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Effect of packaging material and storage on chemical composition and sensory quality of sweet potato crisps

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Abstract
This study investigated the effect of four packaging materials; High density polyethylene (HDPE), Low density polyethylene (LDPE), Plastic (PL), and Aluminium foil (AL), on the composition and sensory properties of sweet potato crisps stored at room temperature (28±2ºC) for three weeks. Moisture content, reducing sugar and free fatty acid of crisps increased with time for each of the packaging materials, with the rate of increase in the order HDPE<PL<AL<LDPE. There was no significant difference (p³0.05) in peroxide values of crisps stored in HDPE across the storage period. The crisps showed between slight and moderate differences in colour, taste, aroma and crispness from freshly fried crisps over the storage period. The order of overall acceptability of the crisps stored in the various packaging materials for the storage period was HDPE (1-3 weeks)>PL (1-3 weeks)>AL (1-2 weeks)>LDPE (1-2 weeks). Crisps stored in AL and LDPE at 3 weeks were the least acceptable.

Key words: sweet potato crisps, packaging, storage, food quality

Introduction

Sweet potato [*Ipomoea batatas* L. (Lam.) is the seventh most important food crop and next to cassava among the root and tuber crops grown in the world (Lebot, 2009). Nigeria is a leading producer of sweet potato in Africa with an estimated production of 3.3 metric tonnes per year, and second in the world, next to China (FAOSTAT, 2012). Sweet potato has a low glycemic index, indicating low digestibility of the starch despite its high carbohydrate content (ILSI, 2008). Sweet potato contains functional components such as polyphenolics, anthocyanins, fibre and carotenoids which serve physiological functions such as anti-oxidation, anti-diabetes, anti-hypertension (Yoshimoto, 2010).

Fried products have been found to be among the sweet potato products that are not only capable of increasing the utilization of sweet potato, but also have high commercial potential (Onumah et al. 2012). Deep fat frying is a simultaneous heat and mass transfer process, which leads to a succession of physical and chemical changes in a product (Hindra and Baik, 2006). The fried products have an attractive colour (golden brown), distinctive mouth feel, pleasant taste as well as fried flavours and unique textural properties (crispy crust formation). In spite of significant fat transfer to the products, frying has been favoured due to its ability to create unique organoleptic properties.

Sweet potato crisps are thin slices of sweet potato roots processed by deep-fat frying. The limited studies published on frying of sweet potato had focused on establishing optimum frying conditions for selected quality attributes of the fried products. For instance, Singh et al 2003 reported that for maximum moisture loss, minimum oil uptake, and crispness, as well as high colour, flavor and texture scores, the optimum conditions were frying temperature of 174.7 °C for 26 sec with the use of varying salt concentrations. According to Brigatto Fontes (2011), frying at 160 °C for 3 min 30 sec in palm olein produced sweet potato chips with moisture content of 7.43% and oil content of 14.46% while a temperature of 180 °C for the same frying period using palm stearin produced chips with moisture and oil contents of 3.47% and 13.1% respectively. Ali et al. 2012 studied the effect of cultivar on quality attributes of sweet potato fries and crisps; no significant difference existed in all the sensory attributes of crisps produced from the cultivars. The effect of cultivar on starch digestibility and predicted glycemic index (GI) of fried sweet potato cultivars have been reported by Odenigbo et al. (2012), all the cultivars had products with low to moderate GI values.

In spite of the potentials of fried sweet potato products to be marketed as healthy snacks, particularly if cultivars rich in provitamin A, ascorbic acid and other functional components are used, post process decrease in quality can take place if the products are allowed to take up moisture or excessive oxygen. Moisture uptake and oxidation can result in leatheriness and rancid off-flavours, respectively. It is therefore important that the chips are packaged in suitable moisture-proof and airtight materials immediately after processing (Woolfe 1992). The shelf life of fried foods is mostly determined by the moisture content after frying; foods such as potato crisps which are thoroughly dried, have a shelf life of up to 12 months at ambient temperature. However the quality is maintained by adequate barrier properties of packaging materials and correct storage conditions (Fellows, 2000a).

Packaging materials for food include plastic films, aluminum foils and paper. The type of packaging used goes a long way in enhancing the presentation, maintenance of freshness and shelf life of food products (Fellows 2000b). The objective of this study was to determine the effect of some of the commonly used packaging materials and storage period on some quality characteristics of sweet potato crisps.

Materials and Methods

Yellow-fleshed sweet potato roots bought from Mile 12 market in Lagos were used. The roots were thoroughly washed under running potable water and peeled manually with a stainless steel kitchen knife. The peeled roots were sliced into discs of 1.2 mm thickness using a plantain slicer (Model No. 714.216 Mother's Choice, Houston, Texas). The slices were washed carefully to remove surface starch, sugars and other substances so as to obtain better quality crisps (Lisinka and Leszczynski, 1992). The sweet potato slices were blanched at 93 °C for 2 min and thereafter drained and surface dried on paper towel before frying. The slices were fried in a deep fat fryer (Model: Platinum PL-DF-2.5L, China) using refined, bleached and deodorized vegetable oil (Turkey brand, Malaysia) at 170 ºC for 3 min. The oil was preheated to the frying temperature prior to frying. The fried crisps were placed on a wire mesh tray to drain the oil and thereafter blotted with tissue paper to remove excess surface oil. Sweet potato crisps were packed in each of four packaging materials; low density polyethylene (LDPE), high density polyethylene (HDPE), aluminum foil tubs (AL) with cardboard cover, and transparent plastic tubs (PL) with transparent plastic cover. The LDPE and HDPE were sealed with an electric heat sealer after placing the samples in them. The packaged sweet potato crisps were stored at room temperature (28±2 °C) over a period of 3 weeks.

Compositional analysis

Moisture content, reducing sugar, free fatty acids and peroxide values of the crisps were determined on freshly prepared crisps and thereafter at weekly intervals. Moisture content of sweet potato crisps was determined by the oven-drying AOAC Method 934.01, procedure 4.1.03, (AOAC, 2000). Reducing sugar was determined by the Lane-Eynon method, by titration in the presence of methylene blue (AOAC Method 923.09, 14th Ed.) Free fatty acid was determined by titration with NaOH in the presence of phenolphthalein indicator, as described by Nielsen (2003). Peroxide value was determined by titration with standardized sodium thiosulphate using a starch indicator as described by Nielsen (2003).

Sensory evaluation

The stored sweet potato crisps were evaluated against freshly prepared samples weekly for changes in sensory attributes and overall acceptability. A 10-member semi-trained panel evaluated the sweet potato crisps for attributes of taste, colour, flavor and crispness using a 'difference from control' test (3-slightly different, 2-moderately different, 1-extremely different) (Watts et al. 1989). A total of five samples were evaluated per session per week, were freshly prepared samples served as reference/control. Overall acceptability test was also conducted by an in-house consumer panel comprising of 30 untrained undergraduate students who were regular consumers of sweet potato, using a '9-point hedonic scale' (9-like extremely, 8-like very much, 7-like moderately, 6-like slightly, 5-neither like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much, 1-dislike extremely (Lyon et al. 1992).

Statistical analysis

Descriptive analysis of the compositional and sensory data was conducted. The data were also subjected to a one-way 'analysis of variance' test to determine if significant differences ($p<0.05$) existed among the samples of sweet potato crisps. Duncan's Multiple Range Test (DMRT) was employed as a post hoc test to separate the means, were differences existed. A multivariate General Linear Model (GLM) analysis was performed to determine the individual and interactive effects of the treatments (packaging material and storage period) on the attributes measured. Significant effects were established at $p \leq 0.05$, 0.01 and 0.001 levels. Pearson's correlation coefficient was computed to determine significant ($p \leq 0.05$) relationship between composition and sensory attributes of sweet potato crisps. The correlation between individual sensory attributes and overall consumer acceptability was also calculated in order to determine the attributes that are important to consumers. Statistical packages used were Microsoft Excel and SPSS Version 16.0 (SPSS Inc., Chicago, IL, USA).

Results and Discussion

Table 1 shows the effect of packaging material and storage period on the moisture content, reducing sugar, free fatty acid and peroxide value of sweet potato crisps. For each of the packaging material, the moisture content of the crisps increased with storage period. This increase in moisture content was significant ($p \leq 0.05$) for each of the packaging material and across the storage period. Samples packed in HDPE exhibited the lowest increase in moisture while samples packed in LDPE exhibited the highest increase. Generally, the order of increase was HDPE < PL < AL < LDPE. Various packaging materials have different barrier properties to moisture. The differences in moisture content may be due to differences in water vapour permeability of the packaging materials. Ammawath et al 2002, reported a similar observation for deep-fat-fried banana chips. During storage, the crisps tend to absorb moisture from the surroundings. Moisture loss or uptake is one of the the most important factors that controls the shelf life of foods. The micro-climate within a package is determined by the vapour pressure of moisture in the food at the temperature of storage and the permeability of the packaging. Control of moisture exchange is necessary to prevent microbiological or enzymic spoilage, drying out or softening of the food, condensation on the inside of packages and resulting mould growth (Fellows 2000b).

The reducing sugar of the sweet potato crisps exhibited significant increase ($p \leq 0.05$) with an increase in storage time for each of the packaging material. The rate of increase was highest in LDPE, followed by plastic tub, then aluminum foil and lowest in HDPE. Reducing sugar is a primary factor that contributes to Maillard reaction when food is cooked. Maillard reaction has played an important role in improving the appearance and taste of foods. It influences food properties like colour, aroma, taste and nutritional value (Martins et al. 2001).

The free fatty acid (FFA) also increased significantly ($p<0.05$) over time for each of the packaging material. Sweet potato crisps stored in HDPE for one week had the lowest FFA value while samples stored in LDPE for three weeks had the highest. Oxidation of lipids, primarily the unsaturated fatty acids of storage oil in plant foods, is a frequent cause of poor shelf life and off-flavours in processed foods. During deep-fat frying, vegetable oils can undergo oxidation, cyclization, polymerization, degradation to volatile compounds, and hydrolysis. A combination of these chemical changes causes off-flavours, rancid aromas, greasy mouth feel, and impaired nutritional value in fried foods. Even during storage, fats can undergo oxidative changes that give rise to objectionable flavours and odours (Ory et al. 1985).

Peroxide value is an indication of deterioration of fats and is used to estimate oxidation. The lowest peroxide values (0.04-0.05 mEq/kg) were found in sweet potato crisps stored in HDPE across the storage period. It is also noteworthy that there was no significant difference ($p>0.05$) in peroxide values of crisps stored in HDPE. For each of the packaging materials, there was a significant increase in peroxide values with increase in storage period from one to two weeks. However, for AL, LDPE and PL, the values decreased significantly ($p \leq 0.05$) as the storage period increased from two to three weeks. This reduction suggests a breakdown of the lipid peroxides to form secondary products (Ory et al. 1985). The moisture content, reducing sugar, free fatty acid and peroxide value were all significantly affected ($p \leq 0.001$) by the individual and interactive effects of packaging material and storage period.

The sensory scores for sweet potato crisps as influenced by storage period and packaging material is shown in Table 2. The stored sweet potato crisps showed between slight and moderate differences in the attributes evaluated compared to freshly-fried crisps over the storage period. Generally, the colour, taste, aroma and crispness were significantly affected ($p \leq 0.05$) by packaging material and storage period. Crisps stored in HDPE had the highest scores for each of the attributes. The order of sensory scores for the crisps was HDPE> PL> LDPE>AL. The colour scores increased significantly (p≤0.05) with increase in storage period for crisps stored in AL and LDPE. Colour scores for crisps stored in HDPE and PL increased significantly (p≤0.05) for the first two weeks and thereafter increased by the third week. For each of the packaging material, crisps stored at 3 weeks had the highest scores for colour.

Table 1: Chemical composition of sweet potato crisps as affected by packaging material and storage period

Packaging material	Storage period (Week)	Moisture Content %	Reducing sugar %	FFA %	PV mEq/kg
	0	2.01a	3.05a	ND	ND
AL	1	3.01d	4.13d	1.54d	0.06a
	2	5.27h	5.11h	2.82g	0.75e
	3	6.16kl	7.09l	3.10i	0.11b
LDPE	1	3.98e	4.95g	1.41c	0.16c
	2	5.98j	6.51j	3.10i	0.87f
	3	6.21l	7.52m	3.38j	0.09a
HDPE	1	2.11b	3.18b	1.13a	0.04a
	2	4.21f	4.58e	2.58e	0.05a
	3	5.48i	5.75i	2.69f	0.05a
PL	1	2.29c	3.44c	1.26b	0.16c
	2	4.41g	4.81f	2.59e	0.20d
	3	6.15k	6.69k	2.90h	0.07a
Min		2.01	3.18	1.13	0.04
Max		6.21	7.52	3.38	0.87
Mean		3.97	4.75	2.38	0.22
SD		1.71	1.56	0.79	0.28
Effects					
PM		***	***	***	***
SP		***	***	***	***
PM x SP		***	***	***	***

Values are mean of two determinations, SD-standard deviation
Values followed by the different alphabets are significantly different (p≤0.05)
AL: Aluminum foil; LDPE: Low density polyethylene; HDPE: High density polyethylene; PL: Plastic
FFA- Free fatty Acid; PV- Peroxide Value; ND – not determined
***significant effect at p≤0.001

Although crisps stored in HDPE and PL showed similar trend in taste, this trend was in opposite direction to those of AL and LDPE; the scores initially reduced from week 1 to week 2 and thereafter increased by week 3.

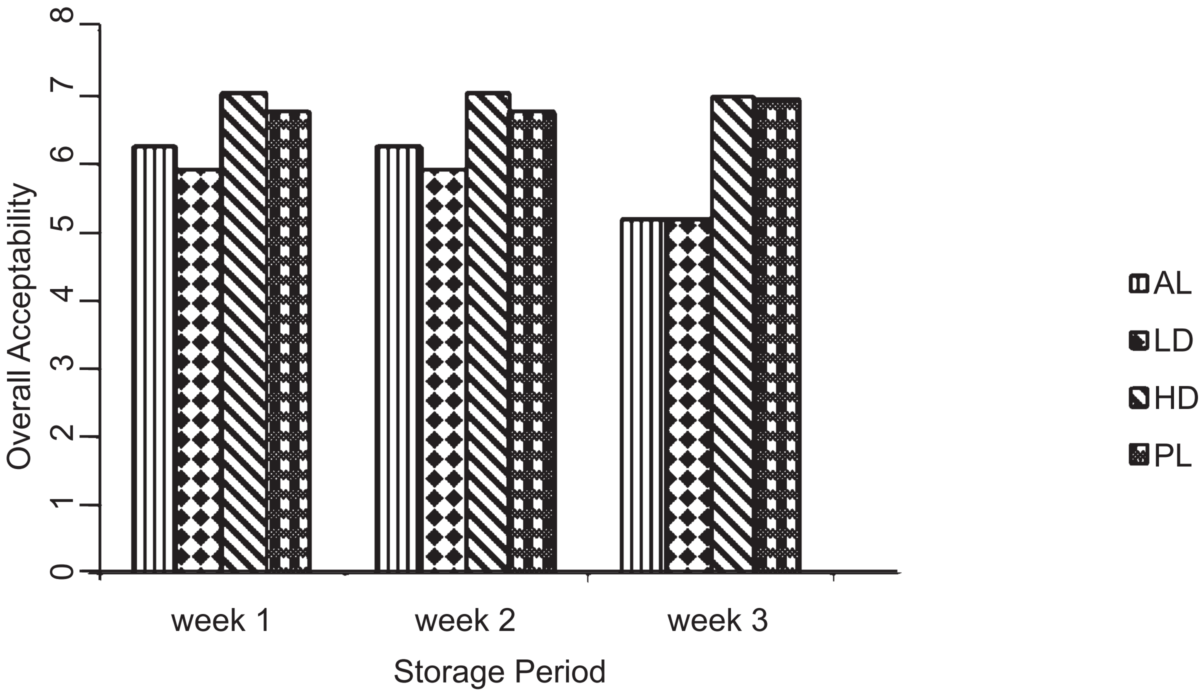
Sweet potato crisps stored in AL and LDPE showed similar trend for taste; the values increased with increase in storage period from week 1 to week 2 and thereafter decreased by week 3. HDPE and PL showed similar trend in taste which was different from those of AL and LDPE. The trend of aroma scores were similar for crisps stored in AL and PL; the scores increased with increase in storage period for the first two weeks and thereafter reduced by the third week. For LDPE, the aroma scores increased with increase in storage period. Crisps stored in HDPE showed an initial decrease in aroma scores by week 2 and thereafter increased by week 3. The trends of crispness scores were irregular for each of the packaging material across the storage period. Nevertheless, samples stored in HDPE and PL had significantly higher scores (p≤0.05) than those in LDPE and AL. The highest attribute score was observed for colour (2.43) and crispness (2.43) followed by taste (2.37) and aroma (2.33) and crispness (2.33). This may suggest the order of importance of these attributes of sweet potato crisps to consumers. All the sensory attributes of the crisps were significantly affected ($p \leq 0.001$) by the individual and interactive effects of packaging material and storage period. The overall consumer acceptability scores for sweet potato crisps as influenced by packaging material and storage period is shown in Figure 1. The order of overall acceptability of the crisps for the storage period was HD (1-3 weeks)>PL (1-3 weeks)>AL (1-2 weeks)>LD (1-2 weeks). Crisps stored in AL and LDPE at 3 weeks were the least acceptable.

Pearson correlation between chemical composition and sensory attributes of sweet potato crisps (table not shown) indicated that only peroxide value and colour showed low but significant correlation (-0.42) ($p \leq 0.05$). On the other hand, overall acceptability showed significant correlations with moisture content (-0.48) ($p \leq 0.05$), reducing sugar (-0.64) ($p \leq 0.01$) and free fatty acid (-0.41) ($p \leq 0.05$), this suggests that the lower the moisture content, reducing sugar and free fatty acid, the higher the acceptability of the sweet potato crisps. There were also significant correlations ($p \leq 0.01$) between overall acceptability and colour (0.57), taste (0.60) and crispness (0.79) of the sweet potato crisps.

Table 2: Sensory scores for sweet potato crisps as affected by packaging material and storage period

Packaging material	Storage period (Week)	Colour	Taste	Aroma	Crispness
AL	1	1.83de	1.67b	1.73a	1.93b
	2	1.87e	1.90e	2.00e	2.30f
	3	1.90f	1.67b	1.77a	1.57a
LDPE	1	1.47a	1.53a	1.90c	1.90b
	2	1.60b	1.90de	2.07f	2.07c
	3	1.80d	1.87d	2.20g	2.07c
HDPE	1	2.07h	2.07g	2.33h	2.30f
	2	2.03g	2.03f	1.97d	2.30f
	3	2.37i	2.37h	2.17g	2.43g
PL	1	2.07h	2.00f	1.87b	2.17d
	2	1.70c	1.73c	2.17g	2.23e
	3	2.43j	2.00f	1.93c	2.33f
Min		1.47	1.53	1.73	1.57
Max		2.43	2.37	2.33	2.43
SD		0.28	0.18	0.18	0.24
Effects					
PM		***	***	***	***
SP		***	***	***	***
PM x SP		***	***	***	***

Values are mean of two determinations, SD-standard deviation
Values followed by the different alphabets are significantly different ($p \leq 0.05$)
AL: Aluminum foil; LDPE: Low density polyethylene; HDPE: High density polyethylene; PL: Plastic
PM-packaging material, SP-storage period
***significant effect at $p \leq 0.001$



AL-Aluminium foil LD-Low density polyethylene HD-High density polyethylene PL-Plastic

Figure 1: Overall acceptability of sweet potato crisps as affected by packaging material and storage period

Conclusion

Among the four types of packaging materials used for sweet potato crisps, HDPE and PL resulted in the least changes in moisture content, reducing sugar, free fatty acid and peroxide value of the sweet potato crisps. Also, crisps stored in HDPE and PL throughout the storage period of three weeks showed the least difference from freshly-fried crisps in terms of colour, taste, aroma, crispness and overall consumer acceptability. This study has shown that both HDPE and PL could be considered as appropriate packaging material to retain important quality characteristics of deep-fat fried sweet potato crisps within the storage period investigated.

References

Ali, N., Falade K.O. and Akingbala, J.O. 2012. Effect of cultivar on quality attributes of sweet potato fries and crisps. Food and Nutrition Sciences, 3:224-232.

Ammawath, W., Che Man, Y.B., Yusof, S. and Rahman, R.A. 2002. Effects of type of packaging material on physicochemical and sensory characteristics of deep-fat fried banana chips. J. Sci. Food Agric. 82:1621-1627.

AOAC. 2000. Official Methods of Analysis. 17th ed. Association of Official Analytical Chemists, Washington, DC.

Brigatto Fontes, L.C., Oliveria, F.G. and Collares-Queiroz, F. P. 2011. Optimization of the deep-fat frying process of sweet potato chips in palm olein or stearin. American Journal of Food Technology 6(5):348-361.

FAOSTAT Food and Agriculture Organization of the United Nations, Statistical Database, Production 2009. http://faostat.fao.org/site/339/default.aspx. Accessed 5th January, 2012.

Fellows, P.J. 2000a. Frying. In: Food processing technology: Principles and practice. Woodhead Publishing Limited, Cambridge, England. Pp 355-362.

Fellows, P.J. 2000b. Packaging. In: Food processing technology: Principles and practice. Woodhead Publishing Limited, Cambridge, England. Pp 462-510.

Hindra, F. and Baik, O.D. 2006. Kinetics of quality changes during food frying. Cri. Rev. Food Sci. Nutr. 46:239-258.

ILSI (International Life Sciences Institute). 2008. Assessment of foods and feeds. Critical Reviews in Food Science and Food Safety 7:81-91.

Lebot, V. 2009. Tropical root and tuber crops:

cassava, sweet potato, yams and aroids. Crop Production Science in Horticulture Series 17. CABI, Oxfordshire, UK.

Lisinka, G. and Leszczynski, W. 1992. Potato science and technology. Department of storage and food technology, Agriculture Academy, Wrocliam, Poland.

Martins, S.I.F.S., Jongen, W M.F. and van Boekel, M. A.J.S. 2001. A review of Maillard reaction in food and implications to kinetic modeling. Trends in Food Science & Technology 11, 364-373.

Matz, A.S. 1993. Snack food technology. Van Nostrand Reinhold, New York.

Nielsen, S.S. 2003. Food Analysis. 3rd ed. Springer, New York.

Odenigbo, A., Rahimi, J., Ngadi, M., Amer, S., Mustafa, A. 2012. Starch digestibility and predicted glycemic index of fried sweet potato cultivars. Functional Foods in Health and Disease 2(7):280-289.

Onumah, G., Dipeolu, A. and Fetuga, G. 2012. Sweet potato Value chain study: Exploring opportunities to promote greater exploitation of the benefits of sweet potato in representative states in Nigeria. CIP Working Paper. International Potato Center, Lima, Peru.

Paine, F.A. and Paine, H.Y. 1992. A handbook of food packaging. Chapman and Hall Publishers, London.

Ory, R.L., St. Angelo, A. J., Gwo, Y.Y., Flick, G.J. and Mod, R.R. 1985. Oxidation-induced changes in foods. In: Chemical changes in food during processing. Richardson T. and Finley J.W. (Eds.). CBS Publishers & Distributors, New Delhi, India. Pp. 205-217.

Sahin, S. 2000. Effect of frying parameters on the colour development of fried potatoes. Eur. Food Res. Technol. 211:165-168.

Singh, S., Raina, C.S., Bawa, A. S. and Saxena, D.C. 2003. Optimisation of processing variables in the preparation of sweet potato chips using response surface methodology. Eur Food Res Technol. 217: 374-381.

Watts, B.M., Ylimaki, G. L., Jeffery, L.E., Elias, L.G. 1989. Basic sensory methods for food evaluation. The International Development Research Centre, Ottawa, Canada.

Woolfe, J. 1992. Sweet potato: An untapped food resource. Cambridge University Press, Cambridge, UK.

Yoshimoto, M. 2010. Physiological functions and utilization of sweet potato. *In*:Ramesh, C.R. and Tomlins, K.I. (eds.) Sweet potato: Post harvest aspects in food, feed and industry. Nova Science Publishers, Inc., New York. Pp 59-89.