



## **Current Status of Guava (*Psidium Guajava* L.) Production, Utilization, Processing and Preservation in Kenya: A Review**

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### **Abstract**

The guava (*Psidium Guajava* L.) tree is extensively grown in the tropical and sub-tropical regions of the world. It is quite resilient, highly productive, has high economic returns and requires minimal care. The fruit is very nutritious with a characteristic flavor and has a high demand internationally especially when processed into pulp, concentrates, ready to serve beverages, wines, as well as jams and jellies. Although Kenya has a favorable climate for guava farming, the fruit's nutritional and economic potential remain highly underutilized due to low adoption of processing and preservation techniques in addition to limited research. This review focuses on guava production utilization, processing and preservation with emphasis on Kenya. There has been progressive increase in the total acreage under guava farming with various varieties of guavas being produced. The country produces as much as 11,327 tons of guava fruits worth 1.1 million US dollars although the fruit is mainly cultivated for local consumption with minimal processing. Naturalized guavas from sprouts of randomly dispersed seeds are common across all the agroecological zones both in the wild and on farms except in the arid areas. The fruit is however, climacteric and has a high rate of perishability resulting to high postharvest losses when in season. Processing of guavas into commercial products can increase the fruit's value, improve farmers' household incomes and enhance their utilization. The guava value chain also remains highly underexploited and since it is a neglected crop, there is need for a multisectoral approach in order to exploit the nutritional and economic potential of the fruit.



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## Introduction

Guava, *Psidium guajava* L., is a small monoecious evergreen tree with a height of between 2 and 10 meters belonging to the Myrtaceae family.<sup>1</sup> It is native to tropical areas of southern Mexico and Northern South America although guava trees have now been grown by many other countries having tropical and subtropical climates, therefore allowing production around the world.<sup>2</sup> The genus *Psidium* (Myrtaceae) consists of about 150 genera and about 5000 species which are widely distributed in the American, Asian and African tropics.<sup>2</sup> The fruit which matures in approximately 120 days after flowering, is fleshy with a characteristic smell and aroma, contains many seeds and can weigh up to 500g depending on the variety and the environment.<sup>1</sup>

The guava tree is quite resilient, highly productive, requires minimal care and has high economic returns.<sup>3</sup> The guava is widely distributed owing to its potential to adapt well to various ecological conditions including wastelands and soils with much higher pH levels (8.6 to 9.6) and it exceeds most other fruit trees in productivity, toughness and adaptability as they are easily naturalized.<sup>4</sup> The dispersion of guavas has successfully been through agents including birds, bats, man and other animals.<sup>4</sup> Commercial guava production involves use of improved guava varieties through various techniques mainly propagations from seeds and vegetative propagations for commercial purposes.<sup>5</sup> However, commercial guava cultivation in East Africa is limited<sup>6, 7</sup> with naturally growing guavas being the most common resulting to guavas with diverse morphological and genetic diversity.

Guava fruits are often consumed fresh but are also suitable for processing into jam, juice, nectar, wine and fruit leather among other products.<sup>8</sup> The fruit is highly nutritious and is a good source of vitamin C, vitamin A, carbohydrates, proteins, minerals, pectin, calcium and phosphorus among other nutrients and can therefore help fight malnutrition.<sup>9</sup> Besides, the guava plant has been widely used in Central and South America, West and North Africa and some parts of South East Asia for treatment of various ailments including, gastrointestinal disturbances as well as applications in the cosmetic and dermatological industry.<sup>10,11</sup>

This review paper focuses on providing information on guava production, utilization, preservation and processing in relation to Kenya based on literature findings.

## Guava Cultivation in Kenya

Fruit production including guavas in Kenya is mainly carried out by farmers with insufficient resources highly hindering fruit species experimentation and diversification.<sup>12</sup> Various varieties of red/pink fleshed, white fleshed and strawberry guava with diverse morphological and genetic diversities grow in Kenya due to the different agro-ecological zones in the country.<sup>7,13-15</sup>

Naturalized guava cultivation is quite common in rural areas across all the agro-ecological regions both in the wild and on farms except in the arid areas.<sup>16</sup> The guava trees grow widely with minimal care from sprouts of randomly dispersed seeds according to the Horticultural Crops Directorate (HCD, Kenya). There has been increased guava production over the years in the country according to HCD data.<sup>7,17</sup> The total acreage under guava farming was estimated to be 1260 - 1806 Ha between 2014 to 2016 and a projected increase in production in the subsequent years. The total production was estimated at over 9800 - 11,327 tons. However due to low economic value, the guava prices have poor returns to farmers resulting to high post-harvest losses. The guava value chain therefore remains widely untapped despite its nutritional significance and economic potential.<sup>18</sup>

Guavas in Kenya are mainly consumed at household level and there is limited research and development aimed at domesticating and commercialization of the fruit which have hindered the establishment and improvement of structured guava value chains in Kenya.<sup>7,19</sup> Furthermore, there are scattered and conflicting information on the guava production as well as very limited documentation on the development programs for the crop.<sup>19</sup> There is also limited information on guava production for consumption and commercial purposes as well as lack of documentation of known guava plantations in Kenya.<sup>7</sup> Moreover, the guava varieties and their performance in the country are yet to be profiled as very minimal studies related to the crop have

been conducted. Consequently, the climatic, soil and agronomic conditions for optimum guava cultivation as well as guava post-harvest processing technologies in the country<sup>7</sup> are not documented.

Sub-Saharan Africa Kenya included is characterized by significantly high rates of micronutrients deficiencies and malnutrition due to limited access and utilization of fruits and vegetable and as well as relatively high level of poverty leading to food and nutritional insecurity especially in the rural areas<sup>20,21</sup> Moreover, there are high postharvest losses as adoption of postharvest technologies remains low therefore contributing to increased poverty and

hidden hunger.<sup>20</sup> Guava value addition in Kenya remains extremely low and therefore there is need for a structured system for policy formulation focused on its trade with an aim of reducing the post-harvest losses, increase employment opportunities as well as maximization of the fruits' value to farmers.<sup>19</sup> Value addition through new products development while ensuring minimal destruction of nutrients is essential so as to combat malnutrition especially during the harsh weather conditions and can generate income that can be utilized to meet household food security for the farmers' through commercialization of guava fruits and the processed products.

**Table 1: Food value of *Psidium guajava* fruit**

<b>Nutrient</b>	<b>Value per 100 g Fresh weight Basis</b>
<b>Proximates</b>	
Water	80.8 g
Energy	68 kcal
Protein	2.55g
Total lipid (fat)	0.95g
Carbohydrate, by difference	14.32g
Fiber, total dietary	5.4g
Sugars, total	8.92g
<b>Minerals</b>	
Calcium, Ca	18mg
Iron, Fe	0.26mg
Magnesium, Mg	22 mg
Phosphorus, P	40 mg
Potassium, K	417 mg
Sodium, Na	2 mg
Zinc, Zn	0.23 mg
<b>Vitamins</b>	
Vitamin C, total ascorbic acid	228.3 mg
Thiamin	0.067 mg
Riboflavin	0.04 mg
Niacin	1.084
Vitamin B-6	0.11 mg
Folate, DFE	49 µg
Vitamin A, RAE	31 µg
Vitamin A, IU	624IU
Vitamin E (alpha-tocopherol)	0.73mg
Vitamin K (phylloquinone)	2.6
<b>Lipids</b>	
Fatty acids, total saturated	0.272
Fatty acids, total monounsaturated	0.087
Fatty acids, total polyunsaturated	0.401

Adapted from USDA,<sup>30</sup>

### Nutritional Properties of Guava

Guava (*Psidium guajava*) fruit is often consumed fresh.<sup>22</sup> The fruits are berries consisting of fleshy pericarps and seed cavities with fleshy pulps and numerous small seeds.<sup>23</sup> The fruit contains high levels of vitamin C (up to 228.3 mg/100 g, fresh weight) with the highest concentration in the unpeeled fruits.<sup>24</sup> Guavas also contain significant levels of essential oils, phenols, triterpenes, flavonoids, saponins, lectins, fiber and fatty acids as well as pectin.<sup>25</sup> Furthermore, the fruits have considerable levels of minerals including phosphorus, calcium, iron and vitamins such as niacin, pantothenic acid, thiamin, riboflavin and vitamin A (Table 1).<sup>25-27</sup>

Guavas are rich in both carotenoids and polyphenolic compounds which give the fruit its antioxidative pigments making the fruit among the highest in antioxidation values.<sup>28</sup> The pigments are responsible for the fruit's skin color as well as that of its flesh. As such, the red-orange colored guavas have been found to contain high levels of the polyphenolic constituents, high carotenoids and pro-vitamin A substances and retinoids compared to the yellow-green colored varieties.<sup>29</sup>

The guava fruits also contains other constituents that have been shown to have various health benefits including, oxalic and malic acids, saponin combined with oleanolic acid among other polyphenolic compounds including; morin-3-O- $\alpha$ -L-lyxopyranoside and morin-3-O- $\alpha$ -L-arabopyranoside, flavonoids, guaijavarin and quercetin.<sup>27</sup>

The findings by Chiveu, (2018)<sup>14</sup> on Kenyan guavas showed significantly low levels of vitamin C compared to the USDA data (Table 1) ranging from 83-147 mg/100 g of fresh fruit. The mineral composition also varied significantly with some varieties extremely low or high as compared to the USDA data. The white-fleshed guavas generally had much more phosphorous, magnesium, sodium, and boron compared to the red-fleshed varieties.<sup>14</sup> These variations may be attributed to the climatic conditions and the fruits' morphological traits<sup>31,32</sup> as well as the maturity levels and the agricultural practices.<sup>33,34</sup> There is need therefore for further research on the nutritional composition of Kenyan guavas and factors influencing the nutrient contents.

**Health Benefits of Guavas**

The guava plant's leaves and the bark have been widely used in the treatment of various

ailments.<sup>26</sup> They possess phytochemicals and natural antioxidants that have been shown to counter chronic diseases as they possess anticancer and antidiabetic properties and therefore reduce risks of contacting and developing Alzheimer's disease, age-linked diseases, prevent liver injuries and cataracts due to their antioxidative and anti-inflammatory properties.<sup>35,36</sup> Moreover, the fruit has hepatoprotective effects<sup>37,38</sup> while the leaf extracts have been used for years to treat various disease in ethnomedical practices due to their high levels of flavonoids mainly quercetin.<sup>27</sup> These include diarrhea, nephritis, stomachache, wounds, anorexia, cerebral ailments, jaundice, dermatitis, epilepsy and hysteria among others<sup>26</sup> (Table 2). The use of guava in ethnomedical practices in Kenya however remains unknown or if it has been practiced, there seems to be no recorded literature on the same.

**Table 2: Ethnomedical uses of the guava across the world**

Country	Usage
Amazonia	For diarrhea, dysentery, menstrual disorders, stomachache, vertigo <sup>26</sup>
Brazil	For anorexia, cholera, diarrhea, digestive problems, dysentery, gastric insufficiency, inflamed mucous membranes, laryngitis, mouth (swelling), skin problems, sore throat, ulcers, vaginal discharge <sup>39</sup>
Cuba	For colds, dysentery, dyspepsia, diarrhea and hypertension <sup>40</sup>
Ghana	Coughs, diarrhea, dysentery, toothache <sup>41</sup>
Haiti	For dysentery, diarrhea, epilepsy, itch, piles, scabies, skin sores, sore throat, stomachache, wounds <sup>26</sup>
India	For anorexia, cerebral ailments, childbirth, chorea, convulsions, epilepsy, nephritis, jaundice. <sup>26</sup>
Malaya	For dermatitis, diarrhea, epilepsy, hysteria, menstrual disorders
Mexico	For deafness, diarrhea, itch, scabies, stomachache, swelling, ulcer, worms, wounds <sup>42</sup>
Peru	For conjunctivitis, cough, diarrhea, digestive problems, dysentery, edema, gout, hemorrhages, gastroenteritis gastritis, lung problems, PMS, shock, vaginal discharge, vertigo, vomiting, worms. <sup>26</sup>
Philippines	For sores, wounds and as an astringent <sup>43</sup>
Trinidad	For bacterial infections, blood cleansing, diarrhea, dysentery <sup>44</sup>

The use of guava in medicinal practices has been studied by several other researchers on various diseases and it has shown potential for treatment of most illnesses across the world.<sup>45</sup> The ethnopharmacological assessments, laboratory

studies and clinical trials have shown that the guava is effective in the treatment of these ailments.<sup>40</sup> Furthermore, the toxicity assessments of the plant's roots, bark, leaves, fruits, flowers and seeds have been found to be safe for medicinal purposes for

both oral and topical uses if administered in infusions and decoction forms.<sup>46</sup> However, further research needs to be conducted in order to isolate functional ingredients that can be used in developing of drugs and other therapeutic products.<sup>45,47</sup>

#### Post-Harvest Losses of Guava Fruit

The guava fruit is a climacteric with a high rate of perishability.<sup>48</sup> The main post-harvest losses in fruits occur through physiological processes due to wilting, shriveling and chilling injuries, pathologically as a result of fungi and bacterial attacks, and physically through mechanical injuries.<sup>49</sup> Losses have been estimated at 20 to 40% in developing countries as compared to about 10 to 15% in developed countries, depending on the crop involved and the season.<sup>49-51</sup>

Guavas, like other fruits have quantitative and qualitative post-harvest-losses occurring at all stages from harvesting, through handling, packaging and transportation, post-harvest storage and during marketing.<sup>52</sup> However, application of proper postharvest practices can help reduce this (Table 3). About 20-25% of guava fruits are damaged and unfit for consumption before they reach the consumers.<sup>53</sup> It is therefore critical that development of affordable processing technology for guava are adopted.<sup>54</sup> The guava post-harvest losses in Kenya remain unaccounted for. This may be attributed to the fruit not being considered as important compared to others such as mangoes and avocados.<sup>7</sup> Furthermore, farmers rarely plant the guava fruit as an income generator compared other fruit trees.

**Table 3: Post harvest losses reduction strategies for fruits**

Stage	Recommended handling
Harvesting	Careful handling during harvest to reduce bruising, scratching and punctures; harvesting during the cooler hours of the day (e.g. the early morning); shading crops once harvested to remove field heat.
Handling	Protecting the crops from injury can minimize pest attacks and physiological and dehydration damage.
Sorting and Cleaning	Sorting and cleaning can increase shelf-life considerably. By separating higher and lower quality crops, the risk that fungi or bacteria spread from damaged crops to others is reduced. Quality parameters like size and color can be determined through the use of visual charts, and allows the crops to be targeted to appropriate markets to maximize revenue.
Packaging	Proper packaging to maintain freshness prevents quality deterioration as well as protecting against physical damage during transportation. Clean, smooth and ventilated containers are key, but the specific type depends on the crop.
Transportation	Use of clean, cool, ventilated and covered vehicles for the transport of perishable crops with transport during the colder hours of the day advised. The smoothness of the road is also important as excessive vibrations and movement can degrade crop quality. Avoid watering the produce before transport as this increases decay. Care during loading and unloading is a simple yet effective way to reduce loss.
Storage	Only crops that meet specific quality standards should be stored (correct level of maturity, undamaged). Optimal temperatures for each commodity should be known and used as shelf-life is longer when stored in optimal temperature conditions.
Processing	Processing allows producers to stabilize the produce, diversify the food supply for enhanced nutrition throughout the year, and generates employment.

Adapted from Kiaya, 2014<sup>55</sup>

The rate of guava deterioration is influenced by various external environmental factors that the harvested guavas are exposed to including, ambient temperatures, relative humidity, air speed and the atmospheric air composition (the ratio of carbon dioxide, ethylene and oxygen) as well as the hygienic conditions of storage area.<sup>49</sup> On average, fresh guavas last for about 3 – 10 days but if some of these factors are controlled, the fruits can last 2 -11 more days depending on the varieties and methods used.<sup>25,56-58</sup>

Guavas undergo high respiration rates and subsequent post-harvest ripening which leads to the fruit perishability.<sup>48</sup> The rate of guava perishability has however been shown to reduce significantly when guavas are packaged in modified forms. Rana *et al.*,<sup>25</sup> reported that storage of guavas at  $7 \pm 3^{\circ}\text{C}$  after shrink and cling wrapping using polythene bags (LDPE) reduced the ripening rates and the physiological weight losses and increased the shelf life by up to 15 days.

The use of salts such as calcium chloride and calcium nitrate has been found to extend the guava freshness as well.<sup>59</sup> This is due to the counteractive effect on ethylene, therefore decreasing the ripening rates and extending the guava life by up to 12 days while storing the fruits at room temperatures. The use of salicylic acid at low concentrations have also been shown to effectively reduce the rate of guava degradation<sup>60</sup> while application of antioxidants such as benzyl adenine have similarly increased the guava shelf life by upto 14 days during storage.<sup>61</sup>

Freeze-drying of guavas and guava pulp has been used to preserve the fruits.<sup>62-64</sup> The technique has been found to be the most appropriate method for drying products especially fruits and vegetables that are highly sensitive to heat.<sup>62</sup> Unlike in conventional drying, freeze drying is carried out at low temperatures ( $-20$  to  $-50^{\circ}\text{C}$ ) that minimizes the shrinking and degradation reactions resulting to products with superior quality.<sup>62,63</sup>

In Kenya and the sub-Saharan Africa in general, postharvest losses are caused by many factors and come in different forms.<sup>65</sup> Pre-harvest factors such as disease and insect infestation are the major causes.<sup>66,67</sup> Other factors that highly influence

post-harvest losses are; bad and inexperienced handling of fruits, poor packaging methods which may lead to physical damages and high temperatures which lead to moisture losses. Furthermore, delayed marketing and poor market distribution strategies which extend the time between harvesting and consumption have often been shown to contribute to postharvest losses as well.<sup>65</sup>

There has been limited research on the post-harvest losses of guavas in Sub-Saharan Africa due to limited processing but the losses have been shown to be as much as 49% as they are not considered to be major fruits.<sup>7,68</sup> The actual postharvest losses of guavas in Kenya however may be extremely high as there is no structured value chain for the locally produced fruits due to lack of marketing and processing.

#### **Guava Value Addition**

The guava has great potential for extensive commercial use because of its ease of cultivation, high nutrient content and ease of processing into various industrial products.<sup>69</sup> There are many products which can be obtained from processing guavas including guava pulp, jam, juice, jelly chocolates, wine and guava powder (which is mostly used in preparation of yogurt)<sup>3</sup> and spray dried soluble guava extracts containing high concentration of antioxidants.<sup>3,70</sup>

#### **Some of the Commercial Products from Guava Include;**

##### **Guava Pulp**

Processing of guavas into pulp provides a convenient form of guava fruits preservation.<sup>71-73</sup> The guava pulp can best be preserved by addition of potassium metabisulphite at low concentrations (0.005 - 0.2%) and storing at low temperatures ( $2-5^{\circ}\text{C}$ ) to avoid nutrient breakdown.<sup>73</sup> The pulp is easily processed into other products such as juices, ready to drink beverages, guava nectars and guava leather<sup>71-73</sup> and can be stored for up to 90 days at  $2-5^{\circ}\text{C}$ .<sup>71</sup>

The process of extraction of the fruit pulp plays a critical role as it determines the quality and yields of the final product.<sup>74</sup> Cold or hot methods can be used for extraction of pulp.<sup>3,74</sup> Hot methods involve a preheating stage in which fruits are blanched before extraction using hot water or steam.<sup>74</sup> Although the

hot methods result to high extraction yield, there is usually browning and off flavors which affects the quality of the end product. On the other hand, cold methods involve pulping of clean fruits without preheating resulting to higher quality pulp although lower yields compared to the hot methods. Pulp can be prepared using either peeled or unpeeled guavas.<sup>3</sup> Peeling of guavas could be through lye peeling using diluted sodium hydroxide (NaOH) or hand peeling although the former is preferable as the product is uniformly peeled and results to higher pulp yield.<sup>74,75</sup> The fruits are then pulped using blenders at household levels or pulpers at the industrial scale after which sieving or straining using muslin clothes or 1 mm stainless steel meshes to remove the seeds.<sup>74,76</sup>

#### **Blended Ready to Serve Beverages**

The guava fruit pulp has been used in preparation of different blended, ready to drink beverages by use of various ratios with other fruits such as anola, papaya and pineapples.<sup>77</sup> According to Jakhar *et al.*,<sup>78</sup> blending of guava pulp with other fruit pulps has been found to improve the product appearance, nutritional value and enhances the flavors of the resultant products.

#### **Dehydrated Guava Products**

Drying preserves fruits through reduction of the moisture content which inhibits growth of microorganisms and prevents enzymatic reactions.<sup>79</sup> There are various drying methods including sun and solar drying which result to contaminated and poor quality products as compared to products obtained through osmotic dehydration, vacuum, freeze and spray drying techniques.<sup>80</sup>

Dehydrated guava slices can be obtained by drying under direct sunlight.<sup>81</sup> Although this method is the cheapest in preservation, it has been found to cause up to 84% losses in the heat labile nutrients such as ascorbic acid and the water soluble vitamins such as thiamine and niacin therefore limiting its application as a suitable preservation method.<sup>81-83</sup>

Osmo-dried guava slices are made from guavas of about 1.5cm thickness dipped in sugary syrups containing 0.05% potassium metabisulphite and citric acid.<sup>84,85</sup> These lead to decrease in the moisture content and increases solid and sugar levels that

have preservative effects. The method has minimal effect on the appearance of the guava slice, their texture as well as the flavor

#### **Guava Jams and Jellies**

Guava jam is produced by cooking of pulp after addition of sugar, jellifying substances and other suitable additives to achieve desired consistency<sup>86</sup>. The jam should correspond to 65- 68° Brix after which it is hot filled into cleaned and sterilized glass jars.<sup>87</sup> Guava jellies are processed from fruits that are slightly ripe. The fruits are cut into small pieces and boiled for about 45 minutes using equal amount of water at low temperatures and the juice extracted by filtration using strainers or clean muslin clothes.<sup>88</sup> Further processing involves addition of sugars to the extracted juice after which the mixture is boiled to 105°C or formation of a sheet when a small portion is cooled off in a spoon.<sup>87</sup> The amount of sugar used depends on the pectin levels of the extracted juices and it ranges from 0.5 kg sugar/kg juice to 0.75 kg sugar/kg juice for pectin-rich juice and low-pectin juices respectively.<sup>87</sup> This is followed by hot filling into clean and sterilized jars.

#### **Guava Juice and Nectars**

The guava juices are prepared from either fresh fruits or the guava pulp. Juice is extracted by squeezing the guava fruits through hydraulic filter press or from the pulp after dilution with water and subsequent filtration.<sup>8</sup> The juice is usually not clear and may require use of pectic enzymes for clearer juices that are easily filtered.<sup>8</sup> Studies by Imungi,<sup>89</sup> showed optimized conditions for the extraction of guava juice using proteolytic enzymes from the Kenyan guavas to be 400ppm of enzyme, at a temperature of 45-50°C for 90 minutes.

Nectars are obtained by addition of water to guava pulp or fresh juice.<sup>90</sup> Permitted additives or sweeteners as well as sugar may or may not be added but the products must have a minimum of 8.5° Brix, 25.0% of the guava puree or juice and acidity of 0.15 % at a pH of 3.4 – 4.<sup>8,90</sup> Currently there are some guava juice products in the Kenyan markets although the guava used in processing are imported.<sup>18,91</sup> Besides, information on the nutritional quality and safety of these local products is not available and therefore a need for a study to be conducted.

Guava juices or nectars can also be blended with other juices in order to boost their nutritional values. Various blended guava nectars have been developed by other researchers<sup>3,72,92,93</sup> who have reported that blending improves the product acceptability, enhances the nutritional content and increases the product stability therefore longer shelf life for the nectars.

The evaluation of the feasibility for commercialization of processed guava from locally procured fruits in Kenya is yet to be conducted. Processing guavas is easily achievable even at the household levels and farmers should be educated on affordable technologies that can help minimize the fruits postharvest losses. It is however critical that during processing, care is taken such that the techniques used to produce products are nutritionally, organoleptically and functionally preservative in order to ensure minimal damage on the nutrients.

#### **Effects of Different Processing Methods on Guava Fruit Nutrients**

Processing of guava into various products significantly affects the nutrient contents of the fruit. These include reduction of the heat labile nutrients such as vitamin C which may reduce by as much 50% and above<sup>94</sup> depending on the intensity and time of exposure to heat. The carbonyl compounds that give the fruit its characteristic aroma as well as other phytochemical degeneration have been shown to occur and are attributed to the enzymatic activities due to exposure to light and oxygen.<sup>94,95</sup> Besides, cutting of guavas also promotes ethylene production which accelerates the senescence processes and higher oxidase activities as well as lipoxygenase enzyme activity leading to fatty acids and carotenoids oxidation.<sup>95</sup>

Losses of ascorbic acid have been shown to occur by as much as 20.4 % and 62.5 % during juice and jam processing respectively,<sup>96</sup> 63% loss in vitamin C and 61.9% in lycopene during nectar manufacture.<sup>97</sup> Drying increases the guava shelf life with minimal degradation of the fruit's mineral and antioxidant activities.<sup>98</sup> However, freeze drying has been shown to have the least effect on guava dehydration as it has minimal effects on the nutrient content levels as well as the fruits' natural color, flavor and aroma although the method is quite costly.<sup>83,99,100</sup>

There are currently no data on the nutrient contents of processed guava products in the Kenyan markets and these calls for a need on conducting studies on them so as to ascertain the extent of nutrient degradation in processed guava products.

#### **Processing of Guava Wastes**

Processing of guavas into various products results to wastes including seeds, stone cells and fibrous tissues from the skin are generated especially during pulping. These make about 25% and are suitable for processing into animal feeds and other products.<sup>101,102</sup> Guava wastes have been found to contain high levels of crude fiber (as much as 61%), significant quantities of ether extracts (mainly oleic and linoleic acids) and 1,336 kcal/kg - 1,808 kcal/kg metabolizable energy values.<sup>103,104</sup> The minerals, including zinc, iron, potassium, phosphorus and manganese are also present in significant levels in guava seed meal.<sup>105</sup> Guava wastes can be processed into value added food products as well, including pectin, dietary fibre that is obtained from ground dried wastes and powder which can be supplemented in bakery products to boost the dietary fiber and use of the waste as substrate in fermentation for ethanol production.<sup>106</sup>

Incorporation of guava wastes in broiler chicken feeds has been shown to improve the carcass yields<sup>107</sup> while Farid and Kamel<sup>108</sup> have shown that inclusion of about 20% of guava wastes in feeds can effectively be used without interfering with the animals health, their performance and digestibility and has got insignificant effect on the carcass quality. The use of guava wastes as rabbit feed or inclusion in their diets has been found to economize on the costs of feed and positively enhances the growth and health of rabbits with minimal interference in their digestion and the carcass quality.<sup>109</sup> Therefore guava wastes could be processed into commercial products and thus help reduce the pollution from dumping the wastes.

The estimated wastes produced from the Kenyan industries processing guavas have not been documented. There is need therefore for promoting guava processing and assessing the suitability of processed guava wastes from the Kenyan cultivars.



### Conclusion

The guava fruit's nutritional and economic potential remain unexploited in Kenya. More research on the factors limiting its full exploitation needs to be done. Although the Kenya Agricultural & Livestock Research Organization (KALRO) has been in the forefront in promoting guava production through provision of guava seedlings to farmers,<sup>18</sup> a multisectoral approach from the other government bodies, policy makers, farmers, processors and researchers should be set up in order to promote guava production and processing. It is worth noting that guava production can be produced in most counties across the country and therefore there may be need on educating farmers on the fruit's potential. Furthermore, the involved authorities should be in the forefront in providing farmers with the high quality guava seedlings, carrying out extension services on proper agronomic practices for guavas and establishing marketing channels just like with other fruits such as mangoes. Besides, simple processing

and preservation techniques that can be done at the household levels can be promoted through farmer education groups in order to minimize the fruits postharvest losses while the government could also intervene in order to ensure that fruit processors in the country also produce and market guava products from locally sourced guava fruits.

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### Conflict of Interest

The authors declare no conflict of interest.

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