

Effect of Processing and Storage Relative Humidity on Selected Functional Properties of Cocoyam (Colocasia Esculenta) Corm Flour

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Abstract

The effect of processing and storage relative humidity on selected functional properties of cocoyam flours was investigated. Peeled, sliced (3-5mm) taro corms were washed and divided into three parts that were respectively blanched (5 min) in boiling hot water (BT); sulphited in 0.025% metabisulphite ($Na_2S_2O_5$) solution (4 h) and blanched (5 min) in the same solution (SBT); and left untreated (NT) (the control). The slices were sundried (34 ± 2°C, 3 days), milled, sieved (65 mesh screen, 0.208 mm) and the flours stored under 11, 33, 53, 67, 75% and ambient relative humidities (RH). Flours were analyzed for bulk density (BD), water and oil absorption capacities (WAC, OAC), foaming capacity (FC) and foam stability (FS) at 0, 1, 3, 5 and 7 months. Blanching significantly increased the BD, WAC and OAC but significantly reduced the FC and FS. Sulphiting has no influence on these functional properties. The BD decreased during storage with significant reduction at 53% RH and above. WAC decreased significantly with increasing storage time and RH. The OAC increased insignificantly during storage and with increasing RH; attaining the maximum increased at 53% RH. The FC increased with increasing storage time and RH. The increase in FC of flours stored under ambient, 11 and 33% RH was insignificant but significant for storage at 53, 67 and 75% RH. Only NT flour retained 7.44 – 8.80% of its foam after 1 h. The stability of the foam was higher under low storage RH. Interaction of storage RH and time were significant in BD and FS but insignificant in WAC and OAC

Keyword: blanching, cocoyam corm, functional properties, relative humidity, storage, sulphiting

1. 0 Introduction

Taro (Colocasia esculenta), is widely cultivated in tropical and subtropical countries for its edible corms and leaves. It is regarded as the third most important root crop, after yam and cassava, in West Africa (Obomeghevie et al., 1998). It has nutritional advantage considering its higher protein content and amino acid than any tropical root/ tuber crops (Key, 1987); high starch content with small size granules, which results in high digestibility (Howeler et al., 1993; Huang et al., 2000); and high soluble dietary fibre content (Huang et al., 2000). According to the later authors, the combination of small size granules and high soluble dietary fibre contents make taro corms a good carbohydrate source for extruded special products such as infant weaning diets and low glycemic index food.

Cocoyam (taro) corms are highly perishable due to its high moisture content. Its spoilage could be reduced by processing into flour, which stores much longer than the unprocessed corm (Kwateng and Fowler, 1994; Onyeike et al., 1995). According to Adepeju et al (2011), one way of minimizing post-harvest losses and increasing utilization of breadfruit is through processing into flour, which is a more stable intermediate product. McWatters (1983) stated that processing of grains into flours is a gateway to their conversion into foods as it enhances utilization of the grains for processing of many traditional food products and makes food products development easier, more convenient, cost effective and less wasteful of time and energy. Hong and Nip (1990) and Nip (1997) reported that aroid flours could be advantageous in the preparation of myriad products by the food development industry since it could be used in dehydrated soup formulation, baked goods, formulation of baby foods, snacks, breakfast products.

Though cocoyam flour stores better than the corm due to highly reduced moisture content, conversion into flour is not an end to the storage problem. According to Leniger and Beverloo (1975) and Desrosier and Desrosier (1977), all food products are inherently unstable and quality retention depends upon a number of factors including storage temperature, storage relative humidity and storage time. Rockland and Nishi (1980) also reported that maximum stability of natural products had been associated with minimum total moisture until definitive studies on shelled walnuts demonstrated that there was a narrow optimum moisture range, corresponding to a broader water activity (a_w) range, above and below which kernels deteriorated at more rapid rate; and that analogous optimum a_w values are observed for other natural products. Thereafter, it became generally accepted that a_w is more closely related to the physical, chemical and biological properties of foods and other natural products than is total moisture content. Recent works (Owuamanam et al., 2010; Nwanekezi et al., 2010: Nurtama and Lin, 2010) have studied the moisture sorption isotherm of cocoyam flour, which according to Idlimam et al. (2008) are important to improve the conditions of several processes such as dehydration, packaging or storage.

Functional properties are those intrinsic physicochemical characteristics that govern the behavior of nutrients in foods during processing, manufacturing, storage and preparation as they affect food quality and acceptance (Bressani, 1985; Eltayeb et al., 2011). It is further defined as the set of properties that contribute to the desired colour, flavor, texture and nutritive value of a product (Thompson and Edaman, 1981); and as any property (except nutritional) of food ingredients, which affect the utilization of foods. Functionality in a sense is a property of food other than the utilization. The successful performance of flours as food ingredients depend upon chemical composition, functional characteristics and sensory qualities they impart to the end product (McWatters, 1983; Kaur and Singh, 2007; Amon et al., 2011). According to Adepeju et al. (2011), the suitability of flour for use as food or food ingredients will depend on its functional properties. Ammar et al. (2009) stated that the possibility of using starchy staples for bread making depends on the physical and chemical properties of the product.

Food properties are influenced by growing, harvesting and slaughtering practices, preservation and preparation methods, processing and storage conditions, and packaging. This work investigated the effect of processing and storage relative humidity on selected functional properties of cocoyam flours.

2.0 Materials and Methods

2.1 Raw material procurement

Freshly harvested corms of taro (cocoyam) cultivar identified at the Department of Botany of University of Nigeria, Nsukka as Colocasia esculenta var. esculenta was purchased from Ekuluoko market at Afulugo in Igalamela/ Odolu Local Government Area of Kogi State, Nigeria. The cocoyam was stored in a shade under a cashew tree and processed into flour within one week of procurement.

2.2 Processing of cocoyam into flour

Taro corms were washed, peeled into a bowl containing tap water to prevent or limit discolouration of the corms, cut into 3-5 mm thick slices and washed again to remove dirt and mucilage from the cut surfaces. The taro slices were divided into four equal parts. The first part was sun-dried without any treatment (NT). The second was blanched for 5 minutes in equal quantity of boiling tap water (w/v) before sun-drying (BT). The third was soaked for 4 h in 0.025% (250 ppm) sodium metabisulphite ($Na_2S_2O_5$) solution and subsequently blanched in the same solution for 5 minutes (SBT). The treated (BT and SBT) and non-treated (NT) cocoyam slices were sundried (average ambient temperature, 34 ± 2^{o}C) for 3 days on stainless steel trays placed on corrugated iron sheet 2 m above the ground. The dried cocoyam slices were milled using № 1A premier grinding mill driven by a lister engine (Model RLA 201-80014, UK). The resulting cocoyam granules were sieved with Tyler Standard Screen mesh number 65 to give flour particle size below 0.208 mm.

2.3 Storage of cocoyam granules/ flours

The storage relative humidities (RH) for the study were chosen to spread between 11 and 75%. Hence, storage was carried out under RH of 11, 33, 53, 67 and 75%. The RHs were achieved with saturated solutions of lithium chloride (11%), magnesium chloride (33%), magnesium nitrate (53%) and sodium chloride (75%). Combined saturated solutions of potassium nitrate and ammonium chloride, which gives 67.2 – 70 % RH at temperature range of 25^{o}C to 35^{o}C was also chosen because at 30^{o}C, the RH will be slightly below 70 %, which is critical to many microorganisms. Based on the result of the preliminary analysis or investigation on the flours of different particle sizes, flours that passed through 0.2 mm screen (mesh № 65, Tyler Standard Screen) were stored over the saturated solutions. Control samples were stored at ambient temperature (32 ± 2^{o}C), in loosely closed sorption jar void of saturated salt solution. Dry and wet bulb thermometers were installed on the laboratory bench for estimation of the storage relative humidity of the control samples.

2.4 Functional properties determination

The water and oil absorption capacities were determined using centrifugal method as described by Okaka and Potter (1979); foaming capacity and foam stability were determined using the methods of Narayana and Narasinga Rao (1982); while bulk density was determined using the method of Akpapunam and Markakis (1981).

2.5 Statistical analysis

Data were subjected to analysis of variance and means, where significant, were discriminated using Tukey's Least Significant Difference (LSD) test (Gomez and Gomez, 1984).

3.0 Results and Discussion

3.1 Bulk density

The effect of blanching and its combination with sulphiting on the bulk density of cocoyam flours is shown in Table 1. Bulk density was significantly affected ($p < 0.05$) by blanching. The bulk densities of blanched flours (BT and SBT) were significantly ($p < 0.05$) higher than the NT. Ajewole and Ozo (1994) observed the similar increase in bulk density in pregelatinized tannia cocoyam flour. They reported that pregelatinized cocoyam flour was denser (0.7330 g/ cm^3) than the unpregelatinized cocoyam flour (0.5772 g/cm^3) and that since the two are less dense than water (1 g/ cm^3), they can be prepared as slurries. Both storage RH and storage time significantly ($p < 0.05$) affected the bulk density of the cocoyam flours. The flours stored at higher RH (53% and above) exhibited low bulk density. This could be attributed to their more moist condition, which resulted in their caking. Moreyra and Peleg (1980) observed the same for selected food powders and attributed it to formation of open bed structure that is supported by inter-particle forces and liquid bridges. Whereas the bulk density of flours stored at 53% RH and above decreased significantly after one month of storage, those stored at ambient condition and 11 and 33% RH remained unchanged throughout the storage period. The interaction between the storage time and storage RH was significant at 5% confident level. The bulk properties of particulate foods play a direct and major role in many processes, handling and storage operations. High bulk density is desirable in that it offers greater packaging advantage as greater quantity may be packed within a constant volume (Fagbemi, 1999; Adepeju et al., 2011). Indirectly, they can also provide indications of other physical characteristics, notably internal cohesion that may affect the powder's flowability and storage stability (Peleg et al., 1973; Moreyra and Peleg, 1980).

Table 1: Bulk density (g/ cm^3) of treated and untreated cocoyam flours stored at various relative humidities

Treatment	Storage RH	Storage time (months)					
	(%)	0	1	3	5	7	LSD
None	Ambient*	0.779^{a}_{x}	0.782^{a}_{x}	0.778^{a}_{x}	0.781^{a}_{x}	0.781^{a}_{x}	0.012
	11	0.779^{a}_{x}	0.781^{a}_{x}	0.778^{a}_{x}	0.782^{a}_{x}	0.782^{a}_{x}	0.012
	33	0.779^{a}_{x}	0.782^{a}_{x}	0.779^{a}_{x}	0.780^{a}_{x}	0.784^{a}_{x}	0.012
	53	0.779^{a}_{x}	0.740^{b}_{y}	0.746^{b}_{y}	0.741^{b}_{y}	0.722^{b}_{z}	0.012
	67	0.779^{a}_{x}	0.680^{c}_{y}	0.650^{c}_{z}	0.648^{c}_{z}	0.641^{c}_{z}	0.012
	75	0.779^{a}_{x}	0.630^{d}_{y}	0.615^{d}_{z}	0.612^{d}_{z}	0.612^{d}_{z}	0.012
	LSD	0.028	0.028	0.028	0.028	0.028	
Blanched	Ambient*	0.823^{a}_{x}	0.820^{a}_{x}	0.822^{a}_{x}	0.818^{a}_{x}	0.821^{a}_{x}	0.025
	11	0.823^{a}_{x}	0.822^{a}_{x}	0.818^{a}_{x}	0.820^{a}_{x}	0.819^{a}_{x}	0.025
	33	0.823^{a}_{x}	0.820^{a}_{x}	0.823^{a}_{x}	0.821^{a}_{x}	0.820^{a}_{x}	0.025
	53	0.823^{a}_{x}	0.792^{a}_{y}	0.742^{b}_{z}	0.728^{b}_{z}	0.723^{b}_{z}	0.025
	67	0.823^{a}_{x}	0.675^{b}_{y}	0.641^{c}_{z}	0.633^{c}_{z}	0.629^{c}_{z}	0.025
	75	0.823^{a}_{x}	0.635^{c}_{y}	0.638^{c}_{y}	0.638^{c}_{y}	0.644^{c}_{y}	0.025
	LSD	0.032	0.032	0.032	0.032	0.032	
Sulphited & Blanched	Ambient*	0.820^{a}_{x}	0.821^{a}_{x}	0.818^{a}_{x}	0.823^{a}_{x}	0.822^{a}_{x}	0.018
	11	0.820^{a}_{x}	0.822^{a}_{x}	0.821^{a}_{x}	0.823^{a}_{x}	0.816^{a}_{x}	0.018
	33	0.820^{a}_{x}	0.821^{a}_{x}	0.817^{a}_{x}	0.823^{a}_{x}	0.821^{a}_{x}	0.018
	53	0.820^{a}_{x}	0.793^{b}_{y}	0.778^{b}_{y}	0.772^{b}_{z}	0.770^{b}_{z}	0.018
	67	0.820^{a}_{x}	0.670^{c}_{y}	0.633^{c}_{z}	0.628^{c}_{z}	0.624^{c}_{z}	0.018
	75	0.820^{a}_{x}	0.658^{c}_{y}	0.645^{c}_{y}	0.625^{c}_{z}	0.626^{c}_{z}	0.018
	LSD	0.025	0.025	0.025	0.025	0.025	

Values are means of duplicate determinations. Means with different (i) superscripts within a column, (ii) subscripts along the row, are different ($p < 0.05$).

3.2 Water absorption capacity

Comparison of Figures 1-3 and statistical analysis revealed that the water absorption capacity (WAC) of the cocoyam flours was significantly ($p < 0.05$) increased from 2.96 g/g to 3.26g/g by blanching treatment. The effect of heat treatment was also observed by Fagbemi and Olaofe (1998) who reported that precooking increased the WAC of taro from 275 to 300 % and tannia from 325 to 350 %. Also Iwuoha and Kalu (1995) reported an increase in the WAC of flours from cultivars of Colocasia esculenta from 2.49 ml/ g to 2.96 ml/ g after 3 minutes and to 3.44 ml/ g after 30 minutes boiling at 90 ^{o}C. An increase in water absorption capacity of cocoyam flour from 270 to 375 g/ 100 g by boiling was reported by Mbofung et al (2006). The higher water absorption capacity of flours of blanched taro corm indicates that the flour has more hydrophilic constituents. The ability of food materials to absorb water is sometimes attributed to its protein content (Kinsella, 1976, Ali et al., 2013) and starch content (Ali et al., 2013); and to the capacity of boiling to dissociate or alter the protein molecules to monomeric subunits which may have more water binding sites (Lin et al., 1974). Water absorption capacity is the ability of flour to absorb water and swell for improved consistency in food (Adepeju et al., 2011). According to Kinsella et al. (1985), the binding water includes all types of hydrated water and some water remaining loosely associated with protein following centrifugation. The presence of water in foodstuff and its concentration depends on water absorption capacity and stability and this determines to a high degree, the palatability, digestibility, physical structure and technical handling (Rey and Labuza, 1981). Water absorption capacity is desirable in food systems to improve yield and consistency and give body to the food (Osundahusi et al., 2003).

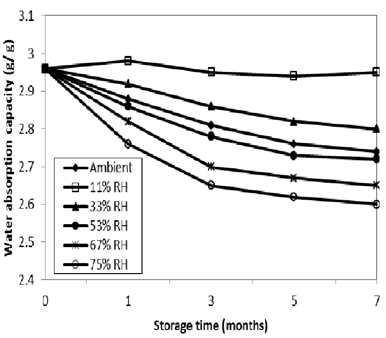

Figure 1. Water absorption capacity of NT cocoyam corm flour stored under various relative humidities

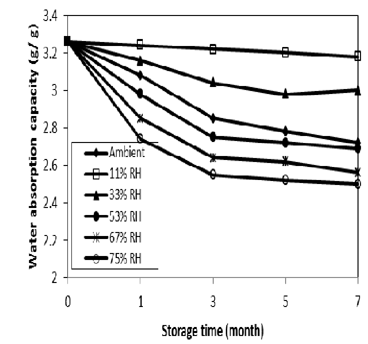

Figure 2. Water absorption capacity of BT cocoyam corm flour stored under various relative humidities

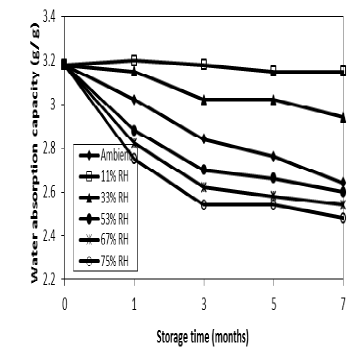

Figure 3. Water absorption capacity of SBT cocoyam corm flour stored under various relative humidities

From Figures 1 - 3, it could be generally observed that the WAC of the cocoyam flours decreased during storage irrespective of the storage RH. The decrease could be attributed to retrogradation – a phenomena associated mainly with amylose, which linear chains align themselves to form crystalloid region (Hodge and Osman, 1976), causing the release of part of its 'bound' water. These regions become hydrophobic as 'bound' water is replaced by intermolecular bonds of carbon-carbon hydroxyl group (Ooraikul and Moledina, 1981). These workers reported that French (1950) suggested that starch retrograde even in the solid state and using solubility of starch as a measure of its retrogradation, they showed that starch can retrograde even at low moisture content of about 7% in potato granules. As the retrograded starch molecules became tightly packed, the amount of water that can be held therein decreases since essentially no water can be held within the crystals (Saltmarch and Labuza, 1980). This could lead to the reduction of WAC of the cocoyam flour. Previous study on this sample revealed that cocoyam corm contains 34.04% amylase and 65.96% amylopectin (Obiegbuna et al., 2013) Aboubakar et al. (2010), however, reported an increase in water absorption capacity during the first three months of storage and a decrease thereafter; and stated that similar patterns were observed by Pilosof et al. (1985) for bean flour, soybean and corn starch and by Borges and Cavidel (1994) for drum dried banana. Ooraikul and Moledina (1981) also observed an increase in WHC of potato granules and advocated that the alignment (crystallization) of starch molecule might have created minute voids in the solid matrix, which will entrap a quantity of water and increase the WHC.

Figures 1 - 3 also revealed that WAC decreased as storage RH increased. This may be attributed to higher moisture content already acquired by the flours stored at higher RH. This is especially true since the quantity of flour used in the determination was not estimated on dry weight basis. The decrease in the WAC with increasing RH of storage can also be attributed to retrogradation. While the important role played by moisture content in retrogradation has been reported, the interdependence of starch retrogradation and moisture has been demonstrated (Hellman et al., 1954). In their study on the spray-dried sweet whey powder, Saltmarch and Labuza (1980) reported that change in the solubility of lactose, on taking water from the surrounding air, resulted in the molecular acquisition of sufficient mobility and space and the consequent rearrangement of lactose into a regular crystal lattice. The increased mobility of starch molecules due to increase in space between them, caused by greater amount of water adsorbed at higher RH, may have led to greater rearrangement of starch molecules into crystal lattice – retrogradation.

Analysis of variance showed that the storage time and storage RH significantly ($p < 0.05$) affected the WHC of cocoyam corm flours. Tukey's test, however, revealed that for the 7 months of storage, WHC was not significantly ($p > 0.05$) affected by storage at ambient RH and low RH of 11and 33% for NT and BT flours. It became significant from the fifth month of storage when stored at 53% RH, and at first month when stored at 67% and 75% RH (at third month for NT flour). The difference in the WHC of flours stored under ambient RH and RH of 11 and 33% was not significant ($p > 0.05$), neither was the difference in WHC of the flours stored at 53, 67, and 75% RH. Significant difference, however, existed between the WHC of flours stored at 53% and 11% RH. The interaction between the storage time and storage RH of cocoyam flours was not significant ($p > 0.05$).

3.3 Oil absorption capacity

The oil absorption capacity (OAC) of cocoyam flours is shown in Figures 4 - 6. Like the WHC, blanching treatment significantly ($p < 0.05$) increased the OAC from 1.16 g/ g to 1.23 g/ g. Fagbemi and Olaofe (1998) and Iwuoha and Kalu (1995) reported similar increase in the OAC of taro and tannia by precooking. The major chemical component affecting oil absorption capacity is protein, which is composed of both hydrophilic and hydrophobic parts. Non-polar amino acid side chain can form hydrophobic interaction with hydrocarbon chains of lipid (Jitngarmkusol et al., 2008; Eltayeb et al., 2011). Generally, the OAC of cocoyam flours stored under ambient RH and other various RH conditions increased during storage (Figures 4 - 6). The figures also revealed that the OAC of cocoyam flours was improved by storage RH. The increase may also be attributed to retrogradation, which creates hydrophobic region through intermolecular bonds of carbon-bound hydroxyl group (Ooraikul and Moledina, 1980). Moreyra and Peleg (1980) also suggested that the formation of an open bed structure that is supported by inter-particle forces and liquid bridges has probably created void inside the flour granules for oil absorption. The maximum OAC was achieved at RH range of 53 and 67% from the third month of storage. Oil and water are immiscible. Therefore, the extra/ marginal moisture content of the flour stored at 75% RH may have limited the oil absorption thereby placing the maximum oil absorption, after the third month of storage, at RH range of 53 and 67%. Neither the storage RH nor the storage time significantly ($p > 0.05$) affected the OAC of the cocoyam flours. The interaction between the storage time and storage RH was not also significant ($P > 0.05$). Fat absorption is an important property in food formulations because fats improve the flavor and mouth feel of foods (Adepeju et al., 2011).

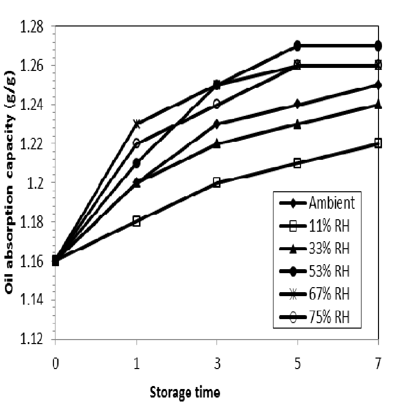

Figure 4. Oil absorption capacity of NT cocoyam corm flour stored under various relative humidities

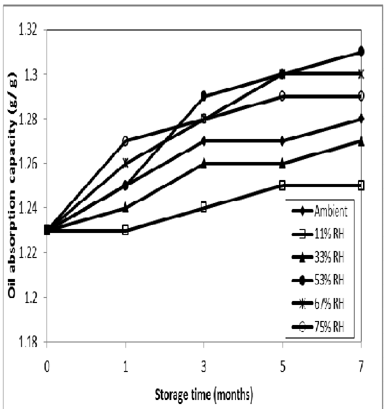

Figure 5. Oil absorption capacity of BT cocoyam corm flour stored under various relative humidities

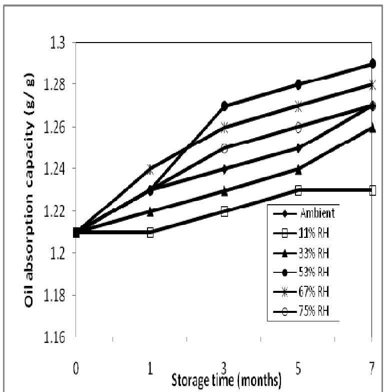

Figure 6. Oil absorption capacity of SBT cocoyam corm flour stored under various relative humidities

3.4 Foaming capacity

The foaming capacity (FC) of cocoyam flours as influenced by blanching, and its combination with sulphiting is shown in Figures 7 - 9. Blanching significantly ($p < 0.05$) reduced the FC of cocoyam flours from 15% to 6%. Fagbemi and Olaofe (1998) reported that the FC of raw taro and Tania flours decreased from 11.8 and 13.8%, respectively, to 5.9 and 7.8% after precooking. The generally low foaming capacity of cocoyam flour has been attributed to the low protein content (Ibebuchi and Uzoegbu, 2002). A similar reduction of foaming capacity was reported for cowpea by heat treatment (Abbey and Ibeh, 1988). Amon et al. (2011) however, reported that the flour of boiled taro corm exhibited the highest foaming capacity and suggested that heating affected positively the primary factors involved in foam formation which are surface tension, viscosity and the character of the protein film. Foaming properties of food are protein related functional properties. According to Kinsella (1981), food foams are composed of gas (air), liquid (water and surface active agent (protein). It is well known that for a protein to have good foaming properties, it has to be very soluble because foaming capacity requires rapid adsorption of protein at the air-water interface during whipping, penetration into the surface layer and reorganization at the interface (Were et al. 1997). Hence, for optimum foam formation, the surfactant should be soluble in the liquid phase and be capable of rapid migration and orientation to form an interfacial film around nascent gas bubbles. Kinsella (1981), however, reported that limited heating, which induces partial unfolding of globular proteins without causing thermal coagulation, facilitates foam formation by increasing their rate of surface adsorption, stable surface pressures and surface concentration. Denaturation is frequently manifested by a reduction in protein solubility (Tumerman, 1977). Excessive heat may have been applied to the cocoyam during blanching thereby leading to the loss of solubility of the protein – the surface active agent. The consequence could be the reduction of foaming capacity.

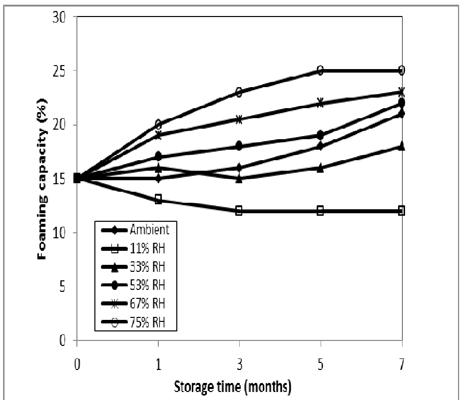

Figure 7. Foaming capacity of NT cocoyam corm flours stored under various relative humiditiesTitle

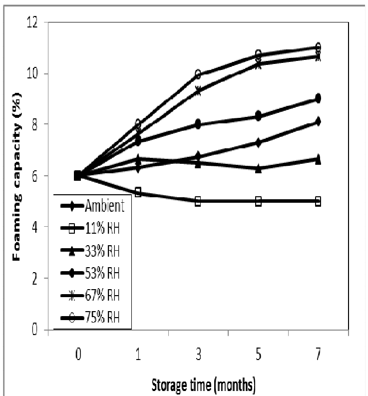

Figure 8. Foaming capaccity of BT cocoyam corm flours stored under variouss relative humidities

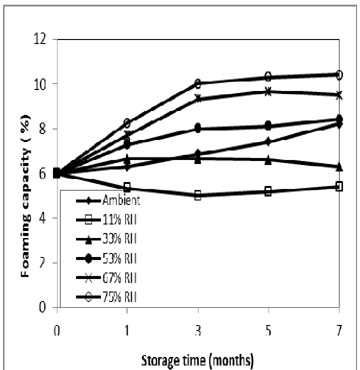

Figure 9 Foaming capacity of SBT cocoyam corm flour stored at various relative humidities

The FC of cocoyam flour generally increased during storage (Figures 7 - 9) with pronounced increase within the first month of storage. It also increased with increasing RH of storage. Tumerman (1977) had reported that residual moisture level is a critical factor in denaturation resistance of dried protein. He observed that egg white, at maximum moisture level of 3% withstood prolonged hold at 60 – 70 ^{o}C without denaturing whereas the heat tolerance was reduced to 50 ^{o}C at 5% moisture. The critical factors for foam formation are the inherent surface activity and the ability of protein to unfold and reorient at the interface and engage in molecular adhesion (Kinsella, 1981). Therefore, lower FC of the flours stored at RH below 53% could be attributed to their protein's greater resistance to unfold caused by their low moisture levels (drier condition).

Analysis of variance showed that the increase in the foaming capacity (FC) was significant ($p < 0.05$). Tukey's test revealed that the FC of the flours stored under ambient RH and the RH of 11 and 33% did not change significantly ($p > 0.05$) during the 7 months of storage whereas those stored under 53, 67 and 75% RH did. The change was significant ($p < 0.05$) at the 7th month of storage at 53 RH and at the first month of storage at 67 and 75% RH. The FC of flours stored at 11% RH significantly differed ($p < 0.05$) from others from the first month of storage. The difference in the FC of the flours stored under 33%, 53% and ambient RH was not significant ($p > 0.05$) for the seven months of storage while that of flours stored under 53% differed significantly ($p < 0.05$) from those stored under 67 and 75% RH after the first month of storage. The interaction between storage time and storage RH was significant ($P < 0.05$).

3.5 Foam stability

Foam stability (FS) in this work denotes the volume of foams retained after 1 h standing rather than half-life of initial foam volumes reported in some work (Kinsella, 1981). The blanched cocoyam flours (BT and SBT) lost all their foams whereas the non-blanched flour (NT) retained 7.44% of its foam after one hour. Fagbemi and Olaofe (1998) reported that the FS of both raw and precooked taro and tannia flours was zero after two hours. Kinsella (1981) had reported a reduction in foam stability (FS) of bovine serum albumen by heating. The loss of the ability to stabilize foam may be indicating that the blanching treatment was excessive, resulting to protein coagulation. Consequently, large air bubbles surrounded by thinner and less flexible protein films (Jitngarmkusol et al., 2008; Eltayeb et al., 2011), which were easier to collapse, were formed.

Although the FC of the cocoyam flours increased during storage and with increasing storage RH (Figures 7 - 9), the FS of cocoyam flours stored at lower RH were higher (Figure 10). This inverse relationship between FC and FS was observed by Jitngarmkusol et al (2008) and Eltayeb et al. (2011) who stated that flours with high foaming ability could form large air bubbles surrounded by thinner and less flexible protein film. This air bubbles might be easier to collapse and consequently lowered the foaming stability. This may be related to their protein's greater susceptibility to unfold and consequently to denature. Excessive protein denaturation may lead to its coagulation. According to Kinsella (1981), the presence of coagulated protein reduces film stability and foam life because they reduce film strength.

Analysis of variance revealed that both storage RH and time significantly ($p < 0.05$) affected the FS of the NT cocoyam flour. Tukey's Least Significant Difference test, however, revealed that the FS of the flour stored under ambient RH and the RH of 53% and below remained statistically the same ($p > 0.05$) during the 7months of storage whereas the flour stored at 75 and 67% RH changed significant ($p < 0.05$) after 1 and 3 months, respectively. The difference in the FS of flour stored under ambient RH and RH of 11 and 33% was not significant ($p > 0.05$) during the 7 months of storage. The FS of the flour stored at 11% significantly ($p < 0.05$) differed from that of 75% from the first month; and from those stored at 53 and 67% RH from the third month. The interaction between the storage time and storage RH was significant ($p < 0.05$).

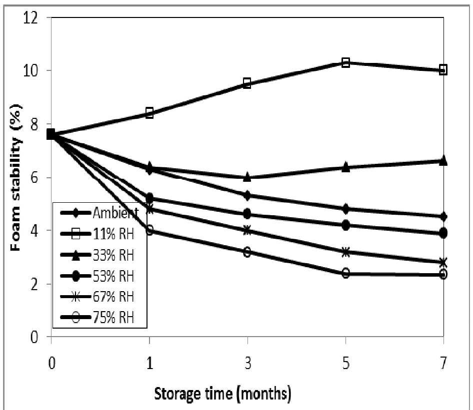

Figure 10. Foam stability of NT cocoyam corm flour stored under various relative humidities

4. 0 Conclusion

The bulk density, water and oil absorption capacities of cocoyam flour were increased by blanching treatment. The foaming properties of the flour were decreased by the treatment. Sulphiting did not influence these properties of the cocoyam flour. Storage of the flours at 53% relative humidities and above affected all the functional properties except the oil absorption capacity and foaming capacity on the negative. Maximum oil absorption capacity was attained on storage at 53 and 67% RH. The functional properties assessed were not influenced by storage at ambient RH of study environment. Cocoyam should be blanched if increased bulk density and oil and water absorption capacities of the flour are required; and should be stored at RH below 53% to retain the functional properties.

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