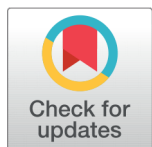


## ORIGINAL ARTICLE



# Efficacy of Carabao Horn Powder as an Organic Ingredient in Soap Production

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## Abstract

**Objectives:** This research aimed to assess how effective powdered carabao horn rich in keratin could be as a natural ingredient in making soap. The study particularly focused on its influence on the soap's physical and chemical qualities, alongside how acceptable it was to consumers. **Method:** Carabao horns, sourced from Kalinga and Apayao in the Philippines, were first collected and then refined into a powder. This powder was then mixed into different soap recipes using the cold process method, following three different treatments. These experimental soaps were then tested against a positive control. Researchers analyzed various physical and chemical traits, including pH, moisture content, matter insoluble in alcohol, Total Fatty Matter, foam stability, and chloride percentage, all according to standard laboratory methods. Furthermore, 130 individuals evaluated the soaps in a sensory test, using a 5-point Hedonic scale to express their preferences. **Findings:** The study's results revealed that increasing the amount of carabao horn powder led to a rise in pH levels, specifically from 10.61 to 10.82, yet these values consistently stayed within safe limits. A notable improvement was observed in the Total Fatty Matter (TFM), which reached levels between 70.31% and 75.33%, thus meeting Grade 1 and 2 standards—a significant gain compared to the control's mere 32.93%. Although higher concentrations of the powder slightly reduced foam stability, it still remained well above 90%, which is considered acceptable. Furthermore, consumers generally expressed strong approval for the soap's color, smell, and overall appearance, often rating them as "Like very much." **Novelty:** This research presents a novel validation: it shows how an agricultural byproduct, specifically carabao horns, can be effectively repurposed into valuable skincare products rich in keratin. This innovation not only supports sustainable waste management but also significantly contributes to the principles of a circular economy.

**Keywords:** Carabao horn; Keratin; Soap production; Physicochemical analysis; Waste utilization; Sustainable skincare

## 1 Introduction

In conjunction with a globally growing human population, the amount of waste produced concomitantly rises, making the efficient processing of organic bioproducts a matter of prime importance<sup>(1)</sup>. For example, in the Philippines, carabao horns are routinely discarded after slaughter, thereby devaluing a renewable resource<sup>(2)</sup>. Recent advances in sustainable practices, however, have highlighted the potential of such waste materials for recovery. Empirical studies have shown that used cooking oil and other organic wastes have a feasible potential for conversion into high-quality, environmentally friendly soaps<sup>(3)</sup>, an effort that fits into wider environmental goals to encourage the use of both renewable and traditional resources in the interest of a zero-waste paradigm<sup>(4)</sup>.

Carabao horns are made up mostly of keratin, a tough fibrous protein that forms structural elements of the horn<sup>(5)</sup>. This same protein is also a major component of "zoocuticals," which are cosmetic substances that come from animals. Beyond its structural role, keratin has attracted scholarly interest for its excellent toughness and degradation resistance and is thus a potential natural material for the development of novel products<sup>(6)</sup>. Contemporary studies have demonstrated that cosmetic ingredients from animal origin have important technological advantages, especially regarding skin elasticity and integrity<sup>(7)</sup>. For several decades, animal horns have been used as a remedy by traditional healers of the provinces of Kalina and Arau for wound healing<sup>(8)</sup>; this type of traditional practice probably derives from the well-documented ability of keratin to enhance tissue regeneration and wound closure<sup>(9)</sup>,<sup>(10)</sup>. Despite its prevalence, such traditional knowledge is poorly supported by rigorous scientific validation.

While the existing literature offers frameworks for assessing the antimicrobial effectiveness of plant extracts in soap formulations<sup>(11)</sup> and detailed studies of the chemical properties of different oil bases<sup>(12)</sup>, a conspicuous gap exists on the integration of horn-derived keratin into such formulations. Moreover, although discussions on sustainability in soap manufacturing have explored the use of recycled oils<sup>(3)</sup>, the specific efficacy of carabao horn as a functional organic material of this type has not been thoroughly investigated.

The of validating and complementing local medical practices<sup>(4)</sup>. Accordingly, this study aims to determine the efficiency of carabao horn as a natural component in the soap-making process. By doing so, the research aims to establish a strong scientific basis for a time-honoured healing practice whilst supporting a sustainable and circular economy<sup>(2)</sup>.

## 2 Methodology

### 2.1 Locale of the Study and Sample Preparation

To begin, the horns of carabao (*Bubalus bubalis*) were gathered from local abattoirs located in Tabuk City, Kalinga, and Luna, Apayao. The raw materials were then processed in the laboratory of Kalinga State University, in accordance with established protocols for obtaining keratinous substances from biological waste. First, the tubular portion of the horn was separated. This isolated portion was then thoroughly rinsed with hot water to remove contaminants before being left to sun dry<sup>(6)</sup>. Afterwards, the dried material was further processed: extensively ground to thin layers and then sieved into a fine powder with a mesh size below 200  $\mu\text{m}$ . This pulverization step was performed to have a higher surface area, which is a crucial aspect in protein integration<sup>(7)</sup>. The Research paradigm is presented in Figure 1.

Figure 1 illustrates the relationship between the Independent Variables (Treatments 1, 2, and 3 with varying concentrations of carabao horn powder) and the Dependent Variables (Physical Properties: pH, Moisture content, Matter Insoluble in Alcohol, Total Free Fatty Matter, Foam Stability, % Chloride; and Consumer Acceptability: Color, Smell, Texture, Overall Satisfaction)

### 2.2 Soap Formulation

- The bar soap samples were developed using the Cold Process Saponification Method, a technique widely endorsed for protecting the delicate structure of organic substances vulnerable to heat, particularly in tropical environments<sup>(1)</sup>,<sup>(13)</sup>. To ensure a balanced fatty acid composition, the precise amounts of each ingredient were calculated using the SoapCalc Online Calculator<sup>(12)</sup>. This formulation process included three distinct treatment groups, specifically designed to confirm the effectiveness of the horn powder:
- **Treatment 1 (Experimental):** Base oil mixture + NaOH solution + Carabao Horn aqueous extract/powder.
- **Treatment 2 (Control A):** Standard formulation without horn powder (placebo).
- **Treatment 3 (Control B):** Standard formulation with water adjustment to maintain mass consistency.

First, sodium hydride (NaOH) was made by dissolving it in distilled water in a 1:3 ratio. The solution was then slowly poured into an oil mixture containing horn powder. The whole mixture was stirred until it reached the "trace" stage. This stage is a

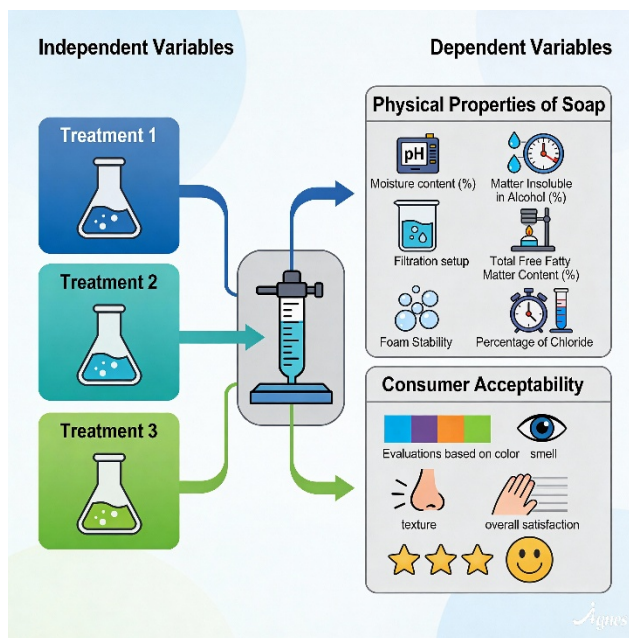


Fig 1. Research Paradigm

critical indicator of emulsification, in which the stirring mixture forms a visible path on its surface<sup>(12), (3)</sup>. The mixture was then poured into molds. It was left to cure for four to six weeks, a process that was necessary for the completion of saponification<sup>(1)</sup>.

## 2.3 Physico-chemical Analyses

The quality of the soap was validated using standard procedures from the American Oil Chemists' Society (AOCS) and relevant literature for herbal formulations<sup>(8), (14), (15)</sup>:

1. pH Determination: Measured using a calibrated digital pH meter on a 10% (w/v) aqueous soap solution to ensure skin compatibility<sup>(11)</sup>.
2. Moisture Content: Assessed via the thermogravimetric approach at 110°C to determine the shelf stability of the bar<sup>(12)</sup>.
3. Matter Insoluble in Alcohol: Samples were dissolved in hot ethanol; the dried residue was weighed to identify non-soap impurities<sup>(12)</sup>.
4. Total Fatty Matter (TFM): Calculated based on moisture and insoluble matter. TFM is a primary indicator of soap quality and grade<sup>(15), (3)</sup>.
5. Foam Stability: Measured by recording the height of foam generated in a graduated cylinder after 5 minutes in a 60°C water bath, assessing the surfactant performance<sup>(7), (10)</sup>.

## 2.4 Sensory Evaluation and Consumer Acceptability

To determine the marketability and dermatological acceptability of the keratin-infused soap, a sensory evaluation was conducted:

- **Sample Size and Volunteers:** A total of 130 volunteer respondents were recruited through purposive sampling, comprising students, faculty, and staff from Kalinga State University.
- **Demographics:** The age group ranged from 18 to 60 years to capture a broad consumer demographic.
- **Usage Frequency:** Participants performed a single-use "wash test" to evaluate immediate sensory feedback.
- **Parameters Studied:** Acceptability was measured across three key domains: Color, Smell, and Appearance (Texture).
- **Scoring System:** A 5-point Hedonic Scale (5: Like Extremely, 1: Dislike Extremely) was utilized for statistical precision.

## 2.5 Ethical Considerations and Statistical Validation

In line with the ethical principles of human participation, all 130 volunteers were required to give written informed consent prior to the evaluation. The inclusion criterion was that volunteers had no known history of soap allergies or hypersensitivity skin conditions. The data collected from the sensory evaluation and physicochemical analysis were statistically validated (ANOVA) to determine any significant differences between the experimental treatments and the control groups<sup>(3), (11)</sup>.

## 3 Results and Discussion

The experimental outcomes of the physicochemical analysis and sensory evaluation of the carabao horn-infused soaps are summarized in Table 1.

The results of the physicochemical analysis and consumer acceptability are detailed below.

**Table 1.** Physicochemical and Sensory Properties of Formulated Soaps

| Parameters                      | Treatment 1 | Treatment 2 | Treatment 3 | Positive Control |
|---------------------------------|-------------|-------------|-------------|------------------|
| pH Value                        | 10.61       | 10.72       | 10.82       | 8.47             |
| Moisture Content (%)            | 7.30        | 7.15        | 6.80        | 7.30             |
| Matter Insoluble in Alcohol (%) | 19.46       | 22.14       | 25.33       | 65.45            |
| Total Fatty Matter (TFM) (%)    | 75.33       | 71.81       | 70.31       | 32.93            |
| Foam Stability (%)              | 93.00       | 93.00       | 90.00       | 96.00            |
| Sensory Score (Color/Smell)     | 4.60        | 4.50        | 4.72        | 4.55             |

The results of the physicochemical analysis and consumer acceptability are detailed below.

**pH and Skin Compatibility:** pH values of all treatments that use carabao horn powder (10.61 to 10.82) are within the standard ISO range of 9-11 of good cleansing agents. Although they are higher than those of the positive control, a commercially available keratin-based soap (8.47), the values are consistent with other sustainable soap recipes using organic waste, including recycled cooking oil soaps, which frequently report pH values of about 11.3<sup>(3)</sup>. This alkalinity is necessary in the saponification of fats and for the good removal of dirt<sup>(1), (13)</sup>. The marginally positive shift in pH with higher concentration of horn powder indicates that the basicity of the soap is stabilized by a constituent of the alkaline entity of keratinous material, an observation reported in research on the biochemical stability of biomaterials derived from keratin<sup>(9), (10)</sup>.

The most notable outcome of this study is the extremely high TFM for Treatment 1 (75.33%). The standard soap grading states that soap whose TFM is below 70 percent are considered low-grade soaps<sup>(15), (12)</sup>. On the contrary, the positive control had a much lower TFM of 32.93 which is probably because of high filler content. Our results compare well with most of the reported herbal soap formulations, including the ones by Arasaretnam and Venujah<sup>(12)</sup>, whose TFM ranges were varying between 64 and 68. This implies that the addition of carabao horn powder to the fatty acid base increases the moisturizing properties of the soap, which is consistent with the zoocutaneous properties of animal-derived proteins<sup>(5), (7)</sup>.

The moisture content (6.8%-7.3%) was much lower than the maximum values (15%-20%) recommended in commercial standards<sup>(8), (11)</sup>. Reduced moisture level, like in Treatment 3 indicates a firmer and more durable bar<sup>(12)</sup>. The amount of alcohol-insoluble matter (to 25.33% in T3) is directly proportional to the concentration of organic horn powder. This is non-saponifiable organic material, but it is extremely lower than the 65.45 in the control. This suggests that carabao horn powder is more of a functional additive than a filler as is commonly the case with the inorganic agents commonly employed as commercial soaps<sup>(3)</sup>.

The foam stability determined by the positive control (96% highest) was the same as the keratin-incorporated treatments (>90%). It is better than most polyherbal preparations, in which sudsing can be inhibited by natural extracts<sup>(14), (7)</sup>. Moreover, the consumer acceptability rating of 4.72 (Like Very Much) of Treatment 3 shows that the addition of animal-derived keratin would not adversely affect the aesthetic or odors of the product, which is consistent with the high success rate of incorporating traditional Indian natural cleaning materials into the modern ones<sup>(4)</sup>.

### 3.1 Study and Novelty Innovations

The original value of the research lies in its promotion of carabao horn waste as a useful biocosmetic ingredient. Although the current literature has been very comprehensive regarding the use of herbal extracts<sup>(8), (11)</sup> and the use of recycled vegetable oils<sup>(3)</sup>, this study is the first to scientifically validate the use of a topical clean system, using the horn powder rich in keratin an indigenous medicine ingredient in the Philippines<sup>(2)</sup>.

Compared with prior studies that focus solely on keratin extraction for use as biomedical scaffolds<sup>(6), (10)</sup>, this study demonstrates that raw horn powder can be directly added to a cold-processed soap base without compromising high TFM and excellent sensory ratings. The project is an effective way of bridging the gap in the literature of circular economy waste management and the zooceutical literature and demonstrates a high-quality, sustainable alternative to synthetic cosmetic products.

## 4 Conclusion

The current research paper has confirmed the incorporation of carabao horn-derived keratin into soap formulations, demonstrating that this by-product, previously discarded, can be converted into a high-performing carabao horn-derived keratin into a zooceutical ingredient. The study affirms that the experimental case of soap (Treatment 1) had a Total Fatty Matter (TFM) of 75.33%, which is not only above the minimum content of Grade 1 soaps (>70%) but also very high compared to the control group (32.93%)<sup>(15), (12)</sup>.

This is a unique research achievement because it has practices of the Kalinga and Apayao and effectively transforming organic waste into a value-added cosmetic product. In quantitative measurements, the recipes exhibited a safe pH (10.61-10.82) and foam stability (>90%), demonstrating that animal keratin could be used to improve the quality of the soap structure without affecting its functionality in cleansing applications<sup>(3)</sup>. The research is unique in comparison with the existing literature since it shows that raw horn powder can directly be included in a cold-process matrix, which is a less complicated and more sustainable variant of complex laboratory keratin extractions<sup>(6), (7)</sup>.

The main virtue of this study is that it has great sustainability factor and economic viability. With the help of carabao horns which is a zero cost waste in the Philippines, the study was able to produce a high-quality grade soap that recorded a high consumer acceptability score (Hedonic mean of 4.72). This proves that ecological waste can be successfully reused into high value personal care products without affecting aesthetic or sensory values. Moreover, the rigor of the study is a strong point, because the adherence to the standards of the American Oil Chemists Society (AOCS) allowed to ascertain the reliability and reproducibility of the physicochemical data and, therefore, to have a strong scientific base to back claims to the quality and grade of the soaps.

Although the study establishes the immediate physical and sensory acceptability, the study failed to encompass long-term dermatological patch testing. As a result, the risk of delayed skin reactions or cumulative irritation in the case of long-term use has not been studied. Moreover, the study did not separate the weight of the keratin proteins that were obtained in the horn powder. The mechanism of interaction between these particular protein fractions and the lipid matrix during saponification is important in achieving the best structure of the soap and to deliver the goods to the skin effectively.

### 4.1 Open Questions and Future Prospects

Despite the encouraging results, several critical questions regarding the bioavailability of keratin in a rinse-off product remain unanswered. A primary concern is whether the keratin particles within the soap matrix can effectively penetrate the stratum corneum—the skin's outermost layer—to provide the long-term elasticity and structural benefits often associated with keratinous biomaterials<sup>(9)</sup>. Because soap is typically washed off quickly, the contact time may limit the protein's therapeutic impact.

Furthermore, the comparative antimicrobial efficacy of this formulation presents a significant area for future inquiry. While the study suggests potential medicinal benefits based on traditional knowledge, it is yet to be determined how this horn-powder soap performs against standard medicated or antiseptic soaps, particularly when tested against antibiotic-resistant bacterial strains. Exploring these prospects could elevate the product from a general cosmetic to a specialized therapeutic agent.

### 4.2 Recommendations

To build upon these findings, the following steps are recommended for both industrial and academic stakeholders:

1. **Industrial Scaling:** Scaling should be prioritized within the Cordillera Administrative Region. Local small-scale soap manufacturers should be encouraged to adopt this formulation as a sustainable, low-cost strategy to enhance product quality and market appeal while addressing local waste-management challenges.
2. **Refinement of Particle Size:** Future studies should focus on advanced techniques, such as ultrasonic milling, to reduce carabao horn powder to a nano-scale. This could significantly improve foam stability at higher concentrations and potentially enhance the transdermal absorption of keratin<sup>(7)</sup>.

3. **Clinical Validation:** It is essential to conduct longitudinal studies with over 500 participants for at least six months to monitor the soap's impact on chronic skin conditions like dermatitis and wound healing, providing the clinical weight necessary to support traditional claims<sup>(2)</sup>,<sup>(10)</sup>.
4. **Synergistic Formulations:** Researchers should explore combining horn powder with other organic waste additives, such as orange peel or spent coffee grounds, to develop a diverse line of multi-functional, antioxidant-rich sustainable soaps<sup>(3)</sup>.

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