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Development of Nutrient-Rich Detox Beverage by Utilization of Underused Plant By-Products

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Abstract: *The growing popularity of functional and detox drinks is allowing for a greater level of sustainability regarding the use of under-utilized edible plants with nutritional and medicinal values. This study created a detox drink from amla leaves (Phyllanthus emblica), pumpkin seeds (Cucurbita pepo), and ash gourd peels (Benincasa hispida), which are rich in dietary fibre, minerals, antioxidants and bioactive compounds yet are usually discarded as waste. To ensure that the final product has a satisfactory functional profile the proportion of each ingredient was adjusted. In addition to the detox drink, mint (Mentha spicata) and ginger (Zingiber officinale) were added to increase the health benefits and flavour of the detox drinks. This produced four different formulations: basic (amla leaf, pumpkin seed and ash gourd peel), ginger enriched, mint enriched and ginger-mint enriched. The method used to extract the nutrients from the detox drink was to heat-processed it using controlled heating and filtration so that it retained the heat-sensitive components of the plants used. Further analysis of the detox drink for its physicochemical, nutritional, antioxidant, sensory and storage stability resulted in the combination of ginger and mint producing the highest level of sensory acceptance with additional anti-inflammatory, digestive, and antimicrobial properties that will allow for the sustainable development of agro-waste*

Keywords: Functional detox beverage, Amla leaf, Pumpkin seed, Ash gourd peel, Plant byproducts, Sustainability

I. INTRODUCTION

Functional beverages, commonly known as detoxification drinks, have grown enormously over the past few years and account for the fastest growing sub-section in the global food and beverage industry due to increased consumer awareness around health, wellness, and preventative nutrition. Detoxification drinks contain a variety of ingredients gives the ability to quench your thirst; they provide physical benefits such as removing toxins from the body, offering antioxidant benefits from the vegetables, improving your digestion and assisting with a healthy immune system. Detox beverages made from fruits, vegetables, and herbs are extremely high in bioactive compounds helps to neutralize free radicals, reduce the oxidative stress which promote healthy cell function (Jordão Júnior et al., 2025; Gülhan, 2017). The most popular option in the marketplace are the plant-based drinks; they are safer with a higher bioavailability and a much lower incidence of adverse reactions. Amla (Phyllanthus emblica) has also been identified as a leading, unbranded candidate for use as a nutraceutical; Amla contains large amount of vitamin C, polyphenols and flavonoids, along with tannin compounds, making it a source of antioxidant, anti-inflammatory, and antimicrobial properties (Gul et al., 2022; Gautam & Shukla, 2017). Pumpkin seeds are not only an excellent source but contain high-quality protein and essential fatty acids, in addition to minerals and phytochemicals beneficial for digestion, immune response, and metabolic function (Samran et al., 2025). The ash gourd peel is very high in fiber and offers bioactive compounds beneficial for detoxification and digestive system maintenance (Sailaja & Parameshwari, 2018). The addition of ginger and mint further enhances the functional properties of the detox beverages due to their enhanced antioxidant properties, greater digestibility, improved flavors, and increased consumer acceptability of the beverages. RTS beverage formulations composed of all of these ingredients have shown excellent stability with regard to the physicochemical properties, retention of antioxidants, and shelf-life (Hirdyani, 2015; Mishra & Sangma, 2017; Surya et al., 2020). The

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agricultural waste products, such as leaves, seeds, and peels are converted into usable commodity items helps support the sustainability goals of the beverage industry by reducing the quantity of food waste generated while providing significant additional nutritional and functional benefits to the consumer (Pérez-Marroquín et al., 2023; Das et al., 2025). When evaluated for their physicochemical, nutritional, and sensory characteristics, detoxification beverages are able to retain their health benefits, quality and flavor (Manivannan & Madhu, 2016). Even though there has been a lot of research done on the individual ingredients, hardly any studies have looked at the combined use of amla leaves, pumpkin seeds, and ash gourd peel in one beverage formulation. Hence, this work is intended to the development of a detox beverage comprising these plant byproducts with high nutrient, antioxidant, and sustainability traits, thus meeting the consumer's requirement for natural functional drinks along with the environmental sustainability goals.

II. MATERIALS AND METHODS

2.1 MATERIALS

To prepare a detox drink, amla leaf (fresh), ash gourd peel, pumpkin seed, ginger, and mint were the main ingredients. A fresh and good-quality selection of all the items was made. Amla leaves and ash gourd peels were procured as underutilized plant by-products from local sources; meanwhile, pumpkin seeds were collected from vegetable processing waste. Ginger and mint were bought from the local market. All the chemicals and reagents utilized in the analysis were of analytical grade, and distilled water was consumed throughout the research.

2.2 METHODS

DRINK PREPARATION

Amla leaves and ash gourd peels were thoroughly cleaned under tap water to remove dirt and impurities, followed by fine chopping. The chopped materials were boiled in distilled water heated to 80–90 °C for a specified time duration to extract bioactive compounds. The extracts were filtered through the filtrate and cooled to room temperature. Pumpkin seeds were cleaned, washed, and dried at low temperature. After light roasting, the seeds were ground processed into fine powder and passed through a sieve to obtain uniform granules. Ginger and mint were washed, chopped, boiled and individually extracted in distilled water and subsequently filtered and cooling to obtain their extracts. Four detox beverage formulations were developed using a base mixture of amla leaf, pumpkin seed. Formulations containing amla leaf, pumpkin seed, and ash gourd peel, with the addition of ginger, mint, or their combination, were standardized to a fixed volume. The powders were then reconstituted in distilled water, subjected to controlled heating, filtered, cooled, and subsequently used for physicochemical, functional and antioxidant analysis.

INGREDIENTS	FORMULATION 1	FORMULATION 2	FORMULATION 3	FORMULATION 4
WATER	100ml	100ml	100ml	100ml
AMLA LEAF	3g	3g	3g	3g
ASH GOURD PEEL	4g	4g	4g	4g
PUMPKIN SEED	2g	2g	2g	2g
GINGER	-	1g	-	1g
MINT LEAVES	-	-	1g	1g

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Fig 2.1 Formulation 1 (Ash gourd peel + Amla leaf + Pumpkin Seed)
Fig 2.2 Formulation 2 (Ash gourd peel + Amla leaf + Pumpkin Seed + Ginger)

Fig 2.3 Formulation 1 (Ash gourd peel + Amla leaf + Pumpkin Seed + Mint)
Fig 2.4 Formulation 1 (Ash gourd peel + Amla leaf + Pumpkin Seed + Ginger + Mint)

2.3 METHODOLOGY FOR TESTS PERFORMED

To evaluate the quality, functional characteristics and consumer acceptance of the final detox drink, it underwent several types of analysis, including nutritional, physicochemical, antioxidant, sensory and shelf-life determination. The standardized protocols used at the lab for all evaluations yielded consistent and reliable data.

2.3.1 DETERMINATION OF NUTRITIONAL ANALYSIS

A. Moisture Determination (Hot Air Oven Method)

The amount of water contained in the samples was calculated based on the following procedure: The clean, dry, and cool moisture dish with obtained weight was W1. Approximately five milliliters (5 ml) of the sample were added to the above-listed item of equipment and weighed (W2). The above item of equipment was heated in a Hot Air Oven at 105 degrees centigrade (°C) for three to four hours until the weight remained the same, and the dried product from the moisture test was weighed (W3).

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B. Protein Estimation (Kjeldahl Method)

The nitrogen content of each sample was analyzed using 5 ml of the sample and digesting with concentrated sulfuric acid with catalyst until the solution was clear. After dilution with distilled water, the solution was distilled using sodium hydroxide to liberate the ammonia from the sample, the ammonia was collected in boric acid and titrated with hydrochloric acid. The quantity of nitrogen found in a sample was converted to the protein amount.

C. Fat Estimation (Soxhlet Extraction)

A thimble containing a volume of dried sample was placed into a Soxhlet extraction unit and extracted with petroleum ether, a nonpolar solvent, over a six- to eight-hour period. Once the extraction was complete, the petroleum ether was evaporated from the residue, the residue was weighed after being dried, and the fat content of the sample was calculated based on the weight of the extractable lipid.

D. Ash Determination (Muffle Furnace Method)

A clean crucible was obtained, and a known weight of the sample was placed into the crucible. The sample was charred on the hot plate and then incinerated in a muffle furnace at 550°C for 4– 6 hours and allowed to cool in a desiccator before weighing. The ash content of the remaining residue is the remaining residue.

E. Crude Fiber Estimation (Acid–Alkali Digestion Method)

After the protein extraction (removal of fats), we dissolved the entire sample in a solution containing sulfuric acid of 1 1/4% and boiled it for 30 minutes. We filtered out the liquid from the solids left behind and then washed and boiled the solids that were left behind with a solution containing 1 1/4% sodium hydroxide for another 30 minutes, filtered these solids and dried them, and weighed them after drying. Next, we heated these filtered and dried solids in a furnace until it burned off all residual organics. The change in weight is representative of the amount of crude fiber present.

F. Carbohydrate Determination (Difference Method)

To find the moisture, protein, fat, and carb values: We measured (experimentally) the percentage of each of moisture, protein, fat, and crude fiber, and subtracted that from 100%, resulting the percentage of total carbohydrate content. All three values give grams of protein per 100 mL of sample.

G. Energy Value Calculation (Atwater Method)

The grams of protein, fat, and carbohydrates measured from the earlier work were multiplied by their Atwater factors (4 for protein, 9 for fat, and 4 for carbohydrates) to yield their contributions to total energy from both protein and carbohydrates respectively for a total contribution to energy. The energy contribution from both groups (protein and carbohydrates) will be expressed in kcal per 100mL sample.

2.3.2 DETERMINATION OF PHYSICOCHEMICAL ANALYSIS

A. pH Determination

The digital pH meter was calibrated using standard buffer solutions of pH 4.0 and 7.0. The electrode had been rinsed with distilled water and immersed in the beverage sample, giving it time to stabilize before the reading, and recording the pH value of the respective sample beverage.

Measurements were conducted in duplicate to maintain accuracy.

B. Titratable Acidity Determination

A known volume of the sample beverage was diluted with distilled water before performing titrations with 0.1N Sodium Hydroxide (NaOH) using phenolphthalein indicator until reaching a pale pink endpoint. The NaOH volume used in titration was recorded, followed by calculation of acidity expressed as a percentage. Each titration was performed in triplicate to improve precision.

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2.3.3 DETERMINATION OF ANTIOXIDANT ACTIVITY (DPPH ASSAY)

A freshly prepared DPPH Solution was mixed with a known volume of the Sample Extract and was maintained in darkness at room temperature for 30 mins before taking the absorbance measurement from UV/Vis Spectrophotometer at 517 nm. The percentage of Radical Scavenging Activity was calculated.

2.3.4 DETERMINATION OF SENSORY EVALUATION (9-POINT HEDONIC SCALE) AND STORAGE

Samples of the beverage products were presented to a trained panel of taste testers in a clean and sanitary manner. The panel of taste testers evaluated the color, aroma, taste, mouthfeel, and overall acceptability of each beverage using a nine-point hedonic scale. The panelists had been given drinking water to cleanse their palates between the different beverage samples, and the average scores for each sensory parameter were determined.

The prepared samples of the beverage products were stored in sterile air-tight containers under both ambient (room temperature) and cold (refrigerated) conditions. Periodic assessment of the impact of pH, acidification, and sensory parameters on the shelf life of food products occurred through periodic observation of visual spoilage (mould growth, discoloration) and odour changes. Acceptable physicochemical and sensory basis determined the maximum shelf life.

III. RESULTS AND DISSCUSSION

3.1 NUTRITIONAL ANALYSIS

Standard AOAC methods were employed to determine proximate composition, which encompasses moisture, ash, protein, fat, crude fiber, carbohydrate, and energy value. The protein content determined is 0.46 g/100 ml and it is mainly contributed by pumpkin seed using the Kjeldahl method. The carbohydrate value is 13.0 g/100 ml calculated by difference method. Using Soxhlet extraction the fat content is seen to be 0.31 g/100 ml. The moisture content in the beverage is 79.1% as determined by the hot air oven method, which is very typical of a functional beverage in terms of high-water content. The ash value obtained through muffle furnace incineration is 7.13% which indicates that the plant ingredients have a good supply of essential minerals. The detox beverage that was produced has an energy value of 56.63 kcal/100 ml using Atwater factors and this indicates it to be a low to moderate calorie functional drink. The estimation was done using the enzymatic-gravimetric method. The approximate fiber content is found to be 0.8 g/100 ml, predominantly coming from the ash gourd peel.

COMPONENT (PER 100 ML)	PROXIMATE ANALYSIS
MOISTURE (g)	79.1
PROTEIN (g)	0.46
FAT (g)	0.31
ASH (g)	7.13
CRUDE FIBER (g)	0.8
CARBOHYDRATES (g)	13.0
ENERGY (Kcal)	56.63

Table 2 Nutritional Analysis

3.2 PHYSICOCHEMICAL ANALYSIS

The physicochemical properties of the drink were examined by means of standard methods. The digital pH meter was put to use for the determination of the pH and the value obtained 5.38 confirmed the slightly acidic character of the beverage which is the main factor affecting its stability. The titratable acidity was ascertained through titration with standardized NaOH and expressed as percentage acidity; the Observed acidity of 0.56% has a flavor and a shelf-life that are both acceptable from a sensory point of view.

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COMPONENT (PER 100 ML)	PROXIMATE ANALYSIS
PH	5.38
TITRATABLE ACIDITY	0.56

Table 3 Physicochemical Analysis

3.3 ANTIOXIDANT ACTIVITY

The DPPH free radical scavenging assay was used to assess the antioxidant potential. The percentage of inhibition was determined through measuring absorbance with a UV–visible spectrophotometer and was reported as percentage scavenging activity. An antioxidant activity of 69.4% inhibition was recorded, with the formulations containing ginger and mint showing the highest values.

3.4 SENSORY EVALUATION

Sensory testing was conducted by a semi-trained panel and used a nine-point hedonic scale to rate the formulations on color, aroma, taste, mouthfeel, and overall acceptability. The formulation with ginger and mint got the maximum sensory ratings of 7.8–8.6 which shows that a perfect balance between the functional ingredients and the consumer's acceptance was reached.

COMPONENT (PER 100 ML)	SENSORY ANALYSIS
COLOUR	7.9
AROMA	8.5
TASTE	8.0
MOUTHFEEL	7.8
OVERALL ACCEPTABILITY	8.1

Table 4 Sensory Evaluation

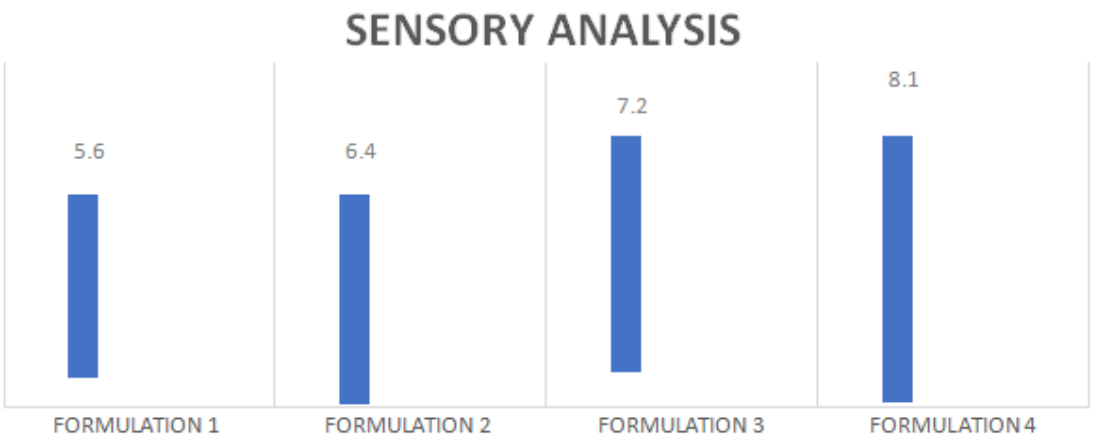

Fig.3.1 Sensory Evaluation

3.5 STORAGE AND SHELF–LIFE STUDY

The prepared drink was kept in sterilized airtight containers under ambient and cold storage conditions. Periodically, changes in pH, acidity, and sensory attributes were monitored to judge shelf-life. Storage stability was determined by the physicochemical and sensory methods and it was found that the detox beverage had approximately 7–10 days of shelf stability at refrigerated temperature (4–8°C) and2–3 days at room temperature without preservatives.

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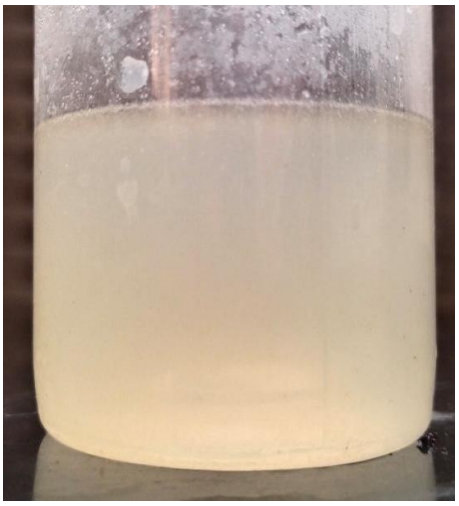

Fig 3.2 Final Detox Drink

IV. CONCLUSION

A Detox Drink that has been enriched with nutrients from less frequently used Plant by-products has been developed from Amla Leaves, Pumpkin Seeds, and Ash Gourd Peels. A Detox Drink developed from Amla Leaves and Pumpkin Seeds, enhanced by the addition of Ginger and Mint showed greater Physicochemical Changes due to Processing, Nutritional Composition, Antioxidant Activity, and Sensory Acceptability than either of the Plant by-products alone. Effect on the Functionality and Consumer Acceptability of a Detox Drink with the Addition of Ginger and Mint was positive. Shelf-life Testing indicated that Detox Drinks are Safe to Keep for a Limited Amount of Time, and Refrigerating the Drink provides the Longest Shelf Life. A Detox Drink can be made without Chemical Preservatives. The work undertaken in this study has opened up possibilities for using Agro Waste to create Value Added Products and for the Development of Eco-Friendly Functional Beverages.

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