REVIEW

PINEAPPLE [*ANANAS COMOSUS* (L.)] PRODUCT PROCESSING TECHNIQUES AND PACKAGING: A REVIEW

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ABSTRACT

Pineapple is one of the most relished fruits in India. In the present literature review, several pineapple varieties like Cayenne, Queen, Spanish, Abacaxi, Kew and Mauritius have been enlisted as well as some pineapple based products like canned pineapple, candied pineapple, pineapple fruit cake, dehdrofrozen pineapple and some other healthy pineapple products have been documented. The processing techniques like canning, baking, osmotic dehydration, freezing, extrusion of fruits etc. for the said products have also been discussed together while describing the products. Some modern packaging techniques have also been discussed to keep the pineapple products available round the year. Some of the products that has been commercialized and ought to be commercialized has been drawn attention in this literature review as pineapple is very important in terms of medicinal values.

KEY WORDS
Pineapple based products, Modern packaging, Pineapple varieties

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INTRODUCTION

Pineapple (*Ananas comosus* L.) is one of the most important commercial fruit crops with several health benefits [1]. It belongs to Bromeliaceae (a large family of American tropics) and is originated from South America [2, 3]. Due to its excellent flavour and taste, pineapple is known as the queen of fruits [1]. The fresh pineapple fruit contains 60% edible portion and the moisture content ranges from 80-85%. The fruit contains 12-15% sugars, 0.6% acid, 0.4% protein, 0.5% ash (mainly K), 0.1% fat, fibre, vitamin A, C and β-carotene and antioxidants mainly flavonoids, citric and ascorbic acid [2,3,4]. The mature fruit contains a proteolytic digestive enzyme [4], Bromelin, which when taken with meals proves to aid in digesting protein by breaking proteins to amino acids. The fruit can be consumed fresh or may be processed into squash, syrup, jelly, vinegar, citric acid to name a few [5,6].

Brazil, Thailand, Philippines, Costa Rica, China and India are major pineapple producing countries and the total area under pineapple cultivation in the world is 909.84 thousand ha with production around 19412.91 thousand tons [1,7]. India has 7% of share in pineapple production across the globe. It is mostly grown in North East region, West Bengal, Kerala, Karnataka, Bihar, Goa and Maharashtra states in India. Pineapple fruit production has increased from 1,362.00 thousand tons in 2006-07 to 1,415.00 thousand tons in 2010-11. West Bengal is the highest in terms of production followed by Assam and Karnataka producing 21.5, 15.6 and 13.1% respectively [7].

Anti-hyperglycemic and analgesic in nature, which leads the way of getting cheaper and alternative option of medicine for reducing blood sugar level in diabetic patients [1,8].

Considering an annual world production of pineapple around 19 million tons [5], only roughly 1/3 is being industrially processed, mainly by canning (30%), juice (4%) and 2/3 is consumed as fresh fruit. To further promote pineapple for industrial processing and value addition, several factors are to be noted: integration of grower and processing industry, fruit type and their application, product portfolio, processing technology, logistics, marketing and promotion, and long term planning [9].

In this review, we seek to document the pineapple cultivars, several products from pineapple and their processing technologies as well as packaging of pineapple.

PINEAPPLE VARIETIES

There are many pineapple varieties which can be divided into four groups namely Cayenne, Queen, Spanish and Abacaxi. There are other cultivars also present like Kew or Giant Kew, Mauritius to name a few [3, 7].

Cayenne

This is the most commonly grown variety of pineapple with high fruit quality. It provides high production, resistance to gummosis and contains spineless leaves. The TSS content of flesh ranges from 12-16^{0}B. Among the Cayenne variety, Smooth Cayenne provides the ideal cylindrical shaped fruit for canning. Other members of Cayenne group are Hilo and Baronne de Rothschild. The first one does not produce slips whereas the second one has spiny leaves [3].

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Queen

The leaves of the fruit are short having many spines which curve back. The fruit yield is moderate and the shape is conical, therefore unsuitable for canning. The flesh of the fruit is golden yellow in colour with outstanding aroma. The eyes of the fruit are small and raised. The TSS content of the flesh ranges from 15-16^{0}B. Natal Queen, Z Queen, Ripley Queen are the subgroups present in this cultivar. The plants of this variety are resistant to most diseases [3].

Spanish

This cultivar has long, narrow, spiny leaves with few, but large, flat eyes. This round shaped variety is pretty good for fresh fruit export but moderate for canning purposes. The flesh is fibrous, deep golden yellow in colour and the TSS ranges between 10-12^{0}B. Singapore Spanish has got smooth leaves and is also good for canning [3].

Abacaxi

Among the Abacaxi group, Pernambuco variety has long spiny leaves and a very long fruit stalk. This pyramid shaped locally consumed fruit has white flesh colour. This variety produces many slips and unsuitable for canning or exporting as fresh fruit [3].

Kew or Giant Kew

Fruits of this cultivar are big in size and deep yellow to coppery yellow in colour. The colour of the flesh is pale yellow to yellow and comes with broad, flat eyes. The TSS content of the flesh ranges from 12-14^{0}B [7].

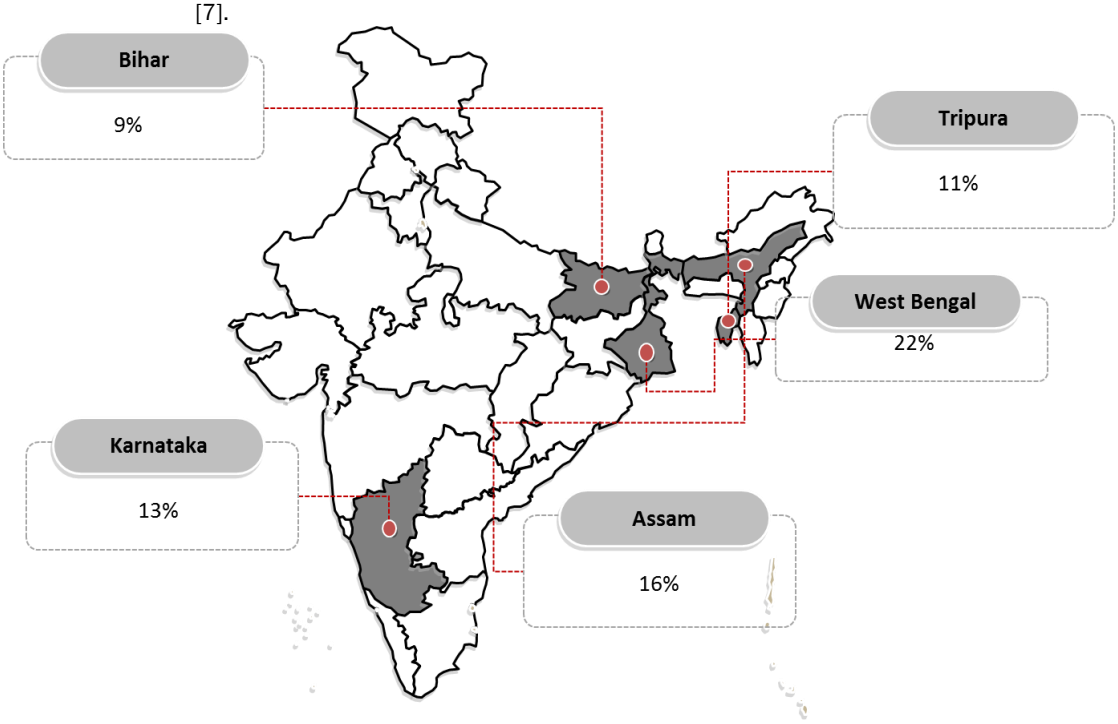

Fig. 1: Leading pineapple producing states in India.

PINEAPPLE PRODUCTS

Canned pineapple

Pineapple is firstly removed from the shell including eyes and cut into cubes of dimension approximately 0.5 cm×0.5 cm×0.5 cm. The cut cubes are blanched for 1 min in hot water at about 90^{0}C and then cooled in tap water [10]. Orange juice, Mango juice and 40% (weight of sucrose/weight of water) sucrose can be used as filling liquor inside the can. Orange and Mango juice TSS content are also adjusted to 40^{0}B. Citric acid and potassium sorbate are added to each solution at 0.2% and 0.1% concentration levels. Pineapple cubes are divided into three parts and each part of pineapple is packed individually with the previously

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prepared solutions at a ratio 2:1 of cubes and solution weights. The canned pineapple is generally pasteurized at 900C for 5 minutes, then cooled and stored at room temperature [11].

Candied pineapple

Pineapples are cleaned, peeled and size reduced into cubes. Then dipped in sucrose solution and food colour is added. Candied pineapple is prepared by boiling until all the syrup was absorbed by the pineapple [4].

Pineapple fruit cake

The batter for the pineapple fruit cake may be prepared by the creaming method. In 500 g of sugar, 1 kg of margarine is mixed using the cake mixer until the batter becomes light and fluffy [12]. In another bowl, eight large eggs are whisked until foamy and firm, then 2 kg of wheat flour and 4 teaspoons baking powder are sieved together with half (1/2) teaspoon of nutmeg. The whisked eggs and flour mixes are folded into the sugar and margarine batter, after that the candied pineapple are added into the cake mix and loaded into a greased pan and baked in an oven at 150^{0}C for 1h [4]. The pineapple cake contains 9.34% protein, 30.97% moisture, 46.97% fat, 0.23mg/100g magnesium, 97.53mg/100g calcium which implies this product is a good source of trace elements that is important to the body as enzyme co-factors and acts as building blocks respectively.

Dehydrofrozen pineapple

The osmotic dehydration is carried out using a sucrose hypertonic solution of 60^{0}B at 40^{0}C. Osmotic dehydration is carried out in a shaker, with a frequency of 75 horizontal oscillations per min, and 1 cm amplitude, containing a 6 Erlenmeyer flask rack. Pineapple samples are placed into each Erlenmeyer that contains 500 ml sucrose solution at 40^{0}C. At pre-established times (30, 60, 120, 180 and 240 min) one Erlenmeyer is removed, and each sample is rinsed with demineralized water at 8^{0}C for 3–5 seconds in order to remove the remaining syrup, and the excess of water is eliminated too, blotted with tissue paper. Afterwards, one portion of this processed fruit is frozen. Osmotic dehydration assays at 45^{0}C are carried out and a fraction is frozen for 12 h. Then it is kept at constant temperature (20^{0}C) in a capped flask for 2 h (for thawing).

Drying is performed in a transversal flow dryer under constant conditions of air velocity (1.5m/s) and temperature (45, 60 or 75^{0}C). Slices of pineapple are placed in aluminum baskets, avoiding any contact among fruit pieces. Samples are extracted from basket and frozen.

Samples of partially dehydrated pineapples are restored at 4^{0}C in capped plastic containers for 12 h prior to freezing. Then, these samples are placed on perforated stainless steel trays, and frozen in chambers with air circulation at – 31.5 ±2^{0}C. During this process copper–constantan thermocouples connected to a data acquisition device are placed in the center of sample which has been processed by different periods of osmotic dehydration; one thermocouple is placed inside the freezer chamber. After 2 h, samples are removed from the chamber, and the thawing process is carried out at constant temperature (20^{0}C) for 2 h, in capped flasks [13].

Pineapple juice

Pineapple juice comes from various places in the processing line of pineapple. It is generally obtained by pressing the shell (cut or scrapings) in the Ginaca machine. It peels the pineapple and forms cylinders from which the slices are made. The small fruits may be chosen which are unsuitable for canning and the fruit portions from drainage crushed pineapple operation. The solid material is then shredded and filter aid (infusorial earth) is mixed with the shredded pieces of pineapple followed by pressing in a hydraulic press. Then the liquid material is subjected to heating to coagulate solids to form thin slurry which then passed through a continuous centrifuge. This removes all the suspended solids including the fibers and other coarse small particles. Pineapple juice is sometimes homogenized to get a cloud stable juice [14]. Pineapple juice is used to treat any type of morning sickness, motion sickness or nausea. Roasted pineapple juice has been utilized for treatment of strangury by different communities in Assam, India [15]. Juice of pineapple is also beneficial for fevers and cystitis [16].

Crushed pineapple

To prepare crushed pineapple, shredded pineapple is first pumped into steam jacketed kettles and heated to 90^{0}C. To ensure optimum consistency of the product some of the juice is drained away. Sufficient heavy sucrose syrup (23^0-35^{0}B) is added to the product if it is to be sweetened. The hot mixture is automatically packed into cans, sealed after giving a short heat processing to ensure quality and finally cooled [14].

Pineapple concentrate

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Pineapple juice may be concentrated in multiple effect vacuum pans or the vacuum pans which operate at below 60^{0}C. If short time evaporators are used, high temperatures up to 82^{0}C have been used successfully. Fresh pineapple juice (12^{0}B) is concentrated up to 45^{0}B for retailing or may be concentrated as high as 60^0-65^{0}B for reusing in other pineapple based manufacturing processes. Recovered essence is mixed with the concentrate and then it is slush frozen and packed either into metal containers (for 45^{0}B) or polyethylene (PE) lined fiberboard containers (for 65^{0}B). Freezing occurs at -23^{0}C. Bulk pineapple concentrate is also added to citrus juices to form frozen juice blends. Pineapple concentrate is also used to produce many types of canned fruit drinks like canned pineapple-grapefruit drink. This drink has exceeded the volume of production of singe strength pineapple juice [14].

Frozen pineapple

Rectangular chunks of pineapple are used to prepare frozen pineapple. The slices can be kept well in syrup of 25^0-49^{0}B for 1 year but forms a stale taste. Ascorbic acid may be added to stabilize the flavor in this case. Smooth Cayenne variety is mainly used for freezing application. The Red Spanish variety develops off-flavors if frozen. Pineapple, due to its fiber content, maintains a good texture after thawing. Pineapple for freezing application is prepared in almost the same manner as in canning, except that the cylinders are passed through additional coring operation to remove the last vestiges of fibrous core. Fruits in bins arrive from the plantation are unloaded onto conveyor belts or into flumes of water and washed thoroughly. After grading into 3-4 sizes, they are peeled and cored in the Ginaca machine. Cored cylinders are inspected, trimmed and diverted to another coring machine followed by fixed blade chunk cutter. Chunks are then filled into 211mm×414mm or No. 10 cans followed by addition of syrup, seaming and conveying directly onto air blast tunnel freezer at -340C. The bulk frozen packages are directly filled from the product line in form of tidbits. Then syrup is added and frozen in a low temperature blast freezer [14].

Pineapple granules

These are made up of 88% soluble solids, mainly sugars, 10% insoluble solids and 2% moisture. They are yellow in colour and passes through a No. 10 mesh screen. Analysis of reconstituted granules show that it have titratable acidity of 0.6, pH 3.7 and TSS 15^{0}B. Granules are generally packed in controlled humidity with a PE bag inside a fiberboard box. Granules are used as a fruit extender, flavor and colour carrier, decorative material and as fruit solids in sauce preparations in bakery goods, dry mixes, cereals, candies, ice cream, gelatin. The low pineapple flavor of granules is increased by using cloudless pineapple juice concentrate (72^{0}B) and reconstituted by mixing 1 part concentrate to 5.5 parts water [14].

Yogurt fortified with pineapple peel powder (PPP)

Crushed pineapple peel is immersed for 30 min in hot water (90^{0}C) to inactivate the proteolytic enzymes and potential pathogens and then it is freeze dried to produce a fine powder. The particle size of powder is standardized to less than 180 mm using sieves followed by sterilizing in UV irradiation for 30 minutes. Set-type yogurts are prepared as described in [17]. Briefly, three lots of milk bases are prepared by reconstituting skim milk powder in warm pure water at 14% (w/v); two lots are then further fortified separately with 1% (w/v) inulin or PPP. Control (without prebiotic supplementation), inulin and PPP fortified milk bases are homogenized and heated to 85^{0}C for 30 min, then cooled to 45^{0}C and aseptically inoculated with 1% (v/v) of each *S. thermophilus* and *L. bulgaricus* cultures. These samples are then divided into two equal portions; one portion is further inoculated with 1% (v/v) of each of *L. acidophilus*, *L. casei* and *L. paracasei* cultures. The final mixes are poured into polystyrene (PS) cups. Then the mixes are incubated at 42^{0}C in an incubator until pH of 4.5 ± 0.05 is achieved. The yogurts are then immediately cooled and stored at 4^{0}C [18].

Pineapple leather

Pineapple is washed, peeled and cut into small pieces followed by grinding in a mechanical grinder to obtain uniform pulp. The extrusion cooking can be carried out in single screw extruder (vented extruder with L/D ratio 30:1 and 22 mm×3 mm die opening). Pineapple fruit pulp can be extruded at lower temperature and screw speed to prevent the phytochemical losses during extrusion cooking. The extrusion cooking is carried out at a barrel temperature of 60-100^{0}C with a screw speed of 50 to 150 rpm. The TSS content of the sample is measured using refractometer in term of brix. Keeping starch (thickening agent) content constant at 2% level, it is added to the fruit pulp and the TSS of pulp is maintained from 10-20^{0}B using sugar. Pineapple fruit leather is dried at 60^{0}C for 1h after extrusion to maintain 20% moisture content in final product. Around 1g of fruit leather is taken and extracted in 20 mL of the solution (16:4 v/v, methanol: water). The extract is then placed in an incubator shaker at 30^{0}C for 5 h followed by centrifugation at 10,000 rpm for 10 min. After centrifugation, the supernatants are stored at -4^{0}C for further analysis like phytochemical properties. Extrusion cooking of fresh produce can be used to enhance the antioxidant activity of the product during processing but it affects most of the phytochemical compounds adversely with the change of temperature, screw speed and brix. The antioxidant activity of pineapple fruit leather increases with increasing barrel temperature [19].

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Table 1: Some pineapple based products and their processing techniques

Name of Products	Technology Used	Reference
Canned pineapple	Canning	14,15
Candied pineapple cake	Creaming, Baking	4
Dehydrofrozen pineapple	Osmotic dehydration, freezing	17
Pineapple juice	Pressing in hydraulic press	1
Pineapple concentrate	Multiple effect vacuum pans	18
Frozen pineapple	Freezing	18
Pineapple leather	Extrusion	23

PINEAPPLE PACKAGING

Edible coating

High molecular weight chitosan (CH), with a deacetylation degree of 82.7%, in 1 wt% acetic acid solution, 98% glacial acetic acid, 1 N sodium hydroxide (NaOH), oleic acid (OA), Tween 80 and food-grade methyl cellulose (MC) have been used to obtain the film-forming dispersions of chitosan. The mixtures are emulsified at room temperature using a rotor-stator homogenizer at 13,500 rpm for 4 min and the pH of all film-forming emulsions is adjusted to 5.2 with 1 N NaOH.

Sodium caseinate (NaCas), calcium caseinate (CaCas), beeswax (BW), oleic acid (OA) and glycerol can be used to obtain the film-forming emulsion of caseinate. Pure sodium caseinate and a mixture of NaCas:CaCas (1:0.5 mass ratio) are dispersed in distilled water. The protein: glycerol ratio is set to 1:0.3 and the protein: lipid ratio is set to 1:0.5 in the emulsions. The lipid part is composed of OA: BW (70:30 mass ratios). After addition of glycerol to aqueous solutions of caseinates, all dispersions are heated to 850C and the amount of beeswax required is added, which melts in the hot solution. After that, it is homogenized at 85^{0}C for 1 min at 13,500 rpm, then for 1 min at 20,500 rpm. The emulsions are then cooled at room temperature and oleic acid is added. Each emulsion is homogenized again with a vacuum high-shear probe mixer for 2 min at 20,500 rpm and finally they are degasified at 7 mbar at room temperature with a vacuum pump.

Four application techniques have been used for coating cylindrically cut pineapple samples. Method I consists sample drying until aw = 0.75 and afterwards dipping at atmospheric pressure in the film-forming solutions for 5 min, with subsequent coating and drying at room temperature; method II consists of sample dipping at atmospheric pressure in the film forming solutions for 5 min before drying until aw = 0.75; in method III sample is dipped at atmospheric pressure in the film-forming solutions two times (each time 5 min), before drying until aw = 0.75; and method IV consists sample dipping in the film-forming solutions applying a vacuum impregnation operation before drying until aw = 0.75. The vacuum impregnation operation consists of applying a vacuum pulse (50 mbar for 3 min) to the immersed sample, and then restoring the atmospheric pressure while the sample remains immersed for 2 min more. In all the cases, the said procedure is carried out at 25^{0}C and the ratio of the weight of coating solution: sample is 20:1 [20].

UV-C light treatment and packaging into PA/PE pouches

Samples are prepared by removing crown leaves and fruit bottom and then the pineapples were peeled, cored and wedged using a pull-down manual equipment. Pineapple stick is obtained and one stick is introduced to UV-C light treatment (200 J/m2) and packed into PA/PE pouches (30×15 cm, 0.090 mm, 20/70), which are then sealed [14].

Packaging into PA/PE pouches and UV-C light treatment

Samples are prepared by introducing one untreated pineapple stick into a PA/PE pouch followed by sealing the pack and UV-C light treatment (200 J/m2). The irradiance on the pineapple stick surface has been found to be 32 W/m2, due to the 20% screening effect of the plastic material. These samples are then exposed to 160 J/m2 UV-C light fluence.

UV-C light treatments have shown to exert a high potential for shelf life extension by decreasing microbial growth during storage. The treatment is also efficacious even when the product is packed before exposure to light, which potentially allows in preventing post-treatment contaminations during processing. However, there is a limitation that this process requires packaging single fruit sticks to avoid shadowing effects among food items. In addition, it is mandatory to adopt unprinted packaging materials which allow transmittance of UV-C light and therefore, there is a need for consideration of applying label or a secondary printable package to provide the consumer with the necessary information [21].

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Packaging using bio preservative on fresh cut pineapple

Nisin possesses a broader antimicrobial activity than most other bacteriocins and has been shown to be of no or low toxicity. It also has successful functions as a food preservative. The inhibitory effect of nisin is wider than most bacteriocins and it extends to a large variety of gram positive bacteria including spore formers [22]. Solubility of Nisin is good in low pH (3-4) condition. Nisin solution (pH 3-4) is prepared by dissolving citric acid solution in different concentrations of 0.04, 0.05 and 0.06mg followed by soaking them in the above solutions for 5 to 10 minutes. Then it is surface dried for one hour, packed in Polystyrene container and the samples are stored at room (around 250C) and refrigeration temperature (4^0C) for its storage stability.

The bacterial population gets decreased during the storage period for samples treated with bio preservatives compared to control samples with no nisin. Ascorbic acid content in fresh cut pineapple treated with nisin packed in polypropylene is 25.82% at room temperature with a shelf life of 3 days and 28.90% in refrigerated condition with the shelf life of 12 days. The initial total antioxidant activity has been checked as 19.00µg/g in control. In the case of fresh cut pineapple treated with nisin, the total antioxidant activity ranged from 12.30 to 16.00µg/g when stored in differed packaging material at room and refrigerated temperature and checked after 3 days and 12 days of storage respectively [23,24].

CONCLUSION

Pineapple is one of the most relished fruits with ample amount of bioactive compounds present in it. The world pineapple demand has been increasing rapidly. Therefore pineapple and pineapple based products will be of a great demand in recent future not only because of its taste but also a principal compound in terms of health healing in different manner. It is a common fruit in India as well as in some other countries of the world and it contains good amount of various vitamins, carbohydrates, crude fibre, water, different minerals. Generally, the matured pineapple fruit is consumed fresh and juice as source of many essential minerals and vitamins but can also be processed to produce different pineapple based products. Fresh pineapples are rich in bromelain which is used as anti-inflammatory agent as well as reduces swelling in inflammatory conditions such as acute sinusitis, sore throat, arthritis, gout. The Honey Queen Variety of Bangladesh is superior in nutritional content as well as sweetness than the Giant Kew variety of pineapple. Farmers spray growth boosting chemicals and hormones on pineapple flowers to produce large fruit and also apply hormones for early harvesting which may increase the risk of contamination of food materials. Unripe pineapple in some cases is inedible, poisonous and irritates the throat and acts as a purgative. Excessive consumption of ripe pineapple cores leads to formation of fibre balls in the digestive tract. So, beside its high nutritional value there may have some side effects if not consumed properly. To get the fruit and fruit based products available round the year, there should be proper packaging of the processed fruits also. Several conventional techniques like canning and some modern techniques like edible coating, UV ray application, packing by bio preservatives are to be used commercially. There has to be more new products developed from pineapple with keeping or enhancing the nutritional value by modern packaging techniques to provide health benefits to the consumers.

CONFLICT OF INTEREST
There has been no conflict of interest in relation to the work.

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