Effect of Glycine Max (Soybean) Consumption on Renal Functions and Estimated Glomerular Filtration Rate among University Students

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ABSTRACT

Background: Soybean (glycine max) exhibits potential therapeutic effects. **Objectives:** The effect of soybean consumption on renal functions was evaluated. Sodium (Na), potassium (K), chloride (Cl), urea (U), creatinine (Cr), uric acid (UA), and estimated glomerular filtration rate (eGFR) were measured among students. **Materials and Methods**: Thirty male students between 18 and 30 years were recruited. Participants abstained from soybeans and similar food consumption for three weeks. Each received 25g of soybean powder for 30 days in addition to their normal diet. Fasting blood sample was collected on days 0 and 31, and creatinine, urea, uric acid, electrolytes, and eGFR levels were determined. Systemic blood pressure (SBP), diastolic blood pressure (DBP), height, and weight were measured. Questionnaire obtained socio-demographic information. Urea, creatinine, and UA were measured colorimetrically before and after soybean consumption while electrolyte levels were by the ion-selective electrode. Data were analyzed with Paired students t-tests and Pearson r correlation. **Results:** A significant increase existed in the mean plasma concentrations of sodium, potassium, and chloride after soybean consumption (139.79±3.69, 4.61±0.70, 102.79±3.69) compared with the baseline (137.53±3.54, 3.87±0.63, 100.53±3.54) ($p<0.05$) respectively, and significant decreases was observed in uric acid level, systolic and diastolic blood pressures after soybean consumption. Positive correlations were observed between SBP Vs DBP, SBP Vs eGFR, and DBP Versus eGFR, and negative correlations in DBP Vs Cr, BMI Vs K, eGFR Vs DBP, eGFR Vs Na, eGFR Vs Cl, and eGFR Vs Cr levels. **Conclusions:** Soybean consumption has a hypouricaemic effect, and is harmless to the kidney.

Keywords: Soybean (Glycine max), Creatinine, Urea, Uric acid, Electrolytes, Estimated glomerular filtration rate (eGFR).

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BACKGROUND OF STUDY

The use of plants for the treatment of diseases can be traced back to prehistoric times. [1] Between 65% and 80% of the populations of developing countries currently use medicinal plants as remedies, [2] and medicinal plants would be the best source to obtain a variety of drugs. [3] It has been revealed that 15% of 300,000 global plant species has known phytochemical abilities, and it is a welcome idea to process new forms for human consumption. Therefore, all plants should be investigated for a better understanding of their properties, safety, and efficacy.[4] Some plant sources have been shown to exhibit potential therapeutic effects on kidney diseases and soybean is one such plant to reckon with in this context. [5]Recently, researches for food substances that will improve the body functions are gaining grounds thereby assuring better feeding lifestyle and preventing diseases. Food can be considered functional if it can be demonstrated satisfactorily that it positively affects one or more functions of the organism, promoting the benefits cited above.[6]Soybean (Glycine max) is a legume native to East Asia, widely grown for its edible bean which has numerous uses. The pods, stems, and leaves are covered with fine brown or gray hairs. The fruit is a hairy pod that grows in clusters of three to five and contains two or four seeds. The bean is mostly consumed in the form of soybean milk.[6] . It is cultivated all over the world as a major source of oil and protein in livestock feeds but also for human consumption, soil fertility improvement, and, amongst others, for producing industrial products such as soy inks, non-toxic adhesives, candles, and paints.[7] It is grown on about 6% of the world's arable land representing an estimated total area of more than 92.5 million hectares, giving 217.6 million tonnes of production each year. Globally, soybean production rose to over 276 million tonnes in 2013 [8] with the United State of America being the leading producer of soybean, accounting for about 32% of the global production, followed closely by Brazil (29%) and Argentina (17%).[8] Soybean accounts for about 56 and 67% of the total global oilseed production and world supply of protein to be consumed, respectively, and hence, a major source of oil and protein. [9] However, Africa accounts for <1% of global soybean production with about 1,400,000 Mg yr1 while South Africa, Nigeria, and Uganda are the top soybean producers in Africa accounting for about 70% of the continent's production.[10]

Soybean has been reported to differ from other grain legumes because of the presence of high amounts of beneficial components like proteins, fibers, iron, potassium, calcium, magnesium, zinc, and B vitamins, phytosterols, and isoflavones (ISOs). [11] It has high protein content (about 40%) of good nutritional quality,[12] and a high oil content (about 20%) which, together with numerous beneficial nutrients and bioactive factors, make soybean the crop of choice for improving the diets of millions of people in developing countries like Nigeria.[13] Mature seeds of soybean have been reported to contain, approximately 31% carbohydrate, 17% fats, 5% minerals, and 12% moisture. [14] Soybean protein contains an acceptable amount of essential amino acids i.e. histidine, isoleucine, leucine, lysine, phenylalanine, tyrosine, threonine, tryptophan, and valine which are recommended for daily intake as a balanced diet. [15] Soybean is gaining importance as a nutritionally important crop and also becoming popular for its nutraceutical properties as it contains essential amino acids and secondary metabolites such as isoflavone, saponins, and phytic acids, phytosterols, trypsin inhibitors, and peptides. Isoflavone has been implicated in the prevention of different kinds of diseases.[16] Soybean isoflavones have a wide range of activities that probably act synergistically with the soy proteins to mediate favorable effects on renal function.[17] The protein from legumes like soya beans helps to regulate blood sugar, body fluid, kidney, liver function, adrenaline, and other aspects of metabolism.[18] Studies have shown that soya beans possess antioxidant effect[17,18,19] and hypotensive effects.[3] These effects coupled with the presence of high amounts of proteins, fibers, iron, potassium, calcium, magnesium, zinc, and B vitamins, phytosterols, and isoflavones (ISOs) [11,12] points to the possibility that soybean consumption may have renoprotective effects in humans. Interestingly, studies have reported the ameliorative effect of soybean intake on various kidney diseases in both animals [6,7] and human studies[5,15] Kidney disease is a global public health problem that affects more than 750 million persons worldwide.[20] Chronic kidney disease (CKD) is a serious, public health problem with rapidly increasing incidence[21] and an annual mortality of more than one million. [22] Although the magnitude and impact of kidney disease are better defined in developed countries, emerging evidence suggests that developing countries have a similar or even greater kidney disease burden.[23] 10% of the population worldwide is affected by chronic kidney disease (CKD), and millions die each year because they do not have access to affordable treatment.[20] The GBD 2015 study also estimated that, in 2015, 1.2 million people died from kidney failure, an increase of 32% since 2005.[24] In 2010, an estimated 2.37.1 million people with end-stage kidney disease died without access to chronic dialysis.[25] Additionally, each year, around 1.7 million people are thought to die from acute kidney injury.[26] The main risk factors for CKD include race, elevated blood pressure (BP), male sex, obesity, hypertension, type 2 diabetes, smoking, family history of CKD, aging, and lifestyle behaviors such as dietary patterns.[27] Hypertension is estimated to affect 1 billion people worldwide and is the second leading attributed cause of CKD.[28] Importantly, these risk factors are modifiable factors that may be acted upon to minimize the ravaging effect of kidney disease. Hence, Dietary factors are particularly valuable in the prevention and management of kidney disease [29,30]

Soybean is regularly and commonly consumed in Nigeria, especially in Nnewi, Anambra state in various forms of preparations, hence its consumption is widely acceptable. However, people still take it without knowing its effect on the kidney. Although many authorities have x-rayed the effect of soybean intake on kidney function in other countries, research in this regard is scanty in Nigeria. Therefore, the present study evaluated the effect of glycine max (soybeans) consumption on renal functions and estimated the glomerular filtration rate among university students.

METHODS

Study participants

The sample size was calculated using G*Power software version 3.0.10 (Universität Düsseldorf, Germany). Power analysis for the difference between two dependent means was conducted in G*Power to determine a sufficient sample size using an alpha of 0.05, a power of 0.8, and an effect of 0.5. Based on these, the calculated total sample size of 27 has 80% power to detect a difference of 0.25 at a significance level of 0.05

Thirty (30) male students of College of Health Sciences and Technology, Nnamdi Azikiwe University, Nnewi campus were recruited. The study was approved by the Ethics Committee of Faculty of Health Sciences and Technology, Nnamdi Azikiwe University, Nnewi, Anambra State, Nigeria ERC/FHST/NAU/2019/2152.Healthy informed and consented participants between 18 and 30years were recruited whereas; individuals that are sick, on drugs (diuretics or anti-diabetic drugs), or those outside the age range were excluded. Participants abstained from soya bean and similar food consumption for a period of three weeks before the commencement of the study. Six milliliters (6ml) of baseline blood samples (after an overnight fast) were collected from each of the participants on day 0 as control and were dispensed into lithium heparin containers for determination of biochemical parameters (urea, creatinine, uric acid, sodium, potassium, chloride, and bicarbonate). The colorimetric technique was used to measure U, Cr, and UA while electrolyte levels by ion-selective electrode method before and after soybean consumption. Subsequently, in addition to their normal diet, each of the participants was given 25g of soybean powder before breakfast daily for 30 days. After an overnight fast, 6mls of post soya bean consumption (test) samples were collected on the 31st day and the levels of renal function parameters were also evaluated. The questionnaire was used to obtain socio-demographic information such as age, height, sex, demographic factors, and dietary patterns while subjects' weight and blood pressure readings were obtained using a digital body weighing scale(canny, USA) and Walgreens digital blood pressure before and after soya bean consumption respectively.

Plasma creatinine, urea, and uric acid levels were assayed using Jaffe-Slot Alkaline Picric Acid Method, [31] Berthelot Method[32], and Uricase method.[33] Electrolyte determinations were done using Ion-Selective Electrode (ISE) Method. The estimated glomerular filtration rate (eGFR) was calculated using the Modification of Diet in Renal Disease (MDRD) formula as described by [34]

Statistical analysis

The data obtained were presented as mean±SD and the mean values of the baseline and test samples were compared by Students t-test and Pearson r correlation using Statistical package for social sciences (SPSS) (Version 23) software. Statistical significance was tested at p<0.05.

RESULTS

The mean age and height of the subjects studied were 25.03±3.18 years and 1.70±0.10m respectively. The mean weight and body mass index of the participants before soya bean intake did not differ significantly when compared with values observed after soybean consumption (p=0.190; 0.252) respectively. However, there were significant decreases in the mean systolic and diastolic blood pressures in the participants after soybean intake than before consumption (p=0.001; 0.003) respectively.

Table 1: Socio-demographic parameters before and after soybean intake(mean±SD)

Parameters	Before soybean intake	After soybean intake	t-test	p-value
Age(year)	25.03±3.18	-	-	-
Height (m)	1.70±0.10			
Weight (kg)	68.43±9.92	70.00±9.44	0.823	0.190
BMI (Kg/m^2)	23.70±3.84	24.23±3.53	0.393	0.252
SBP (mmHg)	120.97±14.18	110.07±11.14	14.777	0.001*
DBP (mmHg)	72.67±10.33	68.40±5.26	6.912	0.003*

**Statistically significant at p<0.05*

There were significant increases in the mean plasma sodium, potassium, and chloride concentrations after soybean consumption (p=0.033, 0.001, 0.033) respectively, however the increases are within the normal reference ranges, therefore are not clinically significant. However, the mean plasma urea, creatinine, and bicarbonate levels did not differ significantly in the subjects studied after soybean consumption (p>0.05).There was a significant decrease in the mean plasma uric acid level after soybean consumption. (p=0.001), whereas, the mean eGFR did not differ significantly in the subjects studied after soybean consumption (p>0.05).

Table 2: Comparison of some electrolytes and markers of kidney damage before and after intake of soybean (mean±SD).

Parameters	Before soybean intake	After soybean intake	t-test	p-value
Sodium (mmol/l)	137.53±3.54	139.79±3.69	-2.241	0.033*
Potassium (mmol/l)	3.87±0.63	4.61±0.70	-3.712	0.001*
Chloride (mmol/l)	100.53±3.54	102.79±3.69	-2.242	0.033*
Bicarbonate (mmol/l)	23.83±1.62	23.67±1.73	0.404	0.689
Urea (mmol/l)	4.23±0.73	4.22±0.71	0.015	0.988
Creatinine (µmol/l)	76.60±10.27	79.52±6.84	-1.423	0.165
Uric acid(µmol/l)	428.54±37.28	301.08±12.82	3.803	0.001*
eGFR (mL/min/1.73m^2)	137.53±13.11	134.17±9.97	1.303	0.203

Statistically significant at p<0.05.
*

There were significant positive correlations observed between SBP Vs DBP (r=0.390; p=0.033) and SBP Vs eGFR (r=0.480; p=0.007), whereas other parameters were significantly negatively correlated (p<0.05) in participants studied before soybean consumption.

Table 3: Association between the parameters before Soybean Consumption in the participants.

Parameters	r-value	p-value
SBP Vs DBP	0.390	0.033*
SBP Vs Egfr	0.480	0.007*
SBP Vs Creatinine	-0.413	0.023*
DBP Vs eGFR	-0.405	0.026*
DBP Vs creatinine	-0.364	0.048*
eGFR Vs SBP	-0.480	0.007*
eGFR Vs DBP	-0.405	0.026*
eGFR Vs Creatinine	-0.934	0.001*
eGFR Vs uric acid	-0.403	0.027*

**Statistically significant at p<0.05.*

DBP Versus eGFR showed a significant positive correlation (r=0.444; p=0.014), whereas there were significant weak negative correlations in DBP Vs creatinine, BMI Vs K, eGFR Vs DBP, eGFR Vs Na, eGFR Vs Cl, and a strong negative correlation in eGFR Vs creatinine respectively after soybean consumption in the subject studied (p<0.05).

Table 4: Association between the parameters after Soybean Consumption in participants.

Parameters	r-value	p-value
DBP Vs eGFR	0.444	0.014*
DBP Vs creatinine	-0.364	0.048*
BMI Vs K	-0.369	0.045*
eGFR Vs DBP	-0.405	0.026*
eGFR Vs Na	-0.359	0.051*
eGFR Vs Cl	-0.359	0.051*
eGFR Vs creatinine	-0.943	0.001*

**Statistically significant at p<0.05.*

DISCUSSION

Soybean exhibits potential therapeutic effects which should be investigated to evaluate its pharmacological potential.[4,5] The effect of soybean consumption on renal function in male students was evaluated. There was no significant mean BMI value observed in post soybean consumption compared with pre soybean consumption. Soybean peptides may play a role in body weight regulation, possibly by increasing energy utilization. [35] The present study revealed normal body mass index post soybean consumption. This could be related to the quantity of soybean consumed by the participants or perhaps the duration of the study. In this study, a significant decrease existed in the mean systolic and diastolic blood pressures in the participants post soybean consumption compared with the control . This is in keeping with the findings of previous studies.[3,36] This may be due to the isoflavones and phytoestrogen content of the soybean.[36] Isoflavones increase the production of enzymes that make nitric oxide (NO), a substance that dilates or widens blood vessels, hence reducing the pressure created by blood against the vessel walls. This may serve as an adjunct in the prevention and control of hypertension. More so, there were significant increases in the mean plasma sodium, potassium, and chloride levels post soybean consumption compared with pre soybean consumption . There was, however, no significant alteration in the mean plasma bicarbonate concentration post soybean consumption compared with the pre-consumption value . This correlates with the report of [37] which found significant increases in the mean plasma levels of sodium, potassium, and chloride in rats fed with soybean on a short-term basis.[37] This defers the finding of similar studies earlier documented.[7] The increases in the plasma sodium, potassium, and chloride concentrations in this study are probably a result of the high concentration of these electrolytes in soybean. Serum potassium and sodium represent the internal environment of the body and play an important role in the regulation of blood pressure. Increased dietary intake of potassium and sodium may subsequently increase potassium and sodium levels in the blood.[38] More so, the short-term nature of this study may have contributed to the current findings and this is of great clinical importance, especially in cases of hypertension or hypertensive individuals. No significant alterations were observed in the mean plasma creatinine and urea levels in the subjects post soybean consumption compared with pre soybean consumption. This suggests that the consumption of soybeans has no deleterious effects on the kidneys. Plasma urea and creatinine are important biomarkers of kidney function. Serum creatinine is an important indicator of renal health because it is an easily-measured by-product of muscle metabolism. Creatinine is chiefly filtered out of the blood by the kidneys with little or no tubular reabsorption. If the filtering of the kidney is deficient, creatinine blood levels rise. Therefore, creatinine levels in blood and urine may be used to calculate the creatinine clearance, which reflects the glomerular filtration rate.[36]The current results corroborate the earlier reports of similar studies ascertaining the beneficial effects of soybean consumption on kidney function [5,7, 15] Furthermore, the mean eGFR value post soybean consumption did not differ significantly compared with pre soybean consumption ($p>0.05$). The eGFR is an estimation of the capacity of the kidney to filter waste materials from the body. Thus, the current result of eGFR suggests no negative implication of soybean consumption on the overall filtering capacity of the kidney. Tests of renal function have utility in identifying the presence of renal disease, monitoring the response of kidneys to treatment, and determining the progression of renal disease. Interestingly, there was a significant decrease in the mean plasma uric acid level post soybean consumption than pre soybean consumption. The endogenous production of uric acid is mainly from the liver, intestines, and other tissues like muscles, kidneys, and the vascular endothelium [46]. Normally, most daily uric acid disposal occurs via the kidneys.[34] Hyperuricemia is a key risk factor for the development of gout, renal dysfunction, hypertension, hyperlipidemia, diabetes, and obesity. The uric acid lowering effect of soybean in this study qualifies its use as an adjunct in the therapeutic management of gout and arthritis which are conditions in which plasma uric acid levels are usually elevated. This aligns with the earlier study of [39] that documented a significant decrease in uric acid levels post soybean intake. However, this finding does not agree with the record of [40] that showed a significant increase in uric acid levels following their study on the acute effect of soy and soy products on serum uric acid concentration among healthy Chinese men. Their study was a three-hour randomized controlled trial involving different preparations of soy products. Finally, a significant weak positive correlation was observed between SBP Vs DBP and SBP Vs eGFR, whereas other parameters showed a weak negative correlation in participants' pre soybean consumption. DBP Versus eGFR had a weak negative correlation, while weak negative correlations existed in DBP Vs creatinine, BMI Vs K, eGFR Vs DBP, eGFR Vs Na, eGFR Vs Cl, and a strong negative correlation in eGFR Vs creatinine respectively post soybean consumption.

CONCLUSION

The study concluded no harmful effects on the kidney and hypouricemic effect of soymilk consumption at 25g/day pre-breakfast for 30days. Further studies involving a larger sample size and longer-term soybean consumption may be carried out to better ascertain the findings in this study. Soybean milk may serve as an adjunct in the therapeutic management of gout and arthritis.

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Author contributions

ACI, JEO and MCS conceived and designed the research proposal. QGA and VNC performed sample collection, experiments and data analysis. ACI, IN and DFNO contributed to the final version of the manuscript. All authors have read and approved the final manuscript.

Data availability

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

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Conflict of interest
None declared.

Ethical approval

The study was approved by the Ethics Committee of Faculty of Health Sciences and Technology, Nnamdi Azikiwe University, Nnewi, Anambra State, Nigeria ERC/FHST/NAU/2019/2152.

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