

Original Research Article

Sorghum –garlic blended diet prophylactically fed to experimental mice prevent the establishment of *trypanosomes* in the *T.b brucei*- infected animals.

Abstract

Aim: This research work set to investigate the effect of feeding a mixture of two functional foods with a view to ascertain their therapeutic effect against *Trypanosome brucei brucei* in challenged mice.

Experimental design: Complete randomized clinical trial design was used in the experiment. The rats were block for sex and grouped into A, B, C, D, E, F, G, H, I, and J respectively. Each group consists of three (3) rats.

Place and duration of the study: The research work was conducted in the Biochemistry and Nutrition laboratory in the Department of Animal Production Technology, Federal College of Wildlife Management, New Bussa, Niger State, Nigeria. Four weeks feeding trial was used in the cause of the experiment.

Methodology: A total of 30 albino wister rats were randomly grouped into ten (10) treatments each containing 3 rats (i.e. A- J). To groups A- E, feed containing graded level of inclusion of blended Sorghum- Garlic (10 : 1) at 5, 10, 15, 20, and 25% level was fed to them. Group F, were fed the conventional feed only (i.e. Control). Group G, were fed solely with the pulverised *sorghum bicolor* (without Garlic added to it). Group H, were fed with conventional feed supplemented with Garlic only. Another group of three rats, (i.e. group I) were fed with the supplemented diet with the average inclusion rate of 15% for 3 days prior to infection. To the final group (i.e. group J), as in group I but the feeding period prior to infection was extended to 7 days. Parasitaemia was monitored on two days interval while the effects of non prophylactic feeding (25%) and seven days prophylactic feeding (at 12.5%) of the experimental diet on the haematological parameters of rats was also determined.

Results : Feed containing 12.5% level of inclusion of the sorghum-garlic fed to the animals seven days prior to their infection with the parasites proves to be effective against the establishment and subsequent proliferation of the parasites in the experimental animals and significant difference ($P = 0.05$) in the haematological parameters was observed between the group prophylactically fed the sorghum-garlic supplemented diet for seven days prior to infection and the group fed the supplemented diet and infected the following day.

Conclusion: This study demonstrate the potency of prophylactic feeding of sorghum-garlic (functional foods) as nutraceutical against trypanosomiasis and as a haematopoietic agent.

1.0 Introduction

According to the World Health Organization [1] human African trypanosomiasis (HAT) is one of the deadliest disease found on the earth [2]. No vaccine is developed[3], and there is no commercial interest in developing new drugs. Three of the four main drugs used in treatment were registered before 1950. The most recent drug was initially developed as an anti-cancer drug, only by coincidence found to be effective against HAT. HAT is a disease

42 which the poorest of the poor are suffering from [4]. Despite the fact that man is the natural
 43 mammalian host for trypanosomes, studies on animals revealed the involvement of numerous
 44 wild animals such as non-human primates, reptiles, antelopes, and wild bovid in its
 45 transmission and sustenance [5]. Both are usually transmitted by the bite of an infected tsetse
 46 fly and are more common in rural areas [6]. Detectin of infection is via finding the parasite in
 47 a blood smear or in the fluid of lymph node of the suspected individual [7].

48 Animal African trypanosomiasis (AAT) is a serious and delabidating disease of livestock
 49 caused by protozoan parasite of the genus *Trypanosoma* and transmitted cyclically by tsetse
 50 (*Glossina*) and mechanically by other hematophagous flies such as *Tabanus*, *Haomatopota*,
 51 *Stomoxys* and *chrysoys* [8]. Two tsetse transmitted parasites, *T. brucei gambiense* and *T.*
 52 *brucei rhodesiense*, cause human African trypanosomiasis (HAT)/sleeping sickness, which
 53 affects both humans and animals [1]. The remaining tsetse-transmitted trypanosomes
 54 primarily affect animals and cause African animal trypanosomiasis(AAT). The most
 55 important species in this disease are *Trypanosoma congolense*, *T. vivax* and *T. brucei brucei*.
 56 Other species such as *T. simiae* and *T. godfreyi* can also cause AAT. It is major obstacle to
 57 livestock production on the African continent as it prevents full use of land to feed the rapidly
 58 increasing population. The limitations due to tsetse and trypanosome problems continue to
 59 frustrate efforts and prevent progress in the livestock and crop production thus contributing to
 60 hunger, poverty and the suffering of entire communities in Africa [9]. This disease is
 61 therefore a serious impediment to agricultural and economic advancement in the affected
 62 areas [10]. The economic losses due to AAT are approximated to be over 1.5 billion dollars
 63 annually with African farmers spending 35million dollars on treatment within the same time
 64 frame [11]. This very figure show the very high economic losses for the areas infected with
 65 tsetse flies [12]. Added to the economic losses is the tsetse infestation of about 10 million
 66 km² of the fertile land spread across 36 countries on the Africa continents with approximately
 67 7 million km² of the infected land being suitable for mixed agriculture if this disease was
 68 controlled [11]. Out of 165 million cattle found in Africa only 10 million found within the
 69 tsetse belt due to the disease constraint and these are the lowest producing breeds [13] [14].
 70 This devastating disease vastly and directly affects the milk and meat productivity of animals,
 71 reduce the birth rate and increase the abortion rate as well as mortality rate which
 72 cumulatively affect the herd size and herd composition [12] [15].

73 A nutraceutical is referred to as “any substance that is a food or a part of a food that
 74 provide medical or health benefits; including the prevention and treatment of disease” [16].
 75 Today, researchers have identified hundreds of compounds from both plants and animals

76 sources with functional qualities, and they continue to make new discoveries surrounding
 77 the complex benefits of phytochemicals (non-nutritive plant chemicals that have protective
 78 or disease preventive properties) in foods. In Japan, England and other countries,
 79 nutraceuticals already have become part of the dietary landscape. Due to risk of toxicity
 80 or adverse effect of drug, consumers are turning massively to food supplements to improve
 81 health where pharmaceutical fails. This resulted in a worldwide nutraceutical revolution
 82 [17][18]. Over 470 nutraceuticals and functional food products are presently available with
 83 documented health benefits [19]. Many of these new products that are being promoted to
 84 treat various diseases find their origin in the plant kingdom [19]. This is an obvious choice
 85 as many plants produce secondary compounds such as alkaloids, saponnins, terpenoids,
 86 tannins, phenols etc to protect themselves from infections and these constituents may be
 87 useful in the management of human infection. Many of the phyto-medicines are the typical
 88 examples. The old proverb “an apple a day will keep the doctor away” is now replaced by
 89 ‘‘ a nutraceutical a day may keep the doctor away.’’ (Bhaskaran, n.d).

90 Grain sorghum (*Sorghum bicolor* L.Moench;) ranks fifth in worldwide production among
 91 cereal crops after Wheat, Rice Corn and Barley [20][21]. Sorghum is used for human
 92 consumption and animal production [20] as well as industrial products such as alcohol [22].
 93 Over 55% of sorghum grain produced in the world is used for human consumption and about
 94 33% of grain used in animal nutrition [23]. Recent research has demonstrated that the
 95 consumption of whole grains reduces the risk of some major human diseases due to the
 96 dietary fibre and phytochemicals, which are mainly concentrated in the bran, such diseases
 97 are cardiovascular disorders, Neuron degeneration, Cancer, Diabetes and
 98 Hypercholesterolemia as well as being involved with the process of aging [24]^[25]. Sorghum is
 99 a rich source of various phytochemicals including tannins, phenolic acids, anthocyanins,
 100 phytosterols and policosanols [26]. The phytochemicals have potential to significantly impact
 101 human and animal health. Sorghum grain has 95 to 98% of the nutritional value of maize;
 102 vitamin content for corn and sorghum is similar but sorghum has a higher mineral content
 103 than maize [27]. Its rich antioxidant properties makes Sorghum grain to have a lot of
 104 nutritional benefits [28]. It is higher in protein (11.5 to 16.5%) and calories than several other
 105 grains [29]. One hundred gram (100g) of sorghum was found to contain 143g of
 106 carbohydrate, 12g of dietary fibre, and would provide 47% of the recommended daily value
 107 for iron based on a 2,000 calorie intake (³⁰Thompson, 2010). The same 100g of sorghum
 108 contains 325 calories and has 10.8mg of protein, 0mg of sugar, 3.1mg of fat, 6.0mg of fibre
 109 and 0mg of cholesterol. Vitamins and minerals such as: B, B₂, B₃, Calcium (Ca) 5.4% RDA,

Potassium (K) 19% RDA, Iron (Fe) 47% RDA, Phosphorus (P) Recommended Dietary Allowance of 55%, and Sodium (Na) 0.5% RDA were found to be contained in sorghum [30].

Allium sativum, commonly known as garlic, is a species in the onion genus, *Allium*. Its close relatives include the onion, shallot, leek, chive, [31][32]. With a history of human use of over 7,000 years, garlic is native to central Asia,[33] and has long been a staple in the Mediterranean region, as well as a frequent seasoning in Asia, Africa, and Europe. A member of the *Liliaceae* family, garlic (*Allium sativum*) is a cultivated food highly regarded throughout the world. Originally from Central Asia, garlic is one of the earliest of cultivated plants [34]. In 1997, garlic was the most widely used natural supplement in US households. Garlic was also shown to be used more than twice as much as any other natural supplement [35].

That sorghum contained and in sufficient proportion of daily requirement allowance(RDA) of most of the vitamins, minerals and other macromolecules required for all the physiological activities required to sustain life, coupled with its ability to strengthens the immune system, helps in the elimination of toxic waste from the body, increases endurance, assists in blood cells building, boost appetite, relieves diarrhoea, aids rapid recovery, stimulates free flow of blood and lowers cholesterol levels [36] and its content of varied array of phenolic compounds such as simple phenols, hydroxybenzoic acids, hydroxycinnamic acids, flavonoids (flavanols, flavones, flavanones, isoflavones and anthocyanins), chalcones, aurones (hispidol),hydroxycoumarins, lignans, hydroxystilbenes and polyflavans (proanthocyanidins and prodeoxyanthocyanidins) [37][38]. The main thrust of this work is therefore to investigate the possible synergistic activities of the various phytochemicals from these plant samples (i.e.Sorghum and gallic) with a view to come up with a possible functional food(s) that is easily obtainable, affordable, accessible and above all commonly available in the areas mostly ravaged by this dilapidating, and neglected “orphaned” disease of the tropics.

2.0 Materials and Methods

2.1 Samples Collection And Preparation

Ten kilogram (10Kg) of Red variety of *Sorghum bicolor* along with 100g of *Allium sativum* (Garlic variety) were purchased from the Sabo/Wawa Market in Borgu Local Government Area of Niger State, Nigeria. The sorghum was soaked for 2-3 days until it begins to sprout. It was then drained and allowed to dry at room temperature until the moisture content is about 10-15%. One thousand gram (1Kg) of Garlic was crushed using pestle and mortar and then mixed with the dried Sorghum in the ratio 10:1. The mixed sample was then pulverised and sieved through to obtained fine powder. Conventional rat feed was obtained from the sales point. Graded level inclusion of the Sorghum-garlic blend at 5, 10, 15, 20, and 25% were made.

2.2 Trypanosomes used

The breed of the parasite used in this work is *T.b. brucei* which affects both man and domestic animals. The strain of the parasites was obtained from the Nigeria Institute of Trypanosomiasis (NITR), Kaduna, Kaduna State. The parasite was maintained in our Laboratory by serial passage to healthy rats.

2.3 Experimental Animals

A total of 30 Albino winster rats weighing between 137- to 152g were purchased from Food and Nutrition Dept. of the Niger State Polytechnic, Zungeru, Niger State, Nigeria. They were acclimatized for seven (7) days in the Biochemistry and Nutrition Laboratory of Animal Production Technology Department, Federal College of Wildlife Management, New Bussa, Niger State, Nigeria. and used in the experiment. The animals were grouped into ten (10) of A-J treatments each containing 3 rats (i.e. A- J).

2.4 Feeding Experiment and Parasitaemia

From the means of daily consumption of 100% (168g±8.6) conventional feed, 5% (8.4g), 10% (16.8g), 15% (25.2g), 20% (33.6g) and 25% (42g) were replaced with the sorghum-garlic mixture which result to groups A- E respectively. Group F , were fed 12.5% of the conventional feed substituted with the pulverized sorghum (21g) only. Group G , were fed 12.5% of the conventional feed substituted with 12.5% of garlic (21g) only. Group H , were fed 15% (25.2g) of the conventional feed substituted with sorghum-garlic blend for three (3) days prior to infection, Group I were fed 15% as in Group H but the feeding period prior to infection was extended to seven (7) days. Group J received 100% conventional feed and served as positive control. All the feeding experiment lasted for –21 days. In all the

treatments and control, the monitoring of parasitaemia was carried out fortnightly according to the “rapid matching” method of ³⁸Herbert and Lumsden, (1976). All the animals in groups A-G were infected a day after the feeding with the sorghum-garlic blend commenced, while those in groups H and I were infected on the 3rd and 7th day after the feeding with the substituted sorghum- garlic has commenced. Groups J and K served as positive and negative controls respectively.

The infection was carried out as thus: Blood was collected by cardiac puncture with ethylenediaminetetraacetic(EDTA) acid-coated syringe from a heavily infected mouse and immediately diluted with physiological saline to serve as the inoculums. Healthy mice were infected intraperitoneally (*i.p.*) with 0.02 mL of the diluted blood containing 1×10^6 trypanosomes. Monitoring of parasitaemia was done every 48 h by microscopic examination of blood sample taken from the tail of infected mouse pre-sterilised with Methylated spirit.

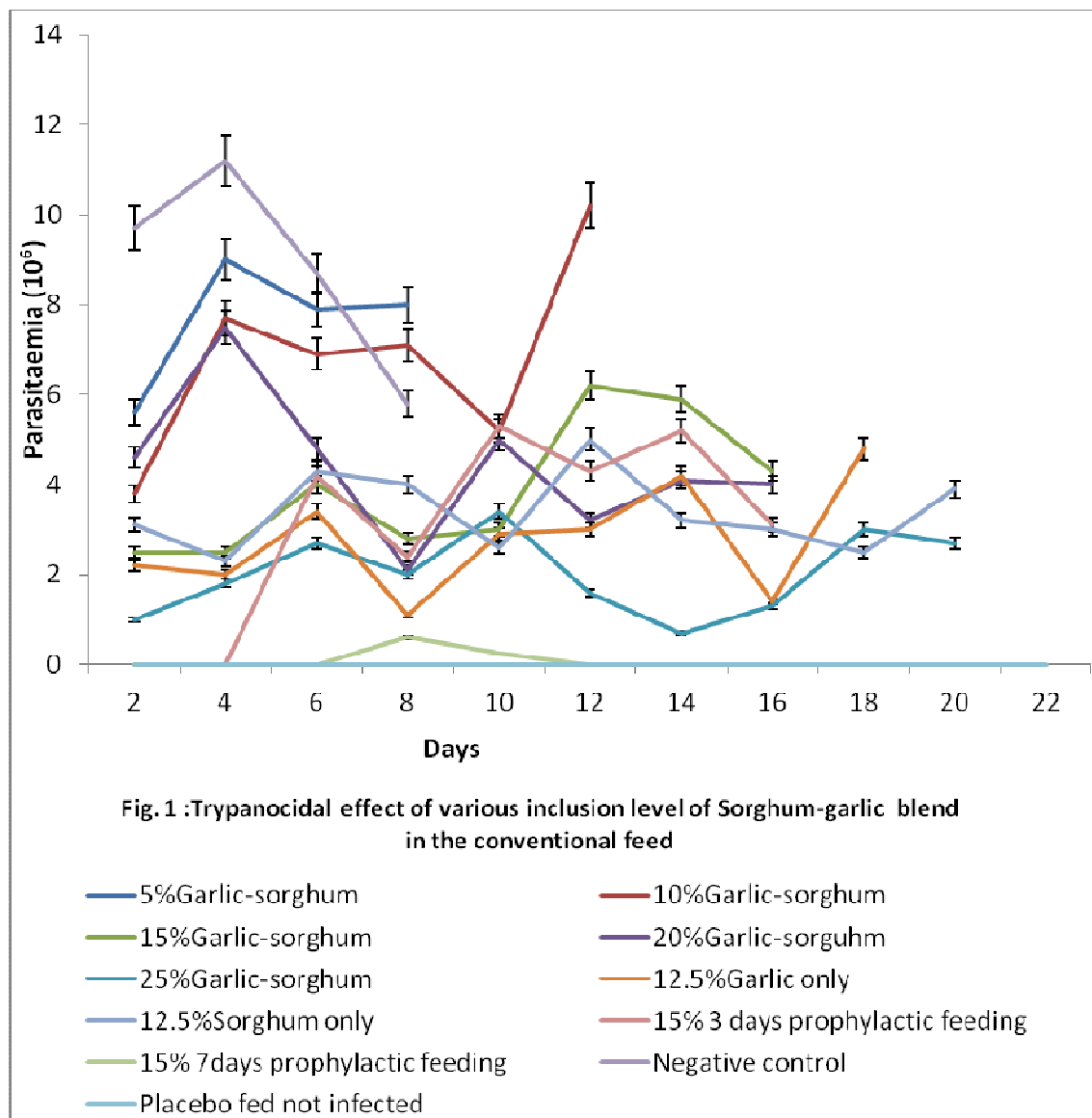
2.7 Determination of hematological parameters

The haematological components including haemoglobin, haematocrite, red blood cells (RBC), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), white blood cells (WBC), granulocyte count (GRA), lymphocytes, platelet count, mean platelet volume (MPV), Plateletcrit and platelet distribution weight (PDW) were determined in the group prophylactically fed for 7 days prior to infection in which clearance was achieved, using the automated haematological analyzer Sysmex kx21, as reported by Bashir *et al.*, [39]

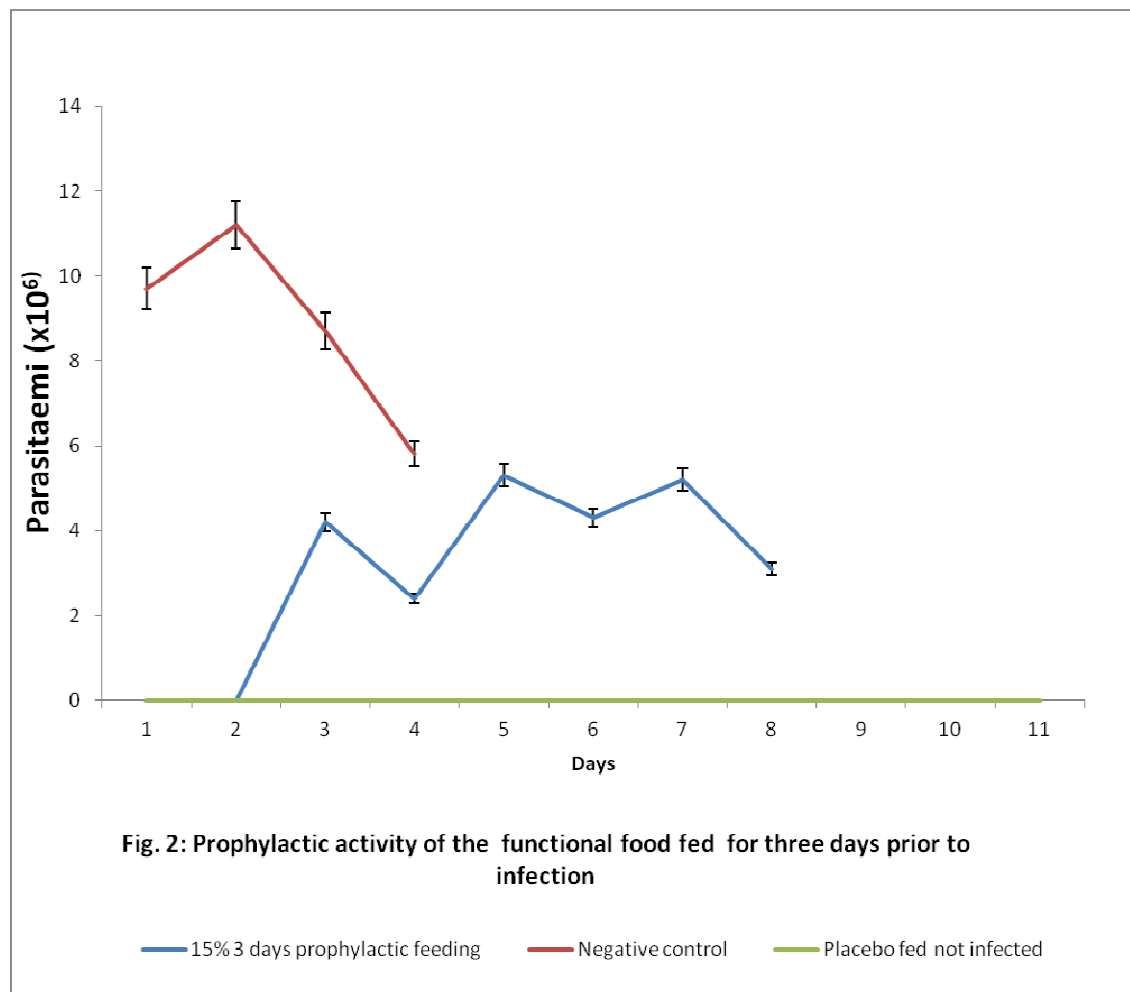
2.9 Statistical Analysis .

Data obtained in this study was subjected to a one-way analysis of variance (ANOVA) to derive mean values of parasitaemia which was compared with least significant difference

201 **4.0 Results**



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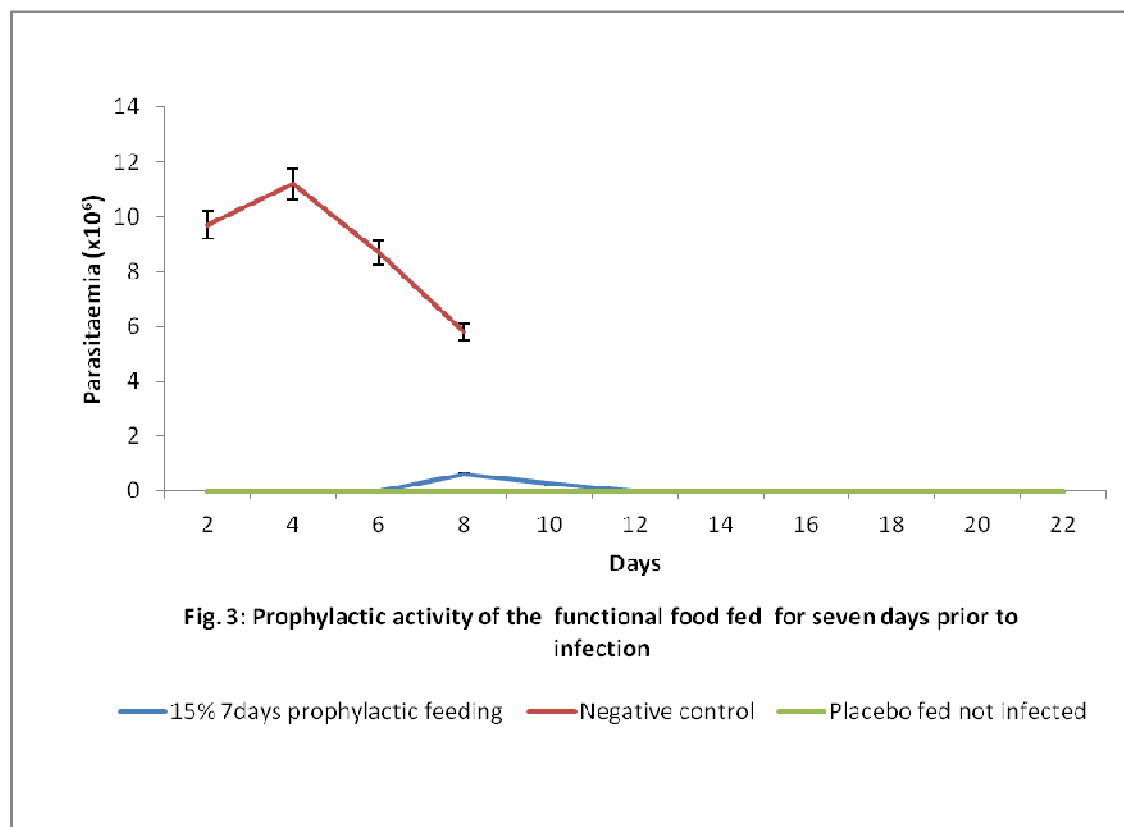


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Parameters	Control rats	12.5% 7 days prior to infection	Non prophylactic 25% inclusion
WBC (x 10 ⁹ /L)	3.71 ± 1.11 ^a	6.58 ± 1.18 ^b	5.29 ± 0.90 ^c
Granulocytes(%)	0.80 ± 0.70 ^a	0.71 ± 0.24 ^a	2.59 ± 0.80 ^b
Lymphocytes (x 10 ⁹ /L)	2.58 ± 0.60 ^a	4.50 ± 0.58 ^b	3.86 ± 0.79 ^b
MCTC (x10 ⁹ /L)	0.21 ± 0.08 ^a	0.12 ± 0.005 ^a	0.28 ± 0.37 ^b
RBC(x10 ¹² /L)	2.69 ± 0.10 ^a	2.89 ± 0.05 ^a	0.48 ± 0.77 ^b
Hematocrite (L/L)	0.24 ± 0.01 ^a	0.22 ± 0.00 ^a	0.21 ± 0.003 ^a
Haemoglobin (g/L)	96.23 ± 1.20 ^a	94.78 ± 1.85 ^a	95.00 ± 5.03 ^a
MCH (pg)	29.96 ± 1.59 ^a	31.50 ± 0.35 ^a	29.67 ± 1.31 ^a
MCHC (g/L)	388.33 ± 2.74 ^a	434.87 ± 3.60 ^b	399.00 ± 2.98 ^a
MCV (fL)	99.23 ± 1.20 ^b	94.93 ± 1.85 ^b	73.33 ± 0.33 ^a
RCDW-cv (fL)	41.13 ± 0.08 ^a	36.23 ± 3.16 ^a	41.43 ± 0.93 ^a
RCDW-sd (fL)	18.00 ± 0.36 ^a	15.97 ± 0.11 ^a	16.00 ± 0.36 ^a
PC (× 10 ⁹ /L)	336.78 ± 36.08 ^a	806.65 ± 6.83 ^b	759.00 ± 26.50 ^c
MPV (fL)	9.00 ± 0.09 ^a	9.79 ± 0.35 ^a	13.01 ± 0.30 ^b

Plateletcrit (L/L)	0.64 ± 0.15^a	1.48 ± 0.15^b	1.78 ± 0.17^b
PDW (%)	19.46 ± 0.41^a	18.59 ± 0.03^a	26.23 ± 1.11^b

Table1: Effects of Non prophylactic feeding and 7-days prophylactic feeding of the experimental diet on haematological parameters of Rats.

LY: Lymphocytes; MCTC: Mid cell total count; RCDW-cv: Red cell width coefficient of variation; RCDW-sd: Red cell width standard deviation; PC: Platelet count; Values are mean $\pm$ SEM of 5 determinations. The values along the same row with different superscripts are significantly different ($P < 0.05$).

3.0 DISCUSSION

The prophylactic benefits of food plants are being investigated for potential use as novel medicinal remedies due to the presence of pharmacologically active compounds. The result from this study clearly indicates that feeding rats diets mixed with Garlic- Sorghum(as functional foods) at the inclusion level of 5- 25% does not exert any trypanocidal nor trypanostatic effect in all the groups fed the functional food (Figs. 3). If not for Nok *et al.*, [41] and Nose, *et al.*, [42] that reported on the in-vitro trypanocidal effect of garlic, there has not been any previous report on the efficacy of prophylactic feeding of either the Sorghum or Garlic alone against trypanosomes, but both due to their high phenolic contents, are known to portray some strong antioxidant activities [43][44][45][46]. The antioxidant activity of phenolic compounds is mainly due to their redox properties, which can play an important role in adsorbing and neutralizing free radicals [47]. An interesting observation made is the inability of the parasites to survive beyond two days *In vivo* in animals fed the mixed diet at 15% inclusion of Garlic-Sorghum blend seven days prior to their infection (Fig.2) whereas, those fed for three days prior to infection had the trypanosomes inoculated into them growing normally and eventually causing the havoc and all the characteristic pathologies it is known to cause. Feeding garlic (only) and Sorghum (only) as functional foods at 12.5% inclusion level separately (Fig.1) does not also prevent or stop the growth and the subsequent multiplication of the trypanosomes in the infected animals.

The possible reason that can be attributed to the efficacy observed when the experimental animals were prophylactically fed Sorghum-Garlic blended diet is because, while most plants, including other cereals, are lacking 3-deoxyanthocyanidins, e.g. apigeninidins and luteolinidins, sorghum is unique in containing a relatively high level of these compounds[48][49]. Sorghum grain is rich in health promoting phytochemicals: phenolic

acids, sterols, policosanols, and anthocyanins. The most abundant anthocyanins in sorghum grain are 3-deoxyanthocyanidins, e.g. apigeninidin and luteolinidin [48][50][51]. The red color of the grain's pericarp is essentially due to the presence of 3-deoxyanthocyanidins[51][52] and[53] demonstrated the effective therapeutic effect of sorghum proanthocyanidins against human melanoma. The binding of proanthocyanidins with proteins participates in their antibacterial activity[54][55]. Proanthocyanidins have been shown to inhibit the growth of human immunodeficiency virus 1 (HIV-1), influenza virus, and herpes simplex virus by blocking their entry in the host cells[56][57]. The mechanism of proanthocyanidins toxicity against microbes is related to inhibition of hydrolytic enzymes, interactions to inactivate microbial adhesions and cell envelope transport proteins, and non-specific interaction with carbohydrates[58]. Among sorghum flavanols, the flavan-4-ols have particular therapeutic interest because of their antitumor activity[59][60][61]. Flavan-4-ols revealed strong host mediated antitumor activity, which is due to the enhancement of immune response of the host animals through the actions on tumor cells and some immunocytes[62][63]. The anti cancer activities of 3-deoxy anthocyanidins in sorghum pericarp against the HL-60 cell line, derived from a patient with acute leukemia, and HepG2 is an adherent cell line derived from liver tissues of a hepatocarcinoma patient has been well elaborated by[64]. While on one hand the green, dry "folds" in the center of the garlic clove are especially pungent. The sulfur compound allicin, produced by crushing or chewing fresh garlic, produces other sulfur compounds: ajoene, allyl polysulfides (Diallylsulphides, Diallyldisulphides and Triallyltrisulphides) and vinylthiols. the presence of S-allylcysteine has also been observed in garlic. Despite the fact that Garlic is known for causing bad breath (halitosis)[65], as well as causing sweat to have a pungent "garlicky" smell, which is caused by allyl methyl sulfide (AMS)[66]. AMS is a volatile liquid which is absorbed into the blood during the metabolism of garlic-derived sulfur compounds; from the blood it travels to the lungs and from there to the mouth, causing bad breath; and skin, where it is exuded through skin pores[67][68]. Garlic has been used for thousands of years as a remedy for many different ailments, including intestinal disorders, flatulence, worms, respiratory infections, skin diseases, wounds, and symptoms of aging. Modern research indicates that garlic may help improve heart health in a number of different ways. It is a blood thinner that helps to lower both high blood pressure and blood triglycerides. The anti-arthritis property of garlic is due to diallyl sulphide and thiacremonone [69]. Garlic also has anti-inflammatory properties. Several population studies also show an association between an increased intake of garlic and a reduced risk of certain cancers, including colon, stomach, esophagus, pancreas, and breast

cancer.[70][71. Garlic's anti-cancer properties are due to the allyl sulphides it contains[72]. One special interesting area of research on garlic and cancer prevention involves meat cooked at high temperatures. Heterocyclic amines (HCAs) are cancer-related substances that can form when meat comes into contact with a high-temperature cooking surface (400°F/204°C or higher). One such HCA is called PhIP (2-amino-1-methyl-6-phenylimidazopyridine). PhIP is thought to be one reason for the increased incidence of breast cancer among women who eat large quantities of meat because it is rapidly transformed into DNA-damaging compounds. Diallyl sulfide (DAS), one of the many sulfur-containing compounds in garlic, has been shown to inhibit the transformation of PhIP into carcinogens[73][74]. DAS blocks this transformation by decreasing the production of the liver enzymes (the Phase I enzymes CYP1A1, CYP1A2 and CYP1B1) that transform PhIP into activated DNA-damaging compounds.. Additionally, garlic is a triple threat against infections, offering antibacterial, antiviral, and antifungal properties. Garlic has even been found to be effective at killing antibiotic-resistant bacteria, including MRSA. Observation has been made that virtually most of the drugs with trypanocidal activities were observed to also display some cytotoxic (Anti cancer) and antitumor activities; it can be seen that Anthocyanins, Pro anthocyanidins and 3-deoxyanthocyanidins contained in sorghum and the diallyl sulphide found in garlic inhibits the transformation of PhIP (a type of compound that has been associated with increased incidence of breast cancer) into carcinogen. The probable interaction of these compounds in Sorghum and Garlic might synergistically impair with one or more of the survival pathways of the trypanosome as observed (Fig. 3). Also, the positive immunomodulatory effect observed as a result of sustained feeding of the experimental animals (for seven days) with the Sorghum- Garlic(as functional foods) can clearly be seen from the Haematological parameters in (Table1) which might be an additional attribute to the ability of the experimental animals to resist the infection by the parasites.

Currently, most antiparasitic drugs are considered orphan drugs with the main exception of antimalarials. Economic considerations of the pharmaceutical industry outweigh all others, because of the very low return of the developmental costs. Therefore, it is necessary to find alternative and cheaper ways to approach the treatment of trypanosomal disease[6]. This could be achieved by looking into the possibilities of utilising one or combination more than one functional food substances commonly available, affordable and accessible with nutraceutical properties that could serve the same purpose. Sorghum contains large quantities of phenolics and other compounds of use in human foods to prevent deterioration of health.

Different phenols with varying properties exist, but relatively little effort to demonstrate the potential of these compounds in human health has been made. Of all the cereals, sorghum has the potential to be bred specifically to produce high levels of different phenols that can be easily concentrated by simple processes. These special sorghums have reasonable grain yields and agronomic characteristics that make them productive and economical to produce. The future is bright, but significant investment in evaluation and feeding trials to demonstrate their health promoting properties is required[75]

Ethical approval

All authors hereby declare that "Principles of laboratory animal care" (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee

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