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Evaluation of Storage Stability of Cookies made from Breadfruit Flour

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Abstract—Cookies are consumed as a snack, ready-to-eat and convenient food. The utilization of composite flour in the development of cookies is replacing wheat flour thereby enhancing the quality of the product. But, the quality assessment of cookies made with composite flour is greatly influenced by storage conditions. Therefore, the present research was conducted to evaluate the storage stability of wheat-breadfruit incorporated cookies. Cookies were prepared from wheat flour and breadfruit flour in different combinations. Based on the nutritional and sensory properties of freshly prepared cookies, the three best treatments were selected along with the control for the shelf-life evaluation and packed in aluminium laminated foil and stored under the conditions of $30 \pm 1°C$ temperature and 75-80% RH. Quality evaluation was done at two weeks intervals for 12 weeks of the storage period. Among the treatments, cookies prepared from 40% breadfruit flour contained 4.97% of moisture, 2.62% of ash, 9.46% of protein, 1.51% of fibre and 16.46% of fat content after 12 weeks. According to the sensory analysis, there were significant differences ($p<0.05$) among the treatments in terms of colour, taste, texture, aroma and overall acceptability. Microbial counts were within the acceptable range up to the entire storage period. Therefore, based on the nutritional, organoleptic and microbial qualities, the cookies produced with 40% of breadfruit flour was the best treatment compared to other combinations at the end of 12 weeks storage period.

Keywords—Breadfruit flour, composite cookies, quality, storage, wheat flour

I. Introduction

A cookie is a traditional wheat flour-based food product that is made from unpalatable dough and turned into a delicious snack using heat in the oven (Ikuomola *et al*., 2017). It is a component of bakery items that are widely enjoyed by people of all ages all around the world (Sengev *et al*., 2015). Cookies are available, accessible, and affordable snacks that incorporate important digestive and nutritional aspects (Adeyeye and Akingbala, 2015). The principal ingredient of the cookie is wheat flour. Therefore, the importing of wheat might lead to an economic drain, higher bakery product costs, and a threat to food security. There is a need to establish a strategic plan for the utilization of low-cost local resources in the manufacture of cookies (Abioye *et al*., 2018).

Research has shown that non-wheat-based composite flour may be used to make cookies with good nutritional and sensory qualities (Taiwo *et al*., 2017). Therefore, the fortification of cookies has progressed in recent years to increase their nutritional and functional qualities (Awolu *et al*., 2017). Composite flour will assist to prevent massive post-harvest losses in bakery products. It will also result in higher output owing to the market, therefore increasing the usage of the crop (Olaoye and Onilude, 2008).

Breadfruit (Artocarpus altilis) is the main crop of the South Pacific (Ragone and Raynor, 2009) but is nowadays extensively grown across the tropics. The plant is well-adapted to a variety of tropical temperatures and grows in the humid tropics, where many other basic crops, particularly cereals, fail to grow (Ragone, 2011). Almost all of Africa, South and Southeast Asia, Latin America and the Caribbean, and Oceania are all ideal locations to grow breadfruit. These areas consist of a higher number of undernourished populations (FAO, 2012). By growing breadfruit plants in these areas we can decrease food insecurity. Jones *et al*. (2013) highlighted that breadfruit can decrease food insecurity in developing countries. It is a multifunctional agroforestry tree with a wide distribution and that is mainly used for its nutritious, starchy fruit that is high in carbohydrates, calcium and phosphorus, minerals, and vitamins (Famurewa *et al*., 2015; Pradhan *et al*., 2013; Ragone and Cavaletto, 2006). However, the breadfruit is healthy, inexpensive, and available throughout the season, the usage of breadfruit is limited in the food industry (Omobuwajo, 2003). According to the Recommended Dietary Allowances, Breadfruit (1,000 calorie serving) can fulfil over 100% of carbohydrate and fibre requirements, over 50% of K and Mg, over 20% of protein, vitamin C, Fe, Ca, and P, and over 8% of folic acid (Jones *et al*., 2011; Jones *et al*., 2013). Some varieties are also high in the carotenoid

(Englberger *et al*., 2003; Meilleur *et al*., 2004; Ragone and Cavaletto, 2006).

Because of their limited shelf life, the fruits should be consumed within five days of harvesting. The necessity to properly use all existing foods to alleviate poverty and hunger is currently gaining considerable interest in many developing countries (Famurewa *et al*., 2015). By limiting prolonged ripening and microbial development, reducing the moisture level of breadfruit helps to make a shelf-stable product (Amusa *et al*., 2002). Breadfruit may be utilized in a variety of ways once it has been dried to an appropriate level. To prevent the nutritional loss, the breadfruit slices are dried at 80°C for 4-6 hours. Dried fruit can be eaten or used as it is, or it can be ground into flour in a grinder. One of the most important factors restricting its availability is its poor storability since the fruits quickly deteriorate physiologically after harvesting.

Processing breadfruit into flour, a more stable intermediate product, is one approach to reduce post-harvest losses and enhance usage (Ragone and Cavaletto, 2006). There is a need to produce a suitable wheat replacement made from locally grown crops that is nutritionally equivalent or superior and has appropriate quantities of dietary fibre. Food and Agricultural Organization (FAO/WHO, 1994) have identified the necessity for the development and utilization of low-cost local resources in the development of popular goods like cookies. Cookies with high sensory and nutritional qualities were made with non-wheat-based composite flour (Okpala and Okoli, 2011). Normally, cookies have a longer shelf life with lower moisture content. But, there is a great impact on the quality characteristics of composite flour due to storage conditions. Therefore, this research study was conducted to evaluate the storage stability and physicochemical parameters of wheat-breadfruit incorporated cookies during 12 weeks of storage period at 30±1°C of temperature and 75-80% relative humidity.

II. MATERIALS AND METHODS

A. Materials

The research study was carried out at the Department of Agricultural Chemistry, Faculty of Agriculture, Eastern University, Sri Lanka. The quality breadfruits were purchased locally from the home garden of a villager from Vantharumoolai, Batticaloa. Other major ingredients such as wheat flour, sugar, baking powder, salt, margarine and vanilla essence were purchased from the supermarket of Batticaloa. All the chemicals used in the analysis were of AR grade obtained from the Department of Agricultural Chemistry.

B. Preparation of Breadfruit Flour

The flow chart for the preparation of breadfruit flour is shown in Figure 1.

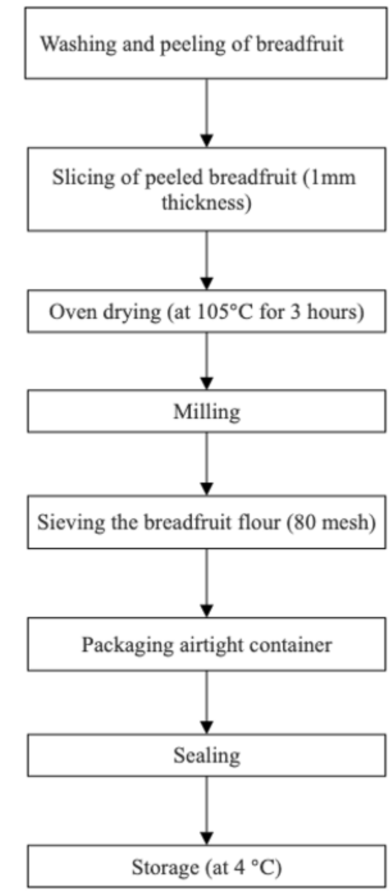

Figure 1: Flow Chart for the Preparation of Breadfruit Flour

C. Development of Wheat-Breadfruit Flour Composite Cookies

Cookies were developed using the method described by Chioma and Donald (2018) with some modifications. Six composite flour mixtures were obtained by blending wheat flour and breadfruit flour in the ratio of 100:0 (T_1), 80:20 (T_2), 60:40 (T_3), 40:60 (T_4), 20:80 (T_5) and 0:100 (T_6). The 50g of sugar and 50g of margarine were mixed at medium speed using a beater until getting fluffy cream texture. The composite flour, baking powder, vanilla essence and salt were added to the fluffy cream. Each sample was mixed until a uniform smooth dough is obtained. This was then rolled to a sheet of about 5 mm thickness on a board using a rolling pin. Cookie cutters were used to cut the sheet into desired shapes and sizes which were subsequently baked in an oven at about 200°C for 10 min, allowed to cool, packed and stored at ambient conditions.

D. Evaluation of Storage Stability of Wheat-Breadfruit Flour Composite Cookies

The most preferred wheat-breadfruit composite cookies, such as T_2, T_3, and T_4, as well as control, were chosen for further storage study based on a nutritional and sensory assessment of freshly prepared composite cookies. Cookies were packaged in aluminium laminated foil, which is a common commercial packaging material. For 12 weeks, cookies packs were kept under the conditions of 30°C temperature and 75-80% of RH. Up to 12 weeks, the quality parameters were evaluated once every two weeks. Wheat-breadfruit flour blend cookies were analyzed for moisture, ash, protein, fat and fibre according to AOAC (2000) methods. The difference method was used to calculate the nitrogen-free extract - NFE (Boye *et al*., 2010). The moisture content of the food product is determined by using the oven (Model: Sanyo Japan) at 100-105°C for overnight. Then the loss of weight of food products is mainly moisture content. The ash content of the food sample is determined by using a muffle furnace (Model: STXMF112) at 450°C until all the carbon has been burnt. The fat is extracted from the moisture free material with petroleum ether of boiling point 40-60°C for 3- 4 hours using a soxhlet extractor (Model: BST/SXW-6). The residue after evaporation is ether extract content.

The protein content is calculated from the nitrogen content of the food, determined by using the Kjeldahl digester (Model: MBC-6/N). When the food sample is digested with con. Sulphuric acid where the organic form of nitrogen is converted into ammonium sulphate. The digested material containing ammonium sulphate is distilled with an excess of alkali and the ammonium liberated is absorbed in a known excess of standard acid using methyl red as an indicator. The unreacted acid is then determined by back titration with the standard alkali. The nitrogen content in the sample (N) multiplied by the factor 6.25 gives the protein content. The estimation of fibre is based on treating the moisture and fat-free material with 1.25% diluted acid then with 1.25% alkali, thus imitating the gastric and intestinal action in the process of digestion. The material left undissolved is considered as fibre content.

The sensory evaluation was done by a panel consisting of 30 trained members. The cookies were tested for different sensory quality characteristics such as colour, taste, texture, aroma and overall acceptability with the use of a seven-point hedonic scale.

E. *Microbial Analysis of Wheat-Breadfruit Flour Composite Cookies*

Nutrient Agar was used to assessing the total plate count of cookies. The dilutions were produced up to 10^{-4}. With the aid of laminar airflow, the entire procedure was carried out in a completely sterile environment. Incubation was done for 48 hours at 37°C, with results expressed in CFU/g. The total plate count of cookies was evaluated during a period of 1, 2 and 3 months (Chandru *et al*. 2010).

F. *Statistical Analysis*

The experiment was carried out in a complete randomized design and data related to nutritional and sensory evaluation during storage were examined by Analysis of Variance (ANOVA) at a 5% of the significance level. The comparison of means of the sensory evaluation was done using Tukey's studentized range test and for nutritional analysis using Duncan's Multiple Range Test through Statistical Analysis System (SAS) software.

III. Results & Discussion

A. *The Moisture, Protein, Fat and NFE Content of Composite Cookies at the Initial Stage*

Table 1 shows the moisture, protein, fat and NFE content of composite flour cookies during the initial stage.

The most desired wheat-breadfruit cookies were chosen (T_1 - control T_2, T_3 and T_4) to evaluate the storage stability based on the nutritional (Table 1) and sensory evaluation of freshly produced wheat-breadfruit cookies. These cookies were packaged in aluminium laminated foil and kept under the conditions of 30 ± 1°C temperature and 75-80% RH.

B. *Proximate Composition of Wheat-Breadfruit Flour Composite Cookies during Storage*

(i) *Moisture Content*

Moisture content is a good predictor of storage period stability; higher moisture level encourages microbiological contamination and chemical reactions, which can lower food quality and reliability. A moisture level of less than 14% is suggested for long-term preservation, indicating a good capability during storage (Adeleke and Odedeji, 2010, Ogunlakin *et al*., 2012).

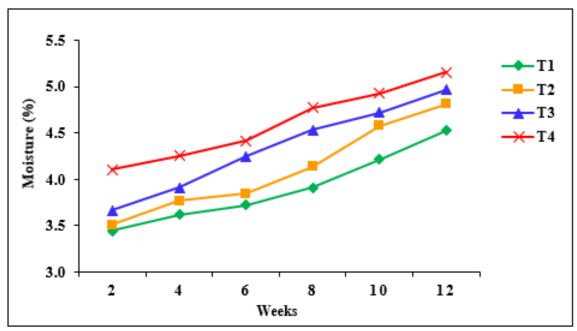

Figure 2: Moisture Content of Composite Flour Cookies during Storage
(T_1: 100% WF; T_2: 80% WF 20% BF; T_3: 60% WF 40% BF; T_4: 40% WF 60% BF)

Figure 3 illustrates the fluctuations in moisture content of the cookies throughout storage. Moisture content increased significantly ($p<0.05$) during the period of storage, according to DMRT. T_1 which is 100% wheat flour added cookies has a slow rate of an increasing trend than other treatments. In all treatments, there was no significant difference ($p<0.05$) from the 2^{nd} to 4^{th} weeks of the storage period. Similar trends were observed in Akbar and Ayub (2018) and Waheed *et al*. (2010). Because cookies are very hygroscopic, they absorb moisture from the air during storage.

(ii) *Ash Content*

High-temperature biochemical interactions between simple sugars, amino acids, and/or proteins can cause mineral loss by producing covalently attached minerals (Passos *et al*., 2013). Because the product of this process is more resistant to hydrolysis, their mineral-binding capabilities can be preserved. Because of the

Table I: The Moisture, Protein, Fat and NFE Content of Cookies

Treatment	Moisture	Protein	Fat	NFE
T_1	3.40 ± 0.04^f	12.48 ± 0.03^a	20.50 ± 0.04^a	59.92 ± 0.05^e
T_2	3.47 ± 0.04^e	11.49 ± 0.02^b	19.28 ± 0.08^b	61.51 ± 0.04^d
T_3	3.59 ± 0.02^d	10.94 ± 0.05^c	18.52 ± 0.07^c	61.96 ± 0.12^d
T_4	3.87 ± 0.05^c	10.76 ± 0.04^{bc}	17.12 ± 0.06^d	62.75 ± 0.28^c
T_5	4.24 ± 0.07^b	9.54 ± 0.04^d	15.62 ± 0.05^e	64.13 ± 0.45^b
T_6	4.40 ± 0.04^a	9.12 ± 0.07^e	14.58 ± 0.04^f	65.12 ± 0.32^a

The values are means of triplicates $\pm$ standard error. Values with the different superscripts in lower case letters in the same column are significantly different at p<0.05. (T_1: 100% WF; T_2: 80% WF 20% BF; T_3: 60% WF 40% BF; T_4: 40% WF 60% BF; T_5: 20% WF 80% BF; T_6: 100% BF).

hygroscopic nature of the product, some of the water-soluble minerals dissolve in water, resulting in mineral loss during manufacturing and storage.

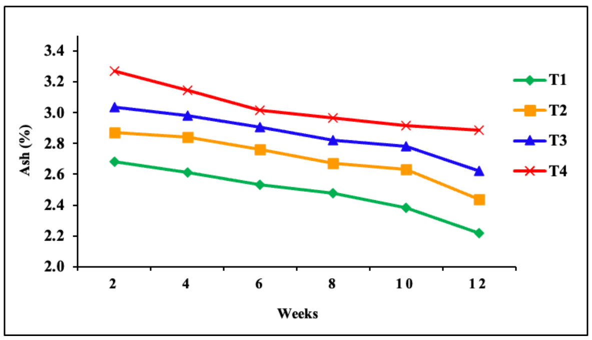

Figure 3: Ash Content of Composite Flour Cookies during Storage
(T_1: 100% WF; T_2: 80% WF 20% BF; T_3: 60% WF 40% BF; T_4: 40% WF 60% BF)

Figure 4 shows the fluctuations in ash content of cookies during storage. According to DMRT, ash content decreased significantly (p<0.05) throughout the storage period. Ash content of T_1, T_2 and T_3 treatments has very little changes from 2nd to 4th week than T_4 (100% Breadfruit flour). Even though T_4 (100%) breadfruit flour added cookies) has a very slow rate of decreasing trend from the 6th week until the end of the study period. Similar trends were observed in Akbar and Ayub (2018) and Waheed *et al*. (2010).

(iii) *Protein Content*

Figure 5 illustrates the changes in protein content of cookies throughout storage. According to the DMRT, the protein content of wheat-breadfruit flour cookies decreased significantly (p<0.05) through the storage period. T_1, T_2 and T_3 have every slow rate of decreasing trend than T_4. There were no significant differences (p>0.05) in all treatments throughout the study period. This can happen as a result of the Maillard reaction, and it's a key source of quality deterioration in many foods. The Maillard reaction degrades protein nutritional value while also reducing the solubility and stability of proteins (Fennema, 1996). Another reason for the decreasing protein trend might be the cookies' high moisture content. Bilgicli *et al*. (2007) conducted a similar study and found that the protein levels were decreased. During processing and storage, certain flour proteins in wheat flour and breadfruit flour can undergo

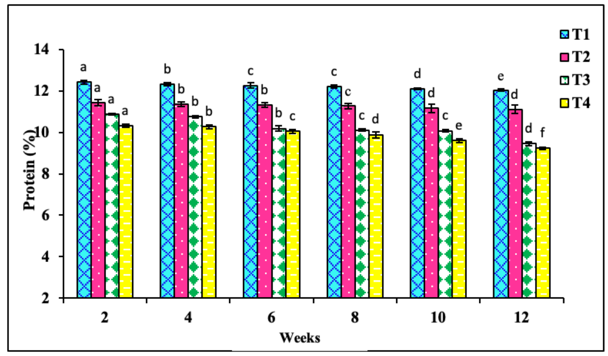

Figure 4: Protein Content of Composite Flour Cookies during Storage
The values are means of triplicates. The vertical bars indicate the standard error.(T_1: 100% WF; T_2: 80% WF 20% BF; T_3: 60% WF 40% BF; T_4: 40% WF 60% BF)

modifications such as protein cross-linking, protein-carbohydrate interactions, and protein denaturing. This non-enzymatic process might cause food to spoil and shorten its shelf life (Singh, 2000).

(iv) *Fibre Content*

Figure 6 shows the changes in fibre content of cookies throughout storage. As shown in Figure 6, the fibre content of all treatments varies relatively little during storage. Fibre content decreased significantly (p<0.05) in all treatments throughout the storage period, according to DMRT. Even though, T_3 has a very slow rate of decreasing trend than all other treatments. There was no significant difference (p>0.05) in fibre content of T_3 from the 6th week until the end of the study period.

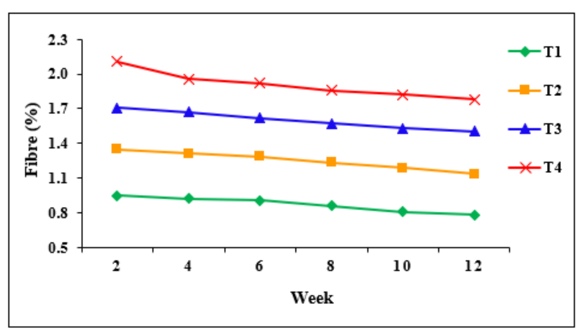

Figure 5: Fibre Content of Composite Flour Cookies during Storage
(T_1: 100% WF; T_2: 80% WF 20% BF; T_3: 60% WF 40% BF; T_4: 40% WF 60% BF)

The fibre content of the cookies analyzed was similar to that of Hussein *et al*. (2011) and Waheed *et al*. (2010).

Heat-treatment processes can have a variety of effects on dietary fibre. In breadfruit and wheat flour, higher temperatures cause weak bonds between polysaccharide chains to dissolve. The formation of Maillard reaction products and resistant starch fractions which add to the lignin concentration are all reactions that might impact the dietary fibre content and characteristics during processing.

(v) *Fat Content*

Figure 7 shows that the fat content decreased significantly ($p<0.05$) over the storage period. This trend was similar to the results of Pasha *et al*. (2002), who observed that the fat content of bakery goods decreased as the moisture level increased. T_1 and T_2 which are control and 20% breadfruit flour added cookies have a very slow rate of decreasing trend in fat than other treatments. This may be due to the low initial moisture content in the biscuits. There were no significant differences ($p>0.05$) in all treatments through the study period.

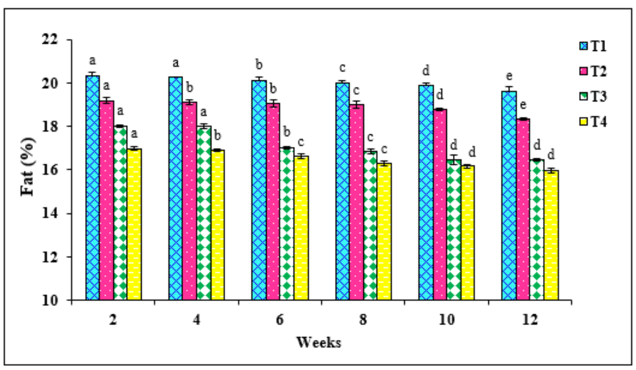

Figure 6: Fat Content of Composite Flour Cookies during Storage
The values are means of triplicates. The vertical bars indicate the standard error. (T_1: 100% WF; T_2: 80% WF 20% BF; T_3: 60% WF 40% BF; T_4: 40% WF 60% BF)

Due to the inclusion of air, fat can aid in the leavening of a product. Fat or oil shortening contributes to the tenderization of baked goods by inhibiting gluten formation and starch gelatinization. One of the primary causes of food deterioration is lipid oxidation. Unsaturated fatty acids undergo autoxidation due to the ambient oxygen and moisture absorption during storage resulted in a reduction in fat content (Brooker, 1998). By preventing gluten production and starch gelatinization, fat and oil help in the texture of bakery goods (Patrignani *et al*., 2014). Fat enhances the flavour and mouth feel of foods, and it is an important ingredient in food composition, particularly in cookies (Iwe and Egwuekwe, 2010).

(vi) *Nitrogen Free Extract (NFE)*

Table 2 shows the changes in NFE content of cookies throughout storage. According to the DMRT, the NFE content of wheat-breadfruit flour cookies increased significantly ($p<0.05$) through the storage period. This trend was similar to the findings of Akbar and Ayub (2018). It might be due to the decreasing trend in the ash, protein, fat and fibre content and increasing trend in the moisture content of the composite flour cookies throughout the storage period. T1 which is 100% wheat flour added cookie and T_2 have a slow rate of increasing trend than other treatments. In all treatments, there were significant differences ($p<0.05$) of NFE content from the 2^{nd} to 12^{th} weeks of the storage period.

C. Sensory Evaluation of Wheat-Breadfruit Cookies after the Storage Period

Figure 8 represents the sensory scores of the wheat-breadfruit flour cookies after storage. According to the results obtained from sensory evaluation, there were significant ($p<0.05$) differences in organoleptic characteristics like colour, taste, texture, aroma, and overall acceptability between treatments. Based on the overall acceptability ratings, the cookie with 40% breadfruit flour added got the highest mean value. The organoleptic properties of cookies have altered slightly during storage. They reviewed data on cookie acceptability that matched the findings of Pasha *et al*. (2011), who discovered a slight decrease in the consumer acceptability of pulse-based cookies. This might be attributed to the Maillard reaction as well as the oxidation of fat. Due to the fat oxidation off flavours and taste will develop. Maillard reaction has an effect on sensory characteristics during food preservation (Fennema, 1996).

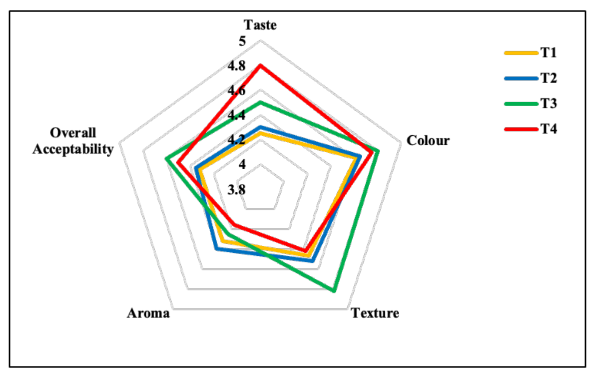

Figure 7: Sensory Properties of Cookies at the end of Storage
(T_1: 100% WF; T_2: 80% WF 20% BF; T_3: 60% WF 40% BF; T_4: 40% WF 60% BF)

D. Microbial Analysis of Wheat-Breadfruit Cookies during Storage

Total plate counts were used to assess microbiological quality to the level of general microbiological contamination. The total plate count of these cookies was in the range of 0×10^1 to 3.98×10^3 CFU/g during 12 weeks of storage. Most foods have microbial count limits that have been suggested to maintain them safe for eating (Ogunjobi and Ogunwolu, 2010). However, following processing, the product should be stored in proper packing materials capable of avoiding contamination and the consequent development of spoiling

Table II: NFE Content of Composite Flour Cookies during Storage

Weeks	T_1	T_2	T_3	T_4
2	60.17 ± 0.64^f	61.65 ± 0.65^c	62.68 ± 0.66^e	63.21 ± 0.65^f
4	60.27 ± 0.46^e	61.62 ± 0.57^d	62.68 ± 0.74^e	63.49 ± 0.85^e
6	60.45 ± 0.57^d	61.72 ± 0.85^b	64.0 ± 0.43^d	63.97 ± 0.48^d
8	60.53 ± 0.43^c	61.66 ± 0.56^c	64.12 ± 0.87^c	64.22 ± 0.65^c
10	60.61 ± 0.29^b	61.67 ± 0.75^c	64.43 ± 0.78^b	64.56 ± 0.45^b
12	60.80 ± 0.18^a	62.17 ± 0.45^a	64.98 ± 0.58^a	64.95 ± 0.78^a

The values are means of triplicates ± standard error. Values with the different superscripts in lower case letters in the same column are significantly different at p<0.05.
(T_1: 100% WF; T_2: 80% WF 20% BF; T_3: 60% WF 40% BF; T_4: 40% WF 60% BF)

bacteria. The safe amount of bacterial count for cookies, according to Banusha and Vasantharuba (2014), should be less than 1×10^4 CFU/g. Microbial analysis revealed that the overall plate count was within the acceptable limit, and the cookies produced were safe for consumption.

IV. CONCLUSION

The shelf-life evaluation showed that cookies containing 40% of breadfruit flour have the best storage stability and are highly suitable for consumption in terms of quality attributes without any significant changes observed after 12 weeks of storage under the conditions of 30±1°C temperature and 75-80% RH while comparing with other treatments. The composite of the breadfruit flours up to 40% with wheat flour in baking might decrease the demand for wheat imports while also increasing the nutritional and organoleptic properties of cookies. The findings of this study might be useful in the production of high-fibre, low-gluten, and low-fat cookies.

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