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*Full-length Research Article*

# Raw Garlic Homogenate Ameliorates Cardiometabolic Effects of High Caloric Intake in Wistar Rats

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**Summary:** Fructose consumption has increased tremendously due to higher intake of sweeteners in beverages, and this has been suggested to increase caloric intake. Higher caloric intake has been linked with diverse health consequences such as obesity, diabetes and cardiovascular diseases. Garlic (Allium sativum) has also been reported to be protective against adverse dietary effects. We hypothesized that increased caloric intake via sweetened drinks can cause hemorheologic, haematopoietic, nutritional, and metabolic derangements and that raw garlic homogenate (RGH) consumption can mitigate these adverse effects. Therefore, we investigated the effects of increased caloric intake via sweetened drinks as well as examined the potential of RGH to ameliorate such effects in Wistar rats. Twenty male Wistar rats were randomly divided into four groups (n=5): Control, Fructose (F) given fructose-sweetened drink (FSD), *Allium sativum* (AS) given RGH (250 mg/kg/day) and F+AS given FSD and RGH (250 mg/kg/day) for nine weeks. Fluid intake, energy intake, body weight gain, systolic blood pressure, diastolic blood pressure, heart rate, abdominal circumference, total cholesterol, triglycerides, very low density lipoprotein cholesterol, fasting plasma glucose, packed cell volume, leukocyte count, plasma viscosity, aspartate aminotransferase, alkaline phosphatase and total protein were significantly higher in F group when compared with Control while they were significantly lower in the RGH-treated groups in comparison with F group. The findings of this study revealed that sugar-sweetened beverages can substantially increase caloric intake, even with significantly reduced food intake, and that RGH can ameliorate the adverse effects of high caloric intake in Wistar rats.

**Keywords:** *Allium sativum, fructose, liver enzymes, hemorheology, metabolic syndrome.*

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## INTRODUCTION

Metabolic syndrome (MS) is a cluster of disorders such as obesity, dyslipidaemia, hyperglycaemia and hypertension (Saklayen, 2018; Ojetola et al., 2021). These disorders are closely associated with varying pathways that lead to cardiovascular diseases. Metabolic syndrome affects about a quarter of the world's adult population (International Diabetes Federation, 2006; Ranasinghe et al., 2017; Saklayen, 2018). Despite the efforts to curtail the surge in its prevalence, it keeps rising due to its aetiology that has been traced to different metabolic derangements. Most of these derangements are centered on environmental (dietary pattern, smoking, sedentary lifestyle) and genetic interplay (Artinano and Castro, 2009). Dietary sources linked to its aetiology include excessive intake of alcohol (Fan et al., 2008), high salt intake (Takase et al., 2020), excessive intake of high fat diet (Ojetola et al., 2021) and high carbohydrate (sucrose, fructose, high fructose corn syrup) diet (Mamikutty et al., 2014). However, whether fructose by itself is capable of inducing metabolic derangements has been a subject of controversy among researchers (Rizkalla, 2010; USDAHHS, 2010; Walker et al., 2014).

Current treatment regimen for ameliorating MS involves a combination of multiple drugs which is challenging for patients, resulting in reduced compliance by affected individuals. Hence, more attention is given to the use of nutraceuticals such as Allium sativum in reducing the risk and progression of metabolic abnormalities. Allium sativum has been used extensively as a spice and as medication for prevention and treatment of diseases. In vitro studies have reported anti-oxidant, and antimicrobial effects of Allium sativum and its components (Panpatil et al., 2013) while in vivo studies have also showed that Allium sativum possesses anti-inflammatory and hyperlipidemic effects (Choudhary et al., 2013; Nemat et al., 2013). Allium sativum's bioactive component depends on its preparation (Quesada et al., 2020). Of all Allium sativum preparations, raw garlic and garlic powder were reported to have the greatest physiologic activity (Majewski, 2014).

Additionally, the major bioactive components of Allium sativum are its organosulphur compounds (Quesada et al., 2020), and RGH's organosulphur constituents were reported to be allicin (85%) and diallyl disulphide (15%) (Locatelli *et a*l., 2014). Therefore, this study was designed to investigate the effects of increased caloric intake via fructose-sweetened drinks and to examine the potential of RGH to ameliorate these effects in Wistar rats.

## MATERIALS AND METHOD

**Chemicals and reagents:** The assay kit used for fasting plasma glucose (FPG) was obtained from Sigma-Aldrich, St. Louis, USA; those used for lipid profile (total cholesterol, triglyceride, and lipoproteins) were obtained from Fortress Diagnostic (Antrim, UK), while those used for total protein, albumin, globulin, alanine aminotransferase (ALT), alkaline phosphatase (ALP), and aspartate aminotransferase (AST) were obtained from Elabscience Biotechnology Inc., USA.

**Animals:** Twenty male Wistar rats (100 to 120g) used for this study were procured from a local breeder in Ibadan, Oyo State, Nigeria, and then acclimatised at the Animal House of the Department of Physiology, University of Ibadan, Nigeria, for a 14-day period with free access to water and feed. These rats were kept in polythene cages throughout the study period, and the experimental procedures were approved by the University of Ibadan Animal Care and Use Research Ethics Committee (UI-ACUREC/19/0140). The procedures of the experiment also conform to the National Institutes of Health (NIH) Guide for the Care and Use of Laboratory Animals and the study was reported in accordance with Animal Research: Reporting of *In Vivo* Experiments (ARRIVE) guidelines.

**Preparation of fructose-sweetened drink and raw garlic homogenate:** A fructose-sweetened drink was prepared by dissolving 15 g of fructose (D-fructose >99% obtained from Central Drug House Fine Chemical, Delhi, India) in distilled water to make a 100 mL solution. Fructose was introduced in drinking water to represent human consumption in sugar-sweetened beverages. Fresh *Allium sativum* cloves (obtained from Bodija market, Ibadan, Oyo State, Nigeria) were peeled and blended with SAISHO S-748 blender, forming a juicy paste. Raw garlic homogenate was prepared each day freshly. The dose of 250 mg/kg/day was used as it had earlier been demonstrated that RGH at this dose was helpful in animal models of insulin resistance and heart disease, and no undesirable effect was reported (Banerjee and Maulik, 2002; Padiya *et al*., 2011).

**Experimental design:** The rats were given standard rat chow, with differences in water and Allium sativum consumption, for 9 weeks. The rats were randomly distributed into four groups containing five rats each (n=5), namely: The control group received distilled water, the Fructose (F) group received a fructose-sweetened drink (FSD), the Allium sativum (AS) group received RGH, and the F+AS group received the combination of FSD and RGH. Raw garlic homogenate was administered by oral gavage once daily.

**Estimation of fluid and feed intake:** The daily leftover feed and fluid were subtracted from the amount given at the beginning of the day. The feeders and drinkers were fixed so that spillage was impossible.

**Energy content was calculated as follows:**
*Energy (kcal) =*
*4 × (g protein) + 4 × (g carbohydrate) + 9 × (g fat).*

**Proximate analysis of feed**
The proximate analysis of the feed is shown in Table 1

**Table 1:**
Proximate analysis of feed

| Constituents | Composition (%) |
|---|---|
| Moisture | 10.45 |
| Nitrogen-free extract | 57.8 |
| Proteins | 18 |
| Fats | 3.45 |
| Ash | 6.70 |
| Fibre | 3.6 |

**Measurement of blood pressure and estimation of leukocyte count, packed cell volume and plasma viscosity:** Blood pressure was determined using the tail-cuff method at the end of the experiment as described by Ojetola *et al.* (2021); plasma viscosity was measured as described by Omoregie *et al.* (2008); leukocyte count was determined as described by Dacie and Lewis (1984); and packed cell volume was determined as described by Abudu and Sofola (1994).

**Anthropometric measurement:** Abdominal circumference was measured in centimeters around the anterior abdomen using a white thread and a marker; the thread was then stretched across a metre rule to determine the circumference. Body weight was measured at the beginning and end of the experiment using an electronic weighing scale. The percentage of body weight gain was computed as follows:

Percentage of body weight gain =

$$\frac{Increase\ in\ body\ weight\ (g)}{Initial\ body\ weight\ (g)} \text{ X 100}$$

Rat length (cm) was measured between nasal and anal region using white thread and marker and the thread was stretched across a meter rule to determine the body length.

**Biochemical assays:** To obtain serum, blood was allowed to clot. The clotted blood was then centrifuged at 1372 x g for 15 min, at – 4°C using a cold centrifuge (Centurion Scientific Ltd., West Sussex, United Kingdom). The resultant supernatant serum samples were pipetted into separate plain bottles. Blood cells were separated from plasma as described by Ojetola *et al*. (2021). Plasma was used for fasting plasma glucose determination while serum was used for other biochemical assays. High density lipoprotein cholesterol (HDL), triglycerides, total cholesterol, total protein, albumin, globulin, ALT, ALP, AST and FPG were measured with commercially available kits in accordance with manufacturer's instructions.

However, low density lipoprotein cholesterol (LDL) was calculated using Friedewald equation (Friedewald *et al*., 1972). Atherogenic index was estimated as log (triglyceride/HDL) (Popoola *et al*., 2022) while very low density lipoprotein cholesterol (VLDL) was calculated as described by Ojetola *et al.* (2021).

**Adipose tissue changes:** Abdominal adipose tissue which comprises the omental, retroperitoneal and epididymal fat (excluding subcutaneous fat) were removed, dapped with gauze and weighed. Total abdominal fat was calculated as follows (Dupas *et al*., 2017):

Total abdominal fat (% body weight) =

$$\frac{abdominal\ adipose\ tissue\ weight\ (g)}{body\ weight\ (g)} \times 100$$

**Termination of the experiment:** The rats were euthanized as follows; diazepam (0.4 mg/kg) and ketamine (40 mg/kg) (Quttainah *et al*., 2004; Özkan *et al*., 2010) were administered intramuscularly into the left hind leg, anthropometric measurements were taken in the anaesthetized rats (Poudyal *et al*., 2010), blood was collected through retro-orbital plexus and abdominal adipose tissue was immediately removed. Lack of respiration and non-response to firm hind limb toe pinch (done with fingers) were used for death confirmation.

**Statistical Analysis**

Data were expressed as Mean ± Standard Error of Mean (SEM). All data were analysed with GraphPad prism 7.0 (GraphPad Software, San Diego, CA). One-way analysis of variance (ANOVA) and *Post hoc Tukey* test were used for multiple group comparison and $P<0.05$ was considered statistically significant.

## RESULTS

**RGH reduces fructose-induced increase in plasma viscosity and plasma protein levels:** Plasma viscosity increased significantly (p=0.0061) in fructose group when compared with control group (Table 2). However, plasma viscosity reduced significantly in AS group when compared with both fructose (p<0.0001) and fructose + AS groups (p=0.0024). There was significant increase in globulin (p=0.0142), albumin (p=0.0193) and total protein (p=0.0006) in F group when compared with control group; however, albumin and total protein decreased significantly (p=0.0121 and 0.0258 respectively) in F+AS group when compared with F group. Also, the three variables decreased significantly (p=0.0111, p=0.0049 and p=0.0003 respectively) in AS group when compared with F group. No significant change was seen in Albumin/Globulin ratio (Table 2).

**RGH reduces fructose-induced alteration in liver enzymes, leukocyte count, and packed cell volume:** Alkaline phosphatase and AST increased significantly (p=0.0441 and p=0.0026 respectively) in F group when compared with the control group (Table 2). Aspartate aminotransferase also increased significantly (p=0.0108) in F+AS group when compared with control group. AST decreased significantly in AS group when compared with both F (p=0.0074) and F+AS (p=0.0347) groups. No significant change was seen in ALT (Table 2). Leukocyte count increased significantly (p=0.0246) in F group when compared with control group while it decreased significantly (p=0.006) in F+AS group when compared with F group (Figure 1). The F group also reflected a significant increase (p=0.0355) in packed cell volume when compared with control, but this was decreased in the AS group (p=0.0197) when compared with F group (Table 2).

***RGH reduces fructose-induced increase in lipid levels:*** There was a significant increase in triglycerides (p=0.0121), total cholesterol (p=0.0013), VLDL (p=0.0121) and HDL (p=0.0007) in F group when compared with control group. Total cholesterol and HDL decreased significantly (p=0.0288 and p=0.0202 respectively) in F+AS group when compared with F group. The four variables also decreased significantly in AS group (p=0.0121, p=0.0152, p=0.0121 and 0.0202 respectively) when compared with F group. However, no significant difference was seen in atherogenic index and LDL across groups when compared with control group (**Table 3**).

**Table 2:**
Effect of raw garlic homogenate on proteins, liver enzymes and packed cell volume

| | Control | F | AS | F+AS |
|---|---|---|---|---|
| **Plasma viscosity (cP)** | 1.62 ± 0.04 | 1.82 ± 0.03[a] | 1.48±0.03[b] | 1.71 ± 0.04[c] |
| **Globulin (g/dl)** | 3.77 ± 0.15 | 4.5 ± 0.35[a] | 3.73 ± 0.06[b] | 4.13 ± 0.21 |
| **Albumin (g/dl)** | 2.67 ± 0.06 | 3.03 ± 0.15[a] | 2.57 ± 0.03[b] | 2.63 ± 0.09[b] |
| **Total protein (g/dl)** | 6.6 ± 0.06 | 7.4 ± 0.06[a] | 6.5 ± 0.12[b] | 6.97 ± 0.09[bc] |
| **Albumin/Globulin ratio** | 0.67 ± 0.03 | 0.67 ± 0.03 | 0.73 ± 0.03 | 0.67 ± 0.03 |
| **ALP ($ul^-$)** | 76 ± 2.08 | 87 ± 1.15[a] | 84 ± 3.21 | 82 ± 2.53 |
| **ALT ($ul^-$)** | 26.67 ± 1.2 | 29.67 ± 0.88 | 27.67 ± 0.88 | 27 ± 0.58 |
| **AST ($ul^-$)** | 35.67 ± 0.67 | 42 ± 1.15[a] | 36.67 ± 0.67[b] | 40.67 ± 0.67[ac] |
| **AST/ALT ratio** | 1.34 ± 0.04 | 1.42 ± 0.03 | 1.33 ± 0.04 | 1.51 ± 0.04[c] |
| **Packed Cell Volume (%)** | 46.33 ± 1.67 | 54.33 ± 0.67[a] | 45.33 ± 2.67[b] | 49.33 ± 0.67 |

*Values were expressed as mean ± SEM and n = 5 in each group. Data were analysed using ordinary one-way analysis of variance and post hoc Tukey test. [a]p<0.05 is significant when compared with control, [b]p<0.05 is significant when compared with fructose and [c]p<0.05 is significant when compared with AS. F = fructose, AS = Allium sativum, ALP = alkaline phosphatase, ALT = alanine aminotransferase, AST = aspartate aminotransferase.*

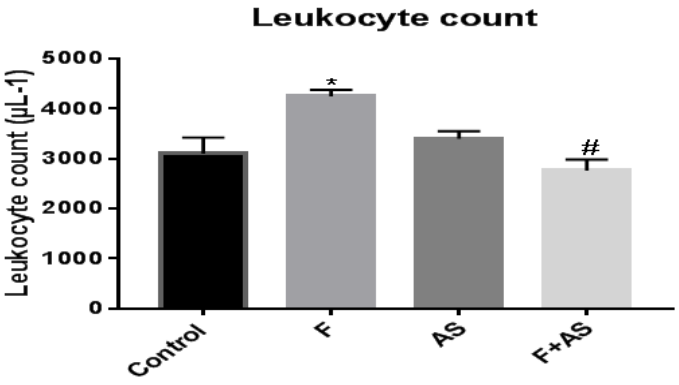


**Figure 1:**
Effect of raw garlic homogenate on leukocyte count. Values were expressed as mean ± SEM and (n = 5). Data were analysed using ordinary one-way analysis of variance and *post hoc Tukey test.* *P<0.05 is significant when compared with control and #P<0.05 is significant when compared with fructose. F = fructose and AS = *Allium sativum*.

**Table 3:**
Effect of raw garlic homogenate on lipid profile

| | CONTROL | F | AS | F+AS |
|---|---|---|---|---|
| **Triglycerides (mg/dl)** | 45.3 ± 0.88 | 51.3 ± 0.88[a] | 45.3 ± 1.2[b] | 49.0 ± 1.0 |
| **Total cholesterol (mg/dl)** | 66.5 ± 1.04 | 73.5 ± 0.65[a] | 68.5 ± 0.65[b] | 69.0 ± 1.35[b] |
| **LDL (mg/dl)** | 25.0 ± 1.22 | 21.5 ± 0.65 | 23.0 ± 0.71 | 23.3 ± 1.11 |
| **VLDL (mg/dl)** | 9.07 ± 0.18 | 10.27 ± 0.18[a] | 9.07 ± 0.24[b] | 9.80 ± 0.20 |
| **HDL (mg/dl)** | 32.3 ± 1.03 | 41.8 ± 0.63[a] | 35.8 ± 0.85[b] | 35.8 ± 1.93[b] |
| **Atherogenic index** | 0.15 ± 0.01 | 0.09 ± 0.01 | 0.11 ± 0.01 | 0.13 ± 0.02 |

*Values were expressed as mean ± SEM and n = 5 in each group. Data were analysed using ordinary one-way analysis of variance and post hoc Tukey test. [a]P<0.05 is significant when compared with control and [b]P<0.05 is significant when compared with fructose. F = fructose, AS = Allium sativum, LDL = low-density lipoprotein cholesterol, VLDL = very low-density lipoprotein cholesterol, HDL = high-density lipoprotein cholesterol.*

**Table 4:**
Changes in blood pressure and anthropometric variables

| | CONTROL | F | AS | F+AS |
|---|---|---|---|---|
| **MAP (mmHg)** | 101.2 ± 0.66 | 133.8 ± 5.53[a] | 80.2 ± 4.41[ab] | 113.2 ± 2.44[abc] |
| **SBP (mmHg)** | 127.4 ± 1.03 | 153.8 ± 6.37[a] | 110.4 ± 0.98[ab] | 137.6 ± 3.47[bc] |
| **DBP (mmHg)** | 88.0 ± 1.41 | 124.4 ± 5.90[a] | 65.6 ± 6.30[ab] | 99.8 ± 3.61[bc] |
| **Heart rate (bpm)** | 358.67 ± 4.33 | 377.0 ± 2.00[a] | 357.67 ± 0.67[b] | 375 ± 3.06[ac] |
| **Body weight** | 194.33 ± 8.33 | 234.33 ± 3.18[a] | 204.67 ± 9.35 | 205.00 ± 3.00 |
| **Body Weight Gain (%)** | 30.90 ± 3.50 | 48.69 ± 3.33[a] | 36.67 ± 5.15 | 35.45 ± 0.78 |
| **Body length** | 23.18 ± 1.21 | 22.6 ± 0.12 | 22.13 ± 0.08 | 23.63 ± 0.31 |
| **Abdominal Circumference (cm)** | 13.77 ± 0.19 | 15.87 ± 0.13[a] | 13.8 ± 0.4[b] | 14.57 ± 0.23[b] |
| **Total Abdominal Fat (% body weight)** | 1.66 ± 0.05 | 2.21 ± 0.26 | 1.01 ± 0.06[b] | 1.85 ± 0.21[c] |

*Values were expressed as mean ±SEM and n=5 in each group. Data were analysed using ordinary one-way analysis of variance and post hoc Tukey test. [a]P<0.05 is significant when compared with control, [b]P<0.05 is significant when compared with fructose and [c]P<0.05 is significant when compared with AS. F = fructose, AS = Allium sativum, MAP = mean arterial pressure, SBP = systolic blood pressure, DBP = diastolic blood pressure.*

**RGH reduces fructose-induced increase in blood pressure and fasting plasma glucose levels:** Systolic blood pressure (SBP) and diastolic blood pressure (DBP) increased significantly (p<0.0001 and p<0.0001 respectively) in F group when compared with the control group. However, both decreased significantly in F+AS (p=0.0027 and 0.0003, respectively) and AS (p<0.0001 and p<0.0001, respectively) groups when compared with the F group. Mean arterial pressure (MAP) also increased significantly in F (p<0.0001) and F+AS (p=0.0425) groups when compared with control group while it decreased significantly in both F+AS (p<0.0003) and AS (p<0.0001) groups when compared with F group. Heart rate increased significantly in F (p=0.0082) and F+AS (p=0.0156) groups when compared with control group. Heart rate also increased significantly in F (p=0.006) and F+AS (p=0.0113) groups when compared with AS group (Table 4).

Fasting plasma glucose increased significantly (p=0.002) in F group when compared with control group whereas glucose levels of F+AS and AS groups decreased significantly (p=0.0026 and p=0.0484 respectively) when compared with F group (**Figure 2**)". It should be placed under the sub-heading "RGH reduces fructose-induced increase in blood pressure and fasting plasma glucose levels."

**RGH reduces fructose-induced increase in anthropometric measurements:** There was significant increase in body weight (p=0.0117), body weight gain (p=0.0311) and abdominal circumference (p=0.0019) in F group when compared with control group whereas abdominal circumference decreased significantly in F+AS and AS groups (p=0.0303 and p=0.0021 respectively) when compared with F group. Total abdominal fat reduced significantly in AS group when compared with both F and F+AS groups (p=0.0051 and p=0.0361 respectively). Also, no significant difference was seen in body length (Table 4).

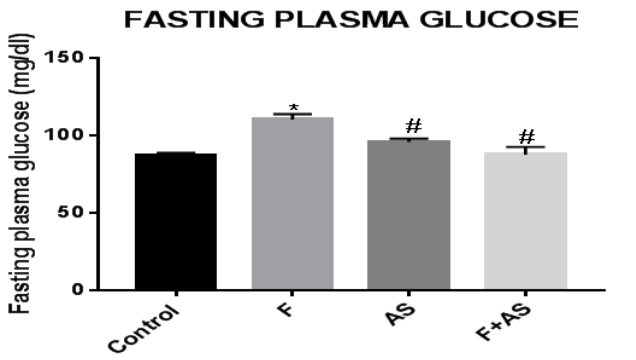


**Figure 2:**
Effect of raw garlic homogenate on fasting plasma glucose. Values were expressed as mean±SEM and (n = 5). Data were analysed using ordinary one-way analysis of variance and *post hoc Tukey test.* *P<0.05 is significant when compared with control and #P<0.05 is significant when compared with fructose. F = fructose and AS = *Allium sativum*.

**Alterations in fluid, feed, and energy intake:** Fluid and energy intake increased significantly in F (p<0.0001 and p<0.0001) and F+AS (p<0.0001 and p<0.0001) groups when compared with control group while both decreased significantly in AS group when compared with F (p<0.0001 and p<0.0001) and F+AS (p<0.0001 and p<0.0001) groups respectively. Additionally, fluid intake was significantly reduced in the AS group compared with the control group (p=0.0135) (Figures 3 and 5). Also, feed intake decreased significantly in the F and F+AS groups compared with the control (p=0.0001 and p<0.0001) and AS (p=0.0018 and p=0.0003) groups, respectively (Figure 4).

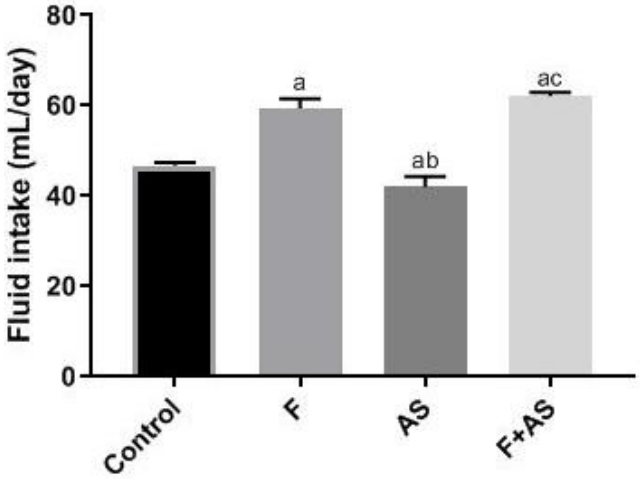


**Figure 3:**
Effect of raw garlic homogenate on fluid intake. Values were expressed as mean±SEM and (n = 5). Data were analysed using ordinary one-way analysis of variance and *post hoc Tukey test.* aP<0.05 is significant when compared with control, bP<0.05 is significant when compared with fructose and cP<0.05 is significant when compared with AS. F = fructose and AS = *Allium sativum*.

## DISCUSSION

In the current study, increased caloric intake via FSD single-handedly caused hypertension, increased fasting plasma glucose, dyslipidemia and obesity, along with increased levels of plasma viscosity, plasma proteins, liver enzymes and leukocyte count as observed from comparison between group F and control. Raw garlic homogenate ameliorated most of these abnormalities, as observed by comparison between RGH-treated rats and F rats; however, this was not due to reduced feed or fluid (FSD) intake, as there was no significant difference in fluid and feed intake between F and F+AS groups. Although the feed intake in fructose-fed rats (F and F+AS groups) was significantly lower than that in non-fructose-fed rats (control and AS groups), the fructose-fed rats had astronomically higher energy intake than the non-fructose-fed rats. This study showed the deleterious effect of high energy intake via sweetened drink on hemorheologic, nutritional, metabolic, and haematologic variables.

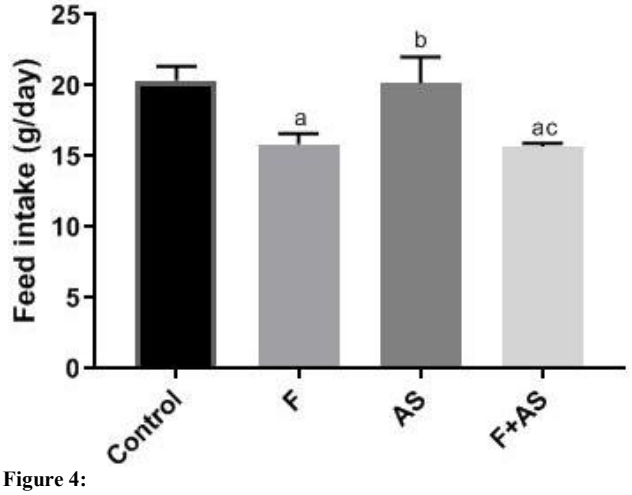


**Figure 4:**
Effect of raw garlic homogenate on feed intake. Values were expressed as mean±SEM and (n = 5). Data were analysed using ordinary one-way analysis of variance and *post hoc Tukey test.* aP<0.05 is significant when compared with control, bP<0.05 is significant when compared with fructose and cP<0.05 is significant when compared with AS. F = fructose and AS = *Allium sativum*.

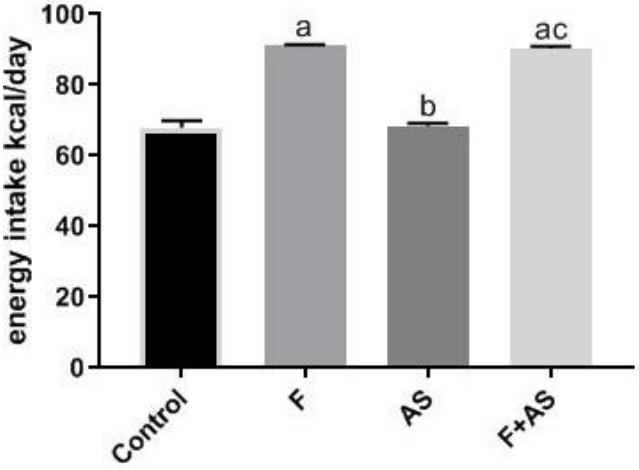


**Figure 5:**
Effect of raw garlic homogenate on energy intake. Values were expressed as mean±SEM and (n = 5). Data were analysed using ordinary one-way analysis of variance and *post hoc Tukey test.* aP<0.05 is significant when compared with control, bP<0.05 is significant when compared with fructose and cP<0.05 is significant when compared with AS. F = fructose and AS = *Allium sativum*.

The increase in obesity parameters, namely, body weight, body weight gain, and abdominal circumference in the F group showed that fructose is obesogenic, while the reduction of these parameters in RGH-fed rats is via suppression of body fat (total abdominal fat) and alteration of lipid profile (Shi *et al*., 2019). The significantly higher plasma triglyceride and total cholesterol levels in the F group when compared with the control group showed that

fructose is lipogenic. This effect may result from increased flux of free fatty acids from the periphery to the liver, which promotes hepatic triglyceride production and consequently accelerates the assembly and secretion of triglyceride-rich very low-density lipoprotein particles (Gorter *et al*., 2004). Allicin, the principal bioactive component of RGH is known to inhibit the main enzymes that takes part in cholesterol and triglyceride biosynthesis (Hosseini and Hosseinzadeh, 2015; Quesada *et al*., 2020). This can explain RGH's reduction of these variables.

Triglyceride is a source of fatty acid and experimental studies have pointed to serum fatty acid as an important inducing molecule of the innate immune system via activation of toll-like receptors. Some studies also suggested that fatty acid activates B cell toll-like receptor 4 and that stimulation of B cell toll-like receptor by fatty acid is necessary for increased globulin (Shi *et al*., 2006). Therefore, the higher globulin concentration in F group might be attributed to increased triglyceride. Reduction of globulin by RGH is accounted for by its reduction of triglyceride in this study.

Clinically, hyperproteinemia and increased serum AST suggests liver damage (Chen *et al*., 2018) which had been linked with increased fructose consumption (Tappy, and Le, 2010; Mamikutty *et al*., 2014). Raw garlic homogenate's reduction of total protein is attributed to allicin's hepatoprotective property (Hosseini and Hosseinzadeh, 2015).

Systemic inflammation is suggested to be the underlying mechanism linking serum ALP with increased fructose consumption as serum ALP is known to be associated with inflammatory markers such as plasma viscosity. In this study, plasma viscosity and leukocyte count, a non-specific marker of systemic inflammation increased significantly in rats given fructose (F group) (Doube *et al*., 1989). Reduction of ALP, plasma viscosity and leukocyte count by RGH is suggested to be due to allicin's ability to reduce inflammation (Doube *et al*., 1989; Jesri *et al*., 2005; Osei-Bimpong and Burthem, 2017; Darooghegi-Mofrad *et al*., 2019).

The fructose induced increase in FPG after intake of FSD corroborates findings of some researchers who reported that fructose is diabetogenic. This fact has been a subject of controversy among researchers (Rizkalla, 2010; USDAHHS, 2010; Walker *et al*., 2014). Reduction of FPG by RGH is suggested to be due to allicin's effect (Wang *et al*., 2015).

The exact cause of fructose induced hypertension is still a subject of controversy, however, increased levels of haematocrit, leukocytes, platelets, serum proteins, blood lipids and obesity greatly raises plasma and blood viscosities (Rogers and Estes, 2021). Consequently, peripheral resistance to the flow of blood increases, yielding rheological alterations, and in the presence of fructose induced hyperglycemia may result in hypertension (Cinar *et al*., 2001). In this study we observed significantly increased, packed cell volume, leukocytes, serum proteins, blood lipids, obesity and plasma viscosity in F group. The increased heart rate observed is also suggested to be caused by increased FPG which was observed in this study (Tarvainen *et al*., 2014). Raw garlic homogenate significantly reduced these variables and consequently blood pressure in treated rats. Also, Allicin, the principal bioactive compound in RGH have been reported to improve blood vessel elasticity and diminish blood viscosity (Choudhary *et al*., 2013).

In conclusion, this study revealed that increased caloric intake via fructose sweetened drink solely increased haematopoiesis, metabolic risk factors and hemorheologic variables along with increased, energy intake, fluid intake, serum proteins, liver enzymes and systemic inflammation markers in Wistar rats. Also, most of these effects were attenuated by raw garlic homogenate, however, further human studies may be needed to establish raw garlic homogenate's role in mitigating adverse effects of high caloric intake.

***Authors' Contributions***

*The authors' responsibilities were as follows – EOA and AAF: designed research; EOA: funded research; EOA and OMA: conducted research and acquired data; EOA: analysed data; AAF: Supervised research; EOA, AAO and JNA: wrote paper; and all authors: read and approved the final paper.*

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