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ABSTRACT

Among cereal grains, wheat has high potential to produce gluten protein that imparts strength and elasticity to the dough that influences the texture of bakery products. Storage temperature has been shown to affect the quality attributes of wheat flour but few research studies have been conducted to evaluate the effect of storage conditions prevailing in Sri Lanka on wheat flour properties. Therefore, a study was conducted to evaluate the influence of storage temperature on the quality characteristics of wheat flour during short term storage. The freshly milled wheat flour samples from Prima Ceylon Private Ltd, Chinabay, Trincomalee were stored for 8 weeks at room temperature (35°C and the RH of 50-60%) and air conditioned temperature (27°C and the RH of 60-70%). The quality characteristics such as moisture, wet gluten, gluten index and ash content and biological characteristics of weevils count and total bacterial count of flour samples were evaluated at 2 weeks interval during the entire storage period. Moisture content decreased significantly ($p<0.05$) with the storage duration at two different storage temperatures. Visco-elastic properties such as wet gluten and gluten index of flour samples decreased during storage and more markedly affecting the flour quality at room temperature storage. Biological and microbiological characteristics were influenced by storage temperature since the water activity was the main factor influencing their survival. The storage temperatures significantly influence the quality parameters of wheat flour and play an important role in ageing process of the flour. Based on the results of this study, the quality characteristics of wheat flour were better preserved during storage at air conditioned temperature of 27°C with 60-70% RH compared to room temperature of 35°C with 5060% RH.

Key words: Gluten, quality evaluation, rheological property, storage temperature, wheat flour

INTRODUCTION

Wheat (*Triticum aestivum*) is grown more on land than any other food crop in the world. Wheat was a key factor enabling the emergence of city-based societies at the start of civilization because it was one of the first crops that could be easily cultivated on a large scale, and had the additional advantage of yielding a harvest that provides long-term storage of food (Delcour and Hoseney, 2010). Milling is the process separating germ from bran and grinding the germ to produce flour. Milling aims to separate the anatomical parts of the kernel to produce flour with minimal inclusion of bran particles. White flour is made from the endosperm only. Flour composition and functionality determine product quality. A total of 57% of processed wheat flour is used in the baking and confectionery industry, 16% is used for domestic consumption, 17% for dough, 12% for cookies and 2% for the production of drugs, glue and animal feeding (Chang and Ferrari, 2014).

Wheat flour is a dynamic product with both constituent and functional requirements. The uses of flour are many and varied. Wheat flour contains high amount of starches, which are known as polysaccharides. The kinds of flour used in cooking include all-purpose flour, self-rising flour, and cake flour including bleached flour. Constituents such as protein and ash generally dictate the end-use of flour. The higher the protein content the harder and stronger the flour, and the more it will produce crusty or chewy breads (Stone and Morell, 2009). The important quality parameters for wheat flour performance are moisture, wet gluten, gluten index, ash, weevils count and flour microbiology. These parameters are the indicators of milling performance and flour quality of the wheat flour. Wheat flour quality is directly related to the wheat gluten formed by mixing the flour with water and with the use of appropriate application of mechanical work to form a viscoelastic network, whose structure is the basis for bakery and pasta products.

Gluten is a plastic-elastic protein fraction of wheat flour responsible for physical dough properties. It has been generally accepted that any increase in total protein content of the flour results in an increase in gluten content. It is important to note that the quantity of protein or gluten is not a measure for gluten quality. Gluten quality is characterized by the degree of extensibility and elasticity (Hoseney *et al*., 1986). Technologists consider gluten as the functional part of dough which influences many product qualities. Although oat, rye, barley and triticale have gluten proteins in their nutritional composition, only wheat has sufficient amounts (8-20%) for the formation of a strong gluten network, which differentiates it from other cereals (Dendy and Dobraszczyk, 2009). The quantity and quality of gluten is among the main parameters to be investigated in order to determine the quality of the baked product. Therefore, in this study, efforts have been made to evaluate the changes occur in the parameters determining the quality of wheat under different storage temperatures.

MATERIALS AND METHODS

This study was carried out at the Prima Ceylon (Pvt.) Limited, Chinabay, Trincomalee.
This company is milling wheat grain into wheat flour and distributes throughout Sri
Lanka. Freshly milled wheat flour samples of 500g were placed in polypropylene bags of 20 x 10 cm and automatically vacuum packed using a sealing machine (Model: 400 T) in a way that no contaminants or insect infestations were allowed. The flour samples were stored for 8 weeks at room temperature of 35°C at the RH of 50-60% and at air conditioned temperature of 27°C at the RH of 60-70%.

3.4.5 Evaluation of Flour Quality Parameters

A. Physico-chemical analysis

1. Moisture Content

The wheat flour sample of 500 g was mixed thoroughly to get a uniform distribution of flour. The metal moisture cans were taken and weighed in an analytical balance (Mettler AE 200). Uniformly mixed 10g sample was taken in the moisture cans and the cans were placed in the oven at 130^{o}C for 1 hour. The dry weight was recorded after cooling the cans in the desiccator.

2. Wet Gluten Content (Glutomatic Method)

Test chambers were assembled with metal sieves between persplex tube and perforated stainless steel bottom. The sieve was moistened thoroughly to achieve a capillary water bridge which prevents the water loss. Sample of 10 g was taken in test chambers; 5 ml sodium chloride salt solution was pipetted into the test chamber, and gently shaken to spread the mixture evenly allowed to be washed in gluten machine for 5 minutes. After the washing the test chamber was lowered and the washed wet gluten was taken and then it was allowed for centrifugation for 1 minute. The centrifuged wet gluten was weighed and weight was converted to percentage multiplying by 10.

3. Gluten Index

Wheat flour samples of 10 g were taken in gluten test chambers and 15 ml sodium chloride salt solution was added. The contents were allowed to be washed in glutomatic machine for 5 minutes. After that, the washed wet gluten was taken and it was allowed for centrifugation. The wet gluten was taken from the centrifugation cups in a way that the portion remained inside the cup separately and the gluten which leaked outside the cup separately. Both portions were weighed and the gluten index was calculated.

4. Ash Content

Clean ash crucible was taken and their weights were recorded using a digital balance (Mettler AE 200). A flour sample of 5 g was taken in the crucible and the crucibles were placed in the electric muffle furnace at 600^{o}C for 6 hours. Later the crucibles were cooled in a desiccator and weighed to get the ash weight of the flour.

B. Biological Tests

1. Weevil test

The flour sample was subjected to sieving by 250 micrometer pore sized sieve. After that number of weevils present in the sieve was noted.

2. Total bacterial count test

Microorganisms present in the sample is enumerated by mixing the sample solution with a suitable agar and incubated at 35ºC for 48 hours to form visible separate colonies. Media for growing the bacteria is Potato Carrot Agar (PCA). The Petri dishes were arranged for each dilution of flour sample (10^{-1}, 10^{-2} and 10^{-3}). Sample of 1 ml from each dilution tubes was pipette out and inoculated in petri dishes according to serial 10-fold dilution. Then about 15 – 20 ml PCA media was poured into the petri dishes and they were rotated first clockwise then anti-clockwise. The culture was incubated under 35ºC for 2 days and the colonies were counted by placing the petri dishes in colony counter.

RESULTS AND DISCUSSION

3.4.6 Physico-chemical properties

The results of the physico-chemical parameters with regard to the moisture, gluten index and ash of wheat flour sample under different storage temperatures are presented in Table 1. Results of the moisture content (%) of the samples stored under room temperature and air conditioned for the period of 8 weeks showed that moisture content is simultaneously affected by both storage temperature and relative humidity.

Table 1: Influence of Storage Temperature on the Physico-chemical Parameters of Wheat Flour

Storage Duration (Weeks)	Moisture (%) R/T	A/T	Gluten Index R/T	A/T	Ash (g) R/T	A/T
0 (Fresh)	13.6^{b}	13.6^{b}	94.17^{b}	94.17_{ab}	0.508^{a}	0.508^{a}
2	12.8_{ab}	13.2^{a}	92.25^{ab}	93.79_{ab}	0.501^{a}	0.506^{a}
4	12.9_{ab}	13.2^{a}	92.07^{ab}	93.09^{a}	0.493^{a}	0.491^{a}
6	12.8^{ab}	13.1^{a}	91.07^{a}	92.97^{a}	0.524^{a}	0.500^{a}
8	12.2^{a}	13.0^{a}	90.01^{a}	92.19^{a}	0.517^{a}	0.510^{a}

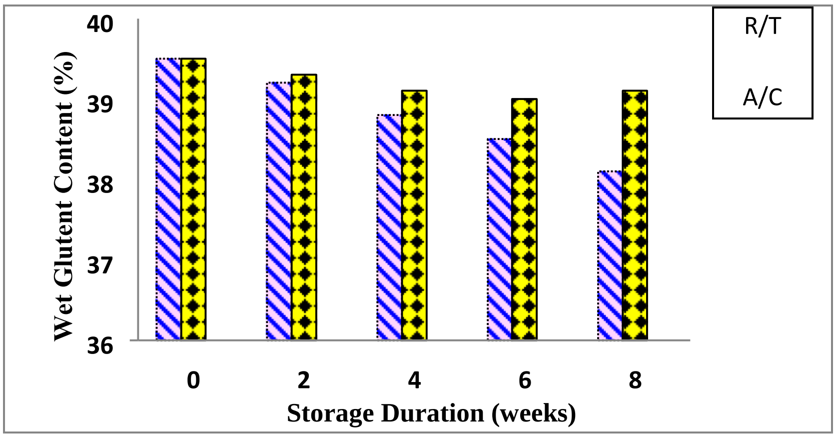
R/T - Room Temperature 35°C A/T - Air Conditioned Temperature 27°C Values are means of triplicates.

Treatment means in a column having common letter(s) are not significantly different by DMRT 5%.

The initial moisture content of the fresh milled flour was 13.6%. However, after 8 weeks the moisture content of these sample decreased significantly ($p<0.05$) to 12.2% under room temperature storage and 13.0% under air conditioned storage, respectively. The moisture losses were low during storage due to the low hygroscopic property of the wheat flour. Fellers and Bean (1977) reported that the moisture content of the wheat flour during storage should be 10-12% for the safe and long term storage.

Cereal chemists are aware that not only quantity but also quality of gluten protein is an important component in producing good quality products. Thus, determination of gluten content is required to assess the quality of the wheat flour. The gluten index of the fresh milled samples decreased from 94.17% to 90.01% at room temperature storage and 94.17% to 92.19% under air conditioned storage. Storage at room temperature and duration significantly ($p<0.05$) affected the gluten index of the wheat flour. Under refrigerated storage conditions, the gluten index decreased during storage however, the changes was not significant ($p>0.05$) from the initial value. Therefore, aging of flour caused the gluten index to show a steady decrease, thus the gluten quality remained unchanged during refrigerated storage of flour for 8 weeks.

Among the wheat flour quality parameters, gluten strength is one of the important characteristics determining the industrial use of the flour for bread, cakes and pasta. As shown in the Figure 1, wet gluten content was affected by storage temperature and relative humidity.



3.4.7

R/T - Room Temperature (35°C)   A/C - Air Conditioned Temperature (27°C)

Values are means of triplicates.

3.4.8. Figure 1: Influence of Storage Temperature on Wet Gluten Content of Wheat Flour

The initial wet gluten content of the fresh milled samples was 39.5%. After 8 weeks of storage, the wet gluten content of the flour samples dropped to 38.1% under room temperature storage and 39.2% under air conditioned storage, respectively. Under refrigerated conditions, the wet gluten content decreased during storage however, the changes were not significantly different ($p>0.05$) from the initial gluten content of the wheat flour. Based on the values of the wet gluten, the quality of the wheat flour was not significantly affected during refrigerated storage of 8 weeks. Jennifer (2013) reported that high temperatures (>35°C) decrease the gluten quality as the gluten protein become less elastic and more brittle during storage at elevated temperatures for more than 2 weeks.

The initial value of ash content of the fresh milled samples was 0.508g and it was increased up to 0.517g under room temperature storage and 0.51g under air conditioned storage, respectively.

3.4.10 Biological quality parameters

The weevil counts and total bacterial count under different storage temperatures are presented in Table 2. According to the results, the weevils were not observed in samples even after 8 weeks of storage under both storage temperature conditions. However, it is recommended that storing flour samples under air conditioned storage with the temperature below 15ºC would give the best results and improve the shelf life of the wheat flour with acceptable quality.

Table 2: Influence of Storage Temperature on Biological Quality of Wheat Flour

Storage Duration	Weevil Count		Total Bacterial Count	
(Weeks)	R/T	A/C	R/T	A/C
0 (Fresh)	0	0	470	470
2	0	0	410	510
4	0	0	580	530
6	0	0	610	640
8	0	0	500	750

R/T - Room Temperature (35°C) A/C - Air Conditioned Temperature (27°C)

Values are means of triplicates.

The different storage temperatures influenced the bacterial count of flour samples differently. The initial bacterial count of flour was 470 at 13.6% moisture content. The results confirmed that both the storage temperature and storage time did not have a significant influence on the bacterial count of flour sample. The bacterial counts of sample were very low under both storage conditions from initially. Normally the bacterial population of the fresh milled sample should be in the range of 1000 to 100,000 per gram (Jennifer, 2013). But the bacterial populations of flour samples under two different storage were lower than 1000. This means that the microbial quality of the flour is good following 8 weeks storage.

CONCLUSIONS

The tested storage temperatures significantly influence the moisture contents of the wheat flour, however, the relative humidity played a major role compared to storage temperature on the moisture levels of the flour. Gluten index reduced in during storage at both temperatures and this was more pronounced in the flour stored at room temperature. The ash content was not significantly affected by the temperature and the storage duration.

There were no weevils observed in samples stored under both temperatures. Flour stored at room temperature showed low bacterial counts than air conditioned stored samples indicating the high microbial quality of the wheat flour samples. The storage temperatures significantly influence the quality parameters of wheat flour and play a significant role in ageing process of the flour. It is important to take preventive measures for maintaining the gluten content unchanged to safeguard the flour quality unaffected. Therefore, it could be recommended to store the wheat flour under air conditioned temperature of 27°C with 60-70% RH to maintain the flour quality characteristics at optimum level for better baking quality.

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Food and Cash Crop Diversity of Mid Country Homegardens with Special Reference to Nawalapitya, Sri Lanka

1. Abstract

Homegardens evolved through centuries around the dwellings having intimate associations with crops, trees and with or without livestock in tropical countries. Food and cash crops plays a dynamic role in family nutrition and household economy. Therefore, identification of food and cash crop diversity were done in 2016 at Aluthgama village, Nawalapitiya with the objective of classification of homegardens based on the food and cash crop diversity. Number of species was counted and categorized among 53 homegardens. The data was analyzed after calculation of *Shannon Weiner index* (H) and *Simpson index* (S). Evenness was calculated using both indices, and cluster analysis was performed using these indices.

Total number of crop species recorded were 171. The mean number of crop species per homegarden was 81±25. Fifty-three crop species belonged to the vegetable and allied crops category, 71 crop species to the fruit crop category, and 47 crop species to income generating and home utility crop category. Significantly different, two clusters of home gardens were identified which differed in their H and S values. The H values were 2.43 and 2.32, in Cluster 1and 2 respectively. Similarly, S values were 0.92 and 0.88, evenness based on H were 0.10 and 0.12, and based on S were 0.73 0.61 in Cluster 1 and 2 respectively, all of which differed significantly (P=0.0001) in the two clusters.

Classification of homegardens based on food and cash crop diversity will cater the identifying possibilities of improving homegardens towards a more diverse agroecosystem to

Homegarden clustering, sustaining agro-biodiversity, securing nutritional needs,

Keywords: diversity indices, food and cash crop diversity, home garden classification

2. **Introduction and research problem/issue**

Homegarden system in Sri Lanka is very well adapted to the island agro ecological and geographic conditions, thus, best compromise with its socio-economic, cultural and ecological needs (Pushpakumara*et al.*, 2012). Influence of household economic conditions, cultural and social factors, more concretely climatic and soil factors are some of the leading factors that affect plant diversity. Very little information exists regarding biodiversity which can be used as a valuable tool to classify homegarden systems in a particular location. Objectives of this study were to determine food and cash crop diversity, and then to classify the homegardens in the area (Aluthgama village, Nawalapitiya) based on the diversity of food and cash crops.

3. **Research Methodology**

This study was conducted in 2016 in the Aluthgama village, Nawalapitiya (longitude 7°03′N, latitude 80°32′E, altitude 600 m), Sri Lanka. A total number of 53 homegardens were randomly selected for the study.

Number of food and cash crop species having direct or indirect value as food and/ or income generating in each homegarden was counted, which were grouped into three main groups and sub groups as fruit crops (top layer >10 m, medium layer 5-10 m, bottom layer <5 m and vine fruits), vegetable and allied crops (vegetables, root/ tuber, leafy, condiments and other food/cereals), and income and home utility crops (food and timber value, pure timber, cash crops, miscellaneous and non timber or food). The data were analyzed after calculation of *Shannon Weiner index* (H), *Simpson index* (S) and evenness/dominance calculated using the two indices (Canadian Forest Products Ltd, 2003).

4. **Results and findings**

Amongst the selected 53 homegardens, the total number of crop species recorded was 171, and each homegarden composed of a minimum of 26 crop species. The mean number of crop

species per homegarden was 81±25. Of the recorded 171 crop species, 53 crop species belonged to the vegetable and allied crops category, 71 crop species belonged to fruit crop category, and 47 crop species belonged to income and home utility crops category. Of these, 20 crop species were found extensively in more than 90% of homegardens. Further, 17 fruit crop species, 07 vegetable and allied crop species, and 05 income and home utility crop species were found only very rarely, in less than 10% of the homegardens. According to the results of the cluster analysis two clusters of homegardens could be identified.

The mean index values of H, S and evenness were significantly different (P=0.0001) between the two clusters. i.e. H of Cluster 1: 2.43 and Cluster 2: 2.32, S of Cluster 1: 0.92 and Cluster 2: 0.88, evenness based on *Shannon Weiner Diversity* Index of Cluster 1: 0.10 and Cluster 2: 0.12, and based on Simpson's index of Cluster 1: 0.73 and Cluster 2: 0.61. In a study conducted on species richness and abundance in upland and lowland Mexican gardens revealed diversity indices H of 3.84 and 2.43 respectively. These data were comparable to those recorded in Costa Rica (3.55) and India (2.44) (Galluzzi, 2010). In a study in Bangladesh by Bardhan *et al.* (2012), H value of homegarden agro forestry was 3.50 and in Natural forest 2.99. The S and the H respectively exceeded 0.9 and 3.0 in Thailand (Lattirasuvan *et al.*, 2010). The homegardens in the studied area could be separated in to two clusters. Cluster 1 was superior in terms fruit crops, cash and home utility crops diversity compared to cluster 2, which could have implications on income and nutrition of the households.

Homegardens usually undergo a steady development process, since the composition and use of crops change according to the circumstances and needs of the homegarden owner. Although majority of the homegardens in the studied area well represented the Kandyan homegarden system, careful observation indicated many differences amongst the homegardens. Classification of homegardens for further studies may benefit further development and sustainable management of these homegardens while assuring the food and nutrition security of the households. Homegardens are internationally recognized as strategies for sustaining agro-biodiversity, while at local level, they contribute to securing nutritional needs, livelihoods and incomes. Raising public awareness of the significance of diversity in the agro-ecosystem will benefit not only the households but also whole world to mitigate current issues i.e. climate change, nutritious food scarcity and food production/ security for growing population especially in the developing countries having limited access to a balance diet and to overcome child malnutrition.

5. **Conclusions, implications and significance**

According to these findings, homegarden biodiversity in the studied area more or less similar to the homegarden in other countries, which represent tropical characteristics. Further, this study will cater in identifying possibilities of improving homegardens towards a more diverse agro-ecosystem in facilitating and enhancing food and nutritional security of households within a particular location.

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