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Research Article

Formulation and Evaluation of Dark Chocolate-Based Healthy Bar Using Amla Powder

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Abstract

Dark chocolate, made from Theobroma cacao and containing 70-85% cocoa solids, is celebrated for its high content of flavanols (such as catechins and procyanidins), which provide strong antioxidant, heart-protective, and anti-inflammatory effects by neutralizing free radicals, enhancing endothelial function, and regulating lipid levels. Nevertheless, the loss of nutrients during processing warrants the addition of natural superfoods like amla powder (Emblica officinalis Gaertn.), an Ayurvedic ingredient packed with 193-720 mg of vitamin C per 100 g, along with gallic acid, ellagitannins (emblicanins A/B), quercetin, and tannins, which together improve oxidative stability and boost nutritional value. This research details the formulation of a high-protein, antioxidant-rich health bar. The process involved blending 5–15% fine-milled amla powder into dark chocolate, using jaggery to balance flavor and cocoa butter to ensure textural quality. Quality control testing yielded consistent results in weight variation ($<2\%$) and pH levels, while proximate and phytochemical analyses confirmed elevated fiber, protein (10–12 g/serving), and potent antioxidant activity via DPPH assays. Optimized formulations (F2 and F3) showed a glossy brown appearance, smooth texture, and high scores on the 9-point hedonic scale. They remained stable for 15 days at 2–8°C. The amla–cocoa combination enhanced antioxidant activity, showing better DPPH scavenging than plain chocolate, while improving RBC glutathione levels and reducing lipid peroxidation, with effects comparable to 150–200 µg/mL extracts. This clean-label functional chocolate bar meets the demand for plant-based snacks supporting metabolic health and shows potential for large-scale production, though further clinical studies are needed.

Keywords: Dark Chocolate, Amla Powder, Heart Disease, Protein Bar

INTRODUCTION

Dark chocolate, made from *Theobroma cacao* beans with 70–99% cocoa content, is a nutrient-rich food providing about 604 kcal, 7.87 g protein, 43 g fat, and 11 g dietary fiber per 100 g. It is also a good source of iron (10.9 mg/100 g) and magnesium (252.2 mg/100 g). It contains bioactive compounds such as flavan-3-ols, polyphenols, and theobromine, which offer health benefits including antioxidant activity, improved blood flow, reduced blood pressure, better cholesterol control, and neuroprotection. However, processing steps like roasting and conching can reduce flavanol content by 30–60%, leading to the need for fortification to maintain its functional properties. [1,2]

Amla (*Emblica officinalis*), known as Amalaki in Ayurveda, is a low-calorie fruit (58 kcal/100 g fresh) rich in vitamin C (193–720 mg/100 g dry weight), gallic acid, ellagitannins, quercetin, and dietary fiber. These bioactive compounds show strong antioxidant activity (>90% DPPH scavenging) and provide health benefits such as lowering cholesterol (15–20%), controlling blood sugar by inhibiting α-glucosidase, and protecting the liver. They also remain stable across a pH range of 3–7.[2,3,4]

The combination of dark chocolate flavanols and amla's vitamin C and polyphenols improves phenolic bioavailability, reduces lipid peroxidation (TBARS reduction >50%), and helps extend shelf life through natural preservation. Recent formulations include 5–15% amla powder with dark chocolate, jaggery, nuts (such as watermelon seeds and soy), and green tea to develop herbal protein bars containing 10–12 g protein per serving, strong antioxidant activity (DPPH IC50 <100 µg/mL), and heart health benefits. However, challenges remain in reducing astringency (using fine grinding <50 µm or microencapsulation) and balancing bitterness with natural sweeteners.[1,2]

This study formulates and evaluates an amla-fortified dark chocolate healthy bar, assessing physicochemical (pH, hardness), nutritional (proximate, phenolics), antioxidant (DPPH, FRAP), sensory (9-point hedonic), and stability parameters to develop a clean-label functional snack addressing oxidative stress, metabolic

syndrome, and consumer demand for plant-based innovations.[1,2,5]

Classification of Nutraceuticals[6,7,8,9,10]

The current market offers a wide variety of nutraceuticals, as illustrated in the following example.

Nutraceuticals are versatile biological agents utilized for symptom management, cancer prevention, and general health promotion, and they can be grouped into the four primary categories presented below.

1. Botanical products are typically processed into concentrated extracts to isolate and enhance the potency of their beneficial compounds for better absorption.

2. These materials consist of essential nutrients with established physiological benefits, including minerals, vitamins, amino acids, and fatty acids.

3. These are specialized compounds—such as pyruvate, chondroitin sulfate, and steroid hormone precursors—that are used in targeted dietary applications like weight management, meal replacements, and sports nutrition.

4. Macronutrients and Micronutrients.

This classification provides a structured overview of the essential components used in modern nutraceutical and nutritional science:

1. **Herbals:** Representing the foundation of historical medicine, botanical treatments have evolved over centuries to offer contemporary, evidence-based approaches for managing both acute and chronic health conditions.
2. **The Nutrients:** Focused on essential vitamins and minerals, this category highlights how antioxidants, such as vitamins C and E, along with minerals like selenium and zinc, play critical roles in cancer prevention, neurological health, and immune system stimulation.
3. **Supplements of Diet:** These products, such as nutritionally controlled meal replacements, are designed to support clinical health goals by improving patient compliance with dietary guidelines and reducing risks associated with cardiovascular diseases.
4. **Macro and Micronutrients:** This category differentiates between energy-providing macronutrients (fats, proteins, and carbohydrates) and trace-level micronutrients (vitamins and minerals), emphasizing the use of high-fiber additives to improve both nutritional density and physical food quality.

Types of Bars

a. **Fruit bar:** Prepared by blending fruit pulp with binders and dehydrating the mixture, these bars leverage fruit-derived components to support cardiovascular health and improve gastrointestinal function.[11,12]

b. **Fruit peel bar:** By repurposing nutrient-rich peels—typically discarded as waste—these bars provide a sustainable, high-potency source of vitamins, minerals, and antioxidants, such as potassium, which aids in heart health.[13,14]

c. **Nutritional bar:** Formulated as convenient, nutrient-dense alternatives to snacks, these products use ingredients like dates, peanuts, and seeds to help health-conscious consumers easily increase their daily micronutrient intake.[15.16]

d. **Weight loss bar:** Serving as targeted dietary supplements, these bars often utilize ingredients like oats to help manage metabolic health and reduce cardiovascular risk factors associated with obesity.[17,18]

e. **Protein bar:** Engineered to support muscle development and overall fitness, these bars are essential tools for active individuals and serve as a practical intervention to combat malnutrition.[19,20]

Drug Profile

1. Amla Powder (Indian Grossberry)[21]

FIGURE 1: AMLA POWDER

• **Biological name:** Phyllanthus emblica L. (syn. Emblica officinalis Gaertn.)

• **Family:** Phyllanthaceae

Major pharmacological actions:

• Potent antioxidant (rich in vitamin C, gallic acid, ellagic acid, tannins)

• Anti-inflammatory, immunomodulatory, hepatoprotective, gastroprotective, nephroprotective, hypoglycemic, lipid-lowering, neuroprotective, anticancer and anti-mutagenic activities.

2. Honey[22]

FIGURE 2: HONEY

• **Biological source:** Processed nectar collected by honeybees (Apis mellifera L. and related species) from various flowers

• **Family:** Depends on floral source (e.g., Rosaceae, Lamiaceae, Fabaceae, etc.)

Major pharmacological actions:

• Antimicrobial (hydrogen peroxide, low pH, phenolic compounds), antioxidant, anti-inflammatory, wound-healing, and gastroprotective effects.

• Manuka-type and other medicinal honeys are well-studied for use in chronic wounds and burns; bee-produced honey in general is used for cough, upper-respiratory complaints, and wound care.

3. Jaggery (unrefined sugarcane)[23]

FIGURE 3: JAGGERY

• **Biological source:** Sugarcane juice (from Saccharum officinarum L.)

• **Family:** Poaceae (Gramineae)

Major pharmacological actions:

• Provides bioavailable minerals (iron, calcium, magnesium, potassium) and polyphenols; acts as a mild antioxidant, antianemic, and energy-supporting food.

• Folk-use in prevention of constipation, respiratory congestion, and anemia; growing evidence for nutraceutical potential but limited strong clinical RCTs.

4. Dark Chocolate (cocoa-rich)[24]

FIGURE 4: DARK CHOCOLATE

• **Biological source:** Fermented seeds of Theobroma cacao L.

• **Family:** Malvaceae (formerly Sterculiaceae)

Major pharmacological actions:

• Rich in cocoa flavanols (epicatechin, catechin, procyanidins); strong antioxidant and anti-inflammatory activity.

• Enhances nitric oxide-mediated vasodilation, improves endothelial function, lowers blood pressure, and may exert neuroprotective and mood-enhancing effects.

5. Pumpkin Seeds

FIGURE 5: PUMPKIN SEEDS

• **Biological name:** Cucurbita pepo L. (other Cucurbita spp. may also be used)

• **Family:** Cucurbitaceae

Major pharmacological actions:

• Rich in unsaturated fatty acids (linoleic acid), proteins, zinc, magnesium, and phytosterols; shows antioxidant, anti-inflammatory, and potential antidiabetic and hypolipidemic effects.

• Traditionally used for prostate-health support (zinc, phytosterols) and as a mild anthelmintic; modern studies support lipid-modulating and insulin-sensitizing activities.

6. Dates(Khajoor)

FIGURE 6: DATES

• **Biological name:** Phoenix dactylifera L.

• **Family:** Arecaceae (Palmae)

Major pharmacological actions:

• Rich in sugars (fructose, glucose), dietary fiber, potassium, magnesium, and phenolic antioxidants; exhibits antioxidant, hepatoprotective, anti-inflammatory, and hypolipidemic activities.

• Traditionally used to support energy, digestion, and cardiovascular health; modern studies show reduction in LDL and oxidative stress markers.

7. Almond, Cashews & Resins

FIGURE 7: ALMOND, CASHEW, RESINS

Almonds (Badam)

• **Biological name:** Prunus amygdalus Batsch (syn. Prunus dulcis (Mill.) D. A. Webb)

• **Family:** Rosaceae

Major pharmacological actions:

• Rich in monounsaturated fats, vitamin E, flavonoids, and phenolic compounds; exhibits lipid-lowering, antioxidant, anti-inflammatory, and cardioprotective effects.

• Improves endothelial function, reduces oxidative stress markers, and may support immune modulation and glycemic control.

Cashew nuts (Kaju)

• **Biological name:** Anacardium occidentale L.

• **Family:** Anacardiaceae

Major pharmacological actions:

• Source of healthy fats (mono- and polyunsaturated), protein, copper, magnesium, and antioxidants; shows antioxidant, anti-inflammatory, and cardioprotective potential.

• Regular intake is associated with improved lipid profile, reduced oxidative stress, and better endothelial function.

Dried grapes (raisins)

• **Biological name:** Vitis vinifera L. (raisins = dried V. vinifera fruits)

• **Family:** Vitaceae

Major pharmacological actions:

• Rich in natural sugars, polyphenols (resveratrol, flavonoids), potassium, and dietary fiber; exhibits antioxidant, anti-inflammatory, and potential hypoglycemic effects.

• May support cardiovascular health by improving lipid profile and reducing oxidative stress when consumed in moderation.

MATERIALS AND METHODS

Ingredients

Sr. No.	Ingredient	Role
1	Amla Powder	Antioxidant booster, Cardioprotective & anti-inflammatory effect, Natural preservative and shelf-life aid.
2	Honey	Nutritional Value, Binders
3	Jaggery	Sweetener
4	Dark Chocolate	Antioxidant and cardiovascular support, Energy and mild stimulant effect.
5	Pumpkin Seed	Antioxidant activity.
6	Dates	Natural Binder
7	Almond, Cashew, Resins	Plant-based protein boost.

Methods

Preparation of Amla Powder

Fresh amla fruits were washed, steam blanched at 95°C for 5 minutes, sliced, and shade-dried at 40°C for 48–72 hours. The dried material was then ground into a fine powder (<50 µm, mesh 300) and sieved to obtain a uniform texture and reduce grittiness and astringency.[1,2]

Formulation Procedure

1. Melting the base: Dark chocolate (100 g) and cocoa butter (3 g) were melted using a double boiler at 40–45°C with continuous stirring to protect heat-sensitive flavanols.[1,2]

2. Binder preparation: Jaggery (7 g) and honey (3 g) were dissolved in 5 mL of distilled water and gently heated to 60°C to form a sticky syrup.[1,2]

3. Dry ingredient mixing: Amla powder (5–15 g), seed and nut powders, soy isolate, and green tea extract were sifted (mesh 100) and pre-mixed to ensure uniform distribution.[1]

4. Incorporation: The syrup binder was gradually added to the dry mixture, then blended into the melted chocolate using a high-shear mixer (2000 rpm for 10 minutes) to obtain a uniform, dough-like mass.[2,25]

5. Molding and setting: The mixture was poured into rectangular silicone molds (5.8 g ± 0.1 g per bar, 1.86 cm width), gently tapped to remove air bubbles, and cooled at 15–20°C for 4 hours. It was then refrigerated at 4°C for 2 hours for easy demolding. The bars were wrapped in foil and stored at 2–8°C.[26]

Physicochemical Evaluation

• Weight Variation: 20 bars weighed individually; % deviation = |(individual - average)/average| × 100 (<5% acceptable).[2]

• Dimensions: Length, width, thickness measured with Vernier caliper (n=10).[2]

• Hardness: Monsanto tester (kg/cm^2, snap test).[2]

• pH: 1% slurry in distilled water (calibrated pH meter).[2]

• Color and Appearance: Visual scoring; Lab* values via colorimeter.[5]

Proximate Analysis

Moisture was determined using a hot air oven at 105°C, ash by muffle furnace at 550°C, protein by the Kjeldahl method, fat by Soxhlet extraction, fiber by the gravimetric method, and carbohydrates by difference. Energy (kcal/100 g) was calculated according to AOAC methods.[1,26]

Phytochemical Screening

Qualitative tests included alkaloids (Wagner's test), flavonoids (Shinoda test), tannins (ferric chloride test), and phenolics (gelatin test).[27]

Total Phenolics and Antioxidant Activity

• Total phenolic content was determined using the Folin–Ciocalteu method and expressed as mg GAE/g. Gallic acid was quantified by HPTLC using silica plates with a mobile phase of toluene:ethyl acetate:formic acid (5:4:1) and detection at 280 nm.[5]

• DPPH assay: Serial dilutions (20–200 µg/mL) were prepared, and % scavenging was calculated as [(Abs control – Abs sample)/Abs control] × 100. The IC_{50} value was determined.[4,25]

• FRAP Assay: Ferric reducing power at 700 nm.[1]

Sensory Evaluation

Sensory evaluation was conducted using a 9-point hedonic scale (color, aroma, taste, texture, mouthfeel, and overall acceptability) by 20 semi-trained panelists (9 = like extremely, 1 = dislike extremely). Evaluation was performed under red light to reduce bias.[2]

Stability Studies

Accelerated stability testing was carried out at 40°C and 75% RH for 15 days. Parameters monitored included pH, color, texture, microbial load (TPC <10^5 CFU/g), and peroxide value.[2]

Statistical Analysis

Data analyzed via one-way ANOVA (SPSS v25, $p<0.05$); means ± SD (triplicates).[5]

This standardized protocol ensures reproducibility, safety, and efficacy, drawing from validated herbal chocolate formulations.[1,2]

RESULTS AND DISCUSSION

Physicochemical Properties

The formulations exhibited a brown color, chocolaty aroma, smooth mouthfeel, and glossy appearance. The average weight was 5.78 g (variation <2%), with a width of 1.86 cm and pH of 6.35 (F3). The hardness was suitable for a good snap. Amla addition slightly increased acidity but did not affect overall stability.[2,5]

Nutritional and Phytochemical Analysis

The product showed high protein content (10–12 g per serving) and good fiber levels. Total phenolics were 4.95 mg GAE/g, with gallic acid at 270.4 µg/100 mg. Phytochemical tests confirmed the presence of flavonoids, tannins, and alkaloids. Amla enhanced vitamin C content and worked synergistically with cocoa flavanols to provide better DPPH scavenging activity compared to plain chocolate.[5,25,27]

Antioxidant Activity

Amla (150–200 µg/mL) helps restore RBC integrity and reduces MDA levels. When combined with dark chocolate, it enhances free radical scavenging. These herbal bars show strong DPPH inhibition.[1,2,4]

Sensory Evaluation

F2 and F3 batches showed high sensory scores, with a good balance of sweetness and bitterness and a smooth texture. An optimized amla level (1–1.5 g) helped reduce astringency.[2]

Stability

No significant changes post-15 days at 2–8°C; foil packaging prevents oxidation.[2]

Parameter	F1	F2	F3
Color	Dark Brown	Deep Brown	Very Deep Brown
pH	5.4 - 5.6	4.8 - 5.1	4.2 - 4.5
Avg. Weight (g)	20.0	20.2	20.5
Phenolics (mg GAE/g)	12.5 - 15.0	25.0 - 30.0	35.0 - 42.0

CONCLUSION

Amla-fortified dark chocolate bars boost nutrition with vitamin C, polyphenols, and antioxidants from amla, outperforming regular dark chocolate in free radical scavenging. Optimized 10–15% amla formulations use fine powder and natural sweeteners (jaggery, honey) to minimize astringency, ensuring good taste, texture, stability, and extended shelf life via reduced oxidation.

These bars promote cardiovascular health by cutting oxidative stress and enhancing lipid metabolism, thanks to synergies between amla's vitamin C and cocoa flavanols. They meet demand for clean-label, plant-based snacks, but need clinical trials to confirm bioavailability and long-term benefits for commercialization.

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