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Frequency of consumption of green leafy vegetables and prevalence of hyperglycemia in Ankole and Teso sub-regions of Uganda

Caroline Asekenye[1], Paul Erasmus Alele[2], Patrick Engeu Ogwang[1], Eunice Apio Olet[3]*

[1]*Department of Pharmacy, Faculty of Medicine, Mbarara University of Science and Technology, Mbarara City, Uganda,* [2]*Department of Pharmacology and Therapeutics, Faculty of Medicine, Mbarara University of Science and Technology, Mbarara City, Uganda,* [3]*Department of Biology, Faculty of Science, Mbarara University of Science and Technology, Mbarara City, Uganda*

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**Corresponding author:*
Eunice Apio Olet
Mbarara University of Science and Technology,
Department of Biology, P. O. Box 1410,
Mbarara, Uganda.
Email: eolet@must.ac.ug

ABSTRACT

Background: Type 2 diabetes-related hyperglycemia is a global health problem, with developing countries like Uganda currently experiencing substantial rises in the metabolic disorder. Current hyperglycemia therapies can bring a patient to glycemic target; however, they are costly and have other limitations. Vegetable extracts have health-protecting effects and contain thousands of components with putative hypoglycemic effects, rendering them a cheaper alternative toward prevention and management of hyperglycemia.

Aim: The goal of this study was to determine the frequency and patterns of consumption of green leafy vegetables, and their relationship with the prevalence of hyperglycemia in two sub-regions of Uganda.

Methods: A cross-sectional household survey was conducted in Ankole and Teso sub-regions of Uganda. Using a questionnaire for both face-to-face interviews and focus group discussions, the frequently eaten vegetables and their consumption were documented, and fasting blood glucose levels measured to determine the prevalence of hyperglycemia.

Results: The most frequently eaten vegetables in both sub-regions were *Amaranthus* species. *Brassica species, Cucurbita maxima* L., *Solanum nigrum* sensu lato, and *Phaseolus vulgaris* L. were eaten mostly in Ankole sub-region while *Vigna unguiculata* (L.) Walp. and *Hibiscus sabdariffa* L. were eaten mostly in Teso sub-region. In Ankole sub-region, the vegetables were steamed, while boiling and adding peanut/simsim butter was preferred in Teso sub-region. Consumption of leafy vegetables was higher in Teso sub-region than in Ankole sub-region. The overall prevalence of hyperglycemia was 29.15%; it was higher in Ankole at 35.5% and lower in Teso at 19.5% (95% CI: 0.27 – 0.69).

Conclusion: The difference in prevalence of hyperglycemia is relatively high in these sub-regions. Consumption of different leafy vegetable species and their various preparation methods likely contributes to this prevalence; however, factors such as phytochemical constituents, genetics, and social-economic status could help explain this difference further.

Relevance for Patients: This study reveals that when hyperglycemic patients incorporate the consumption of appropriate vegetables (in the recommended amount) and prepared using methods that preserve and/or augment the nutrients and phytonutrients therein, in their diet, they could control and prevent high blood glucose levels.

1. Introduction

Hyperglycemia is a technical term for blood glucose level higher than optimum [1]. It can be due to either a defect in insulin secretion, insulin action, or both [2,3]. This high blood glucose level, if not managed, increases the risk of developing diabetes, and microvascular and macrovascular complications, which could lead to poor quality of life or/and death. [4]. In 2016, the World Health Organization (WHO) reported that 2.2 million deaths registered worldwide were attributed to high blood glucose levels and the largest number occurred in middle-income countries. The most worrying part is that, more than half of these deaths are premature [5]. Globally, as of 2019, hyperglycemia was prevalent by an estimate of 7.5% (374 million) and was projected to increase to 8% (444 million) by 2030 and 8.6% (548 million) by 2045 [6]. In Africa, the prevalence of hyperglycemia (measured by impaired glucose tolerance) was estimated to rise from 42.9 million (8.3%) in 2017 to 108.6 million (9.5%) in 2045 [7]. Uganda has been reported to have prevalence of diabetes mellitus at 2%, and it is higher in urban areas and in the male gender. Considering sub-regions of the country, the western sub-region was reported to have the highest prevalence (3.3%) of hyperglycemia compared to the eastern (0.8%) and central sub-region (1.6%) [8]. The national prevalence is relatively low, therefore, presenting an opportunity for prevention and management of hyperglycemia. The discovery of insulin and other hypoglycemic drugs have certainly not only reduced mortality from complications originating from hyperglycemia but also reduced morbidity. However, these drugs have been shown to possess inherent limitations and side effects which have on their own claimed lives of the diabetic patients [9-11]. Having long seen that hyperglycemia is a result of abnormal metabolism [12], which in itself, is a reflection from defects in insulin secretion or/and insulin action [3], the causal factors are a heterogeneous group of genetic and environmental factors including diet, endocrine, and autonomic nervous system dysfunction [2]. The diet factor implicated in the cause of hyperglycemia presents an opportunity through consumption of appropriate vegetables, as both secondary prevention measure (to make up for the down side of the current anti-hyperglycemia therapies), and a primary prevention measure (to reduce the risk of its onset), and altogether prevent and control hyperglycemia [13-16]. The plant-based food we consume often contains many sterol-based bioactive compounds [17]. It is well-documented that these compounds could effectively manage the processes of insulin metabolism and cholesterol regulation. Insulin resistance followed by hyperglycemia often results in oxidative stress level enhancement and increased reactive oxygen species production. At the molecular level, these changes induce apoptosis in pancreatic cells and, hence, lead to insulin insufficiency [17]. Globally, vegetables are among the numerous plant adjuncts indispensable for a balanced diet since they charge dietary fiber, phytochemicals, vitamins, and minerals that are all correlated with improved gastrointestinal health and reduced risk of ailments such as hyperglycemia [13,18,19]. *Gymnema inodorum* (GI) is a leafy green vegetable found in the northern region of Thailand. A GI leaf extract has been developed as a dietary supplement for metabolic diabetic control [20]. However, the active compounds in the GI leaf extract are relatively non-polar [20]. The phospholipid component of phytosomes slightly interfered with the anti-insulin-resistant effects of the GI extract by decreasing the glucose uptake activity and increasing the lipid degradation of adipocytes. Altogether, the nanophytosome is a potent carrier for transporting GI phytochemicals to prevent an early stage of type 2 diabetes mellitus (T2DM) [20]. In Africa, leafy vegetables are not just an important component in the traditional diet, they also make the greatest proportion of it due to their abundance and the fact that the leaves are the first vegetable plant part to mature and harvested compared to the flowers, fruits, and seeds [21-24]. For the last 15 years, Solanaceae, Amaranthaceae, and Malvaceae have been and are still the most predominant families that contain indigenous leafy vegetables in Uganda (43.4%, 15.5%, and 11.6%, respectively). Species such as *Amaranthus dubius* Mart. Ex Thell., *Phaseolus vulgaris* L., *Cucurbita maxima* D., *Vigna unguiculata* (L.) Walp., and *Cleome gynandra* L. were grown for majorly food security, income generation, and nutrition purposes [22,24,25] till recently. In Uganda, studies to investigate their chemical composition for the acclaimed disease prevention and treatment purposes are optimistically on a rise [24,26,27]. However, a direct influence of consumption of these vegetables (as part of the traditional diet) on management and treatment of high blood sugar has scantly been looked at. Therefore, this research contributes to this gap by documenting the regional (Ankole and Teso sub-regions) consumption of the most frequently eaten vegetables and prevalence of hyperglycemia in these sub-regions of Uganda.

2. Methods

2.1. Study area

The study was carried out in Ankole and Teso sub-regions of Uganda (Figure 1). The community survey was done in sampled sub-counties of the sampled districts in the sub-regions. There were five districts sampled from the north, east, south, west, and central parts in each sub-region, and four sub-counties from each district sampled from the northern, eastern, southern, and western parts in each districts. During the survey, information on the frequently eaten vegetables, their consumption, and fasting blood glucose (FBG) levels were collected.

2.2. Ankole sub-region of Uganda

Ankole sub-region is located in south-western part of Uganda, with geographical coordinates of latitude: 0° 29' 59.99'' N and longitude: 30° 29' 59.99' E. Most of its ten districts (based on the 2014 national census enumerated areas) lie at about 1806 m above sea level and they are: Bushenyi, Buhweju, Mitooma *https://en.wikipedia.org/wiki/Bushenyi_District*, Rubirizi, Sheema, Ntungamo, Mbarara, Kiruhura, Ibanda, and Isingiro district. However, the selected representative study sub-counties in the representative districts of the region are as follows; Ibanda district (Nyamarebe, Rukiri, Kizuzi, and Bisheshe sub-counties), Kiruhura district (Buremba, Sanga, Kashongi, and Kinoni sub-counties), Mbarara district (Rubindi, Bagumba, Rubayo and Bubaare sub-counties), Rubirizi district (Rutoto, Magambo, Kirugu, and Kyabakara sub-counties), and Ntugamo district (Ngoma, Rwekiniro, Itojo, and Rukoni sub-counties).

Figure 1. Map of Uganda showing the study areas (Drawn from GPS coordinates from the survey Sept-Nov 2021 using Arc GIS Version 10.5 on 19/7/22).

2.3. Teso sub-region of Uganda

Teso sub-region is in the eastern part of Uganda with coordinates of latitude: 1.7159° N and longitudes: 33.6111° E. Most of its eight districts (based on the 2014 national census enumerated areas) (Amuria, Bukedea, Kaberamaido, Katakwi, Kumi, Ngora, Serere, and Soroti district) lie about 1129 m above sea level. The selected representative sub-counties in the representative districts of Teso sub-region were as follows; Soroti district (Gweri, Asuret, Tubur and Kamuda sub-counties), Ngora district (Mukura, Kobwin, Ngora, and Kapir sub-counties), Amuria district (Obalanga, Acuwa, Orungo, and Wera sub-counties), Kaberamaido district (Ochero, Kaberamaido, Anyara, and Bululu sub-counties), and Katakwi district (Ongongoja, Kapujan, Ngariam, and Katakwi sub-counties).

2.4. Ethics approval and consent to participate

The study was approved by Mbarara University of Science and Technology Research Ethics Committee (MUST-REC) under Protocol number MUST-2021-52 and registered with the Uganda National Council for Science and Technology (UNCST) under registration number HS1840ES. Before going to collect data, written permission was first sought from the District Health Officers (DHOs) of the study districts in the two sub-regions. A copy of the approval letter from the DHOs was presented to the in-charge at Health Center III in the study sub-counties, who permitted a nurse and a Village Health Team leader to be recruited as research assistants to collect both data and vegetable samples for identification. The purpose and nature of the study was explained to the participants to allow them to make informed decisions on whether to participate in the study or not. The participants were then requested to sign a consent form to confirm their approval to participate in the study. Both the questionnaire and informed consent form were translated into *Runyankole/Rukiga* and *Ateso* which are the most commonly used dialects in Ankole and Teso sub-regions, respectively.

3. Materials

The main materials in this survey were as follows; informed consent forms, questionnaires, glucometers and strips (On call Plus), portable digital body weighing scale (TilyExpress), and height meter (Seca 213). They were purchased from a certified (Zee pharmaceutical) store and voice recorder (Sony ICD-PX470), in Mbarara City, Uganda.

3.1. Study design and strategy

This study was both qualitative and quantitative. Qualitative design employed a cross-sectional community (household level) survey the frequently eaten vegetables, their preparation methods and consumption patterns were documented, while the quantitative aspect involved measuring the FBG levels.

3.2. Sampling strategy

Multistage sampling strategy was used. The two study sub-regions were purposively selected basing on their known remarkable differences in prevalence of hyperglycemia. The study districts and sub-counties were sampled by stratification.

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The households were, then, sampled using "spinning the bottle" method and a person responsible for meal preparation from each selected household was interviewed. Cochran's (1972) formula for finite population was used to calculate the sample size, that is,

$$n = \frac{t^2 pq}{d^2}$$

Where t is the value for selected alpha level of 0.025 in each tail = 1.96 (from the Z table), (p) is the estimated proportion of the population which has the attributes in question (vegetable consumption and prevalence of hyperglycemia) = 0.5 (since it's unknown), (q = [1-p]) is the estimate of variance = 0.5 and d is the desired level of precision (acceptable margin of error) = 0.05. By adding 10% non-response rate, the final sample size was calculated at 422 individuals. A random sample of 422 households in the target population was deemed enough to give the confidence levels of 95%.

3.3. Data collection methods

3.3.1. Community survey

An interviewer-administered questionnaire for face-to-face interviews and focus group discussions (FGDs) was used to obtain information on demographics of the respondents, frequently eaten vegetables, methods of preparation, and consumption pattern. Furthermore, the FBG levels were taken from household members (only those 18 years and above) of the sampled households using a glucometer. Ten women (responsible for meal preparation) were engaged in FGDs to assess the community-level information. A pre-test with 25 participants (from each study sub-region) was conducted to assess language clarity, ability to include information required, acceptability in terms of length, and the privacy of the participants. This also provided the Cronbach alpha of 92% which ascertained the internal validity of the questionnaire whereas the test-retest ascertained the reliability of 94%. The recorded data in the questionnaire were thereafter harmonized with the noted and recorded information from the FGDs.

Field visits were carried out to collect voucher specimens of frequently eaten vegetable species in each sub-region. Voucher specimens were identified and determined by a botanist both at Mbarara University of Science and Technology and at Makerere University Herbarium.

3.3.2. Statistical analysis

Data were entered in Microsoft Excel 2016 and exported to the Statistical Package for the Social Sciences version 20 for analysis.

Descriptive statistics were used to obtain the frequencies and percentages of demographic and socioeconomic characters of the participants, the most frequently eaten vegetables, and prevalence of hyperglycemia. Chi-square test, stepwise multi-variate logistic analysis was used to identify the variables which significantly impacted and associated with the FBG levels (hyperglycemia status).

4. Results

4.1. Demographic characteristics of participants

Results of the demographic characteristics of participants in this study are summarized in Table 1. Out of the 422 eligible respondents who participated in the study, all were female (persons responsible for meal preparation) and from the sampled households. Of these, 253 resided in Ankole sub-region and 169 in Teso sub-region. The highest number (62.1%) of them were adults and married (30 – 59 years) and the least (13.5%) were widowed and elderly (<60 years). Most had acquired a primary level of education (45.7%) and those with tertiary level were fewer (13%) than those without formal education (15.6%). Most respondents were farmers (71.9%) and the civil servants (8.6%) were less than the non-civil servants (19.3%). Overall, most of the participants were natives of their respective sub-regions, that is, they were born and had spent more than 30 years in residence.

4.2. Frequently eaten vegetables in Ankole and Teso sub-regions of Uganda

Figure 2 shows the frequently eaten leafy vegetables in both sub-regions.

Table 1. Demographic characteristics of participants

Characteristic	**Sub-region**					
	Ankole		**Teso**		**Total**	
Category	***n***	**Weighted %**	***n***	**Weighted %**	***n***	**Weighted %**
Respondents	253	100.0	169	100.0	422	100.0
Age						
18 – 29	65	25.7	38	22.5	103	24.4
30 – 59	151	59.7	111	65.7	262	62.1
≥60	37	14.6	20	11.8	57	13.5
Total	253	100.0	169	100.0	422	100.0
Marital status						
Single	24	9.5	13	7.7	37	8.8
Married	193	76.3	141	83.4	334	79.1
Divorced	14	5.5	5	3.0	19	4.5
Widowed	22	8.7	10	5.9	32	7.5
Education status						
Informal	44	17.4	22	13.0	66	15.6
Primary	100	39.5	93	55.0	193	45.7
Secondary	70	27.7	38	22.5	108	25.6
Tertiary	39	15.4	16	9.5	55	13
Occupation						
Civil servant	23	9.2	13	7.7	36	8.6
Farmers	166	66.1	136	80.5	302	71.9
Non civil servants	61	24.3	20	11.8	81	19.3
Years in residence						
0 – 10	74	29.6	42	25.1	116	27.8
10 – 20	47	18.8	42	25.1	89	21.3
20 – 30	46	18.4	42	25.1	88	21.1
>30	83	33.2	41	24.6	124	29.7

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In overall, *Amaranthus species* (*A. dubius, A. cruentus*) was the most frequently eaten green leafy vegetable by participants in this survey. *V. unguiculata*, *Hibiscus sabdariffa,* and *Balanites aegyptiaca* were eaten only by participants residing in Teso sub-region. On the other hand, *P. vulgaris* and *Solanum nigrum* sensu lato were eaten only by participants residing in Ankole sub-region (Figure 2).

4.3. Local names, habit, and habitat of the frequently eaten vegetables in Ankole and Teso sub-regions of Uganda.

Although most of the vegetable species are the same, their local names differed by study sub-region due to the different local languages spoken therein (Table 2). During the FGDs, participants mentioned that most of these frequently eaten vegetables were either cultivated, grew as weeds (escapes from cultivation) in their homesteads, or collected from the wild. Most of the vegetables were herbaceous and annual.

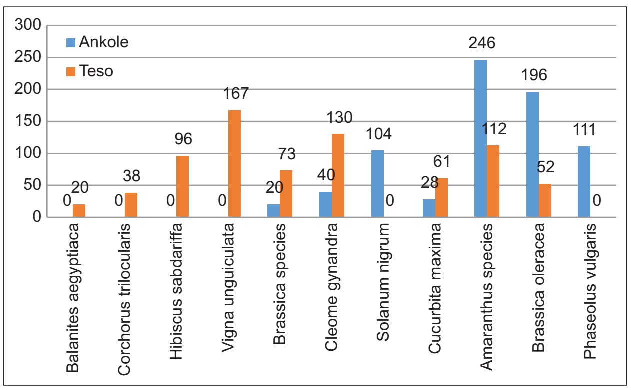

Figure 2. Frequently eaten vegetables in Ankole and Teso sub-regions of Uganda.

4.4. Vegetable collection, preparation method/preservation, amount, and frequency of consumption

All participants reported that the tender leaves and/or shoots are collected. Table 3 shows the times of vegetable collection, preparation method, amount, and frequency of consumption per week. Participants residing in Ankole sub-region collect their vegetables mostly during evening hours of the day (96.2%) whereas most residing in Teso sub-region collect in the afternoon hours (50.4%). For vegetables such as *P. vulgaris*, *V. unguiculata*, *S. nigrum,* and *H. sabdariffa*, the harder leaf parts (petiole, midrib, and harder veins) are first removed and then the remaining leaf parts left under the sun for 10 – 20 min. Depending on the tenderness of the leaves/shoots, they can either be prepared whole or chopped. The practice of drying vegetables in sunlight for preservation, in preparation for periods of scarcity such as the dry season when the climate does not favor their cultivation/growth, was mentioned by most participants from Teso sub-region only. Participants in Ankole sub-region did not preserve the vegetables due to their availability almost throughout the year. Therefore, participants from Ankole sub-region prepared their vegetables fresh, by mostly steaming on top food covered with banana leaves (98.3%) and by mixing them with stews or foods (also known as katogo) (90.3%). Almost all the participants from Teso sub-region prepared theirs fresh (during wet season) and dry (during dry season) by just boiling them alone (67.5%), and/or adding peanut/simsim paste to the vegetables (100%).

During serving of the vegetable stew, quantity was measured by number of servings (50 – 80 g of vegetable stew per serving), and the highest number of servings (five serving spoons) was eaten only by some participants from Teso sub-regions whereas those from Ankole ate at most three serving spoons. In a typical week,

Table 2. Local names, habit, and habitat of the frequently eaten vegetables in Ankole and Teso sub-regions of Uganda

Family, species, accession number	English name	Habit	Habitat	Local name and frequency in sub-region			
				Ankole (Runyankore)	Frequency %	Teso (Ateso)	Freq %
Amaranthaceae, *Amaranthus dubius* Mart. Ex Thell., 51176 and *A. cruentus**)	Amaranth	ah	w/c	Doodo, Emboga Enyabutongo	97.2	Eboga/Ekiliton	66.3
Solanaceae, *Solanum nigrum* L. sensu lato, 51174	Black nightshade	ah/ph	w/c	Enshwiga/Esiiga	41.1		0
Cleomaceae, *Cleome gynandra* L., 51178	African spider flower	ah	w/c	Esogye/Eshoje	15.8	Ecadoi/Akeo	76.9
Brassicaceae, *Brassica campestris* L. (*Acephala* group), 51168	Collard greens	ah	C	Sukumawiki/ Sukuma	7.8	Esukuma/ Sukumawiki	43.2
Brassicaceae, *Brassica oleracea* L. (*Capitata* group), 51175	Cabbage	ah	C	Cabbage	77.5	Cabbage	30.8
Fabaceae, *Vigna unguiculata* (L.) Walp., 51172	Cowpea leaves	ah	C	Omugobe	0.4	Eboo/Boyo	98.8
Malvaceae, *Hibiscus sabdariffa* L., 51177		bs	C		0	Emalakany/ Malakwang	56.8
Malvaceae, Corchorus trilocularis L. 51173	Bush okra	ah	w/c	Mutere	0	Atigo/Alilot	22.5
Fabaceae, *Phaseolus vulgaris* L., 51170	Bean leaves	ah	C	Ebijhamba	43.9		0
Zygophyllaceae, *Balanites aegyptiaca* (L.) Delile, 51169	Desert date	t	W		0	Ecomai/Ekoreete,	11.8
Cucurbitaceae, *Cucurbita maxima* Duchesne, 51171	Pumpkin leaves	ah	w/c	Ekisusha/ Ebishusha/	26.9	Asuswa/Asusa	12.4

Notes: w: Wild; c: Cultivated; w/c: Wild/cultivated; ah: Annual herb; bs: Biennual shrub; t: Tree; ph: Perennial herb; *: Not accessioned

Table 3. Vegetable collection time, preparation methods, quantity served, and frequency of consumption

Character	Category	Sub-region and frequency (%)	
		Ankole	Teso
Collection time	Morning	56.2	43.8
	Afternoon	49.6	50.4
	Evening	96.2	3.8
Preparation method	Steaming	98.3	1.7
	Mixing with in stews or foods	90.3	9.7
	Boiling	32.4	67.6
	Frying	59.6	40.4
	Pasting	0.0	100.0
Quantity eaten	2 serving spoons	100.0	0.0
	3 serving spoons	79.4	20.6
	4 serving spoons	1.6	98.4
	5 serving spoons	0.0	100.0
Frequency of eating (weekly)	<3	88.9	11.1
	3 – 5	64.9	35.1
	More than 5	32.4	67.6

most of the participants from Ankole sub-region ate vegetables for <3 days whereas some from Teso sub-region ate them for more than 5 days.

4.5. Prevalence of hyperglycemia and the distribution of participants' characteristics

Blood glucose levels of the participants were measured during the fasting condition (i.e., FBG) and recorded as normal, pre-diabetic, and hyperglycemia, based on the WHO criteria [28]. During data analysis, the FBG levels were re-categorized into normal and hyperglycemia to better see and discuss the anti-hyperglycemia effect of vegetable consumption. Table 4 summarizes the prevalence of hyperglycemia and the distribution of participants' characteristics. The overall prevalence of hyperglycemia in the study population sample was 29.15%. However, it was higher in participants residing in Ankole sub-region (35.5%) than those in Teso sub-region (19.5%). There is a slight mean difference (5.4 – 5.9 mmol/l) of FBG levels of the participants in the two sub-regions and it is statistically insignificant.

The prevalence of hyperglycemia was highest (i.e., at 40.4%) in the elderly participants (60 years old and above), and it was lowest in youth participants (19 – 30 years old), at 20.4%. In regard to marital status, married participants had the least prevalence of hyperglycemia (at 27.2%) compared to the single, widowed, and divorced (at 35.1%, 38.7%, and 36.8%, respectively).

The participants that had received secondary level of education had the highest prevalence of hyperglycemia (at 34.3%) than those with primary, tertiary, and no formal education at all. The civil servants had the least prevalence of hyperglycemia, at 16.7% whereas the non-civil servants had the highest at 38.3%. Although data on the amount of time spent on the sub-region of residence, physical exercise and its intensity showed impact on the blood glucose levels of the participants, it was not statistically significant.

Table 4. Prevalence of hyperglycemia and distribution of participants' characteristics

Participant characteristics	Category	Hyperglycemia prevalence (frequency %)
Sub-region	Ankole	35.6
	Tes Teso	19.5
	Total	29.1
Age	19 – 30	20.4
	31 – 45	29.0
	45 – 60	31.6
	60 above	40.4
Marital status	Single	35.1
	Married	27.2
	Divorced	36.8
	Widowed	38.7
Education level	No formal education	25.8
	Primary	28.0
	Secondary	34.3
	Tertiary	27.3
Occupation	Civil servant	16.7
	Farmer	28.1
	Non-civil servants	38.3
Years lived in resident sub-region	0 – 10	27.6
	10 – 20	28.1
	20 – 30	21.6
	≥30	37.1
Physical exercise	No	37.0
	Yes	28.6
Alcohol intake	No	29.2
	Yes	29.3
Physical exercise intensity	None	34.6
	Low intensity	33.8
	Moderate intensity	20.6
	Vigorous intensity	29.6
	Total	29.1
Body mass index category	Normal weight	29.0
	Over weight	29.4

4.6. Prevalence of hyperglycemia and vegetable consumption factors

Participants who consumed vegetables for more than 5 days in a typical week had the least prevalence of hyperglycemia (at 15.5%) compared to those who consumed them for <3 days (at 33.3%) (Table 5). Participants that prepared their vegetables by adding peanut/simsim butter had the least prevalence of hyperglycemia (at 16.1%); meanwhile, those that steamed their vegetables had the highest prevalence of hyperglycemia (at 34.3%). Participants that prepared the vegetables by shallow frying them had almost similar prevalence of hyperglycemia with those that boiled them. The

Table 5. Prevalence of hyperglycemia and vegetable consumption factors

Character	Factor	Hyperglycemia prevalence (frequency %)
Preparation method	Steaming	34.3
	Mixing	36.6
	Boiling	23.1
	Frying	27.7
	Pasting	16.1
Number of days per week of eating vegetables	<3	33.3
	3 – 5	31.9
	More than 5	15.5
Number of vegetable servings/meal	2 servings	37.2
	3 servings	33.9
	4 servings	16.1
	5 servings	16.2

prevalence of hyperglycemia with other vegetable consumption factors is shown in Table 5.

4.7. Association of hyperglycemia status with participants' characteristics

The data analyses showed that sub-region of residence, age of participant, vegetable preparation method, quantity, and frequency of the vegetable consumption were factors that independently associated with hyperglycemia status of the participants (Table 6). Participants residing in the Eastern were less likely to be hyperglycemia with an odds ratio (OR) of 0.44 (95% CI: 0.27 – 0.69). Participants of age category of 19 – 30 years were less likely to be hyperglycemia, with an OR of 4.86 (95% CI: 1.86 – 12.69) while participants that consumed <3 serving spoons of vegetables for <3 days in a typical week were more likely to be hyperglycemia with an OR of 0.31 (95% CI: 0.01 – 0.69) and 0.43 (95% CI: 0.20 – 0.90), respectively. Other independent factors are mentioned in Table 6. Other factors that we investigated for association with the hyperglycemia status, but found no association are marital status, level of education, occupation, physical exercise and its intensity, body mass index (BMI), and years lived in the residence.

A stepwise multi-variate logistic analysis was run, age and consumption of *H. sabdariffa* L. were consistently statistically significant through to step 21 of analysis with an increasing statistical significance (Table 7). The younger participants (19 – 30 years old) were less likely to be hyperglycemia compared to the elderly (>60 years old), and participants that consumed *H. sabdariffa*. were less likely to be hyperglycemia as well.

4.8. Key survey outcomes

Table 8 summarizes the key survey outcomes from the present study. The main aspects revolving around the commonly eaten vegetables in Ankole and Teso sub-regions of Uganda and the corresponding hyperglycemia prevalence in these sub-regions are highlighted, with the prevalence in Ankole sub-region being higher.

5. Discussion

The concept of this cross-sectional survey was borne from the national population-baseline survey on prevalence estimates and correlates of impaired fasting glycaemia (IFG) in Uganda [8]. This present study then aimed at finding a scientific base to the reported significant variance in prevalence of hyperglycemia in Ankole and Teso sub-regions of the country. We chose to look at the traditional diets in which vegetables are a great component of, and set out to document the consumption of the frequently eaten vegetables and prevalence of hyperglycemia in these sub-regions. Out of the 422 participants, all were female primarily because they are the persons responsible for meal preparation in households and they are also the gender that controls the power dynamics around decision-making on food procurement/collection and preparation [29]. These participants were sampled from Ankole and Teso sub-regions of Uganda and after data analysis, most were housewives of ages 30 – 59 years, they had acquired a primary level of education, subsistence farming was their occupation, and most were natives of their respective sub-region. These findings are in agreement with the 2020 National statistics on demographics, where most women got married at school going age (15 – 19 years) and ended up doing farming to fend for themselves and their families [30].

5.1. Consumption of frequently eaten vegetables in Ankole and Teso sub-regions of Uganda

Amaranth species (*A. dubius* and *A. cruentus*) were eaten in both sub-regions, although more in Akole than in Teso sub-region. *S. nigrum* was only eaten by participants in Ankole sub-region whereas *H. sabdariffa* was also eaten by only participants in Teso sub-region. These data are in agreement with the regional distribution of the African indigenous vegetable families in Uganda reported by Sseremba *et al.*, 2017 and Musinguzi *et al.*, 2011, which explains that Solanaceae family is more prevalent in Western (Ankole sub-region) than Eastern region (Teso sub-region) of Uganda [22,24]. Despite the low distribution of Amaranthaceae family in Western region, it is noteworthy that it is more eaten due to its cosmopolitan distribution, and availability since the species can be either cultivated, or grows in the wild as weeds, also called voluntary crops (EB Rubaihayo, 2002) supported by the favorable climate. Furthermore, most participants (especially residents of Teso sub-region) narrated that they preferred *Amaranthus* species because among leafy vegetables, it is the simplest to prepare, by boiling in salted water until soft; this has been so even in Northern sub-region of Uganda [31] for over four decades now.

5.2. Local names, habit, and habitat of the frequently eaten vegetables in Ankole and Teso sub-regions of Uganda

In this survey, the vegetable local/vernacular names depended on the dialect(s) spoken by the participants in the study sub-regions and since the interviewers were residents of these sub-regions, mistakes and confusion on the vegetable names were eliminated. Most of the vegetables consumed in both sub-regions

Table 6. Association of hyperglycemia status with participants' characteristics.

Characteristics	FBG category				CI (95%)	*P*-value	OR
	Normal		Hyperglycemia				
	N	%	N	%			
Sub-region							
Ankole	163	64.4	90	35.6	0.27 – 0.69	**0.0003**	0.439
Teso	136	80.5	33	19.5			
Age							
19 – 30	82	79.6	21	20.4	1.86 – 12.69	**0.01**	4.861
31 – 45	103	71.0	42	29.0	0.880 – 4.586	0.98	2.009
45 – 60	80	68.4	37	31.6	0.77 – 3.544	0.189	1.662
60 above	34	59.6	23	40.4			1
Marital status							
Single	24	64.9	13	35.1	0.173 – 0.584	0.385	0.583
Married	243	72.8	91	27.2	0.584 – 3.475	0.437	1.424
Divorced	12	63.2	7	36.8	0.233 – 3.193	0.824	0.862
Widowed	19	61.3	12	38.7			1
Education status							
Informal	49	74.2	17	25.8	0.687 – 5.878	0.203	2.009
Primary	139	72.0	54	28.0	0.472 – 3.219	0.668	1.233
Secondary	71	65.7	37	34.3	0.350 – 2.269	0.810	0.892
Tertiary	40	72.7	15	27.3			1
Occupation							
Civil servant	30	83.3	6	16.7	2.340E008– 2.625E-007	0.000	7.839-008
Farmer	217	71.9	85	28.1	1.331E-008 – 4.695E-008	0.000	2.500E-008
Non-civil servants	50	61.7	31	38.3			1
Years in residence							
0 – 10	84	72.4	32	27.6	0.462 – 1.887	0.849	0.934
10 – 20	64	71.9	25	28.1	0.569 – 2.356	0.686	1.158
20 – 30	69	78.4	19	21.6	0.750 – 3.029	0.250	1.507
>30	78	62.9	46	37.1			1
Physical exercise							
0.00	17	63.0	10	37.0	0.303 – 1.533	0.383	0.681
1.00	282	71.4	113	28.6			
Intensity of physical exercise							
None	17	65.4	9	34.6	0.432 – 2.906	0.816	1.120
LI	45	66.2	23	33.8	0.435 – 1.529	0.525	0.815
MI	54	79.4	14	20.6	0.630 – 2.615	0.492	1.283
VI	183	70.4	77	29.6			1
BMI category							
Normal	176	71.0	72	29.0	0.663 – 1.564	1.00	1.019
Over weight	120	70.6	50	29.4			
Steaming							
No	184	74.5	63	25.5	0.998 – 2327	0.064	0.524
Yes	115	65.7	60	34.3			
Mixing in stews/foods							
No	214	74.3	74	25.7	0.074 – 2.588	**0.029**	1.667
Yes	85	63.4	49	36.6			
Boiling							
No	109	62.3	66	37.7	0.324-0.758	**0.002**	0.495
Yes	190	76.9	57	23.1			

(Contd...)

Table 6. *(Continued)*

Characteristics	FBG category				CI (95%)	*P*-value	OR
	Normal		Hyperglycemia				
	N	%	N	%			
Frying							
No	231	70.4	97	29.6	0.54 – 1.517	0.797	0.911
Yes	68	72.3	26	27.7			
Adding peanut/simsim butter							
No	205	66.1	105	33.9	0.214 – 0.652	**0.000**	0.374
Yes	94	83.9	18	16.1			
Quantity eaten							
2 servings	76	62.8	45	37.2	0.144 – 0.685	**0.004**	0.314
3 servings	109	66.1	56	33.9	0.185 – 0.825	0.014	0.391
4 servings	52	83.9	10	16.1	0.300 – 2.096	0.640	0.793
5 servings	62	83.8	12	16.2			
Days per week							
<3	6	66.7	3	33.3	0.085 – 2.602	0.388	0.471
3 – 5	233	68.1	109	31.9	0.203 – 0.904	**0.026**	0.429
>5	60	84.5	11	15.5			1

Notes: LI: Low intensity; MI: Moderate intensity; VI: Vigorous intensity; P-value, Statistically significant participants' characteristic.

Table 7. Results from a stepwise multi-variate logistic analysis showing only significant variables

Step	Significant variable	*P*-value	95% CI
1	Age	0.01	
	19 – 30	0.00	0.60 – 0.41
	31 – 45	0.13	0.16 – 0.81
	Hibiscus sabdariffa	0.006	1.43 – 8.42
	Age	0.009	
	19 – 30	0.02	0.14 – 0.63
	Hibiscus sabdariffa	0.000	1.72 – 6.27

are annuals and were grown on small scale by intercropping them with other perennials such as coffee, cassava, and bananas. They were also grown in backyards, in kitchen gardens (for residents in town areas) for just household food security, nutrition, and health benefits in general [32-34]. Just as reported in other African countries, some participants in Teso sub-region monocropped some vegetables like *V. unguiculata* on land that is either not previously used or considered to be under-utilized, for its leaves, and seeds later harvested. Few participants planted in swampy land during dry season for household and commercial purposes. The income generated was used for the household, consequently improving on both livelihood and socioeconomic status [35,36]. In both regions, farmers considered traditional leafy vegetables low-income generating crops that did not deserve the attention like the cash crops (coffee, bananas, and cassava).

5.3. Vegetable collection, preparation method/preservation, amount, and frequency of consumption

In both sub-regions, collecting/harvesting method of leafy vegetables depended on whether they were harvested for household consumption or for commercial purposes. Tender leaves/tender stems were plucked for household consumption such that the plant would regrow the leaves and this method would continue for a minimum of 1 month to a maximum of 5 months until the plant has developed fruits. On the other hand, harvesting for commercial purposes was done by uprooting leafy vegetables, washing, and tying in bundles. This practice was also documented by Elizabeth *et al.* (2003); however, this method provides a onetime harvest of vegetables and does not allow the plant to develop seeds for both consumption (in the case of *V. unguiculata*) and sowing in the next season [37-39] affecting sustainable availability of the vegetables and germplasm.

The tender leaves/stems are briefly wilted under direct sunlight for approximately 10 – 20 min, for any insects/worms to crawl/die off. [31,40]. Residents in town councils in both study sub-regions bought vegetables from retail traders in trading centers who, in turn, bought from farmers [41].

The most common method of vegetable preparation in Ankole sub-region is steaming on top of food that is covered with banana leaves. It is because steaming method was already being used in the preparation of staple/traditional food (matooke); this saves time and fuel compared to when the vegetables are prepared separately. Another method of preparation that involves mixing vegetables in other stew or food (also called katogo) is common especially for preparation of breakfast meals [24]. To improve on the taste of stews (beans, fresh ground nut paste), vegetables are cooked together with them. In Teso sub-region, the wilted vegetable tender leaves/stems are washed and, then, boiled singly or in combination with another vegetable specie (the case of *V. unguiculata* and *Corchorus* spp.). These two species are usually cooked together so that the stiffness of *V. unguiculata* is countered by the slipperiness of *Corchorus* spp. To further tenderize the

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Table 8. Summary of the key survey outcomes

Survey outcomes	Ankole sub-region	Teso sub-region
Consumption of vegetables		
Most frequently eaten vegetables	*Amaranthus* spp., *Brassica oleracea, Phaseolus vulgaris*, and *Solanum nigrum*	*Vigna unguiculata, Cleome gynandra, Hibiscus sabdariffa*, and *Amaranthus spp*.
Collection time and vegetable state during preparation	Evening hours, prepared fresh	Afternoon hours, prepared fresh (during wet season) and dry (during dry season)
Preparation methods	Usually one vegetable specie (at a time) prepared by steaming on top of bananas, mixing with other foods (like bananas, cassava) and other stews (such as beans and fresh groundnut paste).	Usually one or two vegetable specie (s) (at a time) prepared by boiling (for some with soda ash), mixing with roasted sesame/groundnut paste.
Quantity served and frequency eaten/week	At most three servings, as side sauce, alongside another main source. Eaten for<3 days/week.	At most five servings as main sauce. Eaten for more than 5 days/week.
Purpose	Eaten as a side sauce, as alternative in time of need, for nutrition.	Eaten as main sauce, for food security, nutrition, and medicine.
Availability	Throughout the year	Only in wet season and preserved (by drying) for dry season.
Cultivation	Intercropped in plantations, grow voluntarily in the compounds and in the wild.	Grown in gardens, grow voluntarily in compounds and in the wild.
Prevalence of hyperglycemia		
Prevalence	35.5%	19.5%

leaves, local salt called "*Abalang*" (filtrate from ash obtained from burning of dry banana peelings, mature cotton stems, and mature amaranths plants) is added, and then, sodium chloride is added to taste. This can be eaten at this stage, or sour milk, groundnut, or sesame paste/butter are added depending on household preference to spice it [29]. *Cleome gynandra* in particular is almost always eaten pasted with groundnut paste, and if eaten when it is simply boiled, it was for relieving body ache, that is why participants in Teso sub-region called it "plant ibuprofen." Later, in 2021, Nakaziba *et al.* also listed it along with *Corchorus* spp., *Vigna unguculatta,* and *H. sabdariffa* among the medicinal vegetables in Northern region (which includes Teso sub-region), having positive effects on the various systems in the body [42]. The addition of either groundnut/sesame butter does not only make the vegetable stew tasty but also complements on its nutritional and medicinal value. Groundnut seeds are reported to contain nutrients such as carbohydrates, proteins, oil, and minerals. These nutrients are indispensable for nourishing the body. Moreover, the oil has high density lipids that are considered the "good" cholesterol because it removes the "harmful bad" type from the blood, thereby reducing its deposition, and in turn reducing body weight gain, a risk factor of hyperglycemia [43,44]. Sesame on the other hand contains a great deal of fiber content in addition to the minerals, making it ideal for improving nutritional status [45]. It is also endowed with a range of phytochemicals [46] beneficial for diabetes. The influence of these phytochemicals has been reviewed in different study deigns including clinical trials and has been shown to positively affect the glycemic makers and metabolic parameters [47,48]. A noteworthy compound in sesame is pinoresinol; it helps to control blood glucose by repressing the activity of maltase enzyme in the stomach [49].

Drying in direct sun is a traditional preservation method often applied by participants in Teso sub-region to increase the shelf life of vegetables up to dry season when they are scarce or not available at all [50]. This method of preservation works by reducing water/moisture to a percentage low enough to prevent or delay bacterial growth and reduce the vegetable weight. However, it is not encouraged because it results in loss of vegetable nutrients such as β-carotene and vitamin C up to 58 and 84%, respectively [50]. Instead, drying in a shade with sufficient aeration was advised [51]. It is however a very rare practice in Ankole sub-region since most vegetables are intercropped in banana and coffee gardens, and during dry season, water/moisture loss is reduced by mulching of gardens with thick layers of grasses, coffee husks, and dry banana leaves and stems, and some farmers store water in built underground reservoirs with tarpaulins inside, [52,53]. In 2006, Musinguzi *et al.*, explained the further decline of preservation of vegetables in Ankole sub-region as a result of limited available knowledge on their nutritional content since more emphasis are placed on commercial, high yielding exotic plants (such as coffee, pineapples and bananas) by both the agricultural extension officers and farmers.

In this study, 86% of the respondents consumed less than the minimum recommended five servings of vegetables per day, which is in agreement with reports from the largest population-based world- wide and the nationwide cross-sectional survey to examine the prevalence of low vegetable consumption [54,55].

According to most participants in Ankole sub-region (especially in town councils), steamed vegetables are usually served as a side dish, that is, a portion (maximum of 2 serving spoonfuls) is served on the plate alongside other foods like cooking bananas (matooke), posho (corn meal which is a dish of maize flour cooked with water to porridge or dough), cassava, rice and sweet potatoes, and eaten with stew on the same or another plate [24], whereas in Teso sub-region, five or more servings of vegetables is eaten with foods such as kalo (bread made of cassava and millet flour), cassava, sweet potatoes, and posho. Clearly, consumption of vegetables is still higher in Teso sub-region than in Ankole sub-region just

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like it was reported by Kabwama *et al.*, 2019 in their national survey [54]. This is due to the availability of a higher number and diversity of vegetable species, eaten interchangeably for several days of a week in households in Teso sub-region [22]. Ankole sub-region residents are mostly cattle farmers and meat consumption is rather more common [56] and generally categorizing their dietary pattern as traditional, high-fat, medium environmental impact as opposed to plant-based, and low environmental impact dietary pattern in Teso sub-region [57]. In both sub-regions, the dietary patterns are transitioning real fast, and there is need to equally fast track intervention.

5.4. Prevalence of hyperglycemia in Ankole and Teso sub-regions of Uganda

The overall prevalence of hyperglycemia was 29.1% in this study. Participants residing in Ankole sub-region had higher prevalence at 35.5% than those in Teso sub-region which was at 19.5%. Although these estimates are much higher than those from the previous national baseline survey (3.3% and 0.8%, respectively) carried out by Bahendeka *et al.*, in 2016, they agree with the trend. These differences could be due to the different definitions and measurements of hyperglycemia or the different health determinants across the population [58,59]. The elderly participants (60 and above years) had the highest prevalence compared to the youth participants (24.4%). This result concurs with that of Van Sande *et al.*, in 1997, who long reported a strong association of hyperglycemia with an advanced age [60], and similarly later by the International Diabetes Federation (IDF) in their global estimates for diabetes prevalence in 2017 [61]. The BMI of participants in our study did not show a statistical significant impact on the prevalence of hyperglycemia, whereas the nationwide baseline survey (2016) reported unclear association between the BMI and hyperglycemia status [8]. This discrepancy could be due to the fact that BMI is an indirect measure of obesity (body fat), a predisposing factor of hyperglycemia, and furthermore, BMI has a non-linear relationship with body fat [62] and hence making BMI an erroneous method of body fat measurement [63], and consequently an erroneous prediction of hyperglycemia.

Participants who were married had the least prevalence of hyperglycemia at 27.2%, this is probably because the married consumed more than five servings of vegetables daily and regularly as shown by Dias *et al.*, 2017 and Kabwama *et al.*, 2019 in their studies [54,64]. These authors explained that marriage and companionship involve social interactions which set stage for food consumption in which regular meals including vegetables are a pattern.

Respondents involved in moderate intensity of physical exercise had the least prevalence of hyperglycemia whereas those who did none at all had the highest prevalence, at 20% and 34%, respectively. This finding supports the conclusion made by Manders *et al.* (2010), who reported that low and moderate intensities of physical exercise, as opposed to high intensities, substantially reduce the prevalence of hyperglycemia. Likewise lack of regular physical exercise is a risk factor of non-communicable diseases in general due to imbalance energy homeostasis [2,65,66].

Participants who prepared vegetables by steaming showed the highest prevalence of hyperglycemia compared to those who boiled and added peanut/simsim butter. This result contradicts other study results which showed that steaming vegetables is probably the most appropriate preparation method since it retains water soluble nutrients and phytochemicals (polyphenolics) beneficial for blood glucose control [67-70]. However, these authors cautioned the duration of steaming vegetables to prevent thermal degradation of components therein, a probable explanation for their loss [71], and hence, higher prevalence of hyperglycemia even when consuming vegetables in the diet. Preparation of vegetables by boiling is preferred for vegetables having phytocompounds that are water-soluble and thermostable as long as the they are cooked in hot adequate water. In addition, the boiling method also inactivates the anti-nutritive compounds (oxalates and tannins) in them (Putriani *et al.*, 2020) [70]. Furthermore, boiling of more than one vegetable species with local salt and addition of sour milk, simsim, and groundnut paste does not only improve on the taste of the vegetable sauce but also compounds the phytochemicals responsible for reducing high blood sugar [72]; meanwhile, the tenderizing local salt is rich in plant based minerals which are beneficial for general health. Since most participants from Teso sub-region preferred this method most, it could explain the lower prevalence of hyperglycemia in the sub-region.

Stir-frying of vegetables even though used by few participants in the study, used to be a preparation method for town and city dwellers. However, due to the fast changing habits of Ugandans in general, it is becoming a traditional preparation method for some vegetables. Residents in Teso sub-region added that the adoption of frying vegetables is increasing with the decreasing availability of groundnut/simsim butter for mixing with the vegetables.

This preparation method was reported to cause the greatest loss of vegetable phytochemicals (phenols) which were repeatedly reported to be responsible for the hypoglycemic benefit [68,71].

Participants in Teso sub-region consumed more than five servings of vegetables per meal which concurs with Kabwama *et al.*, (2019) findings. This could be due to the tasty vegetable sauce resulting from addition of other ingredients (mentioned above) during preparation. In addition, only the vegetable sauce without another was often eaten in a meal for even up to 5 days/week. This frequency provides a clue on the importance of these vegetables for household food security as opposed to just for nutrition purposes. Each geographical region has a cultural identity that includes traditional staples, and our report regarding vegetables consumption is not surprising.

Most of the Ankole participants are cattle keepers therefore, they ate vegetables as a secondary/side sauce (alongside meat or fresh groundnut paste sauce), whenever the other relishes are in short supply or when famine strikes, thereby being an alternative in times of need. This could explain the higher prevalence in the sub-region since the participants consumed less than recommended amount of vegetables as stated in the American Heart Association Dietary guidelines [73] and miss out on the benefits from their multi-dimensional health effects such as improving postprandial glucose [74], elevating parameters associated with T2DM [75,76], and benefiting health status in general [77].

As stated by a number of studies, high fasting blood sugar is a predisposing factor to diabetes mellitus and it is important to consider the other factors associated with it to prevent its development and progression to diabetes [3,16,78,79]. A singular factorial analysis was conducted and there was statistical association of hyperglycemia status with factors such as sub-region of residence, mixing, boiling, and addition of peanut/simsim butter methods of vegetable preparation [8,54,68]. Hyperglycemia status was most likely to be observed in participants residing in Ankole sub-region with OR of 0.439 (95% CI: 027 – 0.69), a prediction which has not changed for the past 3 years [8,54]. These associations are very important information for prioritization of sub-regions during implementation of prevention and/or intervention programs in the country. Preparation of more than one vegetable (for example *V. unguiculata* and *Corchorus trilocularis*) or mixing them with other stews/foods [69] compounds the variety of nutrients and phytochemicals and provides a synergistic benefit for prevention and management of hyperglycemia [72]. It also ensures adequate intake of dietary vitamins, minerals, fiber, and phytochemicals [80,81]. For example, *Amaranthus* species, in Japan, was found to contain 72.6 – 77.05 μg/g fresh weight of total phenolic index [82], *Amaranthus hybridus* in Nigeria had ascorbic acid content of 0.43 mg/g [83] and *H. sabdariffa* contained 0.18 mg/g of fresh weight [84]. Consumption of these compounds, although decrease to a certain degree after vegetable preparation, influences glycemia through different mechanisms such as limiting oxidative processes [85], modulating digestive enzymes [86], gene expressions [87], signaling pathways [88], and glucose transporters [89].

During a stepwise multi-variate logistic analysis, the association of hyperglycemia status with age of participants showed statistically significant results (Table 7), and it confirmed the reports of similar studies where the elderly compared to the youths were more likely to develop hyperglycemia [64,90]. From the same statistical analysis, consumption of *H. sabdariffa* L. showed statistically significant impact on the prevalence of hyperglycemia which is not surprising since this vegetable species has been enormously studied and reviewed worldwide for its beneficial effects on hyperglycemia, its markers, and health in general [91-96]. The lack of impact from other factors, otherwise expected, could reflect challenge in the methodology especially in the evaluation tool.

5.5. Key survey outcomes

Results show that the commonly eaten vegetables in Ankole and Teso sub-regions and how they are processed from harvesting to consumption likely plays a role in regulating occurrence of hyperglycemia, as indicated by the level of prevalence in both sub-regions, though factors such as phytochemical compounds, genetics, and social-economic status could help explain this difference further.

5.6. Study limitations

Since this study was done at one point in time, it is difficult to derive causal relationships from the data analysis, and we also carefully interpreted the associations since we do not really know if the incidence of hyperglycemia was either before or after vegetable consumption.

The prevalence depends on the incidence and length of survival after becoming hyperglycemic, so this survey is insufficient to understand the trend of hyperglycemia in each sub-region.

Information (variables) included in this analysis were self-reported and subject to recall bias.

Participants may have over-estimated their consumption of vegetables as it is a desirable behavior or under-estimated as vegetables are said to be for poor people, and hence, we may have over- or under-estimated the true consumption in both study sub-regions.

However, our survey used a standardized data collection tool. Moreover, we had a large sample size and a high response rate, and so, our findings are sub-regionally representative.

6. Conclusion

The influence of vegetable consumption is a recognized factor for not only general health but also for prevention and management of hyperglycemia. However, there are dynamics in consumption such as appropriate vegetable species, method of preparation, quantity consumed, and frequency that interplay and do weigh in on the achievement of this intended benefit. Results of this study revealed that when the appropriate vegetable species is/are prepared using appropriate method(s) and consumed at recommended amount and frequency, they do yield positive results in prevention and management of hyperglycemia. The observed remarkable difference in prevalence of hyperglycemia in Ankole and Teso sub-regions in this study is a discernible consequence of the significant difference in the vegetable consumption dynamics. Further, research on the phytochemical composition and effect in these most frequently eaten vegetable species is needed; population genetics, and other lifestyle factors in both sub-regions to get a stronger focused and clearer scientific basis for the observed difference in prevalence of hyperglycemia, ultimately guiding to the precise strategies to prevent and manage it.

Community awareness through sensitization programs on health benefits of vegetable consumption for especially women should be reinforced since women control household health behaviors by ensuring availability and preparation of vegetables in meals. This will also demystify the stigma "vegetables are for the poor" since people usually tend to act in favor of good health if they are aware, are convinced, and know how to act. "Health in all policies" [97] should be adopted in the formulation of all policies so that nutrition and health are promoted in parallel with other regional development sectors. Farmers should be supported to encourage the production of these "low income crops" (vegetables) to increase supply.

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Conflicts of Interest

The authors declare no conflicts of interest.

Availability of Data

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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