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Review Article

Medicinal Properties and Food Applications of *Malpighia emarginata* (acerola cherry)

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Abstract

Malpighia emarginata (acerola cherry) can be found growing throughout the Caribbean and other tropical regions. Also known as Barbados cherry or West Indian cherry, the fruit is a rich source of ascorbic acid, flavonoids, anthocyanins, and carotenoids, which contributes to its high antioxidant capacity. Locally the fruit is processed into a refreshing beverage. It may also be dehydrated and fermented. Waste generated during processing has been utilized in the manufacture of bagasse flour. The physiological and biochemical changes occurring as the fruit matures were also explored.

Keywords

Malpighia emarginata; Cherry; Bioactives; Food Applications

Introduction

Malpighia emarginata, also known as Acerola cherry, Barbados cherry and West Indian cherry, is found in the Caribbean and other regions such as the tropical areas of America, Brazil and India.[1] It belongs to the class Magnoliopsida, order Malpighiales, family Malpighiaceae and the genus *Malpighia* (Malpighiaceae) which consists of approximately 130 species and includes *Malpighia punicifolia*, *Malpighia emarginata*, *Malpighia glabra* and *Malpighia umbellata*.[2] The plant, an evergreen shrub, ranges in diameter from 2 m to 4 m and is well suited for growth at 26 ℃, but also grows at temperatures as low as 0 ℃.[2]

The plant contains small leaves with shapes ranging from oval to elliptical. The adaxial surface is dark green in colour and shiny while the ab-axial surface has a light green colour.[2] The leaves range in size from 1.2 cm to 6.0 cm in width and 2.5 cm to 9.0 cm in length.[2] Flowers of the plant contain both male and female reproductive organs but is unable to self-fertilise requiring external factors for pollination to occur.[2] Fruits can be produced throughout the year. Yields are however dependent on the extent to which effective pollination has occurred.[2]

The fruit of the acerola plant is a drupe attaining full maturity 3 to 4 weeks after flowering (Figure 1). It ranges in size from 1-4 cm in diameter and weighs between 2 to 15 g.[1] Within the fruit is a single seed (estimated to be 35 mm in diameter) which is surrounded by an endocarp with three lobes.[2] The fruit also has a thin epicarp and a pulp region known as the mesocarp.[2] When combined, the epicarp and mesocarp account for 70 to 80% of the weight of the fruit.[2]

Figure 1: *Malpighia emarginata* (acerola cherry)

Changes occurring during fruit maturation

As the fruit matures it undergoes various physiological changes. Immature fruits are green, changing to red upon full maturity. In the intermediary stage the fruit is yellow or orange red in colour (Figure 2). During maturation the levels of anthocyanins and beta carotene content increases while the concentration of ascorbic acid declines gradually.[3] Chlorophyll content and fruit acidity also decreases as the fruit matures while the concentration of reducing sugars increases.[4]

Figure 2: Acerola cherries at various stages of maturity

Ripening of the fruit brings about changes in gene expression.[5] In a study conducted by Xu *et al.* (2022) it was observed that during ripening 3470 differentially expressed genes were upregulated whereas 4240 differentially expressed genes were downregulated.[5] Differentially expressed genes demonstrate a statistically significant change in expression levels when subjected to two experimental conditions.[6] The differentially expressed genes impacted include those responsible for lipid, saccharide, vitamin, carotenoid, flavonoid and amino acid metabolism.[5]

Four chalcone synthase genes involved in the ripening of the fruit were identified.[5] Additionally, one chalcone isomerase gene, four flavanone 3-hydroxylase genes, one dihydroflavonol 4-reductase gene, two anthocyanin synthase genes as well as other genes coding for enzymes relating to the flavonoid biosynthesis pathway were detected.[5] Chalcone synthase is a member of the polyketide synthase family of plant enzymes and is an important enzyme in several biochemical pathways such as the flavonoid and isoflavonoid pathways.[7] The phenylpropanoid and polyketide pathways are responsible for the production of flavonoids. In this pathway, one molecule of CoA-ester from cinnamic acid or its derivatives, (for example, coumaric or ferulic acid), is condensed with three molecules of malonyl-CoA with chalcone synthase as the enzyme to form a naringenin chalcone.[7] The enzyme chalcone flavanone isomerase then converts the naringenin chalcone to flavanone through isomerisation.[7] Several different enzymes are involved in synthesizing flavonoids. Dihydroflavonols are formed from flavanones by the action of flavanone 3-hydroxylase after which they are reduced to flavan-3,4-diols, also known as leucoanthocyanins, through the action of the enzyme dihydroflavonol reductase.[7] Anthocyanidin synthase then converts the leuco-anthocyanins to anthocyanins.[7]

In the same study, sixty-seven ascorbate and aldarate genes were identified of which 40 genes were down regulated and 27 genes were up regulated during the ripening of the acerola cherry fruit.[5] The Smirnoff-Wheeler pathway is responsible for the production of ascorbic acid in acerola cherry. One important enzyme in the process is GDP-D-mannose pyrophosphorylase (GMP) which catalyses the production of GDP-d-mannose.[8] GMP mRNA from the species *M. glabra* tends to be in high concentration during the initial stages of ripening and decreases once maturation occurs.[8] GMP is an important enzyme for the synthesis of ascorbic acid. Its mutation can result in limitations to the synthesis

of ascorbic acid.[9] Additionally, a mutation can be lethal to the plant as the enzyme plays a role in the production of structural carbohydrate found in the cell wall and contributes to cell division in higher plants.[9]

Ascorbic acid composition

Acerola cherry is a rich source of ascorbic acid.[10-11] It also contains several other nutrients such as thiamine, riboflavin, niacin, retinol, folate, pyridoxine, glucose, fructose, malic acid, iron, calcium, phosphorous, potassium and fibre.[1] Ascorbic acid is an important nutrient due to its role in collagen, neurotransmitter and carnitine formation.[4] It is also utilised for the synthesis of catecholamines and corticoids.[4] Ascorbic acid ensures that tissues are synthesised and maintained and that the bones and skin are properly formed.[4] Unlike plants and animals, it is an essential vitamin for humans which needs to be included in the diet. Humans lack the l-gulono-1,4,-lactone oxidase enzyme used in the final stage of ascorbic acid synthesis.[1] It has been hypothesized that the daily consumption of three acerola cherries is enough to meet the recommended dietary allowances for ascorbic acid for adults.[1] Ascorbic acid is very sensitive to oxygen and can easily undergo oxidation.[4] The vitamin can also be easily destroyed if the fruit is not properly stored, exposed to high temperatures and low relative humidity.[4] The destruction of ascorbic acid in fruits may also be due to injury sustained during cold storage or physical injury during handling.[4]

Medicinal properties of acerola cherries

Acerola cherries contain phytochemicals such as carotenoids, alkaloids, phenolics, anthocyanins, flavonoids, and ascorbic acid.[12] Polyphenols possess the ability to prevent oxidative stress from occurring as well as inhibit α-amylase and sucrase in the intestine.[13] The fruit also contains pectin which may have the ability to prevent or treat illnesses such as atherosclerosis and obesity.[14] Ascorbic acid is thought to be a possible ally in the fight against obesity.[15] The excess consumption of sugar and fat generally leads to an increase in the production of Reactive Oxygen Species (ROS) in the body.[15] These ROS when found in concentrations higher than that of the antioxidants in the cells, will cause oxidative stress resulting in oxidative damage to body organs, degeneration of proteins, carbohydrates, enzymes, deoxyribonucleic acid and lipids.[15] Acerola cherries contain polyphenols which are able to act as ROS scavengers thus reducing or eliminating the potential for oxidative stress to occur.[15]

It has been theorized that obesity may be controlled by inhibiting the activity of *α*-amylase, *α*-glycosidase and lipase.[16] The first two enzymes participate in the breakdown of carbohydrates into monosaccharides thus allowing for their absorption by the intestinal cells.[16] Lipase is also a key enzyme in the breakdown of triacylglycerols and their subsequent absorption.[16] Phenolic compounds have been considered to be key players in the fight against obesity.[16] Some phenolic compounds, such as tannins, have the ability to bind to carbohydrates, proteins and digestive enzymes.[16] In so doing they form stable complexes preventing absorption from occurring.[16] The phenolic compounds present in methanolic extracts of acerola bagasse flour was determined.[16] The phenolic compounds identified were catechin, epigallocatechin gallate, gallic acid, syringic acid, quercetin, *p*-coumaric acid and epicatechin.[16] The acerola bagasse flour has the ability to inhibit *α*-amylase activity.[16] This may have medicinal application as the inhibition of *α*-amylase may work to decrease or prevent the spike in glycemic levels that usually occurs when carbohydrate is consumed.[16] The acerola bagasse flour possessed the ability to inhibit *α*-glycosidase activity.[16] Hanamura *et al.* (2006) also demonstrated that a crude polyphenolic fraction from acerola cherry exhibited anti-hyperglycemic properties.[17] Faster gastric emptying is usually found in obese persons.[18] The inhibition of *α*-glucosidase will lead to a longer gastric emptying period, a feeling of being full and weight loss.[16] The acerola bagasse flour extract, when exposed to a simulated gastric fluid, had the ability to inhibit both enzymes.[16]

Fractionation of acerola extracts by column chromatography revealed that the extracts exhibited cytotoxic activity against tumour cells.[19] Some hexane fractions were found to possess multidrug resistance reversal activity.[19] Multidrug resistance is due to the different defence mechanisms that occur during or after the treatment of cancer.[20] The hexane fractions had the ability to inhibit the P-glycoprotein which acts as a multidrug transporter.[19] The P-glycoprotein gives cancer cells the ability to pump out drugs thus reducing the cytotoxicity of the drugs.[20] Its inhibition suggests that acerola cherry has the potential to be used in chemotherapy treatment and the possible prevention of cancer.[19]

Processing of acerola cherry

Acerola cherries have been used in the manufacture of fruit juices, jams, jellies, puree, juice concentrates, wines, supplements, yoghurt, and ice cream.[21] Various processing methods such as heating, drying, sonication, concentration, ultrasound,

filtration, and encapsulation have been used in the manufacture of different products from the fruit.[22]

Use as an edible film

Purees of the acerola cherry combined with alginate and corn syrup as the plasticizer, was used to produce an edible film.[23] Cellulose whiskers were added as a reinforcement for the film. This film was considered adequate for use as an edible coating for fruits and vegetables which would lead to shelf life extension.[23] Edible coatings are used in fruits such as mangoes and apples.[24-25] When tested with acerola cherries, the cherries better retained their ascorbic acid content and delayed ripening rate.[23]

Acerola cherry juice

In a study conducted by Matta *et al.* (2004), microfiltration and reverse osmosis were used to clarify and concentrate the juice from the acerola cherry.[26] The fruits were pulped, subjected to enzymatic hydrolysis, clarified by microfiltration then concentrated by reverse osmosis. The results showed a 4.2-fold increase in the amount of ascorbic acid in the concentrated juice. Microfiltration also reduced the microbial load of the product.[26] Pagani *et al.* (2011) also demonstrated that acerola cherry fruit juice can be concentrated via the combination of several membrane processes, namely microfiltration, reverse osmosis, and osmotic evaporation techniques.[27] In this study the levels of ascorbic acid within the concentrated product increased 2.21 times the pre-concentrated product.[27] Additionally, the levels of antioxidant and anthocyanin in the concentrated product increased by 2.28 and 1.41 respectively as compared to the pre-concentrated product.[27] The antioxidant activity and ascorbic acid content of the juice remained unchanged even after processing.[27] There was however a noticeable decline in the levels of anthocyanin after processing which was attributed to the instability of the compound.[27] This processing technique can be considered as a possible replacement for vacuum evaporation which is the traditional method currently utilized.[27]

Sonication has also been utilized to enhance the extraction of acerola cherry juice. Dang and Le (2012) demonstrated that when utilized in conjunction with the enzyme pectinase, 9.2% more juice was extracted as compared to the use of traditional enzymatic treatment alone.[28] The concentration of the enzyme required as well as the proteolytic time was reduced by 27.2% and 24.1% respectively. Juice extracted by this method had more free amino nitrogen, sugars and phenolic compounds as compared to juice that had only undergone treatment with proteolytic enzymes.[28]

Dehydration of acerola cherry

Due to its high ascorbic acid content, attempts have been made to extract and convert the vitamin from the fruit into a powdered form. Additionally, work has been done to convert the fruit itself into powdered form.[29] Microwave drying, hot air drying, cryogenic freezing and vacuum drying have been utilized to dry the fruit.[30] Microwave drying had the shortest drying time.[30] Vacuum drying resulted in products with a greater retention of ascorbic acid.[30] Cryogenic freezing gave better results as compared to traditional freezing and the use of nitrogen vapour.[30] In a study conducted by Franco et al. (2022), it was found that acerola cherry powder was a good natural substitute for ascorbic acid powder in the baking industry.[29] It provided benefits such as increasing the resistance of the dough to deformation without reducing its elasticity.[29] It also offered additional benefits such as a reduction in the hardness of white and whole wheat breads, and maintaining good crust and crumb colour.[29]

Fermentation

Vinegar was produced from acerola cherry juice using *Saccharomyces cerevisiae* and *Acetobacter senegalensis*.[30] After eight days of fermentation at 28-32 °C, the vinegar had an acid content of 6.99%.[30] Acerola cherry has also been utilized in the production of alcoholic beverages such as cider and wine.[30] *S. cerevisiae* was the yeast of choice for the manufacture of acerola cherry wine.[31] The wine exhibited good sensorial properties. Ice cream was also made from acerola cherry via fermentation with *Bifidobacterium longum, Streptococcus thermophilus, Bifidobacterium lactis* and *Lactobacillus delbrueckii* spp. *Bulgaricus*.[32] *Lactobacillus* and *Bifidobacterium* are commonly used as probiotics during the manufacture of dairy products.[32]

Acerola seed by-products

During the processing of the acerola fruit, a large quantity of waste is generated in the form of seed and bagasse.[33] Bagasse refers to the peel and remaining pulp.[33] This waste can be converted into acerola seed flour and acerola bagasse flour.[33] A study conducted by Marques et al. (2013), revealed that both flours contain a large amount of dietary fibres, phenolic compounds and minerals.[33] Acerola seed flour contained more insoluble fibres whereas acerola bagasse flour contained more soluble fibres. This was further demonstrated by Monteiro et al. (2020) who determined that acerola bagasse flour contained dietary fibres (77%) as well as antioxidants such as carotenoids and anthocyanins.[34]

Marques et al. (2013) also concluded that the acerola seed flour was able to absorb both oil and water.[33] It however showed a higher level of oil absorption than water absorption.[33] The flour contains more hydrophobic groups allowing for bonding with the oil.[33] The acerola bagasse flour also had the ability to absorb oil and water, however, unlike the acerola seed flour, it demonstrated a higher level of water absorption than oil absorption.[33] It was theorised that this may be as a result of the high percentage of soluble fibres present in this flour.[33] It was concluded that acerola bagasse flour could be used in the production of meat and bakery products because it allows for more water to be added to the dough which will have a positive impact on the dough handling properties.[33-34]

Acerola bagasse flour also exhibits antimicrobial activity.[35] *Pseudomonas aeruginosa*, *Listeria monocytogenes*, *Salmonella cholerasuis* and *Escherichia coli* were all exposed to acerola bagasse flour extract.[35] Zones of inhibition were formed for each bacterium indicating that the flour possessed antibacterial activity.[35] The flour may therefore be considered for potential use as an antibacterial agent in the food industry.[35]

Conclusions

Acerola cherry is rich in antioxidants which is beneficial to human health. The cherries have been utilized in the production of powders, fermented products, edible films and flour. Processing methods include drying, concentration, filtration, sonication, and fermentation. Waste generated from processing of the fruit can be converted into value added products such as acerola flour which exhibits antimicrobial properties due to its phenolic content.

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Conflict of interest

The authors declare that there are no conflicts of interest to the present work.

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