J Food Sci Technol (September–October 2011) 48(5):525–533
DOI 10.1007/s13197-011-0229-z

REVIEW

Processing, food applications and safety of aloe vera products: a review

Kulveer Singh Ahlawat · Bhupender Singh Khatkar

Revised: 31 December 2010 / Accepted: 2 January 2011 / Published online: 18 January 2011

Abstract Aloe vera is used for vigor, wellness and medicinal purposes since rigvedic times. Health benefits of aloe vera include its application in wound healing, treating burns, minimizing frost bite damage, protection against skin damage from x-rays, lung cancer, intestinal problems, increasing high density lipoprotein (HDL), reducing low density lipoprotein (LDL), reducing blood sugar in diabetics, fighting acquired immune deficiency syndrome (AIDS), allergies and improving immune system. Phytochemistry of aloe vera gel has revealed the presence of more than 200 bioactive chemicals. Aloe vera gel is extracted from its leaves and appropriate processing techniques are needed for stabilization as well as preparation of the end products. The industries involved in processing of aloe vera need Government surveillance to ensure that the aloe vera products have beneficial bio-active chemicals as per claims of the manufacturers. Regulatory bodies also need to look into the safety and toxicological aspects of aloe vera products for food applications. The claims made for medicinal value of aloe products should be supported by authentic and approved clinical trial data. It is presumptive to mention that nutraceutical claims of aloe products made by the manufacturers are numerous. However, approved clinical evidences are available only for lowering LDL, increasing HDL, decreasing blood glucose level, treating genital herpes and psoriases.

Keywords Aloe vera · Food applications · Medicinal value · Processing · Safety

K. S. Ahlawat · B. S. Khatkar (✉)
Department of Food Technology,
G. J. University of Science and Technology,
Hisar 125001, India
e-mail: bskhatkar@yahoo.co.in

Introduction

Aloe vera has been used for its medicinal value for several thousand years. Its applications have been recorded in ancient cultures of India, Egypt, Greece, Rome and China. In biblical times the Egyptians hailed aloe vera as the plant of immortality. The Chinese called it their elixir of youth. The aloe vera has many common names and often referred to as burn plant, first aid plant or medicine plant. Its name is most likely derived from the Arabic word "Alloeh" meaning shining bitter substance. Aloe vera is known by a number of names in the literature i.e. *Aloe barbadensis* Mill, *Aloe chinensis* Bak, *Aloe elongate* Murray, *Aloe indica* Royale, *Aloe officinalis* Forsk, *Aloe perfoliata*, *Aloe rubescens* DC, *Aloe vera* L. var. littoralis Konig ex Bak, *Aloe vera* L. var. chinensis Berger, *Aloe vulgaris* Lam. Most reference books regard *Aloe barbadensis* Mill as correct species name, and *Aloe vera* (L.) Burm f. as a synonym. However, according to the International Rules of Botanical Nomenclature, *Aloe vera* (L.) Burm f. is the legitimate name for this species. (Bradley 1992; Newton 1979; Tucker et al. 1989). The genus Aloe has also been placed taxonomically in a family called Aloeaceae (Farnsworth et al. 1999).

Aloe was originated in tropical Africa and it is now cultivated in warm climatic areas of Asia, Europe and America (Harding 1979). Presently, the use of aloe vera has gained popularity because of herbal movement initiated by naturopaths, yog gurus, alternative medicine promoters and holistic healers. The industry size for aloe raw material is estimated to be about $125 million dollars. The volume of the industry for finished products containing aloe vera is alleged to be around $110 billion dollars (Anonymous 2006). A recent market analysis report indicates that in 2008 Americans have spent almost 40 billion dollars on functional foods, drinks and supplements for the improvement of their appearance as well as to provide energy and added nutrition to handle health issues such as hypercholesterolemia and diabetes. Aloe vera products are among the popular ones for these applications. Today, the aloe vera industry is flourishing and the gel is used in many products such as fresh gel, juice and other formulations for health, medicinal and cosmetic purpose (Eshun and He 2004). However, the fast expanding aloe vera industry urgently needs reliable testing protocols to assess the quality and quantity of bioactive chemicals present in the final products (Bozzi et al. 2007). The product claims must be tested by intensive clinical trials, verified and certified by the Government regulatory authorities to built consumer confidence and safety of the aloe vera products.

Botany of aloe vera

Aloe vera is a spiky cactus like xerophytes. It is a clump forming perennial plant with thick fibrous root which produces large basal leaves, usually 12–16 per plant, weighing up to 1.5 kg when mature. The plant matures when it is about 4 years old and has a life span of about 12 years. The leaves are up to 0.5 m long and 8–10 cm across at the base, tapering to a point, with saw-like teeth along their margins. In a transverse section, the plant shows a slightly concave appearance on the adaxial surface and distinctly convex appearance on the lower abaxial surface (Grindlay and Reynolds 1986). The leaves are covered with thick cuticle, beneath which epidermis and mesophyll are present. Later is differentiated in upper chlorenchyma and lower parenchyma, as the rosette mature, successive leaves have fewer whitish spots and grey-greenish in colour (Eshun and He 2004).

The plant can be harvested every 6–8 weeks by removing 3–4 leaves per plant. Red, yellow, purple or pale stripped flowers are present most of the year growing in a long raceme at the top of the flower stalk which originates from the centre of the basal leaves. The flower stalk grows up to 1.5 m in height. The fruit is a triangular capsule containing numerous seeds. The plant is practically disease free, occasionally black spots may occur on upper surface because of fungal infection or soft rottening may damage whole plant. The causal organism for soft rottening is a bacterium. Frost is another enemy of aloe vera plant and it can not survive in frost conditions (Grindlay and Reynolds 1986). Smoking in field during frost nights is one measure practiced by farmers to protect the plantation from frost.

There are over 250 species of aloe grown world over. However, only two species are grown commercially i.e. *Aloe barbadensis* Miller (Aloe vera) and *Aloe aborescens*. There are at least two other species that have medicinal properties namely *Aloe perry* baker and *Aloe ferox*. Most aloe vera plants are non toxic but a few are extremely poisonous containing a hemlock like substance (Atherton 1998). *Aloe variegate* is a dwarf species which is only a few centimeter in diameter and is a popular house plant.

Phytochemistry of aloe vera

There are as many as 200 different types of molecules in aloe vera (Davis 1997). The aloe vera leaf gel contains about 98% water (Bozzi et al. 2007). The total solid content of aloe vera gel is 0.66% and soluble solids are 0.56% with some seasonal fluctuation. On dry matter basis aloe gel consists of polysaccharides (55%), sugars (17%), minerals (16%), proteins (7%), lipids (4%) and phenolic compounds (1%) (Fig. 1). The aloe vera gel contains many vitamins including the important antioxidant vitamins A, C and E. Vitamin B1 (thiamine), niacin, Vitamin B2 (riboflavin), choline and folic acid are also present (Lawless and Allen 2000). Some authors also suggested the presence of vitamins B12 (cyanocobalamin) in trace amounts which is normally available in animal source (Coats 1979; Atherton 1998).

Carbohydrates are derived from mucilage layer of the plant under the rind, surrounding the inner parenchyma or gel. They comprise both mono and polysaccharides. The most important are the long chain polysaccharides, comprising glucose and mannose, known as the glucomannans [β (1, 4) - linked acetylated mannan]. Xylose, rhamnose, galactose and arabinose are also present in trace amounts along with lupeol (a triterpenoid), cholesterol, campesterol and β-sitosterol. Structural studies on aloe vera gel polysaccharides have shown that the gel is composed of

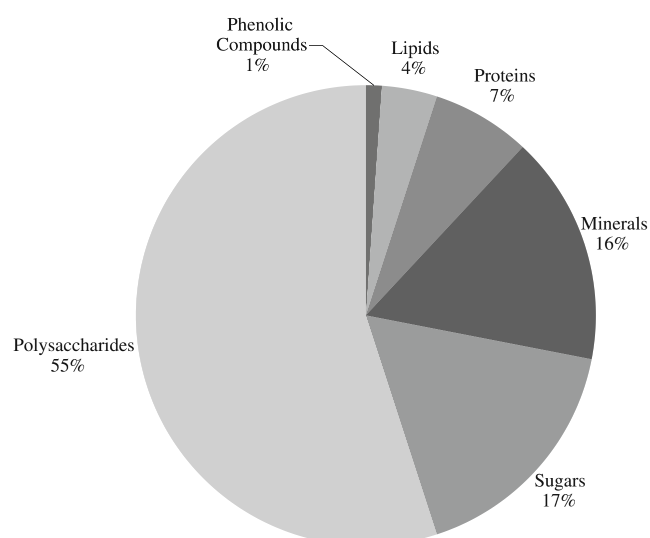

Fig. 1 Chemical composition of aloe vera gel (on dry weight basis) (Luta and McAnalley 2005)

at least four different partially acetylated glucomannans, being linear polymers with no branching and having 1,4 glycosidic linkages with glucose and mannose in the ratio of 1:2:8. The viscosity of gel reduces upon hydrolysis of these sugars. When taken orally some of the sugars bind to receptor sites that line the gut and form a barrier, possibly helping to prevent 'leaky gut syndrome'(Atherton 1997).

Other reports suggest the presence of glucose and a polyuronide consisting of a high molecular weight glucose mannose polyose (M_r 2.75×10^5) and hexouronic acid (Gjestad 1971). Ovadova et al. (1975) reported the presence of uronic acid, which gives galacturonic acid and oligo-saccharides upon fermentative hydrolysis. Meadows (1980) reported that at least six enzymes are present in the aloe vera gel including bradykinase, cellulase, carboxypeptidase, catalase, amylase and oxidase. The carboxypeptidase inactivates bradykinase at site of wound or cut in body and produces pain relieving and anti-inflammatory effect. During the inflammatory process, bradykinase produces pain associated with vasodilatation (Shelton 1991). The gel also contains glutothionperoxidase as well as several isozymes of superoxide dismutase. Wang (1993) reported that potassium and chloride concentration appeared to be excessive in aloe vera juice in comparison to most plant products whereas the sodium content was found lesser in quantity. Calcium, magnesium, copper, zinc, chromium and iron were also found in the aloe products. Magnesium lactate inhibits histidine decarboxylase and prevents the formation of histamine from the amino acid histidine (Shelton 1991). Histamine is released in many allergic reactions and causes intense itching and pain. The prevention of its formation may explain the anti-allergic effects of aloe vera gel.

Anthraquinones are the phenolic compounds present in the sap or yellow exudates of leaf or aloe vera latex. Aloe latex contains a series of glycosides known as anthraquinones, the most prominent being aloin A and aloin B (Tyler 1994). The bitter aloes (dried yellow exudates) consists of free anthraquinones and their derivatives i.e. barbloin-IO-(1151-anhydroglucosyl)-aloe-emodin-9-anthrone, isobarbloin, anthrone–C- glycosides and chromones. These compounds exerts a powerful purgative effects when ingested in large amounts but when low in concentration, they appear to aid absorption from the gut and are potent antimicrobial (Sims et al. 1971) and powerful analgesic agents. Isolation and structure determinations of these chromones from the aloe vera leaves were also studied and these compounds were identified to be 8-C-glycosyl-7-O methyl-(S) aloesol, isoaloeresin D and aloeresin E (Saccu et al. 2001).

Recently, a glycoprotein with anti-allergic properties, called alprogen was isolated from aloe gel. In addition, a novel anti-inflammatory compounds, C-glycosyl chromones, has also been isolated from aloe gel (Hutter and Salman 1996). Saponins are the soapy substances, form 3% of the gel and are general cleansers, having antiseptic properties (Hirat and Suga 1983). The sterols include comperterol, β- sitosterol and lupeol (Coats 1979). Salicylic acid is an aspirin like compound possessing pain relieving properties (Table 1). About 20 out of 22 amino acids and seven of the eight essential amino acids required by human body are also present in aloe vera gel. Major phytochemicals occurring in aloe vera pulp and exudate are summarized in Table 2. Aloe vera juice was evaluated for antioxidant potential and the study showed significant presence of antioxidant in aloe extracts. A 3 years old plant extract exhibits the strongest free radical scavenging activity of 72.19%, which is significantly higher than that of BHT having 70.52% and α-tocopherol with 65.65% (Hu et al. 2003). It is suggested that growth stage in aloe plant plays a vital role in the composition and antioxidant activity (Hu et al. 2003). Aloe vera juice also has antibacterial properties against Gram- positive bacteria (Alemdar and Agaoglu 2009). Anonymous (2008) reported antiviral and antifungal properties of aloe vera.

Processing of aloe vera

Aloe vera gel derived from the leaf pulp of the plant has become a big industry worldwide due to its application in the food industry. It is utilized in functional foods especially for the preparation of health drinks with no laxative effects. It is also used in other food products including milk, ice cream, confectionery, etc. Aloe vera gel is also used as flavoring component and preservative in some foods (Christaki and Florou-Paneri 2010). Thus, a simple and efficient processing technique needs to be developed especially for the aloe beverage industry to improve product quality and safety by preserving the bioactive chemicals naturally present in the intact aloe vera leaf (Eshun and He 2004).

Table 1 Novel components of aloe vera along with their health benefits

Chemical component	Health benefits
Acemannan	Accelerate wound healing, modulate immune system, Antineoplastic and antiviral effects
Alprogen	Anti-allergic
C-glycosyl chromone	Anti-inflammatory
Bradykinase	Anti-inflammatory
Magnesium lactate	Anti-allergic
Salicylic acid	Analgesic, anti-inflammatory

Shelton (1991), Peng et al. (1991)

Table 2 Summary of the phytochemicals of Aloe vera pulp and exudate

Class	Compounds
Anthraquinones/anthrones	Aloe-emodin, aloetic-acid, anthranol, aloin A and B (or collectively known as barbaloin), isobarbaloin, emodin, ester of cinnamic acid
Carbohydrates	Pure mannan, acetylated mannan, acetylated glucomannan, glucogalactomannan, galactan, galactogalacturan, arabinogalactan, galactoglucoarabinomannan, pectic substance, xylan, cellulose
Chromones	8-*C*-glucosyl-(2′-*O*-cinnamoyl)-7-*O*-methylaloediol A, 8-*C*-glucosyl-(*S*)-aloesol, 8-*C*-glucosyl-7-*O*-methyl-(*S*)-aloesol, 8-*C*-glucosyl-7-*O*-methylaloediol, 8-*C*-glucosyl-noreugenin, isoaloeresin D, isorabaichromone, neoaloesin A
Enzymes	Alkaline phosphatase, amylase, carboxypeptidase, catalase, cyclooxidase, cyclooxygenase, lipase, oxidase, phosphoenol, pyruvate carboxylase, superoxide dismutase
Minerals	Calcium, chlorine, chromium, copper, iron, magnesium, manganese, potassium, phosphorous, sodium, zinc
Lipids and miscellaneous organic compounds	Arachidonic acid, γ-linolenic acid, steroids (campestrol, cholesterol, β-sitosterol), triglicerides, triterpenoid, gibberillin, lignins, potassium sorbate, salicylic acid, uric acid
Amino acids	Alanine, arginine, aspartic acid, glutamic acid, glycine, histidine, hydroxyproline, isoleucine, leucine, lysine, methionine, phenylalanine, proline, threonine, tyrosine, valine
Proteins	Lectins, lectin-like substance
Saccharides	Mannose, glucose, *L*-rhamnose, aldopentose
Vitamins	B1, B2, B6, C, β-carotene, choline, folic acid, α-tocopherol

Ni and Tizard (2004), Dagne et al. (2000), Femenia et al. (1999), Choi and Chung (2003)

The production process of aloe vera juice involves crushing, grinding or pressing of the entire leaf of the aloe vera plant to produce a liquid, followed by various steps of filtrations and stabilization (preserving the biological integrity of active ingredient to exert the reported physiological effect upon ingestion or topical application). The resulting juice is then incorporated in or mixed with other preparations or agents to produce a pharmaceutical, cosmetic or food product. In food industry, aloe vera has been utilized as a source of functional food drinks and other beverages including tea. The amount of aloe vera that finds its application in pharmaceutical industry is also substantial as evident by availability of topical ointments, gel preparations, tablets and capsules (Eshun and He 2004).

Unfortunately, because of improper processing procedures many of these so called aloe products contain very little or virtually no active ingredients namely, mucopolysaccharides. In view of known wide spectrum of biological activities possessed by the leaves of aloe vera plant and its wide spread use, it has become imperative that the leaf must be processed with the aim of retaining essential bioactive components up to maximum possible limit or as much as contained in fresh leaf. The general steps involved in the processing of aloe vera are explained in the following paragraphs.

Reception of raw material The aloe vera leaves after harvesting must be transported in refrigerated vans from field to the processing plant. The leaves should be sound, undamaged, mold free and mature (3–4 years) in order to keep all the active ingredients in full concentration (Lawless and Allen 2000). One important factor affecting the composition of final product is the handling of the leaves after its harvesting because the decomposition of the gel matrix starts just after its cutting due to natural enzymatic reactions and the activity of bacteria normally present on the leaves. It can adversely affect the quality of the end product. Thus, the freshly removed leaves are refrigerated within 6 h or the leaves are directly fed to processing plant on the farm itself.

Filleting In this process green rind of leaf is removed to extract the parenchymatous tissue called the gel fillet (Grindlay and Reynolds 1986). It is reported that the aloe gel extracted from the leaf had greater stability than the gel left in the leaf. In order to avoid the loss of biological activity filleting operation must be completed within 36 h of harvesting the leaves (Robert 1997). The presence of anthraquinones is an important factor leading to non enzymatic browning in aloe products (He et al. 2002).

Homogenization and enzymatic treatment It includes crushing or grinding of gel fillet at room temperature (25 °C) in commercial high speed grinder. The crushing or grinding should be completed within 10–20 min in order to avoid the enzymatic browning. Enzymatic treatment of aloe vera gel for a long duration prior to processing is detrimental to polysaccharides (Gowda et al. 1980; Waller et al. 1978; Yagi et al. 1982). It has been reported that the enzyme treatment at 50 °C and within 20 min did not cause loss of biological activity of polysaccharide in aloe vera gel (Maughan 1984).

Filtration and deareation Fibrous material is removed by this step. This operation influences the stability of aloe vera juice. Poor filtration results in sedimentation of aloe juice on storage. The unpasteurized aloe juice is fortified with vitamin C and citric acid to avoid browning reactions, improve flavor and stabilize the juice (Eison-Perchonok and Downes 1982; Kacem et al. 1987; Kennedy et al. 1992; Tramell et al. 1986). Aim of deareation is to prevent oxidation of ascorbic acid which eventually improves the flavors of aloe vera juice (Chan and Cavaletto 1986).

Hot processing and flash cooling In hot processing, sterilization is achieved by treating the aloe liquid with the activated carbon at high temperature (Cerqveira et al. 1999). This step may affect the taste, appearance and the biological activity of aloe gel products. Biological activity of aloe vera gel essentially remains intact when gel is heated at 65 °C for a period less than 15 min. Extended periods or higher temperatures greatly reduce activity levels. After heat treatment, the juice is flash cooled to 5 °C or below within 15 s to preserve biological activity.

High temperature short time treatment (at 85–95 °C for 1–2 min) is an effective method to avoid the off flavor and the loss of biological activity of aloe vera gel. Physico-chemical modification promoted by heat treatment at different temperature range from 30 to 80 °C on acemannan was evaluated by Antoni et al. (2003). Heating promotes significant changes in the molecular weight of the bioactive polysaccharide increasing from 45 KDa in fresh aloe to 75 KDa for samples dehydrated at 70 and 80 °C. The physico-chemical alterations of the main type of polysaccharide may have important implications on the physiological activities attributed to the aloe vera plant.

Cold processing In the cold processing technique, the entire processing steps are accomplished without the application of the heat. Coats (1994) reported the use of enzymes, like glucose oxidase and catalase to inhibit the growth of aerobic organisms within aloe vera gel and thereby sterilizing it. Other sterilization steps reported in the cold processing include exposing the gel to ultraviolet light followed by micron filtration (Maret 1975).

Addition of preservatives and stabilizers In all the processing techniques, preservation can be achieved by the addition of chemical preservatives and other additives. The use of sodium benzoate, potassium sorbate, citric acid and Vitamin E in synergism has been reported by some researchers (Cerqveira et al. 1999; Moor and McAnalley 1995).

Stabilizing agent is added in aloe products to prevent sedimentation of juice upon storage. In an investigation (Yaron et al. 1992) the aloe vera gel was mixed with sulphited polysaccharides isolated from the red micro-algae, guar gum and xantham gum. Rheological studies indicated interaction of aloe vera gel with algal polysaccharides and xantham gum which is depicted by increased apparent viscosities, yield points and in some cases hysteresis but these interactions were not observed with guar gum. These desirable properties did not deteriorate during storage. It was, therefore, proposed that algal polysaccharides or xantham gum could stabilize the network structure of fresh aloe vera polysaccharide.

Storage Aloe vera juice is packed in amber colored glass bottles to avoid the effect of light on the sensitive bioactive agents. Relative humidity and temperature are two most important environmental parameters that affect product quality. These two parameters can also affect the amount of the volatile substance of the juice absorbed by the packaging material (Hernadez and Giacin 1998) and consequently affect the shelf life of the product (Sadler and Braddock 1990).

Aloe juice and its food applications

Traditional method of aloe juice processing In this method lower one inch of the leaf base, the tapering point (2–4 in.) of the leaf top, the short sharp spines located along the leaf margin as well as the top and bottom rind are removed with sharp knife along with the rind parts to which some mucilage remains attached. The fillet and the mucilage are collected from the aloe leaf for further processing. The highest concentrations of the potentially beneficial aloe constituents are found in mucilage as this layer represent the place of synthesis of the beneficial constituents. The material of the mucilage layer, subsequent to their synthesis, is distributed to the storage cells (cellulose-reinforced hexagons) of the fillet (Ramachandra and Srinivasa Rao 2008). The aloe vera gel fillet is washed with deionized water and transferred to the pulper. The pulper is fitted with refrigerated system that keeps the temperature of the extracted juice lower to prevent decomposition. The aloe vera juice is conveyed to a holding tank and kept for 24 h to decant. Holding tank is also refrigerated for preserving the bioactivity of sensitive molecules of aloe vera.

Whole leaf processing method The process was developed in 1980's in USA and undergone continuous improvement by contribution of different workers (Homcare Iberica 1983; Maughan 1984; Coats 1994). The procedure employs cold treatment to ensure product rich in bioactive compounds. In this process the base and tip of leaf are removed. The leaf is cut into sections and ground into particulate slurry in a Fiz Mill (Model D6 Make Arnold equipment company, Ohio) to produce a soup like consistency. The material is then treated with cellulase enzyme which breaks down the hexagonal structure of the fillet and releasing the cell constituents. The rind particles are removed by means of a series of coarse screening filters or passage through a juice press. This liquid is then pumped into large stainless steel sanitized holding tank. Once the tank is filled, it is hooked up to a depulping extractor. This machine removes the large pieces of pulp and rind which are generated by initial grinding process. Now the aloe liquid is passed through a series of filters that removes the aloin and aloe emodin as well as any microscopic traces of leaves, sand or other particles. A press filter is used for this purpose. The press filter's carbon coated plates absorb the aloin and aloe emodin. Aloe liquid is continually passed through the filter press until the aloin and aloe emodin are removed. The filtered product is then placed in a second holding tank and passed through a press filter containing five micron filter paper. The aloe liquid is now ready for stabilization. This process can produce aloe vera juice containing three times more bio-active constituents than traditional hand filleted process (Ramachandra and Srinivasa Rao 2008).

The aloe vera juice finds wide application in food products like production of ready to serve drink, health drink, soft drink, laxative drink, aloe vera lemon juice, sherbet, aloe sports drink with electrolyte, diet drink with soluble fiber, hangover drink with B vitamin, amino acids and acetaminophen, healthy vegetable juice mix, tropical fruit juice with aloe vera, aloe vera yoghurts, aloe vera mix for whiskey and white bread, cucumber juice with aloe vera (Eshun and He 2004; Hamman 2008; Grindlay and Reynolds 1986; Ang et al. 1996; Hastuti 1999; Singh and Singh 2009) (Table 3). Wei et al. (2004) prepared a health beverage from fresh aloe vera leaves. The leaves were washed, pulped, sterilized and filtered, then mixed with different concentrations of Dangshen, Maidong juices and Chinese herbs. Effects of processing conditions e.g. temperature, pH, sucrose, vitamin C and citric acid on the stability of colour and gelatinoids in aloe vera juice were studied and it was concluded that the stability was negatively affected by increasing sucrose and citric acid concentrations while vitamin C and sodium chloride at low concentrations improved the stability. Do-sang et al. (1999) prepared vinegar from aloe vera juice using *Acetobactor sp*. Lee and Hand-Yoon (1997) made aloe vera yoghurt with lactic acid bacteria (single or mixed strains of *Lactobacillus bulgaricus* and *Streptococcus thermophilus*) and compared it with yoghurt prepared using dried skim milk and it was found that quality retention of aloe vera yoghurt at 5 °C for 15 days was better than the milk yoghurt.

Table 3 Food applications of aloe vera products

Aloe vera products	Food applications
Concentrate	Squash, jam, jellies, aloe vera concentrate can also be mixed with tea, water or juice
Gel fillet	Candies, bar, munch, chewing gum, instant aloe vera tea granules, aloe vera gum for sore or bleeding gums, candy type aloe vitamins, aloe vera fruit smoothies
Juice	Ready to serve drink, health drink, soft drink, laxative drink, sherbet, sports drink (with electrolytes), diet drink with soluble fiber, hangover drink with B-vitamins, amino acids and acetaminophen, healthy vegetable juice mix, yoghurts, aloe vera mix for whiskey or other alcohol, white bread with aloe vera, and cucumber juice with aloe vera
Powder	Yoghurt, curd, 'lassi', ice-cream, and aloe vera 'laddu'

Eshun and He (2004), Hamman (2008), Grindlay and Reynolds (1986), Ang et al. (1996), Hastuti (1999), Singh and Singh (2009)

Aloe concentrate and its food applications

The aloe juice can be concentrated under vacuum without the loss of biological activity. The concentration operation must be conducted under 125 mm Hg vacuum at temperature below 50 °C and must not exceed 2 min as higher vacuum and temperature will cause loss of effectiveness of bioactive constituents (Ramachandra and Srinivasa Rao 2008). Concentration is carried out to get aloe vera concentrate of desired consistency to suit various food applications i.e. squash, jam and jellies. The concentrate of aloe can also be mixed with tea, water or juice.

Aloe powder and its food applications

In dehydration method the pure intact aloe vera gel fillets are first washed to remove traces of aloin. Then the fillets are placed into a humidity chamber where desired level of relative humidity and temperature are maintained (Ramachandra and Srinivasa Rao 2008). Here hot air is passed over the fillets to dry them. This material is then ground to powder and packed (Ramachandra and Srinivasa Rao 2008).

Qmatrix drying is a novel proprietary method of dehydration of aloe vera enabling the dehydration of aloe while maintaining its integrity with respect to flavor, colour and bioactivity. It is comparable to freeze drying in quality aspects but without the high operational cost. In freeze drying, gel fillet is lyophilized at −88 °C and 0.01 mm Hg pressure for 65 h to get dried gel fillet. Later is then ground to get aloe powder with moisture content below 4%. Qian (2002) prepared freeze dried powder from ultra-filtration and reverse osmosis of concentrated aloe vera gel. Gautam and Awasthi (2007) prepared aloe vera leaf powder by cutting leaves in small pieces, blending in a mixer and drying them in a tray drier at 50 °C for 12 h. The dried material is then ground into powder in a mixer grinder. Aloe vera powder can be used in curd, lassi, ice-creams, etc. Aloe powder has also been used in the preparation of yoghurts (Lee and Choi 1994; Seoshin et al. 1995)

Safety aspects of aloe vera products

Scientific community is divided into two groups regarding safety of aloe vera products. One group advocates that the aloe vera is quite safe for human consumption. While the other group warns to use it with caution and utmost care to avoid contamination of aloin from the yellow exudates, as aloin is reported as DNA damaging and cancer causing (Lachenmeier et al. 2005). On the contrary scientists have reported that anthroquinones present in aloe vera leaf, including aloin, are beneficial in a number of ways when used in small quantity, though the small quantity is not well defined (Sydiskis et al. 1991).

It is reported that aloe vera gel is safe for external use, allergies are rare and adverse reactions with other medications have not been reported. Aloe should not be used internally during pregnancy, lactation or childhood and by persons suffering from abdominal pain, appendicitis or intestinal obstruction (Kemper and Chiou 1999).

A case of disseminated dermatitis has been reported following application of aloe vera gel to a patient with stasis dermatitis. Several patients who applied aloe vera gel topically following dermabrasion reported burning sensation and development of dermatitis on the face (Hunter and Frumkin 1991). Because of possible contamination by anthraquinones, oral aloe gel may cause symptoms of abdominal cramps and diarrhoea. There have also been several reports of aloe vera gel lowering plasma glucose in laboratory animal and in human (Ghannam et al. 1986). Use of aloe vera is reportedly associated with occurrence of Henoch-Schonlein purpura (HSP) a systemic vasculitis that occurs most often in children who are rarely exposed to drugs or other environmental factors. Acute hepatitis could be linked to ingestion of *Aloe barbdensis* compounds. An acute bullous allergic reaction and urticaria have also been reported to result from the use of aloe vera gel (Morrow et al. 1980).

Studies in mice revealed no acute toxicity in therapeutic doses but in high doses a decreased central nervous system (CNS) activity was noticed (Shah et al. 1989). In chronic treatment decrease in red cell count and significant sperm damage was noticed (Shah et al. 1989). However, no systematic investigation exists in humans on the effect of high doses of aloe vera for longer periods on red cell count and sperm damage (Vogler and Ernst 1999).

Conclusions

Reported therapeutic benefits of aloe vera products are numerous such as helping wound healing, treating burns, minimizing frost bite damage, protection against skin damage from X-rays, lung cancer, intestinal problems. However, approved clinical trial data support its effectiveness for lowering LDL, increasing HDL, decreasing blood glucose level, treating genital herpes and psoriases. Scientific evidences suggest that aloe vera gel is safe for external use, allergies are rare and adverse reactions with other medications have not been reported. However, it is recommended that aloe products should not be used internally during pregnancy or lactation period by women and by persons suffering from abdominal pain, appendicitis or intestinal obstruction. The aloe vera industry is flourishing worldwide and the gel is used in many products including fresh gel, juice and other formulations for health, medicinal and cosmetic purpose. However, the fast expanding aloe vera industry urgently needs reliable testing protocols to assess the quality and quantity of bioactive chemicals present in the final products. The product claims must be tested by intensive clinical trials, verified and certified by the Government regulatory authorities to build consumer confidence and to ensure safety of the aloe vera products.

References

Alemdar S, Agaoglu S (2009) Investigations of in-vitro antimicrobial activity of aloe vera juice. J Anim Vet Adv 8(1):99–102

Ang NU, Intaphan P, Saengo E (1996) Development of orange aloe vera jam. Proceeding of the 13th Rajamangala institute of technology annual conference: Food science and home economics Lampang (Thailand), pp 39–45

Anonymous (2006) For *Aloe vera* as semi finish products like gel, powder and finish products like aloe vera drink or fizzy tablets. Technology transfer and project management network, Ensymm consulting of biotechnology. http://www.ensymm.com/pdf/ensymmProjectstudyAloeVeraproduction.pdf. Accessed on 5 October 2010

Anonymous (2008) *Aloe vera:* History, science and medicinal uses. http://www.healingaloe.com Accessed 5 October 2010

Antoni FG, Pablo S, Susana S, Carmen R (2003) Effect of heat treatment and dehydration on bioactive polysaccharide acemannan and cell wall polymers from *Aloe barbdensis miller.* Carbohydr Polym 51:397–405

Atherton P (1997) *Aloe vera:* myth or medicine. http://www.positivehealth.com Accessed 28 December 2010

Atherton P (1998) First aid plant. Chem Brit 34:33–36

Bozzi A, Perrin C, Austin S, Arce Vera F (2007) Quality and authenticity of commercial aloe vera gel powders. Food Chem 103(1):22–30

Bradley PR (1992) British herbal compendium. British Herbal Medicine Association

Cerqveira L, McKnight LS, Rodriguez S, Turner CE (1999) Bifurcated method to process aloe whole leaf. US Patent 5 925 357

Chan HT, Cavaletto CG (1986) Effects of deareation and storage temperature on quality of aseptically packaged guava puree. J Food Sci 51:165–168

Choi S, Chung MH (2003) A review on the relationship between *Aloe vera* components and their biological effects. Semin Integr Med 1:53–62

Christaki EV, Florou-Paneri PC (2010) *Aloe vera*: a plant for many uses. J Food Agric Environ 8(2):245–249

Coats BC (1979) Hypollergenic stabilized aloe vera gel. US Patent number 4 178 172

Coats BC (1994) Methods of processing stabilized aloe vera gel obtained from the whole aloe vera leaf. US Patent 5 356 811

Dagne E, Bisrat D, Viljoen A, Van Wyk BE (2000) Chemistry of aloe species. Curr Org Chem 4:1055–1078

Davis RH (1997) Aloe vera- A scientific approach. Vantage Press Inc, New York, pp 290–306

Do-Sang L, Ryu II, Kap-Sang L, Yang-See S, Seung-Ho C (1999) Optimisation in the preparation of aloe vinegar by *Acetobactor sp*. and inhibitory effect against lipase activity. Hanguk Non-gwhahak Hoechi 42:105–110

Eison-Perchonok MH, Downes TW (1982) Kinetics of ascorbic acid oxidation as a function of dissolved oxygen concentration and temperature. J Food Sci 47:765–773

Eshun K, He Q (2004) Aloe vera: a valuable ingredient for the food, pharmaceutical and cosmetic industries: a review. Crit Rev Food Sci Nutr 44:91–96

Farnsworth NR, Fong HHS, Mahady GB (1999) Aloe vera gel. In: WHO monographs on selected medicinal plants Vol 1. Malta pp 43–49

Femenia A, Sanchez ES, Simal S, Rosello C (1999) Compositional features of polysaccharides from *Aloe vera* (*Aloe barbadensis* Miller) plant tissues. Carbohydr Polym 39:109–117

Gautam S, Awasthi P (2007) Nutrient composition and physio-chemical characteristics of Aloe vera (Aloe barbadensis) powder. J Food Sci Technol 44(2):224–225

Ghannam N, Kingston M, Al-Meshaal IA, Tariq M, Parman NS, Woodhouse N (1986) The antidiabetic activity of aloe: preliminary clinical and experimental observation. Horm Res 24 (4):288–294

Gjestad G (1971) Chemical studies of aloe vera juice. Adv Front Plant Sci 28:110–112

Gowda D, Neelisiddaiah B, Anjaneyalo Y (1980) Structural studies of polysaccharides from *Aloe saponaria* and *Aloe vanbalenni*. Carbohydr Res 83:402–405

Grindlay D, Reynolds T (1986) The aloe vera phenomenon: a review of the properties and modern uses of the leaf parenchyma gel. J Ethnopharmacol 16:117–151

Hamman JH (2008) Composition and application of aloe vera leaf gel. Molecules 13:1599–1616

Harding TBC (1979) Aloes of the world: a checklist, index and code. Excelsa 9:57–94

Hastuti S (1999) Fresh beverage from aloe vera. Butetin Ilmiah Instiper (Indonesia) 6:39–45

He Q, Liu C, Zhang T (2002) Study on nonenzymatic browning of aloe products and its inhibition methods. Food Sci (Chenses) 23 (10):53–56

Hernadez RJ, Giacin JR (1998) Factors affecting permeation, sorption and migration process in package- products system. In: Food storage stability. CRC Press, Boca Raton, Florida USA, pp 269–329

Hirat T, Suga T (1983) The efficiency of aloe plants, chemical constituents and biological activities. Cosmetics and Toiletries 98:105–108

Homcare Iberica SA (1983) Stabilization of a clear gel from aloe vera leaves. Span ES 502 307. Patent of Introduction

Hu Y, Xu J, Hu Q (2003) Evaluation of antioxidant potential of aloe vera (*Aloe barbdensis Miller*) extracts. J Agric Food Chem 51 (26):7788–7791

Hunter D, Frumkin A (1991) Adverse reaction to Vit E and aloe vera preparations after dermabration and chemical peel. Cutis 47 (3):193–195

Hutter J, Salman M (1996) Anti-inflammatory C-glucosyl chromone from *Aloe barbadensis*. J Nat Prod 59(5):541–543

Kacem B, Mathews RF, Grandall PG, Cornell JA (1987) Non-enzymatic browning in aseptic packaged orange drinks: effects of amino acids, dearation and anaerobic storage. J Food Sci 52:1665–1667

Kemper KJ, Chiou V (1999) Aloe vera. Longwood herbal task and The Center for Holistic Pediatric Education and Research http://www.longwoodherbal.org/aloe/aloe.pdf. Accessed 4 October 2010

Kennedy FC, Rivera ZS, Loyd LL, Warner FP, Jumel K (1992) L-ascorbic acid stability in aseptically processed orange juice in tetra brick cartons and the effect of oxygen. Food Chem 45:327–331

Lachenmeier K, Kuepper U, Musshoff F, MadeaB RH, Lachenmeier DW (2005) Quality control of aloe vera beverages. Electronic J Environ Agric Food Chem 4(4):1033–1042

Lawless J, Allen J (2000) Aloe vera- Natural wonder care. Harper Collins Publishers, Hammersmith, pp 5–12

Lee EH, Choi SD (1994) Studies on the manufacture of aloe yoghurt. J Agric Technol Res Institute Chinju University (Korea Republic) 7:55–59

Lee J, Hand-Yoon YH (1997) Characteristics of aloe vera suspended liquid yoghurt inoculated with *Lactobacillus Casei* YIT 9018. Korean J Animal Sci 39:93–100

Luta G, McAnalley BH (2005) Aloe vera: chemical composition and methods used to determine its presence in commercial products. GlycoSci Nutr 6(4):1–12

Maret RH (1975) Process for preparing extract of aloe vera. US Patent 3 878 197

Maughan RG (1984) Methods to increase colour fastness of stabilized aloe vera. US Patent 4 465 629

Meadows TP (1980) Aloe as a humectant in new skin preparation. Cosmet Toiletries 95(11):51–56

Moor ED, McAnalley BH (1995) A drink containing mucilaginous polysaccharides and its preparations. US Patent 5 443 830

Morrow DM, Rappaport MJ, Strick RA (1980) Hypersensitivity to aloe. Arch Dermatol 116:106–1065

Newton LE (1979) In defense of the name aloe vera. Cactus Succul J GB 41:29–30

Ni Y, Tizard IR (2004) Analytical methodology: The gel-analysis of aloe pulp and its derivatives. In: Reynolds T (ed) Aloes the genus aloe. CRC, Boca Raton, pp 111–126

Ovadova RG, Lapchich VF, Ovodov YS (1975) Polysaccharides in *Aloe arboresens*. Khimija Prirodykh Soedinenii 11:3–5

Peng SY, Norman J, Curtin G, Corrier D, Mc Daniel HR, Busbee D (1991) Decreased mortality of Norman murine sarcoma in mice treated with the immunomodulator, Acemannan. Mol Biother 3:79–87

Qian H (2002) Study on the technology of aloe gel freeze dried powder. Food Fermentation Industry 28:49–52

Ramachandra CT, Srinivasa Rao P (2008) Processing of aloe vera leaf gel: a review. Am J Agril Biol Sci 3(2):502–510

Robert HD (1997) Aloe vera: a scientific approach. Vantage Press Inc, New York

Saccu D, Bogoni P, Procida G (2001) Aloe exudate: characterization by reversed phase HPLC and headspace GC–MS. J Agric Food Chem 49(10):4526–4530

Sadler GD, Braddock RJ (1990) Oxygen permealibity of low density polyethylene as a function of lomonene absorption: an approach to modeling flavour (Scalping). J Food Sci 55:587–590

Seoshin Y, Lee KS, Lee JS, Lee CH (1995) Preparation of yoghurt added with *Aloe vera* and its quality characteristics. J Korean Soc Food Nutr 24:254–260

Shah AH, Qureshi S, Tariq M, Ageel AM (1989) Toxicity studies on six plants used in the traditional Arab system of medicine. Phytother Res 3:25–29

Shelton M (1991) Aloe vera, its chemical and therapeutic properties. Int J Dermatol 30:679–683

Sims P, Ruth M, Zinmerman ER (1971) Effect of aloe vera on Herpes simplex and Herpes virus (strains Zoster). Aloe vera of American Archive 1:239–240

Singh A, Singh AK (2009) Optimization of processing variables for the preparation of herbal bread using *Aloe vera* gel. J Food Sci Technol 46(4):335–338

Sydiskis RJ, Owen DG, Lohr JL, Rosler KHA, Blomster RN (1991) Inactivation of enveloped viruses by anthraquinones extracted from plants. Antimicrob Agents Chemother 35(12):2463–2466

Tramell DJ, Dalsis DE, Malone CT (1986) Effect of oxygen on taste, ascorbic acid loss and browning for HTST pasteurized, single strength orange juice. J Food Sci 51:1021–1023

Tucker AO, Duke JA, Foster S (1989) Botanical nomenclature of medicinal plants. In: Cracker LE, Simon JE (eds) Herbs, spices, and medicinal plants, vol 4. AR Oryx Press, Phoenix, pp 169–242

Tyler V (1994) Herbs of choice. In: The therapeutic use of phyto medicine. Binghamton Pharmaceutical Products Press, New York, pp 131–135

Vogler BK, Ernst E (1999) Aloe vera: a systematic review of its clinical effectiveness. Br J Gen Pract 49:823–828

Waller GR, Mangiafica S, Ritchey CR (1978) A chemical investigation of *Aloe barbedensis Miller*. Proc Okla Acad Sci 58:69–76

Wang YT (1993) Bases of aloe certification. Aloe Today 27–29

Wei L, Chuncheng Y, Huafeng Z, Rugang Y (2004) Preparation of aloe-herbs health beverage. Food Sci China 25:207–209

Yagi A, Shibata S, Nishioka I, Iwarde S, Ishida Y (1982) Cardiac stimulant action of constituents of *Aloe saponaria*. J Pharm Sci 71:739–741

Yaron A, Cohen E, Arad SM (1992) Stabilization of aloe vera gel by interaction with sulfated polysaccharides from micro algae and with xantham gum. J Agric Food Chem 40:1316–1320