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Glycoalkaloids in Potato Tubers: A Toxic Element in Consumer's Meal

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With the rise in production and consumption of potato and potato based products, glycoalkaloids (GAs) formation and its toxicity are projected to become a major area of interest for food safety experts and public health organizations. The quality of stored potatoes is significantly influenced by a variety of factors, such as presence of GAs particularly in the form of α-solanine and α-chaconine, as well as the alterations caused on by various post-harvest processing procedures and storage. The potato (*Solanum tuberosum* L.), which is one of the most significant staple crops in India is low in fat as well as an excellent source of carbohydrates, high-quality protein, fiber, and vitamins. As a result, it plays a crucial role in human nutrition. India occupies 2nd position in potato area and production worldwide. According to the report of National Horticulture Board, 2021-22 potato accounting 2208 hectares area with total potato production in India is 53603 MT. This article provides information available on potato GA with a view to developing strategies to control their levels for health benefits.

What are Glycoalkaloids?

GAs is a family of toxic secondary steroidal metabolites produced by plants of solanaceae family. The substantial anti-cholinesterase activity and disruption of cell membranes caused by steroidal GAs makes them toxic. The antibacterial, insecticidal, and fungicidal activities of GAs explain their effectiveness against a variety of insects, pests, and herbivores. However, humans are also affected by the pharmacological and toxicological properties of GAs. GAs are recognized to enhance flavor in small doses (150 mg GAs kg^{-1} fresh weight), but at concentrations above 200 mg kg^{-1} fresh weight, these chemicals may produce a bitter taste. Furthermore, these substances have the potential to be lethal at doses > 280 mg kg^{-1} fresh weight. GAs mostly found in the flowers, eyes, unripe berries, young, highly metabolic leaves, tubers, and peels of the potato plant (Table 1). The tuber's peripheral layers and the parenchyma of the periderm cells contain the highest concentrations of GAs. Potato contain two GAs *i.e.*, *α*-solanine and *α*-chaconine. Because there is a synergistic impact between these two chemicals if both are present in the same tissue, the toxicity is based on the ratio of *α*-solanine to *α*-chaconine. Furthermore the toxicity of *α*-chaconine is significantly higher than *α*-solanine. The GAs *α*-solanine (141 mg/kg) and *α*-chaconine (95 mg/kg) were specifically identified in the potatoes. The current safe limit for GAs content in potatoes is should be than 200mg/kg. Physical damage, sprouting, temperature, and light exposure are some of the post-harvest variables that may enhance the accumulation of GAs when the food is being stored.

Mechanism of GAs Formation

Although greening and the formation of GAs are closely related, chlorophyll, which is tasteless and nontoxic, is also a key component of greening. Studies show that the biosynthesis of GAs and chlorophyll do not share a direct metabolic pathway. Uncertainty exists regarding the biosynthesis of GAs in potatoes. A biosynthetic pathway including cholesterol, a sterol lacking alkylations at the C-24 position in the side chain, is thought to produce solanidine from cycloartenol, a crucial precursor in the synthesis of plant sterols. The glucosylation or galactosylation of solanidine to produce either *α*-chaconine or *α*-solanine is one of the final steps in the synthesis of GAs. Solanidine's galactosylation is probably catalysed by a different enzyme. There is currently no information available on final glycosylation procedures that result in *α*-chaconine and *α*-solanine. However, scholars state that because alkaloids are by-products of the primary metabolism, it would be conceivable to modify the amount of alkaloid production by modifying the primary metabolism.

Reported Effects of GAs on Human Health

The toxicity of GAs in potatoes can result in serious health risks for people, including as neurological diseases and gastrointestinal difficulties. Headaches, vertigo, nausea, vomiting, diarrhea, and stomach pain are some of the milder clinical signs of GAs poisoning. Other neurological symptoms that patients have described include apathy, restlessness, drowsiness, mental confusion, rambling, incoherence, stupor, hallucinations, shaking, and visual problems. According to researches which has been done on laboratory mammals, the relatively quick onset of GAs toxicity symptoms points to gastrointestinal injury as the primary toxic consequence, with neurological disorders emerging as a result. Acetylcholine, a molecule that conducts nerve impulses, is one of the chemicals that GAs interferes with in order to have an impact on the nervous system. Two processes which directly related to the mechanism of toxicity: the rupture of phospholipids in membrane and inhibition of acetyle-cholinesterase, which causes central nervous system depression and the neurological consequences seen after poisoning (hallucinations, convulsions, depression etc).

Table 1. Levels of GAs in various parts of the potato plant

Plant parts	GA concentration (mg kg^{-1} f.w.)
Flowers	2150– 5000
Leaves	230– 1000
Stems	23– 33
Roots	180– 400
Bitter-tasting tubers	250– 800
Whole tuber	10– 150
Skin (2– 3% of tuber)	300– 640
Peel (10– 12% tuber)	150– 1068
Flesh	12– 100
Cortex	125
Pith	Not detectable
Sprout	2000– 7300

Source: Omayio *et al*., 2016. A Review of Occurrence of Glycoalkaloids in Potato and Potato Products. *Current Research in Nutrition and Food Science.*

GAs Determination Techniques

In order to determine the amount of GAs in potatoes, a variety of techniques can be used. These techniques include colorimetric methods, gas chromatography (GC), mass spectrometry (MS), high-pressure liquid chromatography (HPLC), thin-layer chromatography

(TLC), enzyme-linked immunosorbent assay (ELISA), iso-tachyphoresis, and a biosensor-based approach. The most often used technique seems to be HPLC separation with UV detection since it is quick, precise, and reproducible.

Matrix-Assisted Laser Desorption/Ionization Time of Flight Mass Spectrometry

Another alternative is the prospective use of matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS) to quantify potato glycoalkaloids. Tomatine is used as an internal standard in the development of a MALDI-TOF MS technique for the study of α-chaconine and α-solanine. A number of potato cultivars were subjected to quantitative analysis using MALDI-TOF MS and high-performance liquid chromatography which revealed strong correlation between this two techniques. The new MALDI-TOF MS approach offers a very quick analysis, requires minimal sample preparation, and is approriate for routine glycoalkaloid assessment.

Factors Influencing the Formation of GAs in Potatoes

1. Potato cultivars, field conditions, and environmental factors.
2. Harvesting condition (time and temperature at the time of harvesting), maturity, and degree of sprouting.
3. Mechanical injury, bruising, wounding, cutting, or slicing at the time of handling.
4. Light exposure during storage, which has varying impacts according on wavelength, duration, and intensity
5. Environmental conditions at the time of packaging, storage, transportation, and marketing.

GAs Mitigation Strategies

1. During growth, keep tubers entirely covered in soil.
2. Allow the tubers to mature completely before harvest.
3. Refrain from harvesting in harsh sunshine and at extremely high temperatures.
4. Avoid handling techniques that cause bruising or skinning.
5. Discard sunburnt tubers.
6. Minimize tuber exposure to light during grading and other operations.
7. Avoid the use of transparent plastic bags for washed or brushed potatoes.
8. Using modified atmospheric packaging conditions, Store tubers in the dark or packs them in black polythene.
9. Chemical treatments and storage in a controlled environment can stop the production of chlorophyll, alkaloids, and sprouting.

Conclusion

This article has made it evident that how crucial is to use the appropriate post-harvest methods to reduce GAs accumulation, especially when potatoes are kept at a high temperature and high light level for extended periods of time. The peel and any green components must be eliminated as much as possible during processing. Because of the importance of the varietal effect, potatoes with a lesser susceptibility to accumulate GAs must be chosen for cultivation. In potato, no single method has been demonstrated which substantially limit the accumulation of GAs. It will take more research to determine whether post-harvest procedures that could significantly reduce GAs formation in potatoes. In order to understand the synergistic mechanism of toxicity of α-solanine and α-chaconine, it is also necessary to thoroughly investigate this interaction.

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