A survey of steroidal glycoalkaloid levels in Swedish table potatoes

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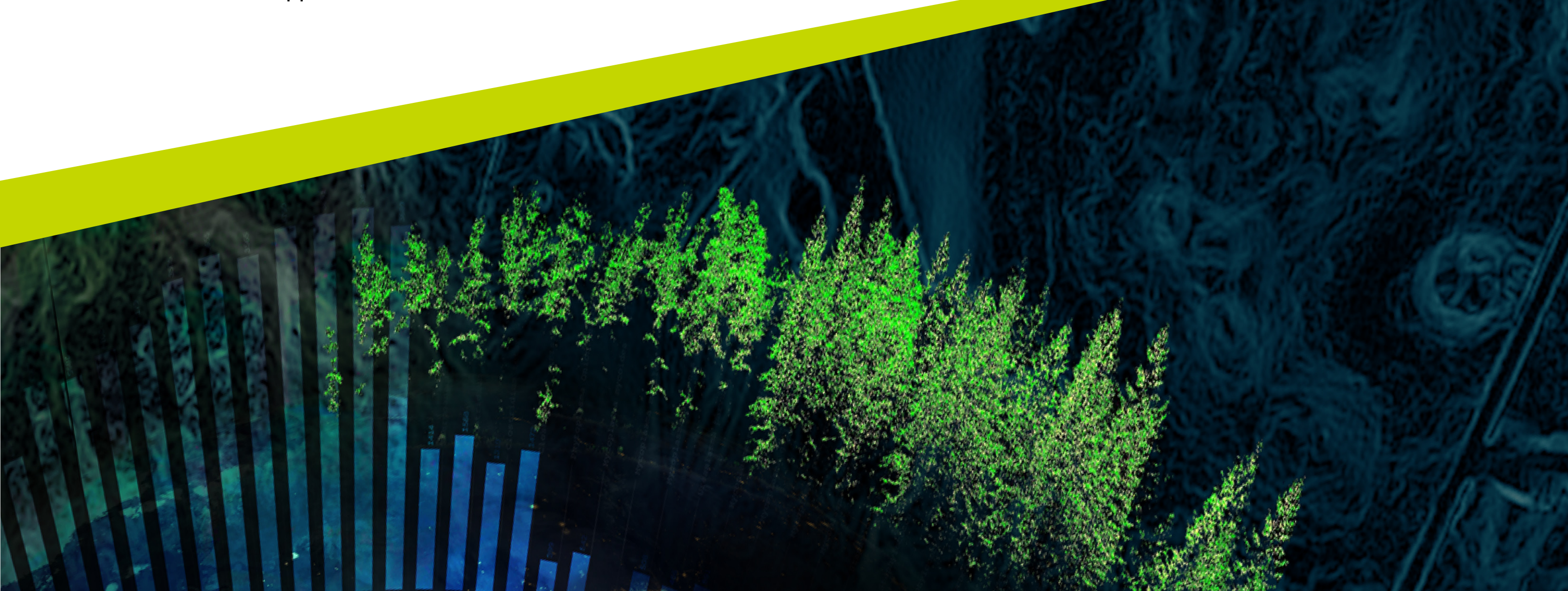

A survey of steroidal glycoalkaloid levels in Swedish table potatoes

En undersökning av glykoalkaloidnivåer i svensk matpotatis

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Abstract

The potato (*Solanum tuberosum ssp. tuberosum*) is today the fourth most important food crop species in the world. The potato tuber is a storage organ rich in nutritious substances such as starch, vitamin C and minerals. However, tubers also contain steroidal glycoalkaloids (SGAs), which in excessive doses can be toxic to consumers. SGAs are present also in other members of the Solanaceae, e.g. in tomato, eggplant, and pepper, but also occur in some species within the Liliaceae. In the cultivated potato, more than 95 % of the SGAs are in the form of α-solanine and α-chaconine. The basal SGA level in tubers at harvest varies strongly between cultivars, and certain stresses such as light and/or damage can increase the SGA levels well above the basal one. The toxicity of SGAs is due both to their interaction with cell membranes and an inhibition of acetylcholinesterase activity. Signs of acute toxicity are abdominal pain, diarrhoea, and vomiting. More severe signs of poisoning are coma, paralysis and even rare cases of death have been reported. To avoid these problems, it is in many countries recommended that potatoes for human consumption should contain less than 200 mg/kg (fresh weight) of SGAs. In Sweden, this limit is legally binding.

Despite the SGA hazard, relatively little is known about SGA levels in tubers that are sold in retail stores, and to what extent the forms of package and display influences the SGA levels. In the present study, the levels of α-solanine and α-chaconine were analysed in table potato cultivars of common use in Sweden. The tubers were purchased in different sorts of packages from food stores in the Uppsala area, or obtained from plants grown outdoors. SGA levels were analysed by liquid chromatography-mass spectrometry (LC-MS).

Results from potatoes grown outdoors at Ultuna in year 2020 showed that the basal SGA level differed between cultivars. Also, the SGA-promoting effect of a light treatment was shown to differ between cultivars. None of the over 50 samples from retail stores contained SGA levels over the upper safe limit of 200 mg/kg.

The knowledge about how cultivars react differently to light treatments can be used by the potato industry to adapt suitable tuber package, display and post-harvest conditions. For example, if some cultivars are more sensitive to light, they might not be suitable for transparent bags but more suitable to sell in dark paper bags to prevent SGA levels from rising. Information about which cultivars that are more prone to maintain low levels of SGAs might also be of importance for potato breeders to breed potatoes with lower levels of SGAs. Finally, results also indicate that the occurrence of tuber batches with high SGA levels is very low under retail conditions (less than 1 in 50; or below 2 %). Future attempts to monitor SGA levels in table potatoes will thus need to be designed accordingly, and include sample numbers well above the 50 used here, to be able to detect a high-SGA sample with reasonable probability.

Keywords: steroidal glycoalkaloids, α-solanine, α-chaconine, potato, *Solanum tuberosum ssp. Tuberosum,* light

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Abbreviations

GAs	Glycoalkaloids
SGAs	Steroidal glycoalkaloids
TGAs	Total glycoalkaloids
LC	Liquid chromatography
MS	Mass spectrometry

1. Introduction

It is common knowledge that potato tubers that have been subjected to light exposure might get a green surface and should be discarded. However, the reason for this is perhaps less known. The green colour does not necessarily correspond to presence of toxic steroidal glycoalkaloids (SGA) but the green chlorophyll indicates that the light exposure could have caused increased formation of toxin in the tuber (Grunenfelder et al. 2006). The SGAs act as a natural defence against pests and pathogens in the potato plant. Some other plants containing SGAs include tomatoes and eggplants (Friedman & McDonald 1997).

The present report focusses on the SGAs in potatoes. More than 80 different SGAs have been found in the potato (Ginzberg et al. 2009). Over 95 % of the glycoalkaloids in potatoes are α-chaconine and α-solanine (Petersson et al. 2013a). SGAs can be found in the whole potato plant where the highest levels are in the flowers and the lowest are found in the tubers (Friedman & McDonald 1997).

The basal level of SGAs in potato tubers have been shown to differ depending on the cultivar. Factors that might increase the SGA levels are certain stresses such as light exposure and wounding. The response to stress has also been shown to vary between different cultivars. The difference in basal level of SGAs and response to stresses are due to genetic factors according to Nahar et al (2017). The Steroidal alkaloid glycosyltransferase (SGT) gene family encode some of the enzymes that give rise to the response to stresses in potatoes. The transcription activity in these genes increases when potatoes are exposed to certain stresses (McCue et al. 2011). However, there are a number of other stress-regulated key SGA genes, acting both before and after formation of the SGA precursor cholesterol (Nahar et al 2017, Merino et al. 2023)

A high intake of total glycoalkaloids (TGAs) from potatoes (an intake of 1 mg/kg bodyweight or higher) can lead to symptoms such as headache, vomiting and diarrhoea in humans. An intake between 3-6 mg of TGAs kg/bodyweight can lead to coma and even death (Schrenk et al. 2020). The limit for how much glycoalkaloids that are approved in Swedish potatoes is 200 mg/kg fresh weight (Livsmedelsverket 2020). The toxicity of glycoalkaloids is due to the interference with cell membranes and their impact on acetylcholinesterase (Mensinga et al. 2005). Cell membranes are disrupted when GAs interact with sterols in the membrane (Schrenk et al. 2020). Acetylcholine is a substance involved in neuronal transmission, and when it is hydrolysed by the enzyme acetylcholinesterase the neuronal transmission stops (Trang & Khandhar 2020). The acetylcholinesterase is inhibited by SGAs, which hinders the hydrolysation of acetylcholine which in its turn leads to a build-up of acetylcholine. This might explain some of the symptoms that can result from excessive intake of SGAs (Schrenk et al. 2020).

However, it should be stressed that potato tubers are nutritious and relatively affordable when considering the nutritional content (McGill et al. 2013). They are a source of certain antioxidants and minerals such as iron and phosphorus (Mishra et al. 2020). These are factors that have contributed to the global success of this crop species.

1.1. General purpose and specific questions

The general purpose of this survey was to examine the SGA levels in Swedish table potatoes.

1.1.1. Questions

- What are the TGA levels in Swedish table potatoes in relation to the upper safe limit of 200 mg/kg?
- Is there a difference in TGA levels between tubers packed differently?
- Is there a difference in TGA levels between tubers of different cultivars?
- Does light and wounding affect the TGA levels in tubers?

2. Background

In the background section some information will follow about potatoes and glycoalkaloids.

2.1. Potatoes

Potatoes have been an important species in the human diet for hundreds of years and are the fourth most important food crop worldwide (Zhang et al. 2017). Around 19 million hectares of land are used in the world for potato production with a yield of 308 million tons of tubers (Food and Agriculture Organization n.d.).

The modern cultivated potato has its origin in South America at the border between Bolivia and Peru. The wild potato plant was probably first domesticated somewhere near Lake Titicaca. Potatoes can be cultivated at many different altitudes and latitudes which demonstrates how multifaceted it is as a crop (Birch et al. 2012).

2.2. Table potatoes

According to the Swedish Board of Agriculture, the Swedish population consumed around 670 000 tonnes of table potatoes and potato products in year 2015. Around half of the potatoes consumed in Sweden are consumed as potato products and the other half are consumed as tubers (Jordbruksverket 2020b). Sweden harvests approximately 550 000 tonnes and cultivates around 17 000 hectares of table potatoes each year (Jordbruksverket 2020a).

2.3. Starch potatoes

In Sweden, around 270 000 tonnes of potatoes are harvested for potato starch production (Jordbruksverket 2019). In 2014 starch potatoes were grown at 6140 hectares. Starch potatoes can be refined to potato flour or used when producing paper (Törnquist 2015).

2.4. Nutritional aspects of potatoes

Potatoes are important in the diet worldwide because of their nutritional content. When compared to many other vegetables and fruits, potatoes are relatively affordable if looking at the nutrient content (McGill et al. 2013).

Potatoes contain starch which is composed of amylose and amylopectin. In raw potatoes the starch is in a resistant crystalline form which the enzymes in the human gut cannot digest. When potatoes are cooked, the starch structure is altered so it becomes gelatinized which makes it more soluble and digestible. If cooked potatoes are left to cool for a while, the starch structure will retrograde making the starch more resistant, thus making it less digestible for the gut enzymes. In the large intestines the resistant starch becomes fermented which produces short-chain fatty acids (SCFAs). SCFAs can then be used by beneficial colonial bacteria (McGill et al. 2013).

Potatoes contain anthocyanins, phenolics, carotenoids and flavonoids which are antioxidants that promote health. Among other important health benefits antioxidants suppress oxidative stress in cells and reduce reactive oxygen species (Mishra et al. 2020).

The content of protein in potatoes is around 2-3 % by fresh weight and around 10 % by dry weight (Mishra et al. 2020). According to the Swedish Food Agency, Asterix potatoes, boiled with salt, contain 1.9 % protein (Livsmedelsverket n.d.). There are three main categories of protein in potatoes. The first is patatins which primarily acts as a storage protein, the second is protease inhibitors and the third is other proteins. Potato proteins are considered to be of high quality because of its high content of essential amino acids (Mishra et al. 2020).

Potatoes are also a source of different minerals, including iron, phosphorus, magnesium and potassium. The mineral content is higher in the potato peel than the flesh, possibly as a result of being in contact with soil (Mishra et al. 2020).

2.5. Glycoalkaloid chemistry

Steroidal glycoalkaloids (SGAs) are glycosylated forms of steroidal alkaloids (SAs) (Cárdenas et al. 2016). SGAs can be found in some members of the family Solanaceae, including tomatoes (*Solanum lycopersicum)* and eggplants (*Solanum melongea*) (Friedman & McDonald 1997). More than 95% of the glycoalkaloids in cultivated potatoes are α-chaconine and α-solanine (Petersson et al. 2013a), although more than in 80 different SGAs have been found in potatoes (Ginzberg et al. 2009).

The basal SGA levels vary depending on the cultivar. The levels of SGAs in tubers can be increased environmental factors and certain stresses such as exposure to light and wounding of the tubers. The SGA levels differ in different potato cultivars depending on the treatment (Petersson et al. 2013a; Nahar et al. 2017).

Genes that are responsible for the response to stresses in potatoes are part of the steroidal alkaloid glycosyltransferase (SGT) gene family. When potatoes are exposed to certain stresses the transcription activity increases in these genes (McCue et al. 2011). The SGT genes 1-3 together encode enzymes that synthesize the two trioses chacotriose and solatriose onto the steroidal aglycone solanidine. This forms the two SGAs α-chaconine and α-solanine (McCue et al. 2011). The precursor to solanidine is cholesterol (Petersson et al. 2013b). α-chaconine and α-solanine contain different primary glycosyl residues, where α-chaconine contain glucose and α-solanine contain galactose (McCue et al. 2007). The mevalonate pathway is also important in the synthesis of SGAs since cholesterol is produced in this pathway (Cárdenas et al. 2016). Genetically engineered plants with lower levels of cholesterol has been shown to have lower glycoalkaloid levels (Arnqvist et al. 2003).

The enzyme UDP-galactose:solanidine galactosyltransferase (SGT1) is involved in the biosynthesis of α-solanine where it catalyses the formation of γ-solanine from solanidine. UDP-glucose:solanidine glucosyl-transferase (SGT2) catalyse the formation of γ-chaconine from solanidine and UDP-glucose. UDP-rhamnose:b-steroidal glycoalkaloid rhamnosyltransferase (SGT3) is involved in the last step in the biosynthesis of both α-chaconine and α-solanine (McCue et al. 2007).

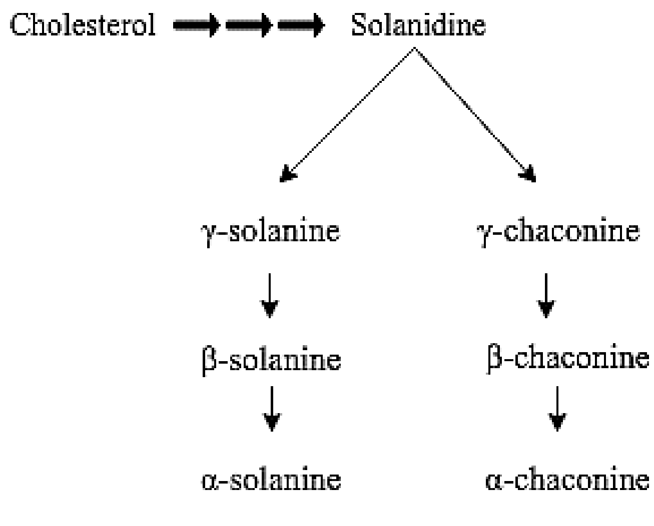

Figure 1. The steroidal glycoalkaloid biosynthetic pathway. Cholesterol is required for the synthesis of solanidine. Solanidine is either synthesised to α-solanine or α-chaconine. Illustration by Johanna Ankarcrona, with inspiration from McCue et al (2007).

In addition to the SGT genes, a small number of other key genes have been demonstrated to be correlated to increased SGA levels during stress responses. These genes encode enzymes acting before as well as after cholesterol formation (Nahar et al. 2017; Merino et al. 2023; Liu 2024).

2.6. Toxicity of glycoalkaloids

Greening of potatoes is an indication that they have been exposed to light (Livsmedelsverket 2020). The greening of the skin that can be seen is an increase of chlorophyll. This greening is not directly related to the glycoalkaloid content but since it accumulates when the tubers are exposed to light it can indicate an increase in glycoalkaloid content (Rymuza et al. 2020).

The Swedish Food Agency recommends that if there is considerable greening of or damage to the potato it should be discarded, but if there is only minor greening or damage those parts can be removed from the potato before consumption (Livsmedelsverket 2020).

In Sweden there is a limit of how much glycoalkaloids are allowed in potatoes of 200 mg/kg (fresh weight) (Petersson et al. 2013a). This limit is set due to the toxicity of glycoalkaloids if this limit is exceeded (Rymuza et al. 2020). High levels of glycoalkaloids are associated with a bitter taste and levels above 200 mg/kg gives a burning sensation in the mouth (Schrenk et al. 2020). One variety that has been removed from the Swedish market because of too high levels of SGAs is Magnum Bonum (Nahar et al. 2017). The precise reason for high SGA in this cultivar is not known, but Merino et al. (2023) showed that Magnum Bonum is much more sensitive to light exposure than other cultivars, and suggested that this property may underlie the high levels.

The limit of 200 mg TGA/kg glycoalkaloids was probably established already in 1924 by Bömer and Mattis. They concluded that this level should be safe for consumers based on their study where potatoes with TGA content between 257-583 mg/kg gave intoxication symptoms whereas levels below 200 mg/kg did not give intoxication. To determine these levels they used the gravimetric method (Schrenk et al. 2020). In 1990, the Swedish National Food administration concluded that 200 mg/kg is the upper limit of TGA that can be accepted. Although, they recommended that the level of GAs should always be kept as low as possible (Schrenk et al. 2020).

Glycoalkaloids (GAs) are present in different amounts in potato plants. The highest levels of GAs are found in the flowers, and the tubers contain the least (Grunenfelder et al. 2006). The glycoalkaloids are part of the plant resistance in potatoes against bacteria, insects, fungi and herbivores (Rymuza et al. 2020).

Since GAs are more abundant close to the peel, small potatoes have higher levels in general because of the ratio between surface area and size (Livsmedelsverket 2015).

It has been shown that whether the potatoes are organically or conventionally grown does not affect the GA levels (Skrabule et al. 2013).

Grunenfelder et al. (2006) states that *"Compared to other common poisons, glycoalkaloids are relatively toxic"*. They compare GAs to arsenic and strychnine where arsenic is acutely toxic at 8 mg/kg body weight and strychnine at 5 mg/kg body weight. Whereas the lethal dose for GAs is in the range from 1.75 mg/kg body weight up to 6 mg/kg body weight.

In the thirty-ninth report of the Joint FAO/WHO Expert Committee on Food Additives it is concluded that levels lower than 100 mg/kg GAs in potatoes is not considered an issue but they could not establish a safe level of intake (Joint FAO/WHO Expert Committee on Food Additives 1993).

The toxicity of GAs is caused by their impact on acetylcholinesterase and cell membranes. The enzyme acetylcholinesterase is inhibited by GAs from potatoes which affect the nervous system (Mensinga et al. 2005). Acetylcholinesterase is an enzyme which is responsible for breaking down or hydrolysing acetylcholine into acetic acid and choline. This stops neuronal transmission and the acetylcholine from spreading and affecting other receptors (Trang & Khandhar 2020). When acetylcholinesterase is inhibited this causes build-up of acetylcholine which might explain some of the symptoms of excessive intake of GAs (Schrenk et al. 2020). GAs interacts with sterols in cell membranes leading to disruption of the membrane which might affect the gastrointestinal tract. Signs of acute toxicity because of ingestion from too much total glycoalkaloids (TGAs) can be abdominal pain, diarrhoea, and vomiting. The lethal dose of TGAs for humans is considered to be approximately 3-6 mg potato TGAs/kg body weight. Cases of coma, paralysis and death caused by too high doses of TGAs have been reported (Schrenk et al. 2020).

Processing of potatoes can decrease the GA content to different extents. For example, peeling of potatoes can decrease the content by 25-75%, boiling of potatoes with skin removed can remove 5-65% of GAs and frying peeled potatoes in oil can decrease it by 20-90%. Although, there are no available data about the chemical properties of the degraded GAs (Schrenk et al. 2020).

2.7. Light effects on glycoalkaloid synthesis

Okamoto et al. (2020) performed a study where they showed that white-, blue- and red light induce glycoalkaloid synthesis in King Edward potatoes, but far-red light does not. They also demonstrated that glycoalkaloid synthesis is not induced in darkness. In the same study it was also found that six genes involved in the biosynthesis of glycoalkaloids were induced by white-, blue- and red light whereas far red light induced the genes a little or did not induce these genes at all. These genes were *HMG1*, squalene synthase (*SQS*), cycloartenol synthase (*CAS1*), sterol side chain reductase (*SSR2*) (which are all involved in the mevalonate pathway), solanindine galactosyltransferase (*SGT1)* and solanidine glucosyltransferase (*SGT2)*. The genes were also differently induced by the light treatments. The gene lanosterol synthase 1 (*LAS1),* which is not involved in the biosynthesis of glycoalkaloids, showed only slight change in expression after any of the light treatments (Okamoto et al. 2020).

In a study performed by Nie et al. (2020) it was shown that black mulching film can inhibit glycoalkaloid synthesis in potatoes. The experiment was performed both in pots and in the field. The black film was compared to control (no film) and white film. The black film gave the best effect against formation of glycoalkaloids whereas white film did not inhibit the formation of glycoalkaloids as effectively (Nie et al. 2020).

2.8. Damage effects on glycoalkaloid synthesis

A study performed by Dale et al (1998), where the response of five potato cultivars were analysed, showed that bruising gave elevated levels of SGA. In the study they had control tubers (whole and unbruised tubers), bruised halved tubers and unbruised halved tubers. Three of the cultivars showed a slight (but significant) increase in SGA levels in the halved unbruised tubers whereas two did not show an increase in SGA levels. All of the cultivars had a significant increase in the SGA levels in the bruised halved tubers (Dale et al. 1998). Another study made by Petersson et al (2013a) on 21 different cultivars of potatoes showed that bruising on the tubers increased the glycoalkaloid content significantly. The damaging was simulated by cutting discs from the centre of the tubers. The tubers showed an increase in glycoalkaloid levels between 50 to 320 % compared to undamaged control tubers. The study also found that the level of solanine increased more than the level of chaconine in stressed tubers.

2.9. Analyses

2.9.1. Liquid chromatography-mass spectrometry

The principle of chromatography is that components are separated in a column where a mobile phase flows through a stationary phase. In liquid chromatography (LC) the mobile phase is liquid (Niessen 2006).

Mass spectrometry (MS) is a microanalytical technique which is used for detection, quantifying the amount of analytes as well as to some extent establish the molecular structure (Kang 2012). In MS, the analyte molecules are transformed to an ionised state and the mass to charge ratio is used to analyse the ions and fragment ions from the ionisation process (Pitt 2009). The ions are separated depending on their mass to charge ratio and pass a mass analyser one at a time to then reach a detector which gives a signal that can be analysed further. Since mass to charge ratio of ions can be found it is then possible to analyse which ions that are present in the sample. It is also possible to determine how much of a substance that is present in a sample depending on the intensities of the ions (Kang 2012).

3. Method

3.1. Tuber material

3.1.1. Tubers purchased from food stores in year 2020

A wide range of different potato cultivars were purchased from Swedish food stores in Uppsala from September to November year 2020. Both conventionally and organically grown potatoes were purchased. The purchased potatoes were in different types of packages. The packages chosen in the store were the ones most easily accessible, i.e. in the front or at the top of a pile of packages. The unpackaged tubers chosen were visibly free of damage. The tubers were kept approximately around 1-7 days in a fridge after purchase before being moved to a freezer. The tubers from retail were not exposed to any stress treatments prior to freezing. Four tubers from each batch were pooled together by cutting a piece from the middle of each tuber and then they were frozen as one sample.

3.1.2. Tubers grown under outdoor conditions in year 2020 (outdoor)

To be able to see the difference in SGA levels between different cultivars and packages the basal SGA level in potato tubers had to be measured. The optimum way of doing this would have been to collect tubers right after harvest at commercial potato farms. Since it would have been challenging and time consuming to collect tubers directly after harvest, tubers were cultivated at SLU. Seven cultivars of potatoes were planted in black 15 litre pots with fertilized soil (P-jord) from Hasselfors Garden at the end of May and the beginning of June 2020. The pots were kept outdoor in a net cage for the whole growing period until harvest. 7 tubers of each variety were planted in one pot respectively. Tubers free from damage and mould were preferably selected. Likewise, tubers similar in size were chosen. When tubers were small, two tubers were planted. The pots were regularly watered throughout the summer until harvest. The tubers were harvested in late September 2020. After harvest, the tubers were rinsed to remove excessive dirt and were kept in a refrigerated dark area approximately 30 days until stress treatments and sampling. Four tubers from each batch were pooled together by cutting a piece from the middle of each tuber and then frozen in the same package.

3.1.3. Light exposure of tubers

The light exposure was performed on tubers that were grown in outdoor conditions in year 2020. Tubers from 7 cultivars (Solist, Bintje, Maris Bard, Princess, Rocket, Asterix, King Edward) similar in size, without detectable damage and absent of greening were chosen for the light treatment. The tubers were put in a light cabinet with continuous light with a flux density of 110 µmol/ (m^2.s), and a temperature of 22°C). The light exposure experiment was performed for 48 hours, respectively 8 days as described (Petersson et al. 2013a). Tubers from 3 cultivars (Bintje, Asterix, King Edward) which during earlier years have shown interesting results were removed from the light cabinet after 48 hours. Tubers from the three cultivars were also left in the cabinet for the light treatment for 8 days. After light treatment, four representative tubers from each cultivar were selected. The selected tubers were cut in discs and one disc from each tuber was paired with discs from the other tubers for glycoalkaloid analysis. Individual discs from each tuber were also frozen for RNA extraction and metabolomic analyses.

3.1.4. Wounding and outdoor

Tubers from each cultivar grown in outdoor conditions in year 2020, similar in size, without detectable damage and absent of greening were chosen for damage treatment and used as control. The tubers were cut into discs and one disc from each potato was paired with discs from the other tubers to act as control for SGA analysis. Individual discs from each tuber were also frozen for RNA extraction and metabolomic analyses. Four discs from each tuber were put in a petri dish (one petri dish for each potato tuber). The petri dishes were then put in paper bags and kept in a dark room with ambient temperature for 48 hours. After 48 hours one disc from each tuber was paired with one disc from the other tubers for glycoalkaloid analysis. Individual discs from each tuber were also frozen for RNA extraction and metabolomic analyses.

3.2. Tuber sampling for SGA analyses

Tuber discs that were aimed for glycoalkaloid analysis were ground in liquid nitrogen by hand with mortar and pestle until turned into a fine powder. The powder was then put in test tubes and the test tubes were placed in liquid nitrogen. The test tubes were then kept in -70°C. The powder was weighed to between 20-30 mg in Eppendorf tubes. The tubes were then put in liquid nitrogen and later kept in -70°C.

3.3. Analyses

Samples for glycoalkaloid detection were sent to the Swedish Metabolomics Centre (SMC) in Umeå where LC-MS analysis was performed.

3.3.1. Statistics

The statistics were performed in Microsoft Excel. To see if the mean values between different groups were significantly different from each other, t-tests were performed with one-tailed distribution, two sample equal variance. When comparing tubers regardless of cultivar, unpaired T-tests were performed and paired T-tests were used when comparing in groups of cultivars. A significance level of p=0.05 was used throughout the study.

4. Results

The results presented in this section are based on the LC-MS analysis of chaconine and solanine content in potato tubers. T-tests were performed in Microsoft Excel to find potential differences between TGA levels in tubers purchased in retail stores and tubers grown in outdoor conditions. T-tests were also conducted to find differences between cultivars, packaging types and treatments. The s/c ratio was also calculated as the mean value of the α-solanine to α-chaconine ratio. This was calculated to see if the formation of chaconine or solanine were stimulated more than the other from different types of handling.

The results showed no significant difference between wounded tubers and tubers grown in outdoor conditions. These results are not shown in this essay.

4.1. TGA levels in tubers purchased in retail stores

Analysis of 57 samples of table potatoes were performed and none of them had TGA levels above the allowed limit of 200 mg/kg. All samples were also under 100 mg/kg which is far lower than 200 mg/kg (Figure 2).

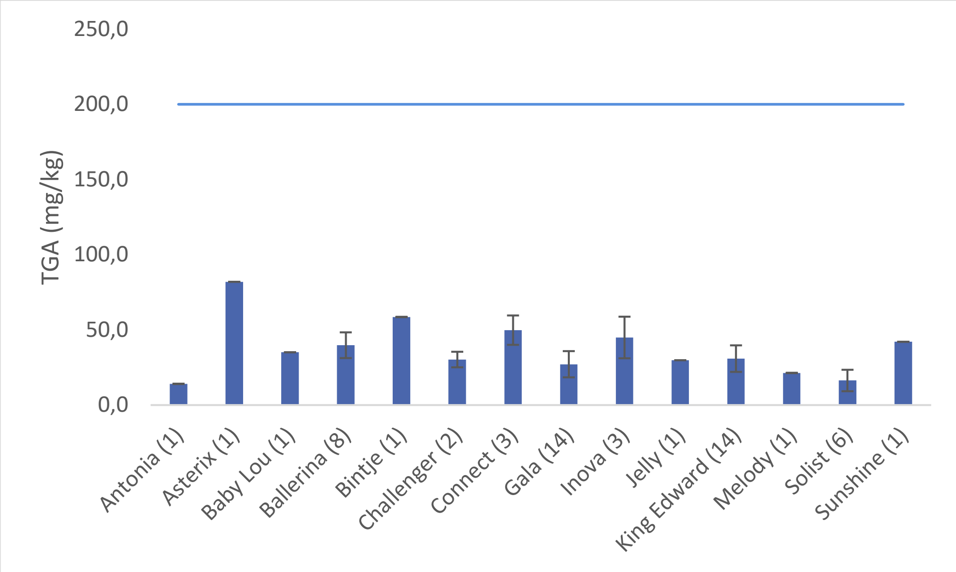

Figure 2. TGA levels in tubers from 57 samples taken from 55 packages purchased from retail stores in Uppsala from September to November 2020. Numbers in parentheses indicate the number of samples (n). Mean TGA value ± SD or range, as calculated for all types of tuber display/package together. The recommended upper safe limit of 200 mg/kg is shown in the graph. For the cultivars with only one replicate there is no standard deviation.

The levels of chaconine and solanine were measured in the tubers from retail stores. The results show that the levels of chaconine were higher than solanine levels in all tubers from retail stores (Figure 3). This was expected from earlier analyses (Petersson et al. 2013a) .

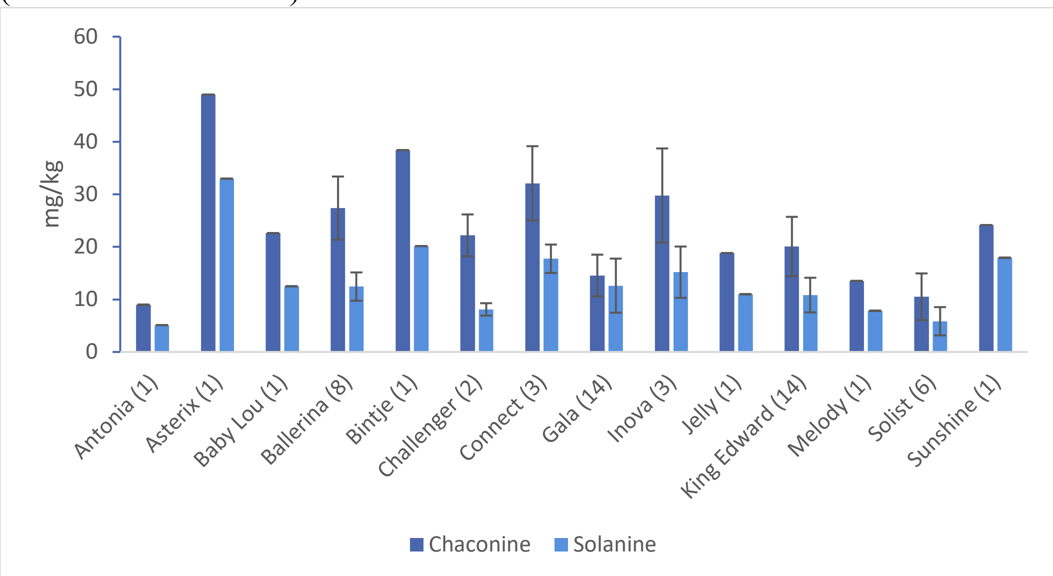

Figure 3. Chaconine- and solanine levels in different cultivars from retail stores. For the cultivars with only one replicate there is no standard deviation.

When comparing four cultivars from retail stores with their outdoor counterparts, all of them had levels lower than 100 mg/kg (Figure 4).

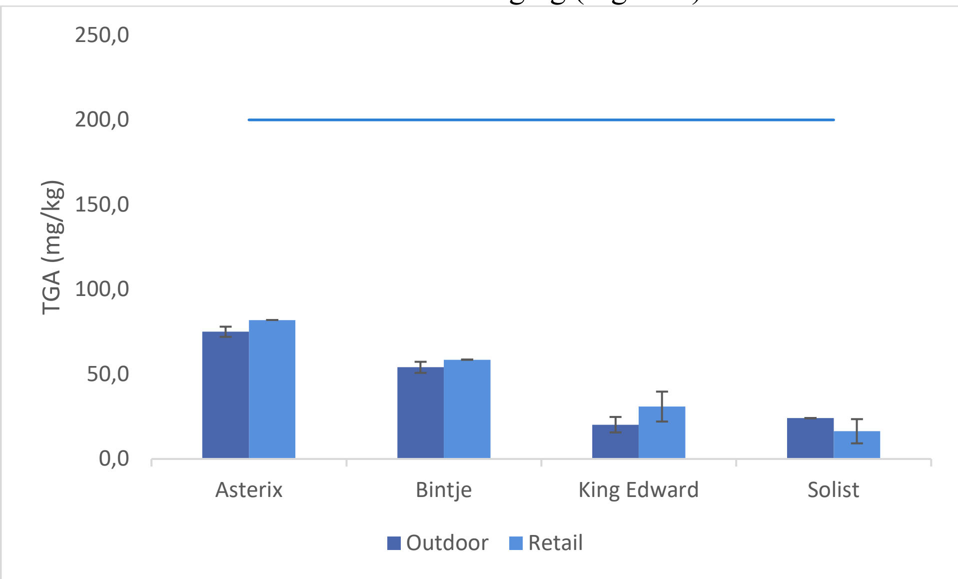

Figure 4. TGA levels in four different cultivars. Asterix retail n=1, Bintje retail n=1, King Edward retail n=14, Solist retail n=6, Asterix outdoor n=2, Bintje outdoor n=2, King Edward outdoor n=2, Solist outdoor n=1. For the cultivars with only one replicate there is no standard deviation. The recommended upper safe limit of 200 mg/kg is shown in the graph.

When comparing the TGA levels in different packages from retail stores to each other and tubers grown outdoors it was shown that both outdoor and all the packages from retail stores had TGA levels lower than 100 mg/kg (Figure 5).

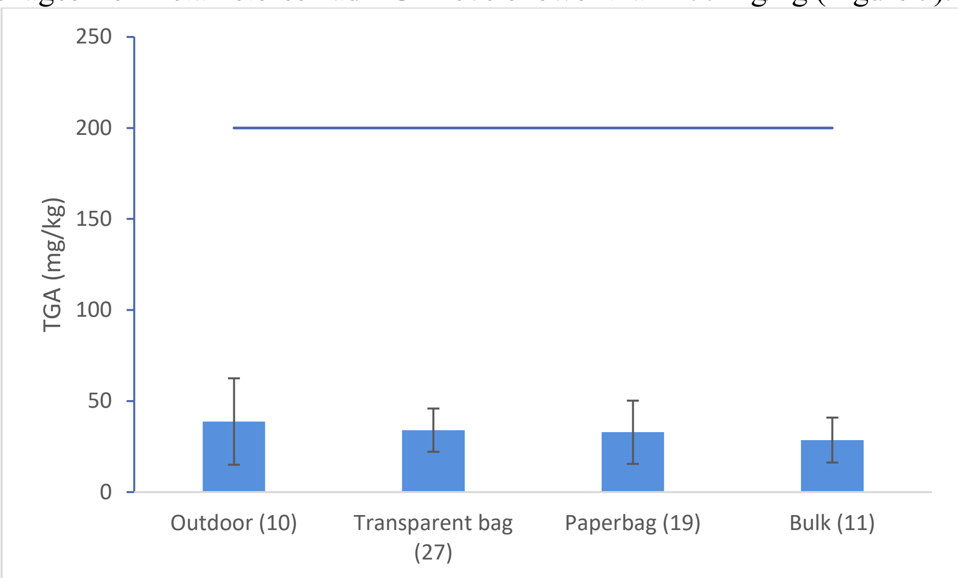

Figure 5. TGA levels in different kinds of packaging and tubers grown outdoor, calculated as the mean of all tubers regardless of cultivar in outdoor conditions and different packages. The outdoor tubers were not subjected to any treatment. The recommended upper safe limit of 200 mg/kg is shown in the graph.

When comparing the ratio between solanine and chaconine in four cultivars from retail stores with their counterparts from tubers grown outdoors, there is no clear difference in the ratio of solanine to chaconine in tubers from retail stores compared to outdoor tubers (Figure 6).

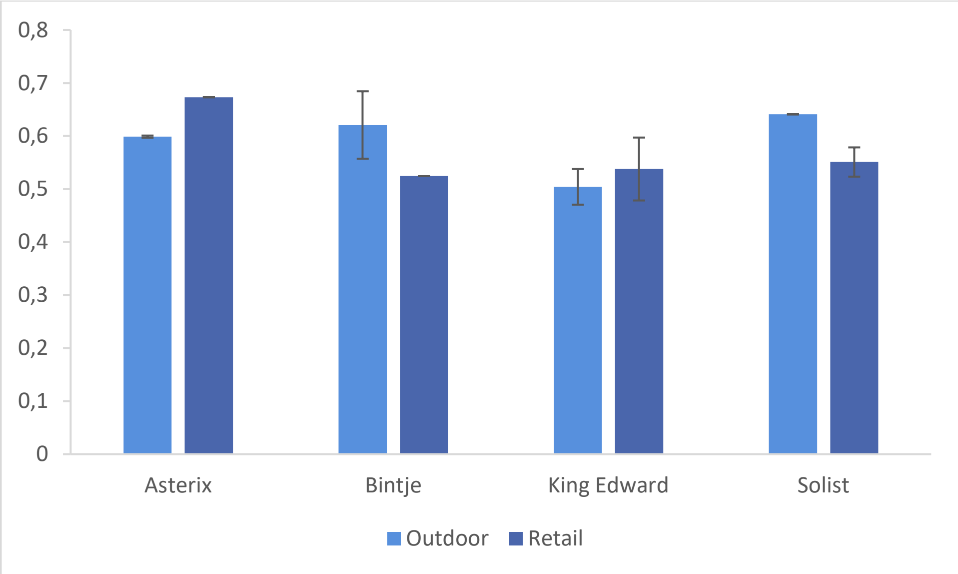

Figure 6. Ratio between solanine and chaconine in tubers from retail and outdoor. Asterix retail n=1, Bintje retail n=1, King Edward retail n=14, Solist retail n=6, Asterix outdoor n=2, Bintje outdoor n=2, King Edward outdoor n=2, Solist outdoor n=1. For the cultivars with only one replicate there is no standard deviation. The outdoor tubers were not subjected to any treatment.

4.2. Tubers grown outdoors subjected to light for 48 hours

When analysing the TGA levels in tubers subjected to light for 48 hours, none of the cultivars exposed to light for 48 hours had TGA levels above the 200 mg/kg limit. The tuber from the cultivar Asterix subjected to light for 48 hours had lower TGA levels than its outdoor counterpart (Figure 7).

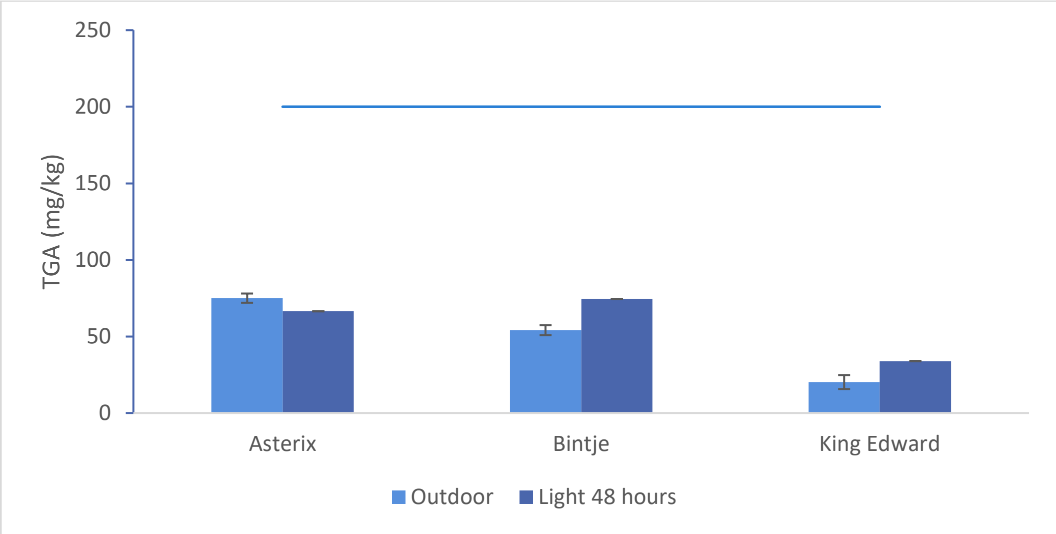

Figure 7. TGA levels in three cultivars after being subjected to light for 48 hours. Asterix light 48 hours n=1, Bintje light 48 hours n=1, King Edward light 48 hours n=1, Asterix outdoor n=2, Bintje outdoor n=2, King Edward outdoor n=2. For the cultivars with only one replicate there is no standard deviation. The outdoor tubers were not subjected to any treatment. The limit of 200 mg/kg is shown in the graph.

The levels of chaconine were higher than solanine levels in all tubers subjected to light for 48 hours (Figure 8), the same was also seen for tubers grown outdoors. When comparing the solanine to chaconine ratio in tubers subjected to light for 48 hours it is shown that the ratio in tubers subjected to light for 48 hours have slightly gone up when comparing to outdoor (Figure 9).

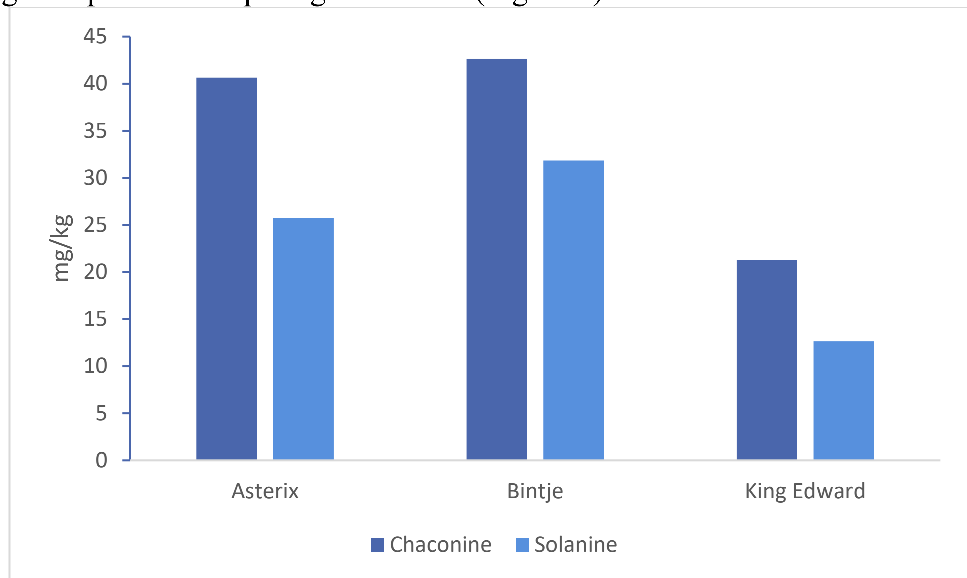

Figure 8. Chaconine- and solanine levels in three different cultivars subjected to light for 48 hours. For tubers subjected to light for 48 hours there is only one (1) replicate per cultivar. For the cultivars with only one replicate there is no standard deviation.

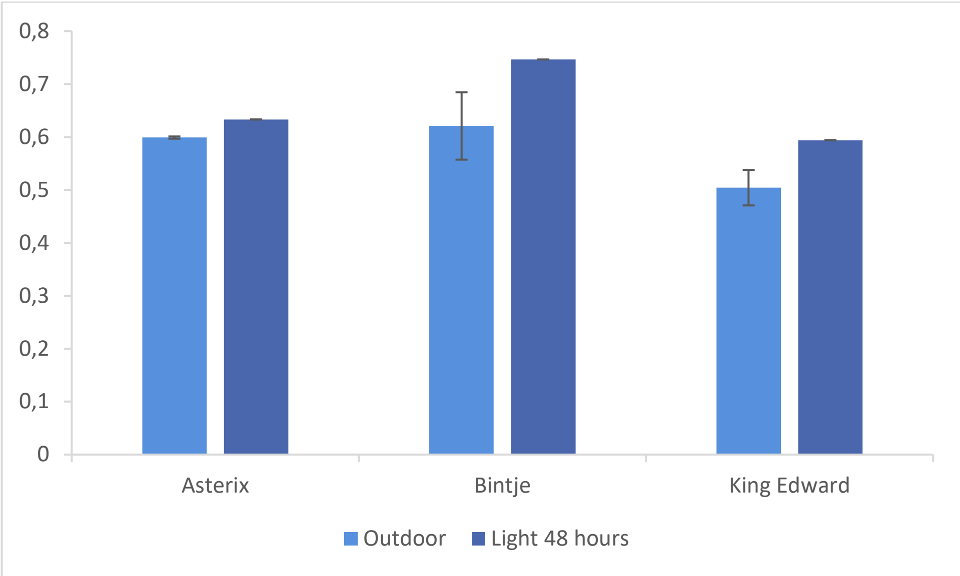

Figure 9. Ratio between solanine and chaconine in tubers exposed to light for 48 hours and outdoor tubers. Asterix light 48 hours n=1, Bintje light 48 hours n=1, King Edward light 48 hours n=1, Asterix outdoor n=2, Bintje outdoor n=2, King Edward outdoor n=2. For the cultivars with only one replicate there is no standard deviation. The outdoor tubers were not subjected to any treatment.

4.3. Tubers grown outside subjected to light for 8 days

Five of seven cultivars subjected to light for 8 days had TGA levels above the 200 mg/kg limit. All cultivars had TGA levels significantly higher than their outdoor counterparts. King Edward and Maris Bard were the cultivars that had levels below 200 mg/kg (Figure 10).

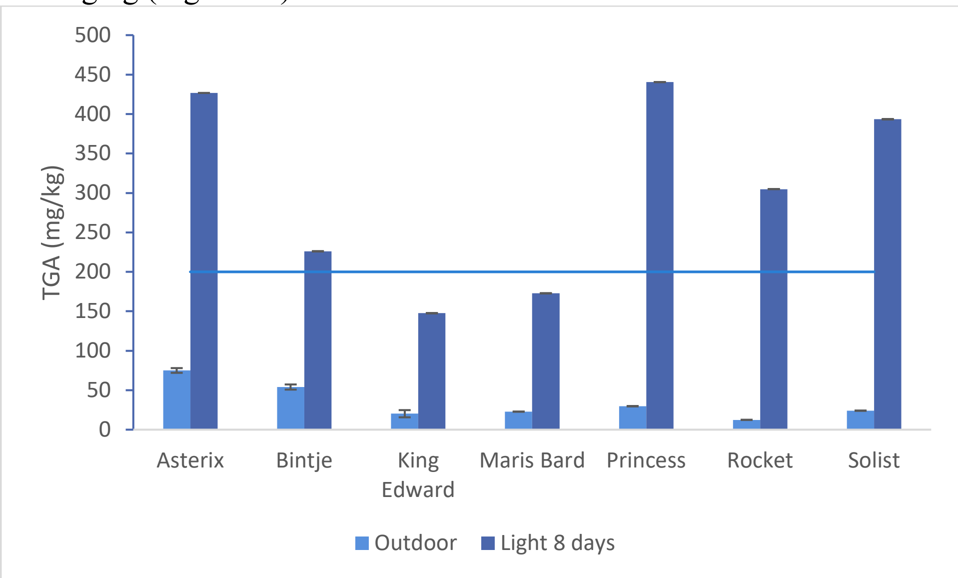

Figure 10. TGA levels in seven different cultivars subjected to light for 8 days. For tubers subjected to light for 8 days there is only one (1) replicate per cultivar. Asterix outdoor n=2, Bintje outdoor n= 2, King Edward outdoor n= 2, Maris Bard outdoor n=1, Princess outdoor n=1, Rocket outdoor n= 1, Solist outdoor n=1. For the cultivars with only one sample there is no standard deviation. The outdoor tubers were not subjected to any treatment. The limit of 200 mg/kg is shown in the graph.

The solanine levels were higher than the chaconine levels in 6 of 7 cultivars exposed to light for 8 days. The only cultivar with higher chaconine than solanine levels was Asterix (Figure 11). The solanine to chaconine ratio when comparing tubers subjected to light for 8 days and tubers grown outdoors does seem to change. Two possible scenarios could be that either the chaconine levels has decreased or the solanine levels has increased. When comparing the cultivars subjected to light for 8 days (Figure 11) and outdoor (Figure 13) it is shown that both the chaconine and solanine has gone up but the solanine levels have increased more than the chaconine. Earlier similar analyses has also shown that the solanine levels have increased more than the chaconine levels (Petersson et al. 2013a).

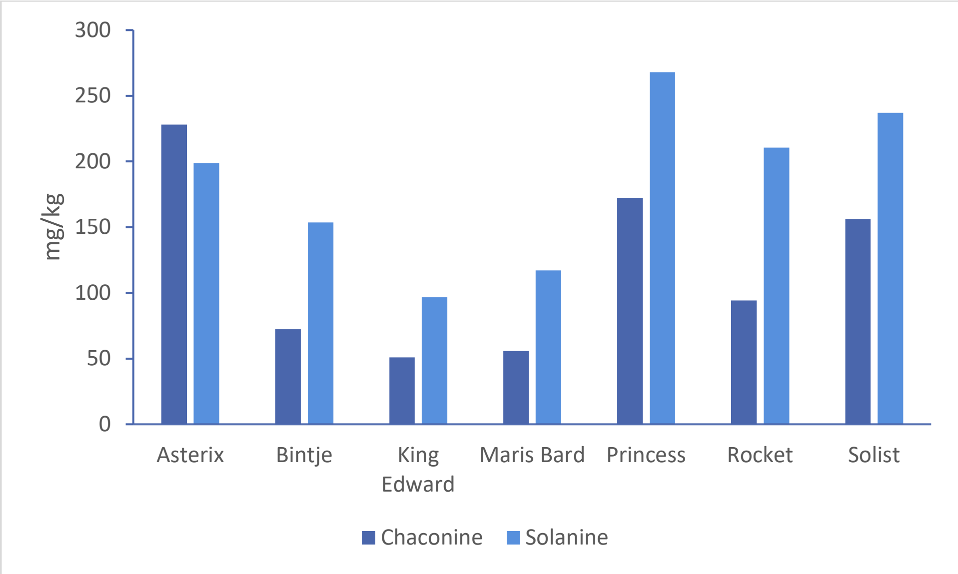

Figure 11. Chaconine- and solanine levels in seven different cultivars subjected to light for 8 days. For tubers subjected to light for 8 days there is only one (1) replicate per cultivar.

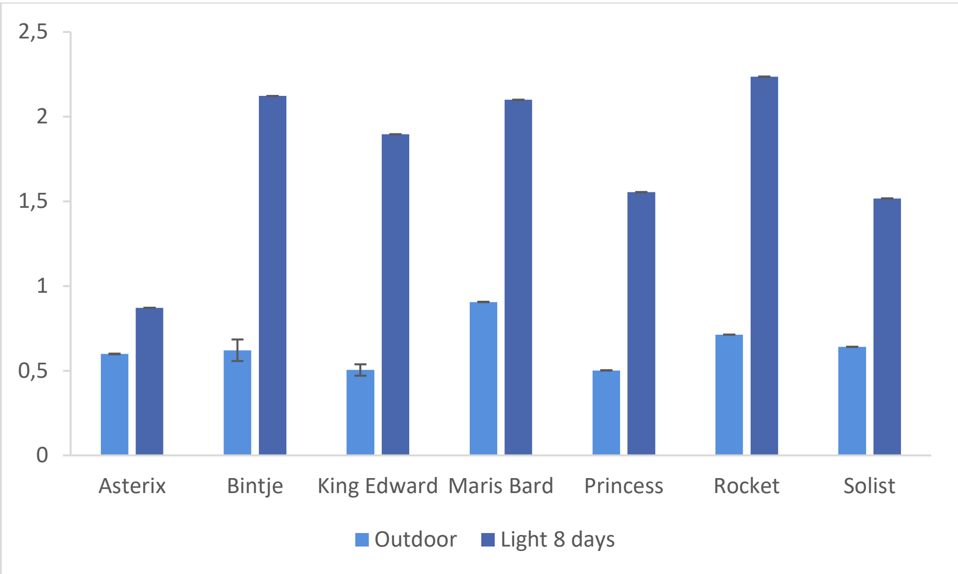

Figure 12. Ratio between solanine and chaconine in tubers exposed to light for 8 days and tubers grown outdoors. For tubers subjected to light for 8 days there is only one (1) replicate per cultivar. Asterix outdoor n=2, Bintje outdoor n=2, King Edward outdoor n=2, Solist outdoor n=1, Maris Bard outdoor n=1, Princess outdoor n=1, Rocket outdoor n=1. For the cultivars with only one sample there is no standard deviation. The outdoor tubers were not subjected to any treatment.

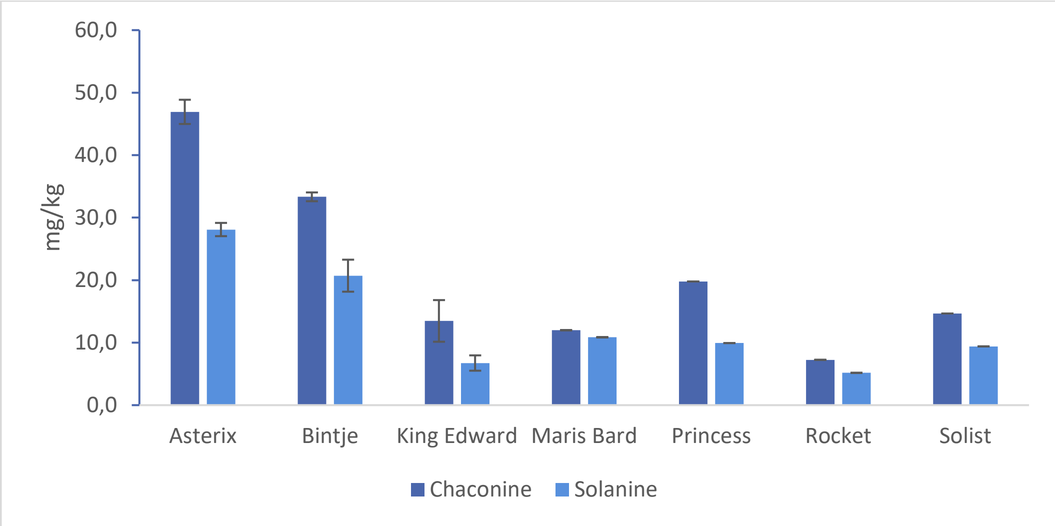

Figure 13. Chaconine- and solanine levels in tubers grown outdoors. Asterix outdoor n=2, Bintje outdoor n=2, King Edward outdoor n=2, Solist outdoor n=1, Maris Bard outdoor n=1, Princess outdoor n=1, Rocket outdoor n=1.

4.4. T-tests

T-tests were performed to show the difference in TGA levels between cultivars, packaging and difference between the storebought tubers and tubers grown outdoors at SLU year 2020.

*Table 1. T-test performed on retail potatoes to show the difference between cultivars, regardless of packaging type. The values marked * show the values that equals or are below 0,005 which indicate a significant difference between the compared cultivars.*

	Ballerina (8)	**Challenger (2)**	**Connect (3)**	**Gala (14)**	**Inova (3)**	**King Edward (14)**
Challenger (2)	0,180					
Connect (3)	0,128	0,087				
Gala (14)	0,004*	0,636	0,001*			
Inova (3)	0,466	0,263	0,644	0,010		
King Edward (14)	0,032	0,926	0,005*	0,271	0,037	
Solist (6)	0,000*	0,047	0,001*	0,016	0,004*	0,002*

The p-value from the t-tests in
Table 1 show that there might be differences in TGA levels between some cultivars from retail stores, for example Ballerina with Solist and King Edward with Connect.

These differences show that some cultivars might be more prone to synthesising glycoalkaloids. The results might also be affected by the packaging since this t-test have been performed regardless of packaging types.

Table 2. T-test performed on tubers from retail to show the difference between packaging, regardless of cultivars.

	Bulk (11)	**Paperbag (19)**
Paperbag (19)	0,479	
Transparent bag (27)	0,212	0,788

The p-value from the t-tests performed on TGA levels in Table 2 show that there are no significant differences between the types of packaging when comparing all tubers from each packaging type. This shows that the type of packaging might not affect the glycoalkaloid levels when comparing packaging independently from cultivars.

Table 3. T-test performed on Gala from retail

Gala	**Bulk (3)**	**Paperbag (4)**
Paperbag (4)	0,912	
Transparent bag (7)	0,848	0,900

Table 4. T-test performed on King Edward from retail

King Edward	**Bulk (5)**	**Paperbag (7)**
Paperbag (7)	0,920	
Transparent bag (2)	0,728	0,698

Neither of the cultivars Gala and King Edward in Table 3 and Table 4 shows that there are any significant differences between the type of packaging. The decision to only perform t-tests for the Gala and King Edward cultivars individually was based on them being the only cultivars available in three different kinds of packages.

A paired t-test was performed to see if there was any difference between the same cultivars that had been grown outdoors and purchased in retail stores (Asterix, Bintje, Kind Edward and Solist). The calculated p-value was 0,432 which shows that there was no significant difference between the tubers grown outdoors and the tubers from retail stores.

*Table 5. T-test performed to show the difference between tubers grown outdoors, store bought potatoes, tubers exposed to light for 48 hours and tubers exposed to light for 8 days. The values marked * show the values that equals or are below 0,005 which indicate a significant difference between the compared treatments.*

	Outdoor (10)	**Light 48 hours (3)**	**Light 8 days (7)**
Light 48 hours (3)	0,151		
Light 8 days (7)	0,000	0,011	
Retail (57)	0,721	0,094	0,000

The p-values of the t-tests in Table 5 involving exposure to light for 8 days indicates that this group is different from the others. A paired t-test was performed to see if there is a significant difference in mean value between tubers grown outdoors and tubers subjected to light for 8 days. The test gave a p-value of 0,0009. This value shows that there might be a significant difference between the tubers grown outdoors and light 8 days.

4.5. Wounding of tubers grown outdoor

In this study, seven different cultivars were exposed to wounding. The results did not show any significant effect therefore these results are not presented.

5. Discussion

5.1. Analysis method

The LC-MS SGA analysis in this study used isotope-labelled internal standards in the mass-spectrometric step to monitor the peak purity and analytic quality. The LC-MS-based analysis methods of today might affect the comparability to earlier studies (using e.g. gravimetric or HPLC analyses). It should be noted that the limit of 200 mg/kg was established with older analysis methods (Schrenk et al. 2020). The TGA levels of the cultivars Asterix, Bintje, King Edward, Maris Bard, Princess and Rocket grown outdoor did not exceed 200 mg/kg. The results aligned well with the results from Petersson et al (2013a). In that study the tubers were also grown outdoors in Uppsala but were quantified by HPLC. This indicates that results obtained by the LC-MS method used in this study might be comparable to those obtained using HPLC, and thus give a representative picture of the quantity of TGA in potatoes.

5.2. Glycoalkaloid levels in tubers from retail stores

The potatoes grown under outdoor conditions were used as a reference to analyse to what extent the TGA levels increased after harvest. When comparing the results from the four cultivars grown outdoors and the same cultivars purchased from retail stores, there was no significant difference between the TGA levels. This indicates that tubers in stores have approximately the same levels as they had when harvested.

The optimal scenario in this study would have been to analyse tubers directly from farmer´s harvest, and then analyse the same batches from a retail store to see if the TGA levels changes throughout the chain.

5.3. Light exposure of tubers

None of the cultivars subjected to light for 48 hours had TGA levels above 200 mg/kg. This indicates that exposure to light might not be a significant problem in stores for a short period of time (at least for the cultivars tested in this essay). Although, this experiment needs to be repeated with more cultivars and replicates to confirm these results.

On the other hand, five of seven cultivars that were subjected to light for 8 days had levels above 200 mg/kg. This indicates that some cultivars were more prone to increase their levels of glycoalkaloids as a response to light exposure. However, none of the tubers from retail conditions showed TGA levels above 200 mg/kg, indicating that the handling of potatoes in retail is adequate to keep the levels of glycoalkaloids low. A paired t-test was performed to see if there was a significant difference between the mean values of TGA levels between tuber grown outdoors and after light exposure for 8 days. The p-value of 0,0009 shows that there is a strongly significant difference between outdoor tubers (38,8 mg/kg) and light treatment for 8 days (301,7 mg/kg). This shows that some types of handling in theory could lead to high levels of TGAs in tubers from harvest to consumer. This emphasizes the importance of correct handling of tubers after harvest.

Figure 11 shows that the solanine levels were higher than chaconine levels after light exposure of the tubers in six of seven cultivars, but that the inverse was true at harvest. This light-induced shift in solanine:chaconine ratio has also been observed in an earlier studies (Petersson et al. 2013a, Nahar et al. 2017). Both chaconine and solanine are synthesised from solanidine. SGT2 is initiates chaconine synthesis, whereas SGT1 is involved in initiation of solanine synthesis (McCue et al. 2007). The light-induced ratio shift might indicate that SGT1 is activated more by light than SGT2 1 (Nahar et al. 2017), and an increased solanine:chaconine ratio can be thus used as an indication of light exposure in the same way as tuber greening. The solanine:chaconine ratio did not significantly differ between tubers from retail, and tubers grown outdoors, which also supports the conclusion that the retail samples most likely had not been subjected to light. This indicates that the tubers from retail have been handled appropriately.

5.4. Practical use of results

The results from this study suggest that tubers from retail do not contain levels of TGA that are harmful for humans according to the limit of 200 mg/kg. This suggests that the routines that producers of potatoes and stores are following protects potatoes from developing high levels of glycoalkaloids.

5.5. Limitations with this study

In this study there were 57 samples from 14 different cultivars for the tubers from retail stores but only 7 samples from the tubers grown in year 2020 in outdoor conditions. In a wider study there would have been more samples from tubers grown outdoor to be able to verify the results. It would also have been desirable that these tubers should have been grown in an open field by a potato farmer and analysed right after harvest to make it more representative of the potato industry. In a wider study it would also be feasible to purchase a larger number of tubers from stores from different kinds of packaging since in this study, no value above 200 mg/kg was detected. To be able to compare different cultivars more accurately, more samples of each cultivar should also have been purchased. It would also be of interest to analyse samples from retails stores over the year, to see if the glycoalkaloid levels vary over the season.

The variation in SGAs depending on different conditions in different years has not been evaluated in this study.

5.6. Further studies

Since potatoes are such an important food crop around the world (McCue et al. 2011) further studies should be made to investigate the glycoalkaloid levels in potatoes and factors that affect them.

The Swedish Food Agency (Livsmedelsverket 2020) recommends to remove green or damaged parts before consumption of potato tubers. An experiment related to this could be to investigate how the glycoalkaloids are distributed in the tubers when exposed to light or wounding. Are there more glycoalkaloids accumulated near the greening or wounded part or is it present in the whole tuber?

In this study, only the levels of glycoalkaloids in 57 samples of retail potatoes were investigated. More extensive studies on retail potatoes are necessary to confirm or reject these results. Results from the present study indicated that the occurrence of tuber batches with high SGA levels is very low under retail conditions (less than 1 in 50; or below 2 %). Future attempts to monitor SGA levels in table potatoes will thus need to be designed accordingly and include sample numbers well above the 50 used here, to be able to detect a high-SGA sample with reasonable probability.

Further studies could also investigate the whole chain from harvest to the consumers refrigerators. Is there anywhere there is a potential risk for glycoalkaloids levels to increase above 200 mg/kg? And what are TGA levels at the time of consumption?

6. Conclusion

In this study there were no signs that retail potatoes might be harmful to ingest. However, the results showed that some cultivars were more prone to develop higher levels of glycoalkaloids when subjected to light. This knowledge might be taken into consideration in the entire transport chain from farmers to consumers.

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Without my wonderful husband's support, this master thesis would never have been finished. Thank you.

Appendix 1

Table 6. Level of chaconine, solanine, TGA, and solanine:chaconine ratio (s/c) in all tuber batches obtained from retail stores. Each sample consisted of four pooled tubers.

Subject ID	Treatment	Chaconine (mg/kg)	Solanine (mg/kg)	TGA	s/c
Antonia	Paperbag	9,0	5,1	14,1	0,570
Asterix	Paperbag	49,0	33,0	82,0	0,673
Baby Lou	Transparent bag	22,6	12,5	35,1	0,553
Ballerina	Paperbag	36,0	15,6	51,6	0,433
Ballerina	Paperbag	23,5	11,4	34,9	0,483
Ballerina	Paperbag	25,3	12,2	37,5	0,483
Ballerina	Transparent bag	21,3	10,2	31,5	0,478
Ballerina	Transparent bag	30,5	12,2	42,7	0,402
Ballerina	Transparent bag	24,8	9,8	34,5	0,394
Ballerina	Transparent bag	21,7	10,8	32,4	0,497
Ballerina	Transparent bag	35,9	17,4	53,3	0,484
Bintje	Transparent bag	38,4	20,1	58,6	0,524
Challenger	Transparent bag	19,4	7,3	26,6	0,375
Challenger	Transparent bag	25,0	8,9	33,9	0,357
Connect	Paperbag	38,9	20,3	59,1	0,521
Connect	Transparent bag	24,8	14,9	39,6	0,601
Connect	Transparent bag	32,7	18,1	50,7	0,553
Gala	Bulk	9,3	7,9	17,3	0,850
Gala	Bulk	9,9	7,7	17,6	0,781
Gala	Bulk	22,3	21,4	43,7	0,957
Gala	Paperbag	14,1	12,0	26,0	0,851
Gala	Paperbag	16,1	13,9	30,0	0,863
Gala	Paperbag	13,1	10,6	23,8	0,809
Gala	Paperbag	16,1	12,3	28,4	0,763
Gala	Transparent bag	10,9	8,5	19,4	0,783
Gala	Transparent bag	15,6	11,3	26,9	0,722
Gala	Transparent bag	10,5	8,4	18,9	0,798
Gala	Transparent bag	18,6	25,7	44,3	1,381
Gala	Transparent bag	20,0	14,2	34,3	0,709

Gala	Transparent bag	15,6	12,7	28,3	0,814
Gala	Transparent bag	11,6	10,1	21,6	0,870
Inova	Bulk	21,3	10,5	31,7	0,492
Inova	Transparent bag	39,1	20,2	59,3	0,517
Inova	Transparent bag	29,0	14,9	43,8	0,513
Jelly	Transparent bag	18,8	11,0	29,8	0,584
King Edward	Bulk	18,0	9,0	26,9	0,499
King Edward	Bulk	19,8	12,8	32,6	0,647
King Edward	Bulk	11,7	6,5	18,2	0,552
King Edward	Bulk	16,2	8,0	24,2	0,491
King Edward	Bulk	32,2	16,7	48,8	0,518
King Edward	Paperbag	15,4	7,1	22,6	0,461
King Edward	Paperbag	14,4	7,1	21,5	0,491
King Edward	Paperbag	16,3	8,1	24,4	0,500
King Edward	Paperbag	17,6	11,8	29,4	0,667
King Edward	Paperbag	28,5	16,2	44,7	0,568
King Edward	Paperbag	24,1	12,0	36,1	0,500
King Edward	Paperbag	23,7	12,9	36,6	0,543
King Edward	Transparent bag	21,9	11,6	33,5	0,528
King Edward	Transparent bag	21,3	12,0	33,2	0,564
Melody	Transparent bag	13,5	7,8	21,4	0,580
Solist	Bulk	7,2	4,1	11,3	0,563
Solist	Paperbag	7,1	3,6	10,7	0,516
Solist	Paperbag	7,3	3,8	11,2	0,520
Solist	Transparent bag	12,0	6,6	18,7	0,551
Solist	Transparent bag	18,5	10,7	29,2	0,576
Solist	Transparent bag	10,8	6,3	17,1	0,581
Sunshine	Bulk	24,2	17,9	42,1	0,742

Table 7. Mean TGA values all cultivars from retail stores

	Chaconine (mg/kg)	**Solanine (mg/kg)**	**TGA**	**s/c**
Antonia	9,0	5,1	14,1	0,570
Asterix	49,0	33,0	82,0	0,673
Baby Lou	22,6	12,5	35,1	0,553
Ballerina	27,4	12,4	39,8	0,457

Bintje	38,4	20,1	58,6	0,524
Challenger	22,2	8,1	30,3	0,366
Connect	32,1	17,7	49,8	0,559
Gala	14,6	12,6	27,2	0,854
Inova	29,8	15,2	45,0	0,507
Jelly	18,8	11,0	29,8	0,584
King Edward	20,1	10,8	30,9	0,538
Melody	13,5	7,8	21,4	0,580
Solist	10,5	5,8	16,3	0,551
Sunshine	24,2	17,9	42,1	0,742

Table 8. Mean TGA values at harvest of tubers obtained from outdoor cultivation in large plastic pots

	Chaconine (mg/kg)	**Solanine (mg/kg)**	**TGA**	**s/c**
Asterix	46,9	28,1	75,0	0,599
Bintje	33,3	20,7	54,0	0,621
King Edward	13,5	6,7	20,2	0,504
Maris Bard	12,0	10,9	22,9	0,906
Princess	19,8	9,9	29,7	0,502
Rocket	7,2	5,2	12,4	0,713
Solist	14,7	9,4	24,1	0,641

Table 9. Mean TGA values in tubers after light exposure for 48 hours.

	Chaconine (mg/kg)	**Solanine (mg/kg)**	**TGA**	**s/c**
Asterix	40,6	25,7	66,4	0,633
Bintje	42,7	31,8	74,5	0,746
King Edward	21,3	12,6	33,9	0,594

Table 10. Mean TGA values in tubers after light exposure for 8 days.

	Chaconine (mg/kg)	Solanine (mg/kg)	TGA	s/c
Asterix	228,0	198,8	426,7	0,872
Bintje	72,4	153,7	226,1	2,122
King Edward	51,0	96,6	147,6	1,896
Maris Bard	55,8	117,1	172,8	2,100
Princess	172,5	268,0	440,5	1,554
Rocket	94,2	210,7	304,9	2,236
Solist	156,3	237,1	393,4	1,517

Table 11. Measurements of chaconine, solanine and TGA contents in tubers grown in outdoor conditions as well as the solanine to chaconine ratio.

	Chaconine (mg/kg)	Solanine (mg/kg)	TGA (mg/kg)	s/c
Mean value	24,1	14,6	38,8	0,6
Standard deviation	14,9	9,0	23,7	0,1
Standard deviation %	61,7	61,2		

Table 12. Measurements of chaconine, solanine and TGA contents in tubers from retail as well as the solanine to chaconine ratio.

	Chaconine (mg/kg)	Solanine (mg/kg)	TGA (mg/kg)	s/c
Mean value	20,6	12,0	32,6	0,6
Standard deviation	9,2	5,4	13,9	0,2
Standard deviation %	44,7	45,2		

Table 13. Measurements of chaconine, solanine and TGA contents in tubers exposed to light for 48 hours as well as the solanine to chaconine ratio.

	Chaconine (mg/kg)	Solanine (mg/kg)	TGA (mg/kg)	s/c
Mean value	34,9	23,4	58,3	0,7
Standard deviation	11,8	9,8	21,5	0,1
Standard deviation %	33,9	41,9		

Table 14. Measurements of chaconine, solanine and TGA contents in tubers exposed to light for 8 days as well as the solanine to chaconine ratio.

	Chaconine (mg/kg)	**Solanine (mg/kg)**	**TGA (mg/kg)**	**s/c**
Mean value	118,6	183,1	301,7	1,8
Standard deviation	67,7	63,0	122,1	0,5
Standard deviation %	57,1	34,4		

	Chaconine (mg/kg)	**Solanine (mg/kg)**	**TGA (mg/kg)**	
Mean value	24,2	13,8	38,0	
Standard deviation	11,2	7,1	17,9	
Standard deviation %	46,3	51,3	47,2	

	Chaconine (mg/kg)	**Solanine (mg/kg)**	**TGA (mg/kg)**	
Mean value	24,2	13,8	38,0	
Standard deviation	11,2	7,1	17,9	

Mean s/c ratio = mean value of the α-solanine/ α-chaconine ratio

Sammanfattning

Potatis är en av världens viktigaste grödor som odlas som livsmedel och är rik på en rad näringsämnen så som stärkelse, C-vitamin och mineraler. Potatis innehåller inte bara nyttigheter utan även glykoalkaloider vilket kan vara giftigt om man får i sig en stor mängd. Symptom på att man har fått i sig för stora mängder glykoalkaloider kan vara kräkningar, diarré och illamående. Det finns fall där personer har fått i sig så mycket glykoalkaloider att de har hamnat i koma, drabbats av förlamning och det exempel på att människor har dött av stora mängder glykoalkaloider. Potatis är del av familjen *Solanaceae* och flera andra grödor i samma familj innehåller glykoalkaloider, till exempel tomat, aubergine och spanskpeppar. Glykoalkaloider finns också i vissa medlemmar i familjen liljeväxter. Mängden glykoalkaloider i potatis vid skörd varierar mellan olika sorter och kan sedan öka om knölarna utsätts för stress som ljusexponering och/eller skada. För att undvika problem med glykoalkaloider finns det i många länder en högsta rekommenderade dos på 200 mg/kg (färsk vikt) glykoalkaloider som potatis får innehålla. I Sverige finns denna gräns och den får inte överstigas enligt lag.

I den här studien undersöktes mängden glykoalkaloider i olika vanligt förekommande potatissorter. Potatisen som undersöktes köptes antingen in från olika butiker i Uppsalaområdet eller odlades utomhus i krukor på Ultuna. Resultatet visade att glykoalkaloidnivån varierade mellan olika potatissorter vid skörd och att inga av de över 50 inköpta potatisarna hade nivåer över 200 mg/kg.