



American Journal of **Food Technology**

ISSN 1557-4571



Academic
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Losses of Ascorbic Acid During Storage of Fresh Tubers, Frying, Packaging and Storage of Potato Crisps from Four Kenyan Potato Cultivars

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ABSTRACT

The ascorbic acid (AA, vitamin C) levels of tubers was determined in four Kenyan potato cultivars (Dutch Robyn, Tigoni, 393385.39 and 391691.96) grown under standard cultural conditions and the effect of storage on fresh tubers was evaluated. Tubers were processed into crisps and the effect of frying temperature, package type, storage temperature and time were also determined. There was significant ($p \leq 0.05$) variation due to cultivar and storage condition was found to affect the levels of ascorbic acid in fresh tubers. There was significant ($p \leq 0.05$) reduction on the level of ascorbic acid (45% on the average) in all the cultivars when tubers were fried into crisps. Packaging type and storage temperature significantly ($p \leq 0.05$) influenced the amount of ascorbic acid retained by crisps within the storage period. It is therefore important for processors to choose lower frying temperature and proper packaging for maximum vitamin C retention. Storage of potato crisps at temperatures beyond 30°C results in lower levels of ascorbic acid retention.

Key words: Ascorbic acid, potato, polyethylene, aluminium foil, corn oil, transparent

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important tuber crop widely consumed in the world (Burgos *et al.*, 2009). It is ranked fifth in terms of human consumption and fourth crop after wheat rice and maize in worldwide production (Horton, 1987; Burlingame *et al.*, 2009). Apart from supply of energy and high quality protein, potato has also been known to be an important source of vitamins and minerals (Woolfe, 1987; Abong *et al.*, 2009a). The contribution of potato and its products as a source of ascorbic acid (AA, Vitamin C) to human diet has, however, been underestimated (Dale *et al.*, 2003).

As an antioxidant and an essential component of most living tissues, ascorbic acid (Vitamin C) has been known to play an important role in protection against oxidative stress (Farvin *et al.*, 2009; Badreh *et al.*, 2009; Burgos *et al.*, 2009). In addition, its role in enhancing the bioavailability of non-haem iron in the human body has been shown (Haase and Weber, 2003; Teucher *et al.*, 2004). Recommended Daily Allowance (RDA) of vitamin C varies not only with age, but also from country to country. The Food and Agriculture Organization (FAO/WHO, 2001) indicated that the

recommended nutrient intake of vitamin C ranges from 25 to 70 mg day⁻¹, depending on age and that as little as 6.5-10.0 mg day⁻¹ of the vitamin will prevent the appearance of scurvy on the body. In previous studies, however, based on available biochemical, clinical and epidemiological studies, the Recommended Daily Allowance (RDA) of ascorbic acid was suggested to be 100-120 mg day⁻¹ for adults to achieve cellular saturation and reduce risk of heart disease, stroke and cancer in healthy individuals (Naidu, 2003).

Potato tubers have been reported to contain up to 46 mg/100 g ascorbic acid in (Fresh Weight Basis) depending on the variety, maturity of the tubers at harvest and the environmental conditions under which they were grown (Nourian *et al.*, 2003; Han *et al.*, 2004). Variety has been known to be the greatest determinant of variation of ascorbic acid concentration in potatoes (Hamouz *et al.*, 2009; Hemavathi *et al.*, 2010). Several authors have reported considerable reduction in the quantities of ascorbic acid during cooking and storage in potatoes, with losses that vary widely according to cultivar, cooking and handling methods. Hagg *et al.* (1998) observed reduction of ascorbic acid with storage in stored peeled potatoes in four Finnish potato cultivars. The concentration of vitamin C decreased markedly during the storage and after 20 weeks, the content had decreased by more than 50% in five cultivars of Tenerife potatoes (Rivero *et al.*, 2003). The levels of ascorbic acid in long term stored samples (6-9 months) can drop down below 10 mg vitamin C/100 g FW (Haase and Weber, 2003).

During preparation and processing further degradation takes place by enzymatic oxidation, thermic degradation and diffusion into blanching and cooking water. During processing total losses of ascorbic acid were found to be 52% for French fries and about 26% for potato crisps, respectively (Haase and Weber, 2003). Thermal degradation of ascorbic acid was pronounced because of the high temperature regime in case of potato crisps production. For proper retention of ascorbic acid, frying temperatures for potato products such as crisps should be carefully selected.

However, all information about the ascorbic acid concentration of potato in fresh, stored potatoes and their products relates to commercial varieties outside Africa. Among the potato products, crisps consumption has increased in Kenya and more so in the urban areas (Abong *et al.*, 2009a). It would therefore be important to ascertain the contribution of potatoes and potato crisps as snack food to ascorbic acid nutrition. The present study sought to determine the ascorbic acid levels of fresh tubers during storage and the effects of processing temperature, packaging and storage conditions on ascorbic acid content of potato crisps from four Kenyan potato cultivars.

MATERIALS AND METHODS

Potato cultivars for processing: Two potato clones coded as 391691.96 and 393385.39 from the International Potato Center (CIP) and two varieties (Tigoni and Dutch Robyn) were grown at the National Potato Research Center, Tigoni (2, 100 m above sea level) in the year 2009/10. These were grown under the standard cultural conditions (Lunghao and Kabira, 1999). After maturity, the crop was dehaulmed two weeks before harvesting. Following harvest, the tubers were allowed to cure for 2 weeks in a naturally ventilated dark store under ambient air conditions (17-22°C/78-90% rh). Analysis of ascorbic acid content in fresh tubers was done during storage. After curing, the tubers were processed into crisps and analyzed for ascorbic acid content variation with storage.

Analysis of stored raw tubers: Approximately 15 kg of tubers from each of the four cultivars were stored in dark store under ambient air conditions (17-22°C/78-90% rh) and also in cold storage (5°C/95% rh). The ascorbic acid concentrations of tubers in ambient storage were determined at 2,

6, 10 and 14 weeks after harvest. For cold stored tubers, ascorbic acid levels were analyzed at 2, 6, 10, 14, 18, 22 and 26 weeks after harvesting. Duplicate samples of 5 peeled tubers per cultivar were prepared for each determination.

Preparation and analysis of potato crisps: Potato tubers were peeled and sliced using an automatic electric slicer (Hitech Systems, Saudi Arabia) to uniform thickness of 1.5 mm. The slices were thereafter washed in cold water to remove surface starch, dried with cloth towel and fried in an institution size, batch type, deep oil fryer (E 6 ARO S.A., La Neuveville, Switzerland) containing about 7 L of Chef corn oil (Premier Oil Mills Ltd., Nairobi, Kenya) at temperatures of 160, 170 and 180°C until bubbling ceased. The fried slices were removed and excess oil drained off for 1 min, cooled and packaged ready for storage and analysis.

Analysis of stored potato crisps: Crisps fried at 170°C were used in this study. Potato crisps for each cultivar were packaged into polyethylene bags (gauge 200 microns) and aluminium foil packs. The major packaging material for potato crisps in Kenya is polyethylene and to a lesser extent, polyethylene lined with aluminium foil (Abong *et al.*, 2009a). The packaged crisps were stored in different environmental conditions as follows: 25, 30 and 35°C. The levels of ascorbic acid were determined after every 4 weeks for 24 weeks.

Ascorbic acid analysis: Ascorbic acid was determined by titration with 2, 6-dichlorophenolindophenol dye as described by AOAC (1984).

Data analysis: All the experiments were arranged in a completely randomized factorial design with three main treatments of frying temperature, packaging and storage temperature. The sub-treatments included packaging material (transparent polyethylene and aluminium foil pack), storage temperatures (25, 30 and 35°C) and storage duration (4 to 24 weeks). Analysis of variance (ANOVA) and least significant difference test for the variables was conducted using the Statistical Analysis System (SAS version 9). Differences at $p \leq 0.05$ were considered significant.

RESULTS AND DISCUSSION

Effect of storage on ascorbic acid levels of fresh potato tubers: Variation in ascorbic acid levels in fresh potato tubers stored under ambient air conditions is shown in Fig. 1.

Ascorbic acid levels significantly ($p \leq 0.05$) differed with the variety. The levels ranged from 65.18 to 73.31 mg/100 g on a dry weight basis (DW) in Dutch Robyn and Tigoni, respectively. For each variety, there was no significant ($p > 0.05$) difference in levels of the vitamin within 6 weeks of storage. On the other hand, ascorbic acid levels significantly ($p \leq 0.05$) reduced from 6 to 14 weeks of storage. There was a significant ($p \leq 0.05$) cultivar-time interaction. The decrease was highest in Tigoni and 393385.39 compared to Dutch Robyn and 391691.96 as the difference between the cultivars narrowed by 14 weeks of storage.

Ascorbic acid levels in fresh potato tubers are mainly determined by cultivar's genetic make-up (Hemavathi *et al.*, 2010). Different workers from different parts of the world have reported diverse variations on concentrations of the vitamin. Burgos *et al.* (2009) evaluated 25 Andean cultivars and reported a range of 22.2 to 121.4 mg/100 g on a dry weight basis (DW) and from 6.5 to 36.9 mg/100 g on a fresh weight basis (FW). Working on 9 Czech potato varieties, Hamouz *et al.*

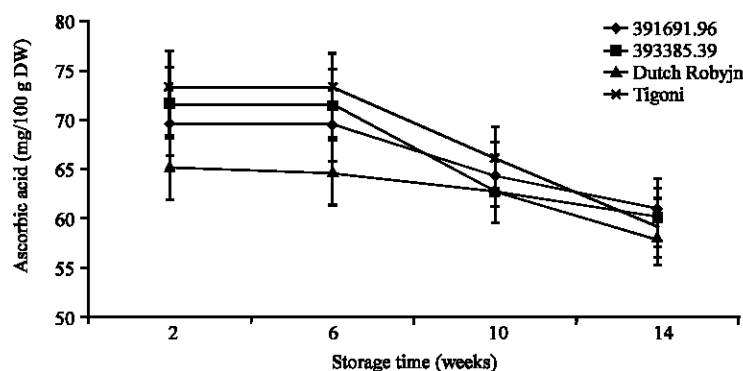


Fig. 1: Effect of storage under ambient air conditions (17-22°C/78-90% rh) on ascorbic acid levels in fresh potato tubers

(2009) reported ascorbic acid levels ranging from 14 to 24 mg/100 g on a fresh weight basis (FW). The ascorbic acid levels on fresh weight basis ranged from 8 to 36 mg/100 g for American varieties (Augustin *et al.*, 1978), 10-17 mg/100 g for Indian varieties (Mishra, 1985) while in Norwegian and Korean varieties it varied from 8.4 to 20 mg/100 g and 16 to 46 mg/100 g, respectively (Nordbotten *et al.*, 2000; Han *et al.*, 2004). In the present study, the concentrations of ascorbic acid in the Kenyan cultivars fall within the range reported in other parts of the world. Potato cultivars differ in physico-chemical composition as influenced by among other factors genetic make-up, geographical location and cultural practices. Even though the levels of ascorbic acid in Kenyan potato cultivars differed from other varieties reported in the world, the ranges in the past studies are generally large. The potato family is similar and hence the relationship all over the world.

Working on 21 green leafy vegetables, Oduokoya *et al.* (2007) reported ascorbic acid ranging from 13 to 187 mg/100 g on dry weight basis. Approximately 100 g of some vegetables like broccoli, red pepper, watercress, cabbage and cauliflower were found to have a range of ascorbic acid of 75-114 mg/100 g while the concentration of the vitamin in fruits like orange, grapefruit, tangerine, papaya and strawberry range from 44 to 93 mg/100 g (Burgos *et al.*, 2009). Ascorbic acid concentrations may in some cases be higher than the average levels in potato tubers. However, the contribution of ascorbic acid from potatoes to the human diet could be higher since in some places potato is a staple food as opposed to vegetables and fruits that are usually complementary components of the diet. The fruits which are major suppliers of the vitamin are rarely eaten by a large part of the population in developing world due to limited supply and high costs. Besides, many potato products such as crisps and French fries are regularly consumed especially in major urban centers (Abong *et al.*, 2009a).

Storage of potatoes under ambient air conditions in a dark store has been recommended in situations where farmers cannot afford cold storage facilities (Kabira and Lemaga, 2006; Gachango *et al.*, 2008). The physico-chemical properties of potatoes stored in such conditions are not adversely changed (Abong *et al.*, 2009b). On the other hand, beyond 12 weeks of storage, for most cultivars sprouting becomes pronounced and the tuber structure is altered rendering the potatoes unsuitable for processing (Nourian *et al.*, 2003). In the present study, ascorbic acid levels were significantly ($p \leq 0.05$) reduced after six weeks of storage under ambient air conditions in a dark store. The retention rate was, however, high ranging from 81 to 89% in Tigon and Dutch Robyn, respectively. It therefore means that potato tubers processed after 6 weeks of storage would still supply a substantial amount of the vitamin depending on the variety and initial concentration.

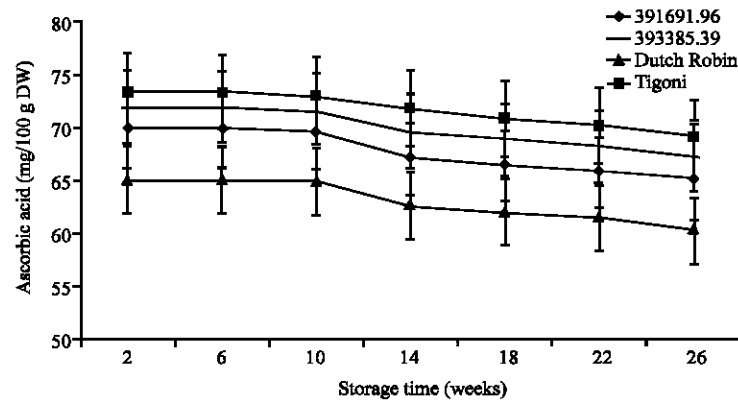


Fig. 2: Variations in ascorbic acid during cold storage of four Kenyan potato cultivars

Variations in ascorbic acid content in cold stored fresh potato tubers for the four Kenyan cultivars are illustrated in Fig. 2. Cold stored potato tubers significantly ($p \leq 0.05$) retained higher ascorbic acid concentrations compared to those stored under ambient air conditions. The vitamin levels in all the cultivars did not significantly ($p > 0.05$) differ with storage time up to 10 weeks. The levels decreased significantly ($p \leq 0.05$) from 10 to 26 weeks of storage. It is worth noting, however, that quite high levels of ascorbic acid were retained in all the cultivars even after 26 six weeks of storage, depending on the initial concentration. The retention ranged from 92 to 94% in Dutch Robyjn and Tigoni, respectively.

The storage changes in potatoes are mainly caused by respiration, transpiration, sprouting, diseases or presence of pests (Rivero *et al.*, 2003). The changes resulting from storage can produce decreases in weight and changes related to quality, such as appearance, flavor, texture and chemical composition (Rivero *et al.*, 2003). Cold storage minimizes the effects of respiration, transpiration and significantly reduces sprouting (Nourian *et al.*, 2003). As such the physical appearance and general texture of the tubers are maintained. Some chemical constituents such as reducing sugars, however, increase beyond required limits when tubers are cold stored. It therefore follows that storing potato tubers under low temperature conditions is appropriate to minimize losses in important nutrients such as ascorbic acid. It is important to note, however, that such tubers from the current Kenyan cultivars may only be used for boiling, baking or stewing as opposed to processing into crisps and French fries since they produce unacceptable dark brown products (Abong *et al.*, 2009a).

Ascorbic acid levels in potato crisps as affected by frying temperature: The variation of ascorbic acid content in potato crisps made from four cultivars under different frying temperatures is given in Table 1. There was significant ($p \leq 0.05$) reduction (45% on the average) of the level of ascorbic acid in all the cultivars when tubers were fried into crisps. The reduction was highest in variety Tigoni while it was lowest in Dutch Robyjn. The reduction levels were significantly ($p \leq 0.05$) higher at 180 than at 160°C. There was, however, no significant ($p > 0.05$) reduction when frying temperature was increased from 170 to 180°C.

The average reduction of 45% found in the present study is comparable to those reported by Burgos *et al.* (2009) on baked and microwaved potatoes. The retention levels of 55% in ascorbic acid were, however, lower than 64% that was reported by Haase and Weber (2003) in potato crisps. Boiling the tubers was reported to reduce ascorbic acid by about 30% (Hagg *et al.*, 1998). During

Table 1: Variation of ascorbic acid¹ in raw tubers and potato crisps from four cultivars at different frying temperatures

Cultivar	Fresh tubers	Frying temperature (°C)		
		160	170	180
391692	69.81±0.66c	42.93±0.85d	41.40±0.41d	40.01±0.43c
393385.4	71.76±0.47b	51.15±0.37a	48.42±0.27a	48.41±0.42a
Dutch Robyn	65.17±0.56d	48.66±0.38b	46.78±0.42b	45.41±0.22b
Tigoni	73.31±0.48a	45.91±0.12c	45.12±0.33c	44.22±0.34b

¹Determined in mg/100 g dry weight basis. Values are Mean±SD. Means with the same letters within the same column are not significantly different at 5% level of significance

Table 2: Variation of ascorbic acid levels (mg/100 g DW) with cultivar, package, storage temperature and time

Cultivar	PKG ¹	ST ²	Storage time (weeks)						
			0	4	8	12	16	20	24
391692	AF ³	25	42.43±0.41de	40.61±0.78e	40.62±0.14d	39.52±0.30e	36.80±0.28f	35.24±0.23e	33.33±0.18e
		30	41.30±0.40e	40.71±1.46e	40.27±0.14d	38.89±0.63ef	36.70±1.87f	34.02±1.53f	31.41±1.62g
		35	41.35±0.43e	41.38±0.42e	39.71±0.66de	39.00±1.07e	36.38±1.56f	34.02±1.53f	29.96±1.62g
	PE ⁴	25	40.99±0.41e	41.12±0.14e	38.61±1.60e	38.07±0.59ef	33.82±1.04h	30.92±1.52h	28.10±0.82h
		30	41.43±0.41e	40.61±0.55e	38.76±0.37e	37.29±0.56f	33.66±0.93h	29.56±0.62h	24.24±0.95j
		35	42.40±0.44de	41.03±2.07e	40.90±0.30d	40.06±2.91e	35.81±2.28f	31.00±1.41h	24.88±1.21j
	AF ³	25	49.42±0.37a	48.99±0.01a	48.66±0.26a	47.36±0.47a	45.48±0.72a	43.14±0.70a	40.88±0.75a
		30	49.38±0.37a	49.10±0.58a	48.31±0.26a	47.00±0.17a	43.79±0.81b	41.17±0.84b	38.51±0.67b
		35	49.41±0.37a	49.30±0.33a	47.67±0.88a	47.33±0.47a	43.13±0.13b	41.17±0.84b	37.06±0.67c
393385.4	PE ⁴	25	49.37±0.37a	49.16±0.26a	44.86±0.35b	42.78±0.06c	38.16±0.23d	34.94±0.06f	29.43±0.07g
		30	49.41±0.73a	48.25±0.35a	44.94±0.06b	42.78±0.56c	37.61±0.55d	33.99±0.01f	27.86±0.11h
		35	49.36±0.37a	49.34±0.48a	45.07±0.90b	43.18±0.38c	37.27±1.03d	32.54±0.20g	26.62±0.01i
	AF ³	25	46.48±0.42b	45.94±0.33b	44.95±0.62b	44.90±0.40b	43.50±0.71b	41.39±0.86b	38.92±0.36b
		30	46.78±0.42b	46.50±0.71b	44.70±0.62b	43.70±0.22bc	40.05±0.09c	37.76±0.34c	35.46±0.33d
		35	46.58±0.42b	46.69±0.45b	43.80±0.58bc	43.46±0.07bc	40.27±0.04c	37.76±0.34c	34.01±0.33d
	PE ⁴	25	46.73±0.42b	45.67±0.62bc	42.90±0.55c	42.82±0.36c	39.27±0.38c	35.84±0.04e	31.07±0.05f
		30	46.66±0.41b	45.95±0.78b	42.56±0.59c	41.78±0.27e	37.49±0.72d	33.43±0.80f	30.04±0.28g
		35	46.78±0.42b	45.78±0.83bc	39.97±0.97de	39.61±0.54e	34.88±0.24g	31.81±0.83h	27.75±0.63h
Dutch Robyn	AF ³	25	46.48±0.42b	45.94±0.33b	44.95±0.62b	44.90±0.40b	43.50±0.71b	41.39±0.86b	38.92±0.36b
		30	46.78±0.42b	46.50±0.71b	44.70±0.62b	43.70±0.22bc	40.05±0.09c	37.76±0.34c	35.46±0.33d
		35	46.58±0.42b	46.69±0.45b	43.80±0.58bc	43.46±0.07bc	40.27±0.04c	37.76±0.34c	34.01±0.33d
	PE ⁴	25	46.73±0.42b	45.67±0.62bc	42.90±0.55c	42.82±0.36c	39.27±0.38c	35.84±0.04e	31.07±0.05f
		30	46.66±0.41b	45.95±0.78b	42.56±0.59c	41.78±0.27e	37.49±0.72d	33.43±0.80f	30.04±0.28g
		35	46.78±0.42b	45.78±0.83bc	39.97±0.97de	39.61±0.54e	34.88±0.24g	31.81±0.83h	27.75±0.63h
	AF ³	25	46.01±0.38b	45.01±0.14bc	43.61±0.15bc	43.47±0.35c	41.98±0.02c	40.06±0.22b	38.22±0.35b
		30	44.97±0.38c	44.21±0.33c	43.36±0.15bc	42.20±0.28c	38.77±0.32e	36.42±0.51d	33.72±0.67e
		35	45.32±0.33c	45.02±0.32c	42.94±0.39c	42.22±1.10c	39.20±0.39c	36.42±0.52d	32.27±0.67f
Tigoni	PE ⁴	25	45.52±0.33c	44.33±0.15cd	40.61±0.76d	39.29±0.25e	34.10±0.12g	30.26±0.74h	25.42±0.73i
		30	45.12±0.38c	44.31±0.02cd	41.09±0.16d	40.20±1.03e	36.38±0.54f	33.02±0.49g	30.25±1.13g
		35	45.18±0.39c	44.59±0.84cd	40.81±0.30d	39.74±1.05e	35.94±0.71f	31.67±0.47h	27.43±0.77h

PKG¹ = Packaging type, ST² = Storage temperature, AF³ = Aluminium foil pack, PE⁴ = Polyethylene. Values are Mean±SD. Means with the same letters within the same column are not significantly different at 5% level of significance

processing, higher frying temperature regimes (>100°C) have been known to be responsible for thermal degradation of ascorbic acid in potato crisps. Hence, higher frying temperatures lead to higher degradation of the vitamin (Sahin *et al.*, 1999; Pirone *et al.*, 2007).

Variation of ascorbic acid levels in potato crisps with packaging, storage temperature and duration: Cultivar variation of ascorbic acid levels with package, storage temperature and duration is presented in Table 2.

Levels of ascorbic acid in fried crisps differed significantly ($p \leq 0.05$) with cultivar ranging from 40.99 to 49.42 in cultivar 391691.96 and 393385.39, respectively. Cultivar 393385.39 had the highest retention of the vitamin followed by Dutch Robyn, Tigoni and 391691.96 in that order.

Packaging type significantly ($p \leq 0.05$) influenced the amount of ascorbic acid retained within a given storage period. There was no significant ($p > 0.05$) variation of the vitamin content within 8 weeks of storage in crisps packaged in polyethylene bags and aluminium foil packs. However, after 8 weeks of storage significant ($p \leq 0.05$) reduction of ascorbic acid was noted in all the cultivars. Crisps packaged in aluminium foil pack retained higher levels of ascorbic acid (78%) compared to those in polyethylene bags which retained 58% after 24 weeks of storage.

Storage temperature had a significant ($p \leq 0.05$) effect on the ascorbic acid levels; there was higher reduction of the vitamin levels at higher temperatures. There was significant ($p \leq 0.05$) temperature, packaging and time interaction effect on concentrations of the vitamin; there was higher retention at 25°C in crisps packaged in aluminium foil pack while the least retention was noted in crisps stored in polyethylene bags at 35°C. The results are in agreement with findings of Hagg *et al.* (1998) who reported that storage of potato products at elevated temperature degrades ascorbic acid levels by 10% on average.

The principal role of food packaging are to protect food products from outside influences and damage, to contain the food and to provide consumers with ingredient and nutritional information. Traceability, convenience and tamper indication are secondary functions of increasing importance. The goal of food packaging is to contain food in a cost-effective way that satisfies industry requirements and consumer desires, maintains food safety and minimizes environmental impact (Marsh and Bugusu, 2007). Packaging in aluminium foil pack increased ascorbic acid retention compared to polyethylene bag.

CONCLUSION

Potato cultivar, storage condition and time were found to greatly influence the levels of ascorbic acid in fresh potato tubers. For maximum retention of ascorbic acid in fresh tubers, cold storage is preferred to ambient air conditions. Frying crisps from the Kenyan potato cultivars at all temperatures significantly reduced the levels of ascorbic acids irrespective of the cultivar. The reduction was highest in variety Tigoni while it was lowest in Dutch Robyn. There was higher retention of the vitamin by crisps from all cultivars when packaged in aluminium foil pack and stored at lower temperature (25°C) when compared with those packaged in polyethylene bags at higher temperature (35°C) storage. It is therefore of great importance for processors to choose lower frying temperature and proper packaging for maximum vitamin retention. Storage of potato crisps at temperatures beyond 30°C will result in lower levels of ascorbic acid retention.

ACKNOWLEDGMENTS

Authors are grateful to the University of Nairobi, DAAD Nairobi office and the National Potato Research Centre (KARI) for financial support. We recognize the role played by potato breeders; Dr. J. Landeo (CIP), Mr. S. Nderitu and Mr. J. Onditi (NPRC) who ensured that the materials were available. We appreciate the Food Science Department team at KARI-Tigoni led by Mrs. N. Ngone and Mr. K. Bethuel who offered their service during sample preparation and evaluation. Laboratory analysis was accomplished with assistance from Mr. J. M'Thika and Ms. R. Kamau, Food Science Laboratory Technicians at the University of Nairobi.

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