Influence of Temperature and Packaging Materials on the Storage Qualities of Soy-Melon “Gari” - A Protein Enriched Cassava Product

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Abstract

The influence of temperature and packaging materials on the storage qualities of soy melon “gari”, a fermented and toasted cassava semolina, were studied. Samples of the protein-enriched “gari” were produced by toasting “gari” together with the soy-melon supplements. They were packaged in Woven sack and HDPE Film and stored under three different temperatures of 10, 30, and 40°C. Samples were withdrawn at 4 weeks interval to measure their changes in chemical compositions during storage. The moisture increased from about 9.36% to about 9.43% and 9.7% at 20° and 30°C respectively, while it was reduced at 40°C. The FFA values increased at 30°C. TBA increased from 0.383 to 0.693, 0.988 and 1.668mg malonaldehyde/kg sample at 20°, 30° and 40°C respectively while it increased to 0.662, 0.960 & 1.523 ppm for the same samples packed in HDPE films. At higher temperature of 40°C, browning increased sharply after about 20 weeks of storage, from about 0.02nm to 0.035nm of change in absorbance per month (dA425). There was an initial increase in total viable count (TVC) of bacteria up to 12 weeks of storage which later decreased again. The mould content increased as the atmospheric temperature (30°C) is being approached, but at 40°C, there were no observable mould colonies throughout the period of study. Therefore packaging and storing gari in HDPE film preserved “gari” better than the Woven sack and “Gari” stored better at temperature lower than 30°C than at high temperature of 40°C.

Keywords: Soy Bean; Melon Seed; "Gari"; Chemical Qualities; Storage Stability; Protein Enrichment

1. Introduction

“Gari” is a fermented, dewatered and toasted starchy granule from cassava which is widely consumed all over West Africa and in Brazil where it is known as ‘farinha de mandioca’ (Lancaster et al., 1982). “Gari” is one of the most popular forms in which cassava (Manihot esculenta Crantz)
also known as manioc is consumed in Nigeria and some other parts of West Africa (Kordylas, 1990). It is a major component of everyday diet in Nigeria providing about 11.835kJ/person/day (Osho, 2003). The wide consumption of gari is attributed to its relatively long shelf life compared to other food products from cassava, as well as the ease of preparation for consumption (Sanni et al., 2008). “Gari” can be consumed directly without cooking by soaking in water without or with a variety of additives such as sugar, coconut, groundnut, fish, meat and stew prior to consumption (Aja, & Adegun, 2009). It can also be made into a stiff gel by mixing with hot water (Adejumo and Raji, 2012) and eaten with soup. Cassava and its products are quantitatively and qualitatively poor in protein content ranging from 0.7-2.6% (Charles et al., 2005; Emmanuel et al., 2012). They are deficient in essential amino acids (Oyenuga, 1968). The most limiting amino acids are methionine, tryptophan, lysine and phenylalanine (Okigbo, 1980). In areas where cassava is a staple food crop, people usually suffer from malnutrition because of the biochemical composition of the tubers and the fact that the supply of animal protein is inadequate in such areas (Aletor, 1993; Naray, 1978). Children happen to be the most vulnerable group in such areas suffering from both protein and calorie malnutrition. An easier or faster alternative route is to provide diets with greater amount of quality protein. This can be achieved through enrichment/fortification programs. The use of plant protein supplement is a cheaper, more viable and most available option for this. Supplementary protein sources must therefore be provided if cassava is to maintain its role as a major source of calories (Raspier and Macgregor, 1969). Many attempts have been made to enrich cassava products with protein from vegetable sources (Some efforts have been made to improve the nutrient content of cassava products [Oshodi (1985), Collins and Temai (1991), Banjoh and Ikenebomeh (1996), Osho, (2003) and Oluwamukomi et al. (2005)]. The production, storage and marketing of “gari” is still mainly carried out by local farmers, processors and foodstuff traders, while only a few highly mechanised processing plants market their products in consumer packaged forms (Oyeniran, 1980). “Gari” is still being packaged, transported and stored in woven sacks with attendant fluctuations in climatic conditions and sometimes it is being sold in the market in bowls with exposed surfaces thus increasing its susceptibility to environmental contaminations (Ogiehor and Ikenebomeh, 2006). The producers of “gari” go about the storage and packaging of this product in a non-scientific way (Oyelade et al., 2001) using hessian bags and transparent plastic polyethylene sheets. Polyethylene is widely used as a packaging material because of its good mechanical properties and low cost however these qualities have been overshadowed by its high non-biodegradable nature and waste disposal problems (Sailaja & Chanda, 2001). The products may look alright from outside, while its quality may be musty and completely bad when it is touched. This is an indication that faulty packaging can conveniently undo all that a food processor has attempted to accomplish by the most meticulous method of manufacturing practice (Fedrica, 2001). The hygroscopic nature of “gari” is a major constraint to its keeping quality. The use of hessian bags by the local producers of “gari” for its packaging is due to the fact that the material is cheap, readily available and durable. The material also has ease of bulk packing and transportation of products with little or no attention paid to the quality of products stored. The hessian bag is not moisture proof or airtight and “gari” which is hygroscopic in nature makes the use of hessian bag grossly inadequate. “Gari” stored in hessian bag in a humid atmosphere can absorb sufficient moisture making them vulnerable to microbial growth. (Adejumo and Raji, 2012)

With the continued interest in the enrichment of “gari” with local protein sources from oilseeds, it is necessary to study the effects of the conditions of storage on the quality and storage stability of soy-
melon enriched "gari" during storage (Oluwamukomi, 2008). Considering the cumbersome nature of production process, the need to have the finished products to cities where large buyers live, the importance of "gari" in dietary intake and the need to meet the increasing international demand, the evaluation and identification of adequate packaging materials that will keep the overall quality of "gari" during distribution and at the point of consumption becomes imperative ((Ogiehor and Ikenebomeh, 2006)). The objectives of this study are therefore to produce soy-melon enriched "gari", subject it to storage stability study and determine the effects of packaging and the temperature of storage on the quality parameters of critical importance to deterioration during storage of the enriched "gari".

2. Materials and Methods

2.1. Source of Materials

Cassava roots (Manihot esculenta Crantz) harvested and used on the same day, were obtained from the research farm of the Federal University of Technology, Akure, Ondo State, Nigeria. Soybean (Glycine max L merriel) and melon seeds (Citrullus vulgaris) used to produce the protein supplements were purchased from the Oja Oba market, in Akure, Ondo State, Nigeria. They were sorted, cleaned, packed and kept under refrigeration until use.

2.2. Sample Preparation

Soy-melon “gari” was produced according to the methods of Banjoh Ikenebomeh (1996) and Oluwamukomi and Adeyemi (2013). Soy and melon protein supplements were first prepared separately in the form of full fat meals before they were compounded and incorporated into the cassava products. The full fat soy meal was produced according to the methods of Sanni and Sobamiwa, (1994). 1 kg of soybean (Glycine max L merriel) were sorted, washed and boiled in water at 100°C for 30minutes. It was dehulled, dried, milled in an attrition mill and packaged in HDPE until ready for further use. The full fat melon meal was produced by toasting 1 kg of melon seeds (Citrullus vulgaris) in an open pan over fire until light brown in colour. They were milled in a Moulinex blender (one single blade, Super Intermet, Japan) to a particle size of 450μm. Using a stepwise calculation procedure (Pearson square) for blend formulation (Plahar and Hoyle, 1991), soy-melon “gari” was formulated to contain the ratios of full fat soy and melon separately taking into consideration maximum complementation of amino acids and protein content of about 15% targeted to satisfy the minimum protein content required under the Food and Agriculture Organization (FAO)/World Health Organization (WHO) Codex Alimentarius Standards (1991).

2.3. Production of Soy-melon “Gari”

The Cassava tubers were peeled manually with a sharp knife, washed and grated in a locally fabricated mechanical grater. The grater was made of a flat galvanized sheet punctured with holes with a big nail with opening of 0.75cm diameter and fixed round a drum-like plank. This was connected through a belt to a 7 hp driving motor. The washed cassava tuber was held by hand and ran over the rotating drum with extreme care that fingered and palm are not bruised (Agunbiade, 2001). They were then packed into Hessian sack and allowed to ferment for 72 hours after which
they were pressed in a mechanical press (Addis Engineering Nig. Ltd, Nigeria) to dewater the mash. The dewatered wet cassava cakes were pulverized with hands and sifted on a local raffia made sieve of mesh (0.3cm x 0.3cm) mounted on a rectangular wooden frame 40cm² to remove the fibers. The sifted cassava meal obtained was enriched with full fat soy-melon using 15% supplementation level and taking into consideration the water content of the mash of 65% (Akingbala et al., 1993) (Figure 1). The white and fluffy cassava meal was then introduced into a wide iron pan (garifyer) piecemeal over wood fire and then toasted being continuously stirred using a self-insulating manual baffle made of calabash from gourd until a full manageable batch is subjectively determined as done (Agunbiade, 2001).

2.4. Accelerated Storage Stability Studies

To the full fat soy-melon “gari” samples was added Butylated Hydroxyl Toluene (BHT) as an antioxidant at 200ppm level based on 10% fat content and Ascorbic acid was added at 75ppm level (Pearson, 1976). 200gms of each sample was packaged into: (i) woven sack (Bacco, Nig PLC) sewn into 15cm x 10 cm size (ii) high density polyethylene (HDPE) film of size 15 x 20cm (50µm [2.15 mils] thickness; water vapour transmission rate: 1.33x 10⁻³ kgmil/m²/PA) . The packaged samples were stored under three (3) different temperatures, viz: 20 ± 2°C, 30 ± 2°C, and 40 ± 2°C. A Thermo hydograph was placed in the storage room to record the temperature and relative humidity of the room atmosphere. Untreated soy-melon “gari”, without additive, served as control. A control sample was kept in a glass bottle flushed with nitrogen and kept at 20 ± 1°C. Samples were removed at monthly intervals and subjected to physicochemical, sensory and microbiological analyses.

2.5. Analyses

The samples were analysed at monthly intervals to determine their quality factors critical to deterioration of oily food materials during storage such as moisture content, free fatty acid, thiobarbituric acid number, and non-enzymic browning and microbiological quality. Moisture content was determined by the oven dry method (AOAC, 2005) by drying triplicate samples in a hot-air circulating oven (Galenkhamp) at 105°C for 5 hours. Free fatty acid, was determined by the methods Pearson (1976). The oil used for the test was first extracted from the sample with petroleum ether (40-60°C). 5gm of the oil was dissolved in 50ml neutral alcohol and allowed to boil. This was quickly titrated with aqueous 0.1M Sodium Hydroxide against phenolphthalein indicator shaking constantly until a pink colour persisted for 15 seconds. The free fatty acid was calculated as (%oleic acid). Thiobarbituric acid (TBA) number (mg malonaldehyde/kg) was determined using the method of Pearson (1976). 10g of the flour was mixed with 48.7ml of water. About 2.5ml of 4M HCl was added to bring the pH to 1.5, followed by an antifoaming preparation (glass beads) in a distillation flask. The flask was heated so that 50ml of distillate was collected within 10minutes of boiling. 5ml of the distillate was pipetted into a glass stopped tube and 5ml of TBA reagent (0.2883g/100ml of glacial acetic acid) was added, shaken properly and incubated by heating in boiling water for 35minutes. A blank was similarly prepared using 5ml of water with 5ml of reagent. The tubes were cooled in water for 10minutes and the absorbance (A) measured against the blank at 538nm using 1cm cells. TBA Number (mg malonaldehyde per kg sample) was calculated as the Absorbance multiplied by 7.8. Ascorbic acid degradation was monitored according
to the method of AOAC (2005) using the 2,6, dichloro-indophenol method. A standard working solution was first prepared by dissolving 100mg ascorbic acid in 100ml of 4% oxalic acid solution in a standard flask (1mg/ml). 10ml was pipetted and made up to 100ml with 4% oxalic acid to make the working standard solution (100ug/ml). 10ml was drawn by pipette and titrated against a freshly prepared or standardized 2, 6, dichloro-indophenol dye. End point ($V_1$) was the appearance of pink colour which persisted for a few seconds. The amount of dye consumed was equivalent to the ascorbic acid expressed as mg of Ascorbic acid equivalent to 1ml of the dye solution. 5g of the “gari” sample was prepared by adding to 4% oxalic acid and make up to 100ml. It was mixed properly and centrifuged to extract the ascorbic acid. 10ml of the supernatant was pipetted and titrated against the standardized dye ($V_2$). Amount of ascorbic acid (mg/100g) sample was calculated as mg/100g sample.

Non-enzymic browning was measured according to the method of Hendel et al (1950) and (Lees, 1975) by monitoring the melanoidin pigment production using the colorimetric method. The extract used was prepared by suspending a 5g sample in 50ml 60% ethanol (v/v) and allowing it to stand for 12hrs. The extract was filtered and its absorbance (A) was measured at 420nm wavelength using ethanol as a blank. The rate of browning was expressed as change in absorbance per month ($\delta A_{420}/$ month) (Lees, 1975).

Microbiological analysis was carried out using the serial dilution method for the total viable count of bacteria and the mould count. 1 g of the sample was weighed out aseptically. This was mixed with 10mls of sterile water. From this, subsequent dilutions were made up to $10^{-4}$ level. 1ml from each of the dilutions was then plated in triplicates on sterile Petri dishes to which molten sterile nutrient agar and malt extract agar were added for bacterial and mould count respectively. The plates were swirled gently to allow for even dispersion of the samples in the media. The agars on the plates were allowed to solidify and the plates were later incubated at room temperature of 37 ± 1℃ for 48 hours for the total viable count of bacteria and 28 ± 1℃ for five days for the mould count, after which the colonies were counted to determine the total viable count of bacteria and mould count in cfu/gm (Harrigan and McCance (1976).

2.6. Statistical Analysis

Means and standard errors of the mean (SEM) of replicate scores were determined and subjected to analysis of variance (ANOVA). Means were separated using The Duncan’s New Multiple Range Test (Steel et al., 1997).

3. Results and Discussion

3.1 Effect of Temperature and Packaging on Moisture Content

The moisture content increased slightly with storage time at 20℃ and 30℃C but decreased significantly at 40℃C (Figs 1 & 2).
Fig. 1. Effect of temperature and packaging on the moisture content of soy-melon and control “gari” stored 20°C and 30°C.

It increased from about 9.36% to about 9.43% and 9.7% at 20°C and 30°C respectively, while it was reduced to about 4.05% for samples packed in woven sack and stored at 40°C. For those in HDPE films it increased to 9.4% and 9.5% at 20 and 30°C respectively but decreased to 4.55% at 40°C. This showed that at 40°C there was a more significant decrease in the moisture content ($P \leq 0.05$). The increase in moisture content at 20 and 30°C may be due to gradual equilibration with the high ambient relative humidity in the refrigerator and the atmosphere, while the decrease in moisture content at 40°C may be due to gradual equilibration with the low ambient relative humidity of the hot air in the incubator leading to evaporation of water from the “gari” granules. These changes in moisture content with changes in storage temperature might have been due to the hygroscopic properties of soy-melon “gari” granules and the relative humidity of the environment. In a similar storage study, Fritsch et al. (1997) observed that the moisture of sunflower kernel was reduced from 5% for samples stored at 4°C and 60-80%R.H to 2.1% at 21°C and 40%R.H and to 1.8% at 30°C and 25%RH. On the effect of packaging materials, the soy-melon “gari” in HDPE showed less change in moisture content. At 20 and 30°C, the rate of moisture gain was faster in the woven sack than in the HDPE (Figure 2a). The rate of moisture loss at 40°C was initially faster in the samples packaged in the HDPE than in the woven sack. This was stopped after 4 weeks when it gained temporary moisture and continued until 20 weeks of storage when the moisture fell again lower than that of woven sack. This could be explained by the fact that condensation of water within the package might have settled on the “gari” making its moisture content to shoot up. This continues until about 20 weeks when the moisture content of the HDPE becomes lower again due to further evaporation. The results were corroborated by the earlier findings of Masood et al. (2004), who observed that an initial decrease of moisture content in wheat was due to relatively low relative...
humidity in atmosphere but after 45 days of storage, higher relative humidity in atmosphere caused the flour moisture to increase up to end of storage. This is also similar to findings of Saxena et al. (1996) who found out that the moisture of ghewar, an Indian traditional sweet decreased in moisture content from 9.0 to 7.6% in LDPE bag. Kumar and Anansdawamy (1981) also observed that a food blend from corn sugar and fat picked up additional moisture of 2.1% in HDPE at the end of 4½ month storage at 27°C. Oyeniran (1980) also observed that white “gari” packed in polythene bag increased from a moisture content of 18.6 to 22.3% in two months. The same “gari” on the other hand packaged in Hessian sack decreased in moisture content from 18.6% to 15.0% within the same period. The FFA, which is a measure of the extent to which the triglyceride in the oil has been decomposed by lipase action, increased slightly with period of storage (P < 0.05). Increase in temperature of storage showed a slight significant increase (p < 0.05) in FFA (Fig 3). Significant increase in FFA was recorded for samples packaged in Woven sack at 30°C. It increased from 1.12% to 1.42, 1.99, and 1.32% at 20º, 30º and 40ºC respectively for the enriched products packaged in woven sack with BHT as an antioxidant. The lowered values of FFA at high temperature of 40°C could have been as a result of less hydrolytic reactions and absence of mould (0 cfu/g). It was observed that as temperature increased to 30°C its FFA content also increased. During storage the free fatty acid content was affected most by moisture content, increasing when the latter exceeded about 9.45% after 16 weeks of storage.

Fig. 2. Effect of temperature and packaging on the moisture content of soy-melon and control “gari” stored at 20º, 30º and 40ºC.
3.2. Effect of Temperature and Packaging on Free Fatty Acid Content

There was an increase in the FFA values with increase in temperature. (Fig.3). The higher FFA values at 30°C could have been due to the permeability of the woven sack, the humidity of the environment (70%) and presence of some few colonies of moulds (< 6 cfu/g), which might have favored some limited hydrolytic reaction responsible for the cleavage of the free fatty acids. Hydrolytic reactions occurring during storage cause fat cleavage which result in liberation of free fatty acids (Kumar and Mishra, 2004).

Fig. 3. Effect of temperature and packaging on the free fatty acid content of soy-melon and control “gari” stored at 20º, 30º and 40ºC.

This showed that deterioration in soy melon “gari” could not have been through hydrolytic rancidity but oxidative rancidity and lipid oxidation as a result of the moisture content being less than 10% and the humidity being less than 70%. This is similar to the findings of Leelavathi et al. (1983) who observed that the FFA content of whole wheat flour (atta) increased with time which might probably have been due to the higher activity of lipase and lipoxidase due to the presence of the enzyme in the germs and the aleurone layers of wheat and the coupling effect of high moisture content. Samples with higher moisture content showed higher FFA values. Packaging did not have any significant effect (p ≥ 0.05) on the FFA (Fig. 3). Both the Woven sack and the HDPE conferred similar protective ability on the Soy melon “gari” in term of production of FFA, although at 30°C the woven sack gave a higher value of FFA than HDPE film. This is similar to the findings of Bhat et al. (1982) that there was no significant increase in free fatty acid content of fried ‘mung dhal’ in both flexible and rigid packages. This is unlike the findings of Ventakesh et al. (1983) who observed an
increase in the FFA contents of ‘Sohan Halva’ packaged in LDPE and HDPE packages, while there was no increase in those packaged in aluminium foil and rigid container.

Kumar and Anadaswamy (1981) packaged a food blend in HDPE and LDPE pouches. They confirmed that the increase in FFA was more pronounced in LDPE pouches. They suggested that the rise in FFA might be due to higher transmission rate to water by the LDPE film than the HDPE film. The higher value of FFA in the Woven sack at 30°C than in HDPE film might be due to the pores of the woven sack which made the sack to be more permeable than the HDPE film. This could have contributed to the higher humidity in the package which could have favored some limited hydrolytic rancidity and other adverse conditions of storage.

3.3. Effect of Temperature and Packaging on Thiobarbituric Acid Content

TBA increased with increasing temperature in the enriched samples (p ≤ 0.05) (Fig 4).

![Graph: Effect of temperature and packaging on the thiobarbituric acid number of soy-melon “gari” and control “gari” stored at 20°C, 30°C and 40°C.](image)

**Fig. 4.** Effect of temperature and packaging on the thiobarbituric acid number of soy-melon “gari” and control “gari” stored at 20°C, 30°C and 40°C.

TBA is a measure of incipient oxidation of three or more double bonds in a fatty system, with the formation of secondary lipid oxidation products (Truyen, 1975) e.g. carbonyls, which are responsible for the sensory impact of lipid oxidation (Hall & Anderson, 1985). The higher the temperature the higher the thiobarbituric acid number measured as mg malonaldehyde/kg sample (Pearson, 1973). For samples packaged in woven sack the TBA increased from 0.383 to 0.693, 0.988 and 1.668 mg malonaldehyde/kg sample at 20°C, 30°C and 40°C respectively while it increased to
0.662, 0.960 & 1.523 ppm for the same samples packed in HDPE films at the same temperatures of 20\(^\circ\)C, 30\(^\circ\)C and 40\(^\circ\)C. This shows that TBA values increased with increase in temperature (p ≤ 0.05). This corroborates the previous findings of Kumar and Anasdaswamy (1981) that ‘Balahar’ a maize based product increased in TBA with increase in temperature. Stapelfeldt et al. (1997) also reported that thiobarbituric acid increased steadily in milk powder stored at accelerated temperature of 45 °C for 60 days.

Packaging had a significant effect on the thiobarbituric acid number of soy-melon “gari” (Fig. 4). It is apparent that the TBA increased slightly faster (p ≤ 0.05) in the sample in woven sack than in sample packed in HDPE film at initial optical density (OD) of TBA for Soy-melon “gari” was 0.383 and this increased to 0.988 and 1.668 by the 32\(^{nd}\) week of storage under accelerated conditions when it was packaged in HDPE film and woven sack respectively. Both packaging material and storage time significantly affected the TBA value. This faster increase in TBA could have been as a result of the pores of the woven sack which might have allowed permeation of moisture and oxygen which coupled with the accelerated high temperature might have led to faster production of malonaldehyde in soy-melon “gari” under storage. This was corroborated by Kumar and Mishra (2004), who observed that packaging material and accelerated temperature of storage both affected the shelf life of soy fortified yoghurt powder when packaged in HDPP and aluminium laminated paper pouch (ALP).

### 3.4. Effect of Temperature and Packaging on Non-enzymatic Browning (NEB)

There were significant effects of temperature on Non-enzymatic Browning in soy-melon “gari” (P ≤ 0.05). At higher temperature of 40\(^\circ\)C browning increased sharply after about 20 weeks of storage, from about 0.02nm to 0.035nm of change in absorbance per month (dA\(_{425}\)) for the soy-melon enriched samples at the 32\(^{nd}\) week of storage (Fig 5). This must have been due to the Maillard reaction at higher temperature of 40\(^\circ\)C leading to non-enzymic browning. Browning did not start at the early part of the study. There was an initial lag period for all the samples which was in line with earlier observation by Saguy et al. (1978) for skim milk, Franzen et al. (1990) for grape fruit juice. This is however contrary to the findings of Kilic et al. (1997) for cheddar cheese where there was no lag period. This lack of lag period in cheddar cheese might have been as a result of the fact that some initial NEB products might have been formed during manufacturing which might have led to the continuation of NEB without any lag period during storage. Instead, a flattening out was observed in the NEB values for soy-melon “gari” at 20 and 30\(^\circ\)C with prolonged storage.

NEB increased with increasing temperature from 30 to 40\(^\circ\)C and storage time. At 20 and 30\(^\circ\)C there was a general flattening out until the end of the study but at 40\(^\circ\)C there was an astronomical increase in NEB after about 20 weeks of storage for sample packaged in HDPE. Burnt off flavour was perceived then which was predominant till the end of the experiment. This behaviour was observed by Plahar and Leung (1985) who observed only relatively little browning for soy-fortified fermented maize meal stored at 25 and 35\(^\circ\)C for 130 days; but at 60\(^\circ\)C sample did not store for more than 10 days or 60 days at 45\(^\circ\)C. There was no significant difference in the browning at low temperature for both samples in woven sack and HDPE, but at 40\(^\circ\)C samples in HDPE was more brownish in color. The browning observed must have been as a result of oxidation of the fat in the full fat soy flour used for compounding the product. This is similar to the findings of Biranda et al.
(1985) that browning increased steadily with storage time in the control sample of PEDHA, a popular dehydrated Indian milk sweet, while in the sample packaged in LDPE-100 there was a significant increase only towards the later part of the storage. In LDPE-300 packaged sample, the absorbance value remained almost constant throughout the length of the storage. It is known that water is a product of non enzymatic browning. This can lead to product inhibition of the reaction. Labuza (1971) observed that the product of oxidation such as aldehyde and ketones can react with protein through Maillard browning which may lead to production of objectionable odor and flavor.

![Graph](image.png)

**Fig. 5.** Effect of temperature and packaging on the non enzymic browning of soy-melon and control “gari” stored at 20°C, 30°C and 40°C.

With the pores around the surface of the woven sack one would have expected the sample in woven sack to be more brownish, but the contrary is the case. This must have been due to the effect of continuous heating at 40°C resulting in lipid oxidation and Maillard reaction occurring in the sample with HDPE while the sample in the woven sack is insulated by the sack from effect of direct heat.

3.5. Effect of Temperature and Packaging on the Changes in Total Viable Count of Bacteria

There was a significant effect of temperature on the total viable count of bacteria for soy-melon “gari” during storage (P< 0.05). There was an initial increase in total viable count (TVC) in soy-melon “gari” from about 200cfu/gm with the time of storage and it decreased again (Fig 6). The initial increase and subsequent decrease were faster at 40°C than at 20°C and 30°C, the decrease was faster until it became nil and there were no colonies found after 16 weeks of storage. This must have been due to the combined effect of prolonged heating at 40°C and relative humidity of 45%,
which must have made the environment unsuitable for growth and proliferation therefore leading to their reduction. However, some microorganisms can survive for long periods in some foods. It had been reported by Ayres et al. (1980) that when commercial dried whole milk powder was stored at relative humidity of 5 to 70%, only 30-70% of the bacteria initially present survived for more than 2 years. He also observed that when egg white was sun-dried to a residual moisture level of 12% and stored at 50, 60, or 70°C, the number of survived Salmonellae varied inversely with moisture level and storage temperature (Ayres et al., 1980).

This means the higher the temperature the lower the number of organisms that survived.

![Graph showing the effect of temperature and packaging on the total viable count of bacteria (cfu/g) of soy-melon and control “gari” under storage](image)

**Fig. 6.** Effect of temperature and packaging on the total viable count of bacteria (cfu/g) of soy-melon and control “gari” under storage

There was a significant effect \( p \leq 0.05 \) of time and temperature on the total viable count of bacteria of the stored soy-melon “gari”.

It was also observed that there was a significant difference in the total viable count of bacteria of soy-melon “gari” packaged in both woven sack and HDPE film (Fig. 6). For samples stored at 30°C, the total viable counts were higher in the sample packaged in the woven sack throughout the storage period. This was due to the low permeability of the woven sack which allowed increase in moisture content which led to an increase in the total viable count. This was supported by earlier findings of Steinkraus (1983) and Ogiehor and Ikenebomeh (2006).
3.6. Effect of Temperature and Packaging on the Mould Count of Soy-melon “Gari”

Temperature had some significant effect on the mould count. It increased as the atmospheric temperature (30°C) is being approached (p ≤ 0.05). However, at 40°C, there were no observable mould colonies throughout the period of study (Fig 7). This might have been due to the low moisture content and the effect of continuous heating at accelerated temperature of 40°C for 32 weeks, which coupled with the low moisture content, did not favor the growth of mould. The moisture content ranged from 9.36 to 9.90% for the enriched samples and 9.91 to 10.74 for the control “gari” samples. When these values were located on the sorption isotherm curves for soy-melon “gari” at 20, 30 and 40°C, they gave corresponding water activity values less than 0.75 which was still within the safe region for the storage of dry products (Chuzel and Zakhia, 1991).

Rockland and Nishi (1980) categorized the optimum water activity of mould, yeast and bacteria to be above 0.80. Storage below this region at low moisture content will confer stability on the dried product.

Samples in the Woven sack had higher mould count than samples in the HDPE films (p < 0.05) (Fig. 7). This might have been due to the porosity of the woven sack allowing for respiration, air and moisture transfer, thereby favoring the growth of mould more than that of the HDPE films. This is in agreement with the findings of Akano et al. (1986) and Oyeniran (1980) who observed that there were no increases in the mould colony counts of both white and yellow “gari” samples stored below safe moisture level in HDPE bags, but they observed increase in samples stored in Hessian sack due to moisture uptake from the atmosphere. Also, samples stored in the plastic containers prevented moisture uptake and retained the initial qualities of the “gari” samples. Oyeniran (1980) also observed similarly that “gari” stored in polythene bags at lower moisture content did not grow mould while that stored in Hessian sacks at moisture content higher than 18.6% increased in mould count, gradually became discoloured before the end of the first month and started caking with bad odour by the end of the second month. Ogiehor and Ikenebomeh (2005) in their recent study also observed that fungal growth were higher in “gari” packaged in the Hessian sack than in those packaged in HDPE film. This might have been partly due to the uptake of moisture from the environment which might have led to condensation of moisture and eventual mould growth since there was tendency for “gari” to decrease or increase its moisture content, in an attempt to equilibrate with the atmospheric relative humidity (Oyeniran, 1980). However, to maintain this safe condition in the polyethylene the moisture content of the “gari” must be lower than the safe level of 12% and the water activity of the environment must not be higher than 0.75. These observations were also supported by previous findings. Masood et al. (2004) observed that higher moisture content favored mould growth. Mould growth was also less in paper bags than in polypropylene bags which they used as the packaging materials. These were comparable with those found by Bothast et al. (1991) and Upadhyay et al. (1994) who also observed similar trends during storage. These results are also in agreement with the previous reports of Efuuwewere and Uwanogho (1990); Turtle (1991) and Paine (1992) which showed that oxygen transfer rate and the permeability characteristics of the packaging materials evaluated to be in the order of polypropylene < polyester < hessian bags which in turn enhances the increase in microbial growth of the packaged “gari”. Microbiological growth is therefore one of the major factors in deciding the most suitable material for packaging a food product (Adejumo and Raji, 2012).
Fig. 7. Effect of temperature and packaging on the mould count (cfu/g) of soymelon and control “gari” under storage

4. Conclusion

Packaging and storing “gari” in HDPE film preserved “gari” better than the Woven sack. “Gari” stored better at temperature lower than 30°C. Storing “gari” above 40°C resulted in “gari” of impaired chemical and sensory qualities. “Gari” became brownish with burnt flavour at high temperature of storage. However, at 40°C, there was no observable mould growth throughout the period of study.

References

http://dx.doi.org/10.1111/j.1745-4549.1993.tb00736.x

http://dx.doi.org/10.1111/j.0308-8258.1993.tb02150.x


http://dx.doi.org/10.1111/j.1365-2621.1985.tb13275.x


http://dx.doi.org/10.1016/j.foodchem.2004.08.024

http://dx.doi.org/10.1111/j.1365-2621.1991.tb02004.x

http://dx.doi.org/10.1111/j.1365-2621.1981.tb02984.x

http://dx.doi.org/10.1002/jsfa.2740520312


http://dx.doi.org/10.1016/0260-8774(90)90029-8

http://dx.doi.org/10.1111/j.1365-2621.1997.tb04018.x

http://dx.doi.org/10.10111/j.1745-4557.1985.tb01056.x
http://dx.doi.org/10.1016/j.jfoodeng.2004.02.022
http://dx.doi.org/10.1007/BF02858697
http://dx.doi.org/10.5897/AJB2005.000-3135
http://dx.doi.org/10.1108/00346650310507118


http://dx.doi.org/10.1111/j.1365-2621.1985.tb13305.x


http://dx.doi.org/10.1111/j.1745-4549.1978.tb00556.x


http://dx.doi.org/10.1002/1097-4628(20010509)80:6<863::AID-APP1164>3.0.CO;2-R


http://dx.doi.org/10.1111/j.1745-4549.1978.tb00556.x


http://dx.doi.org/10.1016/S0955-6946(97)00016-2


