BIOACTIVE EXTRACTS FROM ALOE VERA - APPLICATIONS IN FOOD AND FUNCTIONAL PRODUCTS

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ABSTRACT: *Aloe vera extracts are valuable natural sources of bioactive compounds, including polysaccharides, polyphenols, vitamins, and amino acids, which provide multiple benefits for human health. These compounds have demonstrated antioxidant, anti-inflammatory, antimicrobial, and immunomodulatory properties, making them suitable for use in food and functional products. This paper presents the chemical and bioactive characteristics of Aloe vera extracts, methods for obtaining and preserving them, and their use in the formulation of functional foods, nutritional supplements, and healthy beverages. The integration of Aloe vera extracts into food products can contribute to the prevention of chronic diseases and support a balanced diet, while also offering prospects for innovation in the food industry.*

KEY WORDS: bioactive extracts, functional foods, benefits, health

1. INTRODUCTION

Aloe vera is a valuable ingredient in nutrition and functional product development due to its rich composition of vitamins, minerals, enzymes, polysaccharides, and natural antioxidants. The use of aloe extracts helps support the immune system and balance metabolic processes, being a natural source of bioactive substances that support cell regeneration and protection against oxidative stress [1].

In the food industry, aloe vera is added to juices, syrups, and liquid supplements intended for detoxification and improved digestion, due to its mild laxative effects and intestinal mucosa repair properties. In functional products, its role is amplified by its anti-inflammatory, antioxidant, and immunostimulatory effects, which support overall health and prevent nutritional imbalances associated with modern lifestyles.

Aloe vera extracts are particularly important in the food, pharmaceutical, and cosmetic industries due to their high content of bioactive compounds: polysaccharides (acemannan), vitamins (A, C, E, B12), minerals (zinc, magnesium, selenium), and enzymes with antioxidant and anti-inflammatory action.

In food, these extracts are used to make functional products (juices, gels, capsules), contributing to detoxification, digestive balance, and immunity strengthening [2]. The safety of using Aloe vera extracts depends on their composition. The gel obtained from the inner layer of the leaf is safe for moderate consumption, while the bitter latex (which contains aloin) should be limited or excluded from internal use, as it has a strong laxative effect and can cause intestinal irritation if taken in excess. Certified commercial products contain only purified gel, free of anthraquinones, and are considered safe for daily use [4].

The main methods of obtaining extracts from Aloe vera include: maceration of the leaves in water or ethyl alcohol to extract water-soluble substances – used in the preparation of tinctures and liquid extracts, mechanical pressing of fresh leaves, followed by

filtration and mild thermal stabilization – the preferred method for food juices and pharmaceutical gels, and hydroalcoholic extraction or microfiltration, used industrially for the separation and purification of polysaccharides and active enzymes. Through these methods, standardized extracts are obtained that preserve bioactive compounds in a stable form, offering multiple health benefits and being adaptable to both dietary supplements and state-of-the-art dermo-cosmetic products [3].

2. CHEMICAL COMPOSITION OF ALOE VERA

Aloe vera leaves are rich in a wide range of bioactive compounds:

- mucopolysaccharides: acemannan stimulates cell regeneration and strengthens the immune system.
- anthraquinones: aloin has strong laxative effects but is used with caution.
- vitamins: A (retinol), C (ascorbic acid), and E (tocopherol) act as powerful antioxidants [8].

The inner gel contains polysaccharides with powerful immunostimulatory action, while the outer part of the leaf (latex) is rich in anthraquinones with a pronounced laxative effect. In addition, the plant contains numerous substances with nutritional, anti-inflammatory, analgesic, and antifungal properties, such as essential minerals, vitamins, amino acids, organic acids, phospholipids, enzymes, saponins, and lignins [10].

The monosaccharides in Aloe vera perform exclusively energetic functions, fueling cellular metabolism and supporting cellular regeneration and multiplication processes. Glucose is the monosaccharide par excellence present in Aloe vera, playing a crucial role in providing the energy necessary for tissue healing processes. Its high availability and easy digestibility make it an ideal energy source for the human body [8].

The therapeutic reputation of the Aloe vera plant is largely due to the abundant presence of complex polysaccharides in its gel. These molecules have remarkable biological properties that make them extremely valuable. Acemannan is the emblematic polysaccharide of the Aloe vera plant, responsible for many of its therapeutic effects.

This complex macromolecule is predominantly composed of acetylated mannose units linked by β-(1,4) bonds. Its unique structure gives it remarkable immunomodulatory properties, stimulating macrophage activity and cytokine production. Scientific studies have shown that acemannan accelerates wound healing, stimulates tissue regeneration, and strengthens the immune system [7].

The main *anthraquinones* in Aloe vera:

- aloemodine is a molecule found in the yellow exudate rich in anthraquinones, located on the outside of the gel, under the cuticle of the aloe leaf. It has significant antibacterial and laxative properties. Recent studies have shown that aloemodine has marked antitumor effects, particularly against precancerous and cancerous cells of ectodermal origin.
- aloin is an active ingredient specific to the Aloe vera plant, being an anthraquinone glycoside. The therapeutic effects of aloin include purgative, detoxifying, and antibiotic action [8].

Nutritional constituents of Aloe vera

Aloe vera is an exceptional source of essential nutrients and is considered one of the most complex plants in terms of biochemical composition [4]. Although the place of growth can influence the specific mineral content, this succulent plant contains over 20 different types of minerals, giving it properties comparable to the most complex multi-mineral and vitamin supplements.

Mineral salts - Aloe vera contains numerous minerals essential for the optimal functioning of the human body: Ca, Cr, Fe, P, Mg, K.

Aloe vera also contains:

- fat-soluble vitamins (A, E) and water-soluble vitamins, B vitamins (B1, B2, B3, B6, B9, B12, B15) and vitamin C.

- phospholipids such as choline - an important element for the body, improving the fluidity of cell membranes.

- plant steroids. Unlike artificial steroids (such as cortisone), which can cause numerous side effects, the plant steroids in aloe vera act similarly but without adverse effects. The plant contains four main steroids: cholesterol, lupeol, β-sitosterol, and campesterol. All have clear anti-inflammatory properties, and lupeol also has antiseptic and analgesic effects [8, 10].

- enzymes. Aloe vera contains a wide range of biologically active enzymes involved in digestive, anti-inflammatory, and antioxidant processes (amylase, lipase, catalase, peroxidase etc.) [5,6].

- the saponins in aloe vera have purifying, antiseptic and antimicrobial properties.

The amino acids in aloe vera are classified as:

- essential amino acids. Of the eight amino acids essential for adults, seven are found in aloe vera: phenylalanine, isoleucine, leucine, lysine, threonine, and valine.

- non-essential amino acids. Aloe vera contains nine of the twelve non-essential amino acids necessary for human life: aspartic acid, glutamic acid, arginine, asparagine, glycine, glutamine, proline, and serine [16].

- semi-essential amino acids: cysteine and tyrosine, present in Aloe vera, can be synthesized by the body from phenylalanine and methionine when these are available in adequate amounts.

- plant hormones - the Aloe vera plant contains two specific regulators of vital processes: gibberellins and auxins (indoleacetic acid). These plant hormones stimulate cell growth and healing processes in both plant and animal tissues [12].

3. OBTAINING, STABILIZING, PRESERVING AND UTILIZING ALOE VERA EXTRACTS

3.1. Methods of extracting Aloe vera gel and juice

The extraction of Aloe vera gel and juice is an essential process for harnessing the therapeutic properties of this plant. Extraction methods vary depending on the intended use, whether it is for the preparation of products or direct consumption. The process involves manual or mechanical techniques, each with specific advantages and disadvantages.

a. Extraction using aqueous or alcoholic solutions

Extraction using aqueous or alcoholic solutions is the most commonly used method for isolating bioactive compounds from Aloe vera. In aqueous extraction, distilled water or buffer solutions are used to extract polysaccharides, water-soluble vitamins, and enzymes. It is a safe, non-polluting method that maintains the biological activity of temperature-sensitive compounds. However, this method is not effective for fat-soluble or phenolic compounds [14,18].

Alcoholic extraction uses ethanol, methanol, or other organic solvents to extract phenolic compounds, flavonoids, and certain mineral salts. One of the advantages of this method is that it has a higher yield of fat-soluble and phenolic compounds. These compounds have strong antioxidant properties. Alcoholic extraction can denature sensitive enzymes and requires complete removal of solvents before food use.

b. Extraction by enzymatic and ultrasonic methods

Modern methods aim to maximize yield and protect the integrity of bioactive compounds. In enzymatic extraction, enzymes such as cellulase or pectinase break down the cell wall of the leaves, facilitating the release of polysaccharides and glycoproteins. The method has a high efficiency and selectivity for certain bioactive fractions [18].

In ultrasonic extraction, they generate caveities that break down cell structures and facilitate the diffusion of bioactive compounds. The advantages of this method are shorter extraction time, reduced solvent consumption, and preservation of biological activity. Ultrasonic extraction requires special equipment and parameter optimization to avoid degradation of sensitive compounds [18].

A comparative analysis of methods for extracting Aloe vera gel and juice is presented in Table 1.

Aqueous extraction is ideal for functional foods and beverages because it does not involve toxic solvents, while alcoholic extraction is more suitable for supplements and concentrated extracts with high antioxidant activity [17].

Table 1. Comparative analysis of extraction using water and alcohol solutions [17,18].

Parameter	Aqueous extraction	Alcohol extraction
Extracted compounds	Polysaccharides (acemannan), water-soluble vitamins, enzymes	Phenolic compounds, flavonoids, fat-soluble substances
Efficiency	15–25% of gel weight (depending on leaf type and time)	10–20% of dry plant material
Advantages	Safe, non-polluting, preserves enzymes and sensitive vitamins	Efficient for phenolic compounds and flavonoids; good yield for fat-soluble substances
Restrictions	Does not extract fat-soluble compounds; may require long time	May denature enzymes and water-soluble vitamins; requires solvent removal

Regarding enzymatic and ultrasonic methods, a detailed comparative analysis including extracted compounds, yields, advantages, and limitations is presented in Table 2. It should be noted that enzymatic extraction is very effective for high molecular weight polysaccharides, while ultrasound is versatile and significantly reduces process time, making it suitable for industrial-scale extractions.

Table 2. Extraction using enzymatic and ultrasonic methods

Parameter	Enzymatic extraction	Ultrasonic extraction
Extracted compounds	Polysaccharides, glycoproteins, enzymes	Polysaccharides, phenolics, flavonoids
Efficiency	20–30% of leaf weight (polysaccharides)	25–35% of total plant material
Advantages	Selective, high efficiency, preserves sensitive compounds	Short extraction time, low solvent consumption, preserves biological activity
Restrictions	High cost of enzymes, requires parameter optimization	Requires special equipment, risk of polysaccharide degradation at high intensity

3.2. Stabilization and preservation of extracts

After extraction, the bioactive compounds in Aloe vera are sensitive to oxygen, light, and temperature, requiring appropriate preservation methods such as:

- freeze-drying, which transforms the aqueous gel into a stable powder, preserving the integrity of the polysaccharides and vitamins [13].
- microencapsulation, which allows the incorporation of extracts into a protein or polymer matrix, protecting the compounds from oxidation and releasing them gradually [11].
- refrigeration and vacuum packaging, which slows down enzymatic degradation and oxidation of sensitive compounds.

These methods are essential for maintaining the biological activity of extracts, preparing them for applications in food and functional products. Figure 1 shows a complete overview of the extraction and stabilization methods for Aloe vera.

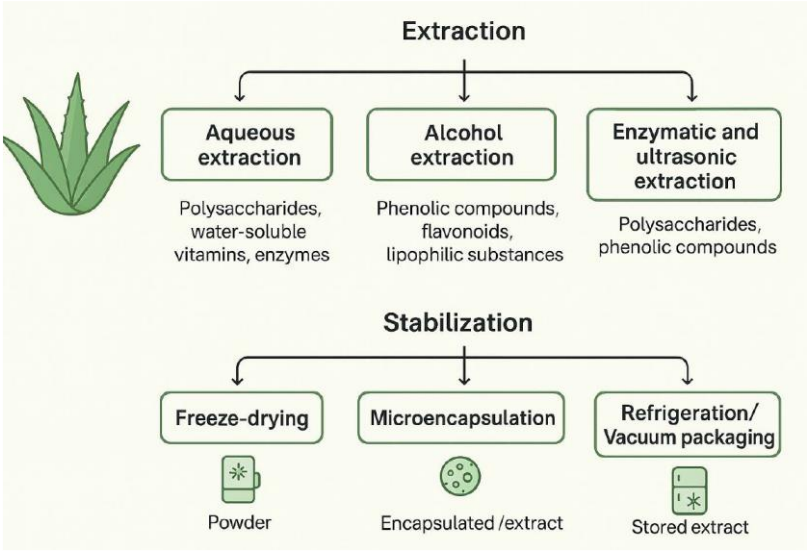

Fig. 1. Extraction and stabilization methods for Aloe vera

3.3. The use of aloe vera extracts in the formulation of functional foods, nutritional supplements and healthy drinks

Aloe vera extracts are widely used in the functional food industry due to their rich content of polysaccharides (acemannan), antioxidants, vitamins, and essential minerals that exert beneficial effects on human health [5,9]. Their applicability covers functional foods, nutritional supplements, and healthy beverages. Table 3 shows the applications in food and functional products obtained from the Aloe vera plant.

Functional food products

Aloe vera extracts are incorporated into various food products due to their digestive, anti-inflammatory, and antioxidant effects.

- in fermented dairy products (yogurt, kefir), the addition of aloe vera gel supports the growth of probiotic strains and improves the texture and stability of the product.
- in gluten-free baked goods, extracts serve as moisturizing agents and a source of functional dietary fiber.
- in dietary food formulations, aloe vera helps lower blood sugar and cholesterol thanks to its sterol compounds and mucopolysaccharides [5,6].

Table 3. Applications in food and functional products obtained from the Aloe vera plant [11,15].

Form of use	Food applications	Specific functional products	Main benefits for the body
Aloe vera gel	Used internally, mixed with water, natural juices, or honey	Liquid supplements for immunity, detoxifying gels	Internal hydration, blood sugar regulation, anti-inflammatory effect, digestive protection
Aloe vera juice	Consumed daily diluted, on an empty stomach, for detoxification	Organic functional detox drinks, natural remedies for digestion	Supports detoxification, regulates intestinal transit, reduces cholesterol
Aloe vera syrup	Added to natural soft drinks or mixed with fruit	Energizing syrups, revitalizing drinks	General tonic effect, increases absorption of vitamins and minerals
Aloe vera tea or macerate	Used to improve digestion and detoxification	Natural hepatoprotective teas and mild laxatives	Antioxidant activity, soothes gastrointestinal inflammation
Aloe vera capsules or tablets	Concentrated form used in food supplements	Nutraceutical products for immunity and metabolism	Lowers blood sugar, protects the intestinal mucosa, reduces inflammation

Nutritional supplements

Aloe vera is used in the form of tablets, capsules, soluble powders, or concentrated gels, benefiting from recognition as a natural nutraceutical [9].

Aloe vera supplements (e.g., Forever Aloe vera Gel or Dacia Plant products) are intended to improve digestion, liver detoxification, strengthen immunity, and increase overall vitality. Acemannan stimulates the immune response and collagen synthesis, which is why these supplements are recommended in antioxidant and anti-aging treatments. Combining them with antioxidant vitamins (C, E) and probiotics amplifies the positive metabolic effects and anti-inflammatory protection [10,11].

Functional and healthy drinks

Aloe vera is a well-known ingredient in healthy drinks designed to hydrate and balance digestion. Non-carbonated juices with 30-99% aloe vera gel, such as Forever Aloe vera Gel or Aloe vera 51% without sugar, offer benefits for intestinal flora, the immune system, and blood sugar control. In smoothies and detox drinks, the gel is used for its refreshing, alkalizing, and tonic effect. Combined with fruit juices, mint, or lemon, the natural extract helps increase hydration and bioactive antioxidant intake.

Nutritional and technological benefits

The use of aloe vera extracts in functional food formulations offers multiple advantages:

- Internal hydration and cell regeneration thanks to mucopolysaccharides.
- Antioxidant and immunostimulant properties through vitamins and plant sterols.
- Prebiotic effect by stimulating beneficial lactic bacteria in fermented products.
- Technological role as a natural stabilizer and mild thickener, useful in transparent beverages or food gels [14].

4. CONCLUSIONS

The study of the chemical composition of the Aloe vera plant has highlighted the presence of valuable compounds such as polysaccharides (acemannan), anthraquinones (aloin), vitamins (A, C, E), minerals (calcium, magnesium), and

essential amino acids. These compounds give the plant its anti-inflammatory, antioxidant, moisturizing, and regenerative properties. Aloe vera is considered a valuable functional ingredient in nutrition due to its content of digestive enzymes, anthraquinones, vitamins (A, C, E, B12), minerals, and bioactive polysaccharides that contribute to detoxification and overall metabolic balance. Thus, we can say that aloe vera has evolved from a cosmetic ingredient into a multifunctional nutraceutical with innovative applications in modern balanced and sustainable nutrition.

Aloe vera extracts are a strategic natural resource in the formulation of modern nutraceuticals, due to the remarkable synergy between their bioactive compounds, which contribute to maintaining the body's homeostasis and preventing inflammatory and metabolic disorders. Recent studies confirm the ability of these extracts to support immune system functions, regulate blood sugar, and stimulate tissue regeneration by increasing collagen synthesis.

Furthermore, responsible use and standardization of the production processes guarantee safety for consumption, making aloe vera a key ingredient for functional foods and supplements designed for a balanced and sustainable diet.

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