The Potential of Solanum aethopicam Supplementation to Reduce the Anthropometric and Biochemical Risk Factors for Non-communicable Diseases among Older Persons in Mukono Municipality, Uganda: A Before-and-After Study

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Abstract

Background:

Non-communicable diseases contribute to over 70% of all deaths globally with the majority of the deaths in low and middle-income countries. Although increased vegetable consumption is a cost-effective intervention to mitigate the burden of non-communicable diseases, little is known about African indigenous vegetables to guide their consumption, especially among older persons. This study, aimed at exploring the potential of dietary *Solanum aethopicam* Shum supplementation in the reduction of the risk of non-communicable diseases among older persons aged 50 years and above in Mukono municipality, Uganda.

Methods:

This was a before-and-after study of 100 community-dwelling older persons aged 50 years and above residing in cosmopolitan Mukono Municipality in central Uganda. The meal of each participant was supplemented with 375g of *Solanum aethiopicum* Shum per day for four weeks. Anthropometric and biochemical parameters were collected at baseline and at the end of the four weeks. All measurements were taken in the morning after an overnight fast. Data was entered into an Excel sheet and transferred to STATA software for analysis. All data was summarized in tables and texts.

Results:

Of the 100 older persons aged 50 to 88 years (mean 63 ± 10), 60% were females and on average, males were older than females. Based on the body mass index, five percent were underweight, 40% were normal, and 55% were overweight or obese at baseline. After supplementation with Solanum aethiopicum Shum, three percent were normal, 44% were normal and 53% were overweight or obese. Also, there was a mean reduction in the participants' weight, body mass index, mid-upper arm circumference, abdominal girth, hip circumference, and C-reactive protein.

Conclusion:

The results suggest that supplementation of the older persons' diet with Solanum aethiopicum Shum improves their nutrition status, and leads to a reduction in the mean weight, body mass index, mid-upper arm circumference, abdominal girth, hip circumference, and C-reactive protein levels. Dietary supplementation with Solanum aethiopicum Shum should be promoted as a potential strategy to reduce the risk of non-communicable diseases among older persons.

Background

Globally, there is an increasing burden of Non-communicable diseases (NCDs) likely to retard the achievement of the health-related sustainable development goals (SDGs) by 2030 (WHO, 2018). The NCDs contribute to over 70% of all deaths globally with majority of the deaths occurring in low and

middle income countries (LMICs) (Bigna and Noubiap, 2019). The rise in NCDs in LMICs is attributed to the adoption of western diets with low vegetables, unplanned urbanization promoting fast foods, and the increased aging population due to improved life expectancy. Increased vegetable consumption is a potential mitigating strategy for the control of NCDs in LMICs of Sub-Saharan Africa given the availability of vegetables in most LMICs (Woodside *et al.*, 2023). Although studies in Brazil suggest that less than 20% of older persons, especially females, adhere to the daily recommended vegetable consumption (Bolbinski *et al.*, 2023), data on vegetable consumption in Africa is scarce. However, an earlier population-based study in South Africa among 3,840 older persons aged 50 years and above, noted an adherence to daily vegetable consumption of 31.5% among males and 28.6% among females, and adherence was poor among black South Africans (Peltzer and Phaswana-Mafuya, 2012). Therefore, the disproportionate vulnerability of older persons to the modifiable risk factors of NCDs like unhealthy diets require tailored evidence-based dietary interventions.

High dietary vegetable composition is a measure of diet quality and is associated with favorable anthropometric parameters and blood biomarkers likely to reduce the risk of NCDs. For instance, a study to assess the role of diet quality on the onset of NCDs among Americans aged 50 years and above, suggested that high vegetable diet was associated with reduction in C-reactive protein (CRP)-a general inflammatory biomarker associated with increased risk of diverse NCDs (Zhao and Andreyeva, 2022). A dietary intervention study among 612 older persons aged 65 years and above in Europe demonstrated that adherence to a high vegetable diet was associated with reduction in the risk of frailty and reduction in the CRP, with consequent reduction in the risk of NCDs (Ghosh *et al.*, 2020). Therefore, in LMICs like Uganda, dietary supplementation with African indigenous vegetables (AIVs) may contribute to the mitigation of the increasing burden of NCDs. *Solanum aethiopicum* (African eggplant) is one such AIV whose Shum, Gilo and Kumba edible groups have varied medicinal and nutritive values, but underutilized despite its availability in Uganda (Han *et al.*, 2021). This study therefore, aimed at exploring the potential of dietary *Solanum aethopicam* Shum supplementation in the reduction of the risk of NCDs among older persons aged 50 years and above in Mukono municipality, Uganda.

Methods

The aim of the study was to determine the effect of supplementation of the diet of older persons aged 50 years and above with *Solanum aethiopicum* on the anthropometric parameters and blood C-reactive protein. This was a before-and-after study of 100 older persons aged 50 years and above residing in Mukono Municipality in central Uganda. The municipality is occupied by a cosmopolitan community with a tendency to a western type of diet characterised by low vegetable consumption. A total of 100 community-dwelling male and female adults aged 50 years and above were recruited through mobilization by ten community development officers who compiled a list of all older persons residing in the five divisions of Mukono municipality. A total of 220 willing older persons were invited to stakeholders' meetings in their locality and informed about the study including the eligibility criteria. Subsequently, 100 participants participated in the study (Fig. 1).

The inclusion criteria were: residence within Mukono municipality for at least six months, residence within two kilometer radius from a community development officer, willingness to add Solanum aethiopicum Shum to the usual diet, no previous hypersensitivity reaction to vegetables, not being a known patient with Diabetes mellitus, hypertension or on chronic medication. Each participant provided informed consent, and all research procedures were conducted in accordance with the Helsinki Declaration. Participants on food supplements were excluded. This study was conducted after obtaining ethical approval from the Uganda Christian University research and ethics committee. Each community development officer was allocated ten participants within a two kilometer radius of her/his residence for follow up and ensure adherence to the diet supplemented with *Solanum aethiopicum* Shum during the intervention period. Each participants' dinner meal was supplemented with 375g of steamed of *Solanum aethiopicum* per day for four weeks. During the four weeks, participants were not allowed to feed on any other vegetable except *Solanum aethiopicum* Shum. All the *Solanum aethiopicum* was cultivated under the same condition, packaged at the central location, and delivered by the designated community development officer who supervised the steaming. All participants and caretakers were trained on how to steam the *Solanum aethiopicum* Shum before initiation of the study, and then every week. The Participants and their household members were counselled on the importance of adhering to the modified diet, and monitored by a designated community development office.

Anthropometric and biochemical parameters were collected at baseline and at the end of the four weeks by trained research assistants. All measurements were taken in the morning after an overnight fast as previously described (Papaioannou, Kadi and Nilsson, 2022). The demographic data was collected only at baseline. All data was collected using a pre-tested questionnaire. All anthropometric measurements were performed based on standard guidelines (Başıbüyük *et al.*, 2021). The mid upper arm circumference (MUAC) was measured to the nearest 0.1 cm using a MUAC tape. Weight was measured to the nearest 0.1Kg in light clothing with the use of a calibrated electronic scale (SECA 869 Digital floor scale, Capacity: 250 kg), and the height was measured to the nearest 0.1 cm with the use of a Portable Height-Length Measuring ShorrBoard High quality hardwoods with weather-resistant finish (Stadiometer, ShorrBoard (0-211cm x 0.1cm). The Body mass index (BMI) was calculated as weight in Kilogram divided by squared height in meters (Kg/m^2). Waist and Hip circumferences, and abdominal girth were measured using an anthropometric tape to the nearest 0.1cm as previously described (Krishnan, Adams et al. 2018). Then, the waist-to-hip ratio was determined. A licensed laboratory technologist collected venous blood and analysed it for the levels of CRP as previously described (Tian *et al.*, 2019).

Data was entered into an excel sheet and exported to STATA software version 15.0 (StataCorp LP, College Station, TX, USA) for univariable and bivariable analysis. At univariable analysis, the means with corresponding standard deviations, the medians with corresponding interquartile ranges, and the ranges were obtained for each continuous variable, while the frequencies and corresponding percentages were obtained for categorical variables. The nutrition status was based on the BMI since it is a proven method of assessing the nutrition status among older persons (Başıbüyük *et al.*, 2021). The effect of dietary supplementation with *Solanum aethiopicum* was assessed using a paired sample t-test after testing for

the assumptions. For each mean difference, a corresponding 95% confidence interval was obtained and a two-sided p-value. All variables with a p-value of less than 0.05 were deemed statistically significant. All the results were summarized in tables.

Results

A total of 100 older persons aged 50 to 88 years (mean 63 ± 10; median 62, IQR: 54 to 70) participated in this study. Of these, 60% were females, and on average, males were older than females. Based on the BMI, five percent of the 100 participants were underweight (BMI < 18.5), 40% were normal (BMI: 18.5 to 24.9), and 55% were overweight or obese (BMI ≥ 25) at baseline. After supplementation with *Solanum aethiopicum* Shum, three percent were normal, 44% were normal and 53% were overweight or obese. On average, the weight, body mass index, mid upper arm circumference, abdominal girth, waist circumference, hip circumference, and waist-to-hip ratio were higher among females compared to males (Table 1

Table 1
Baseline characteristics

Variable	Mean (SD)	Median (IQR)	Range
Age in Complete years			
All participant (n = 100)	63 (10)	62 (54 to 70)	50 to 88
Age of females (n = 60)	62 (10)	61 (53 to 67)	50 to 86
Age of Males (n = 40)	**66 (9)**	**67 (59 to 71)**	50 to 88
Weight in Kilograms			
Overall	69.6 (14.1)	66.5 (60.3 to 81.5)	37.6 to 109.4
Weight of females	**70.6 (13.6)**	**68.2 (61.9 to 84.0)**	37.6 to 96.1
Weight of males	68.2 (14.8)	65 (57.7 to 76.3)	45.9 to 109.4
Height in meters			
Overall	1.6 (0.1)	1.6 (1.6 to 1.7)	1.5 to 1.8
Height of females	1.6 (0.1)	1.6 (1.5 to 1.6)	1.5 to 1.8
Height of males	1.7 (0.1)	1.7 (1.6 to 1.7)	1.5 to 1.8
Body mass index (BMI)			
Overall BMI	26.4 (5.3)	25.6 (22.3 to 29.9)	16.7 to 38.5
BMI of females	**27.8 (5.2)**	**27.1 (24.5 to 31.4)**	16.7 to 38.5
BMI of males	24.3 (4.9)	23.1 (21.0 to 28.5)	17.0 to 37.9
Mid-upper arm Circumference (MUAC)			
Overall MUAC	30.0 (4.1)	29.8 (26.5 to 33.0)	22.9 to 41.0
MUAC of females	**30.9 (4.1)**	**30.9 (28.9 to 33.3)**	22.9 to 35.4
MUAC of males	28.6 (3.6)	28.6 (26.2 to 31.7)	22.9 to 35.4
Abdominal girth (ABG) in cm			
Overall	93.3 (13.9)	93.0 (83.4 to 101.9)	60.7 to 127.5
ABG for females	**96.0 (13.7)**	**98.9 (84.9 to 103.1)**	60.7 to 120.6)
ABG for males	89.4 (13.3)	88.0 (78.9 to 96.8)	70.5 to 127.5
Waist circumference (WC) in cm			
Overall	97.9 (12.7)	97.2 (87.6 to 106.0)	75.0 to 129.9
WC for females	**102.0 (12.2)**	**101.5 (94.8 to 109.5)**	77.5 to 129.9

Variable	Mean (SD)	Median (IQR)	Range
WC for males	91.7 (10.9)	88.4 (85.0 to 100.0)	75.0 to 125.0
Hip circumference (HC) in cm			
Overall	95.1 (12.7)	95.0 (85.8 to 106.5)	71.2 to 128.2
HC for females	**100.7 (11.7)**	**98.4 (93.1 to 108.5)**	74.6 to 128.2
HC for males	86.8 (9.1)	85.8 (81.0 to 90.9)	71.2 to 109.2
Waist-to-Hip ratio (WHR) in cm			
Overall	1.0 (0.1)	1.0 (1.0 to 1.1)	0.8 to 1.2
WHR for females	1.0 (0.1)	1.0 (1.0 to 1.1)	0.8 to 1.2
WHR for males	**1.1 (0.1)**	**1.1 (1.0 to 1.1)**	**0.9 to 1.2**
C-Reactive protein (CRP) in mg/L			
Overall	0.4 (0.5)	0.2 (0.1 to 0.4)	0.1 to 2.8
CRP for females	0.4 (0.4)	0.2 (0.1 to 0.4)	0.1 to 2.8
CRP for males	0.4 (0.6)	0.2 (0.1 to 0.5)	0.1 to 2.7

Effect of Solanum aethiopicum supplementation on the Anthropometry and C-reactive protein of older persons aged 50 to 88 years

After supplementation with Solanum aethiopicum Shum, there was a mean reduction in the participants' weight, body mass index, mid upper arm circumference, abdominal girth, hip circumference, and C-reactive protein. The mean reductions in all anthropometric parameters were not statistically significant, while the reduction in C-reactive protein was statistically significant (Table 2).

Table 2
Effect of *Solanum aethiopicum* supplementation on the Anthropometry and C-reactive protein of older persons aged 50 to 88 years

Variable	Mean (SD)	Mean difference (SD)	95% Confidence interval	t-statistic (df)	P-value
Baseline weight (Kg)	69.6 (14.1)	0.5 (9.0)	-1.32 to 2.26	0.52 (99)	0.60
Post-intervention weight (Kg)	**69.1 (14.7)**				
Baseline BMI	26.4 (5.3)	0.3 (3.7)	-0.50 to 0.98	0.64 (99)	0.53
Post-intervention BMI	**26.1 (5.2)**				
Baseline Mid-upper arm circumference (cm)	30.0 (4.1)	0.2 (3.3)	-0.47 to 0.85	0.56 (99)	0.57
Post-intervention MUAC (cm)	**29.8 (4.2)**				
Baseline abdominal girth (cm)	93.3 (13.9)	0.5 (11.5)	-1.76 to 2.75	0.44 (99)	0.66
Post-intervention abdominal girth (cm)	**92.8 (14.2)**				
Baseline waist circumference (cm)	**97.9 (12.7)**	0.4 (13.7)	-3.11 to 2.34	-0.28 (99)	0.78
Post-intervention waist circumference (cm)	98.3 (16.0)				
Baseline Hip circumference (cm)	95.1 (12.7)	1.4 (8.6)	-0.35 to 3.07	1.58 (99)	0.11
Post-intervention hip circumference (cm)	**93.8 (12.1)**				
Baseline waist-to-hip ratio	1.0 (0.1)	0 (0.1)	-0.04 to 0.01	-1.41 (99)	0.16
Post-intervention waist-to-hip ratio	1.0 (0.1)				
Baseline C-Reactive protein	0.4 (0.5)	0.1(0.4)	**0.01 to 0.15**	2.20 (99)	**0.03**
Post-intervention C-Reactive protein	**0.3 (0.4)**				

Discussion

This study entailed 100 community-dwelling older persons aged 50 years and above, majority (60%) being female. After supplementation with *Solanum aethiopicum* Shum, the nutrition status based on BMI improved: underweight reduced from five to three percent, normal nutrition status increased from 40–44%, and overweight or obese reduced from 55–53%. These findings are consistent with the results of a systematic review of 57 articles that suggested that vegetable consumption improves the BMI of older person (Bouzas, Bibiloni and Tur, 2019). At baseline, the average, weight, body mass index, mid upper arm circumference, abdominal girth, waist circumference, hip circumference, and waist-to-hip ratio were higher among females compared to males in this study (Table 1). This gender difference in anthropometry among older parson was also noted in a cross-section study of 2,721older persons aged atleast 65 years in Turkey that were also predominantly females (Başıbüyük *et al*., 2021). This gender difference may be due to the differences in the feeding habits and food preferences (Peltzer and Phaswana-Mafuya, 2012); this should be put into consideration when designing tailored dietary interventions.

In this study, each participant was given 375grams of fresh leafy vegetables of *Solanum aethiopicum* Shum per day to ensure that even with the varied feeding behaviour, all participants would consume the minimum daily recommended amount of vegetables. Reports from a recent comprehensive systematic review suggest an increase protection against mortality due to NCDs as the dose of vegetables increase from 100grams per day to 200grams per day; and no additional benefit beyond a daily dose of above 300grams (Woodside *et al*., 2023). However, other authors affirm that a daily consumption of a minimum of 400g of vegetables is beneficial in the reduction of the risk for NCDs (Bolbinski *et al*., 2023). There may be variation in daily dose requirement for maximum benefits dependent on the vegetable type, preparation method and the meal composition. In this study, all participants fed on steamed *Solanum aethiopicum* Shum to ensure uniformity in the benefits, and tolerability since steaming was the most agreeable method of vegetable preparation among the participants. However, there is a possibility that the variations in the participants' meals that were supplemented with *Solanum aethiopicum* Shum led to varied bioavailability and subsequently their outcome.

After supplementation with *Solanum aethiopicum* Shum, there was a mean reduction in the participants' weight, body mass index, mid upper arm circumference, abdominal girth, hip circumference. Although the reductions were not statistically significant (Table 2), it is of clinical significance especially among older persons with deranged anthropometric parameters. The lack of statistical significance in this study may be due to the small sample size that was based on the available number of older persons eligible to participate in the study. The findings are in agreement with a community-based cross-sectional study of 252 older persons in Sweden that suggested that increased consumption of vegetables improves the anthropometric parameters and subsequently reduce the risk of metabolic syndrome (Papaioannou, Kadi and Nilsson, 2022).

There was a statistically significant reduction in the levels of C-reactive protein following supplementation of the diet with *Solanum aethiopicum* Shum (Mean difference 0.1 ± 0.4; 95%CI: 0.01 to 0.15; $p = 0.03$). This is consistent with the findings in a study conducted in the United states of America among older persons aged 50 years and above (Zhao and Andreyeva, 2022). These two studies in diverse

populations of older persons demonstrate that vegetable supplementation reduces the risk of NCDs. Relatedly, a meta-analysis of twenty-three case-control studies suggested that reduction in C-reactive protein reduces the risk of neurological disorders common among older persons (Qiu *et al.*, 2019). Therefore, vegetable supplementation is a potential cost-effective intervention to mitigate the ravages of NCDs in resource-limited settings.

Conclusion

The findings of this study suggest that a higher proportion of older persons in Mukono municipality have abnormal BMI predisposing them to NCDs. The supplementation of the usual diet of older persons with *Solanum aethiopicum* Shum improves their nutrition status due to the reduction in the mean weight, body mass index, mid upper arm circumference, abdominal girth, hip circumference, and C-reactive protein levels. Therefore, dietary supplementation with *Solanum aethiopicum* Shum should be promoted as a potential strategy to reduce the risk of NCDs among older persons.

Abbreviations

1. ABG: Abdominal girth
2. BMI: Body mass index
3. CRP: C-reactive protein
4. HC: Hip circumference
5. LMICs: Low and middle income countries
6. NCDs: Non-communicable diseases
7. Upper arm circumference
8. Waist circumference
9. WHR: Waist-to-hip ration

Declarations

Ethics approval and consent to participate: Ethical approval to conduct this research was obtained from the Uganda Christian University Research and Ethics Committee. Each participant gave informed consent to participate in the study.

Consent for publication: All authors consented to the publication

Availability of data and materials: The dataset used and/or analysed during this current study are available from the corresponding author on reasonable request

Competing interests: The authors declare that they have no competing interest

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Authors' contributions:

E.K.B Conceptualized the idea, mobilized resources for the research, and provided overall leadership of the study

M.J.N, MM, and K.A Supervised the cultivation of Solanum aethiopicum, packaging, distribution, and adherence to consumption

GT, ST, and C.N supervised data collection, and data analysis, and wrote the main manuscript

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Figures

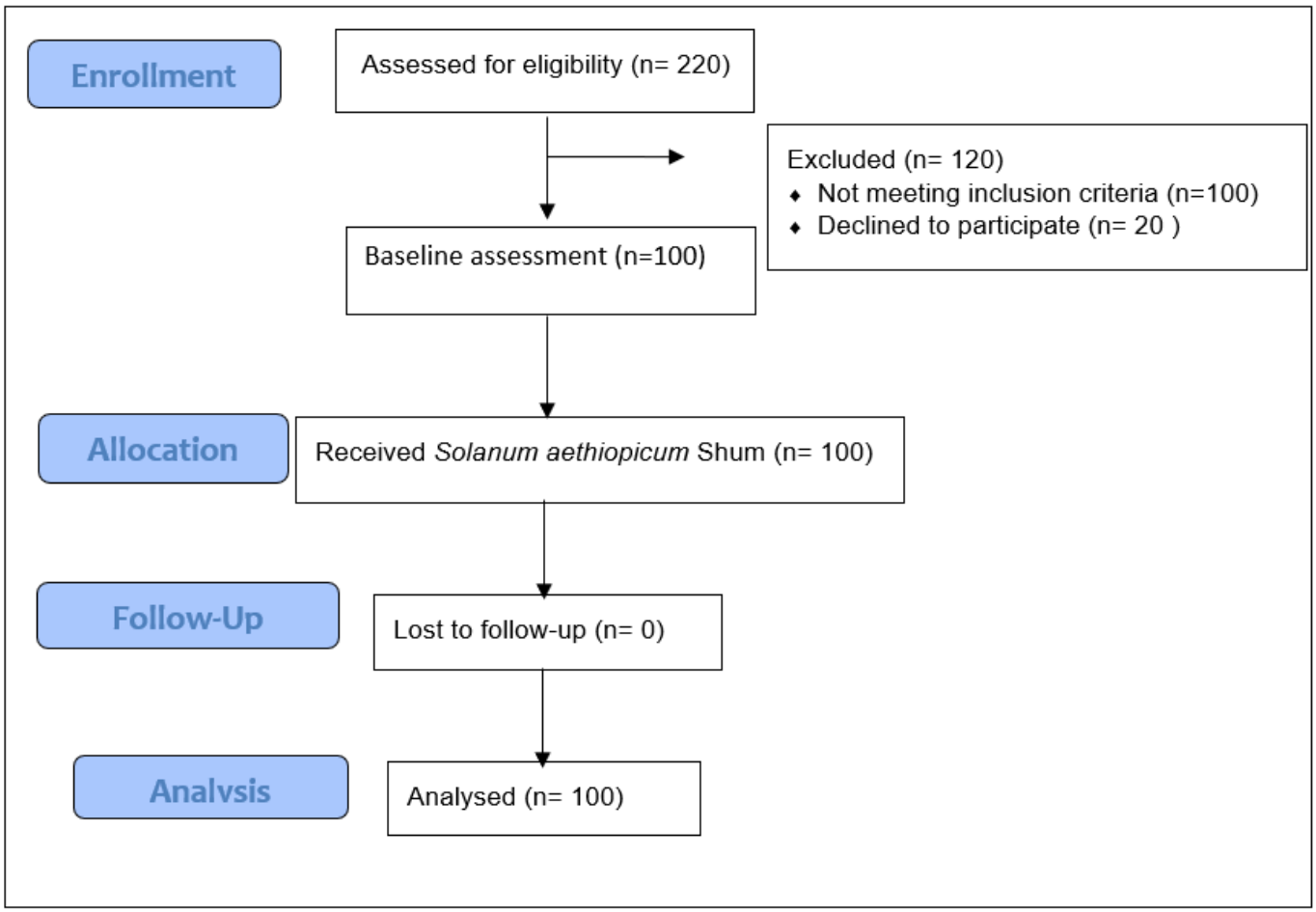

Figure 1

Flow diagram of participants