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A Review on Emerging Non-Traditional Applications of Cocoa

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ABSTRACT – *Cocoa (Theobroma cacao L.) has long been prized for its role in confectionery and beverages. However, recent research highlights its diverse bioactive compounds with promising applications beyond food. This review synthesizes current evidence on non-traditional uses of cocoa plant parts, such as leaves, pods, beans, butter, shells, and pulp, in cosmetics, dermatology, pharmaceuticals, functional foods, and sustainability. Cocoa leaves exhibit cytotoxic activity against breast cancer cells, while pod husks demonstrate tyrosinase inhibition relevant to skin-whitening formulations. Cocoa beans and powder provide potent antioxidants that remodel dermal microstructure, and cocoa butter offers superior emollient and percutaneous absorption properties compared to paraffin. Valorization of cocoa shells and pulp contributes dietary fiber, functional beverages, and bioethanol, supporting circular bio-economy initiatives. Collectively, these findings underscore cocoa's potential as a multifunctional resource for health, beauty, and sustainability, warranting further clinical validation and scalable extraction technologies.*

Keywords: Non-traditional applications, cocoa bio-actives, antioxidant properties, circular bio-economy

INTRODUCTION

Cocoa, or its scientific name, *Theobroma cacao* **L.**, is cultivated across the tropics and remains a cornerstone of agricultural economies in developing nations.

Global chocolate demand drives a massive agro-industrial machine, but traditional harvesting and fermentation processes are highly inefficient in terms of biomass utilization. For every ton of dry cocoa beans produced, up to 10 tons of cocoa pod husks and vast quantities of mucilage and bean shells are generated. Disposing of this residual biomass presents both an environmental hazard, frequently acting as a reservoir for phytopathogens like *Phytophthora* sp., and a significant loss of biochemical potential. Emerging evidence suggests that cocoa's phytochemicals, such as flavonoids, tannins, phenols, and fatty acids, possess therapeutic, cosmetic, and nutritional properties.

The uses of cocoa in non-food applications are not common, besides moisturizers and lip balm products that are usually seen on the shelves. Recent studies suggested that cocoa has many benefits towards health care and hence, has a great potential to formulating into various grooming and personal care products. Indeed, all plant parts of cocoa, right from the leaves to the fruits, contain wholesome compounds beneficial to skin care and sources for other non-traditional uses of cocoa such as functional foods. For instance, study showed cocoa butter might not increase bad LDL cholesterols, which has close correlation to reducing heart illness (Jia *et al*., 2010).

The primary objective of this review is to systematically elucidate the bioactive compounds present across diverse cocoa plant tissues and explore their potential in non-traditional, value-added sectors.

MATERIALS AND METHODS

The review focused on bioactive compounds and functional properties of cocoa plant parts, including leaves, pod husks, beans, butter, powder, shells, and pulp, which are beyond their conventional use in confectionery. Applications in cosmetics, dermatology, pharmaceuticals, functional foods, and sustainability were prioritized.

A comprehensive search was performed across major scientific databases including PubMed, Scopus, Web of Science, and Google Scholar. Keywords used included "cocoa bio-actives," "cocoa leaves," "cocoa pod husk," "cocoa butter," "cocoa shells," "cocoa pulp," "non-traditional applications," "cosmetics," "pharmaceuticals," and "functional foods." The search covered publications from 2000 to 2026, with additional emphasis on recent studies (2020–2026) to capture emerging trends. Inclusion criteria were peer-reviewed journal articles, conference proceedings, patents, and book chapters reporting experimental, clinical, or applied studies on cocoa-derived compounds. Non-scientific sources, anecdotal reports, and studies lacking methodological detail were excluded.

Titles and abstracts were screened for relevance, followed by full-text evaluation. A total of

52 records were initially identified through database searches and manual reference checks. After removing duplicates and non-relevant studies, 38 articles were retained for full-text assessment. Of these, 36 publications met the inclusion criteria and were incorporated into the final synthesis.

The findings were organized thematically according to cocoa plant part and application domain. Comparative tables and figures were used to highlight key insights. Narrative synthesis was employed to integrate biochemical evidence with applied outcomes, while gaps in clinical validation and scalability were identified for future research.

BIOACTIVE COMPOUNDS IN DIFFERENT COCOA PLANT PARTS

Cocoa Leaves

Cocoa leaves, often overlooked compared to cocoa beans, are merging as a valuable resource for medicine, agriculture, and sustainability.

Phytochemical analyses reveal biochemical constituents, such as tannins, flavonoids, steroids, and phenols were present in the ethanolic extracts of cocoa leaves (Sagabaen, 2024; Supriyanto *et al*., 2014). The amount of which varies and is influenced by leaf age and plant age. Studies showed the total polyphenols in old leaves showed a higher yield of 28.4% - 32.4%, while that in young leaves was 19% - 27.3% (Osman *et al*., 2004; Othman *et al*., 2007). Nevertheless, the total catechin content in the old and young leaves was 5.25% and 9.75%, respectively.

Compared to green tea (Table 1), cocoa leaves exhibit moderate flavonoid content but strong antioxidant activity, positioning them as candidates for functional beverages and therapeutic formulations. (Sagabaen, 2024; Subhashini *et al*., 2010; Zainal *et al*., 2022).

Table 1: *Compounds composition of cocoa leaves and green tea*

Compound Class	Cocoa Leaves	Green Tea
Flavonoids	Present (quercetin, catechin): 40-60 mg QE/g)	High (EGCG, catechin): 80-100 mg QE/g)
Tannins	Moderate	High
Phenols	Abundant (120-150 mg GAE/g)	Abundant (200-250 mg GAE/g)
Alkaloids	Trace (<1%)	Caffeine (high)
Antioxidant Potential	Strong (IC_{50}: 40-60µg/mL in DPPH)	Very Strong (IC_{50}: 10-20µg/mL in DPPH)

Note. QE = quercetin equivalents; GAE = gallic acid equivalents; IC_{50} = inhibitory concentration at 50%.

Tannins may be involved in the antimicrobial activity (Palombo, 2006) whereas flavonoids and phenols are for antioxidant properties. Hence, these compounds have beneficial medicinal properties for pharmaceutical and therapeutic purposes. Research also indicates genistic acid in cocoa leaves is for its antirheumatic and analgesic properties.

Recent studies confirm that *Theobroma cacao* leaf extract (CoaLeX-1) shows significant cytotoxic effects against breast cancer cells, particularly the human-derived MCF-7 line, reducing cell viability in a dose-dependent manner. This suggests cocoa leaves may contain bioactive compounds with anticancer potential (Zainal *et al*., 2024).

Cocoa Pod Husk (CPH)

The exocarp of the cocoa fruit, or CPH, accounts for 70–80% of the fruit's dry weight and traditionally left to rot in plantations to return minerals to the soil (Nguyen *et al*., 2025).

The CPH has been described as a natural laminated material consisting of three distinctly different layers: epicarp, mesocarp and endocarp (outer, middle and inner pericarp, respectively). The endocarp is a soft whitish tissue protecting the delicate cocoa beans. The mesocarp displays a hard-composite

structure able to hold the cocoa beans in place even under high impact. While the epicarp, the outermost relatively soft layer is the colored cover (yellow, red, or green depending to clones) and it turns black indicating rot due to degradation. Study showed high proportion of ash (47%), hemicellulose (50%) and minerals (K, Ca and P) (41–66%) predominated in the epicarp. Fiber (crude, Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF)) (44-48%) and cellulose (53%) in the mesocarp. Protein (50%), crude fat (50%) and pectin (59%) in the endocarp (Campas-Vega *et al*. 2018).

Several studies confirm that cocoa pod husk extract exhibits strong tyrosinase inhibitory activity (IC_{50} = 155.58 µg/mL), making it a promising natural ingredient for skin-whitening and cosmetic applications. Recent research highlights its phenolic and flavonoid content as the main contributors to this effect (Azila *et al*., 2014; Janma *et al*., 2025; Rutnakornpituk *et al*., 2026).

Recent studies show that cocoa pod husks can be upcycled into cosmetic ingredients, acting as natural exfoliates while also delivering antioxidants, hydration, and anti-aging benefits. Their fibrous structure makes them effective for scrubs, while polyphenols and pectin contribute to skin health.

Fibrous particles from ground husks provide gentle mechanical exfoliation, removing dead skin cells without harsh abrasives. Their biodegradable nature makes them eco-friendly compared to synthetic microbeads. Polyphenols and phenols from CPH offer antioxidant activity, protecting skin from oxidative stress and premature aging. Pectin from CPH may improve skin hydration and texture, acting as natural moisturizers. Minerals such as potassium, calcium, and magnesium may support skin vitality.

Cocoa pod husk may add fiber and essential minerals to livestock diets. However, methyl xanthine content (Theobromine (<0.5% dry weight) and caffeine (<0.05% dry weight) may restrict its uses as animal feed.

Cocoa Beans

Cocoa beans contain up to 120 mg/g polyphenols, primarily catechins and epicatechins (Samuel, 2018; Tee *et al*., 2021). Study revealed that fresh cocoa beans and well-fermented dried cocoa beans gave comparable amount of extractable total phenolic contents (TPC). Nevertheless, there was a significant drop of TPC on the roasted cocoa beans (Samuel & Arief Huzaimi, 2020).

Cocoa beans aqueous extracts show strong antioxidant activity in both 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging and ferric-reducing antioxidant power (FRAP) assays, with freeze-dried extracts at 50 ppm reducing ~1.8 µmol/L ferric ions and effectively quenching DPPH radicals. This confirms their high polyphenol-driven antioxidant potential (Samuel, *et al*, 2022).

Recent clinical imaging studies confirm improved dermal density and hydration after topical application of cocoa antioxidants (Figure 1).

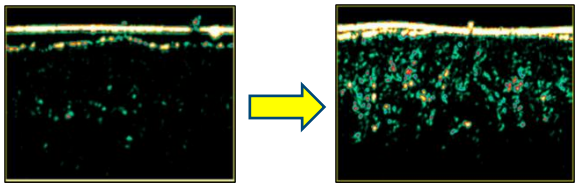


Figure 1: Ultrasound Imaging of Dermal Structure Before and After Cocoa Antioxidant Application (Images contributed by Dr Norliza Abdul Wahab)
Note. Left image shows baseline dermal echogenicity; right image shows increased echogenicity after one month of topical cocoa extract use, indicating improved collagen alignment and hydration.

The dark background at the left image of Figure 1 represents areas of low echogenicity and corresponds to less dense tissue, such as dehydrated or damaged dermal matrix. The increase in colored spots (right image) indicates higher echogenicity and is associated with improved dermal density, better collagen fiber alignment, and enhanced hydration. These suggests a positive remodeling effect on the skin's microstructure after one-month of product use, perhaps due to the cocoa antioxidant, effectively reduce oxidative stress in the cells tissues.

Cocoa Butter

Cocoa butter is rich in saturated and monounsaturated fatty acids, primarily stearic acid, palmitic acid, and oleic acid. Stearic acid is notable because, unlike other saturated fats, it has a neutral effect on blood cholesterol levels, making cocoa butter less harmful to cardiovascular health compared to animal fats (Tušek *et al*., 2024). The presence of oleic acid contributes to improved lipid profiles (Edo *et al*., 2023).

Cocoa butter is well tolerated by human skin because its fatty acid profile closely resembles that of skin lipids, especially oleic and palmitic acids, which support hydration, barrier function, and compatibility. Its high stearic acid content makes it an excellent occlusive, reducing water loss and protecting against dryness (Table 2).

Table 2: *Fatty Acid Composition of Cocoa Butter Compared to Human Skin Lipids*

Fatty Acid	Cocoa Butter (%)	Human Skin (%)	Role in Skin Compatibility
Myristic	0.1	2.1	Minor role; present in skin sebum
Palmitic	26.7	20.2	Common in both; supports barrier structure
Stearic	35.7	11.2	High in cocoa butter; provides occlusive protection
Palmitoleic	0.2	3.8	Important for sebum; low in cocoa butter
Oleic	32.8	30.8	Nearly identical levels; enhances skin softness and absorption.
Linoleic	2.7	15.1	Lower in cocoa butter; essential for barrier repair, but supplementation often comes from other oils.
Linolenic	0.1	0.3	Trace amounts in both.

Note. Values represent approximate percentages of total fatty acid composition.

Cocoa butter has been studied in percutaneous absorption research as a vehicle that enhances the delivery of active compounds through the skin as in figure 2 (Samuel *et al*., 2000; Zoumas *et al*., 1998). This makes cocoa butter a promising base for topical therapies in dermatology and cosmetics.

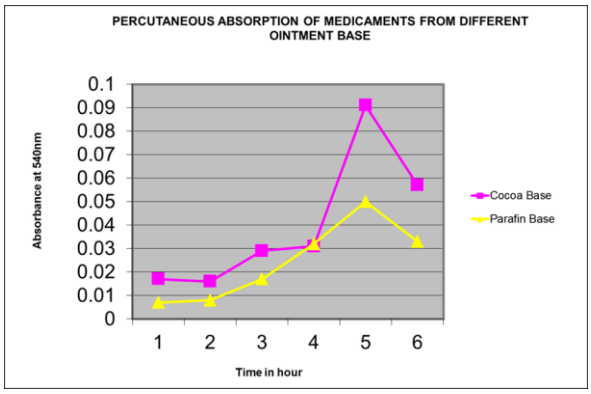


Figure 2: Percutaneous Absorption of Salicylic Acid from Cocoa Butter vs. Paraffin Preparations (Samuel et al., 2000)
Note. Cocoa butter formulation demonstrated superior absorption compared to paraffin, supporting its role as an effective topical delivery vehicle.

Cocoa Powder

Cocoa powder shares the same antioxidant benefit as cocoa beans. Nevertheless, it is not just about the antioxidant benefits, but also about the color palette it offers through alkalization. Hence, it bridges skincare and makeup by being both functional (protecting skin from oxidative stress) and aesthetic (provide a safe alternative to artificial colorants) (Norliza, 2010).

Alkalization, or also known as Dutch processing, is to treat cocoa beans or nibs with an alkaline solution such as potassium carbonate, resulting the natural reddish-brown cocoa becomes darker, ranging from light brown to deep black. Alkalization also reduces acidity, making cocoa smoother and more neutral in pH, hence, making it significantly milder and less irritating for sensitive skin than raw natural cocoa powder.

Clinical studies demonstrate that topically applied cocoa powder successfully deposits antioxidant polyphenols (such as catechin and epicatechin) directly into the stratum corneum, helping to neutralize free radicals and mitigate UV-induced oxidative damage (Draelos *et al*., 2024). Furthermore, in vitro and clinical trials confirm that cocoa derivatives significantly enhance skin hydration, promote the production of hyaluronic acid, and improve overall skin elasticity while reducing wrinkles (Lee *et al*., 2024).

Cocoa Shells (CS)

Removed during the de-hulling process to isolate the cocoa nibs, CS constitutes 10–20% of the total cocoa bean weight. Undermined by its historical use as a low-grade fertilizer, CS is exceptionally abundant in dietary fiber, polyphenols, and theobromine (Panak Balentić *et*

al., 2018). Table 3 shows the typical composition of cocoa shells.

Table 3: *Cocoa shell composition and potential benefits (Djali et al., 2023; Fakhlaei et al., 2020)*

Component	Approximate Range	Potential benefits
Dietary fiber (Insoluble fiber dominates)	30 – 50%	1. supporting digestive health 2. may use as exfoliating in cosmetics
Proteins	10 – 20%	Contains amino acids beneficial for skin and hair care
Lipids	2 – 5%	Cocoa butter residue - moisturization
Polyphenols (Flavonoids, Catechins, Procyanidins)	109 – 133 mg GAE/g	Antioxidant, anti-aging
Alkaloid	Theobromine : 16-22 mg/g Caffeine: 3.7 – 6.5 mg/g	Circulation, skin toning
Minerals (Calcium, Magnesium, Potassium, Phosphorus, Iron)	6 – 10% (as ash)	Essential for metabolic and skin health

Note. Values are approximate ranges based on dry weight composition. Dietary fiber is predominantly insoluble, supporting digestive health and exfoliation in cosmetic formulations. Polyphenols (flavonoids, catechins, procyanidins) provide antioxidant and anti-aging activity. Alkaloids such as theobromine and caffeine may enhance circulation and skin toning. Mineral content contributes to metabolic and skin health, while proteins and lipids add functional value for food and personal care applications.

Biotechnological applications are increasingly targeting CS for the recovery of active biocompounds. It serves as a potent raw material for extracting antioxidants, antivirals, and antimicrobials for the pharmaceutical and cosmetic industries. Furthermore, the cell-wall components of CS can undergo enzymatic biotransformation to produce feruloylated oligosaccharides, which serve as highly effective prebiotic and functional food ingredients (Sánchez *et al*., 2023).

Cocoa Pulp

Cocoa pulp is the white, sweet, mucilaginous substance surrounding cocoa beans, composed mainly of water (80–85%), sugars (10–15%), organic acids (1–3%), and pectin (Samuel & Mahera, 2025). While approximately 25% of it is essential to initiate the natural fermentation of the beans, the remaining 75% is traditionally lost as "sweating." The challenges and limitations of cocoa pulp utilization are it is high perishable, difficult to collect and stabilize at scale and often discarded despite its value. Valorizing cocoa pulp for powdered cocoa pulp juice (extending its shelf life), fermented beverages (as functional foods) and bioethanol could increase the farmer income stream, and consequently achieving sustainability goals.

In industrial biotechnology, its rich organic profile has proven to be an exceptional alternative culture medium. Recent study show that incorporating cocoa pulp into laboratory growth media yields recovery rates exceeding 90% for yeasts (*Saccharomyces cerevisiae*) and lactic acid bacteria (*Lactiplantibacillus plantarum*), outperforming many traditional commercial culture mediums (Guzmán-Armenteros *et al*., 2025).

In dermatological science, it is well established that naturally derived organic acids, particularly alpha-hydroxy acids (AHAs) such as citric and malic acids, act as keratolytic agents by diminishing corneocyte cohesion within the stratum corneum (Babilas *et al*., 2012; Kornhauser *et al*., 2010). Consequently, it is hypothesized that the organic acid profile indigenous to cocoa pulp (Frankdux *et al*., 2026) may similarly facilitate epidermal desquamation and cellular turnover. This mild chemical exfoliation has the potential to improve skin topography and ameliorate hyperpigmentation, while potentially mitigating the barrier disruption and erythema frequently associated with high-concentration synthetic AHAs (Tang & Yang, 2018). Nonetheless, comprehensive in vivo clinical trials are required to quantitatively evaluate the specific corneodesmolytic efficacy and exact cellular turnover rates induced by cocoa pulp extract on human skin.

CONCLUSIONS

Cocoa-based skincare often found in natural beauty brands and spa treatments. Products like cocoa scrubs, hydrating masks, and anti-aging creams are popular because they combine traditional herbal care with

modern cosmetic science. Cocoa is a versatile ingredient that offers both functional benefits (hydration, elasticity) and sensory appeal (color, aroma). Cocoa is generally non-comedogenic and allergies is rare. The valorization of cocoa by-products represents a critical intersection of waste management and industrial innovation. Transitioning CPH, CS, and cocoa pulp into functional foods, nutraceuticals, and biotechnological substrates effectively closes the loop on cocoa production. Future research must focus on scaling these green extraction technologies and establishing economically viable supply chains to ensure these non-traditional applications can meet commercial demand.

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