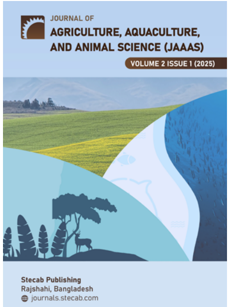

Journal of Agriculture, Aquaculture, and Animal Science (JAAAS)

Volume 2 Issue 1, (2025)

https://doi.org/10.69739/jaaas.v2i1.197

https://journals.stecab.com/jaaas

Published by
Stecab Publishing

Research Article

Evaluation of Sorghum-Oat-Soybean Ready-To-Use Therapeutic Food (RUTF) on Nutritional Recovery and Biochemical Profiles in Rats

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About Article

Article History

Submission: December 01, 2024
Acceptance : January 06, 2025
Publication : January 12, 2025

Keywords

Enzymes, Formulated, Malnutrition, Rats, Therapeutic

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ABSTRACT

Mortality due to severe acute malnutrition is one of the leading causes of death especially among children in developing countries. Ready-to-use therapeutic foods (RUTFs) have become the beacon of hope in the new management scene of malnutrition. The study is aimed at the management and assessing the effectiveness of nutritional rehabilitation of malnourished rats. A 33-day study was conducted on 20 Wistar rats which were divided into five different cages randomly and were fed with varying ratios of Sorghum-Oat-Soybean (SOS) Ready-to-Use-Therapeutic Food (RUTF) formulations as well as two controls RUTFS. Results showed pre-starvation body weights of the experimental animals ranged from 104.76g (S1 group) to 106.37g (C0 group). Subsequent to 5 days of starvation, a significant reduction in body weight was observed, with values ranging from 75.05g (S1 group) to 76.11g (S3 group). Following 21 days of nutritional intervention with SOS-RUTF, significant inter-group differences ($p < 0.05$) were detected in body and organ weights; hemoglobin, cholesterol, and triglyceride levels, ALT, AST, and ALP enzyme activities. The three SOS-RUTFs findings with of different ratios study revealed that SOS-RUTF enhanced formulations brought back the body weight, and organ weight was normal, balanced the biochemical parameters and corrected the hepatic and bone enzyme activities to near normal. These findings have important implications for the treatment of severe acute malnutrition. The study shows that the easily available, inexpensive, and nutritious SOS-RUTF can be used in clinical nutrition and is viable as an option for use in community interventions. This is especially so in developing countries where proper nutritious food is a luxury.

Citation Style:

Utah-Iheanyichukwu, C., Ibeji, N. E., Oguizu, A. D., & Allison, T. T. (2025). Evaluation of Sorghum-Oat-Soybean Ready-To-Use Therapeutic Food (RUTF) on Nutritional Recovery and Biochemical Profiles in Rats. *Journal of Agriculture, Aquaculture, and Animal Science, 2*(1), 7-14. https://doi.org/10.69739/jaaas.v2i1.197

1. INTRODUCTION

Ready-to-use Therapeutic Foods (RUTFs) are the ready-to-use forms of therapeutic foods which are prepared as foods and are used in the management of severe acute malnutrition in children and adults (World Health Organization, 2013). RUTFs are made of peanut pasta, vegetable oil, sugar, and milk and provide about 500-550 kcal energy per 100g serving (Collins *et al.*, 2018). They are prepared in a way that provides people with SAM nutrients including vitamins and minerals (National Institutes of health, 2020). Research has shown high efficient management of mortality rate as well as recovery with RUTFs (Isanaka *et al.*, 2017) and better outcomes in children suffering from malnutrition (Schoonees *et al.*, 2013). RUTFs benefits are easy to eat and no cooking (World Health Organization, 2013), long shelf life of 12months (Collins *et al.*, 2018), and cheaper than regular therapeutic diets (World Health Organization, 2013).

Sorghum (Sorghum bicolor) is a cereal grain which is used as a vital food source worldwide, especially in dry and semi-dry regions of the world (National Academy of Sciences, 1996). Sorghum is a grain rich in nutrients such as protein (7-13%) (Susetyowati *et al.*, 2019), dietary fiber (2-6%) (Kumar *et al.*, 2018), minerals (iron, zinc, potassium) (World Health Organization, 2013), and antioxidants (polyphenols, flavonoids) (Awika *et al.*, 2017). Intake of sorghum has several health benefits like gluten-free, good for celiac patients (Awika *et al.*, 2017); anti-inflammatory compositions (Kumar *et al.*, 2018); cardiovascular health (National Institutes of Health, 2020); and anti-cancer compositions (Susetyowati *et al.*, 2019).

Oat (Avena sativa) is a cereal grain and a staple food around the globe, comprising of needed nutrients which benefits health. Oats have great quantities of fiber (8-12%) (Slavin, 2008), protein (10-15%) (Tiwari & Cummins, 2013), minerals (such as iron, zinc, potassium) (World Health Organization, 2013), and antioxidants (like Avenanthramides) (Chen, 2018). Consumption of oats has been associated to lesser cholesterol levels (Anderson *et al.*, 2010), healthier cardiovascular health (Katz, 2013), improved digestive system (Slavin, 2008), and lowers the risk of type 2 diabetes (Hou *et al.*, 2015).

Soybean (Glycine max L) is a known crop in both the pulse and oilseed categories (Glacco *et al.*, 2016). It is part of the Papilionaceous family, is an upright yearly herb reaching up to 1.5 meters height, with pods containing 3 to 4 beans of different colors (Glacco *et al.*, 2016). Legumes usually attributed to as pulses, peas, or beans, are edible seeds from leguminous plants of the leguminosae family, which entails several varieties (Glacco *et al.*, 2016). Soybean is made up of 40% protein and 20% fat and makes it significant against malnutrition issues, although it contains anti-nutrients such as phytates and saponins (Glacco *et al.*, 2016).

This research was set to determine the impact of Sorghum-Oat-Soybean Ready-to-Use Therapeutic Food (RUTF) on several physical and biochemical measures in rats. From the outcomes of this study, it targets to assess the therapeutic abilities of Sorghum-Oat-Soybean RUTF in addressing malnutrition and promoting overall health.

2. LITERATURE REVIEW

Wistar rat was developed in 1906 at Wistar Institute which indicated a necessary achievement in the usage of rodent models for scientific inquiry (Campbell *et al.*, 2017). Superseding the house mouse, this albino strain has since become a much needed necessary tool in biomedical investigations. Wistar rats possess distinctive physical features such as broad cranial structure, extended auricular appendages, and caudal length consistently shorter than their body length. The Wistar rat has begotten many progeny strains which include Sprague Dawley, Long-Evans, and additional notable strains. As a basic stock, the Wistar rat has contributed to the development of over 50% of latter laboratory rat strains (Campbell *et al.*, 2017), rooting its status as a foundation of scientific investigation.

Campbell *et al.* (2017) carried a research which indicated that male rodents consuming high glycaemic index (HGI) diets tend to show increased body weight, adiposity, and glucose-related measures compared to those on low glycaemic index (LGI) diets. The study asserts that LGI diets may be beneficial, other nutrient such as fiber content, like resistant starch (RS), may on their own affect metabolism.

Mhlomi *et al.* (2022) conducted an experiment on male Albino rats, assessing the effects of protein-deficient diets supplemented with Moringa oleifera leaf meal (MOLM). They grouped the rats into five groups, with different protein-deficient diets augmented with different ratios of MOLM over 28 days. Their findings showed that MOLM supplementation slightly mitigated weight loss caused by protein deficiency; while it negatively impacted certain physical aspects of the rats. Specifically, MOLM improved some blood parameters but affected kidney function. Furthermore, histopathological assessments affirmed adverse effects from protein deficiency, purporting that raw MOLM could not replace dietary protein in its entirety.

Wang *et al.* (2020) investigated the protein quality of three green microalgal species and the effects of mechanical cell wall disruption on Sprague-Dawley rats. After feeding the rats with experimental diets gotten from these microalgae, they found that mechanical disruption significantly enhanced protein digestibility without major chnages in amino acid profiles. Their results pinpointed the potential of these microalgae as good source of protein for both humans and animals, specifically when subjected to mechanical disruption, offering cost-effective and efficient product development opportunities.

In 2013, Sasidharan and colleagues (2013) developed specific semi-purified diets, both normal and high-fat, for studying diet-induced metabolic disorders in albino rats. After assessing various diets based on parameters like body weight, adiposity, and blood markers, they identified NCD I and HFD I as the most suitable for inducing metabolic alterations, particularly obesity and dyslipidemia, in Winstar rats. These diets induced conditions like fatty liver and type 2 diabetes, making them ideal for research focused on diet-induced metabolic disorders in albino rats.

Abdulmaguid (2018) worked on the impact of various foods like barley, oat, walnuts, almonds, hazelnuts, and peanuts on the health and fertility of male rat testes. Forty-eight adult male rats were fed with a diet that included cereals (10% barley and oat) and nuts (2.5% each of walnuts, almonds, hazelnuts, and peanuts) after being injected with nicotine for 30 days. The findings showed that nicotine injection led to visible reductions in body weight, feed efficiency, organ weight, sperm motility, progressive sperm movement, sperm count, and induced changes in testicular tissue. The study purports that including cereals and nuts into the diet may counteract the negative effects of nicotine, probably benefiting male rats, persons with high nicotine consumption, as well as smokers.

3. METHODOLOGY

3.1. Materials

The formulation of the Sorghum-Oat-Soybean Ready-to-Use Therapeutic Food (RUTF) utilized the following components - Sorghum (Sorghum bicolor), Oat (Avena sativa), Soybean (Glycine max), Soy oil (Glycine max oil), Sucrose, Customized mineral mix, and Vitamin blend. All ingredients, including sorghum, oat, soybean, milk, vegetable oil, and sugar, were sourced from Ariaria International Market, Aba, Abia State, Nigeria, to ensure freshness and quality.

Experimental animals: Twenty (20) adult male Wistar rats. Equipment: Lancet pins, animal cages, oral gavage, scissors and forceps, K3 EDTA bottles, plane bottles, bench centrifuge, needles and syringes.

Dietary interventions: Prepared Ready-to-Use Therapeutic Food (RUTF) samples, Koroko RUTF, and Chikkun chicken finisher feed.

3.2. Processing of raw materials

To ensure the production of high-quality RUTF, the raw materials underwent rigorous processing and quality control measures: Cleaning and drying - Materials were washed and sun-dried to eliminate dust and moisture; Thermal processing - Roasting at 157°C for 15 minutes, with continuous agitation, enhanced nutritional bioavailability; Dehulling (Soybeans) - Mechanical removal of hulls from roasted soybeans using a grinding stone; Milling - Hammer mill grinding produced a uniform powder; and Particle size reduction - Sieving ensured optimal particle size for RUTF production. These processing steps guaranteed the removal of impurities, enhanced nutritional value, and achieved the required particle size for effective RUTF formulation.

Table 1. Ingredients Used for the Formulation of the Sorghum-Oat-Soybean RUTF

Formulation of SWS-RUTF

Ingredients	**Formulations (%)**		
	SOS-RUTF1	SOS-RUTF2	SOS-RUTF3
Sorghum	25	25	20
Soybean	30	25	35
Oat	10	15	10
Soya oil	20.4	20.4	20.4
Sugar	13	13	13
Mineral/ vitamin Premix	1.6	1.6	1.6

Modification of Steve and Jeya (2004)

3.3. Production of RUTF

The powdered ingredients, comprising: Sorghum seeds, Soybeans, Oat, Sugar, and Mineral/vitamin premix were blended with soya oil using a mechanical mixer.

The processing conditions: Soya oil heating - 70°C for 2 minutes; Gradual addition of powdered ingredients with simultaneous stirring; Post-addition stirring - 15 minutes at vigorous speed to ensure homogeneity and cohesion. The formulated RUTF products were packaged in nylon airtight bags and stored in cartons at ambient temperature. As per Manary (2006), mechanical mixing is essential for large-scale RUTF production, while hand mixing is feasible for small quantities.

3.4. Animal study

This study received approval from the Animal Research Ethics Committee of the Veterinary Teaching Hospital, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria (Clearance Number: MOUAU/VTH/A3/027).

3.5. Animal Procurement

This study utilized 20 adult male Wistar rats (age range: 12-14 weeks; weight range: 105-106g), obtained from the Animal House facility, Department of Zoology and Environmental Biology, Michael Okpara University of Agriculture, Umudike. The animals were acclimatized for 2 weeks and housed in standard cages (temperature: 22±2°C; humidity: 50-60%; lighting: 12h light/dark cycle). Prior to experimentation, rats were fed standard chow ad libitum.

3.6. Housing of rats

Prior to the commencement of the study, the animal house was thoroughly washed and disinfected. Twenty adult male Wistar rats were randomly distributed into five groups (S1, S2, S3, C0, and C1) of four rats each.

3.7. Acclimatization and housing conditions

Rats were housed in aluminum cages and allowed to acclimatize for 7 days to facilitate adaptation to their new environment and living conditions.

3.8. Diet and water

During the acclimatization period, rats had access to Chikkun finisher's mash (Chikkun feed, Nigeria) and clean water ad libitum.

3.9. Pre-experiment procedures

Initial body weights were recorded before commencement of the experiment. Subsequently, rats were subjected to starvation-induced malnutrition for 5 days, with only water provided.

3.10. Experimental design

The experiment consisted of a 33-day study period, divided into: Acclimatization phase (7 days); Starvation phase (5 days); and Treatment phase (21 days)

3.11. Animal welfare and ethics

All animal experiments were conducted in compliance with international guidelines for the care and use of laboratory animals (National Research Council, 2011; Orieke *et al.*, 2019).

3.12. Experimental design for rat study

Sex was used in assessing the rats as all the rats were male rats (female rats were not used due to the occurrence of mating and pregnancies – which can affect parameters), and all the rats were age mate.

3.13. Animal groupings

The animals were grouped into five groups consisting of four rats each.
Group 1: Animals were fed with SOS-RUTF1 (sorghum 25%, oat 20%, soybeans 30%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).
Group 2: Animals were fed with SOS-RUTF2 (sorghum 25%, oat 25%, soybeans 25%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).
Group 3: Animals were fed with SOS-RUTF3 (sorghum 20%, oat 20%, soybeans 35%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).
Group 4: Control group fed with normal rat feed – Chikkun finisher's mash.
Group 5: Animals were fed with the standard RUTF – Koroko RUTF (made in Nigeria).
At the end of the three weeks of feeding, animals from each group were anesthetized and decapitated. Blood samples and organs were collected in labeled sample containers, and serum was collected.

3.14. Determination of rats body composition and biochemistry parameters

The body weight, organ (brain, liver, kidney) weight, biochemistry (hemoglobin, cholesterol, triglycerides), hepatic and bone enzymes (Alanine Transaminase (ALT), Aspartate Transaminase (AST), Alkaline Phosphatase)) were tested and accessed using Suckow and Stevens (2017) and Orieke *et al* methods (2019). All biochemical and physiological assessments were conducted according to the methods described by UNICEF (2020) and Orieke *et al.* (2019).

3.15. Statistical analysis

All values are expressed as mean ± standard deviation (SD). Data analysis was performed using Statistical Package for Social Sciences (SPSS) version 20. Data were subjected to: One-way analysis of variance (ANOVA) to determine significant differences between groups; and Bonferroni post hoc test to identify specific pairwise differences. A probability value (p-value) < 0.05 was considered statistically significant.

4. RESULTS AND DISCUSSION

4.1. Results

Table 2 indicates various body weights of the Wistar rats at different stages of the experiments. Pre-starvation Body Weight value ranged between 104.75g for Sample-1 group to 106.03 for Control-0 group. This shows that all the rats were of almost same body weight before the start of the experiment. Post-starvation Body Weight ranged between 75.08g for Sample-1 group to 76.11 for Sample-2 group, which showed severe loss of weight indicating severe malnutrition. For Post-treatment Body Weight values were 185.41g for Sample-1 group, 179.00g for Sample-2 group, 180.80g for Sample-3 group, 110.55g for Control-0 group, and 187.67g for Control-1 group. All treatment groups were significant ($p<0.05$). Body weight gained, 79.96g for Sample-1 group, 74.76g for Sample-2 group, 74.82g for Sample-3 group, 4.52g for Control-0 group, and 82.34g for Control-1 group. A significant difference ($p < 0.05$) was observed in body weight gain among treatment groups. Rats fed SOS-RUTF formulations (Samples 1-3) and Koroko (Control-1) showed substantial weight gain compared to the Control-0 group. Results indicated initial body weights were comparable across groups, severe weight loss occurred in post-starvation, indicating malnutrition, SOS-RUTF formulations and Koroko significantly improved body weight post-treatment, while Control-0 group showed minimal weight gain.

Table 2. Weight dynamics of wistar rats fed with formulated RUTF throughout the experiment

Treatment groups	Pre-starving body weight (g)	Post-starving body weight (g)	Post treatment body weight (g)	Body weight gain (g)
Sample 1	105.45±2.65a	75.05±6.00e	185.41±4.62e	79.96±3.22b
Sample 2	104.76±3.61a	76.11±21.39c	179.00±25.00c	74.76±2.5a
Sample 3	105.98±3.79a	75.49±24.99a	180.80±28.58a	74.82±2.15a
Control 0	106.03±5.03a	76.00±31.61d	110.55±26.00d	4.52±7.51d
Control 1	105.33±4.58a	75.67±17.67b	187.67±17.79b	82.34±1.04c

Values are presented as mean ± standard deviation (n = 5); and values with different letter superscripts are significantly ($P<0.05$) different from any paired mean within the column.
Sample-1 Group-1: SOS-RUTF1 (sorghum 25%, oat 20%, soybeans 30%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).
Sample-2 Group-2: SOS-RUTF2 (sorghum 25%, oat 25%, soybeans 25%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).
Sample-3 Group-3: SOS-RUTF3 (sorghum 20%, oat 20%, soybeans 35%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).
Control-0 Group-4: Chikkun finisher's mash.
Control-1 Group-5: Standard RUTF – Koroko RUTF (made in Nigerian)

The Organ Weight of the Rats fed with RUFT Samples as shown in Table 3. Brain weight: All RUTF-fed groups exceeded 1.00g, while Control-0 was below the benchmark. Liver weight: RUTF-fed groups (13.67-14.00g and 16.70g for Control-1) showed significant increases compared to Control-0 (8.83g). Kidney weight: Control-1 (4.97g) and RUTF-fed groups (2.53-3.20g) demonstrated significant gains compared to Control-0 (1.07g). Results indicate that RUTF formulations significantly improved organ weights, suggesting enhanced nutritional recovery and organ function. All parameters for treatment groups were significant (p<0.05).

Table 3. Organ weights of rats fed with formulated RUTF

Treatment groups	Brain weight (g)	Liver weight (g)	Kidney weight (g)
Sample 1	1.2±1.05d	13.67±0.72c	2.80±1.47c
Sample 2	1.37±1.50c	12.93±0.71c	2.77±1.60b
Sample 3	1.44±1.82b	14.00±1.46b	3.93±0.19e
Control 0	0.7±2.13a	8.83±1.48b	1.07±1.35d
Control 1	2.3±1.79b	16.70±1.86a	4.97±1.79a

Values are presented as mean ± standard deviation (n = 5); and values with different letter superscripts are significantly (P<0.05) different from any paired mean within the column.
Sample-1 Group-1: SOS-RUTF1 (sorghum 25%, oat 20%, soybeans 30%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).
Sample-2 Group-2: SOS-RUTF2 (sorghum 25%, oat 25%, soybeans 25%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).
Sample-3 Group-3: SOS-RUTF3 (sorghum 20%, oat 20%, soybeans 35%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).
Control-0 Group-4: Chikkun finisher's mash.
Control-1 Group-5: Standard RUTF – Koroko RUTF (made in Nigerian).

Table 4. Hematological and lipid profile parameters of rats administered RUTF samples

Treatment groups	Hemoglobin (Hb) (g/dL)	Cholesterol (mg/dL)	Triglycerides (mg/dL)
Sample 1	16.31±0.21a	68.61±0.08a	82.70±0.13c
Sample 2	15.72±0.29b	72.76±0.15c	77.95±0.22a
Sample 3	15.31±0.12c	72.41±0.12d	72.90±0.13a
Control 0	8.71±0.11b	52.80±0.07c	49.91±0.18a
Control 1	16.87±0.09b	83.12±0.06b	82.74±0.03c

Table 4 shows the Hematological and lipid profile of the Rats fed with RUFT Samples. For Hemoglobin (Hb), Sample-1 group has 16.31g/dL, 15.72g/dL for Sample-2 group, 15.31g/dL for Sample-3 group, 8.71g/dL for Control-0 group, and 16.87g/dL for Control-1 group. All RUTF-fed groups showed significant increases in hemoglobin compared to Control-0 as values were significant (p<0.05). All cholesterol values were significant (p<0.05) as all were above 50mg/dL with Control-1 group scoring highest values (83.12mg/dL) followed by Sample-2 group (72.76mg/dL), Sample-3 (72.31mg/dL), Sample-1 (68.61mg/dL) and Control-0 group with the least values of 52.80mg/dL. All groups exceeded 50 mg/dL, with Control-1 and Sample-2 groups demonstrating highest values. Cholesterol levels were significantly elevated in all RUTF-fed groups. All triglycerides values were above 70mg/dL (72.90mg/dL for Sample-3 group, 77.95mg/dL for Sample-2 group, 82.70mg/dL for Sample01 group, and 82.74mg/dL for Control-1 group) except for Control-0 group which has a value of 49.91mg.dL which is below the bench mark. Triglyceride levels were significantly (p<0.05) increased in Sample-1 and Control-1 groups.

Values are presented as mean ± standard deviation (n = 5); and values with different letter superscripts are significantly (P<0.05) different from any paired mean within the column.
Sample-1 Group-1: SOS-RUTF1 (sorghum 25%, oat 20%, soybeans 30%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).
Sample-2 Group-2: SOS-RUTF2 (sorghum 25%, oat 25%, soybeans 25%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).
Sample-3 Group-3: SOS-RUTF3 (sorghum 20%, oat 20%, soybeans 35%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).
Control-0 Group-4: Chikkun finisher's mash.
Control-1 Group-5: Standard RUTF – Koroko RUTF (made in Nigerian).

Table 5 shows Hepatic and Bone Enzymes Parameters of the Rats fed with RUFT Samples. For Alanine Transaminase (ALT), Sample-1 group has 41.30U/L, 39.07U/L for Sample-2 group, 46.03U/L for Sample-3 group, 11.63U/L for Control-0 group and 48.17U/L for Control-1 group. All RUTF-fed groups showed significant (p<0.05) increases compared to Control-0. Aspartate Transaminase (AST) values were significant (p<0.05) except for Sample-3 and Control-0 groups; Control-1 group scoring highest values (81.13U/L) followed by Sample-1 group

Table 5. Hepatic and Bone Enzyme Parameters of Rats Administered RUTF Samples

Treatment groups	ALT (U/L)	AST (U/L)	ALP (U/L)
Sample 1	41.30±2.21e	73.43±1.76a	126.00±1.25d
Sample 2	39.07±8.99b	62.57±2.85c	151.70±2.74a
Sample 3	46.03±4.09a	67.07±1.88b	156.00±4.35a
Control 0	11.63±6.35d	49.40±1.74b	83.90±5.62c
Control 1	48.17±2.31c	81.13±1.31a	140.57±1.90b

(73.43U/L), Sample-3 (67.07U/L), Sample-2 (62.57U/L) and Control-0 group with the least values of 49.40U/L. Control-1 and Sample-1 groups demonstrated highest values, with significant differences except for Sample-3 and Control-0 groups. All Alkaline Phosphatase (ALP) values were above 100U/L (126.0U/L for Sample-1 group, 140.57U/L for Control-1 group, 151.70U/L for Sample-2 group, and 156.00U/L for Sample-3 group) except for Control-0 group which has a value of 83.90U/L which is below the bench mark. All RUTF-fed groups exceeded 100 U/L, with significant elevations except for Sample-2 and Sample-3 groups.

Values are presented as mean ± standard deviation (n = 5); and values with different letter superscripts are significantly (P<0.05) different from any paired mean within the column.

ALT: Alanine Transaminase.

AST: Aspartate Transaminase.

ALP: Alkaline Phosphatase.

Sample-1 Group-1: SOS-RUTF1 (sorghum 25%, oat 20%, soybeans 30%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).

Sample-2 Group-2: SOS-RUTF2 (sorghum 25%, oat 25%, soybeans 25%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).

Sample-3 Group-3: SOS-RUTF3 (sorghum 20%, oat 20%, soybeans 35%, soy oil 13.4%, sugar 10%, and mineral/vitamin mix 1.6%).

Control-0 Group-4: Chikkun finisher's mash.

Control-1 Group-5: Standard RUTF – Koroko RUTF (made in Nigerian).

4.2. Discussion

Severe Acute Malnutrition (SAM) in children and adults is characterized by weight loss or underweight status, defined as a Body Mass Index (BMI) below normal ranges (WHO, 2013). This study induced malnutrition in Wistar rats through starvation, resulting in significant weight loss. However, upon administration of formulated Ready-to-Use Therapeutic Food (RUTF) and Control RUTF, the rats exhibited substantial weight gain, indicating the efficacy of RUTF in promoting nutritional recovery. The formulated RUTF comprised sorghum, oat, soybean, soya oil, sugar, and mineral/vitamin mix in optimal proportions (UNICEF, 2020). Notably, rats in the Control-1 group, receiving Control RUTF-Koroko, demonstrated greater weight gain due to its high protein and fat content, rendering it nutrient-dense. Formulated RUTF promoted significant weight gain, indicating adequate nutritional content. Control RUTF-Koroko, with high protein and fat content, yielded greater weight gain. This study underscores the potential of RUTF formulations in addressing severe acute malnutrition, highlighting the importance of nutrient-dense ingredients in promoting optimal nutritional recovery.

Organ weights are established benchmarks for assessing health status, with standard ranges documented for brain, heart, lungs, liver, kidneys, spleen, and pancreas (Baker, 2016; Harkness & Wagner, 2016). Malnutrition can significantly impact organ development and function. This study's findings indicate that rats fed formulated Ready-to-Use Therapeutic Food (RUTF) exhibited organ weights (brain, liver, and kidneys) within standard ranges (Baker, 2016). This suggests that the formulated RUTF's ingredients possess adequate nutritional value, conferring nutritional and health benefits (Rao *et al.*, 2015; Kumar *et al.*, 2018; World Health Organization, 2013). Formulated RUTF supports optimal organ development and functions. RUTF's nutritional content aligns with established standards for health and well-being. The study's results recommend the formulated RUTF as a viable option for therapeutic food formulations, providing essential nutrients for individuals suffering from malnutrition. The findings support the incorporation of sorghum, oat, soybean, soya oil, sugar, and mineral/vitamin mix in RUTF formulations to promote optimal health outcomes.

Blood parameters, including hemoglobin (Hb), hematocrit (Hct), Red Blood Cell (RBC) count, White Blood Cell (WBC) count, glucose, cholesterol, and triglycerides, serve as critical indicators of malnutrition, particularly when values fall below normal ranges (WHO, 2013; WHO, 2020). Similarly, in Wistar rats, these parameters are established markers of nutritional status (Kaneko *et al.*, 2015; National Research Council, 2011). This study's assessment of hemoglobin, cholesterol, and triglycerides revealed that formulated Ready-to-Use Therapeutic Food (RUTF) maintained blood parameters within adequate ranges (Loeb & Quimby, 2016). These findings suggest that consumption of this RUTF by malnourished individuals may not only promote weight gain but also restore blood parameters to normal ranges. This implies that formulated RUTF supports optimal hematological and lipid profiles; and RUTF consumption may mitigate malnutrition-related blood parameter abnormalities. The study's results provide evidence for the efficacy of formulated RUTF in promoting nutritional recovery and maintaining healthy blood parameters, supporting its potential as a therapeutic food intervention for malnourished individuals.

Enzymes play a vital role in catalyzing chemical reactions essential for various bodily functions (WHO, 2020). In rodents, enzymes include Alanine transaminase (ALT), Aspartate transaminase (AST), Alkaline phosphatase (ALP), and Creatine kinase (CK) (Suckow & Stevens, 2017). This study investigated the effects of formulated Ready-to-Use Therapeutic Food (RUTF) on hepatic and bone enzymes profiles in Wistar rats. The results demonstrated that formulated RUTF improved the rats' hepatic and bone enzyme levels, maintaining ALT, AST, and ALP within relatively normal ranges (Norris, 2015). Findings showed that formulated RUTF enhanced enzyme profiles in Wistar rats, and ALT, AST, and ALP levels; and also were restored to near-normal ranges. The study's results suggest that consumption of formulated RUTF by malnourished individuals may restore optimal enzyme function and regain vitality and overall health. This study provides evidence for the efficacy of formulated RUTF in improving enzyme profiles and promoting nutritional recovery in Wistar rats, supporting its potential as a therapeutic food intervention for malnourished individuals.

5. CONCLUSIONS

This study evaluated the efficacy of a formulated Ready-to-Use Therapeutic Food (RUTF) comprising sorghum, oat, soybean, soya oil, sugar, and mineral/vitamin mix in addressing severe acute malnutrition (SAM) in Wistar rats. The results demonstrated that RUTF promoted significant weight gain and improved body mass index (BMI); RUTF maintained blood parameters (hemoglobin, cholesterol, and triglycerides) within adequate ranges; RUTF improved enzyme profiles (ALT, AST, and ALP) and restored them to near-normal ranges; and RUTF supported optimal organ development and function. The study's findings support the use of sorghum, oat, soybean, soya oil, sugar, and mineral/vitamin mix in RUTF formulations to promote optimal health outcomes.

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