Journal of Nutrition and Food Security
Shahid Sadoughi University of Medical Sciences
School of Public Health
Department of Nutrition
Nutrition & Food Security Research Center

eISSN: 2476-7425 pISSN: 2476-7417 JNFS 2022; 7(4): 512-524 Website: jnfs.ssu.ac.ir

Toxicological Effects on Selected Tissues of Rats Fed Glycoalkaloid-Rich and Light-Exposed *Solanum Tuberosum*

Ayodeji Oluwafemi Idowu; PhD*[1], Aduke Oluremi Saliu; PhD[2], Babamotemi Oluwasola Itakorode; PhD[1], Cecilia Nireti Fakorede; PhD[3] & Rotimi Olusanya Arise; PhD[4]

[1] Department of Biochemistry, College of Basic Medical Sciences, Federal University of Health Sciences, Otukpo, Benue State, Nigeria; [2] Department of Environmental Health Science, School of Health Sciences, National Open University of Nigeria (NOUN), Abuja, Nigeria; [3] Department of Microbiology, College of Natural and Applied Sciences, Oduduwa University, P.M.B. 5533, Ile-Ife, Osun State, Nigeria; [4] Department of Biochemistry, School of Life Sciences, University of Ilorin, P.M.B 1515, Ilorin, Kwara State, Nigeria.

ARTICLE INFO

ORIGINAL ARTICLE

Article history:
Received:2 Jun 2021
Revised: 26 Sep 2021
Accepted: 20 Oct 2021

Corresponding author:
id4phemy@gmail.com
Department of Biochemistry, College of Basic Medical Sciences, Federal University of Health Sciences, Otukpo, Benue State, Nigeria.

Postal code: 972261
Tel: +23 47062701307

ABSTRACT

Background: Exposure of potato tubers to light causes accumulation of glycioalkaloids in the tubers and overdose of glycoalkaoids are associated with some toxicity. This study aims to investigate the effect of consuming sunlight exposed tubers of Irish potato on some selected tissues of rats. **Methods:** Freshly harvested tubers of *Solnum tuberosum* were purchased from a farmland and were randomly grouped into five groups. Groups 1- 4 consisted of tubers exposed to sunlight (including visible and invisible light e.g. ultraviolet) for a period of 1, 2, 3, and 4 week(s), respectively, while group 5 served as the control and consisted of freshly harvested tubers of Irish potato that have not been exposed to sunlight. The glycoalkaloids content was determined in both the non-exposed (control) and sunlight exposed tubers. Thereafter the tubers were formulated as diet and administered to rats. Biochemical analyses on serum lipid profile, enzymes of selected tissues (serum, liver, and kidney) and lipid peroxidation were carried out. **Results:** The results showed that the total glycoalkaloids content of the exposed sunlight groups (230, 250, 270, and 300 mg/kg fresh weight, respectively) significantly increased compared to the control group (100 mg/kg fresh weight). A significant reduction ($P < 0.05$) in activities of alanine aminotransferase, aspartate aminotransferase and a significant upsurge ($P < 0.05$) in alkaline phosphatase activity was observed in the selected tissues of sunlight-exposed potato tuber animal groups compared to the (non-exposed) group. Lipid peroxidation assessment revealed a significant upsurge ($P < 0.05$) in malondialdehyde formation and a mild alteration in serum lipid profile. **Conclusion:** The study concluded that consumption of sunlight exposed *Solanum tuberosum* tubers may pose a threat on vital organs of the body irrespective of duration of exposure.

Keywords: *Solanum tuberosum; Glycoalkaloids; Alanine aminotransferase; Aspartate aminotransferase; Lipid peroxidation*

Introduction

Potatoes (*Solanum tuberosum*) are herbaceous perennial plants without roots belonging to the plant family *Solanancae*, which also includes tomatoes, egg plants, and peppers. Potato is a

This paper should be cited as: Oluwafemi Idowu A, Oluremi Saliu A, Oluwasola Itakorode B, Nireti Fakorede C, Rotimi Arise O. ***Toxicological Effects on Selected Tissues of Rats Fed Glycoalkaloid-Rich and Light-Exposed Solanum Tuberosum.*** *Journal of Nutrition and Food Security (JNFS)*, 2022; 7(4): 512-524.

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]
[DOR: 20.1001.1.24767417.2022.7.4.6.1]
[DOI: 10.18502/jnfs.v7i4.11062]

widely consumed food crop in Europe, South-America, and Africa as vegetables and source of carbohydrates (Sukrasno and Kusmardiyani, 2014). Potatoes are also sometimes called "Irish potatoes" to distinguish them from sweet potatoes (Turner and Molyneaux, 2004). There are over 100 varieties of potatoes worldwide belonging to eight or nine species, one of which is the "Irish potato". There are also genetically modified varieties used for industrial purposes. Potatoes are rich in nutrients, such as carbohydrates, proteins, minerals (K, Na, P, Fe, Zn), and vitamins, such as vitamin B_1, vitamin B_2, vitamin B_3, vitamin B_6, vitamin B_9, vitamin C (Beals, 2019, Freedman and Keast, 2012, McGill *et al.*, 2013), as well as different phytochemicals like carotenoids and natural phenols, viz. chlorogenic acids (4-O-caffeoylquinic, 5-O- caffeoylquinic, 3,4-dia caffeoylquinic, and 3,5-dia caffeoylquinic acids (Friedman *et al.*, 1997). These nutrients seem to be predominantly present between the flesh and skin. Nutritionally, *Solanum tuberosum* (*S. tuberosum)* is well known for its carbohydrate-rich content (Murniece *et al.*, 2011) and the abundant type of the carbohydrate found in potatoes is starch (Adeyeye and Akingbala, 2014). This starch is not easily hydrolyzed in the gastrointestinal tract by digestive enzymes thus are regarded as resistant starch. This resistant starch is reported to show close functional role like fiber, since it provides bulk, protect against cancer of the colon, enhances glucose tolerance and sensitivity of body cells to insulin, and reduces plasma cholesterol level as well as the storage of fat (Hylla *et al.*, 1998). Despite these nutritional values, potatoes contain toxic compounds called glycoalkaloids (Friedman, 2015, Ostrý *et al.*, 2010). Glycoalkaloids are a group of nitrogen-containing compound having a molecule of sugar moiety and an alkaloid. Alpha solanine and alpha chaconine are the predominant forms of glycoalkaloids found in *S. tuberosum*. Glycoalkaloids are produced naturally in potatoes to defend them against insects, pests, pathogens like fungi, bacteria, etc. and also to give flavor to the potatoes. The concentration of glycoalkaloids in potato varies among species and plant parts; flowers have the highest concentration, following by leaves, shoots, roots, stems, and tubers (Friedman and Dao, 1992, Jadhav and Salunkhe, 1975). Glycoalkaloids can accumulate in potato owing to a number of factors, including weather, light exposure, mechanical injury, aging, storage conditions, and sprouting (Friedman *et al.*, 1997). In potatoes, glycoalkaloids concentration of 200 mg/kg fresh potatoes is considered safe for consumption (Friedman and Levin, 2009, Friedman *et al.*, 1997, Mensinga *et al.*, 2005, Şengül *et al.*, 2004). High dose of glycoalkaloids gives a bitter taste, produces a burning irritation, and is toxic to the body system (Gregory *et al.*, 1981, Percival, 1999). The symptoms associated with toxicity of glycoalkaloids include gastrointestinal disorders, such as nausea, diarrhea, vomiting, and stomach cramps, as well as neurological disorders, such as headache and dizziness, while in severe cases, can cause coma and death. Once glycoalkaloids are formed, they are not totally destroyed even by cooking or storage in the dark (Edwards *et al.*, 1998, Friedman *et al.*, 2003). Among all the factors that contribute to the accumulation of glycoalkaloids in potato, light exposure is the most widely acknowledged cause of glycoalkaloids accumulation (Friedman *et al.*, 1997, Percival, 1999), which can take place during packing, storage, and processing of the potato.

In Nigeria, farmers are faced with storage challenges of farm products, including Irish potatoes. The potato tubers sold in most markets by sellers are usually exposed to sunlight (consisting of visible light and invisible light e.g. UV) for a long period to prevent them from spoilage due to absence or poor storage facilities before selling. It could result in the accumulation of glycoalkaloids in the tubers, since post-harvest exposure of potatoes to light dramatically promotes the synthesis of glycoalkaoids in potatoes, thus creating food safety problems for consumers. Therefore, the current study aims to investigate the effects of consuming *S. tuberosum* tubers exposed to light.

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]
[DOR: 20.1001.1.24767417.2022.7.4.6.1]
[DOI: 10.18502/jnfs.v7i4.11062]

Materials and Methods

Collection and exposure of potato tubers to sunlight: One hundred and fifty freshly harvested tubers of *S. tuberosum* were purchased from a farmland around Mid-October 2018 in Jos, Plateau State, North-Central, Nigeria. They were rinsed under running tap water to remove dirt particles and were grouped into five groups of thirty tubers. The tubers in groups 1-4 were placed in different trays and exposed to sunlight, consisting of visible and invisible light (e.g. ultraviolet) for 5 hours a day during a period of 1-4 week(s). In this period, they were rotated at intervals in the tray to ensure complete exposure to sunlight. Group 5 represented the control group consisting of non-exposed/freshly harvested tubers.

Drying of sample: The sunlight-exposed and non-exposed potato tubers (control) were chopped and oven dried at 60 ^{o}C following the duration of exposure to sunlight (week 1, 2, 3, and 4 respectively). The dried *S. tuberosum* tuber samples were milled into fine powder using a mechanical blender and used as a source of carbohydrate to formulate diet (**Appendix Table 3**); thereafter it was administered to rats.

Extraction of glycoalkaloids: Glycoalkaloids of both the freshly harvested (non-exposed) tubers and the sunlight exposed tubers was extracted using a standard method in a shake extraction as described by AOAC (Association of Official Analytical Chemists, 2000). Then, 100 g of dried-powder sample of *S. tuberosum* was weighed using an analytical weighing balance into the extracting medium (containing 60% acetonitrile in 0.4 M acetic acid (v/v) with 1 $mgcm^{-3}$ sodium bisulphate). The mixture in the extracting medium was shaken continuously for 24 h to get an optimal extract. Bisulphate was added during extraction to prevent loss of glycoalkaloids by oxidation.

Purification of glycoalkaloids: The glycoalkaloids was purified by precipitating with aqueous ammonia (NH_4OH) at pH 10 (Bushway *et al.*, 1988). Then, 75 ml of the extract mixture was measured from the extracting medium into a beaker and 100 ml of ammonium hydroxide was added to precipitate the glycoalkaloids from other matrixes in the extract. The precipitate was decanted leaving behind glycoalkaloids which was evaporated to dryness using a water bath.

Quantification of glycoalkaloids: Prior to precipitating out the glycolakaloids from the mixture, an empty beaker was weighed. The beaker was weighed again following the precipitation of the glycoakaloids. The amount of glycoalkolids in each group of potato sample was calculated using the expression:

$W_2 - W_1$

W_2 = weight of beaker containing dry glycoalkaloids isolate

W_1 = Weight of empty beaker

Experimental rats and chemicals: Twenty five albino rats (*Rattus novergicus*) with mean weight of 125 ± 0.25 g were bred in the Animal House at the Department of Biochemistry, University of Ilorin, Kwara State, Nigeria. Assay kits for serum lipid profile and enzyme analysis (alkaline phosphatase, alanine, and aspartate transaminase) were products of Randox Laboratories Antrim, United Kingdom. All other chemicals used were of standard quality.

Animal grouping, care, and feed administration: Rats were randomly divided into 5 treatment groups (1-5) consisting of five rats in each group and were fed formulated diet of *S. tuberosum* tubers for 30 days as described below:

Group 1 rats received diet formulated from sunlight exposed tubers of *S. tuberosum* for one week.

Group 2 rats received diet formulated from sunlight exposed tubers of *S. tuberosum* for two weeks.

Group 3 rats received diet formulated from sunlight exposed tubers of *S. tuberosum* for three weeks.

Group 4 rats received diet formulated from sunlight exposed tubers of *S. tuberosum* for four weeks.

Group 5 rats received diet formulated from non-exposed tubers (control group).

The experimental rats were cared for according

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24767417.2022.7.4.6.1]
[DOI: 10.18502/jnfs.v7i4.11062]

to the international instruction for the care and use of laboratory animals as enlisted by National Research Council (1996) and were caged under the required laboratory conditions. They were fed with commercial pellet and given enough water throughout the duration of the experiment. The University of Ilorin ethical committee on the use of experimental animals gave the ethical approval for the animal protocol.

Tissue homogenates and serum preparation: After administration of the formulated diet for 30 days, animals were anesthetized with diethyl ether. Venous blood was collected by adopting the procedure of collecting blood into blood sample bottles (Narayanan *et al.*, 1984). The blood in the bottles was allowed to clot and then span at 3000 revolution/minutes for 5 minutes and the supernatant was collected thereafter as described by Ogbu *et al* (Ogbu and Okechukwu, 2001). The rats were then sacrificed and the liver, kidney, heart, and intestine were removed. They were placed in 0.25 mol/dm^3 sucrose solution (1:5 $^{w/v}$) in the refrigerator, homogenized, and centrifuged. The supernatants were preserved in the refrigerator until further use for biochemical analysis (Ngaha *et al.*, 1989).

Assay of biochemical indices: Alkaline phosphatase (ALP) activity was measured by the procedure of Ahmed (Ahmed and King, 1960) while alanine transaminase (ALT) and aspartate transaminase (AST) activities were measured using the procedure of others (Reitman and Frankel, 1957, Varshney and Kale, 1990). The method for estimation of malondialdehyde (MDA) level was employed to determine lipid peroxidation. The total cholesterol (TC), triglyceride (TG), high density lipoprotein cholesterol (HDL-c), concentrations for serum lipid profile were determined by adopting the procedure highlighted by Assmann (Assmann *et al.*, 1984). Low density lipoprotein cholesterol (LDL-c) concentration was calculated from Friedewald's equation (Friedewald *et al.*, 1972).

Data analysis: All experimental assays were conducted in triplicate. The mean and standard error of mean values were estimated using GraphPad (version 6.01; Prism 6 for Windows) software.

Results

The glycoalkaloids contents of the light exposed and non-exposed *S. tuberosum* tubers are depicted in **Table 1**. The results showed that accumulation of glycoalkaloids in the potato tubers of group(s) 1, 2, 3, and 4 was time-duration dependent on sunlight exposure. This means that concentration of glycolalkloids in the tubers increased as the duration of exposure of the tubers to sunlight lengthened. The highest glycoalkaloids content (300 mg/kg body weight) was recorded in tubers exposed to sunlight for four weeks (Group 4), followed by tubers exposed for three weeks (Group 3, 270 mg/kg body weight) and then by tubers exposed for two weeks (Group 2, 250 mg/kg body weight). However, the tubers exposed to sunlight for 7 days recorded the least glycoalkaloids content (Group 1, 230 mg/kg body weight) compared to the non-exposed tubers (control) which showed 100 mg/kg body weight of glycoalkloids, a value lower than what was recorded for all exposed tubers.

The effect of the administration of diet formulated with exposed tubers of *S. tuberosum* to sunlight on serum lipid profile (TC, TG, HDL-c, and LDL-c) of rats is depicted in **Table 2**. There was a significant increase ($P < 0.05$) in the TC level of rats administered the formulated diet of *S. tuberosum* tubers exposed to light in all the test groups irrespective of the duration or length of exposure to sunlight compared to the control (non-exposed tubers). The concentration of TG significantly dropped in the serum of rats in groups 1, 3, and 4 in comparison to the control. On the other hand, serum LDL-c and HDL-c concentrations significantly ($P < 0.05$) increased in the entire test groups fed with formulated diet of the sunlight exposed tubers. However, the significant increase ($P < 0.05$) observed in HDL-c value was time-dependent with respect to duration of sunlight exposure.

A significant increase ($P < 0.05$) in MDA level

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]
[DOR: 20.1001.1.24767417.2022.7.4.6.1]
[DOI: 10.18502/jnfs.v7i4.11062]

was observed in all the selected organs (liver, kidney, heart, and intestine) of rats in group 1 compared to the control group (**Figure 1**). Conversely, the production of MDA significantly ($P < 0.0$) decreased in all the selected organs of rats in other groups of 2, 3, and 4 compared to the control group (**Figure 1**). **Figures 2-4** depicts the effect of consuming light exposed *S. tuberosum* tubers on enzyme activities in rat tissues. The administration of the formulated diet of light exposed tubers of *S. tuberosum* caused a significant marked increase ($P < 0.05$) in ALP activity of all the selected organs studied in groups 1-4 compared to the control group. The increase observed in ALP activity in the selected organs resulted in a concomitant decrease of ALP activity in the serum of groups 2 and 4. However, this activity was not significantly ($P > 0.05$) different in the serum of groups 1 and 3 compared to the control group (**Figure 2**). Activity of ALT decreased significantly ($P < 0.05$) in the selected organs (liver, kidney, heart, and intestine) of all the test groups in comparison with the control. The decrease of ALT activity observed in the selected organs of rats in all the sunlight exposed groups resulted in a concomitant decrease ($P > 0.05$) in serum ALT activity rats fed with the sunlight exposed tubers groups compared to the control (**Figure 3**). It was noticed that the activity of AST decreased significantly ($P < 0.05$) in liver, kidney, and heart of the entire test groups compared to the control (group administered diet formulated with non-exposed tubers). The decrease in activity of AST noticed in these organs resulted in an increase in AST activity in the serum of group 1 and group 2 rats compared to the control (**Figure 4**).

Table 1. Glycoalkaloids content of sunlight exposed tubers of *Solanum tuberosum*.

Groups	Glycoalkaloids content (mg/kg)
Control	100 ± 1.87
1	230 ± 1.67
2	250 ± 0.87
3	270 ± 1.27
4	300 ± 1.75

Group 1, 2, 3, and 4: Tubers exposed to sunlight for duration of one, two, three, and four week(s), respectively; Values are mean of three replicates ± SEM

Table 2. Serum lipid profile of rats administered diet formulated from sunlight exposed tubers of Solanum tuberosum.

Variables	Control	Group 1	Group 2	Group 3	Group 4
TC (mMol/l)	19.93 ± 0.38^{a}	21.22 ± 0.56^{b}	25.94 ± 0.50^{c}	22.99 ± 0.49^{b}	22.89 ± 0.33^{b}
TG (mMol/l)	11.73 ± 0.53^{a}	10.53 ± 0.48^{b}	11.35 ± 0.57^{a}	10.02 ± 0.35^{b}	10.04 ± 0.18^{b}
HDL-c (mMol/l)	10.44 ± 0.23^{a}	14.81 ± 0.81^{b}	11.53 ± 0.99^{c}	12.93 ± 0.57^{d}	13.24 ± 0.54^{e}
LDL-c (mMol/l)	3.01 ± 0.07^{a}	3.57 ± 0.84^{b}	4.97 ± 0.68^{c}	4.90 ± 0.22^{c}	5.09 ± 0.24^{c}

TC: Cholesterol, **TG:** Triacyglycerol, **HDL-c:** High Density Lipoprotein, **LDL-c:** Low Density Lipoprotein, Values are mean of 5 replicates ± SEM, Values along the row with different superscripts are significantly different ($P < 0.05$).

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24767417.2022.7.4.6.1]
[DOI: 10.18502/jnfs.v7i4.11062]

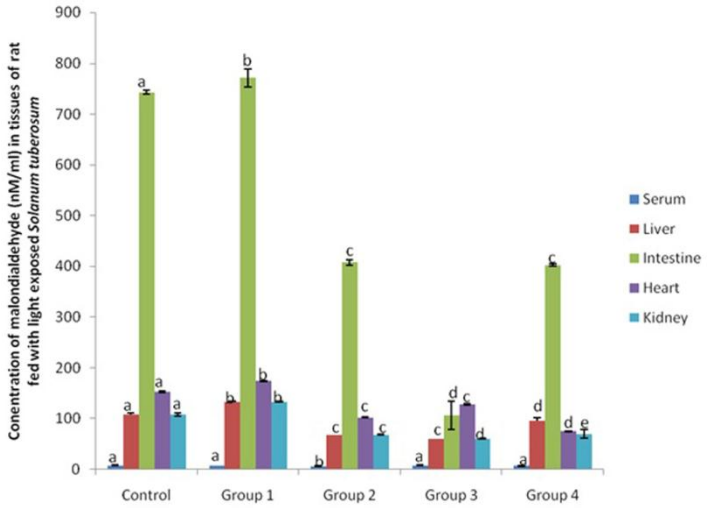


Figure 1. Concentration of malondialdehyde in the selected tissues of rats fed with formulated diet of sunlight exposed *Solanum tuberosum* tubers.
Values are mean of 5 replicates ± SEM. Values with different superscripts are significantly different ($P < 0.05$).

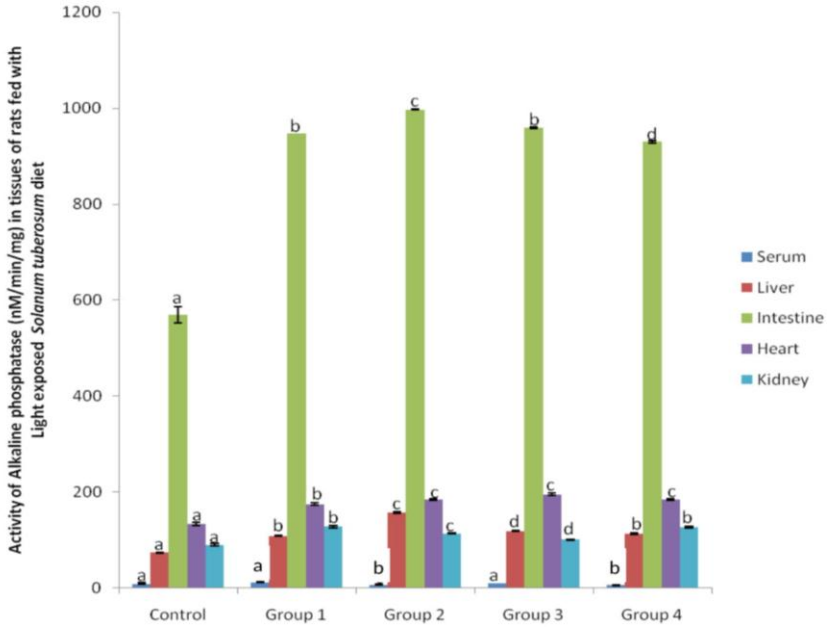


Figure 2. Activity of Alkaline phosphatase in the selected tissues of rats fed with formulated diet of sunlight exposed *Solanum tuberosum* tubers.
Values are mean of 5 replicates ± SEM. Values with different superscripts are significantly different ($P < 0.05$).

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]
[DOR: 20.1001.1.24767417.2022.7.4.6.1]
[DOI: 10.18502/jnfs.v7i4.11062]

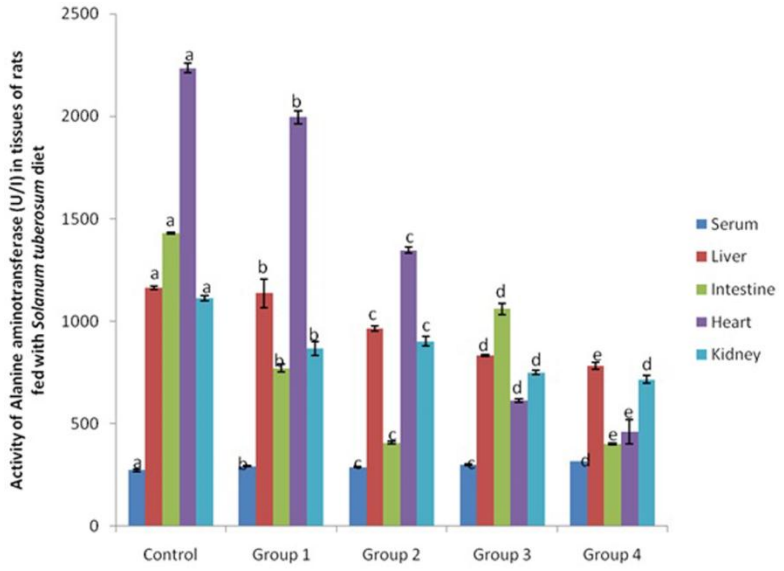


Figure 3. Activity of Alanine aminotransferase in the selected tissues of rats fed with formulated diet of sunlight exposed *Solanum tuberosum* tubers.
Values are mean of 5 replicates ± SEM. Values with different superscripts are significantly different ($P < 0.05$).

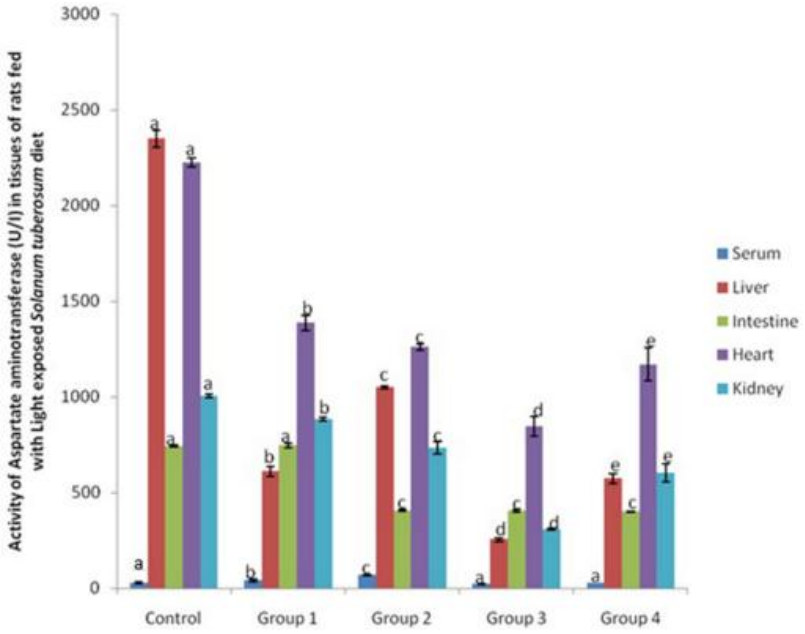


Figure 4. Activity of Alanine aminotransferase in the selected tissues of rats fed with formulated diet of sunlight exposed *Solanum tuberosum* tubers.
Values are mean of 5 replicates ± SEM. Values with different superscripts are significantly different ($P < 0.05$).

Discussion

In this study, only the non-exposed tubers of *S. tuberosum* contained glycoalkaloids content below the critical limit of 20 mg/100 g fresh weight, which is a concentration considered safe for consumption. The glycoalkaloids content of the sunlight-exposed tubers which was higher than the non-exposed (freshly harvested) tubers and was above the upper limit (200 mg/kg fresh weight), indicates that time or length of exposure of potato tubers to light affect glycoalkalods content. Although in this study, the intensity of the sunlight was not measured, it is

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]
[DOR: 20.1001.1.24767417.2022.7.4.6.1]
[DOI: 10.18502/jnfs.v7i4.11062]

possible that intensity of the sunlight in each day on the exposed tubers also contributes to the glycoalkoloids accumulation recorded in the exposed tubers. It has been reported that light intensity has a significant effect on the rate of glycoalkaloids accumulation in potatoes (Percival *et al.*, 1996). The glycoalkaloids content which increased significantly in a time-dependent manner upon exposure to sunlight in this study is in line with the study of Kasnsk *et. al* (Kasnak and Artik, 2018) who reported a time-dependent increase in glycoalkaloids content of two potato cultivars upon exposure to indirect sunlight. Additionally, the findings of the current study are in line with previous studies (Grunenfelder *et al.*, 2006, Percival, 1999, Rymuza *et al.*, 2020, Tanios *et al.*, 2018). They reported that exposure of potato tubers to natural light (e.g. sunlight) and artificial light (e.g. fluorescent and mercury light) accelerates glycoalkaloids content. The results showed that the total TG contents of the sunlight exposed tubers were higher than the non- exposed tubers to sunlight (freshly harvested). Further reports in literature indicate that light is an active elicitor of glycoalkaloids synthesis in potatoes (Dale *et al.*, 1993, Jadhav *et al.*, 1981). It is also possible that the illumination effect of ultraviolet and infrared light as components of sunlight act as elicitor factors contributing to the glycoalkaloids accumulation in this investigation. The exposure of potato tubers to mercury light, consisting of ultraviolet and infrared components of light like sunlight, also showed high TGA content in different cultivars (Percival, 1999). In the present study, TC level was significantly higher in the test groups consisting of rats administered the formulated diet of *S. tuberosum* tubers exposed to sunlight compared to the control. This increase observed in TC concentration suggests that the light exposed *S. tuberosum* formulated diet might have induced the activation of β-oxidation, thereby making acetyl coA readily available as a substrate for the biosynthesis of cholesterol. Thus, disease conditions like high blood pressure and heart diseases could arise. This observation also lends credence to the other study (Keukens *et al.*, 1996), in which they observed that glycoalkaloids selectively permeabilized cholesterol containing biomembranes. TG is the principal storage form of fats in mammals playing a central role in regulating lipoprotein interactions to maintain lipid metabolism. The significant fall in TG level (**Table 2**) following the administration of the diet formulated with tubers of *S. tuberosum* after exposure to sunlight in the test groups could be attributed to the inhibitory effect of glycoalkaloids. It was higher in the groups administered diet formulated with the light-exposed tubers on lipolytic enzymes resulting in depletion in the storage of fatty acids, so that they were not converted to TG. Glycolakaloids are known to inhibit a wide range of metabolic enzymes, including those involved in digestion and neurotransmission (Gultekin *et al.*, 2000). LDL-c is the primary carrier of plasma cholesterol. LDL-c is called the bad cholesterol because it accumulates gradually in the arteries, since it transports cholesterol from the hepatocytes to the peripheral tissues and cells of the body, where it breaks away from the lipoprotein and utilized by the cells. Cholesterol attached to low density lipoproteins is mainly the one that accumulates in atherosclerotic deposits in the blood vessels. This is due to the fact that low density lipoproteins enter the arterial wall and combine with reactive oxygen species to form oxidized low density lipoproteins. They cannot be destroyed by white blood cells, but instead deposit in the artery, resulting in hardening of the arteries and subsequent cardiac attack (Kunitomo, 2007). A significant increase observed in LDL-c value following the administration of the formulated diet of sunlight exposed *S. tuberosum* tubers may possibly support the chances of developing heart disease. It could be due to the fact that high levels of bad cholesterol (LDL-c) play a role in in the development of cardiovascular diseases. However, HDL-c is regarded as good cholesterol known to exhibit anti-atherogenic properties. It transports cholesterol from the tissues of the body to the hepatocytes, thus decreasing the concentration of cholesterol present in the tissues and the chances of developing atherosclerotic build-up. Since HDL-c removes cholesterol from the tissues, the increased

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]
[DOR: 20.1001.1.24767417.2022.7.4.6.1]
[DOI: 10.18502/jnfs.v7i4.11062]

HDL-c in the present study suggests that the increased HDL-c level may be appropriate for the upsurge levels of LDL-c, TG, and TC in this study. It could impede atherosclerotic build-up and subsequently cardiovascular diseases (Gordon *et al.*, 1977). It has been established that high HDL-c level correlates inversely with coronary heart disease (Philip, 1994), impedes atherosclerotic build-up, and subsequently reduces the risk of developing cardiovascular disease (Gordon *et al.*, 1977).

MDA is employed as an indicator to assess the degree of oxidative stress in living organism. Oxidative stress, which induces protein, DNA, cell, and damaged tissues, is caused by reactive oxygen species which penetrate the cell membranes and deteriorate the lipid components of the membrane. MDA formation which increased significantly in all the selected organs of rats could imply that the administered diet increased localized oxygen generation or generation of reactive oxygen species which induced oxidative stress resulting in the damage of the organs via lipid peroxidation. Measuring the activities of bio-marker enzymes in tissues and extracellular compartment is an important and commonly known method in disease investigation and diagnosis (Malomo, 2000, Oloyede and Sunmonu, 2008). Such measurement is used to infer damage or assault on organs caused by drugs or other chemical agents. ALP, ALT, and AST are biomarker enzymes measured routinely for the diagnosis of tissues disease (e.g. liver disease), monitor therapy; assess disease course and prognosis of patients with tissue diseases. ALP is employed to checkmate the functionality of the cell membrane and endoplasmic reticulum of tissues (Akanji *et al.*, 1993, Wright and Plummer, 1974). Phosphatases are needed in a particular proportion in tissues for adequate organs functioning. However, their high doses constitute a threat to the living cells whose activities depends on phosphate esters, since they are capable of hydrolyzing orthophosphate monoesters in the organs (Butterworth and Moss, 1966). The observed increase in ALP activity in the liver, kidney, heart, and intestine of rats fed with light-exposed *S. tuberosum* diet in this study suggests that the diet might have caused the stimulation or activation of the enzyme (Akanji *et al.*, 1993). It may also be an indication of increased functional activity of the tissues causing the *de novo* synthesis of the enzyme in the selected tissues (Yakubu *et al.*, 2001). *De novo* production of enzymes like ALP has been reported in cancer and other diseases. Transaminases, such as ALT and AST are known to play a prominent role in degradation of amino acids as well as in providing necessary intermediates for gluconeogenesis. These enzymes are also used to infer cellular or tissue damages and hence are called biomarkers. The decrease observed in ALT activity in the selected organs of the test groups without a significant alteration of the enzyme activity in the serum may be an indication that the formulated diet of *S. tuberosum* tubers stored under sunlight containing glycoalkaloids caused the inhibition or inactivation of ALT *in situ* rather than altering the membrane permeability of the enzyme. It could cause the leakage of the enzyme into the extracellular fluids, since no corresponding alteration was noticed in ALT activity in the serum of the test groups. AST activity which significantly reduced in the liver, kidney, heart, and intestine with a corresponding significant increase in the serum of the animals may be an indication of altered membrane permeability or alteration of the organs integrity (Gee *et al.*, 1996, Wróblewski and Ladue, 1955) by glycoalkaloids resulting in leakage of AST from the studied organs into the serum. Glycoalkaloids have been proposed to be capable of disrupting cell membranes by forming complexes with cholesterols of the cell membrane (Keukens *et al.*, 1995). A study by observed a manifested change in membrane integrity of rats and human intestinal mucosal epithelial cells following their exposure to glycoalkaloids especially chaconine and solanine (Gee *et al.*, 1996). Normally, enzymes are found at low concentrations in the extracellular compartment, unless the organs are damaged as a result of assault on the organs by chemical agents or drugs or xenobiotics and therefore leakage of enzymes from the diseased tissues to serum could be manifested. A number of illnesses and death from consuming potatoes with higher

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]
[DOR: 20.1001.1.24767417.2022.7.4.6.1]
[DOI: 10.18502/jnfs.v7i4.11062]

glycoalkaloids concentration above the critical limit have been reported (Friedman *et al.*, 1997). Overall, the results from this study could be a valuable source of information for consumers as it shows that even a few days of exposure of Irish potato tubers to sunlight significantly increased the glycoalkaloids content above the recommended limit value and also demonstrated a significant effect on vital organs of the body.

Conclusion

In conclusion, the study revealed that exposure of Irish potato tubers to sunlight as a means of preservation by local sellers to avoid its spoilage could cause glycoalkoloids accumulation in the tubers and may pose threats on vital organs of the body of consumers. Thus the study recommends that exposure of *S. tuberosum* tubers as means of preservation among marketers should be discouraged.

Acknowledgements

The authors appreciate the Department of Plant Biology University of Ilorin for the assistant in authenticating the potato species and the Department of Zoology, University of Ilorin for helpful ethical and technical advice. Our gratitude also goes to the Animal handling units, Department of Biochemistry University of Ilorin, Kwara State, Nigeria who provided the experimental animals for the research.

Conflict of interest

The authors declare that there is no conflict of interest.

Idowu OA designed and conducted the research and also wrote the paper, Saliu OA provided the essential reagents and materials used for the research, Fakorede CN also conducted the research and collated the data from the study, Itakorode OB conducted the statistical analysis and Arise RO supervised the research and also did the proof reading of the paper. All authors have read and approved the final manuscript.

Financial assistance

This research did not receive any form of finance and the research was self-funded.

References

Adeyeye SA & Akingbala JO 2014. Evaluation of nutritional and sensory properties of cookies produced from sweet potato-maize flour blends. *Researcher*. **6 (9)**: 61-70.

Ahmed Z & King E 1960. Kinetics of placental alkaline phosphatase. *Biochimica et biophysica acta*. **45**: 581-592.

Akanji MA, Olagoke OA & Oloyede OB 1993. Effect of chronic consumption of metabisulphite on the integrity of the rat kidney cellular system. *Toxicology*. **81 (3)**: 173-179.

Assmann G, Jabs H-U, Kohnert U, Nolte W & Schriewer H 1984. LDL-cholesterol determination in blood serum following precipitation of LDL with polyvinylsulfate. *Clinica Chimica Acta*. **140 (1)**: 77-83.

Association of Official Analytical Chemists 2000. The Association of Official Analytical Chemists, Gaithersburg, MD, USA. Methods.

Beals KA 2019. Potatoes, nutrition and health. *American journal of potato research*. **96 (2)**: 102-110.

Bushway A, Bushway R & Kim C 1988. Isolaton, partial purification and characterization of a potato peel glycoalkaloid glycosidase. *American potato journal*. **65 (11)**: 621-631.

Butterworth P & Moss D 1966. Action of neuraminidase on human kidney alkaline phosphatase. *Nature*. **209 (5025)**: 805-806.

Dale M, Griffiths D, Bain H & Todd D 1993. Glycoalkaloid increase in Solarium tuberosum on exposure to light. *Annals of applied biology*. **123 (2)**: 411-418.

Edwards EJ, Saint RE & Cobb AH 1998. Is there a link between greening and light-enhanced glycoalkaloid accumulation in potato (Solanum tuberosumL) tubers? *Journal of the science of food and agriculture*. **76 (3)**: 327-333.

Freedman MR & Keast DR 2012. Potatoes, including French fries, contribute key nutrients to diets of US adults: NHANES 2003-2006. *Journal of nutritional therapeutics*. **1 (1)**: 1-11.

Friedewald WT, Levy RI & Fredrickson DS 1972. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24767417.2022.7.4.6.1]
[DOI: 10.18502/jnfs.v7i4.11062]

use of the preparative ultracentrifuge. *Clinical chemistry*. **18 (6)**: 499-502.

Friedman M 2015. Chemistry and anticarcinogenic mechanisms of glycoalkaloids produced by eggplants, potatoes, and tomatoes. *Journal of agricultural and food chemistry*. **63 (13)**: 3323-3337.

Friedman M & Dao L 1992. Distribution of glycoalkaloids in potato plants and commercial potato products. *Journal of agricultural and food chemistry*. **40 (3)**: 419-423.

Friedman M & Levin CE 2009. Analysis and biological activities of potato glycoalkaloids, calystegine alkaloids, phenolic compounds, and anthocyanins. In *Advances in potato chemistry and technology*, pp. 127-161. Elsevier.

Friedman M, McDonald GM & Filadelfi-Keszi M 1997. Potato glycoalkaloids: chemistry, analysis, safety, and plant physiology. *Critical reviews in plant sciences*. **16 (1)**: 55-132.

Friedman M, Roitman JN & Kozukue N 2003. Glycoalkaloid and calystegine contents of eight potato cultivars. *Journal of agricultural and food chemistry*. **51 (10)**: 2964-2973.

Gee J, et al. 1996. Effects of saponins and glycoalkaloids on the permeability and viability of mammalian intestinal cells and on the integrity of tissue preparations in vitro. *Toxicology in vitro*. **10 (2)**: 117-128.

Gordon T, Castelli WP, Hjortland MC, Kannel WB & Dawber TR 1977. High density lipoprotein as a protective factor against coronary heart disease: the Framingham Study. *American journal of medicine*. **62 (5)**: 707-714.

Gregory P, Sinden SL, Osman SF, Tingey WM & Chessin DA 1981. Glycoalkaloids of wild, tuber-bearing Solanum species. *Journal of agricultural and food chemistry*. **29 (6)**: 1212-1215.

Grunenfelder LA, Knowles LO, Hiller LK & Knowles NR 2006. Glycoalkaloid development during greening of fresh market potatoes (Solanum tuberosum L.). *Journal of agricultural and food chemistry*. **54 (16)**: 5847-5854.

Gultekin F, Ozturk M & Akdogan M 2000. The effect of organophosphate insecticide chlorpyrifos-ethyl on lipid peroxidation and antioxidant enzymes (in vitro). *Archives of toxicology*. **74 (9)**: 533-538.

Hylla S, et al. 1998. Effects of resistant starch on the colon in healthy volunteers: possible implications for cancer prevention. *American journal of clinical nutrition*. **67 (1)**: 136-142.

Jadhav S & Salunkhe D 1975. Formation and control of chlorophyll and glycoalkaloids in tubers of Solanum tuberosum L. and evaluation of glycoalkaloid toxicity. *Advances in food research*. **21**: 307-354.

Jadhav S, Sharma RP & Salunkhe D 1981. Naturally occurring toxic alkaloids in foods. *CRC critical reviews in toxicology*. **9 (1)**: 21-104.

Kasnak C & Artik N 2018. Change in some glycoalkaloids of potato under different storage regimes. *Potato research*. **61 (2)**: 183-193.

Keukens EA, et al. 1996. Glycoalkaloids selectively permeabilize cholesterol containing biomembranes. *Biochimica et Biophysica Acta (BBA)-Biomembranes*. **1279 (2)**: 243-250.

Keukens EA, et al. 1995. Molecular basis of glycoalkaloid induced membrane disruption. *Biochimica et Biophysica Acta (BBA)-Biomembranes*. **1240 (2)**: 216-228.

Kunitomo M 2007. Oxidative stress and atherosclerosis. *Journal of the pharmaceutical society of Japan*. **127 (12)**: 1997-2014.

Malomo S 2000. Toxicological implication of ceftriaxone administration in rats. *Nigerian journal of biochemistry and molecular biology*. **15 (1)**: 33-38.

McGill CR, Kurilich AC & Davignon J 2013. The role of potatoes and potato components in cardiometabolic health: a review. *Annals of medicine*. **45 (7)**: 467-473.

Mensinga TT, et al. 2005. Potato glycoalkaloids and adverse effects in humans: an ascending dose study. *Regulatory toxicology and pharmacology*. **41 (1)**: 66-72.

Murniece I, et al. 2011. Nutritional composition of freshly harvested and stored Latvian potato (Solanum tuberosum L.) varieties depending on

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24767417.2022.7.4.6.1]

[DOI: 10.18502/jnfs.v7i4.11062]

traditional cooking methods. *Journal of food composition and analysis.* **24 (4-5)**: 699-710.

Narayanan C, Joshi D & Mujumdar A 1984. Hypoglycemic action of Bougainvillea spectabilis leaves. *Current science.* **53 (11)**: 579-581.

Ngaha E, Akanji M & Madusolumuo M 1989. Studies on correlations between chloroquine-induced tissue damage and serum enzyme changes in the rat. *Experientia.* **45 (2)**: 143-146.

Ogbu S & Okechukwu E 2001. The effect of storage temperature prior to separation on plasma and serum potassium. *Journal of medical laboratory science.* **10**: 1-4.

Oloyede O & Sunmonu T 2008. Decrease in activities of selected rat liver enzymes following consumption of chemical effluent. *Journal of applied sciences and environmental management.* **12 (3)**.

Ostrý V, Ruprich J & Skarkova J 2010. Glycoalkaloids in potato tubers: the effect of peeling and cooking in salted water. *Acta alimentaria.* **39 (2)**: 130-135.

Percival G 1999. The influence of light upon glycoalkaloid and chlorophyll accumulation in potato tubers (Solanum tuberosum L.). *Plant science.* **145 (2)**: 99-107.

Percival G, Dixon GR & Sword A 1996. Glycoalkaloid concentration of potato tubers following exposure to daylight. *Journal of the science of food and agriculture.* **71 (1)**: 59-63.

Philip D 1994. Plasma enzymes in diagnosis In Clinical Chemistry in Diagnosis and Treatment. *European liquid biopsy society (ELBS).* **15**: 299-313.

Reitman S & Frankel S 1957. A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases. *American journal of clinical pathology.* **28 (1)**: 56-63.

Rymuza K, et al. 2020. The Effect of Light Exposures on the Content of Harmful Substances in Edible Potato Tuber. *Agriculture.* **10 (5)**: 139.

Şengül M, Keleş F & Keleş M 2004. The effect of storage conditions (temperature, light, time) and variety on the glycoalkaloid content of potato tubers and sprouts. *Food control.* **15 (4)**: 281-286.

Sukrasno YMS & Kusmardiyani S 2014. Influence of Cooking Methods on Chlorogenic Acid Content of Potato Peels (Solanum tuberosum L.). *International journal of pharmacognosy and phytochemical research.* **6 (3)**: 488-491.

Tanios S, Eyles A, Tegg R & Wilson C 2018. Potato tuber greening: a review of predisposing factors, management and future challenges. *American journal of potato research.* **95 (3)**: 248-257.

Turner S & Molyneaux H 2004. Agricultural science, potato breeding and the Fredericton Experimental Station, 1912-66. *Acadiensis.* **33 (2)**: 44-67.

Varshney R & Kale R 1990. Effects of calmodulin antagonists on radiation-induced lipid peroxidation in microsomes. *International journal of radiation biology.* **58 (5)**: 733-743.

Wright PJ & Plummer DT 1974. The use of urinary enzyme measurements to detect renal damage caused by nephrotoxic compounds. *Biochemical pharmacology.* **23 (1)**: 65-73.

Wróblewski F & Ladue JS 1955. Lactic dehydrogenase activity in blood. *Proceedings of the society for experimental biology and medicine.* **90 (1)**: 210-213.

Yakubu M, Akanji M & Salau I 2001. Protective effect of ascorbic acid on some selected tissues of ranitidine-treated rats. *Nigerian journal of biochemistry and molecular biology.* **16 (2)**: 177-182.

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24767417.2022.7.4.6.1]

[DOI: 10.18502/jnfs.v7i4.11062]

Appendix

Table 3. Gross composition (g/1000g) of diet formulated with tubers of *S. tuberosum*

Ingredients	Control	Group 1	Group 2	Group 3	Group4
Carbohydrate source (Potato)	516	516	516	516	516
Protein source	250	250	250	250	250
Soybean oil	40	40	40	40	40
Potato	-	516	516	516	516
Fibre	40	40	40	40	40
Sucrose	100	100	100	100	100
Vit/Minerals	50	50	50	50	50
DL-methonine	4	4	4	4	4

[Downloaded from jnfs.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24767417.2022.7.4.6.1]
[DOI: 10.18502/jnfs.v7i4.11062]