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Fe, Zn, Ca and K Hydroxides Interactions with Flavonoids, Alkaloids, Tannins and Steroids, and their Effect on the Binding Capacity of Cellulose within the Cuticle of the Solanaceae Family Fruits: A Review

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Abstract: ***The chemical composition and concentrations of Zn, Fe, Na, K, and Ca hydroxides vary in the epidermis of potato, brinjal, tomato, and golden berry (members of the Solanaceae family), with about 17% zinc, 34% calcium, and 55% iron. Proteome (enriched protein) 63%, involved in plant defence at the epidermis. Phenolic compounds such as glycoalkaloids, flavonoids, and tannins, along with 7.7% ash, 3.4% pectin, 14.7% protein, 2.2% cellulose, 66.8% starch, 0.9% of reducing sugars and 1.4% of total soluble sugars. This study aimed to determine the decomposition rate, antioxidant activity, and total phenolic content (TPC). Some crucial points were reviewed within the cuticle layers for the decomposition rates of cellulose by metallic hydroxides. Lower levels of tannin and higher levels of alkaloids and anthocyanins decrease decomposition rates in golden berry, but higher levels of glycoalkaloids in potato increase decomposition rates.***

Keywords: Minerals, potassium, tuber, membrane barrier, total phenolic content (TPC)

1. Introduction

Fe, Cu, Mn, and Zn are required micronutrients for plant growth, development, and reproduction (Maathuis and Diatloff 2013; Riyam et al. 2022). These transition metals Fe, Cu and Mn, are redox active (Maathuis and Diatloff 2013). Ca and K are the main ion transporters. They participate as important cofactors in a broad range of biological processes, such as photosynthesis, chlorophyll biosynthesis, respiration, electron transport chain and/or carbohydrate and lipid metabolism (Vatansever et al. 2017;Kobayashi and Nishizawa 2012;Mir et al. 2021;Schmidt and Husted 2019). It performs structural and/or catalytic functions in a variety of physiological functions such as carbon dioxide fixation, protein synthesis and ion exchange (Saboor et al. 2021). The proteome was enriched in proteins whose activity is characteristic of actively dividing tissues, such as cell proliferation in C1 metabolism and the oxidative respiratory chain. Proteins (63%) are involved in plant defence responses to biotic and abiotic stresses. Five peroxidase isozymes with flavonoids, alkaloids, tannins, **and steroids** that may play a role in suberization processes. *Solanum melongena* var. esculentum (Brinjal), Solanum tubrosum (potato), Solanum lycopersicum (tomato) and Physalis peruviana (golden berry) are economic plant belonging to the family Solanaceae, mostly herbaceous plants, and the fruit is a berry are grown mainly for food and medicinal purposes (Igwe *et al.,* 2003). Phytochemical studies have yielded flavonoids, alkaloids, tannins and steroids; medicinal properties of the plants are derived from their chemical constituents. The chemical detection of extracts showed that they were rich in flavonoids with antioxidant activities. A study proposed a more physiologically relevant explanation in the phenolic-linked antioxidant activity and alpha-glucosidase inhibitory potential of eggplant, which can reduce hyperglycemia-induced pathogenesis. The plant's antioxidant property is due to the flavonoids. The terpenes (steroids) make it useful for bronchitis. The analgesic property is due to the alkaloids. Besides having many traditional uses, *Solanum melongena* is reported to exhibit many important chemical compositions of the tomato fruit epidermis, specifically the cuticle, is primarily composed of cutin, waxes, and polysaccharides like cellulose and pectin. Additionally, the cuticle contains phenolic acids like p-coumaric acid and p-hydroxybenzoic acid, as well as flavonoids. The distribution and type of these compounds vary within the cuticle layers, with some being more concentrated in the outermost layers for UV protection. Cutin, the main structural component of the cuticle, provides mechanical and thermal protection to the fruit. Waxes on the outer surface of the cuticle they help in water resistance and protection. Polysaccharides in the inner layers include cellulose and pectin, which contribute to the cell wall structure. Phenolic Acid in the outermost layers acts as a UV-B shield. Flavonoids, during ripening and contribute to the overall structural and functional properties.

The potato epidermis, or periderm, is composed of suberin, a complex polymer, along with other chemical components like

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phenolic compounds, glycoalkaloids and various fatty acids were composed of suberized phellem cells (Reeve et al., 1969). Suberin's monomers include glycerol, long-chain α, ω-diacids, ω-hydroxyacids, alkanoic acids, and alkan-1-ols. Other components include phenolic compounds like chlorogenic acid and its derivatives, which contribute to antioxidant and anti-inflammatory properties, and glycoalkaloids like solanine and chaconine, which exhibit antimicrobial activity. The potato epidermis also contains nonpolar metabolites like nonpolar waxes, saturated and unsaturated fatty acids, saturated dicarboxylic acids, monoacylglycerols, 1-alkanols, n-alkanes, sterols, and polyphenolics, and polar metabolites like quinic acid, phenolic amines, phenolic acids, and flavonoid glycoalkaloids. The fractions obtained by this give 7.7% ash, 3.4% pectin, 14.7% protein, 2.2% cellulose, 66.8% starch, 0.9% of reducing sugars and 1.4% of total soluble sugars. Toxic steroidal glycoalkaloid (Krits et al., 2007) act as a ‘battery’ of defence components, and further expands the concept of its protective role.

A protective layer composed primarily of cutin17, a polymer of hydroxy and epoxy fatty acids and fatty alcohols, along with varying amounts of phenolic compounds. The cuticle acts as a barrier against water loss, regulates gas exchange, and protects against pathogens and UV light. chlorogenic acid, naringin, resveratrol, and quercetin, which are known for their antioxidant properties and potential[16/17] health. There are some points within the cuticle layers which is primarily composed of cutin, waxes, and polysaccharides like cellulose and pectin contain phenolic acids like p-coumaric acid and p-hydroxybenzoic acid, as well as flavonoids reaction rates to help avoid decomposition. In this review, we want to establish a relation between metallic hydroxide diffusion with the cuticle to hinder the decomposition rate at the surface of fruits of the Solanaceae family.

2. Literature

Total phenolic content (TPC) (Kriengsak et al. 2006)[2] and FRAP values of brinjal extracts varied from 48.67±0.27 to 61.11±0.26 mg GAE/100 g fresh weight and 4.19±0.11 to 7.46±0.26 mmol of FeS04/g fresh weight, respectively(K. M. Somawati et.al.)[1] Brinjal with dark purple lines (S3) showed the highest antioxidant activity as quantified by FRAP and TPC while brinjal with light purple lines (S2) showed the least. Purple brinjal with no lines (S1) displayed the highest DPPH radical scavenging activity with an IC50 value of 3.51±0.62 mg/ml, while S3 demonstrated the strongest total antioxidant activity as measured by ABTS assay with an inhibition of 40.45%. In the FTC assay, the percent inhibition of linoleic acid oxidation ranged from 15.11±1.31 to 26.74±2.85. The total phenolic content (TPC) of the extracts was determined calorimetrically as Addition of NAA at the concentration of 1 mg/l, and 0.5 mg/l of BA led to the higher weight of callus (978 mg) (Ghoson S. Saleh, 2015)[4], . The chemical detection showed the presence of alkaloids, flavonoids, tannins, steroids, and glycosides in callus extract as compared to its contents in root and fruit extracts. Heavy metals like lead, cadmium, or mercury can accumulate on the cuticle and potentially penetrate the plant tissue, affecting its growth and health. Some metals may also interact with the cuticle by altering its permeability or causing oxidative stress, which can damage the plant. (Shrivastava et al., 2012; Srivastava and Sanja, 2011)[4]. Selective interactions of chiral amino acids and with different hydrophilicities/ hydrophobicities exhibit different chiral selectivity[18] preferences in the selectivity preference with D-isomers, and stereochemical matching with metallic hydroxides. These different chiral selectivities resulting from the amino acid hydrophilicity/hydrophobicity reduce the decomposition process.

Data in Physalis peruviana fruit contains phenols (125.4mg/g DW), flavonoids (6.39mg/g DW), tannins (14.8mg/g DW), alkaloids (3.37 g/100g DW), anthocyanins (6.68µg/100g FW) and carotenoids (1.53mg/100g FW). The antioxidant capacity and total phenolic content in fruit of Physalis peruviana were 57.67% and 145.22mg GAE/100g, respectively(Hossam S et.al. 2019)[5]. Physalis peruviana have high nutritional value because of its high contents of vitamins, minerals and antioxidants. These plants also have potential medicinal properties like antibacterial, anti-inflammatory, and antioxidant properties (Dimayuga et al. 1998; Yen et al. 2010)[6]. The presence of the secondary metabolites in Physalis peruviana has contributed to its medicinal value as well as physiological activity (Sofowara 1993). Carotenoids are responsible for the orange colour in the fruit of P. peruviana L. (Ramadan and Morsel 2003). β-carotene is very important in the prevention of certain human diseases such as cancer. The reason that carotenoids have antioxidant activity is that they deactivate free radicals generated in tissues (Castro et al. 2008)[7]. Suberin, a complex polymer, along with other chemical components like phenolic compounds, glycoalkaloids and various fatty acids in the epidermis of potato, are composed of suberized phellem cells (Reeve et al., 1969) and includes glycerol, long-chain α,ω-diacids, ω-hydroxyacids, alkanoic acids, and alkan-1-ols. Other components include phenolic compounds like chlorogenic acid and its derivatives, which contribute to antioxidant and anti-inflammatory properties, and glycoalkaloids like solanine and chaconine, which exhibit antimicrobial activity. Alkanols, n-alkanes, sterols, and polyphenolics, and polar metabolites like quinic acid, phenolic amines, phenolic acids, flavonoid glycoalkaloids and toxic steroidal glycoalkaloid (Krits et al., 2007) act as a ‘battery’ of defence components, and further expand the concept of its protective role.

3. Experimental

Materials and Methods: The concentrations 1 mg/l and 0.5 mg/l for chemical detection showed the presence of alkaloids, flavonoids, tannins, steroids, and glycosides in extracts of the root and fruit. Fruits contain arginine, aspartic acid, histidine, 5-HT, delphinidine 3 bioside (nasunin), oxalic acid, solasodine, ascorbic acid, tryptophan, etc (Rai and Pandey, 1997). The pH 5.8, agar (0.8%), then sterilized by autoclaving at 121 C for 20 min at -20 °C. Proteins were extracted in 2.5 ml ice-cold buffer containing 0.1 M TRIS-HCl pH 8, 5% (w/v) sucrose, 2% (w/v) SDS, 50 mM dithiothreitol (DTT), and a mixture of protease inhibitors (Complete_ tablets, Roche, Germany). All the chemicals and solvents used by researchers of analytical research grade were used during their research.

4. Result and Discussion

The influence of tannin and iron ions on the water resistance minimizes the reduction of the contact area. Two phases in the absorption behaviour in two-phase can be defined: the ability of the structural network, which is deformed under stress and the nature of interactions [29], is of the order of 10% long-range interactions at the critical strain ≈ 0.19%. The low Fe content in potato skin (±4.1 mg/100 g) and the suboptimal extraction conditions, including time, temperature, solvent ratio, and stirring. In addition, Fe is generally bound as a complex with tannins or phenolic compounds, which may not be completely broken down in 70% ethanol. Toxins fascinate and restrict their effects on a particular target cell with specific chemical reactions, which have been better understood in modern knowledge of quality cloning, protein arrangements, three-dimensional crystallographic structures, and poison refinement. Exotoxins and endotoxins are the two main kinds of toxins that can be delivered by both Gram-positive and Gram-negative microbes, and protein functions, including phospholipase, adenylate cyclase, metalloprotease, protease, ADP-ribosylation, and deoxyribonuclease, were present in exotoxins, which are produced by a range of bacteria, including Clostridium, Botulinum, and Diphtheria poisons. The majority of these microscopic organisms obstruct their harmful effects on the contaminated host by producing toxins. It is still unclear exactly how the bacterial exotoxins function; however, they cross the membrane barrier, enter cells, or move across the membrane barrier, and then secrete the toxin directly.

The main components that affect microbes are proteins like lysozyme, lactoferrin, and secretory IgA, lacto- and myeloperoxidase, histamines, and agglutinins, which have direct antimicrobial actions. Mucins also play a key role by binding and aggregating microorganisms, as well as providing lubrication and a food source. Additionally, electrolytes such as phosphates and bicarbonates, along with enzymes, help control the pH, and some, like amylase, can be bound by microbes. The binding capacity of Sodium, potassium, calcium, and chloride and minerals which are present and their binding capacity resists penetration of microbes on the surfaces. (Fe), Affects eggplant growth and composition, Calcium (Ca) influences antioxidant systems, which can indirectly affect the fruit ages. calcium (Ca) can influence the eggplant's internal biochemistry. In studies, calcium treatment has been shown to improve the fruit's antioxidant capabilities by increasing levels of enzymes like catalase and superoxide dismutase, and also ascorbic acid (a key non-enzymatic antioxidant)

Table 1: Quantitative phytochemical analysis of fruit constituents values in the Solanaceae family

In the ethanolic extract, Total	Physalis peruviana Golden berry	Solanum lycopersicum Tometo	Solanum tubrosum (potato	Solanum esculentum (Brinjal
Phenols (mg/g DW	125.4	0.35- 997.45	36.24	7.36
Favonoids(mg Quercetin/g DW)	6.39 ± 0.47	11.0 ±0.94	2.29	7.79
Tannins (mg Tannic acid/g DW)	14.82 ± 0.62	Very Low	Very Low	Not found
Alkaloids (g/100 g DW)	3.365 ± 0.006	0.01628	0.00122	0.01412
Anthocyanins (µg/100g FW)	6.675 ± 0.18	0.25	1.6	0.088
Carotenoids (mg/100 g FW)	1.53 ± 0.06	13.0	0.5-1.0	42.96±0.8

Data in Table 1 shows that the ethanolic extract of *Physalis peruviana,* Solanum lycrsicum, Solanum tubrosum and *Solanum* esculentum fruit contains phenols 125.4mg/g DW, 0.35 to 997.45 mg GAE/g DW, 36.24 and 7.36 g DW. Phenolic concentration was highest in S.lycopersicum but too much variability was shown, and least in S. esculentum. Flavonoid content (6.39mg/g DW), 11.0, 2.29 and 7.79, higher in S. lycrsicum 11.0 and lower in S. tubrosum and brinjal and golden berry have almost the same values. Tannins in golden berry is (14.8mg/g DW), very low quantity in tomato and potato and not available in brinjal. Alkaloids (3.37 g/100g DW) in golden berry were reported to be higher and very low in potato. Anthocyanins (6.68µg/100g FW) are high in golden berry and low in brinjal (0.088). Carotenoids (1.53mg/100g FW) similar topotato(0.5-1.0) but too much higher in brinjal (40.96).

Solanaceae family members having different hydroxyl (-OH) groups, for phenols were 4, flavonoids and carotenoids 1 each, Tannins, alkaloid and tometine having 12, while anthocyanins have 3. Tomatine, anthocyanins and tannins with 12 hydroxyl group are more resistance and reduce the decaying process. Carbon atoms in a ring were reported 2-15 (table 2). Flavonoid (15) and tomatine(9+3R) have higher values and anthocynin has lower by3. Number of benzene and non-benzene ring reported maximum in alkaloid and anthocyanin 3, tomatine 3 non-benzene ring. Pyridine ring is present only in alkaloids and tomatine-1. In β Carotene, hydrocarbons with extensive conjugated double bonds, are generally stable to alkalies under normal conditions and do not undergo direct chemical reactions[9]. Tennis easily reacts due to sufficient hydroxyl groups than tometine, anthocyanin, and least by hydroxyflavinoid (fig. 2). Natural toxins, glycoalkaloids, low levels of these toxins are do not usually pose adverse effects[10] usually[10]. However, rotting may contain high levels of glycoalkaloids and the majority of the toxins are present in the fruits of the Solanaceae family with 12 –OH, 9-C atoms, rings up to 5and 1pyridine ring. The decomposition rate is slower in the golden berry and faster in the potato. Tometine and tennin, due to the higher –OH group (fig.1), may increase the rate of decomposition.

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Table 2: Relation of –OH, C atoms, No. of rings and N- atoms in a ring

In ethanolic extract	No of –OH gp	No. of C atoms	No. of Rings	No. of N -Pyridinering
Phenols	4	7	1	0
Flavonoids	1	15	1	0
Tannins	2-12(3)	7	1	0
Alkaloids	12	9	2-5	1
Anthocyanins	3	3	3	0
Carotenoids	1	7	1	0
A-Tomatine	12	9+3R	0, 3NB	1

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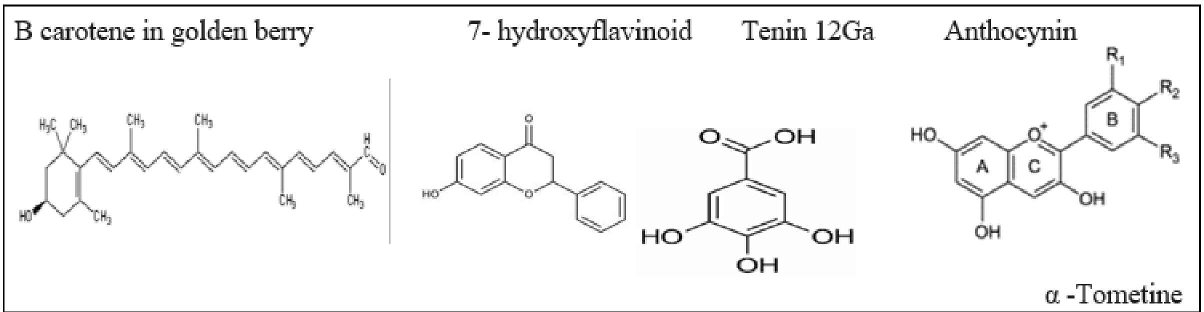

Figure 1: Structures of some important compounds present in epidermis of Solanaceae family members.

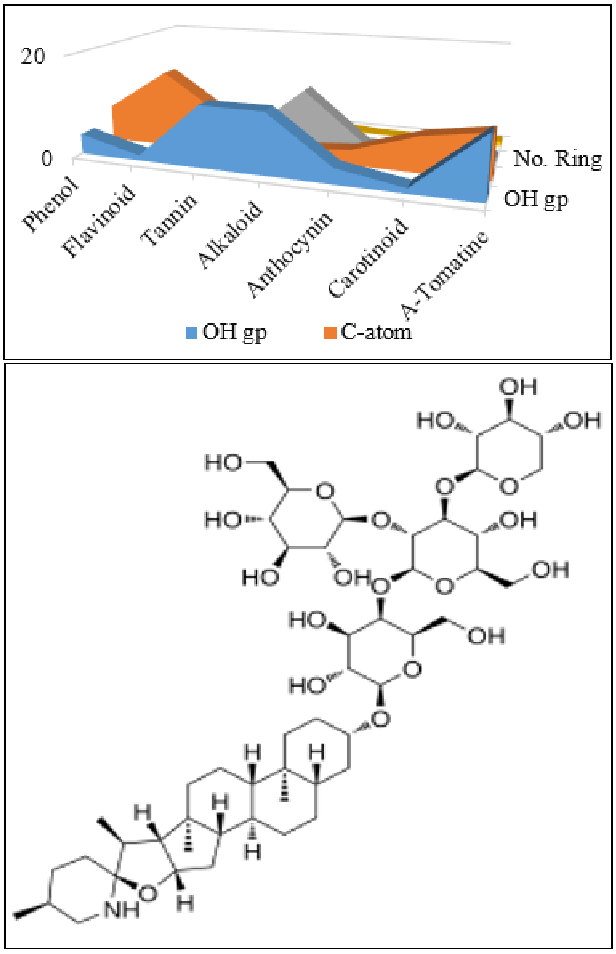

Figure 2: A relation of C-OH group with benzene ring and pyridine ring

In Figure 2, a relation was found that most of the compound found no rings which are unstable while benzene ring compounds are more stable than non benzanoids. Selective interactions of chiral amino acids and with different hydrophilicities/hydrophobicities exhibit different chiral selectivity preferences in the selectivity preference with D-isomers, and stereochemical matching with metallic hydroxides. These different chiral selectivities resulting from the amino acid hydrophilicity/hydrophobicity reduce the decomposition process.

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5. Conclusion

This review reveals a relationship between the chemical composition of the epidermis and metallic hydroxides (Zn, Fe, Na, K, Ca) in some members of the solanaceae family. The concentrations of most minerals were about 17 % to 55 %, proteins were enriched in actively dividing tissues consisting (63%). Proteome, cutin17 and suberin, a complex polymer, along with other chemical components like phenolic compounds, glycoalkaloids, flavonoids, and tannin's along with 7.7% ash, 3.4% pectin, 14.7% protein, 2.2% cellulose, 66.8% starch, 0.9% of reducing sugars and 1.4% of total soluble sugars. Some lacking points within the cuticle layers, which are primarily composed of cutin, waxes, and polysaccharides like cellulose and pectin contains phenolic acids like p-coumaric acid and p-hydroxybenzoic acid, as well as flavonoids reaction rates to avoid decomposition. We have try to establish a relation between metallic hydroxide diffusion with the cuticle to hinder decomposition rate at surface of fruits of solanaceae family. A lower tannin content and higher levels of alkaloids and anthocyanins in golden berry result in slower decomposition rates compared to potato tubers. Carotenoid concentration were higher in brinjal (40.96g/100gDW) and low concentration of anthocyanin (0.088) Solanaceae family members having different hydroxyl (-OH) groups, for phenols were 4, flavonoid and carotenoids 1 each, Tannins, alkaloid and tometine having 12 while anthocyanin have 3. Tomatine, anthocyanins and tannins with 12 hydroxyl group are more resistance and reduce decaying process. Carbon atoms in a ring were reported 2-15. Flavonoid (15) and tomatine (9+3R) have higher values, and anthocyanin has lower values by 3. Number of benzene and non-benzene rings reported: maximum in alkaloid and anthocyanin (3), tomatine (3) non-benzene ring. Pyridine ring present only in alkaloids and tomatine-1. In β Carotene, hydrocarbons with extensive conjugated double bonds are generally stable to alkalies under normal conditions and do not undergo direct chemical reactions. Tennis easily react due to sufficient hydroxyl groups than tometine, anthocynin and least by hydroxy-flavinoid. Natural toxins, glycoalkaloid's low levels of these toxins are do not pose adverse effects usually. However rotting may contain high level of glycoalkaloids and the majority of the toxins are present in the fruits of solanaceae family with 12 –OH, 9-C atoms, benzene rings up to 5 and 1pyridine ring. The decomposition rate is slower in golden berry and faster in potato. Tometine and tennin, due to the higher –OH group, may be responsible for the increased rate of decomposition.

In Context to Nation

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