

Development and Quality Evaluation of a Fruit-Based Functional Beverage from Beetroot, Apple, Orange and Carrot

Pallavi Pandey

Department of Food Technology, Parul Institute of Applied Sciences, Parul University,
Vadodara (Gujarat) India

Dr. Pankaj Parmar

Department of Dairy and Food Technology, Parul Institute of Technology, Parul University,
Vadodara (Gujarat) India

Abstract

The human body is made up of a fundamental structural protein called collagen. Oxidation, environmental factors, and inadequate intake of vitamins and minerals are some of the factors that contribute to its depletion. Minimally processed fruit- and vegetable-based beverages are a convenient and acceptable vehicle for delivering these vitamins. The present work aims to develop a fruit-based functional drink with gamboge juice and a natural sweetener as natural acidulant and sweetener, and to evaluate its nutritional, sensory, storage, and economic characteristics with specific reference to collagen-supporting nutrients.

Fresh vegetables were washed, trimmed, and cold-pressed to obtain juice. Orange and lemon are rich in vitamins C and E, carrot is a major source of provitamin A, and Beta vulgaris rubra (beetroot), apple, and the selected sweetener are important contributors of antioxidants and minerals. Information on process efficiency was provided by the juice yield for each raw material, which ranged from about 50% for gamboge to more than 80% for apple and carrot. Four blends were prepared by varying the relative proportions of apple, orange, and carrot while keeping gamboge and the sweetener within a narrow functional range, which resulted in blends that differed in colour, flavour, and expected nutrient distribution but were comparable in overall composition and processing.

The beverages were evaluated for their pH and basic quality attributes, with all blends showing a slightly acidic pH of around 4, a range considered favourable for microbiological safety and for the stability of ascorbic acid during short-term storage. The potential of the product to support collagen maintenance was examined in terms of the contribution of vitamin C, β -carotene, and glutathione from the fruits and vegetables. A panel of judges used a hedonic scale to assess sensory quality. A blend with a higher proportion of orange and beetroot was the most preferred. The use of gamboge juice and the natural sweetener extended the shelf life from 7 days to 15 days. A simple cost analysis showed that the drink can be produced at a moderate price per litre, suggesting feasibility for small-scale commercial production or institutional use.

The findings show that a cold-pressed beetroot–apple–orange–carrot drink can be developed as a natural functional beverage that aligns with consumer preference for clean-label products. Because of its good sensory properties, short-term ambient stability, and reasonable production cost, the product shows promise for further scale-up as a food-science-based functional drink

targeting skin and general health.

Keywords: Fruit-based functional beverage, beetroot–apple–orange–carrot drink, cold-pressed juice, collagen-supporting drink, antioxidant activity, physico-chemical properties, sensory evaluation, shelf life, production cost.



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1. Introduction

1.1 Background on Collagen and Skin Health

Collagen is the primary structural component of the human body and makes up about one-third of total body protein [1]. In the skin, collagen provides mechanical reinforcement to the overlying layers. Skin resilience, elasticity and structural integrity are largely determined by the amount of type I and type III collagen present [1].

Collagen has a unique triple-helical structure composed of three polypeptide α -chains rich in the repeating sequence Gly–X–Y [1]. This triple helix allows the formation of robust fibrils and fibres with extensive post-translational modification. Skin elasticity and mechanical strength are further supported by the integration of elastin and glycosaminoglycans, which act as a scaffold for blood vessels [1]. Dermal fibroblasts help maintain normal skin architecture and function [1].

Collagen plays a central role in wound healing. After a skin injury, fibroblasts migrate into the wound bed and form a new collagen matrix that is initially thicker and more disorganised than normal dermis. Collagen fibres require adequate synthesis and proper remodelling for optimal function. Impaired collagen production, structure or turnover can lead to increased skin fragility, delayed healing and signs of ageing.

From early adulthood onwards, collagen homeostasis becomes progressively imbalanced. Studies show that human skin loses elasticity with age [1]. Aged skin tends to have a thinner dermis [2]. Varani et al. reported that changes in fibroblast function and altered mechanical signalling in aged dermis contribute to decreased synthesis of type I and type III collagen [2]. Fine lines, wrinkling, loss of firmness and elasticity, as well as functional changes such as diminished resilience and slower repair, are visible features of these underlying alterations.

Smoking, environmental pollution and ultraviolet (UV) exposure can accelerate the effects of ageing. Reactive oxygen species (ROS) generated by UV radiation and environmental stress directly damage cellular components and alter signalling pathways that regulate collagen synthesis and degradation [3]. Down-regulation of collagen-related genes can lead to a net loss of dermal matrix [3]. Chronically photo-exposed skin often appears more aged than skin of the same chronological age that is protected from sunlight [3]. Functional foods and beverages rich in vitamins and minerals have therefore attracted interest as an adjunct approach to support collagen synthesis and protect the dermal matrix through nutrition [4]. A fruit–vegetable drink relevant to the maintenance of skin health is the focus of the present study.

1.2 Nutritional Factors Influencing Collagen Synthesis

An adequate intake of vitamins and trace elements is needed for the synthesis of collagen. Procollagen α -chains are first synthesised in the rough endoplasmic reticulum and then undergo extensive post-translational modification [5]. These reactions require essential cofactors. When any of these components are limiting, triple-helix stability and cross-link density are reduced, which compromises the mechanical strength of collagen and can lead to delayed wound healing, as seen in scurvy.

Ascorbic acid is the most important vitamin in collagen metabolism. It is necessary to maintain the active-site iron of prolyl and lysyl hydroxylases [4]. Insufficient vitamin C intake leads to under-hydroxylated procollagen, impaired triple-helix formation and reduced production of stable collagen. In addition to supporting fibroblast proliferation and protecting the skin from harmful UV radiation, vitamin C has a direct role in collagen synthesis [4]. Experimental studies show that vitamin C can increase the synthesis of type I collagen in fibroblasts [4]. Humans cannot synthesise vitamin C, so regular intake of vitamin-C-rich foods is necessary.

The amino acid composition of collagen is also nutritionally significant. The unique triple-helical structure depends on the presence of glycine, proline and hydroxyproline, which account for a large fraction of the total sequence [1]. In the Gly–X–Y motif, glycine appears at every third position, allowing tight packing of the three chains, while proline and hydroxyproline help stabilise the helix through steric effects and hydrogen bonding [1]. The potential benefit of the fruit-based drink therefore depends on the consumer's overall intake of high-quality dietary protein. Iron, copper and zinc are also important trace elements involved in collagen cross-linking and antioxidant defence [1].

Protecting newly formed collagen also requires limiting oxidative stress. Reactive oxygen species generated by pollution, UV radiation and normal cellular metabolism can cause degradation of the dermal matrix [3]. Vitamins C and E help protect the body from oxidative damage and reduce inflammation [3]. Carotenoids accumulate in the skin [7]. Intervention studies have shown that higher consumption of carotenoid-rich foods or supplements can modestly enhance photoprotection and improve some aspects of skin appearance [7].

A blend of fruits and vegetables forms the basis of the drink formulated in the present study. In particular, orange and lemon provide vitamin C and other antioxidants. Although the drink is not intended as a complete solution for collagen health, it is conceptually positioned as a convenient, minimally processed source of micronutrients that can complement a balanced diet to support collagen synthesis and protect the dermal matrix from oxidative damage.

1.3 Functional Foods and Beverages

Over the last few decades, there has been a shift in consumer expectations from foods that only provide energy and basic nutrients towards products that promote health and help reduce the risk of chronic disease. Functional foods are foods that have been shown to benefit one or more target functions in the body in a way that is relevant to health, well-being or disease prevention [10]. Some products contain plant sterols or added vitamins and minerals; fruit- and vegetable-based products are also considered functional foods.

Most scientific and regulatory definitions share common elements: functional foods are consumed as part of a normal diet, they contain bioactive components that provide health benefits beyond basic nutrition, and their claimed effects should be supported by sound scientific evidence [10]. Functional foods are attractive because they can be integrated into everyday eating patterns and allow value addition in established categories.

Functional beverages are one of the fastest-growing segments. This group includes fortified fruit juices, sports and energy drinks, probiotic and prebiotic beverages, plant-based drinks, herbal infusions and ready-to-drink teas and similar products [12]. They are convenient, easy to consume in controlled portions and can efficiently deliver water-soluble components such as vitamins and minerals, making beverages suitable carriers of bioactive ingredients. By adapting them to a wide range of flavours, it is possible to achieve both health benefits and high sensory appeal. Functional beverages are an important vehicle for ingredients targeting immune function, digestion, cognitive performance, physical endurance and skin appearance [11].

Fruit- and vegetable-based beverages typically contain a wide range of vitamins and minerals [10]. Increased consumption of fruits and vegetables, including in juice form, has been linked to reduced risk of cardiovascular disease and other chronic conditions [14]. These beverages provide vitamins and minerals that support collagen synthesis and protect the walls of blood vessels, which is relevant from a skin-health perspective. Combining different fruit and vegetable juices is one way to deliver complementary micronutrients.

Safety and sensory aspects must be considered in drink development. Many components are sensitive to heat, oxygen and light, so processing methods should be chosen to minimise losses. Because pasteurisation can degrade vitamins, there is growing interest in minimal or non-thermal processing methods [12]. The impact of a product is limited if it is not acceptable to consumers. The cold-pressed fruit–vegetable drink developed in this study is based on the functional-beverage model. The formulation aims to provide a beverage that is easy to consume and pleasant in taste, aligning food-science principles with current consumer demand for natural, health-oriented products.

1.4 Fruit–Vegetable Juices as Functional Beverages

Functional beverages that combine the benefits of both fruits and vegetables in a single product are referred to as fruit–vegetable juices. Both vegetables and fruits are rich in vitamins and minerals [10]. In a ready-to-drink format, these plant matrices can deliver significant amounts of both hydrophilic and lipophilic antioxidants. Several studies have shown that regular consumption of fruit and vegetable juices is associated with improved antioxidant status and beneficial changes in biomarkers related to cardiovascular and metabolic risk [12].

Mixed fruit–vegetable juices offer complementary nutritional and sensory profiles. Orange, carrot and beetroot provide vitamin C, organic acids and a range of phytochemicals. Such blends often have higher total antioxidant capacity than single-component juices [12]. Blending also helps to moderate strong notes from some vegetables and improve colour and mouthfeel without the need for artificial additives.

Several of the key nutrients discussed in Sections 1.1 and 1.2 can be delivered in a single serving of fruit–vegetable juice. Citrus components are essential for collagen production and are a major water-soluble antioxidant source in the skin [4]. Carotenoids from carrot can accumulate in the skin [7]. Compounds in apple and beetroot may help limit the effects of oxidative stress [3]. A fruit–vegetable drink can therefore serve as a convenient vehicle for such bioactive compounds.

Processing conditions strongly influence the nutritional quality of these juices. Thermal pasteurisation and clarification of juices can cause losses of heat-labile components [12]. In response to consumer demand for natural, fresh-like products, there is growing interest in minimally processed options [12]. Cold-pressing helps retain the original vitamins and aroma compounds. In the present study, the base of the drink is made from cold-pressed juices, which provide natural acidity and mild antimicrobial properties.

The benefits of functional juices must be aligned with their sensory quality. Vegetables such as carrot and beetroot can impart strong flavours and a dense texture, which may limit acceptability if used alone or in high proportion. Blending them with sweeter and more acidic fruits like apple and orange, and adjusting the acidity with honey and lemon, makes it possible to obtain a drink that is both palatable and nutritionally targeted. Sensory evaluation by a 20-member panel confirmed that balanced fruit–vegetable blends can achieve good acceptability. The four formulations developed in the present work embody this approach: they explore different ratios of beetroot, apple, orange and carrot, while keeping lemon and honey within functional limits. As outlined in Section 1.3, juices are a promising vehicle for delivering collagen-supportive nutrients in a form that fits easily into the daily diet.

1.5 Rationale for Selection of Beetroot, Apple, Orange, Carrot, Lemon and Honey

The ingredient combination used in this study was selected to satisfy three main criteria: nutritional relevance, skin health support, and good sensory acceptability, along with practical availability and cost. The drink, as formulated, provides vitamin C, β -carotene, polyphenols, betalains and minor antioxidants. Together, these help to create a product that fits consumer expectations for a “natural” functional beverage rather than a highly processed or artificially flavoured one.

The drink has a core vegetable component. Juice and extracts from red beetroot contain compounds with antioxidant and free-radical-scavenging properties [15]. The deep red colour imparted by these pigments reinforces the functional positioning of the beverage. Carrot is an important source of provitamin A with documented skin-related benefits [17]. The data show that carrot makes a meaningful contribution to the formulation. To avoid sensory rejection, both carrot and beetroot are combined with sweeter fruits.

The high levels of vitamin C in orange and lemon make them suitable natural acidulants. Studies show that ascorbic acid is an important component of the diet and serves as a major water-soluble antioxidant in the skin [4]. In this formulation, orange and lemon juices lower the pH of the blend into a slightly acidic range, which is beneficial for the stability of vitamin C and helps prevent yeast growth. The stronger vegetable notes of carrot and beetroot are balanced by the addition of orange and lemon.

Apple is a fruit widely associated with general health benefits. Apples contain a variety of compounds that contribute to their anti-ageing properties [19]. The natural sweetness and mild fruity flavour of apple juice improve overall acceptability for a wide range of consumers and help to harmonise the flavour profile of the drink, making it suitable for regular consumption.

The clean-label positioning of the product led to honey being chosen as a natural sweetener. The antibacterial and antiviral properties of honey are attributed to small amounts of bioactive compounds [21]. Phenolic constituents are the main contributors to its radical-scavenging activity [21]. The modest extension of shelf-life observed in this study is supported by the antimicrobial effects of honey. At the same time, honey imparts a familiar taste and natural image that help distinguish the drink from conventional commercial beverages.

Overall, the combination of carrot, orange, lemon, apple, beetroot and honey reflects a balanced design that integrates technological feasibility and sensory quality. The formulation supports the positioning of the developed product as a fruit-vegetable functional beverage.

1.6 Research Gap and Need for the Study

A substantial body of work has examined the effects of vitamin C, carotenoids and polyphenols on skin health. Many products marketed for “beauty from within” or “skin freshness” contain vitamins and botanical extracts, often in the form of supplements or highly processed drinks. However, the focus has rarely been on whole-nutrient-based beverages that deliver multiple collagen-supporting nutrients in a minimally processed format.

Improved antioxidant status and reduced risk of chronic disease have been associated with higher fruit and vegetable consumption [10]. Only a small number of studies have formulated and evaluated fruit-vegetable beverages with a clear rationale for skin support. Commercial collagen drinks often rely on added vitamins and intensive processing, and rarely report detailed information on formulation, processing, stability, cost and sensory evaluation within a single, coherent study. There is a gap in research that combines gentle processing with natural preservation to meet consumer expectations for minimally processed, clean-label functional beverages [12].

The literature describes the nutritional properties of different fruits and vegetables, but there is a lack of studies that combine these ingredients in carefully balanced formulations and then evaluate, within one framework, their pH, yield, nutritional characteristics and sensory acceptability. Academic documents often report physiological effects without considering cost and consumer acceptance, while commercial products provide limited scientific detail.

In the present study, a cold-pressed fruit–vegetable drink based on beetroot, apple, orange and carrot, with lemon and honey as natural acidulant and sweetener, was developed. This work aims to provide both scientific justification and practical feasibility for positioning this beverage as a functional drink that aligns with current consumer preferences for natural, minimally processed products.

1.7 Aim and Objectives of the Study

The overarching purpose of this study was to develop a fruit-based functional drink using apple, orange and carrot, with lemon juice and honey as natural acidulant and sweetener, and to evaluate its suitability as a collagen-supportive beverage from a nutritional science perspective. The product was conceptualised as a cold-pressed, minimally processed drink that could deliver key vitamins and minerals relevant to collagen synthesis and protection, while remaining sensorially acceptable, safe for short-term storage, and economically viable.

To translate this overall purpose into measurable tasks, the work was structured around a set of specific objectives covering analytical evaluation, sensory quality, storage behaviour and cost. These objectives were designed to give a comprehensive picture of the product's performance, moving beyond simple nutrient profiling to include practical aspects that are important for potential real-world application.

Specific objectives of the study are:

1. To develop a fruit vegetable functional drink with lemon juice and honey incorporated as natural acidulant and sweetener, using cold-press extraction and preparing multiple variants with different juice proportions.
2. To determine the juice yield from individual raw materials, the pH of the final blends, and the contribution of key vitamins and minerals from selected ingredients.
3. To evaluate the antioxidant activity of the formulated drinks using appropriate in vitro assays, in order to understand their overall free-radical–scavenging potential and relate it to their compositional profile.
4. To assess the sensory properties and consumer acceptability of the different formulations using a 9-point hedonic scale with a 20-member panel, and to identify the most preferred formulation on the basis of these scores.
5. To study the shelf life of selected products under ambient storage conditions by monitoring visual appearance and sensory quality over time, with particular attention to the role of lemon juice and honey.
6. To estimate the production cost of the drink on a per-litre basis.

These objectives ensure that the developed drink is examined not only for its potential to deliver collagen-supportive nutrients, but also for its technological robustness, sensory performance and cost viability, providing a well-rounded basis for positioning it as a practical functional beverage.

2. Literature Review

2.1 Collagen, Skin Ageing and Oral Nutritional Approaches

Both intrinsic and extrinsic skin ageing can be traced back, in part, to the gradual decline of collagen, the main structural component of the dermis. Ageing leads to loss of firmness, wrinkling and impaired barrier function as fibroblast activity decreases and existing fibres become thinner and less organised. Chronic low-grade inflammation in sun-exposed areas accelerates the up-regulation of matrix metalloproteinases, which further degrade collagen [3]. There is strong interest in oral interventions that can support the body's own collagen network. Several systematic reviews and meta-analyses report improvements in skin hydration, elasticity and fine lines following oral supplementation. These effects are thought to arise partly from increased availability of collagen-derived peptides and amino acids, and partly from improved antioxidant and micronutrient status. Experts emphasise that protection against oxidative damage and an adequate micronutrient profile are key determinants of collagen turnover.

Fruits and vegetables are rich in both cofactors and antioxidants, and are therefore considered an alternative approach to direct collagen supplementation. Carotenoids and polyphenols can accumulate in the skin and modulate oxidative and inflammatory pathways. It is increasingly recognised that plant-based foods can help support dermal structure. Recent reviews suggest that multi-nutrient approaches are likely to be more effective than single-nutrient strategies [25]. The present study does not attempt to supply collagen directly, but instead focuses on a beverage that delivers vitamins and minerals from whole fruits and vegetables. A product that supports the collagen system through cofactors and antioxidant protection may be more compatible with everyday eating habits than concentrate-based supplements. The literature therefore provides a strong conceptual basis for the development of beverages based on plant ingredients.

2.2 Functional Foods, Beverages and Skin Health

Functional foods are foods that are beneficial to one or more target functions in the body in a way that is relevant to health or disease-risk reduction. This concept has expanded from its early focus on cardiovascular and metabolic benefits to include areas such as immune function, cognitive performance and digestive health. Foods and beverages designed to improve skin appearance, barrier function or resilience to environmental stressors are also considered part of this broader functional portfolio when their claims are supported by evidence.

Functional beverages are one of the most dynamic segments within functional foods. They are convenient, easy to dose, and well suited for delivering water-soluble bioactives. “Beauty drinks” and “skin health” beverages have appeared in many markets. However, many such products are highly processed, contain added sugars, flavours and preservatives, and are closer to liquid supplements than to traditional foods. Information on their composition, efficacy and sensory attributes is often limited. Fruit- and vegetable-based beverages can instead be viewed as foods rather than supplements. Reviews suggest that plant-based beverages may contribute to improved skin barrier function, reduced UV damage and attenuation of inflammation. Tomato-based drinks and berry blends, for example, have shown photoprotective effects in early clinical settings. In such products, functional positioning is built around nutrient-rich raw materials.

The present study therefore formulated a fruit–vegetable drink with a clearly articulated rationale linked to skin health. The drink is derived from vitamins, minerals and phytonutrients naturally present in plant foods. It responds both to scientific evidence on plant-based skin benefits and to consumer demand for natural, minimally processed, “clean-label” functional beverages.

2.3 Fruit and Vegetable Intake, Carotenoids and Skin Appearance

A growing body of research links higher fruit and vegetable consumption with visible changes in skin appearance. Increased intake of fruits and vegetables over relatively short periods has been

shown to increase the redness and yellowness of skin tone. Observers tend to rate these colour changes as healthier and more attractive, suggesting that diet can influence appearance within a timeframe relevant to consumer expectations. Studies show that skin colour is related to dietary patterns. Cross-sectional analyses indicate that individuals with higher fruit and vegetable intake tend to have higher cutaneous carotenoid levels and more golden skin tones, while intervention trials demonstrate that increasing intake within the same individuals produces within-subject changes in skin colour. Higher carotenoid status has also been associated with improved photoprotection.

The mechanism is thought to involve carotenoids accumulating in the skin, where they can help shield against oxidative damage that contributes to collagen breakdown. Polyphenols present in fruits and vegetables may further modulate oxidative and inflammatory pathways. In this context, a drink rich in carrot and other selected ingredients, when consumed regularly, can contribute to a dietary pattern supportive of skin appearance and dermal maintenance. In practice, beverages are an accessible way to increase fruit and vegetable intake among populations that struggle to meet recommended servings. The finding that skin colour responds relatively quickly to dietary change has even been proposed as a motivational tool to encourage higher consumption in younger adults. These observations suggest that positioning a product around both skin health and appearance may be justifiable if the beverage genuinely delivers carotenoid- and polyphenol-rich ingredients.

2.4 Fruit Vegetable Juices, Antioxidant Capacity and Processing

The antioxidant properties of fruit and vegetable juices have been widely studied. Many commercial juices show substantial free-radical-scavenging activity due to their vitamin C and phenolic content. Several studies report that juices made from mixed fruits and vegetables have higher total antioxidant capacity than those made from a single component. Human intervention trials using fruit-vegetable juice concentrates have demonstrated improvements in biomarkers related to oxidative status and disease risk.

The final antioxidant capacity of a juice is strongly influenced by processing and storage. Thermal pasteurisation can degrade heat-labile vitamins. High-pressure processing and pulsed electric fields can better preserve sensitive nutrients but are often impractical in small-scale settings due to equipment costs. In contrast, cold-press extraction combined with mild preservation and short shelf life can achieve acceptable safety and quality while limiting nutrient loss.

Storage time and temperature also affect antioxidant levels in fruit and vegetable juices. Although vitamin C and phenolic content decline over time, many products retain functionally relevant antioxidant capacity during the first one to two weeks of storage, supporting the development of juices that emphasise freshness. In this study, natural acidity from orange, lemon and honey was used to stabilise apple-based juice blends. The work provides practical information on how a simple, low-oxygen, low-heat process can preserve meaningful levels of antioxidant capacity over a limited shelf-life period.

2.5 Bioactive Profile of Selected Ingredients for Collagen-Supportive Beverages

The anti-inflammatory, vascular and antioxidant effects of fruits and vegetables are directly relevant to skin and connective tissue health. The main bioactive components of the selected ingredients—including vitamins, carotenoids, betalains, polyphenols and selected minerals—are summarised in Table 1, with emphasis on their potential roles in supporting collagen synthesis, protecting dermal structures and modulating oxidative stress.

Table 1: Selected ingredients, major bioactive components and reported skin/collagen-related actions

Ingredient	Major bioactive components (relevant here)	Collagen / skin-related actions reported in literature	Key refs*
Beetroot (Beta vulgaris L.)	Betalains (betacyanins, betaxanthins), phenolic acids, flavonoids, nitrate, potassium	Strong antioxidant and radical-scavenging capacity; potential to reduce oxidative stress and inflammation, support vascular function and tissue perfusion, indirectly benefiting skin and ECM integrity	[3], [15], [16]
Carrot (Daucus carota L.)	β -carotene and other carotenoids, phenolic compounds	Major dietary source of provitamin A; carotenoids accumulate in skin, contribute to photoprotection, quench singlet oxygen and support appearance and antioxidant defence	[7–9], [17], [18]
Orange & lemon (Citrus spp.)	Vitamin C, flavanones (e.g. hesperidin), phenolic acids, organic acids	Provide ascorbic acid necessary for collagen hydroxylation; contribute to antioxidant status and may support vascular and dermal health; acidity also aids product stability	[4], [10], [14]
Apple (Malus domestica)	Flavonoids (quercetin, catechin, epicatechin), phenolic acids (chlorogenic acid), fibre (pectin)	Antioxidant and anti-inflammatory effects; may complement citrus and carrot components in protecting dermal matrix from oxidative damage	[19], [20], [29]
Honey	Phenolic compounds, flavonoids, organic acids; low water activity and acidity	Demonstrated antioxidant and antimicrobial activity; may contribute modestly to protection against oxidative stress and support shelf life as a natural preservative	[21], [22]

From a formulation standpoint, these ingredients are complementary. Carrot and citrus fruits provide carotenoids that can accumulate in the skin and enhance photoprotection. The drink is enriched with a range of bioactive compounds, and natural preservation is supported by the antimicrobial action of honey. The choice of these plant materials is consistent with practical considerations in food product development, as they are familiar to consumers and relatively affordable. The dissertation shows how their sensory profiles can be blended in different ratios to achieve balanced flavour and high hedonic scores. The literature supports the relevance of each component individually, and this work brings them together in a single drink that supports collagen maintenance.

3. Materials and Methods

3.1 Study Design and Overview

The intent of the experiment was to develop and evaluate a functional drink based on cold-pressed juices of apple, orange and carrot, with lemon juice and honey used as natural acidulant and sweetener. Four formulations with different juice ratios were prepared and compared. Juice yield, basic physico-chemical properties, sensory acceptability, short-term shelf-life and product cost per litre were analysed. The process steps are shown in Figure 1.

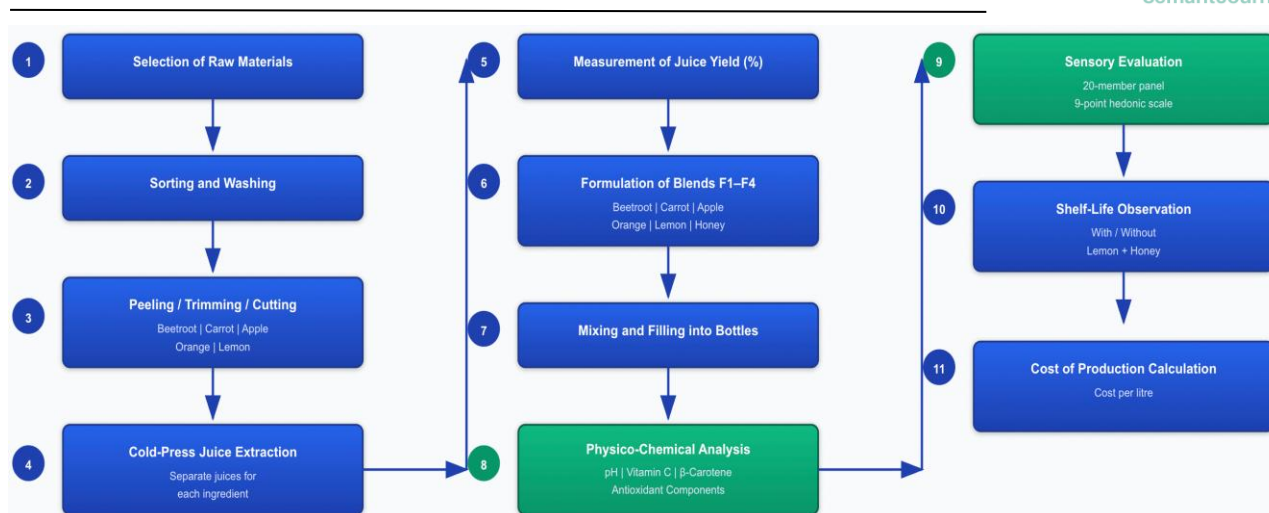


Figure 1: Workflow

3.2 Raw Materials and Ingredient Preparation

The fresh fruits and vegetables were procured in good condition. Commercial food-grade honey was used as the natural sweetener. Fruits and vegetables were washed under running potable water. Inedible parts (peels where applicable, stalks, and damaged portions) were removed. Carrots and beetroot were fed directly into the cold-press juicer. Apples and citrus fruits were cut and deseeded as required. No synthetic additives, colours, or flavours were used.

3.3 Juice Extraction by Cold Pressing

A cold-press juicer was used to obtain the juice. The cold-press method was chosen to minimise heat generation and mechanical shear during processing, in order to preserve heat-sensitive vitamins and other bioactive compounds. The prepared raw materials were fed into the juicer and the juice was collected in clean food-grade containers. The pomace was discarded. Juice yield (%) for each raw material was calculated as:

$$\text{Juice yield (\%)} = (\text{Weight of juice obtained} / \text{Weight of raw material}) \times 100$$

The final drink composition was estimated using these yields.

3.4 Beverage Formulations

To balance the nutritional contributions of the fruits and vegetables, the cold-pressed juices were blended in different proportions. The formulations were defined on a volume basis.

Table 2: Composition of the experimental drink formulations (v/v %)

Formulation n	Beetroot juice	Carrot juice	Apple juice	Orange juice	Lemon juice	Honey
F1	60	20	10	10	—	—
F2	30	—	10	50	10	—
F3	40	10	40	—	—	10
F4	20	30	—	30	10	10

All blends were prepared by measuring the required amount of each juice and honey, mixing thoroughly, and immediately filling food-grade bottles. The product thus consisted only of fruit/vegetable juices and honey. The above four formulations were selected for detailed analysis after preliminary trials.

3.5 Physico-Chemical Measurements

3.5.1 pH of Final Blends

The pH of each formulation was measured using a digital pH meter. The instrument was calibrated with two different buffer solutions. The final formulations had pH values between 4.0 and 4.3, reflecting the influence of lemon and citrus juices on overall acidity and providing a suitable range for the stability of vitamin C and other nutrients, as reported in the results section.

3.5.2 Collagen-Supportive Nutrient Estimation

Collagen-relevant nutrients were estimated for each formulation by combining:

- Standard nutrient composition data for raw juices, and
- The percentage contribution of each juice in the blend.

These data were used to derive approximate values for vitamin C and β -carotene. The anti-ageing potential was further interpreted from the qualitative contribution of apple and honey. The derived values formed the basis for the summary table.

3.6 Preservation Strategy and Shelf-Life Observation

Lemon juice and honey were used as natural preservation aids. Lemon juice contributed to lowering the pH. Preliminary trials showed that the final beverage contained 2% lemon juice and 5% honey (v/v). Shelf-life was evaluated by storing the beverage under ambient conditions without synthetic preservatives. Samples were observed for up to 21 days for signs of gas formation, phase separation, mould growth, and changes in sensory quality. The beverage was acceptable for about 7 days without the addition of lemon juice and honey, and for up to 2 weeks in the variant containing these natural preservation aids.

3.7 Sensory Evaluation

Sensory evaluation was carried out using a semi-trained panel. The panel evaluated all four formulations (F1–F4) under controlled conditions. To minimise bias, each sample was served in random order. Plain water was provided to cleanse the palate between samples.

Panelists assessed the following attributes:

- Taste (sweetness, acidity, overall flavour balance)
- Colour / appearance (visual appeal, intensity and uniformity)
- Texture / mouthfeel (smoothness, absence of fibrous/gritty particles)
- Aroma (freshness and pleasantness)
- Overall acceptability

A 9-point hedonic scale was used. Panelists were also asked to indicate their most preferred formulation. The most acceptable blend was identified using mean hedonic scores.

3.8 Antioxidant Activity Index

An antioxidant activity index for each formulation was derived based on:

- Estimated vitamin C content per 100 mL,
- Estimated β -carotene and other carotenoids per 100 mL, and
- The qualitative contribution of apple polyphenols.

Formulations with the highest combined levels of these nutrients were interpreted as having the strongest antioxidant potential. This approach was consistent with the data structure presented in the original dissertation.

3.9 Cost of Production

The cost of production per litre of beverage was calculated considering:

- Cost of fresh fruits and vegetables at local market rates,
- Cost of honey per litre of drink,
- Yield losses estimated from measured juice outputs,
- Packaging material costs (bottles, caps, labels), and
- Approximate operational costs (labour and utilities) for small-scale production.

The total raw material plus processing cost was computed for each formulation. The final estimated cost for the selected formulation was approximately ₹3.50 per litre, indicating that the product could be competitively priced relative to other functional beverages while still delivering added nutritional value.

3.10 Statistical Analysis

Sensory scores were expressed as mean $\pm$ standard deviation. Differences among formulations were evaluated using analysis of variance (ANOVA), followed by post-hoc comparison of means to identify the most acceptable formulation. Descriptive statistics were used for cost estimates. The period of acceptable quality, with and without natural preservation aids, was summarised qualitatively. The overall purpose of the analysis was to identify a formulation that was both sensorially acceptable and economically feasible.

4. Results and Discussion

The main findings of the study on the development of a plant-based functional drink formulated from beetroot, apple, orange, carrot, lemon, and honey—with emphasis on its collagen-supportive potential, processing performance, sensory quality, shelf-life, and cost-effectiveness—are presented in this chapter.

4.1 Nutritional Composition of Raw Ingredients

Table 3 summarises the nutritional profile of the selected ingredients. Apple, orange, carrot, lemon, honey, and beetroot together provide a spectrum of vitamin C, provitamin A, iron, and moderate natural acidity.

Table 3: Nutritional composition of ingredients used in the drink

Ingredient	Vitamin C (mg/100 g)	Beta-carotene (μ g/100 g)	Antioxidants (mg/100 g)	Iron (mg/100 g)	pH value
Beetroot	4.9	0	7.5	0.8	6.5
Apple	4.6	0	4.1	0.1	3.3
Orange	53.2	0	9.1	0.1	3.8
Carrot	5.9	8280	3.4	0.3	6.0
Lemon	53.0	0	8.4	0.2	2.0
Honey	0.3	0	5.0	0.4	3.9

The formation of the triple helix in the skin is dependent on prolyl and lysyl hydroxylases. Carrot juice can act as a pro-vitamin A source and support skin renewal, while regular consumption of apple, carrot, and beetroot may help reduce oxidative stress on the skin. The ingredient pH values (2.0–6.5) also have important formulation implications. The lower pH of lemon and orange

provides acidity that helps maintain a balanced flavour profile, while the higher pH of carrot and beetroot helps to moderate sourness. Overall, the nutrient composition supports the principle that a blend of these juices can act as a functional beverage.



Figure 2: Representative images of individual ingredients (beetroot, apple, orange, carrot, lemon and honey) highlighting their colour and visual freshness

4.2 Juice yield and implications for process efficiency

The table shows the cold-pressing yield. Apple juice had the highest yield efficiency, followed by carrot and beetroot.

Table 4: Cold-pressing yield for each juice

Juice type	Weight of raw ingredient (kg)	Yield (L)	Yield efficiency (%)
Beetroot	5	3.8	76
Apple	5	4.2	84
Orange	5	3.5	70
Carrot	5	4.0	80
Lemon	5	2.5	50

Under cold-pressing conditions, apple and carrot have a softer tissue structure, which favours higher juice recovery. The good yield from beetroot also supports the feasibility of its inclusion in the blend. Lemon's lower yield is expected due to its tighter segment structure and higher peel thickness, but even at modest volumes it is valuable as a natural acidulant and preservative. The yield values show that a cold-pressing process can efficiently recover juice volume while helping to retain vitamin C and other sensitive compounds.

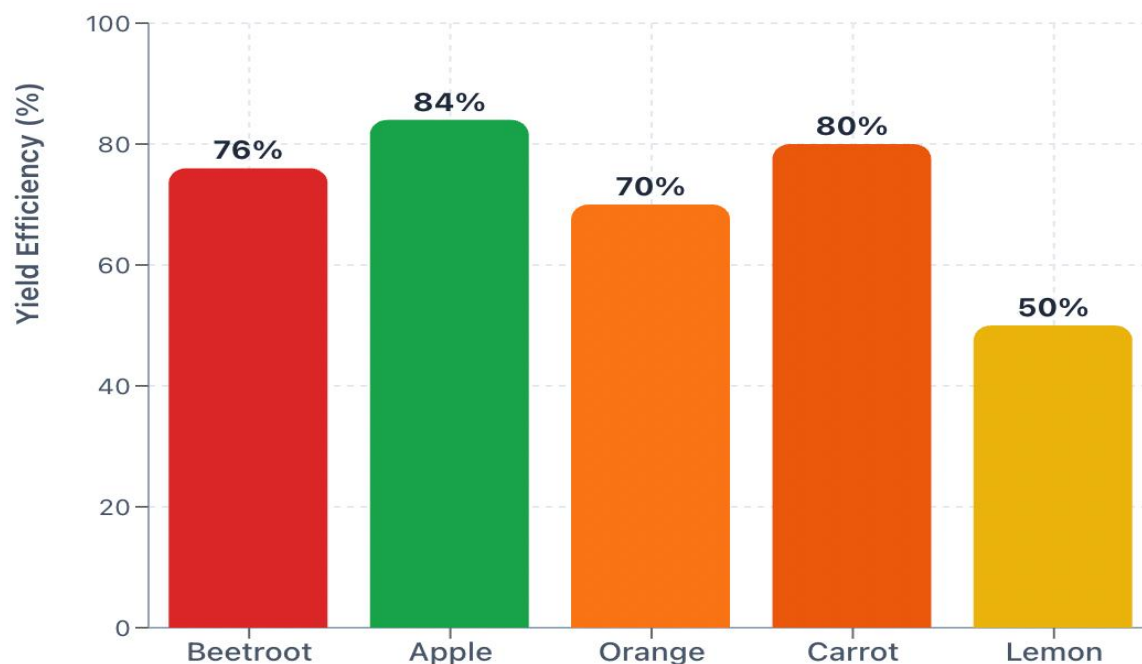


Figure 3: Bar chart of yield efficiency (%) for beetroot, apple, orange, carrot and lemon juices obtained by cold-pressing

4.3 Sensory optimisation of formulations

The different proportions of apple, orange, carrot, lemon and honey were evaluated using a 9-point hedonic scale. The mean panel scores are summarised in Table 5.

Table 5: Sensory evaluation results for formulations (9-point hedonic scale)

Attribute	F1 (60% beetroot, 20% carrot, 10% apple, 10% orange)	F2 (50% orange, 30% beetroot, 10% apple, 10% lemon)	F3 (40% apple, 40% beetroot, 10% carrot, 10% honey)	F4 (30% carrot, 30% orange, 20% beetroot, 10% lemon)
Taste	7.8	8.2	7.5	7.3
Colour	7.5	8.0	8.1	7.8
Texture	7.0	7.5	7.2	7.4
Aroma	7.3	7.6	7.5	7.2

The highest taste score was recorded for Formulation 2, indicating that a higher orange proportion combined with apple, lemon and beetroot produced the most acceptable flavour balance. The perceived freshness and sweetness of the beverage are likely enhanced by the added acidity from lemon and the strong citrus notes. Formulation 3, with equal proportions of apple and beetroot, achieved the highest colour score of 8.1, reflecting the visually appealing deep red hue contributed mainly by beetroot juice.

All four formulations were well accepted by the panel, and the scores for texture and aroma fell within a narrow, positive range. The levels of carrot and orange in the blend are reflected in the favourable texture scores for Formulations 2 and 4. The sensory results show that consumer-oriented optimisation requires balancing functional ingredients with taste and overall acceptability. Formulation 2 therefore supports its selection as the lead formulation for a functional drink aligned with market expectations for fruit-based beverages.

4.4 Physicochemical properties and shelf-life

4.4.1 pH of final formulations

The products fell within a mildly acidic pH range, which is favourable for the retention of vitamin C and general product stability.

Table 6: pH value of final drink formulations

Formulation	pH value
Formulation 1	4.2
Formulation 2	4.1
Formulation 3	4.3
Formulation 4	4.0

The small differences in pH mainly reflect variation in orange and lemon content: higher proportions of lemon and orange resulted in lower pH values. Such a pH window is advantageous because it:

- Inhibits the growth of many spoilage micro-organisms,
- Enhances the stability of ascorbic acid, and
- Aligns with consumer expectations for health-oriented beverages.

4.4.2 Effect of honey and lemon on shelf-life

The shelf-life of the beverage was compared with and without honey and lemon. The shelf-life increased when honey and lemon were incorporated as natural preservatives.

Table 7: Shelf-life of drink with and without natural preservatives

Condition	Shelf-life (days)
With honey and lemon	15
Without preservatives	7

Low water activity, together with the presence of organic acids and antimicrobial compounds, helps suppress microbial growth. A clean-label functional beverage without synthetic additives corresponds to an emerging demand in the health-oriented drinks market.

4.5 Collagen-related functional components in the blends

The collagen-related functional components contributed by each juice are highlighted in Table 8.

Table 8: Collagen-boosting components in each juice

Juice type	Vitamin C (mg/100 g)	Beta-carotene (µg/100 g)	Antioxidants (mg/100 g)
Beetroot	4.9	0	7.5
Apple	4.6	0	4.1
Orange	53.2	0	9.1
Carrot	5.9	8280	3.4

The bulk of vitamin C is contributed by orange and lemon juice. The β -carotene in carrot can be converted into vitamin A. Consuming apple and beet, which also contain polyphenols and betalains, can help reduce the risk of free-radical damage to the body. The combination of these juices in the formulation offers a multi-pronged approach to skin health by:

- Stimulating collagen synthesis via vitamin C,
- Supporting skin structure and renewal via pro-vitamin A, and

- Protecting collagen and the extracellular matrix via phenolic and betalain antioxidants.

4.6 Consumer acceptance and economic feasibility

4.6.1 Consumer acceptance

The consumer acceptability of the drink was further assessed using an extended panel, with scores for appearance, flavour, texture, aroma and overall acceptability recorded on a 9-point hedonic scale. Several samples achieved “like very much” levels for appearance, taste and overall acceptability. The formulation based on apple, orange, carrot, lemon and honey can deliver both functional benefits and high sensory acceptance, consistent with earlier reports that consumers respond positively to fruit-based blends.

4.6.2 Cost analysis and production feasibility

The cost of raw materials per batch is shown in Table 9.

Table 9: Cost analysis of raw ingredients per batch

Ingredient	Cost per kg (USD)	Quantity used (kg)	Total cost (USD)
Beetroot	1.20	3	3.60
Apple	2.00	3	6.00
Orange	1.50	3	4.50
Carrot	1.00	3	3.00
Lemon	2.50	1	2.50
Honey	3.00	0.5	1.50
Total	—	—	21.10

The main cost drivers are orange and apple, which reflect their typical market prices, while beetroot and carrot are relatively cost-effective. When labour, utilities, marketing and overheads are included, the estimated production cost per litre remains competitive. The cost profile indicates that the developed drink can be positioned as an affordable functional product in the emerging skin-health beverage segment.

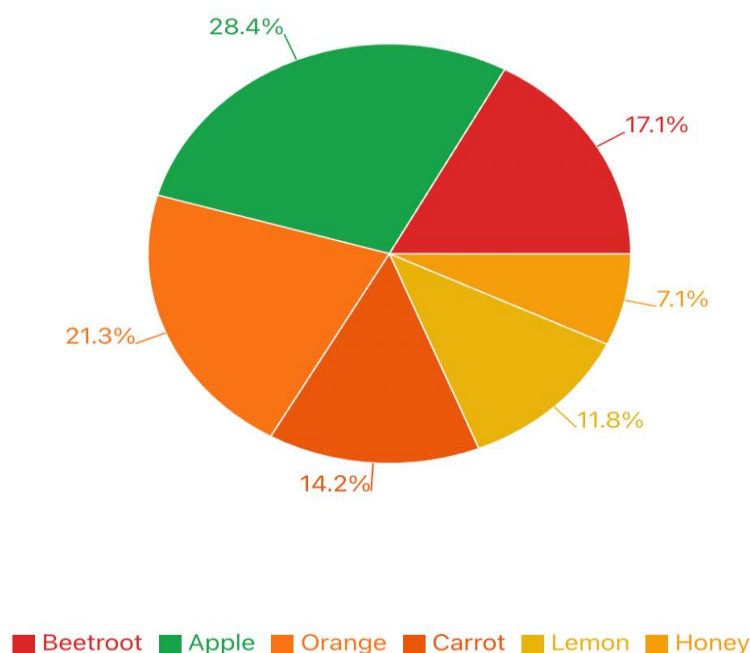


Figure 4: Pie chart showing relative cost contribution (%) of each ingredient to the total raw material cost per batch

4.7 Overall Discussion

A cold-pressed blend of apple, orange, carrot, gamboge and honey can be formulated into a drink with clear nutritional features relevant to skin health and hydration. Orange and lemon are the main sources of vitamin C, while carrot provides β -carotene, as indicated by the analysis of the raw ingredients. When these juices were combined, stable colour and flavour, high scores for taste, colour and overall acceptability, and a drink with mild acidity were achieved.

The results show that a simple, low-input preservation strategy using gamboge and honey extended shelf-life by about two weeks. This supports the feasibility of developing a clean-label functional drink that relies on natural acidity and the antimicrobial activity of honey for short-term stability. The drink can be produced at a cost level comparable with many premium juices and other beverages, while offering a clearer, science-based rationale for its proposed benefits. Overall, the findings indicate that plant-based, minimally processed beverages can be used to support skin health.

4.8 Limitations and Scope for Future Work

This study has some limitations that should be acknowledged. The assessment of collagen-supportive potential was based on the content of vitamin C, β -carotene and related nutrients, rather than on direct measurement of biological markers. The functional potential was inferred from ingredient composition and existing literature. In addition, the shelf-life study was limited to ambient storage and a short observation period; refrigerated storage and more advanced microbiological testing were beyond the scope of the present work.

Future research could address these gaps by studying fibroblast responses and changes in skin parameters after consumption of the drink. High-pressure processing or refrigerated distribution could be explored to further extend shelf-life. The formulation could also be tailored for specific consumer groups, such as older adults, athletes or beauty-focused markets.

5. Conclusion

The aim of the present study was to develop and evaluate a cold-pressed fruit–vegetable drink with the purpose of supporting skin health. Analysis of the raw ingredients showed that orange, lemon and apple are good sources of vitamins and antioxidants. When these ingredients are combined, a set of key vitamins and minerals relevant to collagen synthesis and protection is obtained. Cold-pressing of individual juices yielded good process efficiency, particularly for apple and carrot, with beetroot and orange also performing well, indicating that the process is technically feasible for all selected raw materials. The final formulations had mildly acidic pH values of 4.0–4.3, a range that favours vitamin C stability, provides a degree of microbial protection and delivers the refreshing acidity expected of a fruit-based drink.

Several attributes achieved mean hedonic scores approaching “like very much”. The formulation with the higher orange proportion was the most preferred, as it offered the balance of sweetness and acidity required for consumer acceptance. These findings show that the drink can meet sensory expectations, which is important for sustained consumption. Gamboge and honey were included as natural preservatives, extending product acceptability from 7 days without preservatives to 15 days with them. This demonstrates that the drink is not only sensorially promising but also economically viable for small-scale commercial production in the functional beverage segment.

Overall, the study shows that a functional drink can be produced from common fruits, vegetables and honey using cold-press technology, while achieving acceptable shelf-life, strong consumer appeal and reasonable cost. Future work can build on this foundation by testing biological effects on skin parameters in controlled studies, exploring alternative processing and packaging to further extend shelf-life, and tailoring the formulation for specific target groups.

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