batch variability was not assessed. As a result, the findings may not fully reflect product-quality consistency across different production batches. The research also focused on physicochemical and cost analyses and did not evaluate microbiological safety or effectiveness. Consequently, no conclusions can be

made regarding the microbial quality, therapeutic efficacy, or overall safety of these products. Future research should sample multiple batches over time and include microbiological and efficacy tests to provide a more comprehensive evaluation of the herbal medicines marketed for typhoid.

5. Conclusion

The study revealed that most of the products had intact primary packaging and contained basic identification and traceability information; however, important deficiencies were identified in dosing information, patient-use information, and packaging-related requirements. Physicochemical analysis revealed pH values ranging from 5.0 to 7.02, extract weights per dose from 0.05 g to 0.96 g, and relative density between 0.9998 and 1.006. Principal component analysis and hierarchical clustering grouped the products into two categories: one comprising P-1, P-2, P-3, P-5, P-6, and P-8, associated with higher costs and dose-related variables, and another including P-7, P-9, and P-10, distinguished by greater relative density and higher weight per dose. Regulatory authorities should conduct regular inspections of marketed products to ensure ongoing consumer safety.

CRediT authorship contribution statement

PGJA: Experimentation, data analysis, interpretation, and manuscript drafting. **MEBG:** Conceptualisation of the project and review of the draft manuscript. **NYPK:** Experimentation and manuscript drafting. **AAO:** Experimentation and manuscript drafting. **FWAO:** Data analysis, interpretation, and manuscript review. **OAA:** Manuscript writing and review.

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Declaration of competing interest

The authors declare that there are no conflicts of interest concerning the publication of this paper.

Data availability

Data can be provided upon request.

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