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RESEARCH ARTICLE
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EFFECT OF STORAGE ON PHYSICOCHEMICAL, ANTIOXIDANT AND SENSORY PROPERTIES OF WASTE-BASED READY-TO-USE THERAPEUTIC FOOD (RUTF) FORMULATED FROM INDIGENOUS SEED FLOURS FOR ACUTE MALNUTRITION MANAGEMENT

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ABSTARACT
This study sought to formulate and assess a Ready-to-Use Therapeutic Food (RUTF) designed to address severe acute malnutrition (SAM) using RUTF made from the flours of waste seeds of pumpkins, watermelons, melons, soybeans and sunflowers. The research investigated the physicochemical and antioxidant properties of RUTF samples with different ratios of seed flour over 360 days of storage. Water activity, peroxide and acid values, total flavonoid content, and some sensory attributes were measured. The results demonstrated that higher amounts of pumpkin, watermelon, and melon seeds (T3) improved oxidative stability, reduced rancidity, and enhanced the antioxidant potential of the product. The findings support the feasibility of using nutrient-rich waste seed flours to produce cost-effective, shelf-stable in RUTF that addresses malnutrition in underprivileged regions.

Key Words: Ready-to-Use Therapeutic Food, Malnutrition, Physicochemical, Antioxidant, Nutrient

1. Introduction

Malnutrition remains one of the most pressing public health challenges around the world, especially in developing countries like Pakistan in the context of undernutrition along with food scarcity, low income level, and poor health service system. Children are the most important asset of any nation and their healthy growth and development is crucial for their wellbeing. Asim and Nawaz (2018) state that southern Asia including Pakistan, India, and Bangladesh accounts for about 500 million children under the age of five suffering from various grades of malnutrition. The malnutrition crisis in Pakistan worsened after the 2022 catastrophic floods and throughout the COVID-19 pandemic which, alongside socio-political instability, crippled food distribution and healthcare systems in the country. UNICEF states that approximately 40.2% of children in Pakistan are stunted, 28.9% are underweight, and 17.7% are wasted, substantially exceeding the global emergency benchmark (Idris, 2021).

Severe Acute Malnutrition (SAM) is a major cause of childhood mortality, especially in children under five, owing to extreme wasting and nutritional edema. The community-based approach of SAM management through Ready-to-Use Therapeutic Foods (RUTF) is more economical compared to hospital treatment (Saleem *et al.,* 2021). Importation of RUTF in Pakistan increases transport expenses as well as time and health care costs. Culturally, they are peanuts based which makes them less acceptable (Akram *et al.,* 2016). Efforts by World Food Programme aim at local production to develop RUSF using indigenous ingredients such as chickpeas (Kureishy *et al.,* 2019).

Simultaneously, the global challenge of food waste, especially the waste related to the processing of fruits and vegetables, has both economic and environmental impacts. The seeds of vegetable and fruits that are commonly consumed, such as pumpkin, melon, and watermelon, are often thrown away though they contain considerable amounts of proteins, indispensable fatty acids, minerals, and bioactive compounds (Dotto *et al.,* 2020; Benmeziane *et al.,* 2023). Addressing the problems of undernourishment and food waste would be possible through the sustainable utilization of these nutrient-rich waste products. Earlier research has already confirmed the medicinal and nutritional value of the seeds of pumpkin, watermelon (*Citrullus lanatus*), and melon (*Cucumis melo*) with specific emphasis on their food fortification and therapeutic potential (Meghwar *et al.,* 2024; Sahin *et al.,* 2022).

The purpose of the study is to assess the physicochemical and antioxidant properties of RUTF with formulated flours from pumpkin, watermelon, melon, soybean and sunflower seeds in different proportions. More specifically, the study evaluates how various ratios of seed flour affect water activity, lipid oxidation (peroxide and acid) color stability, and flavonoid loss during storage. It was anticipated that the findings demonstrated the feasibility of using waste-based seed flours in developing stable, nutrient-dense RUTF with longer shelf life, lower rancidity, higher antioxidant properties, and thus, aid sustainable nutrition approaches in vulnerable populations.

2. Methodology

2.1. Material procurement

The present study was designed to evaluate optimizing the formulation of waste based ready to use therapeutic food for Acute Malnutrition Management by applying *in Vivo* experiments. The whole raw material was purchased from the local market of Faisalabad.

2.2. Processing of raw materials

The pumpkin, watermelon, melon, sunflower and soybean seeds were cleaned, sorted and soaked in hot water for 10-20 minutes. Then dried in a cabinet dryer at 50°C for 5 hours. Later, the dried seeds were roasted and ground in grinder after this the flour was sieved and stored in airtight plastic bags. White sugar crystals were ground in grinder and then packed in airtight plastic bags (Javed *et al.,* 2021).

2.3. Basic formulation of RUTF

The preparation of product was done on the basis of specification of basic nutrient composition given by Pandav *et al.* (2020).

2.4. Development of RUTF

The seeds flour including pumpkin, watermelon, melon, soybean and sunflower was mixed with other ingredients like milk powder and sugar in order to achieve the required level of nutrients such as vitamin, mineral, proteins etc. After mixing the dry material proper amount of oil was added to form the paste. The finished product was stored at ambient temperature for further analysis of end product (Javed *et al.*, 2021).

2.5. Physicochemical Properties

2.5.1. Water activity determination

According to the procedure of Moustiés *et al.* (2022) the water activity was assessed in triplicate. One gram of sample was taken to determine water activity by using water activity meter at a temperature of 25°C.

2.5.2. Peroxide value (PV) determination

Peroxide value was determined by iodometric titration method. Take 200 milligram of sample were dissolved in 1mL of chloroform. The mixture was subsequently incorporated with 1.5mL of acetic acid and 0.1mL of saturated potassium iodide, agitated for 1 minute and then left in the dark for 5 minutes. Iodine indicator and 7.5mL of distilled water were added to the solution further 0.002N $Na_2S_2O_3$ was added titrations until the colour vanished. The PV was calculated using the formula as per described by Javed *et al.* (2021).

$$\text{PV} = (Vs - Vb) \times N \times \frac{1000}{W}$$

where PV = mEqO2/kg of lipid

Vs = volume of $Na_2S_2O_3$ used in the sample (mL)

Vb = volume of $Na_2S_2O_3$ used in the blank sample (mL)

N = normality of Na2S2O3 (mEq/mL)

W = lipid weight (g)

3.5.6. Acid value (AV) determination

Acid value was measured by titrating approximately 200g of sample with 0.4mL of ethanol/diethyl oxide (50:50, v/v). Following the addition of phenolphthalein, the solution was titrated with 0.01N KOH until the pink hue lasted for at least 10s. A blank sample was performed prior to the first titration and the AV was computed using the following AOAC (2019) equation and expressed as oleic acid equivalents:

$$\text{AV} = (Vs - Vb) \times N \times \frac{283.46}{10 - W}$$

2.6. Antioxidant analysis

2.6.1. Determination of total flavonoid content

The total flavonoid content was determined according to method of Asen *et al.* (2021).

2.6.2. Determination of total phenolic content

The total phenolic content of purposed RUTF was examined by following protocol of Karale *et al.* (2022).

2.6.3. Determination of DPPH

The determination of DPPH of various purposed RUTF was evaluated by the method described in Alshehry *et al.* (2020).

2.7. Sensory evaluation of RUTF

The resulted RUTF was evaluated for appearance, taste, texture, mouthfeel, aroma, color and overall acceptability at 0,180 and 360 days by trained panel. Trained panel using nine-point hedonic scale which includes extremely liked (9) very much liked (8), moderately liked (7), slightly liked (6), neither liked nor disliked (5), then slightly disliked (4), moderately disliked (3) and (2) very much disliked (Hadi *et al.*, 2022).

2.8. Statistical analysis

The obtained data was subjected to statistical analysis under one way and two-way ANOVA. All the analysis was conducted in triplicates and explained by mean ± S.D. The level of significance determined by using software Statistix 8.1 (Montgomery *et al.*, 2013).

3. Result and Discussion

3.1. Physicochemical Properties

3.1.1. Water activity

Water activity (aw) is a measurement of the water that is not bound to components in the food and therefore available for microbial growth. Water activity is an important property that used to predict food stability and safety with respect to microbial growth, rates of deteriorative reactions and physical properties (Fontana, 2000). Based on the results of the mean square analysis, the impact of storage time was highly significant ($p \leq 0.01$), however treatments, their interaction with time, or any combination thereof showed significant variations ($p \geq 0.05$). Table 1 shows the initial water activity values of T_3 (0.44±0.06%) and Control T_0 (0.46±0.09%). All formulations, however, showed declining trend over 360 days. At the end of the storage period, T_3 recorded the lowest water activity of 0.29±0.02%, while T_0 had the highest at 0.33±0.07%. The mean water activity decreased overall from 0.45% at day 0 to 0.30% by day 360. Although there was a decrease throughout the duration, the differences among treatments remained non-significant. These results agreed with Mousties *et al.* (2022) who recorded water activity values of 0.23% to 0.40% in RUTF with soybean, sesame, and sunflower. Campos *et al.* (2019) recorded a water activity for sunflower seeds as 0.20±0.52.

Table 1: Effect of treatments and storage on water activity (%) of waste based RUTF

Treatments	Days			
	0	180	360	Means
T_0	0.46±0.09	0.40±0.08	0.33±0.07	0.39
T_1	0.45±0.08	0.37±0.05	0.31±0.04	0.38
T_2	0.45±0.07	0.39±0.07	0.30±0.03	0.39
T_3	0.44±0.06	0.38±0.04	0.29±0.02	0.37
Means	0.45^{a}	0.38^{b}	0.30^{c}	

Where, $\mathbf{T_0}$= Control, $\mathbf{T_1}$= Pumpkin, Watermelon and Melon Seeds Flour 10%, Soybean and Sunflower Seeds Flour 35%, $\mathbf{T_2}$=Pumpkin, Watermelon and Melon Seeds Flour 20%, Soybean and Sunflower Seeds Flour 20%, $\mathbf{T_3}$=Pumpkin, Watermelon and Melon Seeds Flour 30%, Soybean and Sunflower Seeds Flour 5%

3.1.2. Peroxide value

Peroxide value measures the formation of peroxides in unsaturated fats, which occurs when double bonds break, leading to the production of short chain volatile compounds responsible for rancid odors (Canneddu *et al.*, 2016). The peroxide content in edible oils reflects their oxidative state and consequently their susceptibility to rancidity (Buthelezi *et al.*, 2019).

The peroxide value demonstrates lipid oxidation and the beginning stages of rancidity in a substance. Analyzed data showed significant findings ($p \leq 0.01$) for treatments, storage days, and interactions between both. As shown in Table 2, all treatments demonstrated the same increasing trend of storage duration leading to higher peroxide values. Initially, values ranged from 0.21±0.01meqO_2/kg in T_3 to 0.61±0.01meqO_2/kg in T_2. At 360 days, maximum levels of T_2 were 1.30±0.09meqO_2/kg while T_1 (1.10±0.06meqO_2/kg) and T_0 (0.82±0.02meqO_2/kg). T_3 remained at the lowest of 0.69 ± 0.10 meq O_2/kg. The mean peroxide values over time significantly increased from 0.44 to 0.98meqO_2/kg. Peroxide value increased during storage that lead to rancidity when stored for longer period of time.

Higher peroxide values indicate fat rancidity, while moderate values indicate peroxide depletion after reaching high concentrations (Pizarro *et al.*, 2013). The results of the currant study are in accordance with the findings of Javed *et al*. (2021), determined peroxide value 1.11-1.78meqO_2/kg oil in various RUTF formulations having chickpea, mung bean and peanut. Another researcher group, Alfawaz, *et al.* (2004) have reported peroxide value of 0.8(meq peroxide/kg oil in pumpkin seed flour.

Table 2: Effect of treatments and storage on peroxide value (meqO_2/kg) of waste based RUTF

Treatments	Days			
	0	180	360	Means
T_0	0.45±0.01^h	0.67±0.01^e	0.82±0.02^d	0.64^c
T_1	0.51±0.01^g	0.83±0.02^d	1.10±0.06^b	0.82^b
T_2	0.61±0.01^f	0.97±0.02^c	1.30±0.09^a	0.96^a
T_3	0.21±0.01^i	0.42±0.02^h	0.69±0.10^e	0.44^d
Means	0.44^c	0.72^b	0.98^a	

Where, **T_0=** Control, **T_1=** Pumpkin, Watermelon and Melon Seeds Flour 10%, Soybean and Sunflower Seeds Flour 35%, **T_2**=Pumpkin, Watermelon and Melon Seeds Flour 20%, Soybean and Sunflower Seeds Flour 20%, **T_3**=Pumpkin, Watermelon and Melon Seeds Flour 30%, Soybean and Sunflower Seeds Flour 5%

3.1.3. Acid value

The acid value represents the amount of potassium hydroxide (mg) needed to neutralize the free acids in 1g of substance. It serves as an indicator of the breakdown of triacylglycerols into free fatty acids which negatively impacts the quality of the substance. Oxidation contributes to spoilage and degrades the quality of oils and fats leading to an increase in acid value. Similarly, when oil undergoes oxidation it exhibits higher acid value. In high quality oil the acid value should be very low (<0.1). A rising acid value is a clear sign of oxidation, which result in gum and sludge formation (Sharma *et al.*, 2015).
As demonstrated in Table (3) acid values were influenced significantly by treatments ($p \leq 0.01$), duration of storage ($p \leq 0.01$), and their interaction ($p \leq 0.05$). Based on the results shown in Table, acid values were 0.13±0.01g/100g (T_3) and 0.30±0.03g/100g (T_0) at the start of storage. After 360 days, T_1 showed the highest value of 0.63±0.07g/100g, while T_3 had the lowest at 0.40±0.04g/100g. All treatments showed gradual increase in acid value, with the overall mean increasing from 0.18g/100g at day 0 to 0.53g/100g at day 360. The higher values noted in T_1 and T_2 are a direct result of greater proportions of soybean and sunflower seeds used, which are know for their higher polyunsaturated fatty acid composition, making them prone to oxidation. The above findings are in harmony with Alfawaz (2004), who examined acid value in pumpkin seeds. The acid value obtained was in the ranged from 0.53±0.25mg KOH. Coradi *et al.* (2017) confirmed the increased in acid value in sunflower seeds during storage. Acid value increased with prolong storage due to the storage condition and type of packaging. Their findings revealed that during 3 months storage of sunflower seeds flour the acid value increased from 0.846 to 0.964g/100g

Table 3: Effect of treatments and storage on acid value (g/100g) of waste based RUTF

Treatment	Days			
	0	180	360	Means
T_0	0.30±0.03^{de}	0.40±0.05^c	0.56±0.06^b	0.42^a
T_1	0.17±0.02^f	0.34±0.03^d	0.63±0.07^a	0.38^b
T_2	0.14±0.02^{fg}	0.30±0.03^{de}	0.53±0.05^b	0.32^c
T_3	0.13±0.01^g	0.29±0.03^e	0.40±0.04^c	0.27^d
Means	0.18^c	0.33^b	0.53^a	

Where, **T0=** Control, **T1=** Pumpkin, Watermelon and Melon Seeds Flour 10%, Soybean and Sunflower Seeds Flour 35%, **T2**=Pumpkin, Watermelon and Melon Seeds Flour 20%, Soybean and Sunflower Seeds Flour 20%, **T3**=Pumpkin, Watermelon and Melon Seeds Flour 30%, Soybean and Sunflower Seeds Flour 5%

3.2. Antioxidant analysis

3.2.1. Total Flavonoid Content (TFC)

TFC is a crucial parameter for evaluating the antioxidant potential of food formulations. Results indicated that treatments, storage time, and their interaction all had highly significant effects **(**$p \leq 0.01$). At initial, the highest TFC was found in treatment T_3 with (59.33±1.19mg QE/100g), followed by T_2 (40.40 ±1.05mg QE/100g), T_1 (25.22±0.04mg QE/100g), and T_0 (15.46±0.02mg QE/100g) (Table 4). Treatment T_3 exhibited the highest mean TFC value of 55.98±1.15mg QE/100g, which gradually decreased over time but remained the highest TFC of 54.45±1.11mg QE/100g after 360 days. In contrast, T_0, T_1, and T_2 showed greater declines of TFC during the storage period, with these values at 9.79 ± 0.01, 19.82 ± 0.01, and 36.00 ±1.01mgQE/100g, respectively, by 360 days. These findings demonstrate pumpkin, watermelon, and melon seed flours significantly enhance the antioxidant profile of RUTF due to their high content of flavonoids and polyphenols, which are known to have the ability to scavenging free radicals (Mohamed *et al.*, 2016).

One of the researcher groups, Gagour *et al.* (2022) concluded that sunflower seeds have high total flavonoids i.e. 25.37±0.19mgQE/g. However, Olubunmi *et al*. (2019) observed flavonoid content in melon seeds as 20.67mgQE/g. The current results are in harmony with the work done by Malencic *et al*. (2012), who carried out flavonoid content analysis for soybean seeds and noticed the range 4.94 to 6.22mgGAE/g. Similarly, Hagos *et al*. (2023), demonstrated that pumpkin seeds exhibit total flavonoids in the ranged from 51.1 to 58.5mgQE/100g among various varieties.

Table 4: Effect of treatments and storage on TFC (mg QE/100g) contents of waste based RUTF

Treatments	Days			
	0	**180**	**360**	**Means**
T_0	15.46±0.02^{j}	12.11±0.01^{k}	9.79±0.01^{l}	12.45^{d}
T_1	25.22±0.04^{g}	22.91±0.01^{h}	19.82±0.01^{i}	22.65^{c}
T_2	40.40±1.05^{d}	38.00±1.04^{e}	36.00±1.01^{f}	38.13^{b}
T_3	59.33±1.19^{a}	55.98±1.15^{b}	54.45±1.11^{c}	56.59^{a}
Means	35.10^{a}	32.25^{b}	30.02^{c}	

Where, $\mathbf{T_0}$= Control, $\mathbf{T_1}$= Pumpkin, Watermelon and Melon Seeds Flour 10%, Soybean and Sunflower Seeds Flour 35%, $\mathbf{T_2}$=Pumpkin, Watermelon and Melon Seeds Flour 20%, Soybean and Sunflower Seeds Flour 20%, $\mathbf{T_3}$=Pumpkin, Watermelon and Melon Seeds Flour 30%, Soybean and Sunflower Seeds Flour 5%

3.2.2. Total Phenolic Content (TPC)

Total phenolic content the total amount of phenolic compounds in a sample, typically expressed as milligrams of gallic acid equivalents per gram. Phenolic compounds are plant metabolites known for their antioxidant properties, which help neutralize free radicals and reduce oxidative damage. Regular consumption of phenolic rich foods is associated with reduced risks of cardiovascular diseases, cancers and neurodegenerative disorders (Kowalczyk *et al*., 2012). Table (5) demonstrated T_3 had the highest TPC of 56.48 ± 0.67mg GAE/100g on day 0 and declined to 50.53±0.61mg GAE/100g after 360 days. Likewise, the treatments and storage periods had significant impact on the total phenolic content (TPC) as well ($p \leq 0.01$). This formulation, which had the highest amounts of pumpkin, watermelon, and melon seed flours, seems to retain phenolic compounds better than others. On the other hand, T_1 and T_2 formulations, which had lower amounts of these seed flours, showed greater declines in phenolic compounds. It concluded that the presence of these specific seed flours, particularly the high phenolic pumpkin seed flours, stabilized and retained phenolic compounds during storage. The comparatively higher stability of T_3 suggests that this formulation provide stronger antioxidant protection over time and greater resistance to oxidative degradation. According to Gagour *et al.* (2022), sunflower seeds exhibitd relatively high phenolic content 49.73±0.35mgGAE/g than other seeds. The current results for total phenolic content are in close association with the work done by Nyam *et al.* (2013), they reported 22.92±0.61mg GAE/100g TPC in pumpkin seeds. Similarly, Andjelkovic *et al*. (2010), investigated total phenolic content in pumpkin seeds as 24.5–30.7mgGAE/g. The TPC (80.6±0.4 to 102±1.2 mgGAE/g) reported by Hagos *et al*. (2023) supported this research work by confirming that pumpkin seeds contain high total phenolic content.

Table 5: Effect of treatments and storage on TPC (mgGAE/g) contents of waste based RUTF

Treatments	Days			
	0	**180**	**360**	**Means**
T_0	36.36±0.29^g	33.45±0.27^h	29.77±0.25^i	33.19^c
T_1	32.25±0.20^h	28.00±0.19^j	26.25±0.17^k	28.83^d
T_2	45.38±0.45^d	43.35±0.44^e	39.91±0.41^f	42.88^b
T_3	56.48±0.67^a	53.07±0.64^b	50.53±0.61^c	53.36^a
Means	42.62^a	39.47^b	36.61^c	

Where, **T_0**= Control, **T_1**= Pumpkin, Watermelon and Melon Seeds Flour 10%, Soybean and Sunflower Seeds Flour 35%, **T_2**=Pumpkin, Watermelon and Melon Seeds Flour 20%, Soybean and Sunflower Seeds Flour 20%, **T_3**=Pumpkin, Watermelon and Melon Seeds Flour 30%, Soybean and Sunflower Seeds Flour 5%

3.2.3. DPPH Radical Scavanging Activity

The DPPH (2,2-diphenyl-1-picrylhydrazyl) assay is widely used method to assess the free radical scavenging ability of antioxidants in sample. The DPPH activity indicates strong potential to combat oxidative stress, which is linked to various chronic diseases (Yamauchi *et al*., 2024). The DPPH radical scavenging activity demonstrated significant differences between treatments and over time with respect to storage durations ($p \leq 0.01$) (Table 6). On day 0, the highest DPPH activity was observed in T_3 (79.97±0.70%) followed by T_0 (68.74±0.65%), T_2 (57.05±0.60%), and T_1 (40.58±0.45%). After 180 days, T_3 exhibited the highest radical scavenging activity (75.38±0.69%) while T_1 showed the lowest (35.32±0.44%). At 360 days, T_3 maintained the highest activity (70.46±0.67%), followed by T_0 (61.33±0.59%), T_2 (49.82±0.50%), and T_1 (31.07±0.40%). These results indicate that T_3, containing a greater proportion of seed flours with high antioxidant potential, managed to retain radical scavenging activity most stably throughout the entire storage period. The current findings on free radical scavenging potential are closely align with the work of Malencic *et al*. (2007), who reported DPPH activity 22.87 to 48.17% in various varieties of soybean seeds. However, Ijarotimi *et al*. (2022) measured DPPH activity 29.2 to 41.9% for methanolic and water extracts of melon seeds. The watermelon seeds extract showed relatively higher radical scavenging activity 59.88 to 94.46% at different concentrations (Tabiri *et al*., 2016). According to Neglo *et al*. (2021), watermelon seeds exhibited relatively high DPPH activity 41.10%. Similarly, Seidu *et al*. (2016) carried out DPPH assay for watermelon seeds and noticed the ranged from 39.89 to 61.11% indicating variations in their antioxidant activity.

Table 6: Effect of treatments and storage on DPPH (%) contents of waste based RUTF

Treatments	Days			
	0	**180**	**360**	**Means**
T_0	68.74±0.65^c	65.76±0.63^d	61.33±0.59^e	65.28^b
T_1	40.58±0.45^i	35.32±0.44^j	31.07±0.40^k	35.66^d
T_2	57.05±0.60^f	52.07±0.58^g	49.82±0.50^h	52.98^c
T_3	79.97±0.70^a	75.38±0.69^b	70.46±0.67^c	75.27^a
Means	61.59^a	57.13^b	53.17^c	

Where, **T_0**= Control, **T_1**= Pumpkin, Watermelon and Melon Seeds Flour 10%, Soybean and Sunflower Seeds Flour 35%, **T_2**=Pumpkin, Watermelon and Melon Seeds Flour 20%, Soybean and Sunflower Seeds Flour 20%, **T_3**=Pumpkin, Watermelon and Melon Seeds Flour 30%, Soybean and Sunflower Seeds Flour 5%

3.3. Sensory evaluation of RUTF

The product appearance is major factor that influences the overall acceptability among various consumers. The mean values regarding appearance (Table 7) exhibited highly significant variations among the treatments while, storage intervals showed non-significant difference. The maximum appearance score was assigned to T_0 (7.35) followed by, T_1 (6.77), T_2 (6.36) and T_3 (7.23) among treatments. Taste is one the most important factors in acceptability (liking or disliking) of a product. In case of taste, the highest score 7.34 was given to T_3 followed by T_0 (7.04)), and T_2 (5.49) whereas, the lowest score was assigned to T_1 (4.98). The maximum texture scores were assigned to T_0 (7.61) trailed by T_3, T_2 and T_1 as 7.47, 6.69 and 6.15, respectively. The storage caused non-significantly decline in texture score from 7.01 to 6.94 at 0 and 360 day correspondingly. The means for mouthfeel of instant RUTF indicated maximum score for T_0 (7.09) followed by T_3 (7.02), T_2 (6.72) and T_1 (6.50) storage also showed non-significantly decrease in the mouthfeel score from 6.86 to 6.80 during 360 days. The maximum color scores (7.15) were assigned to T_1 whilst, T_1 gained the minimum score (5.98). The maximum scores for smoothness 6.99 were assigned to T_3 whilst, the minimum score 6.65 were attained by T_1. The storage revealed non-significant reduction in score from 6.93(0 day) to 6.81(360 day) as explicated in the Table 7. It is evident from the findings that highest scores 7.16 were given to T_0 whilst, the minimum score 5.99 for T_1. Overall acceptability scores gradually declined from 6.63 to 6.55 during storage of instant RUTF.

The present results are also related with work of Yazew *et al.* (2022) they observed significant difference in appearance of three different types of RUTF prepared from maize grains, pulses and cooking banana fruit. The difference is due to the concentration difference of banana flour. The findings of instant study are in harmony with the outcomes of Choudhury *et al.* (2018), reported appearance and flavor scores showed variations in these traits after 12 months of locally produced chickpea, rice and lentils RUTF. Likewise, Adewumi *et al.* (2022) explicated that flavor scores of ready to use therapeutic food prepared with bambara groundnut moringa oleifera leaf. Similar decreasing tendency for smoothness was observed in locally produce RUTF that showed significant differences as compared to standard peanut base RUTF.

Table 7: Effect of treatments and storage on Sensory Parameters of waste based RUTF

Treatment	Sensory Parameters	Days			
		0	**180**	**360**	**Mean**
T_0	**Appearance**	7.53±0.17	7.40±0.17	7.11±0.17	7.35^a
T_1		6.88±0.17	6.77±0.16	6.67±0.16	6.77^c
T_2		6.40±0.17	6.38±0.16	6.31±0.16	6.36^d
T_3		7.30±0.17	7.24±0.17	7.16±0.17	7.23^b
Mean		7.02^a	6.94^b	6.81^c	
T_0	**Taste**	7.08±0.21	7.04±0.24	7.00±0.26	7.04^b
T_1		5.38±0.21	4.98±0.23	4.58±0.21	4.98^d
T_2		5.50±0.20	5.49±0.23	5.48±0.25	5.49^c
T_3		7.47±0.21	7.27±0.24	7.28±0.26	7.34^a
Mean		6.36^a	6.21^{ab}	6.07^b	
T_0	**Texture**	7.63±0.35	7.61±0.34	7.58±0.33	7.61^a
T_1		6.17±0.34	6.16±0.33	6.12±0.32	6.15^d
T_2		6.69±0.34	6.70±0.33	6.69±0.32	6.69^c
T_3		7.55±0.34	7.45±0.33	7.39±0.33	7.47^b
Mean		7.01	6.98	6.94	
T_0	**Mouthfeel**	7.10±0.16	7.11±0.16	7.05±0.16	7.09^a
T_1		6.52±0.16	6.49±0.15	6.47±0.15	6.50^d
T_2		6.75±0.16	6.70±0.15	6.73±0.15	6.72^c
T_3		7.06±0.16	7.04±0.16	7.0160±0.16	7.02^b
Mean		6.86	6.84	6.80	
T_0	**Color**	7.22±0.18	7.13±0.17	7.11±0.17	7.15^a
T_1		6.01±0.11	5.99±0.11	5.94±0.10	5.98^d
T_2		6.20±0.15	6.18±0.14	6.16±0.14	6.18^c

T_3		7.12±0.16	7.08±0.15	7.07±0.15	7.09^b
Mean		6.64	6.60	6.57	
T_0	**Smoothness**	7.06±0.14	6.94±0.12	6.89±0.11	6.96^a
T_1		6.69±0.14	6.65±0.13	6.61±0.10	6.65^c
T_2		6.90±0.07	6.93±0.06	6.86±0.05	6.89^b
T_3		7.09±0.14	6.99±0.13	6.91±0.12	6.99^a
Mean		6.93^a	6.87^b	6.81^c	
T_0	**Overall Acceptability**	7.22±0.16	7.15±0.13	7.11±0.12	7.16^a
T_1		6.02±0.19	6.00±0.15	5.95±0.14	5.99^d
T_2		6.20±0.09	6.19±0.10	6.14±0.11	6.18^c
T_3		7.11±0.14	7.07±0.13	6.99±0.12	7.05^b
Mean		6.63^a	6.60^b	6.55^c	

Where, **T_0=** Control, **T_1=** Pumpkin, Watermelon and Melon Seeds Flour 10%, Soybean and Sunflower Seeds Flour 35%, **T_2**=Pumpkin, Watermelon and Melon Seeds Flour 20%, Soybean and Sunflower Seeds Flour 20%, **T_3**=Pumpkin, Watermelon and Melon Seeds Flour 30%, Soybean and Sunflower Seeds Flour 5%

Conclusion

The study confirmed that waste-based RUTF formulations using indigenous seed flours remained nutritionally and sensorially acceptable during storage. Physicochemical properties such as peroxide and acid values increased over time, while antioxidant content and sensory attributes slightly declined but stayed within acceptable limits. The results support the use of agro-waste ingredients for shelf-stable, effective RUTF products.

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