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Development and Storage Stability of Cookies from Whole Wheat, Sweet Potato and *Mucuna utilis*, Composite Flour

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Authors' contributions

This work was carried out in collaboration among all authors. All the authors collaborated in carrying out this research. Authors JIA and RNA conceived the idea and designed the experiment. Author KJC did the laboratory work and analysis. All the authors interpreted the results. Author KJC wrote the initial manuscript after all the authors had made inputs. All the authors proofread, corrected and approved the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aim: This study evaluated the effect of storage conditions at ambient (28 ± 2°C) and refrigeration temperature (4 ± 2°C) on the physicochemical properties of Cookies made from Composite flours in the ratio of 50: 30: 20; 50:20:30 (whole wheat, sweet potato flour or *Mucuna utilis* respectively).

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Methodology: Flours were obtained from whole wheat (W), peeled and sun-dried potato (S), and boiled oven-dried *mucuna (BM)* and toasted oven-dried *mucuna (TM)* bean seed. Cookies made from 100 % whole wheat flour served as control. The physicochemical properties of the cookies were evaluated using standard methods and the data obtained were statistically analyzed.
Results and Discussion: The results showed an increase in protein (8.17 % - 18.84 %), crude fiber (1.57 – 7.38 %), and fats (8.81- 14.59 %.). The vitamin values decreased in all the samples after storage except vitamin E (1.05 – 1.87 mg/100 g (before storage) and vitamin E (1.08 -1.92) which remained unaffected after the storage period. After 30 days of storage, the percentage free fatty acid (FFA) values ranged from (0.39 – 0.56 % for samples stored under refrigerated conditions as against 0.58- 0.79 % observed in ambient temperature storage. The Peroxide value showed a slight increase in refrigerated samples (3.9 – 6.98 meq O_2/kg) as against that of ambient temperature storage which had higher values (8.22 -12.58 meq O_2/Kg).
Conclusion: The FFA and peroxide values of samples W50 S30 BM20 and W50 S20 BM30 were within acceptable limit under refrigerated condition indicating that boiling treatment is better preferred than toasting. The study indicated that refrigerated storage is a more suitable storage condition than ambient storage.

Keywords: Development; storage stability; mucuna composite flour; cookies.

1. INTRODUCTION

Cookies are soft dough biscuits commonly consumed in most parts of the world by children and adults [1]. A cookie is a conventional wheat flour-based food product produced from unpalatable dough with the application of heat and transformed into an appetizing product [2]. Cookies are ready-to-eat, convenient, and cheap snack food products containing digestive and dietary principles of vital importance [3]. Cookies are traditionally produced from refined wheat flour which is low in protein (7 – 14%), and deficient in essential amino acid (lysine) [4]. Secondly, wheat is not grown in tropical regions including Nigeria for climatic reasons and so to produce baked goods in these regions with limited supplies of wheat flour huge amount of foreign exchange is spent on wheat importation. Therefore, to improve the nutritional quality of cookies, reduce the cost of wheat importation, and add economic value to locally available, cheap, and nutritious grains composite technology should be applied. Composite flours can be defined as either binary or ternary mixtures of flours from some other crops with or without wheat flour [5]. Composite flour is considered advantageous in developing countries as it reduces the importation of wheat flour and encourages the use of locally grown crops as flour [6]. Composite flours from legumes and tubers have been reported to have higher protein concentrations and calorific values [7]. Cookies with high sensory ratings have been produced from blends of wheat and full-fat soya [8]. In several different studies, wheat-based composite flour cookie production has been reported by Onoja et al. [9] and Ajanaku et al. [10]. This was aimed at promoting the development of diversified, nutrient-rich nutritious, and healthy bakery products [11].

Mucuna utilis (velvet bean) is one of the indigenous lesser utilized and lesser-known edible legumes with a low human preference for food but has a high potential as an energy and protein source. Mucuna possesses adequate amounts of protein, essential amino acids, polyunsaturated fatty acids (PUFAs), dietary fiber, and essential minerals and vitamins comparable to other common legumes, along with the presence of beneficial bioactive compounds. It is comparable to soybean in terms of amino acids and mineral profile [12].

Sweet potato roots are a good source of carbohydrates, generally low in protein and fat, and rich in ascorbic acid, vitamins B1, B2, B6, and B5 respectively, folic acid, and vitamin E. The overall protein quality is good and levels of essential amino acids compare significantly to the FAO reference protein [13]. This study is aimed at producing cookies from composite flours of wheat, sweet potato, and mucuna bean, evaluating the physicochemical qualities, and also studying the storage stability of the cookies.

2. MATERIALS AND METHODS

2.1 Raw Materials

The freshly harvested and dried Mucuna bean seeds, whole wheat grains, sweet potato tubers, and other baking ingredients were procured from

Ogbete Main Market of Enugu, Enugu State, Nigeria. Analytical reagents were obtained from the Food Science and Technology Laboratory of Madonna University Nigeria, Akpugo Campus.

2.2 Experimental Design/ Sample Preparation

The freshly developed cookies were subjected to storage at ambient (28°C) and refrigerated temperatures for 30 and 60 days intervals of time respectively. Oil was extracted from the cookies and PV and FFA of the extracted oil were determined fortnightly. Likewise, the physical characteristics and microbial evaluation of the cookie were checked fortnightly.

2.3 Production of Cookies Samples

Cookies were produced using the straight dough method described by Chauhan et al*.* [14]. The fat and the sugar were mixed thoroughly; until both formed a homogenous mixture (fluffy). All the other ingredients (flour, salt, baking powder, and milk) were properly mixed in separate bowls properly. The mixed fat and sugar were added to the ingredients and mixed thoroughly to form dough and kneaded. They were rolled out thinly on a cutting board and cut out into circular shapes and the diameter was measured using a micrometer screw gauge (0.3 cm), and placed in a baking pan. The cut dough was transferred to the oven (SANS XY-880S) and baked at a temperature of 100 °C for 15 minutes. The baked cookies were allowed to cool at room temperature and then packaged in an airtight container.

2.4 Physical Characteristics of Cookies Samples

Developed cookies were evaluated for physical characteristics like weight; diameter, thickness, and spread ratio were calculated by standard procedures [15].

2.5 Statistical Analysis

The data were statistically analyzed using the statistical package for social science (SPPS) software version 17.0 for Windows, SPSS Inc. Illinois, USA). The least Significant Difference procedure was used to separate significantly different means at p<0.05.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Cookies

The result of the proximate composition of the composite cookies is presented in Table 1. The protein contents of the samples ranged from 8.17% - 18.84% with sample $W_{50}S_{20}BM_{30}$ which consisted of 50% wheat flour 20% sweet potato and 30% boiled mucuna flour having the highest protein content and the control sample W_{100} having the least value of 8.17%. The samples differed significantly (p <0.05) in the mean protein content from each other. The results indicated that the composite cookie samples were richer in protein content than the 100% wheat-based cookies. The higher protein content could be attributed to the high level of substitution of wheat flour with mucuna flour. Hence, these cookies could be used to ameliorate protein energy malnutrition. The observation in this study is in line with the study of Iyayi and Taiwo [12] which revealed that mucuna possess adequate amounts of protein and essential amino acids.

The ash content of the various cookie samples was significantly different from each other. The values ranged from 1.96-3.06% with Sample $W_{50}S_{30}TM_{20}$ which comprised 50% whole wheat, 30% sweet potato, and 20% toasted mucuna flour having the highest ash content whereas sample $W_{50}S_{20}TM_{30}$ which is made up of 50% wheat, 20% sweet potato, and 30% toasted mucuna flour having the least value. The cookies made from the composite flours had higher ash content when compared to the control sample (W_{100} cookies). This could be attributed to the inclusion of sweet potato and mucuna seed flours. Ash content could be used as an index for estimating the mineral composition of food material [16]. This suggests that cookies from the composite flour blends will provide more minerals to the consumers than the reference sample.

The moisture content of the cookies ranged from 11.28-13.7%. Sample W50 S30 BM20 had the highest moisture content and was not significantly (p<0.05) different from W50 S20 BM30 possibly because both samples contain boiled mucuna. However, samples W50 S30 TM20 (11.28%) had the lowest moisture content but were not significantly (p<0.05) different from W50 S20 TM30 and W100 with moisture values of 12.7 and 12.73%. From the results, the moisture content decreased with the increased substitution with toasted mucuna flour. Moisture

Table 1. Proximate composition of cookies

Samples	Protein	Ash	Fat	Moisture	Crude Fiber	CHO	Energy
$W_{50}S_{30}BM_{20}$	16.30±0.04	2.24^{cd}±0.03	11.09^{c}±0.06	12.76^{b}±0.03	3.39^{b}±0.08	55.44^{b}±0.04	386^{d}±0.23
$W_{50}S_{20}BM_{30}$	18.84^{bc}±0.04	2.90^{bc}±0.02	10.91^{c}±0.02	13.70^{b}±0.03	7.38^{a}±0.08	48.16^{c}±0.01	368.3^{bc}±0.28
$W_{50}S_{30}TM_{20}$	14.23^{b}±0.06	3.06^{a}±0.08	14.59^{a}±0.24	11.24^{a}±0.10	3.78^{b}±0.02	51.57^{b}±0.26	409.59^{a}±0.24
$W_{50}S_{20}TM_{30}$	14.79^{a}±0.12	1.96^{b}±0.08	10.15^{b}±0.08	11.28^{a}±0.04	1.57^{c}±0.03	51.82^{b}±0.15	373.14^{c}±0.21
W_{100}	8.17±0.05	2.16^{d}±0.02	8.81^{d}±0.02	12.73^{b}±0.04	2.18^{c}±0.30	65.94^{a}±0.18	375.78^{c}±0.30

Values are means of triplicate determinations. Means with different superscripts along the same column are significantly different ($p \leq 0.05$). key: Where CHO=Carbohydrate: $W_{50}S_{30}BM_{20}$=50 % Whole wheat+30 % Sweet potato flour + 20% boiled Mucuna flour, $W_{50}S_{20}BM_{30}$= 50%Whole wheat+20% Sweet potato flour + 30% boiled Mucuna flour, $W_{50}S_{30}TM_{20}$= 50%Whole wheat+30% Sweet potato flour + 20% toasted Mucuna flour, $W_{50}S_{20}TM_{30}$= 50%Whole wheat+20% Sweet potato flour + 30% toasted Mucuna flour, W_{100}= 100% Whole wheat flour is an important parameter when considering cookies' Storage stability because its high level significantly enhances microbial spoilage of the cookies.

The fat content of the cookies ranged from 8.81-14.59%. The fat content of the control cookies (100% wheat flour cookies) was significantly ($p \leq 0.05$) lower than the fat contents of all the test cookies. The increased level of fat observed in the cookies was a result of many factors which included the contribution of up to 8% fat from mucuna flour to the composited flour. This observation is in line with the reports that mucuna contains high levels of polyunsaturated fatty acids which are essential nutrients [17]. The biscuit produced with mucuna flour substitute could play a role in supplying the body with this essential fatty acid.

The crude fiber content of cookies ranged from 1.57 – 7.38% and differed significantly ($p \leq 0.05$) from each other. The crude fiber increased with the increasing level of substitution of boiled mucuna flour from 2.18% in whole wheat flour to 7.58 in W50 S20 BM30 wheat, sweet potato, mucuna flour. The crude fiber values decreased as the level of substitution of toasted mucuna flour increased with samples W50 S30 TM20 (3.78%) and W50 S32 TM30 (1.57%) which comprised 50% whole wheat flour, 20% sweet potato, and 30% toasted Mucuna. These values however, were significantly higher than that of the control sample (2.18%). The values obtained were within the recommended FAO/WHO [18] level of not more than 5 % for both children and adults. These values would enhance gastrointestinal tract and cardiovascular health.

The carbohydrate contents of composite cookies decreased with increased mucuna flour supplementation and ranged from (48.16-65.94%) and the lowest (48.16%) content was found in sample W50 S20 BM30 (with 30% mucuna flour) compared to the control which has a value of 65.94%. The carbohydrate contents of all the composite cookie samples were significantly lower than that of the 100% whole wheat cookies. A similar decreasing trend of carbohydrate content due to blending with legume flours has been reported in previous studies done on millet, plantain, and soybean composite flour reported by Bolarinwa et al. [19] because of starch contents in the mucuna flours. The carbohydrate content decreased significantly ($p < 0.05$) with the increase in Mucuna flour substitution.

The energy content of composite cookies ranged from 368.3 – 410.58 KJ/100 g with sample W50 S30 TM20 (50% wheat flour, 30% sweet potato, and 20% Toasted Mucuna) having the highest value compared to sample W50 S20 BM30 (50% wheat, 20% sweet potato, and 30% Mucuna) which has a relatively low figure of (368.3 KJ/100 g). The trend was similar to that of carbohydrates above. The observed differences in energy contents of the samples could be attributed to variations in the protein, fat, and carbohydrate content of the samples.

3.2 Storageability Study on the Cookies

3.2.1 Free fatty acid (ffa) and peroxide value composition

The results of the free fatty acid (FFA) and peroxide value composition of oil extract from fresh cookies and cookies stored for 60 days under ambient and refrigerated conditions are presented in Fig. 1. and 2. respectively. The FFA values for fresh cookies ranged from 0.38-0.61%. The control sample (W_{100}) had the highest FFA of 0.61% and it differed significantly ($p < 0.05$) from the FFA of the rest of the samples. Free fatty acid measures the extent to which triacylglycerols in the oil or fat have been decomposed by lipase action. However, upon storage, there was a slight increase in the FFA level of refrigerated samples during the 30 days of storage. The values ranged from 0.39 – 0.56% for samples stored under refrigerated conditions as against 0.58 - 0.79% observed in the ambient temperature storage. The increase in FFA was significantly higher in ambient temperature storage than in refrigerated storage. The reason for the FFA rise may be due to environmental factors such as temperature, relative humidity (moisture), and the nature of the packaging material used which promoted fat hydrolysis during storage.

The peroxide values of the oil from fresh cookies ranged from 3.0-5.17 meqO_2/Kg. Samples $W_{50}S_{30}TM_{20}$ and $W_{50}S_{20}TM_{30}$ had higher values than the other samples. This may be due to the toasting treatment given to the flour which may have enhanced oxidation of unsaturated fats. Despite this, the other samples had values within the acceptable limit of 3 meq O2/kg. Peroxides are products of primary oxidation whose concentration may fluctuate over time as it is easily converted into other oxidation product with time [20].

The findings of this study (increase in percentage FFA) was similar to the report of Singh, [21] who observed an FFA increase in a soy-fortified biscuit as the storage period advanced.

The peroxide values ranged from 8.22 -12.58 meq O_2/Kg for ambient temperature storage and from 3.9 – 6.98 meq O2/kg. The lower peroxide value indicated the good quality of oil and good preservation status. The high values recorded during ambient temperature storage were due to elevated temperature which encouraged thermal decomposition of fat. Peroxide value is a measure of the level of oxidation of fat in the early stage of storage expressed in terms of milliequivalents of active oxygen per kilogram (meq O_2/Kg). The values increased significantly under both conditions but the level of deterioration of the fat was significantly higher in ambient temperature than in refrigerated temperature.

From the result obtained above, it could be concluded that fatty food stored in refrigerated conditions will have higher shelf life than those stored at ambient temperature. During refrigerated storage, the peroxide formation was gradual and steady owing to low temperature which might not favor thermal hydrolysis hence low FFA and peroxide values throughout the study period.

Data on the effect of storage conditions on the FFA and PV after 30 days of storage are presented in Table 1. At the end of 60 days of storage of the cookies under ambient temperature and refrigerated temperature storage, there was an increase in the FFA content of the cookies but the increase at ambient temperature was rapid and had higher values due to the higher temperature of storage. Low refrigerated temperature resulted in gradual triglyceride breakdown which gave rise to lower FFA values. Sixty days storage maintained the same trend as 30 days with samples stored at ambient temperature recording higher values of both FFA and peroxide values.

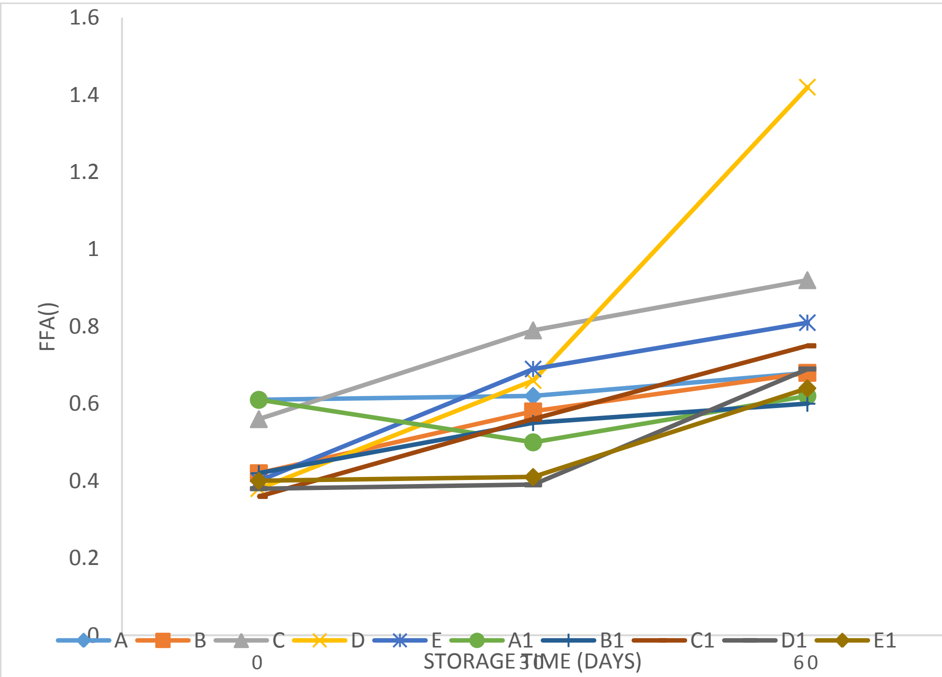

Fig. 1. Changes in FFA values during 60 days storage of cookie

KEY: Values are means of triplicate determinations. Key A= 100 % Whole wheat flour cookie and stored under ambient conditions, B = 50 % Whole wheat+20 % Sweet potato + 30 % toasted Mucuna flour cookies and stored under ambient conditions; C= 50 %Whole wheat+30% Sweet potato + 20 % toasted Mucuna flour cookies and stored under ambient conditions, D= 50 %Whole wheat+20 % Sweet potato + 30 % boiled Mucuna flour cookies and stored under ambient conditions; E = 50 % Whole wheat+30 % Sweet potato + 20 % boiled Mucuna flour cookies and stored under ambient conditions; A_1= 100 %Whole wheat flour and stored under refrigerated conditions; B_1 = 50%Whole wheat+20% Sweet potato + 30% toasted Mucuna flour cookies and stored under refrigerated conditions; C_1= 50 %Whole wheat+30% Sweet potato + 20 % toasted Mucuna flour cookies and stored under refrigerated conditions, D_1= 50 % Whole wheat+20 % Sweet potato + 30 % boiled Mucuna flour cookies: and stored under refrigerated conditions; E_1 =50 % Whole wheat+30 % Sweet potato + 20 % boiled Mucuna flour cookies and stored under refrigerated conditions

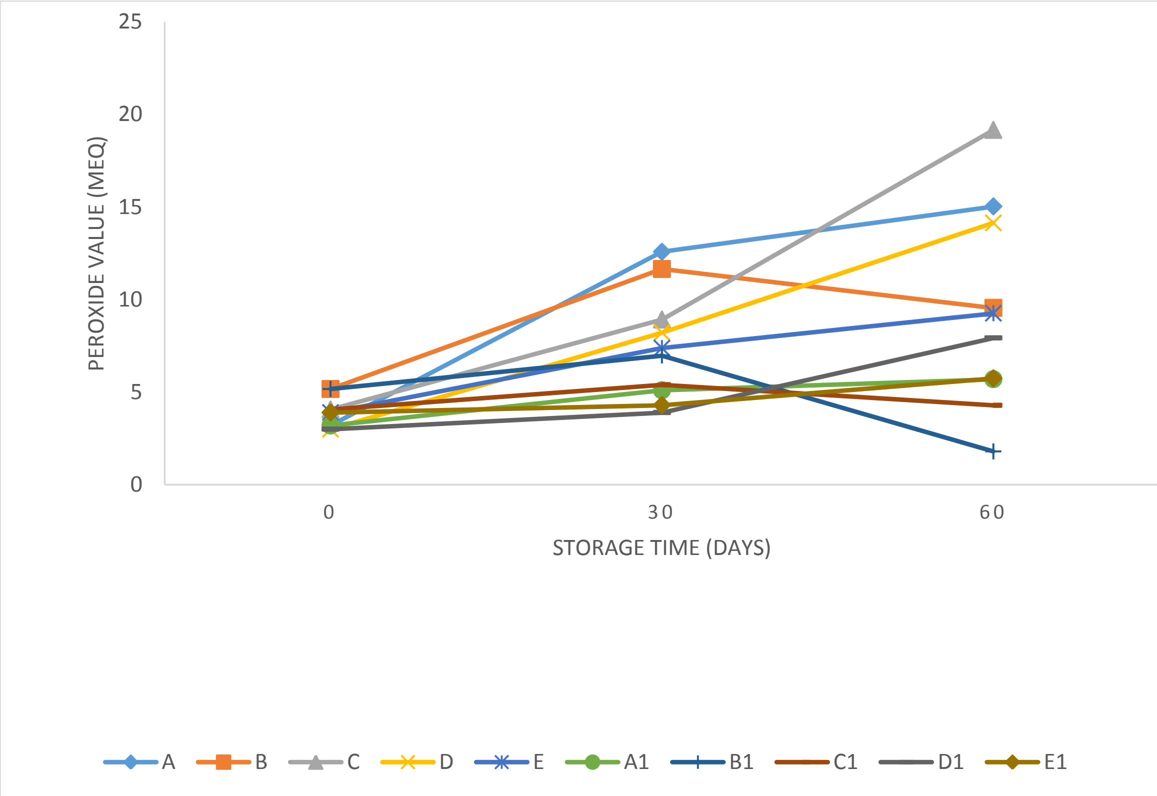

Fig. 2. Changes in peroxide value of cookies during 60 days of storage

Values are means of triplicate determinations. Key A= 100 % Whole wheat flour cookie and stored under ambient conditions, B = 50 % Whole wheat+20 % Sweet potato + 30 % toasted Mucuna flour cookies and stored under ambient conditions; C= 50 %Whole wheat+30% Sweet potato + 20 % toasted Mucuna flour cookies and stored under ambient conditions, D= 50 %Whole wheat+20 % Sweet potato + 30 % boiled Mucuna flour cookies and stored under ambient conditions; E = 50 % Whole wheat+30 % Sweet potato + 20 % boiled Mucuna flour cookies and stored under ambient conditions; A_1= 100 %Whole wheat flour and stored under refrigerated conditions; B_1 = 50%Whole wheat+20% Sweet potato + 30% toasted Mucuna flour cookies and stored under refrigerated conditions; C_1= 50 %Whole wheat+30% Sweet potato + 20 % toasted Mucuna flour cookies and stored under refrigerated conditions, D_1= 50 % Whole wheat+20 % Sweet potato + 30 % boiled Mucuna flour cookies: and stored under refrigerated conditions; E_1 =50 % Whole wheat+30 % Sweet potato + 20 % boiled Mucuna flour cookies and stored under refrigerated conditions

3.2.2 Effect of storage on the vitamin content of the cookie

The changes in the vitamin composition of the cookies during the 60 days of storage under ambient and refrigerated conditions are presented in Figs. 3.-5. The vitamin B_1 contents ranged from 0.41-0.91 mg/100 g. Sample $W_{50}S_{30}BM_{20}$ which comprised 50 % whole wheat, 30 % sweet potato, and 20 % boiled mucuna flours compared well with the control sample (W_{100}) as both did not differ significantly from each other. Both had the least value (0.01mg/100 g). However, sample $W_{50}S_{30}TM_{20}$ had the highest value of 0.41 mg/100 g followed by sample $W_{50}S_{30}TM_{20}$ (0.23 mg/100 g). The low thiamin values recorded in samples $W_{50}S_{30}BM_{20}$ and $W_{50}S_{20}BM_{30}$ could be attributed to boiling treatment. Vitamin B1 (Thiamin) is a water-soluble vitamin and may have been leached out during the boiling operation of the mucuna bean as compared to the toasting treatment. Vitamin B1 is essential for glucose metabolism and it plays a vital role in the proper functioning of the nerves, muscles, and heart. The Vitamin B2 content of the cookies ranged from 0.01 -0.05 mg/ 100 g. The Vitamin B_3 (niacin) content of the cookies ranged from 0.09 - 0.2 mg/100 g with sample $W_{50}S_{20}TM_{30}$ recording the highest value (0.2 mg/100 g) while sample $W_{50}S_{20}BM_{30}$ had the least (0.09 mg/100 g). Composite flour cookies had significantly higher values of Vitamin B3 than the control sample (W_{100}). Vitamin B_3 is useful in lowering serum cholesterol, reducing high blood pressure, preventing fatty build-up in the liver, maintaining the nervous system, and helping to reduce depression [22]. Vitamin E content of the cookies ranged from 1.05 – 1.87 mg/100 g with sample $W_{50}S_{30}BM_{20}$ having the least mean value (1.05 mg/100 g) while sample $W_{50}S_{20}BM_{30}$ had the highest of 1.87 mg/100 g. The observed high vitamin E level is in agreement with the reports that ground beans and sweet potatoes are good sources of vitamin E [23]. Vitamin E is a potent chain-breaking antioxidant that inhibits the production of reactive oxygen species molecules when fat is oxidized and during the propagation of free radical reactions.

The vitamin B1 content after storage ranged from 0.02 - 0.1 Mg/100 g for refrigerated storage conditions of the cookies. There was a constant reduction in the vitamin B1 content of refrigerated temperature-stored cookies. Vitamin B2 mean values ranged from 0.01 – 0.14 mg/100 g for refrigerated storage which showed similar downward trend as in Vitamin B1 except for sample $W_{50}S_{20}BM_{30}$ which showed a sharp rise in vitamin B2 value. The sharp rise may be attributed to extraneous factors during the experiment. Vitamin B3 mean values ranged from 0.03 – 0.28 mg/100 g for refrigerated storage as against 0.09 - 0.2 mg /100 g values recorded before storage. There was no significant variation in Vitamin B3 before and after storage. This showed that the storage condition is suitable for vitamin B3.

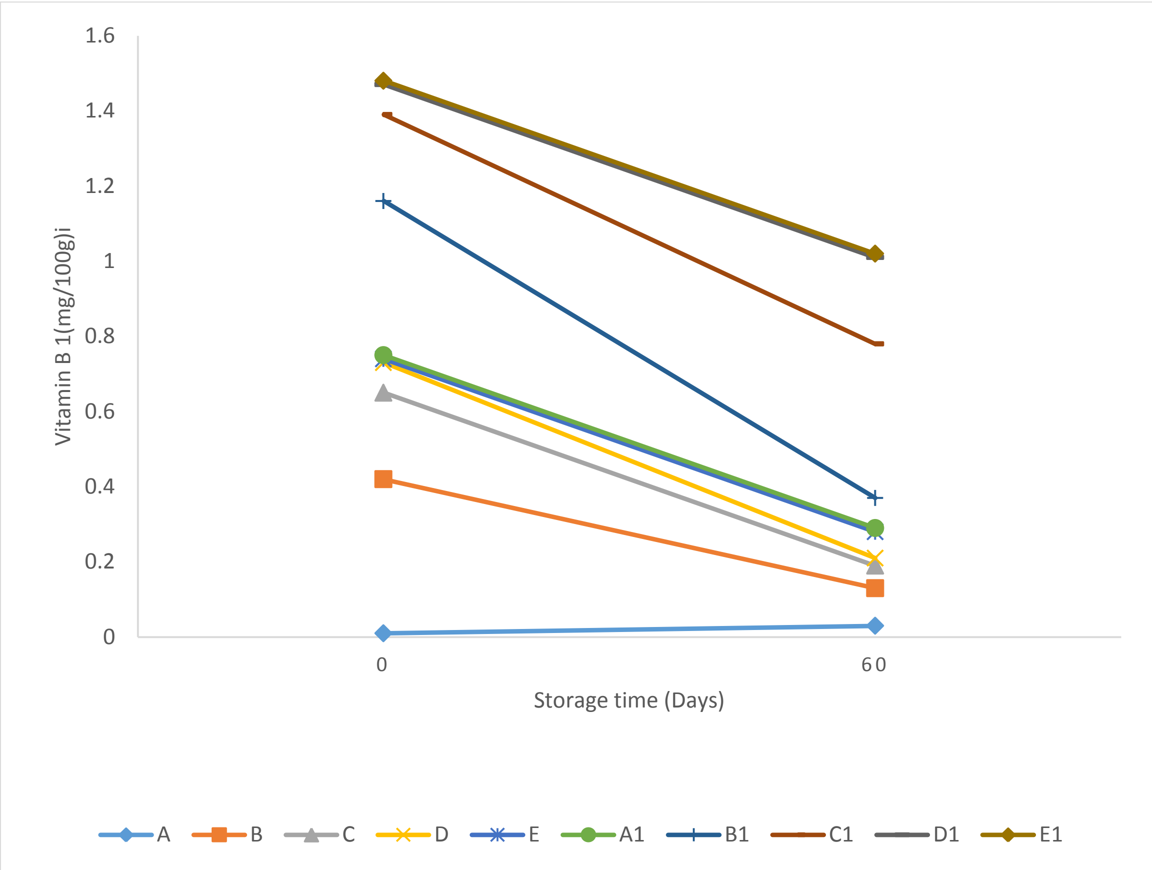

Fig. 3. Changes in vitamin B_1 contents of cookies stored for 60 days

KEY: Values are means of triplicate determinations. Key A= 100 % Whole wheat flour cookie and stored under ambient conditions, B = 50 % Whole wheat+20 % Sweet potato + 30 % toasted Mucuna flour cookies and stored under ambient conditions; C= 50 %Whole wheat+30% Sweet potato + 20 % toasted Mucuna flour cookies and stored under ambient conditions, D= 50 %Whole wheat+20 % Sweet potato + 30 % boiled Mucuna flour cookies and stored under ambient conditions; E = 50 % Whole wheat+30 % Sweet potato + 20 % boiled Mucuna flour cookies and stored under ambient conditions; A_1= 100 %Whole wheat flour and stored under refrigerated conditions; B_1 = 50%Whole wheat+20% Sweet potato + 30% toasted Mucuna flour cookies and stored under refrigerated conditions; C_1= 50 %Whole wheat+30% Sweet potato + 20 % toasted Mucuna flour cookies and stored under refrigerated conditions, D_1= 50 % Whole wheat+20 % Sweet potato + 30 % boiled Mucuna flour cookies: and stored under refrigerated conditions; E_1 =50 % Whole wheat+30 % Sweet potato + 20 % boiled Mucuna flour cookies and stored under refrigerated conditions

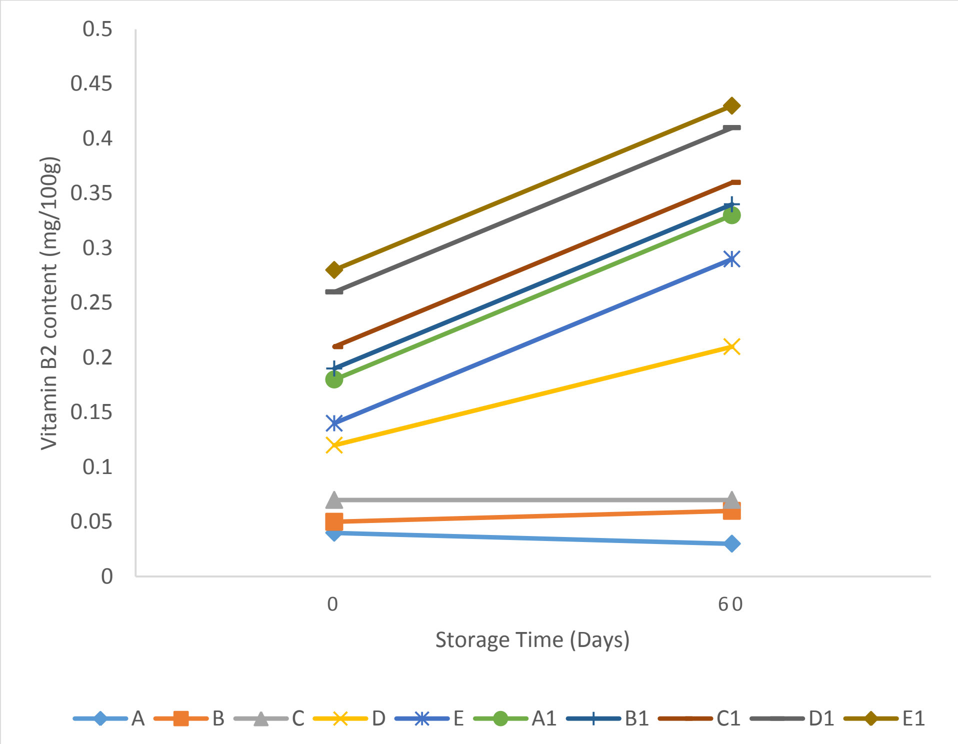

Fig. 4. Changes in vitamin B_2 contents of cookies stored for 60 days

Keys: Values are means of triplicate determinations. A=cookies made from100%Whole wheat flour and stored under ambient conditions B = COOKIE made from 50 % Whole wheat+20 % Sweet potato flour + 30% toasted Mucuna flour and stored under ambient conditions C= COOKIE made from50 % Whole wheat+30% Sweet potato flour + 20% toasted Mucuna flour and stored under ambient conditions, D= COOKIE made from 50%Whole wheat+20 % Sweet potato flour + 30 % boiled Mucuna flour: and stored under ambient conditions E =COOKIE made from 50 %Whole wheat+30 % Sweet potato flour + 20 % boiled Mucuna flour and stored under ambient conditions, A_1=COOKIE made from100 % Whole wheat flour and stored under refrigerated conditions B_1 = COOKIE made from 50 % Whole wheat+20 % Sweet potato flour + 30 % toasted Mucuna flour and stored under refrigerated conditions C_1= COOKIE made from 50 %Whole wheat+30 % Sweet potato flour + 20% toasted Mucuna flour and stored under refrigerated conditions, D_1= COOKIE made from 50%Whole wheat+20 % Sweet potato flour + 30 % boiled Mucuna flour: and stored under refrigerated conditions E_1 =COOKIE made from 50 % Whole wheat+30 % Sweet potato flour + 20 % boiled Mucuna flour and stored under refrigerated conditions

3.2.3 Effect of storage conditions on physical properties of cookie before and after storage

The physical properties of cookies before and after storage are presented in Tables 2.a and 2.b. There was a general increase in the diameter of the cookies during the storage. The diameter of the cookies before storage ranged from 3.75-5.20 cm. The diameter of the cookies after 60 days of storage under ambient conditions of (28±2 ^{O}C) increased from 4.80-5.20 cm while for refrigerated samples it increased from 4.45-5.20 cm. The increased trend was significant (p≤0.05) among the samples except for sample W50 S30 TM20 which did not vary before and after storage. The increase could be due to the absorption of moisture from the storage environment. The observation was in line with the report of Hussein et al. [24]. The thickness values before storage ranged from 0.55 – 0.85 cm while the values obtained after storage ranged from 0.45 - 0.75 cm. There was a significant (p≤0.05) reduction in the thickness of cookies after storage. A similar trend was observed in an earlier study by Tahira et al. [25]. The spread ratio values before storage ranged from 5.54 – 9.27 but increased significantly from 5.54 – 11.35 after storage. Comparing the two storage conditions there were no significant differences between spread ratio values obtained after refrigerated and ambient storage respectively. The average breaking strength ranged from 1.05 – 6.59 N before storage and increased from 1.05 – 9.99 N after storage. The increase was significant (P≤0.05) in all the samples except for samples W50 S30 TM20 and W50 S20 TM30 which recorded a significant drop in breaking strength. The findings of this work were in line with the report of Tyagi et al. [26] who observed that breaking strength increased with the substitution of wheat flour with mustard seed flour.

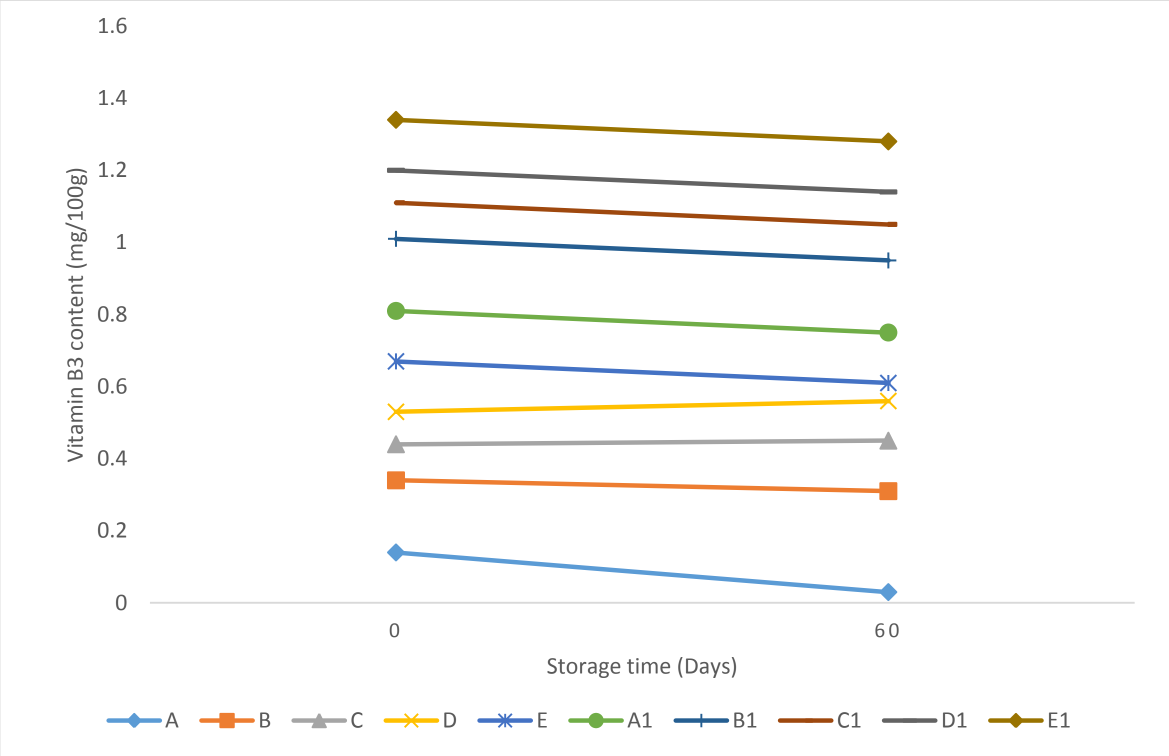

Fig. 5. Changes in vitamin B_3 contents of cookies stored for 60 days

Values are means of triplicate determinations. Key A= 100 % Whole wheat flour cookie and stored under ambient conditions, B = 50 % Whole wheat+20 % Sweet potato + 30 % toasted Mucuna flour cookies and stored under ambient conditions; C= 50 %Whole wheat+30% Sweet potato + 20 % toasted Mucuna flour cookies and stored under ambient conditions, D= 50 %Whole wheat+20 % Sweet potato + 30 % boiled Mucuna flour cookies and stored under ambient conditions; E = 50 % Whole wheat+30 % Sweet potato + 20 % boiled Mucuna flour cookies and stored under ambient conditions; A_1= 100 %Whole wheat flour and stored under refrigerated conditions; B_1 = 50%Whole wheat+20% Sweet potato + 30% toasted Mucuna flour cookies and stored under refrigerated conditions; C_1= 50 %Whole wheat+30% Sweet potato + 20 % toasted Mucuna flour cookies and stored under refrigerated conditions, D_1= 50 % Whole wheat+20 % Sweet potato + 30 % boiled Mucuna flour cookies: and stored under refrigerated conditions; E_1 =50 % Whole wheat+30 % Sweet potato + 20 % boiled Mucuna flour cookies and stored under refrigerated conditions

Table 2a. Physical properties of cookie before storage

Sample	Diameter	Thickness	Spread ratio	Breaking strength
$W_{50}S_{30}BM_{20}$	4.70 ±0.14^b	0.85±0.07^a	5.54±0.29^b	1.06 ±14.14^b
$W_{50}S_{20}BM_{30}$	4.65 ±0.07^b	0.80 ±0.14^c	5.89 ±0.95^b	1.05 ±7.07^b
$W_{50}S_{30}TM_{20}$	5.20 ±0.14^a	0.55 ±0.07^b	9.27 ±0.32^a	6.51 ±0.41^c
$W_{50}S_{20}TM_{30}$	3.75 ±0.21^c	0.55 ±0.21^b	7.29 ±2.43^b	6.49 ±0.71^c
W100	4.85 ±0.07^b	0.65 ±0.07^b	7.50 ±0.04^b	1.20 ±1.41^a

Means ± standard deviation of triplicate determinations. Means with different superscripts along the same column are significantly different (p≤0.05). key: Where CHO=Carbohydrate: $W_{50}S_{30}BM_{20}$=50% Whole wheat+30% Sweet potato flour + 20 % boiled Mucuna flour, $W_{50}S_{20}BM_{30}$= 50 % Whole wheat+20 % Sweet potato flour + 30 % boiled Mucuna flour,$W_{50}S_{30}TM_{20}$= 50 %Whole wheat+30 % Sweet potato flour + 20% toasted Mucuna flour,$W_{50}S_{20}TM_{30}$= 50 % Whole wheat+20 % Sweet potato flour + 30 % toasted Mucuna flour,W_{100}= 100% Whole wheat flour

Table 2b. Physical properties of the cookie after 60 days storage

Sample code	Diameter		Thickness		Spread ratio		Breaking strength	
	Ambient	Refrigerated	Ambient	Refrigerated	Ambient	Refrigerated	Ambient	Refrigerated
$W_{50}S_{30}BM_{20}$	5.20±0.28[a]	5.20 ±0.28[a]	0.75 ±0.07[a]	0.70 ±0.14[a]	6.98 ±1.03[c]	7.63 ±1.94[c]	6.01 ±1.41[d]	6.99 ±2.12[c]
$W_{50}S_{20}BM_{30}$	5.00±0.14[a]	5.15 ±0.3[a]	0.70 ±0.1[a]	0.60 ±0.00[a]	7.32 ±1.68[c]	8.59 ±0.59[c]	9.99 ±0.71[a]	6.03±3.54[d]
$W_{50}S_{30}TM_{20}$	5.05±0.07[a]	5.15 ±0.35[a]	0.45 ±0.07[a]	0.60 ±0.14[a]	11.35±1.63[a]	8.90 ±2.69[c]	1.29 ±3.5[e]	6.02±2.12[d]
$W_{50}S_{20}TM_{30}$	5.00±0.14[a]	4.85 ±0.07[a]	0.45 ±0.07[a]	0.65 ±0.07[a]	6.39 ±0.01[c]	7.52±0.93[c]	1.20±1.41[c]	9,99±1.41[a]
W100	4.80±0.00[a]	4.45 ±0.21[a]	0.45 ±0.07[a]	0.65 ±0.07[a]	10.80±1.69[b]	7.34±0.47[c]	5.98±2.83[d]	8.99±0.71[b]

Means ± standard deviation of triplicate determinations. Means with different superscripts along the same column are significantly different (p≤0.05). key: Where CHO=Carbohydrate: $W_{50}S_{30}BM_{20=}$50%Whole wheat+30% Sweet potato flour + 20% boiled Mucuna flour, $W_{50}S_{20}BM_{30=}$ 50%Whole wheat+20% Sweet potato flour + 30% boiled Mucuna flour,$W_{50}S_{30}TM_{20=}$ 50%Whole wheat+30% Sweet potato flour + 20% toasted Mucuna flour,$W_{50}S_{20}TM_{30}$= 50%Whole wheat+20% Sweet potato flour + 30% toasted Mucuna flour,W_{100}= 100%Whole wheat flour

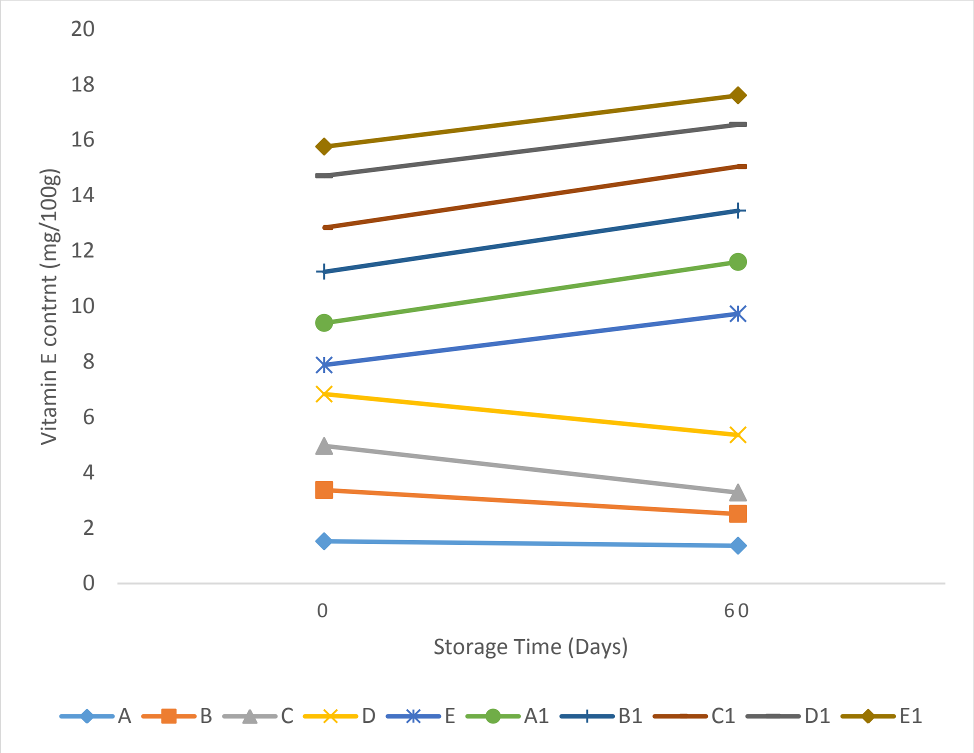

Fig. 6. Changes in vitamin E contents of cookies stored for 60 days

KEY: Values are means of triplicate determinations. Key A= 100 % Whole wheat flour cookie and stored under ambient conditions, B = 50 % Whole wheat+20 % Sweet potato + 30 % toasted Mucuna flour cookies and stored under ambient conditions; C= 50 %Whole wheat+30% Sweet potato + 20 % toasted Mucuna flour cookies and stored under ambient conditions, D= 50 %Whole wheat+20 % Sweet potato + 30 % boiled Mucuna flour cookies and stored under ambient conditions; E = 50 % Whole wheat+30 % Sweet potato + 20 % boiled Mucuna flour cookies and stored under ambient conditions; A_1= 100 %Whole wheat flour and stored under refrigerated conditions; B_1 = 50%Whole wheat+20% Sweet potato + 30% toasted Mucuna flour cookies and stored under refrigerated conditions; C_1= 50 %Whole wheat+30% Sweet potato + 20 % toasted Mucuna flour cookies and stored under refrigerated conditions, D_1= 50 % Whole wheat+20 % Sweet potato + 30 % boiled Mucuna flour cookies: and stored under refrigerated conditions; E_1 =50 % Whole wheat+30 % Sweet potato + 20 % boiled Mucuna flour cookies and stored under refrigerated conditions

4. CONCLUSION

Cookies made from wheat-sweet potato–mucuna composite flour resulted in an increase in protein, fiber, and other nutrients. The study showed that wheat, sweet potato, and mucuna are suitable for cookie production and different storage conditions influenced the spoilage of cookies. The FFA and peroxide values of samples W50 S30 BM20 and W50 S20 BM30 were within acceptable limit under refrigerated condition indicating that boiling treatment is better preferred than toasting. Cookies from toasted mucuna based composite flour deteriorated in quality as the storage advanced to sixty days. Vitamin E was not affected by the storage of cookies at refrigerated temperatures. Therefore, cookies stored in refrigerated conditions have higher shelf life than those stored at ambient temperature, indicating that refrigerated storage is a more suitable storage condition than ambient storage.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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