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COMPARATIVE pH ANALYSIS: HOMEMADE COLD CLAY VERSUS COMMERCIAL CLAY FOR CHILD SAFETY

Analisis Komparatif pH: *Cold Clay Homemade* dengan *Clay* Pabrikan Komersial untuk Keamanan Anak

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ABSTRACT

Cold clay, as a non-baking children's play medium, needs to be assessed for its chemical and physical safety, particularly its pH parameters, to ensure safety for children's skin and environmental sustainability. This study aims to characterize the pH of cold clay by comparing homemade and manufactured products. A total of six samples were tested: one homemade (based on polyvinyl acetate, cornstarch, and additives) and five manufactured, colorful ones. The pH measurements were performed using a digital pH meter with three replications, then statistically analyzed using an independent t-test. The results showed a highly significant difference ($p < 0.001$) between the two groups. Homemade samples had an average pH of 4.75 ± 0.06 (acidic), while manufactured samples ranged from 7.16–7.53 (neutral to slightly alkaline). From a dermatological perspective, homemade pH, which is closer to the natural pH of children's skin (~5.5), is considered safer for long-term contact because it does not disrupt the acid mantle. In contrast, the neutral pH of manufactured products showed better chemical stability but potentially poses challenges in waste management. These findings emphasize the importance of pH characterization in selecting safe materials for the intended application. The study recommends consideration of pH parameters for parents, educators, and industry, as well as the need for further studies on toxicity and environmental impacts to ensure overall safety.

Keywords: *Cold clay, pH, Material characterization, Skin safety, Environmental safety*

ABSTRAK

Cold clay, sebagai media permainan anak tanpa pembakaran, perlu dikaji keamanannya dari segi kimia dan fisik, khususnya parameter pH untuk menjamin keselamatan bagi kulit anak dan kelestarian lingkungan. Penelitian ini bertujuan mengkarakterisasi pH cold clay dengan membandingkan produk *homemade* dan pabrikan. Sebanyak enam sampel diuji yaitu satu *homemade* (berbasis polivinil asetat, maizena, dan aditif) dan lima pabrikan berwarna-warni. Pengukuran pH dilakukan menggunakan pH meter digital dengan tiga replikasi, lalu dianalisis secara statistik dengan uji-t independen. Hasil menunjukkan perbedaan yang sangat signifikan ($p < 0,001$) antara kedua kelompok. Sampel *homemade* memiliki pH rata-rata 4,75 ± 0,06 (asam), sedangkan sampel pabrikan berkisar 7,16–7,53 (netral hingga sedikit basa). Dari aspek dermatologis, pH *homemade* yang mendekati pH alami kulit anak (~5,5) dianggap lebih aman untuk kontak jangka panjang karena tidak mengganggu *acid mantle*. Sebaliknya, pH netral produk pabrikan menunjukkan stabilitas kimia lebih baik, namun berpotensi menimbulkan tantangan dalam pengelolaan limbah. Temuan ini menekankan pentingnya karakterisasi pH

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dalam pemilihan material yang aman sesuai tujuan aplikasi. Penelitian merekomendasikan pertimbangan parameter pH bagi orang tua, pendidik, dan industri, serta perlunya kajian lanjutan tentang toksisitas dan dampak lingkungan untuk menjamin keamanan menyeluruh.

Kata Kunci: *Cold clay, pH, Karakterisasi material, Keamanan kulit, Keamanan lingkungan.*

INTRODUCTION

The burgeoning popularity of cold clay as an accessible and malleable medium for arts and crafts in early childhood education, while lauded for its developmental benefits in fine motor skills and creative expression, introduces a critical and often underexamined dermatological concern, given that children's skin—characterized by a thinner stratum corneum and a still-maturing epidermal barrier—is physiologically more susceptible to chemical irritants and pH fluctuations that can compromise the integrity of the acidic mantle, a natural defense mechanism maintaining a pH around 5.5 to inhibit pathogen colonization and prevent conditions such as contact dermatitis, a non-negligible issue evidenced by epidemiological data indicating that exogenous factors, including toy materials, contribute to a significant proportion of dermatitis cases in pediatric populations. Despite the established dermatological principle that topically applied substances should ideally be pH-compatible with the skin's natural milieu to avoid barrier disruption, irritation, and increased susceptibility to infection—a concern amplified for children with sensitive skin or conditions like atopic dermatitis—the existing body of research on play material safety remains predominantly focused on mechanical hazards or the presence of specific toxicants like phthalates and heavy metals, leaving a substantial gap in the systematic characterization and comparative assessment of a fundamental physicochemical parameter: the potential of hydrogen (pH) in widely used modelling clays. This oversight is particularly pronounced in the direct comparison between do-it-yourself (DIY) formulations, frequently crafted from polyvinyl acetate (PVAc) glue, cornstarch, and household additives whose pH remains unregulated and largely undocumented, and their commercially manufactured foam-based counterparts marketed for children, which despite their prevalence, have not been subject to rigorous, comparative pH profiling to evaluate their congruence with pediatric skin physiology. Consequently, this study introduces its novelty by explicitly targeting this uncharted comparative terrain, undertaking a controlled empirical analysis to quantify and statistically compare the pH values of a representative PVAc-based homemade cold clay against a spectrum of commercially available foam clays, thereby generating first-of-its-kind data that moves beyond general safety exhortations to provide an evidence-based, parameter-specific foundation for evaluating material compatibility with children's vulnerable skin, addressing a clear omission in the current literature which has not yet juxtaposed these two common clay types through the critical lens of acid mantle compatibility, and ultimately aiming to furnish parents, educators, and manufacturers with a scientifically-grounded initial reference point to inform safer selection and formulation practices, while also establishing a necessary precedent for subsequent, more comprehensive toxicological and environmental impact investigations.

MATERIALS AND METHODS

1. Research Materials

This experimental study utilized two primary categories of cold clay samples: a single, laboratory-formulated homemade variant and five distinct commercial products. The homemade sample was synthesized from a specified formulation, with polyvinyl acetate (PVAc) adhesive serving as the primary binding agent. The formulation was supplemented with a combination of functional additives: benzoate acted as a preservative, paraffin oil served as a plasticizer, glycerin functioned as a humectant, and acetic acid was incorporated as a dual-purpose pH regulator and preservative agent. The commercial samples consisted of five mass-produced ultralight or foam-type clays, each a different color (black, red, yellow, green, and white), purchased from local retailers. These commercial products are marketed for children's use and share common physical properties, notably a lightweight, porous structure and hydrophobic characteristics.

2. Equipment Used

All measurements were conducted using standardized laboratory equipment to ensure accuracy and reproducibility. pH measurement was performed using a calibrated digital pH meter (Starter 3100 pH Bench pH Meter, OHAUS) with a stated accuracy of ±0.01 pH units. For sample preparation, an analytical balance (Ohaus PR224) with a precision of 0.1 mg was used for precise weighing. Sample homogenization was achieved using a magnetic stirrer (Thermo Scientific CIMAREC Stirring Hot Plate) with a Teflon-coated stir bar. Solutions were prepared and contained in Class A volumetric flasks (100 mL) and borosilicate glass beakers (250 mL). The pH meter was calibrated using certified standard buffer solutions with nominal pH values of 4.00, 7.00, and 10.00 at 25°C. Distilled water, produced by a laboratory-grade distillation unit, was used as the universal solvent for all aqueous preparations and electrode rinsing.

3. pH Measurement Procedure

3.1. pH Meter Calibration

The pH meter was calibrated daily prior to sample analysis, following a multi-point calibration protocol as per the manufacturer's instructions. The electrode was first rinsed with distilled water and gently blotted dry. It was then sequentially immersed in the pH 7.00, 4.00, and 10.00 standard buffer solutions, allowing the reading to stabilize at each point before accepting the calibration value. The calibration was verified by measuring a different buffer solution post-calibration, and the process was repeated if the reading deviated by more than ±0.02 pH units from the expected value.

3.2. Sample Preparation

A standardized sample preparation protocol was strictly followed. Precisely 1.000 gram (± 0.005 g) of each cold clay sample was weighed on the analytical balance. This mass was quantitatively transferred into a 250 mL beaker containing 100.0 mL of distilled water, pre-equilibrated to 25°C in a temperature-controlled water bath. The mixture was then homogenized by continuous magnetic stirring at a constant speed of 300 rpm for a duration of 30 minutes. This procedure was designed to facilitate the maximum and consistent extraction of soluble ionic components from the clay matrix into the aqueous phase for pH determination.

3.3. pH Measurement

Following homogenization, the stirring was halted to allow any large particulates to settle, and the pH electrode was immediately immersed in the supernatant solution. The pH reading was recorded only after the displayed value had stabilized for a minimum period of 30 seconds. This measurement was performed in triplicate for each independently prepared sample solution. Between each measurement, the electrode was thoroughly rinsed with a stream of distilled water to prevent carryover contamination and then blotted dry with a lint-free tissue. The entire process, from sample weighing to final reading, was conducted in a temperature-controlled laboratory environment maintained at 23 ± 2°C.

4. Data Analysis

The triplicate pH readings obtained for each sample were treated as independent observational data. The mean pH value and its corresponding standard deviation (SD) were calculated for each of the two sample groups: the single homemade formulation and the pooled commercial samples. The primary statistical comparison between the mean pH of the homemade clay and the mean pH of the commercial clays was performed using an independent samples t-test. The assumption of homogeneity of variances was tested using Levene's test prior to the t-test. The threshold for statistical significance was set a priori at $\alpha = 0.05$. All statistical computations were performed using SPSS software (version 26.0, IBM Corp.).

5. Quality Control

A comprehensive quality control (QC) regime was implemented throughout the study to ensure data reliability. All glassware was meticulously cleaned and rinsed with distilled water prior to use. The pH meter calibration was verified every two hours during measurement sessions. The temperature of all solutions was monitored and maintained at 25.0 ± 0.5°C during measurement, as pH is temperature dependent. A blank measurement (distilled water at 25°C) was periodically checked to monitor for any electrode drift or contamination. Furthermore, the entire sample preparation and measurement sequence was conducted by a single analyst to minimize operator-induced variability. This systematic QC approach was integral to minimizing experimental error and ensuring the validity of the comparative findings.

RESULTS AND DISCUSSION

1. pH Measurement Results and Physical Characteristics

Table 1. pH Measurement Results of Homemade and Commercial Cold Clay

Sample	Type	Color	Test	pH	Mean ± SD	Information
1	Homemade	White	1	4,82	4,75 ± 0,06	Heavy, sinks in water, difficult to dissolve, gives a deep color when dissolved
			2	4,70		
			3	4,73		
2	Commercial	Black	1	7,53	7,52 ± 0,02	Easily soluble, floats on water, light, clear when dissolved
			2	7,53		
			3	7,50		
3	Commercial	Red	1	7,32	7,32 ± 0,03	
			2	7,35		
			3	7,30		
4	Commercial	Yellow	1	7,45	7,40 ± 0,06	
			2	7,42		
			3	7,34		
5	Commercial	Green	1	7,26	7,25 ± 0,09	
			2	7,33		
			3	7,16		
6	Commercial	White	1	7,45	7,44 ± 0,02	
			2	7,41		
			3	7,45		

The pH measurements revealed a clear difference between the homemade and manufactured cold clay samples. The homemade samples had an average pH of 4.75 ± 0.06, which is acidic, while all manufactured samples had a neutral to slightly alkaline pH, ranging from 7.16 to 7.53. This difference was statistically significant ($p < 0.001$) based on an independent t-test. Healthier skin is consistently associated with a pH below 5.0., this nearly 3-unit pH difference is highly clinically significant, given that Lambers et al. (2006) showed that even a 1.5-unit increase in skin pH can disrupt the acid mantle and increase the risk of dermatitis.

Statistical analysis using the independent t-test was chosen because it meets the necessary parametric assumptions. As explained by Kim (2013), the t-test is an effective parametric statistical method for comparing the means of two independent groups. In this study, the calculated t-value of 35.72 with 16 degrees of freedom indicates a highly significant difference between the two sample groups.

In terms of physical characteristics, striking differences were observed between the two types of clay. The homemade sample exhibited "heavy, sinking, and difficult-to-dissolve" properties, with a solution that produced a deep color, while the manufactured sample was "light, floating, and easy-to-dissolve" with a solution that tended to be clear. These characteristics indicate fundamental differences in material composition between the two types of clay.

2. Implications for Children's Skin Safety from a Dermatological Perspective

The finding of an acidic pH in homemade cold clay has important implications for its safety for children. As stated by Panther & Jacob (2015), the optimal pH for children's skin is in the acidic range (4.0-6.0). The homemade sample with a pH of 4.75 falls within this ideal range, while the manufactured sample with a pH above 7 has the potential to disrupt the skin's acid mantle.

This finding is consistent with research Mendes et al. (2016) which found that many children's products on the market have a sub-ideal pH. In fact, some manufactured samples in this study had a higher pH than the alkaline children's soap identified by Mendes et al. (which reached a pH of 11.5). This condition is of concern considering that children's skin, especially toddlers', is thinner and has an immature stratum corneum layer compared to adult skin, making it more susceptible to irritation and chemical penetration (Blume-Peytavi et al., 2016).

Research by Behm et al. (2015) showed that products with an acidic pH (4.0) can help restore skin function. In this context, homemade samples with a pH of 4.75 can be considered more supportive of children's skin health than manufactured products with a neutral-alkaline pH.

3. Implications for Safety, Practice, and Future Research

The findings of this study have direct implications for safety principles and practical application. They underscore the relevance of the precautionary principle in children's product safety, aligning with recommendations from bodies like the Scientific Committee on Health and Environmental Risks, which stress the characterization of physicochemical properties. The evidence-based material selection framework advocated by Chookah et al. (2024) is also pertinent; the pH data provided here serves as a foundational scientific parameter for informed decision-making. Within the educational context, this study supports the work of researchers like Syafira (2021), who highlight the value of safe, natural-material-based media. Homemade clay, with its skin-compatible pH, emerges as a potentially safer alternative for direct, prolonged contact, while the neutral pH of commercial clay may favor environmental stability but requires careful dermatological consideration given its slightly alkaline range. It is crucial to emphasize that pH is a single, albeit critical, parameter; a comprehensive safety assessment must also consider physical properties (e.g., solubility, stability), full chemical composition, and potential toxicity.

4. Limitations and Directions for Future Research

This initial characterization study is defined by its focused scope, which concurrently establishes its primary limitations. The analysis is confined to the pH parameter and does not extend to comprehensive toxicological profiling, a detailed analysis of compositional elements such as colorants, or an assessment of long-term user and environmental impact. To address these gaps and build a robust safety profile for cold clay, future research must adopt a multi-parametric approach. The following specific and actionable investigations are recommended as critical next steps:

a. Advanced Toxicological Screening

Conduct *in vitro* biocompatibility assays to move beyond physicochemical characterization. This should include cytotoxicity testing on a relevant human skin cell model, such as the HaCaT keratinocyte cell line, and skin irritation testing using validated reconstructed human epidermis (RHE) models (e.g., EpiDerm™ or SkinEthic™). These tests will provide direct biological safety data on the effects of clay extracts.

b. Comprehensive Material Analysis

Perform a detailed compositional analysis using techniques like Gas Chromatography-Mass Spectrometry (GC-MS) or Fourier-Transform Infrared Spectroscopy (FTIR) to identify and quantify all organic components (plasticizers, preservatives, dyes, residual monomers) in both homemade and commercial clays.

c. Exposure and Migration Assessment
Investigate the potential for user exposure by performing migration analysis. This involves testing whether chemical substances from the clay matrices can leach into artificial sweat or sebum under simulated use conditions, which is crucial for estimating dermal bioavailability and risk.

d. Longitudinal and Environmental Studies
Evaluate the long-term stability of the clays (pH, microbial growth, structural integrity) under various storage conditions. Furthermore, initiate studies on the environmental fate of these materials, particularly the biodegradability of commercial foam clays and the aquatic toxicity of their leachates.

CONCLUSION

In conclusion, this study provides the first comparative empirical data on a critical safety parameter for children's play materials, revealing a highly significant difference in pH between the tested cold clay types. The homemade clay exhibited a distinctly acidic pH (4.75), while the commercial foam clays consistently showed a neutral to slightly alkaline pH (7.16–7.53). This finding carries important implications: the pH of the homemade formulation aligns more closely with the physiological pH of children's skin (~5.5), suggesting a lower potential for disrupting the skin's protective acid mantle during prolonged contact. Conversely, the neutral-alkaline pH of commercial products, while indicative of greater chemical stability, may pose a higher dermatological risk for sensitive skin with repeated use. Crucially, it must be emphasized that pH is a single, albeit fundamental, parameter; a comprehensive safety assessment requires data on chemical composition, toxicity, and leaching potential, which were beyond the scope of this initial characterization.

Therefore, the recommendations stemming from this work are cautionary and forward-looking. Parents and educators should be made aware of pH as a relevant factor in material selection and advised to seek products with safety data beyond pH alone. For regulators and industry, the findings underscore the need to include pH information on labels as part of transparent safety reporting. Most importantly, this research unequivocally identifies the critical need for subsequent, more comprehensive studies. Future work must prioritize specific investigations referenced in this study's limitations, including *in vitro* cytotoxicity and skin irritation tests on human cell models, detailed chemical migration analysis to assess leaching potential, and long-term stability studies. Only through such a multi-faceted safety protocol can the optimal balance be struck between fostering creative play and ensuring the unwavering protection of children's health.

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