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RESEARCH ARTICLE

Glycoalkaloids in commercial potato varieties traded in Nairobi, Kenya [version 1; peer review: awaiting peer review]

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Abstract

Background: Glycoalkaloids are naturally occurring toxins in potatoes which, at high levels, pose food safety concerns to consumers. Their concentrations in potatoes are dependent on postharvest handling, variety and stress factors tubers are exposed to. Limited information, however, exists on levels of glycoalkaloids in commercially traded potato tubers in Kenya. The current study sought to determine the glycoalkaloid levels in potatoes traded in Nairobi, Kenya.

Methods: Three potato varieties, *Shangi*, *Dutch Robbin* and *Royal* sold in open-air markets and supermarkets were randomly sampled and their glycoalkaloid levels determined by high-performance liquid chromatography.

Results: The levels varied significantly ($p < 0.05$). The *Shangi* variety had the highest glycoalkaloids with a mean of $410.35 \text{ mg kg}^{-1}$ dry weight with samples from supermarkets having the highest levels (550.8 mg kg^{-1}). The same variety from open air markets averaged $382.26 \text{ mg kg}^{-1}$ dry weight compared to the *Dutch Robbin* (129.2 mg kg^{-1} dry weight) and *Royal* variety (98.2 mg kg^{-1} dry weight) which had the least levels of glycoalkaloids.

Conclusions: The levels in sampled tubers did not exceed the recommended levels of 1000 mg/kg on dry weight basis and, therefore, consumption of these potatoes would not raise safety concerns. There is, however, a need to ensure that marketing of tubers is carried out under conditions that minimize occurrence of glycoalkaloids, especially for the *Shangi* variety, which is the most common in the markets but had relatively high levels of these toxins. There is also a need to educate marketers on the need for proper storage and handling of potatoes during marketing to avoid risk of accumulation of glycoalkaloids.

Keywords

Glycoalkaloids, Commercial potato varieties, Nairobi

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Introduction

Potatoes are an important food crop in sub-Saharan Africa (SSA). The estimated annual production of potatoes in SSA in 2016 was 11.6 million tonnes (FAOSTAT, 2018). Potatoes are ranked among the four most important and largely consumed food crops globally, the others being rice, wheat and maize (King & Slavin, 2013). Potatoes provide the consumers with nutrients such as carbohydrates, vitamins and minerals (Furrer *et al.*, 2016) and improve the nutrient density of diets when incorporated into other foods (Gibson & Kurilich, 2013).

Glycoalkaloids, which naturally occur in potato tubers, compromise their safety at higher levels and can render the tubers or the derivative products unsuitable for consumption, with levels beyond 200 mg kg⁻¹ fresh weight being considered unsafe for human consumption (Smith *et al.*, 1996a). The most common glycoalkaloids in potatoes are α -solanine and α -chaconine. α -chaconine occurs in a somewhat higher proportion and is the most potent of the two, being twice as toxic as α -solanine (Friedman, 2006).

Glycoalkaloid levels in potatoes traded in the market may be influenced by transportation and storage conditions (Chuda *et al.*, 2004). Potatoes that are sprouting or subjected to light exposure, inappropriate storage, extreme temperature, wounding, and mechanical injury accumulate glycoalkaloids at a faster rate (Cantwell, 1996). In addition, the level of accumulation of glycoalkaloids in potatoes subjected to these stress factors varies among tuber varieties (Furrer *et al.*, 2016).

Ware potatoes are made available to consumers through different marketing systems and handling of these potatoes may influence the formation and accumulation of glycoalkaloids. In Kenya, the potato forms a major part of the diet of many consumers. It is incorporated into local Kenyan dishes or may be eaten boiled, baked or fried. Furthermore, processed potato products such as crisps and French fries (locally known as chips) are in high demand among urban consumers and hence are a great part of menus in restaurants and hotels in major urban centers (Abong' *et al.*, 2009). Of interest to food safety, however, is that in Kenyan markets, it is not uncommon to find potatoes exposed to stress factors thus exposing consumers to the dangers of glycoalkaloids. However, the exposure of Kenyan consumers to these toxins as a result of consuming potatoes and potato products is not supported by adequate data. Furthermore, not much has been done to quantify the levels of glycoalkaloids in tubers traded in Kenyan markets, meaning that the level of risk to consumers has not been adequately documented. The current study, therefore, sought to establish the glycoalkaloid levels of potatoes traded in various markets and supermarkets in Nairobi, Kenya.

Methods

Study area

The study was carried out in Nairobi County, Kenya in February and March 2018. The county hosts the capital city of Kenya and has nine sub-counties: Makadara, Embakasi, Starehe, Langata, Kasarani, Westlands, Kamukunji, Dagoretti and Njiru.

The county's population is estimated to be over 3 million (KNBS, 2009). Most of the people are low income earners hence live in slums. The county has many markets dealing in food stuffs with most of these food markets being open air markets. Five sub-counties were purposively selected for this study: Dagoretti, Westlands, Embakasi, Kamukunji and Starehe. These were purposively selected because most of Nairobi's population is concentrated in these areas. From these five sub-counties, five major markets were purposively selected from which samples (from both open-air markets and supermarkets) were obtained. The five markets were Kawangware (Dagoretti), Kangemi (Westlands), Wakulima (Starehe), Kona (Embakasi) and Gikomba (Kamukunji).

Sampling

Sample size determination. A total of 48 potato samples were used for the study; this figure was obtained using the formula of Fisher *et al.* (1991). From the 48 samples, 31 samples were collected from supermarkets and 17 samples were obtained from open-air markets.

Sample collection. Three potato varieties were used in the study: *Shangi*, *Dutch Robijn* and *Royal*. These were purchased from open air markets (*Shangi* only) and supermarkets (all three varieties). Only *Shangi* variety was obtained from the open-air markets since it was the most common and easily available variety in the markets during the sampling period.

Sample analysis

Determination of moisture content. Moisture content of different potato varieties was determined in triplicate on fresh weight basis as per AOAC (2005) method number 930.15. The oven used was memmert 40500-IP20 (Schutzart, Germany).

Determination of glycoalkaloids. The levels of glycoalkaloids were determined by high pressure liquid chromatographic (HPLC) methods using Waters HPLC (Waters 2695- Waters Corporation, USA) and detection set at a wavelength of 202 nm using photodiode array detector (Waters 2996, USA).

Sample preparation

Potato samples obtained from each market were mixed thoroughly into one batch, from which a single sample was picked randomly for analysis. Randomness was ensured by picking tubers from the top section, middle section and bottom section of the mixed batch. This was done for all the samples from all the five markets thus resulting into five open-air market *Shangi* samples for analysis (representing the five study sub-counties). The same procedure was followed for the supermarket samples, resulting in five *Shangi* supermarket samples, two *Dutch Robijn* samples and two *Royal* samples for analysis.

Tubers were washed under running water, dried using cloth towel, peeled and chopped into 5mm pieces. Next, 20 g of each set were oven dried to a constant weight at 105°C. The dry samples were ground and packaged in sealed plastic bottles and stored for chemical analysis.

Extraction of glycoalkaloids. A 2-g sample was mixed with 20 ml extraction solution comprising of water, acetic acid and sodium hydrogen bisulfite at of 100 ml/5 ml/0.5 g, respectively and shaken for 15 minutes by Burrell vertical shaker (Burrell Corp, Pittsburg, UK). Clarification of the mixture was then done by centrifugation for 30 min at 800g using Labofuge A (Heraeus, Germany).

Cleaning of extract. Acetonitrile (5 ml) followed by 5 ml extraction solution were used in conditioning solid phase extraction (SPE) columns (Strata, Phenomenex). Into these columns, 10 ml of the supernatants were passed through the SPE columns at a controlled pressure after which SPE 4 ml wash solution (15% acetonitrile) was used to wash the glycoalkaloids. This was followed by elution with 4 ml LC mobile phase (60% acetonitrile in 0.01 M phosphate buffer) at a rate of 1–2 drops/s. The final volume collected was adjusted to 5 ml with LC mobile phase filtered through a 0.45- μ m filter into vials and frozen ready for injection.

Chromatographic analysis

The HPLC instrument (Waters-2595, USA) was fitted with stainless steel LC column—250 $\times$ 4.6 mm, packed with Hypersil ODS (Shandon Southern Products Ltd., Astmoor, UK), 5- μ m particle size, C18 phase. The operating conditions included a flow rate of 1.5 ml/min, injection volume of 50 μ l, run time of 15 minutes, column temperature of 40°C and wavelength detection set at 202 nm. Glycoalkaloids were calculated based on external calibration curves generated from standards stock solutions and expressed as mg GAS/kg on dry weight basis.

Statistical analysis

The data were analyzed using GenStat version 15 software. Descriptive statistics in terms of mean and standard deviation were generated for moisture content and glycoalkaloids levels. Test for significant differences in the means was performed using one-way ANOVA at $p < 0.05$. Means that were statistically different were separated using Fisher's LSD test ($p \leq 0.05$).

Results and discussion

Moisture content of potato varieties

The moisture content between the samples varied significantly ($p < 0.05$) (Table 1). However, there were no significant differences ($p > 0.05$) in the moisture content for the sampled potato varieties obtained from supermarkets and open-air markets. The *Royal* variety had the highest moisture content (77.08%), while *Shangi* had 76.56% and *Dutch Robjin* had the least with 76.42%. These findings are lower than those reported by other researchers (Elbatawi *et al.*, 2008; Zhang *et al.*, 2018). However, these values are in agreement with other studies where similar findings have been reported (Hafezi *et al.*, 2015; Sablani & Mujumdar, 2006; Xiao *et al.*, 2011). These variations may be attributed to transpiration due to exposure of potatoes to sunlight and higher temperatures during marketing as well as the high relative humidity and long period on shelves before marketing (Chourasia *et al.*, 2005). Moisture content of all potatoes analyzed,

Table 1. Moisture content of marketed potato varieties on fresh weight basis.

Sample	Moisture content (%)	Sample	Moisture content (%)
1. D1	77.45 $\pm$ 0.91 ^{cde}	SW4	77.85 $\pm$ 2.05 ^{cdef}
2. D2	76.45 $\pm$ 0.77 ^{bcd}	SD1	76.72 $\pm$ 6.46 ^{bcd}
3. D3	75.5 $\pm$ 1.13 ^{bcd}	SD2	76.2 $\pm$ 3.81 ^{bcd}
4. D4	76.3 $\pm$ 0.70 ^{bcd}	SD3	76.6 $\pm$ 2.40 ^{bcd}
5. R1	77 $\pm$ 0.28 ^{cdef}	SD4	75.3 $\pm$ 3.67 ^{abc}
6. R2	78.35 $\pm$ 1.34 ^{de}	SE1	77.15 $\pm$ 3.18 ^{cde}
7. R3	79.51 $\pm$ 0.83 ^{ef}	SE2	76.96 $\pm$ 2.74 ^{cde}
8. R4	72.8 $\pm$ 1.27 ^{ab}	SE3	78.05 $\pm$ 1.20 ^{cde}
9. R5	77.75 $\pm$ 2.15 ^{cde}	SE4	75.45 $\pm$ 2.61 ^{bcd}
10. CN1	77.55 $\pm$ 2.33 ^{cdef}	SK1	71.21 $\pm$ 1.13 ^a
11. CN2	75.1 $\pm$ 0.84 ^{abcd}	SK2	76.91 $\pm$ 1.42 ^{bcd}
12. CN3	76.6 $\pm$ 0.56 ^{bcd}	SK3	77 $\pm$ 1.70 ^{def}
13. GK1	78.2 $\pm$ 2.68 ^{cdef}	SK4	72.03 $\pm$ 1.92 ^a
14. GK2	76 $\pm$ 0.56 ^{bcd}	SS1	74.1 $\pm$ 2.54 ^{abc}
15. GK3	76.8 $\pm$ 1.83 ^{bcd}	SS2	76 $\pm$ 1.69 ^{bcd}
16. KN1	75.85 $\pm$ 0.63 ^{bcd}	SS3	79.85 $\pm$ 2.19 ^f
17. KN2	77.15 $\pm$ 2.89 ^{cdef}	SS4	78.25 $\pm$ 0.21 ^{def}
18. KN3	77.2 $\pm$ 0.84 ^{cdef}	SS5	75.81 $\pm$ 0.2 ^{bcd}
19. KW1	76.35 $\pm$ 1.20 ^{bcd}	SS6	76.45 $\pm$ 2.33 ^{bcd}
20. KW2	75.45 $\pm$ 0.91 ^{bcd}	WK1	76.85 $\pm$ 1.84 ^{bcd}
21. KW3	77.2 $\pm$ 0.84 ^{cdef}	WK2	75.8 $\pm$ 0.84 ^{bcd}
22. SW1	76.16 $\pm$ 1.51 ^{bcd}	WK3	78.4 $\pm$ 2.40 ^{def}
23. SW2	75.75 $\pm$ 2.62 ^{bcd}	WK4	75.8 $\pm$ 1.31 ^{abcde}
24. SW3	77.7 $\pm$ 2.263 ^{cdef}	WK5	76.3 $\pm$ 1.3 ^{abcd}

Values are given as mean of duplicate samples $\pm$ SD (standard deviation), $n = 48$. Means with different superscript letters are significantly different (Tukey's test, $p \leq 0.05$).
D-Dutch Robjin; R-Royal; CN-Shangi from Kona market; GK-Shangi from Gikomba market; KN-Shangi from Kangemi market; KW-Shangi from Kawangware market; SD-Shangi from supermarkets in Dagoretti; SE-Shangi from supermarkets in Embakasi; SK-Shangi from supermarkets in Kamukunji; SS-Shangi from supermarkets in Starehe; WK-Shangi from Wakulima market

alongside glycoalkaloid content, is available as *Underlying data* (Musita *et al.*, 2020).

Glycoalkaloid levels in traded potato varieties

The total glycoalkaloid levels varied significantly ($p < 0.05$) among the samples (Table 2 and Table 3). The *Royal* potato variety had the lowest glycoalkaloids levels (104.8 mg kg⁻¹), then the *Dutch Robjin* (136.1 mg kg⁻¹); the *Shangi* (483.6 mg kg⁻¹) variety had the highest levels of glycoalkaloids on dry weight basis. The values for *Dutch Robjin* and *Shangi* varieties were,

Table 2. Glycoalkaloid levels (mgkg⁻¹dw) in potato varieties traded in Nairobi.

Sample	α -solanine (a) (mg kg ⁻¹)	α -chaconine (b) (mg kg ⁻¹)	Total (a+b) (mg kg ⁻¹)	Ratio (b/a)
D1	59.5±4.03 ^a	69.8±2.12 ^{abcd}	129.3±6.15 ^{ab}	1:1.2
D2	76.45±0.94 ^a	54.5±2.86 ^{ab}	103.3±1.92 ^a	1:0.7
D3	61.9±2.31 ^a	93.1±5.18 ^{abcde}	154.9±2.87 ^{abc}	1:1.5
D4	72.9±4.76 ^{ab}	83.7±7.52 ^{abcde}	156.6±12.28 ^{abc}	1:1.1
R1	51.3±1.48 ^a	50.6±1.63 ^{ab}	102±0.14 ^a	1:1.0
R2	44.1±0.6 ^a	50.3±0.93 ^{ab}	94.4±0.33 ^a	1:1.1
R3	55.9±2.84 ^a	56.2±7.06 ^{ab}	112.1±9.9 ^{ab}	1:1.0
R4	47.7±2.73 ^a	49.7±0.83 ^a	97.4±3.56 ^a	1:1.0
R5	57.3±1.36 ^a	60.6±1.68 ^{abc}	117.9±0.32 ^{ab}	1:1.1
CN1	255.1±13.06 ^{ijk}	255.9±78.42 ^{ijklm}	480.9±91.48 ^{hijk}	1:1.0
CN2	299.4±1.3 ^{opq}	389.6±15.6 ^{rst}	689±16.9 ^{mnp}	1:1.3
CN3	177.6±4.33 ^{efgh}	187.4±3.56 ^{ghij}	365±7.89 ^{efgh}	1:1.1
GK1	134.2±1.63 ^{cd}	233±17.54 ^{hijkl}	367.1± 15.91 ^{efgh}	1:1.7
GK2	325.7±20.58 ^{pqr}	409.8±2.25 ^t	735.5±22.83 ^{nop}	1:1.3
GK3	208.6±29.77 ^{klm}	244.6±10.25 ^{ghijklm}	453.2± 19.52 ^{hij}	1:1.2
KN1	109.8± 9.81 ^{cd}	122.6± 1.56 ^{abcde}	232.4±11.37 ^{bcd}	1:1.1
KN2	178.1± 2.67 ^{efgh}	405.5± 38.42 st	583.6±41.09 ^{klm}	1:2.3
KN3	128.2±11.98 ^{cd}	166.2 ±10.11 ^{efghi}	294.3±1.87 ^{defg}	1:1.3
KW1	53.8± 3.9 ^{bcd}	140.8± 8.63 ^{abcde}	194.6± 12.59 ^{abcd}	1:2.6
KW2	215.8±16.77 ^{hij}	522.1± 61.15 ^u	737.9± 77.92 ^{op}	1:2.4
KW3	257.1± 6.71 ^{klmn}	338.2± 19.29 ^{opqrst}	595.3±26 ^{klm}	1:1.3
WK1	383.4±11.38 ^s	366.7±19.37 ^{qrst}	750±30.76 ^p	1:1.0
WK2	108.2±26.35 ^{bc}	196.2±147.67 ^{ghijk}	304.4±174.02 ^{defg}	1:1.8
WK3	143.8±7.43 ^{cdef}	223.4±121.55 ^{hijkl}	367.1±128.98 ^{efgh}	1:1.6
WK4	192±8.49 ^{hij}	180.7±1.91 ^{ghij}	372.6±10.39 ^{efghi}	1:0.9
WK5	206.4±5.77 ^{ghi}	194.4±7 ^{ghijk}	400.8±12.77 ^{ghi}	1:0.9
SD1	291.5±16.78 ^{nop}	260.4±38.11 ^{ijklmn}	551.9±21.33 ^{kl}	1:0.9
SD2	285.2±6.42 ^{mnp}	301± 15.04 ^{mnpq}	586.3±21.46 ^{klm}	1:1.1
SD3	281.5±2.64 ^{mno}	269.5±33.45 ^{klmno}	551.1±30.82 ^{kl}	1:1.0
SD4	279.2±14.98 ^{lmno}	301.2±20.58 ^{mnp}	580.4±35.55 ^{klm}	1:1.1
SE1	125.8±14.35 ^{cd}	144.8±6.87 ^{bcdefg}	270.6±21.23 ^{cde}	1:1.2
SE2	350.9±25.39 ^{rs}	378.7±13.64 st	729.5±39.03 ^{nop}	1:1.1
SE3	157.1±20.3 ^{bc}	152.8±0.25 ^{cdefg}	309.9±20.05 ^{defg}	1:1.0
SE4	339.6±25.1 ^{qr}	299.6±8.06 ^{lmnop}	639.2± 17.04 ^{lmno}	1:0.9
SK1	271.8±66.31 ^{lmno}	272.7± 84.43 ^{klm}	544.5±150.73 ^{kl}	1:1.0
SK2	239.6±41.41 ^{kl}	282.5±116.12 ^{klm}	522.1±157.53 ^{kl}	1:1.2
SK3	305.4±27.65 ^{opq}	329.8±51.12 ^{opqrs}	635.1±78.77 ^{lmno}	1:1.1
SK4	230.8±19.73 ^{ijk}	310.1±100.88 ^{nop}	540.9±120.61 ^{kl}	1:1.3
SS1	239.1±26.52 ^{kl}	379.4±78.51 ^{rst}	618.5±105.3 ^{lmno}	1:1.6
SS2	181.60.18 ^{gh}	311±15.21 ^{nopq}	492.1±75.39 ^{ijk}	1:1.7
SS3	296.8±39.3 ^{nop}	294.9±7.71 ^{lopqr}	591.8±31.59 ^{klm}	1:1.0
SS4	256.7±0.02 ^{klmn}	358.4±65.63 ^{pqrs}	615.1±61.65 ^{lmn}	1:1.4

Sample	α -solanine (a) (mg kg ⁻¹)	α -chaconine (b) (mg kg ⁻¹)	Total (a+b) (mg kg ⁻¹)	Ratio (b/a)
SS5	137.8±22.78 ^{defg}	296.1±29.92 ^{lopq}	433.9±7.13 ^{hij}	1:2.1
SS6	183.9±2.71 ^{gh}	205.9±9.18 ^{ghijk}	389.8±6.47 ^{efghi}	1:1.1
SW1	194.2±13.22 ^{cde}	158.8±62.3 ^{defgh}	278.8±57.76 ^{def}	1:1.3
SW2	194.2±13.22 ^{ghi}	197.5±25.88 ^{ghij}	391.8±39.1 ^{fghi}	1:1.0
SW3	119.9±4.54 ^{cd}	153.7±54.99 ^{cdefg}	273.6±50.45 ^{cdef}	1:1.3
SW4	194.2±13.22 ^{ghi}	197.5±25.88 ^{ghijk}	391.8±39.1 ^{fghi}	1:1.0

Values are given as mean of duplicate samples $\pm$ SD (standard deviation), $n = 48$. Means with different superscript letters in the same column are significantly different (Tukey's test, $p \leq 0.05$). D, *Dutch Robbin*; R, *Royal*; CN, *Shangi* from Kona market; GK, *Shangi* from Gikomba market; dw, dry; weight; KN, *Shangi* from Kangemi market; KW, *Shangi* from Kawangware market; WK, *Shangi* from Wakulima

Table 3. Average glycoalkaloid levels (mg kg⁻¹ dw) in potato varieties traded in Nairobi.

Market/variety		α -solanine (a) (mg kg ⁻¹)	α -chaconine (b) (mg kg ⁻¹)	Total (a+b) (mg kg ⁻¹)	Ratio b/a
Open-air markets (<i>Shangi</i> variety)	Wakulima	206.7± 100.65 ^a	232.2±96.7 ^a	439.0±182.6 ^a	1:1.1
	Kawangware	175.6±96.46 ^a	333.7±173.0 ^a	509.3±254.7 ^a	1:1.9
	Gikomba	231.8±87.58 ^a	283.8±98.6 ^a	515.6±173.0 ^a	1:1.2
	Kona	234.0± 55.26 ^a	277.6±98.7 ^a	511.6±152.6 ^a	1:1.1
	Kangemi	138.7 ± 32.41 ^a	231.4±137.4 ^a	370.1±168.8 ^a	1:1.7
<i>Shangi</i> overall	Open air	199.0±80.84 ^b	267.1±119.88 ^b	466.1±185.1 ^b	1:1.3
	Both markets	217.1±60.81 ^b	266.2± 80.95 ^b	483.6±99.09 ^b	1:1.2
Supermarkets	<i>Shangi</i>	231.0 ±84.8 ^B	266.2± 80.95 ^B	497.2±102.2 ^B	1:1.2
	<i>Dutch Robbin</i>	60.8±9.52 ^A	75.3±16.0 ^A	136.1 ±23.89 ^A	1:1.2
	<i>Royal</i>	51.3±5.42 ^A	53.5±5.2 ^A	104.8±10.0 ^A	1:1

Values are given as means of samples $\pm$ SD (standard deviation), $n = 48$. Means with different lowercase superscript letters along the column are significantly different for the respective glycoalkaloids in the *Shangi* variety traded in both open-air markets and supermarkets. Means with different capital letter superscripts along the column are significantly different for the respective glycoalkaloid levels obtained from different varieties traded in the sampled supermarkets (Tukey's test, $p \leq 0.05$).

however, higher than those reported in a similar study, where the values ranged from 55.6 to 122.3 mg kg⁻¹ (Bejarano *et al.*, 2000). The values in the current study may be indicative of poor post-harvest handling of potatoes during marketing as well as the varietal influence on glycoalkaloid levels. Since the *Shangi* variety had higher levels of glycoalkaloids than the other varieties, it is possible that many Kenyan consumers are exposed to these toxins, given this variety is the most common on the market.

The levels of glycoalkaloids in potato tubers from the *Shangi* varieties procured from supermarkets and open air markets did not have significant differences ($p > 0.05$) with the former having the highest levels of glycoalkaloids at 497.2 mgkg⁻¹ compared to

levels in *Shangi* samples obtained from open air markets which averaged 466.1 mgkg⁻¹ (Table 3). The high levels of glycoalkaloids in the supermarket samples may be an indication of long periods of exposure to fluorescent light and longer periods before sales from the supermarket shelves. During these periods, the tubers accumulate chlorophyll and subsequently have increased levels of glycoalkaloids. Light plays a significant role in chlorophyll formation, resulting in “greening” on the surface of the potato. This “greening” has been associated with a rise in the concentration of glycoalkaloids, especially α -solanine (Pavlista, 2001). There is need for the local supermarkets and other retail shops to make use of greening scales that have been developed for discarding greened potatoes from retail displays so as to

ensure that the potatoes sold in wholesale and retail shops are safe for consumption (Grunenfelder *et al.*, 2006a; Grunenfelder *et al.*, 2006b). These retail outlets could also substitute the fluorescent lighting in the display shelves with mercury lighting since studies have shown the rate of glycoalkaloids accumulation can be reduced by using mercury lighting instead of fluorescent lighting during display (Percival, 1999). This is attributed to the fact that mercury illumination contains few spectral lines (ultraviolet and infrared), which are less likely to enhance synthesis of glycoalkaloids and chlorophyll, unlike fluorescent light which contains ultraviolet spectra (Nema *et al.*, 2008).

The concentrations of α -solanine and α -chaconine for the samples varied significantly ($p < 0.05$) and ranged from 47.7 to 206.6 mg kg⁻¹ and 50.5 mg kg⁻¹ to 283.1 mg kg⁻¹, respectively (Table 2). The ratio of α -solanine to α -chaconine ranged from 1:0.7 to 1:2.6. Glycoalkaloid intoxication is relative to this ratio and the ratio should, therefore, be as low as possible since these toxins occur simultaneously in potato tubers (Friedman, 2006). The ratios reported in this study are in agreement with other studies, which have reported variations from 1:0.5 to 1:7 (Kozukue *et al.*, 2008; Lisińska *et al.*, 2009; Tajner-Czopek *et al.*, 2008; Valcarcel *et al.*, 2014).

None of the sampled potato tubers exceeded the recommended safety levels of 1000 mg kg⁻¹ dry weight, assuming a water content of 80% (Valcarcel *et al.*, 2014) which is equivalent to 200 mg kg⁻¹ on fresh weight basis (Smith *et al.*, 1996b). Therefore, consumption of these varieties would result in insignificant glycoalkaloids intoxication to consumers. However, it is important to note that these toxicants have been found to bioaccumulate in the body, especially if daily consumption of foods containing the glycoalkaloids occurs (Omayio *et al.*, 2016).

Disparities in the levels of glycoalkaloids reported could also be a result of varietal effect. Studies have shown that some potato varieties tend to accumulate higher levels of glycoalkaloids compared to others. These findings are, therefore, in agreement with other studies (Aziz *et al.*, 2012; Bejarano *et al.*, 2000; Friedman *et al.*, 2003; Valcarcel *et al.*, 2014). The *Shangi* variety has also been shown to sprout easily when exposed to stressful conditions which is an indication of elevated levels of glycoalkaloids (Abong' *et al.*, 2015).

The rate of glycoalkaloids accumulation is also dependent on the storage conditions. Light and temperature have been shown to be stress factors that lead to accumulation of the toxins (Griffiths *et al.*, 1998; Grunenfelder *et al.*, 2006a). The rate of glycoalkaloid accumulation is about 20% higher when potatoes are exposed to light and direct sunlight as compared to storage in dark conditions. Synthesis and accumulation of glycoalkaloids when potatoes are stored at 24°C has also been shown to be about twice the rate at 7°C (Cantwell, 1996; Griffiths *et al.*, 1998;

Sengül *et al.*, 2004). It has been reported that generally, there is poor handling of potatoes by traders in Kenya, which continues to increase the risk of consumer exposure to glycoalkaloids (Musita *et al.*, 2019). Differences in storage conditions for the potatoes from both open-air markets and supermarkets could have contributed to the levels of glycoalkaloids reported.

Conclusions and recommendations

The glycoalkaloids levels of the marketed potatoes did not exceed the recommended safety levels. Therefore, minimal intoxication would occur to consumers. However, it would be of interest for future studies to be conducted to assess the effect of long-term exposure to low levels of these toxins, a common occurrence among Kenyan consumers. The supermarkets samples had higher levels of glycoalkaloids and there is a need for the traders to be sensitized on appropriate handling of potatoes during marketing.

It is also essential that consumers and potato handlers select potato cultivars with minimal glycoalkaloid occurrence to ensure that there is minimum glycoalkaloid intoxication. Additionally, consumers are advised to peel potatoes before cooking to reduce the amount of glycoalkaloids since most of the toxins are concentrated in the peel.

Moreover, postharvest practices that will reduce occurrence of glycoalkaloids are paramount. Relevant authorities should, therefore, be involved in raising awareness and implementation of post-harvest handling policies among potato vendors. These include storage of potatoes at lower temperatures, of about 5°C–10°C, keeping potatoes away from direct sunlight and marketing in opaque plastic films and bags that minimize effect of light on tubers. Furthermore, supermarket vendors need to be sensitized to ensure regular rotations of potatoes in retail shops exhibitions and replace fluorescent lighting with mercury lighting for potatoes on display.

Data availability

Figshare: Sample and data_glycoalkaloids in potatoes_Consolata Musita.xls. <https://doi.org/10.6084/m9.figshare.12301424.v1> (Musita *et al.*, 2020).

This file contains the moisture and glycoalkaloid content of each sample analysed in this study.

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](#) (CC-BY 4.0).

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