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Utilization of Indian gooseberry (Phyllanthus emblica L.) as foods

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ABSTRACT

This study aimed to investigate the consumption of amla as a food by conducting a thorough literature analysis and a field survey with unstructured, in-depth interviews. Amla or Indian gooseberry (*Phyllanthus emblica* L.) is rich in phytochemicals, and their pharmaceutical potentials have been extensively reported. However, their utilization as foods is not well documented. Thai recipes use whole or minced fresh amla fruits as an ingredient in some spicy dishes, such as chili pastes, soups, and salads. Like other Asian countries, amla could be processed into products such as juice, preserves, pickles, and dried amla. Ten amla dishes and products were selected for evaluation of their ascorbic acid contents and antioxidant properties (total phenolic compounds, total flavonoids, DPPH, and FRAP assays). High-heat processing resulted in a marginal reduction of ascorbic acid in amla dishes and products. Processing methods also affected antioxidant activities, and they varied depending on processing conditions and product types. The processing of amla into juice slightly decreased antioxidant activities. Thai foods that used amla as an ingredient exhibited less antioxidant activity than those made of fresh amla. The antioxidant activities of pickled and preserved amlas were substantially diminished due to their high salt and sugar content. On the contrary, dried amla demonstrated enhanced antioxidant activities as a result of its reduced moisture content and the presence of concentrated phytochemicals. Given its substantial phytonutrient content and lack of utilization, the results obtained from this research contribute to the promotion of amla as a valuable food ingredient.

Contribution/Originality: Amla, or Indian gooseberry, is rich in phytochemicals, and their pharmaceutical potential has been extensively reported. In addition to its pharmacological use, amla also serves as a valuable element in foods. It can be processed into a variety of dishes as well as products that exhibit strong antioxidant properties.

1. INTRODUCTION

Amla, often known as Indian gooseberry (*Phyllanthus emblica* L.), is an important yet underutilized traditional fruit of Indian origin. It is a deciduous tree from the Euphorbiaceae family and the Phyllanthoidae subfamily (Muzaffar, Sofi, Makroo, Majid, & Dar, 2022) and it has been shown to be a fruit crop that may be ideal for desert settings. It is robust, productive, and extremely profitable even when grown carelessly in drought and salinity environments of arid and semi-arid climates (Meena et al., 2022).

The fruit is known by various vernacular names like Indian gooseberry in English, amla in Hindi, An-mole in Chinese, Dhatri phala in Sanskrit, Mirabolano emblica in Italian, Aamlah in Persian, Anola in Kashmiri, Aavnlaa/Amlaj in Urdu, Amba in Nepalese, Popok Melaka in Malaysian, Phyllanthe Emblic in French, Nelli Kayi in Kannada, and Ma-kham Pom in Thai (Muzaffar et al., 2022).

Amla has a high nutritional profile and is a source of amino acids (alanine, aspartic acid, glutamic acid, proline, and lysine) and minerals (calcium, iron, and potassium). Among fruits, amla is one of the richest sources of vitamin C (Gantait, Mahanta, Bera, & Verma, 2021). It also contains various phytochemicals, such as alkaloids, polyphenols, and tannins (Tewari, Kumar, & Sharma, 2019). Those active compounds are responsible for their therapeutic and medicinal functions (Muzaffar et al., 2022).

Amla is a source of amino acids (proline, glutamic acid, alanine, aspartic acid, and lysine) and minerals (calcium, potassium, and iron) and has a high nutritional profile. People widely recognize Amla as a fruit abundant in vitamin C (Gantait et al., 2021). Additionally, Tewari et al. (2019) have identified it as the primary source of many phytochemicals, including polyphenols, alkaloids, and tannins. The pharmacological and therapeutic capabilities of these active substances have been well documented (Muzaffar et al., 2022).

Previous reports have extensively documented the pharmaceutical potential of amla. These include antioxidant, antimicrobial, anti-inflammatory, adaptogenic, analgesic and antipyretic, antitumor, antiulcerogenic, and hepatoprotective activities, either in combined formulation or amla alone (Almatroodi et al., 2020; Earpina et al., 2020; Gaire & Subedi, 2014; Kapoor, Suzuki, Derek, Ozeki, & Okubo, 2020). Ayurvedic and traditional medicines in Thailand have long documented its use as an antitussive remedy. Amla fruit extracts have been developed into a variety of traditional medicines or health products (Booncharoen, Thepnorarat, & Akarasereenont, 2022).

Previous researches have shown that amla has many useful pharmaceutical properties, such as anti-inflammatory, antipyretic, antimicrobial, antitumor, antiulcerogenic, analgesic, adaptogenic, and hepatoprotective activities. Both combined formulations and amla used alone have demonstrated these activities (Almatroodi et al., 2020; Earpina et al., 2020; Gaire & Subedi, 2014; Kapoor et al., 2020). The antitussive properties of this substance have been documented in Ayurvedic and traditional medicinal practices in Thailand. Many traditional medications and health products have utilized amla fruit extracts (Booncharoen et al., 2022).

However, the elevated acidity and astringent flavor profile of amla restricts it use as a food source. Additionally, the fruits are susceptible to a range of postharvest losses. Therefore, in India and most Asian countries, it is processed into a variety of food products by mixing with other ingredients to compensate for astringent flavors. It can also be processed as an Ayurvedic tonics (Meena et al., 2022; Muzaffar et al., 2022; Tewari et al., 2019).

Given the significant role of amla as therapeutic foods within local communities and its considerable potential for utilization as nutraceuticals and functional foods, the primary objective of this study was to investigate the many food products derived from amla, with a specific emphasis on Thai cuisine. The study also investigated the antioxidant qualities and vitamin C contents of the amla meals in order to verify their high concentration of phytochemicals. The findings could substantiate the suggested use of amla in a variety of food items, augment the advantages for farmers, and stimulate the local economy.

2. METHODOLOGY

2.1. Exploration of Amla Consumption as Foods

An extensive literature review from books, local texts, and websites was conducted to explore and classify Thai foods with amla. We conducted a field survey and unstructured in-depth interviews in four locations (North, Central, Northeast, and South of Thailand) to gather additional data. The information about amla cuisine culture and evolution was summarized, and an extensive list of amla dishes or products commonly available in Thailand was created.

We conducted an extensive literature review to explore and classify Thai cuisines using amla. Additional data was collected through a field survey and unstructured, in-depth interviews conducted with experts, including sage villagers, food technologists, and expert Thai chefs. We compiled a comprehensive compilation of amla foods and processed products typically found in Thailand, encompassing a summary of the cultural and evolutionary aspects of amla cuisine.

Ten amla dishes and products were selected for evaluation of their ascorbic acid contents and antioxidant capacities (total phenolic compounds, total flavonoids, DPPH, and FRAP assays), in comparison with fresh amla fruits. These included amla dishes (chili paste with amla and Tom Plong spicy soup), amla preserves (whole, paste, and dried forms), dried amla (powder, shreds, and herbal tea forms), pickled amla, and amla juice. These selections covered all types of amla dishes and products available in Thailand; meals, preserves, pickles, juice, and dried products in various forms.

All the selected amla dishes and products were prepared in duplicate from the same lot of amla fruits (harvested in November 2022 in Chiang Mai province, Thailand). The recipes or processes used for making the selected dishes and products are shown in Table 1. Ingredients and materials required for the recipes and processes were purchased from local markets in Chiang Mai province, Thailand.

Table 1. The recipes or processes for the selected dishes/products.

Amla dishes/products	Recipes or processes
Chili paste with amla	Ingredients (Fresh amla fruits 150 g, dried fish 100 g, peeled shallot 20 g, peeled garlic 20 g, fresh green or red chili 15 g, palm sugar 15 g, and fish sauce 1 tbs) are coarsely ground by hand using a stone mortar and pestle to become a paste. It is normally served with fresh vegetables as a side dish.
Tom Plong spicy soup	Place ingredients (Minced dried chili 15g, shallot 15g, shrimp paste 10g, sugar 10g, fish sauce 2 tbs, tamarind paste 1 tbs) in a soup pot with chicken stock (1,000 mL) and bring to boil, then add prawns or shrimps (100 g), and dried fish fillets (In pieces) 50 g, bring to boil again.
Amla preserves (Whole, paste and dried forms)	- Whole amla fruits (3,000 g) are washed and blanched in boiling water. Boiled amlas are soaked in calcium hydroxide solution (2%) to improve firmness. Sugar syrup (80 °Brix 4,000 mL) is prepared and brought to boil. The amlas are added to the sugar syrup and cooked over a slow flame until the amlas are soft. The mixture is allowed to cool, and then kept covered in a cool dry place for 7 days. The whole mixture is finally boiled again for 15 minutes, discarded excess syrup, allowed to dry, and cool completely at room temperature. This yielded whole amla preserves. - For paste, whole amla preserves (500 g) were coarsely ground using a stone mortar. - For dried forms, amla preserves in paste (500 g) were subsequently dried by hot air oven at 60°C for 6 hours.
Pickled amla	Prepare 12% brine solution (4,000 mL) with added calcium hydroxide (2%), bring to boil, and allow cooling at room temperature. Place amla fruits (3,000 g) into clear glass jars, add the prepared brine solution to cover all the fruits and let ferment for 10 days.
Dried amla (Powder, shreds, and herbal tea forms)	- For shreds, amla fruits (2,000 g) are cut into pieces and soak in 2,500 mL of 5% brine solution for 10 minutes, discard brine solution and let the cut amla pieces to be dried in ambient temperature for 1 hour before placing them in a hot air oven at 60°C for at least 12 hours or until the final water activity is less than 0.6 (As required by Thai food laws). -For powder, dried amla shreds were ground using pin mill (LG-30B commercial herb grinder, LFM food machinery, China). -For herbal tea infusion, the amla powder (90%) and dried green tea powder (10%) were mixed by weight and put in tea bag (3 g each).
Amla juice (Ready to drink)	Wash and clean amla fruits (2,000 g), cut into pieces and then extract the juice using a juicer (Philips model HR1947/30). The juice was pasteurized at 85°C for 10 minutes.

2.2. Ascorbic Acid Contents

The concentration of ascorbic acid, or vitamin C, was measured using the 2,6-dichlorophenol-indophenol titration technique. We combined the homogenized sample (10 g) with a 3% solution of metaphosphoric acid, then filtered using a muslin cloth, and finally brought up to a total volume of 100 ml. we transferred a 5 ml portion of the solution to a 100 ml conical flask and then titrated with the dye indicator until a pale pink color developed and remained for around 20 seconds. The concentration of vitamin C was quantified as mg of ascorbic acid per 100 g of the sample (Sonkar, Rajoriya, Chetana, & Venkatesh Murthy, 2020).

2.3. Antioxidant Properties

The whole dishes/products were blended using a kitchen blender and then homogenized (VELP, OV5 homogenizer, VELP Scientifica Srl, Italy). The homogenized samples were extracted using 70% methanol (1:25, v/v) under heating conditions at 50 C for 30 min in a water bath (Kumari & Khatkar, 2016). We collected the supernatant of the extracts using centrifugation.

2.3.1. Determination of Total Phenolic and Flavonoid Content

Total phenolic contents (TPC) of the extracts were measured according to the method described earlier (Luque-Rodríguez, de Castro, & Pérez-Juan, 2007). We mixed 2 mL of 0.25 N Folin-Ciocalteu phenol reagents and 0.4 mL of extract. Add 1.6 mL of 7.5% (w/v) sodium carbonate to the mixture and heat in a water bath at 50°C for 5 min. The absorbance was measured at 760 nm using a spectrophotometer (GENESYS™ 10S, Thermo Fisher Scientific Inc.) after cooling in darkness. The gallic acid standard curve was used to calculate phenolic content as mg GAE/100g sample (fresh weight).

For total flavonoid content (TFC), the extract (0.25 mL) was combined with 1.25 mL distilled water and 75 µL 5% sodium nitrite. After 6 min, 150 µL of 10% aluminum chloride was added and left for 5 min before mixing with 0.5 mL of 1 M sodium hydroxide and 775 µL of distilled water. A 510 nm absorbance of the solution was measured using a spectrophotometer. TFC content was expressed as milligram catechin equivalent (mg CE)/100g sample (fresh weight).

2.3.2. Antioxidant Activity

The ability of the extracts to scavenge 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radicals and ferric reducing ability of plasma (FRAP) assay were determined to indicate antioxidant activity.

For DPPH, The sample (50 µL) was mixed with 200 µL of 100 mM DPPH solution in methanol. A reduction in absorbance was recorded at 517 nm after 30 minutes of incubation at room temperature in darkness. We used Butylated hydroxytoluene (BHT) as a positive control for this assay. Inhibitory activities of various concentrations of the extracts were assessed to determine half maximal inhibitory concentration (IC_{50}) in µg/g (fresh weight) (Nuengchamnong, Krittasilp, & Ingkaninan, 2009).

For FRAP assay, FRAP was prepared from 2.5 mL of 2,4,6-tripyridyl-s-triazine (TPTZ) (10 mM) in hydrochloric acid (40 mM) and 2.5 mL of ferric chloride (20 mM) in 25 mL of acetate buffer (0.3 M, pH 3.6). FRAP reagent (1.5 mL) was mixed with 100 µL of distilled water and 100 µL of the diluted sample. We measured the absorption at 593 nm using trolox as the standard. We expressed the results as µg trolox equivalent (TE)/g (fresh weight).

2.4. Statistical Analysis

The experiments were run in at least duplicates, and the mean values with standard deviations were reported. Minitab software version 18 was used for One-way Analysis of Variance (ANOVA) and Tukey post-hoc test to identify the significant difference at 95% confidence level (α=0.05).

3. RESULTS AND DISCUSSIONS

3.1. Amla Dishes and Amla Products in Thailand

Figure 1 illustrates the typical amla dishes from Thailand. Although direct consumption of amla is limited because of its high acidity and astringent taste, which limits its palatability. However, Thai dishes find its way to utilize fresh amla as a food ingredient. Certain spicy Thai dishes incorporate amla fruits with other ingredients. Nam Prik Ma-kham Pom (chili paste) is the mixture of minced amla fruits, chili, shallot, garlic, palm sugar, fish sauce, and dried fish fillet (Figure 1a). Fresh amla fruits, as a whole or in pieces, are used in some spicy soups, such as Tom Plong (Figure 1b) which also contains minced dried chili, shallot, shrimp paste, sugar, fish sauce, tamarind paste, prawns or shrimp, and dried fish fillet. In northeastern part of Thailand, local people use amla in spicy soups with whole freshwater fish (*Macrognathus siamensis*), chili, lemon grass, galangal, kaffir lime leaf, basil leaf, and fermented fish sauce (Figure 1c). Amla can also be used in different styles of spicy Thai salads. Whole amla with Ka-pi sauce (coconut sugar, fish sauce, shrimp paste, shallot, chili, dried chili powder) or Pla-ra sauce (replaced shrimp paste with fermented fish sauce) (Figure 1d) can be found in all regions of Thailand. Northern region of Thailand consumes spicy salad made from alma and green baby tamarind with black rice field crab paste (Nam-poo) (Figure 1e).

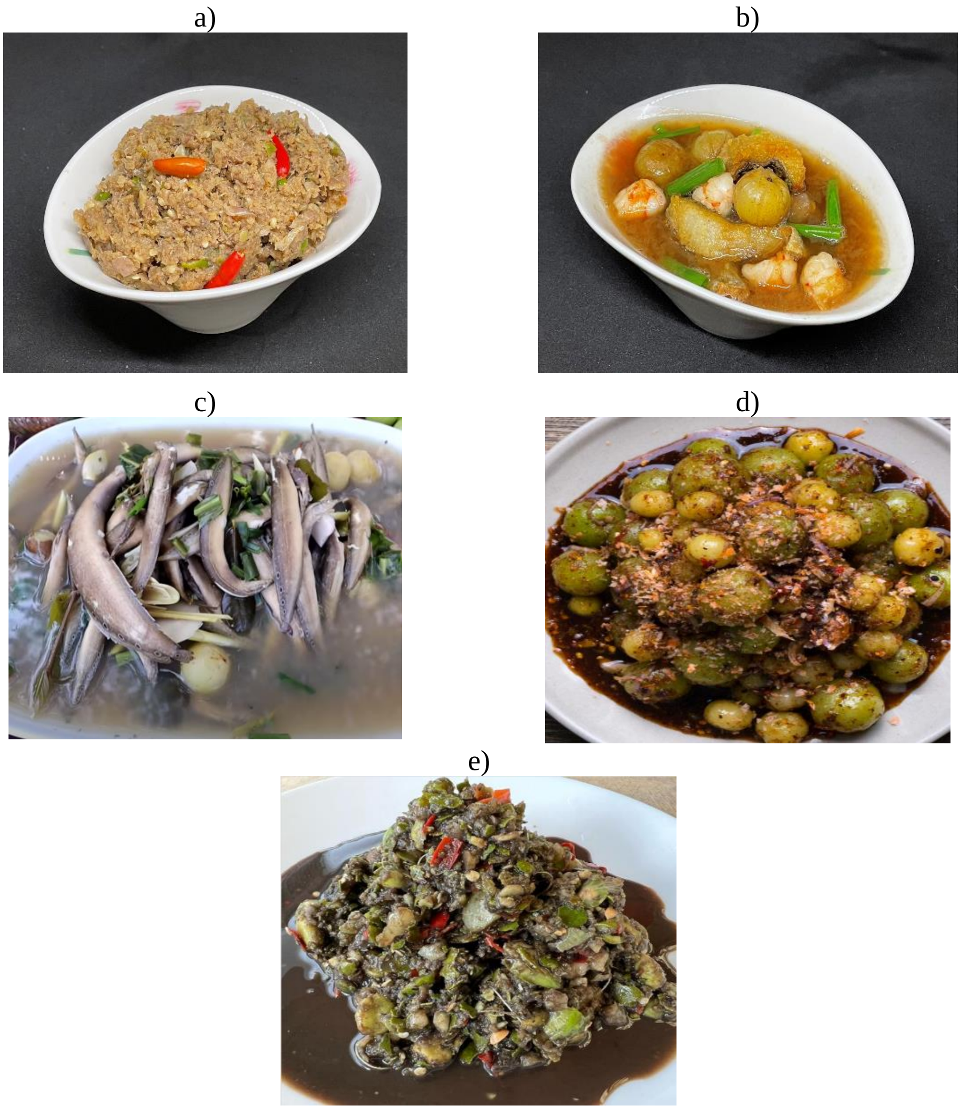


Figure 1. Amla dishes commonly available in Thailand; a) Chili paste with amla, b) Tom Plong spicy soup, c) Amla in spicy soups with whole freshwater fish, d) Amla salad with Pla-ra sauce, e) Amla salad with black rice field crab paste (Nam-poo).

A spicy Thai dish usually contains not only hot chilies but also seasonings of sweet, sour, salty, bitter, and umami (Trachootham et al., 2018). Amla fruit exhibits different tastes such as sweet, sour, bitter, and astringent (Tewari, Kumar, & Sharma, 2023), which could blend well with Thai spicy foods.

Similar to other parts of Asian countries, amla is processed into a variety of products, as illustrated in Figure 2.

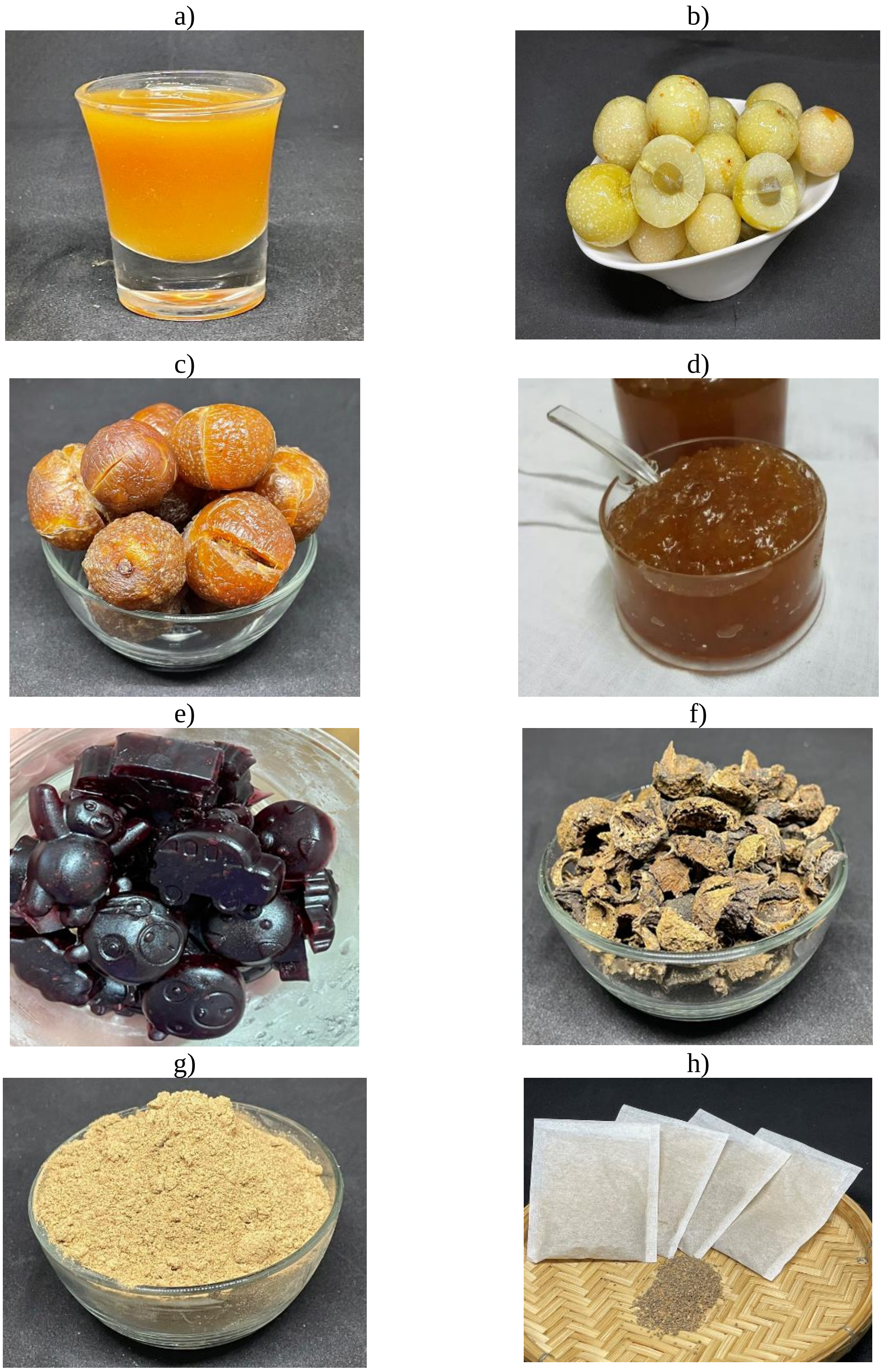


Figure 2. Amla products available in Thailand; a) Amla juice, b) Amla pickles, c) Amla preserves, d) Amla jams, e) Amla jellies, f) Dried amla shreds, g) Dried amla powder, and h) Dried amla herbal tea (Infusion).

Amla juices in the form of ready-to-drink or concentrated juices are readily available on the market (Figure 2a). They are available in both natural and flavored juices. You can also mix amla juice with other juices or honey to counteract their astringent taste. Commercial processing of amla juices usually faces reduction in ascorbic acid content and browning of the juice due to enzymatic activity (Kumari, Khatkar, & Duhan, 2019). Thermal pasteurization at 75–95 °C or sterilization at temperatures exceeding 100 °C, followed by the incorporation of certain chemical preservatives such as potassium metabisulphite (KMS), can extend the shelf life of the juices, but they adversely affect thermally sensitive components in amla, resulting in loss of quality and increased browning (Petruzzi et al., 2017; Tewari et al., 2023).

Pickling fruits and vegetables involves preserving foodstuffs under high acid concentrations that fall into two types (i) fermented and (ii) unfermented pickling (Behera, El Sheikha, Hammami, & Kumar, 2020). Amla pickles in Thailand are usually produced by the fermented process, using brine concentrations of about 10-12% with added calcium hydroxide (texture enhancer), artificial color, seasonings, and some preservatives (Figure 2b). some countries prohibit the use of salicylic acid as a preservative in pickled foods. Pickles were found to contain high content of salicylic acid, which may result from the synthesis of salicylic acid by bacteria during fermentation and/or the addition of herbs and spices during the process, as the latter are a good source of salicylic acid (Kęszycka, Szkop, & Gajewska, 2017).

Preserves, which utilize sugar to prolong the storage of foods, are among the earliest methods of food preservation; nevertheless, they have lasted beyond becoming outdated and are still popular nowadays. The name preserves cover a broad range of products, including jams butters, marmalades, and conserves, as well as ordinary preserves. Preserves contain the largest fruit pieces, while jams contain smaller pieces that are crushed or chopped with added acid. Regulations regarding preserves vary depending on countries, generally, a preserve is minimally 45 parts prepared fruit with 55 parts sugar and is concentrated to 65% or higher solids, resulting in a semisolid product. People commonly use pectin and acids to achieve the gelling texture of preserves. An amla preserve, called amla murabba, is commonly consumed in India. In Thailand, amla preserves are usually made by the "cooking method" using the whole amla fruits. In this method, the preserved material is cooked in sugar to the point of crystallization and the resultant product is stored dry (Figure 2c). We wash and blanch fresh amla fruits in boiling water. Then, boiled amlas are soaked in calcium hydroxide solution to improve firmness. Sugar syrup (heavy syrup) is prepared and brought to boil. You can opt honey as a healthy alternative. Next, we add the amlas into sugar syrup and cooked them over a slow flame until they become soft. The mixture is allowed to cool, and then kept covered in a cool, dry place for several days. Finally, boil the entire mixture once more to lessen its astringency, let it cool completely, and package it. Alternatively, the "no cooking method," in which blanched amlas are placed in a container in layers over layers sandwiching dry sugar, can be used. This method employs less heat so it is more effective in terms of nutrient retention (Priya & Khatkar, 2013).

The key mechanism in fruit preserves is osmotic dehydration, with sugar syrups as the solute. Water flows from fruits to syrups, and along with water, some components such as minerals, vitamins, fruit acids etc. also move towards the solution. The sugar migrates towards the fruits. Osmotic dehydration lowers the water activity of fruits and is preferred over other methods due to their color, aroma, nutritional constituents, and flavor compound retention value (Yadav & Singh, 2014). As amla preserves are sweet and soft in texture, they can be used as the ingredients for making other products such as soft candies and fillings. Subsequent drying of amla preserves using modern techniques such as freeze-drying produces dried and crunchy amla products with no astringent taste.

Amla jams (Figure 2d) and jellies (Figure 2e) are types of preserves that utilize methods other than osmotic dehydration. Traditional manufacturing techniques for jams and jellies involve the utilization of four essential elements: fruit, pectin, sugar, and acid. Gelation occurs when the components are present in the correct quantities. Four important ingredients-pectin, sugar, acid, and water must be added in the right amounts for gelation to happen. This is what makes the polymer network that gives fruit jams and jellies their texture (Dhyani & Khali, 1993). In order to achieve optimal gelation while preparing amla jams or jellies, it is necessary to add or change the quantities of pectin or acid. Additionally, when using high-methoxyl pectin, sugar is always required.

Dried amla products in the form of amla shreds (Figure 2f) or powder (Figure 2g) are classified as valuable products (Sonkar et al., 2020). The conventional drying method starts with hot water or steam blanching, followed by sun drying. Blanching is important because it controls enzymatic decay and retains the color and texture of the amla (Prajapati, Nema, & Rathore, 2011). Blanching also helps in reducing drying time by modifying its structure, thus providing a good quality product (Kingsly, Goyal, Manikantan, & Ilyas, 2007). Although, few disadvantages have been reported, these included leaching of nutrients and color (Lavelli, Zanoni, & Zaniboni, 2007). According to (Muzaffar et al., 2022) dried amla shreds treated with chemical blanching and sun drying with the addition of common salt (3%) were reported to exhibit good quality.

Sun drying, the most economical traditionally practiced method, is dependent on weather conditions and the requirement of long drying time. Solar dryers improve the quality of products, but there are problems with solar radiation limitations and large-scale adaptation. Cabinet tray drying can overcome the disadvantages mentioned above, providing fast, more hygienic, and uniform drying (Kingsly et al., 2007) but the installation and energy consumption are costly. In Thailand, parabolic greenhouse solar dryers are widely used nowadays. This type of dryer minimizes the limitations of open-sun/mechanized drying and improves the quality of dried products. Solar tunnel greenhouse dryer has been used to dry amla candy and the quality of the solar dried amla candy is far better than that of open sun/mechanized drying (Patil & Gawande, 2018). People often ground dried amla shreds into small pieces or powder and used as herbal infusions (herbal tea) (Figure 2h).

3.2. Ascorbic Acid Content

Ascorbic acid or vitamin C content of the amla dishes is shown in Figure 3. Fresh amla exhibited the highest content of ascorbic acid. All amla dishes and processed amla products contained significantly less ascorbic acid than the fresh ones. In this study, the retention of ascorbic acid in amla juice is significantly high. While the other products showed a marginal decrease in ascorbic acid contents. Ascorbic acid is relatively unstable to heat, oxygen, and light. Therefore, retention of ascorbic acid has been commonly used as an indicator in processed foods for the retention of other heat sensitive nutrients as well (Jain & Khurdiya, 2004; Kumari et al., 2019).

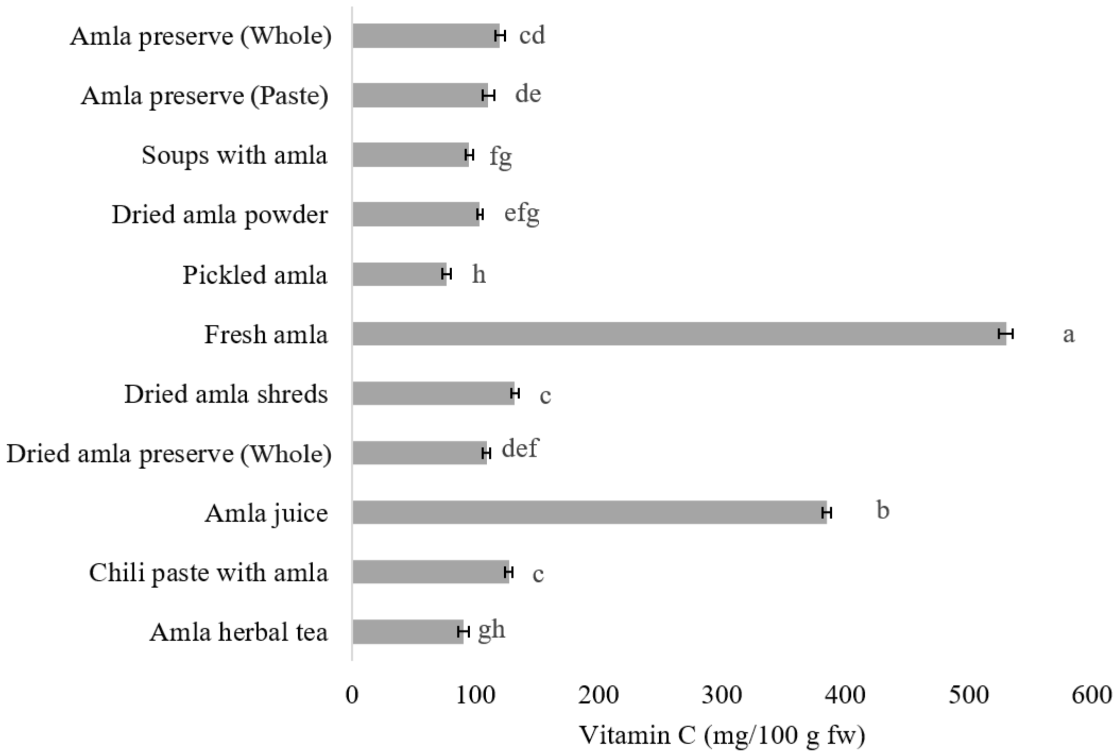
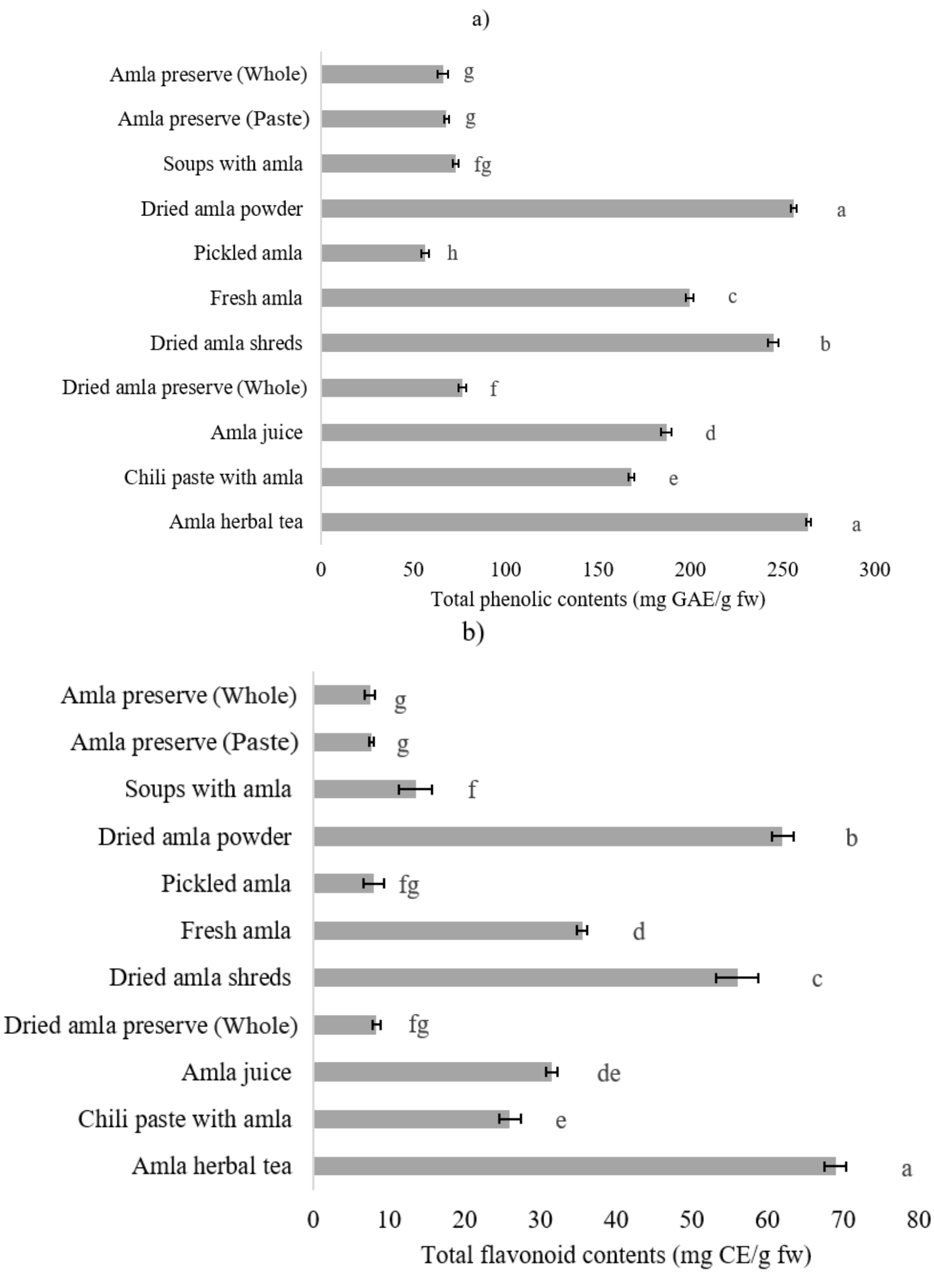


Figure 3. Ascorbic acid contents of the fresh amla and their dishes/Products.

The ascorbic acid degradation kinetics in amla during cooking were investigated and they followed first-order reaction kinetics, where the rate constant increased with an increase in temperature (Nisha, Singhal, & Pandit, 2004). Hence, if possible, processing at low temperatures is recommended, though this is unavoidable in some cases. Pickling and preserves lose ascorbic acid in several steps, starting from blanching and during the processing in which brine or syrup solutions are used. The large osmotic gradient between the solutions and the amla fruits promoted leaching of water-soluble components, including ascorbic acid, out of the fruit (Yalim & Özdemır, 2003). Exposure to oxygen and light during long processing times as well as during storage could also elevate the loss of ascorbic acid.

3.3. Antioxidant Properties

A total of 10 amla dishes/products were selected for determination of antioxidant properties in comparison with fresh amla. TPC, TFC, FRAP and DPPH radical scavenging activity (IC_{50}) of the amla dishes/products as well as fresh amla are shown in Figure 4; a) TPC, b) TFC, c) DPPH and d) FRAP.



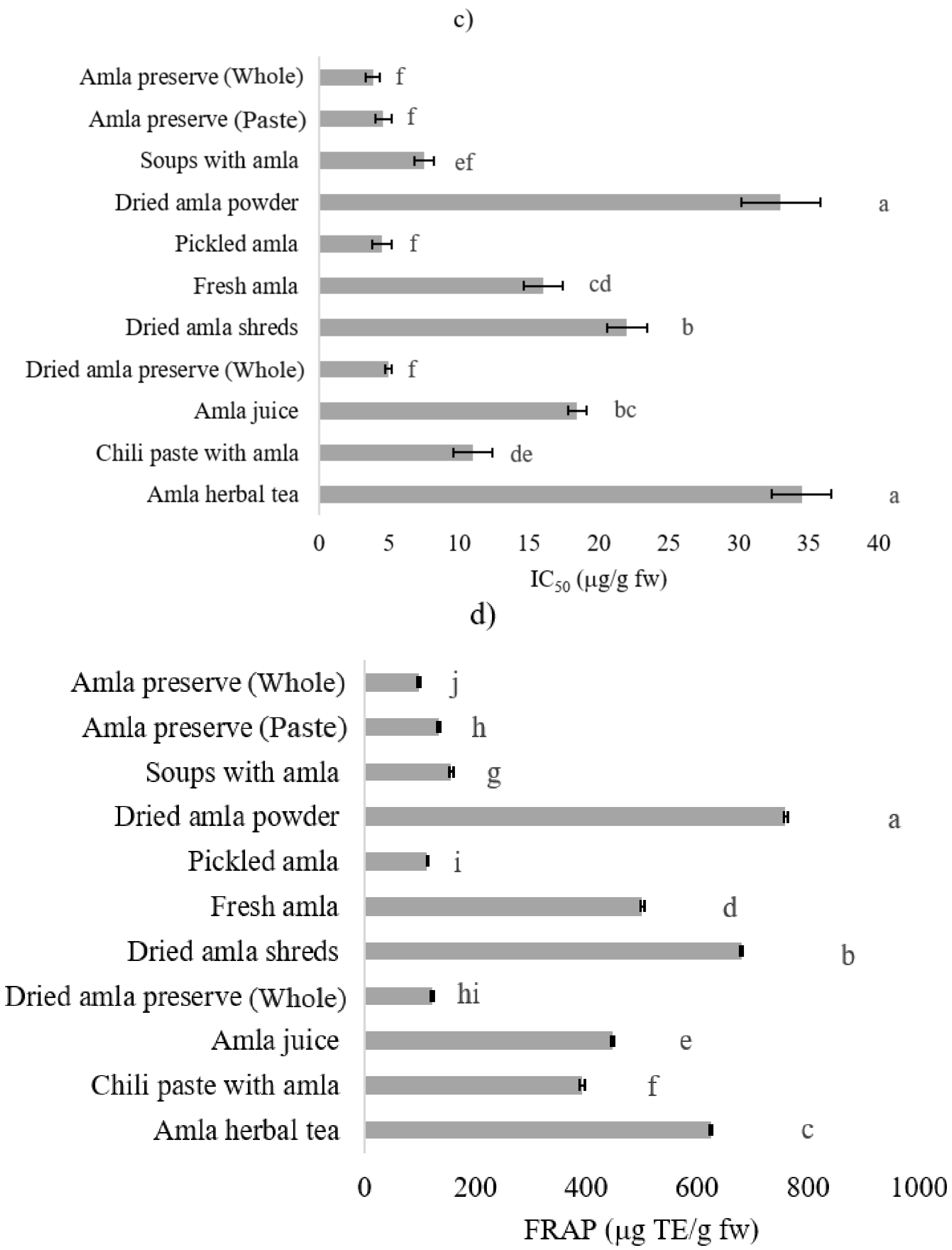


Figure 4. Antioxidant properties of the fresh amla and their dishes/Products; a) Total phenolic contents, b) Total flavonoid contents, c) DPPH (IC50), and d) FRAP.

As mentioned earlier, fresh amla is an excellent source of various phytochemicals (Tewari et al., 2019) which are responsible for their medicinal and therapeutic properties (Muzaffar et al., 2022). Though, direct consumption of amla is limited due to its high acidity and astringent taste. Thus, it is processed into a variety of products, but such processing methods affect the antioxidant activities of the processed amla. These effects varied depending on processing conditions and product types. Processing of amla to juice slightly decreased antioxidant activities, as evidenced by decreased TPC, TFC, FRAP, and DPPH radical scavenging activity. Thai foods that used amla as an ingredient exhibited less antioxidant activity than fresh amla. Notably, other ingredients in the foods also affected antioxidant activity. Due to its concentrated form and the presence of many phytochemicals, chili paste that contained amla showed a high level of antioxidants. This contrasts with soups that undergo dilution by the addition of water.

The use of high salt and sugar amounts in pickling and preserved amlas significantly reduced antioxidant activities. This finding is in line with previous reports (Karpagavalli, Amutha, Padmini, Palanisamy, & Chandrakumar, 2014; Puranik, Mishra, Yadav, & Rai, 2012). Notably, both fresh and processed amlas contained considerable amounts of antioxidant components, although their capacities varied. Processing methods of the pickles and preserves may cause low antioxidant components and antioxidant activity in the products as compared to the fresh fruits (Nurul & Asmah, 2012). It has been reported that antioxidant retention was higher in pickles than sweet preserve (Divya, Jamuna, & Jyothi, 2016) however, this study found similar retention. This is understandable as various factors were involved, including plant sources and processing conditions, as well as different antioxidant activity assays being employed.

This study highlights the increased antioxidant activities of both dried amla and amla herbal tea, which includes both dried and ground amla powder. As compared to fresh fruits, polyphenolic content and antioxidant activity of dried fruits are expected to be high due to their low moisture content and concentrated phytochemicals (Reddy, Sreeramulu, & Raghunath, 2010) as evidenced in the dried amla products in this study. Apart from the concentration of polyphenolics during drying, the antioxidant capacity may be elevated by the formation of chemical derivatives with superior antioxidant activity or compounds with pro-oxidant activity (Yilmaz & Toledo, 2005). However, extreme drying process could lead to losses in total polyphenolic compounds and changes in ratios of free to total polyphenolics. As such, the net antioxidant activity reflects cumulative effects of polyphenolic losses and production of chemical derivatives with superior antioxidant activity (Bennett et al., 2011).

The majority of prior research in scientific literature concerning the antioxidant content of fruits and vegetables has demonstrated that food processing reduces the antioxidant content of processed foods. This is consistent with the general perception of consumers. Nevertheless, a number of scholarly articles have recently suggested that the assessment of the nutritional value of processed fruits and vegetables should encompass not only the vitamin C content but also the activity of additional antioxidant phytochemicals (Nayak, Liu, & Tang, 2015). Thermal processing enhanced antioxidant activities in some products (Nayak et al., 2015; Panyayong & Srikaeo, 2022). This applied to dried amla and ground dried amla powder used as the main ingredient in amla herbal tea, as evidenced in this study.

4. CONCLUSION

There is no doubt that amla possesses a rich source of various phytochemicals, but its utilization as food has not yet been emphasized. This study explored the use of amla as a food in Thailand. Amla fruits serve as a functional ingredient in some Thai recipes, such as chili paste, soups, and salads. Fresh amla contains considerably high ascorbic acid concentrations, but heat treatment resulted in a marginal reduction of ascorbic acid. Processing techniques can have both positive and negative impacts on the antioxidant properties of amla dishes and products. Most processing methods, such as juice pasteurization, salt pickling, and sugar preservation, reduce antioxidant capacity. However, drying amla removes moisture and thus concentrates phytochemicals, resulting in enhanced antioxidant capacity. The pharmaceutical potentials of amla have been well recognized, and this study supports the utilization of amla as a food in which one can still expect its phytochemical profile.

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