Solar drying of okra—effects of selected package materials on storage stability

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The effect of package material, physical form, and storage time on colour, viscosity and moisture content of solar-dried okra (Hibiscus esculentus) during storage was studied using two packaging materials (polyethylene and cotton), two physical forms of solar-dried okra (unmilled (whole) and milled (powdered)), at weekly intervals over a 6 week storage period. Results showed that package material and storage time significantly (P<0.01) affected all quality parameters monitored. The effect of physical form was significant (P<0.01) only on the colour (L′ and a′ values) of the products. The combined effect of packaging material and storage time significantly (P<0.01) affected colour (a′ values) and moisture content. Changes in moisture content of solar-dried okra was noted to affect, and most times highly correspond to changes in, some quality parameters. Overall analysis showed that powdered dried okra kept in a polyethylene package survived storage best.

Keywords: okra, packaging, dried products, moisture content, storage.

INTRODUCTION

Packaging plays an important role in determining the stability of foods by influencing those factors which cause or contribute to food deterioration during storage. The nature of a package determines the composition of air inside the package, which in turn is known to affect the rate and extent of nutrient loss and microbial activity among other things. For example, ascorbic acid being oxygen sensitive may easily be lost from products stored in oxygen-permeable packages (Salunkhe et al., 1991). By providing a barrier against oxygen, plastic films restrict the growth of normal aerobic spoilage micro-organisms and help extend the shelf-life of packaged foods (Eustace, 1981). Lower stability towards water activity-dependent deteriorative processes, could be expected for products packaged in low-density polyethylene films (LDPE) compared with those in high-density polyethylene films (HDPE), due to the lower oxygen and water vapour permeability of HDPE (Valencia and Goycoolea, 1992). Packaging is therefore supposed to provide the correct environmental conditions for shelf-life extension of foods, and as such, needs far greater thought and care than is customarily realized.

Okra (Hibiscus esculentus L.) is a very popular fruit (normally consumed as a vegetable) in Ghana. The fresh, young and tender fruits are used as boiled vegetables for preparing stews and as additives for soups and stews. They may also be dried and pounded into powder for use as flavouring in these dishes. In general, when okra is used for local dishes, it is for the purpose of providing flavour, thickening (viscosity) and colour (aesthetic appeal). They also provide some amount of vitamins, dietary fibre, calories and minerals (Tindal, 1983; Ihekoronye and Ngoddy, 1985).

The traditional method for preserving okra involves slicing and sun-drying of the fruits until they become brittle (Kordylas, 1991). Dried products are either packaged whole in baskets, jute sacks, polyethylene sacks and gourds, or they are pounded into powder and packaged in bowls, gourds, cotton and polyethylene bags. Information on how these various packaging
forms affect the quality of the dried okra in storage is limited.

The objective of this study was to investigate the effect of various package materials and physical forms of dried okra (milled or unmilled) on some nutritional and sensory qualities of dried okra during storage.

**MATERIALS AND METHODS**

**Experimental design**

A randomized complete block design of two factors, comprising two packaging materials, seven storage times and two physical forms as blocks, were used for this study. Two batches of okra sample were used, and duplicate determinations per batch were carried out for the parameters monitored. Statistical analysis (ANOVA) and linear regression analyses \((n = 12)\) were carried out on data obtained using the **MICROSOFT EXCEL** (1992) statistical programme.

**Sample preparation and drying**

Fresh okra fruits were obtained from farms near Kumasi. These fruits were harvested 5–8 days after fruit set, and those measuring 60–100 mm long and 15–20 mm in diameter were sorted out and selected for the study. After washing with tap water and draining, the fruits were sliced into 10 mm thick transverse slices, using a fruit slicer, after which they were dried in a solar tent dryer for 48 h under the following conditions: temperature, 30–60°C; air speed, 0–0.2 m/s (thermal anemometer); load, 1.5 kg/m². The slicer and dryer were designed and manufactured by the Mechanical Engineering Department of the University of Science and Technology, Kumasi, Ghana. The slice thickness and drying time were based on results obtained from previous studies (Adorn et al., 1996).

About half of the dried slices of okra were milled into a coarse powder (powder, \(P\)) using a laboratory mill (Karl Kolb, Scientific Technical Supplies, D-6072, Dreieich, West Germany) and the remaining half packaged whole as dried products (whole, \(W\)).

**Packaging**

Two packaging materials, polyethylene and cotton were used in this study.

1. 20 g samples of each physical form (i.e. powdered and whole) were packaged in 100×150 mm² sealed polyethylene (Polytex Industries Ltd, Accra, Ghana) bags (poly).
2. 20 g samples of each physical form were packaged in 100×150 mm² sealed flour sacks (Gafco Flour Mill, Tema, Ghana) made from cotton material (cotton).
3. 20 g samples of each physical form were placed in open 100 ml glass beakers to serve as a control.

Packaged samples were then stored under ambient conditions \((28 ± 3°C, 74 ± 4%RH)\) and analyzed weekly for colour, viscosity and moisture content over a storage period of 6 weeks.

**Analysis**

Moisture content of the samples was determined using AOAC official methods of analysis (AOAC, 1984).

Colour on the \(L^a b^*\) colour system was determined using a Minolta Chroma Meter (model CR-200, Minolta Camera Co. Ltd, Japan) on the milled samples. The Chroma meter was calibrated with a standard white tile \((L = 97.63, a = -0.48, b = +2.12)\). Viscosity was determined by boiling 2 g of milled sample in 100 ml distilled water for 5 min. The resulting solution was cooled, filtered (cheese cloth) and its viscosity determined using the U-tube viscometer technique (Kirk and Othmer, 1955; British Pharmacoepia, 1980). Viscosity was calculated relative to distilled water per gram of sample taken.

**RESULTS AND DISCUSSION**

**Moisture content**

The results obtained showed a general increase in moisture content (Fig. 1) with storage time. Dried okra samples in different package materials showed significantly different \((P<0.01)\) moisture contents, but the physical form did not significantly \((P>0.05)\) influence the moisture content. Dried okra packaged in cotton and control materials were not different \((P>0.05)\) in their moisture contents throughout the 6 week storage period. Samples stored in polyethylene films showed a markedly lower moisture content \((P<0.01)\) compared with the other packages. Moisture content in polyethylene packages remained fairly unchanged up to Week 3, before there were any significant \((P<0.05)\) increments, with poly-W showing a more rapid increase than poly-P samples. After 4 weeks, poly-W okra had higher moisture content \((P<0.01)\) than poly-P okra. Analysis of the data indicated that the combined effects of packaging form and storage time on moisture content of dried okra was highly significant \((P<0.01)\).

The amount of water vapour reaching the interior of an intact pack and hence of water reaching the packaged products will be determined by the permeability of the packaging material. Polyethylene films have a far lower permeability to water vapour compared to cotton materials. Accordingly, accessibility of water vapour from the surrounding air to polyethylene products would be expected to be lower than in products packaged in cotton and the control products. These reasons...
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may have accounted for lower moisture contents in polyethylene film-packaged dried okra compared to the other packaged samples. Higher stability towards water activity dependent deteriorative processes could thus be expected for polyethylene film packaged dried okra when compared with the other package forms.

**Colour**

Colour components of dried okra responded differently to various controlling factors during storage. The physical form was observed to affect visual lightness ($L^*$) and green/red colour ($a^*$) ($P \leq 0.01$). All colour components were also affected by type of package material and storage time ($P \leq 0.01$). The interaction of these two factors also influenced significantly ($P \leq 0.01$) the green/red colour of samples, but had no effect on visual lightness.

Figure 2 shows that cotton and control okra rapidly lost their green colour during storage ($a^*$ values become more positive), while poly okra samples maintained their green colour up to 4 weeks of storage before there was any significant change compared to the initial green colour at Week 0. Green/red colour values strongly correlated with moisture content in poly ($r = 0.96$), cotton ($r = 0.85$) and control ($r = 0.92$) packages. Overall analysis revealed powdered products were greener (more negative $a^*$ values) than whole products packaged in similar package materials. With respect to package materials, the order of decreasing greenness was: poly > control > cotton.

Visual lightness or whiteness of dried okra remained fairly unchanged or varied minimally for all samples, except for whole products packaged in cotton and control materials, which recorded decreasing visual lightness with storage time (Fig. 3). Whole products were generally darker ($P \leq 0.01$), and varied more in visual lightness than powdered products in similar packages.

The desirable green colour of okra is due to the presence of chlorophyll pigments (Tindal, 1983; Yamaguchi, 1983). Chlorophyll degradation in plant tissues can occur through low pH-catalysed reactions leading to brown pheophytin pigment formation (Okoli et al., 1988), and loss of green colour ($a^*$ values become more positive). Dried okra in storage absorbs water, the rate and extent depending on the permeability of the package among other things. At the right moisture content, respiration could continue in the dried okra tissues, leading to utilization of sugars and production of acids. These reactions have a complex interdependence on water activity or moisture content. The acids produced could cause chlorophyll degradation. This phenomenon has been reported by Kordylas (1991) to occur in open-air sun-dried okra if drying is not rapid enough, especially in poor drying weather.

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**Fig. 1.** Changes in moisture content of solar-dried okra stored in poly, cotton, and control packages.

**Fig. 2.** Changes in green colour of solar-dried okra stored in poly, cotton, and control packages.
Non-enzymatic browning is also known to occur in dried foods during protracted storage. This produces dark pigments and destroys the natural colour of foods (Ihekoronye and Ngoddy, 1985; Salunkhe et al., 1991). The chemistry of these reactions are very complex and numerous mechanisms have been advanced to explain them. Their understanding is further complicated by their complex dependence on factors such as water content, water activity, type and state of tissue, environmental conditions, etc. (Hodge, 1953). Compared to powdered okra, whole okra with a better tissue organization presents a higher possibility of reactants involved in non-enzymatic browning reactions coming together in the right environment for reactions to occur. These reasons probably accounted for the rapid darkening (lower \( L^* \) values) of whole okra stored in cotton and control packages. The dependence of these reactions on moisture content is shown by the high correlation between \( L^* \) values and moisture content for cotton-W \((r = -0.97)\) and control-W \((r = -0.98)\) samples, as well as a wider variation in \( L^* \) values for poly-W samples as moisture content increased.

**Viscosity**

There was a general decrease in viscosity recorded for all okra samples irrespective of package material or physical form (Fig. 4). Though the effect of physical form was not significant in determining viscosity of dried okra in storage, package material and storage time did significantly \((P \leq 0.01)\) influence viscosity of the samples. On average, poly products retained more of their original viscosity than other packaged products, with whole okra packaged in cotton sacks \((cotton-W)\) showing a more rapid loss of initial viscosity.

Viscosity, an important sensory attribute which serves for consumer appeal, is caused by mucilages present in okra. With moisture uptake, dried plant tissues could continue to respire, leading to sugar utilization and acid production (Kordylas, 1991). Acid hydrolysis at low \( pH \) can cause selective chain cleavage of polysaccharides in okra mucilage into short-chain sequences or blocks (Blanshard and Mitchell, 1979). But the traditional concept of polysaccharide gel network, involving junction zone formation for producing viscosity in solutions requires a minimum chain length \((15-20\) residues) for stable associations between polysaccharide chains (Whistler, 1973). Thus, by occupying binding sites on intact polymer chains, without contributing to intermolecular crosslinking, the presence of products of acid hydrolysis (short-chain segments) can disrupt network formation and thus reduce viscosity in solution (Blanshard and Mitchell, 1979). The viscosity trend observed in this study may be attributed to the above reasons. The influence of moisture content on viscosity is shown by the observed correlation coefficients \((r)\) of \(-0.78, -0.83, \) and \(-0.88\) for poly, cotton, and control samples, respectively.

From the results obtained in this study, it was evident that, for dried okra in storage, moisture content played
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a major role in determining the product quality at various time periods. Changes in moisture content of dried okra was noted to affect, and most times highly correspond to changes in certain quality parameters. This seems to suggest that rehydration of dried products during storage through absorption of water from the surrounding air, is one of the single most important quality deteriorating factors. This underscores the need to keep dry products in storage cool and dry. The use of high moisture barrier packaging materials is therefore advocated for long-term storage of dried okra. The good performance of polyethylene film package in this study supports this suggestion. Nevertheless, the effects of storage time and physical form of the product cannot be overlooked, as they also contribute to some quality changes observed. These factors were observed to modify the effects of moisture content. The maintenance of a better tissue organization in whole dried products compared with powdered ones contributed to higher quality deterioration in whole products. Intact tissues provide the right environment and condition which favour deteriorative reactions.

CONCLUSION

In comparison with other packages employed in the study, polyethylene films acting as a high moisture barrier material caused minimal change in moisture content of samples, and hence minimal quality deterioration of dried okra. The use of polyethylene films or other high moisture barrier materials is therefore recommended for storing dried okra for long-term storage. The effectiveness of polyethylene film packaging in preserving dried okra quality is however related to some extent on the storage time and physical form of the product.

REFERENCES


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