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Nutrient contents of raw and processed products from Kenyan potato cultivars

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ABSTRACT

Objective: To determine the nutrient contents of raw and processed products of Kenyan potato cultivars.

Methodology and results: Eight potato cultivars (Tigoni, Desiree, Dutch Robyjn, Kenya Karibu, Kenya Sifa, CIP 393385.47, CIP 391696.96 and CIP 393385.39) were grown under local standard cultural conditions. The mature crop was harvested and allowed to cure at ambient air conditions (15-19 °C /86-92 % RH) for three weeks before evaluation. Proximate and mineral compositions of raw and boiled tubers and of freshly prepared and frozen French fries were determined. Significant ($P \leq 0.05$) variations between the cultivars were observed especially in dry matter content. Total ash was significantly ($P \leq 0.05$) reduced on boiling basically due to leaching. Apart from increase in fat content, frying did not significantly ($P > 0.05$) reduce any chemical constituent while freezing significantly ($P \leq 0.05$) reduced total ash, crude protein and total carbohydrate contents. All the cultivars had high levels of sodium and potassium.

Conclusions and application of findings: With the exception of increase in fat content, frying does not adversely affect the proximate, chemical and mineral composition of the potatoes. Even though boiling and storage in frozen form significantly ($P \leq 0.05$) decreases total ash, carbohydrates and mineral content; as well as iron, manganese, zinc, potassium, calcium and magnesium, these are retained in considerably high amounts to warrant use of these processing technologies. Therefore, Kenyan potatoes can be utilized in any processed form, especially the new technology of processing frozen French fries, without adversely affecting the nutritional content and other quality aspects.

Key words

Potato cultivars, nutrient contents, French fries, proximate composition, minerals

INTRODUCTION

Irish Potato (*Solanum tuberosum L.*) is the most widely grown food crop after rice, wheat and maize (Burton, 1989). The crop has its origins in the Andes Mountains of Peru and Bolivia from where it spread throughout the world. In Kenya, potato is the second most valuable staple food crop after the cereal grains (MoA, 2005). Potatoes are increasingly becoming important in the diets of many Kenyans. Besides being incorporated into traditional dishes, they are also eaten boiled, baked or fried. In major urban centers, they are becoming popular in form of French fries and crisps (Walingo *et al*., 2004).

The potatoes were introduced by the British farmers and colonial officials into Kenya during 1880s. Once introduced into the country, new varieties were developed to suit local conditions, with resistance developed to pests and diseases through controlled plant breeding (Durr & Lorenzl, 1980). Currently, many varieties that differ in texture, flavour, shape and colour are grown in Kenya. These varieties include Tigoni, Dutch Robyjn, Kenya Sifa, Kenya Karibu, Asante, Roslyn Tana, Desiree and Kenya Baraka. The development of new varieties has, however, not been adequately supported by regular analysis to determine the nutritional value and suitability for domestic and industrial use.

The most important potato products in Kenya are chips, followed by crisps, potato based snack foods and frozen chips. The demand for these products has rapidly increased over the years (Walingo *et al*., 1997; Walingo *et al*., 2004). Therefore, potatoes are a principal source of carbohydrates and protein, and also contribute some vitamins and minerals in the diets of many Kenyans.

Variation in proximate and nutrient composition of potatoes has been reported by many authors (Smith, 1967; Austin, 1975; Austin *et al*., 1978; Toma *et al*., 1978; Imungi, 1987). The variations between varieties depends on many factors including temperature and rainfall during the growth season, soil and nutrient elements, area, cultural practices, maturity, method of harvesting and genetic make-up (Burton, 1966; Smith, 1977). Most reports are on potatoes grown outside Kenya, and information concerning nutrient composition of Kenyan potatoes is generally lacking.

The present study was designed to determine the proximate and mineral compositions of eight Kenyan cultivars as influenced by variety and some processing methods.

MATERIALS AND METHODS

Plant materials: Five potato varieties (Tigoni, Desiree, Dutch Robyjn, Kenya Karibu and Kenya Sifa) and three promising clones coded CIP393385.47, CIP391696.96 and CIP393385.39 from the International Potato Center (CIP) were grown at the National Potato Research Center, Tigoni in the year 2007 under standard cultural conditions (Lung'aho & Kabira, 1999). After maturity, the crop was dehaulmed two weeks before harvesting. The harvested tubers were then allowed to cure at ambient air conditions (15-19 °C/86-92 % RH) for three weeks. The processing and evaluation were carried out in the food science laboratories at the Kenya Agricultural Research Station (KARI) in Tigoni (processing), the Jomo Kenyatta University of Agriculture and Technology (chemical analysis) and at the College of Agriculture and Veterinary Sciences of the University of Nairobi (validation of chemical analysis results).

French fries preparation: Potato samples (10 tubers per cultivar) were hand-peeled, and cut lengthwise using a hand-operated chip cutter producing 12x12 mm strips in cross-section. The cut strips were washed to remove surface starch and air dried before frying using a deep fat fryer (frifri E6 ARO S.A Neuveville Swisse-Switzerland) equipped with a thermostatically controlled electric heating coil. The strips were pre-fried at 170 °C for 2 min (par frying) and finish-fried afterwards at the same temperature for 5 additional minutes. The oil was drained off (1 min), and chips were placed on plates and left to cool at room temperature before packaging into polyvinyl chloride bags (gauge 125). The chips in sealed packages were taken to the laboratory for evaluation. For frozen storage, the par-fried chips were packaged into polyvinyl chloride bags (gauge 125), sealed and stored in deep freezer at -18 °C for three months. At evaluation time, the chips were removed from freezer and finish-fried at 170 °C for 2 minutes.

Nutrient content analysis

Dry matter content: Five whole tubers were randomly selected for each cultivar and chopped into small cubes (1-2 cm pieces), and mixed thoroughly. Dry matter content was determined by drying triplicate 20 g samples at 80 °C for 72 hr in a forced air oven.

Specific gravity: Specific gravity was determined using raw tubers according to weight under water method as described by Ludwig (1972) and Kabira and Lemaga (2006).

Moisture content: The moisture content of the products was obtained by standard analytical methods (AOAC, 1984). Triplicate samples (5 g) were weighed in aluminum dishes and oven dried at 105 °C to constant weight. Loss of weight due to drying was converted to percent moisture content.

Fat content: Chips were finely ground in a blender and 5 g sample was put into a thimble, 16-hr Soxhlet extraction was conducted using analytical grade petroleum ether (boiling point 40-60 °C) as described by Lulai and Orr (1979).

Total ash, crude fibre and protein: Total ash, crude fibre and protein as total nitrogen were determined by standard analytical methods (AOAC, 1984).

Total carbohydrates: Total carbohydrates were determined by difference: 100- (crude fibre + crude fat + crude protein + total ash + moisture content).

Minerals: Iron, Manganese, Zinc, Potassium, Calcium, Magnesium and Sodium were determined by AOAC (1984) methods while phosphorus was determined by AOAC (1996) methods.

Data analysis: Data were subjected to analysis of variance (ANOVA) and means separated by the Least Significant Difference test using Statistical Analysis System (SAS version 9).

RESULTS AND DISCUSSION

Specific gravity and dry matter content: The specific gravity of the cultivars varied from 1.075 in clone 393385.39 to 1.092 in variety Dutch Robyjin when evaluated immediately after harvesting (Table 1). Whereas no significant differences were noted within cultivars, there were significant (P≤0.05) differences in the dry matter contents of the cultivars ranging from 20.56 % in clone 393385.39 to 24.66 % in Dutch Robyjn. This range of dry matter content falls within the recommended levels (>20 %) for French fries processing operations (Kabira & Lemaga, 2006).

Table 1: Specific gravity and dry matter contents of 8 potato cultivars.

Cultivar	Specific gravity ± sd	Dry matter content ± sd
393385.39	1.075 ± 0.003	20.556 ± 0.092
393385.47	1.083 ± 0.003	22.836 ± 0.250
391691.96	1.076 ± 0.002	20.973 ± 0.421
Desiree	1.087 ± 0.003	22.213 ± 0.163
Dutch Robyjn	1.092 ± 0.003	24.660 ± 0.178
Kenya Karibu	1.081 ± 0.001	21.136 ± 0.239
Kenya Sifa	1.082 ± 0.002	20.880 ± 0.191
Tigoni	1.084 ± 0.002	22.283 ± 0.375

Results are means of three replicate determinations.

Proximate composition: Raw and boiled potato tubers had lower average energy content than French fries; averaging 334 KJ per 100 g. Variations of dry matter content leads to variation in carbohydrate content in potatoes which in turn contribute to a range of energy contents (Lisinska & Leszczynski, 1989). Such variations in energy were also reported in North America (Toma *et al*., 1978). According to Woolfe (1987), raw potato tubers have lower average energy content (318-334 KJ/100 g) compared to other roots and tubers such as sweet potato (485 KJ/100 g), yam (444 KJ/100 g) and cassava (607 KJ/100 g). In the present study, French fries had increased amounts of energy (776-941 KJ/100 g) possibly attributed to the absorbed oil during frying (Burton, 1989; Lloyd *et al*., 2004). These values are slightly lower than average values of 1165 KJ/100 G reported by Woolfe (1987). The differences could be attributed to varieties that have different dry matter contents and absorb fat differently on processing. Processing significantly (P≤0.05) increased energy levels in all the cultivars, meaning that it is beneficial to people who are in great need of energy to consume processed potato products.

Carbohydrate content varied in the cultivars from 16.34 to 19.74 %, which compares well with the average value of 17.5 % reported by Lisinska and Leszczynski (1989). The potato carbohydrates are classified as starch, non-starch and sugars. Starch is mainly found in pockets called granules in form of amylopectin and amylose, and contributes a major part of the dry matter and hence to the energy value of potatoes. The potato crude protein content at an average of 1.89% (FWB) in raw tubers is comparable to that of most root and tuber staples. The protein composition is, however, slightly different with potato having higher digestibility and more of the amino acid lysine. The protein is also known to have low levels of the sulphur-containing amino acids, methionine and cystine. Hence, potato can complement other staples such as maize that lack the lysine but have plenty of sulphur amino acids (Woolfe, 1987; Kabira, 1990).

The crude fibre content ranged from 1.04-1.22 % in raw tubers, which compares well to those reported (Woolfe, 1987; Paul & Southgate, 1978) of 1-2 g/100 g on fresh weight basis. Crude fibre originates from the plant polysaccharides and may be part of starch that is resistant to hydrolysis by digestive enzymes. Compared to other raw items, its level in potato is similar to that in sweet potatoes but lower than in other root and tuber crops. Potato cooked as French fries offers a more concentrated source of crude fibre (1.21-2.12 %).

The total ash content of the Kenyan potatoes averaged 0.94% per 100g in raw tubers. French fries had higher ash content at 1.01 to 1.14 %. This range compares well with those reported by Burton (1989). There exists a large range of minerals that form part of the ash content as reported by many authors. The variation has been attributed to soil type, application of fertilizers and potato variety.

Table 2: Proximate composition of raw and processed products of 8 Kenyan potato cultivars (g/100 g)-Fresh Weight basis.

Cultivar	Potato product	Energy KJ	Moisture Content	Carbo-hydrates	Crude Protein	Crude Fat	Crude Fibre	Crude Ash
Tigoni	Raw	358 ± 0.33	76.90 ± 0.36	19.28 ± 0.15	1.91 ± 0.07	0.09 ± 0.18	1.22 ± 0.05	0.95 ± 0.16
	Boiled	340 ± 0.32	78.20 ± 0.35	17.78 ± 0.03	2.33 ± 0.25	0.08 ± 0.25	1.15 ± 0.07	0.80 ± 0.04
	Fresh fries	792 ± 0.20	53.96 ± 0.22	35.37 ± 0.29	3.77 ± 0.08	3.62 ± 0.78	1.47 ± 0.25	1.81 ± 0.08
	Frozen fries	776 ± 0.30	57.36 ± 0.21	31.85 ± 0.10	3.23 ± 0.10	4.99 ± 0.85	1.21 ± 0.08	1.36 ± 0.06
Kenya Karibu	Raw	320 ± 0.22	79.10 ± 0.29	16.85 ± 0.23	2.08 ± 0.45	0.09 ± 0.10	1.06 ± 0.35	1.09 ± 0.04
	Boiled	313 ± 0.25	79.78 ± 0.30	16.34 ± 0.21	2.16 ± 0.16	0.08 ± 0.09	1.05 ± 0.11	0.89 ± 0.16
	Fresh fries	879 ± 0.11	49.45 ± 0.13	37.20 ± 0.04	4.75 ± 0.15	4.68 ± 0.73	1.64 ± 0.21	2.28 ± 0.13
	Frozen fries	766 ± 0.13	58.45 ± 0.12	29.31 ± 0.41	3.63 ± 0.14	5.69 ± 0.84	1.27 ± 0.04	1.65 ± 0.18
Kenya Sifa	Raw	322 ± 0.30	79.50 ± 0.40	17.63 ± 0.17	1.32 ± 0.63	0.12 ± 0.08	1.06 ± 0.19	0.76 ± 0.44
	Boiled	312 ± 0.32	80.15 ± 0.44	16.59 ± 0.03	1.81 ± 0.16	0.11 ± 0.14	1.07 ± 0.21	0.69 ± 0.16
	Fresh fries	813 ± 0.20	54.15 ± 0.25	34.93 ± 0.44	3.69 ± 0.04	4.42 ± 0.90	1.36 ± 0.23	1.45 ± 0.05
	Frozen fries	775 ± 0.23	58.77 ± 0.26	30.59 ± 0.56	2.77 ± 0.18	5.75 ± 0.76	1.13 ± 0.10	0.99 ± 0.28
393385.47	Raw	334 ± 0.32	78.59 ± 0.58	17.80 ± 0.21	1.89 ± 0.23	0.12 ± 0.06	1.00 ± 0.13	0.89 ± 0.33
	Boiled	321 ± 0.30	79.56 ± 0.58	16.95 ± 0.34	1.95 ± 0.28	0.11 ± 0.04	1.07 ± 0.16	0.76 ± 0.01
	Fresh fries	785 ± 0.52	54.52 ± 0.30	35.13 ± 0.63	3.92 ± 0.45	3.48 ± 0.62	1.26 ± 0.14	1.69 ± 0.18
	Frozen fries	776 ± 0.52	57.56 ± 0.34	32.14 ± 0.20	3.29 ± 0.16	4.84 ± 0.38	1.13 ± 0.08	1.04 ± 0.28
Desiree	Raw	327 ± 0.20	78.88 ± 0.46	17.33 ± 0.62	1.92 ± 0.72	0.13 ± 0.02	1.11 ± 0.02	1.07 ± 0.12
	Boiled	315 ± 0.21	79.78 ± 0.46	16.51 ± 0.04	2.03 ± 0.32	0.13 ± 0.21	1.13 ± 0.04	0.91 ± 0.12
	Fresh fries	823 ± 0.42	53.78 ± 0.22	33.96 ± 0.59	4.00 ± 0.02	4.97 ± 0.92	1.22 ± 0.21	2.07 ± 0.22
	Frozen fries	810 ± 0.44	57.67 ± 0.30	29.46 ± 0.13	3.29 ± 0.29	6.93 ± 0.62	1.33 ± 0.07	1.55 ± 0.35
391691.96	Raw	320 ± 0.50	79.40 ± 0.25	17.40 ± 0.04	1.61 ± 0.39	0.05 ± 0.18	1.14 ± 0.04	0.76 ± 0.40
	Boiled	312 ± 0.51	80.02 ± 0.26	16.74 ± 0.34	1.76 ± 0.78	0.06 ± 0.25	1.12 ± 0.09	0.68 ± 0.10
	Fresh fries	928 ± 0.25	46.78 ± 0.02	41.30 ± 0.58	4.38 ± 0.39	4.31 ± 0.78	1.69 ± 0.25	1.54 ± 0.01
	Frozen fries	768 ± 0.24	58.44 ± 0.04	31.18 ± 0.92	3.15 ± 0.14	5.11 ± 1.00	1.23 ± 0.16	0.89 ± 0.04
393385.39	Raw	323 ± 0.12	79.22 ± 0.50	17.03 ± 0.04	2.01 ± 0.28	0.10 ± 0.17	1.10 ± 0.18	0.95 ± 0.11
	Boiled	314 ± 0.10	79.89 ± 0.49	16.43 ± 0.34	2.09 ± 0.52	0.11 ± 0.14	1.12 ± 0.15	0.81 ± 0.53
	Fresh fries	941 ± 0.44	46.98 ± 0.11	38.87 ± 0.58	4.83 ± 0.24	5.55 ± 0.49	1.58 ± 0.45	2.19 ± 0.13
	Frozen fries	776 ± 0.36	58.33 ± 0.16	29.05 ± 0.92	3.54 ± 0.28	6.11 ± 0.49	1.45 ± 0.24	1.52 ± 0.08
Dutch Robygyn	Raw	389 ± 0.16	75.06 ± 0.35	20.64 ± 0.36	2.39 ± 0.13	0.09 ± 0.05	1.04 ± 0.05	1.01 ± 0.23
	Boiled	377 ± 0.14	76.02 ± 0.40	19.74 ± 0.61	2.55 ± 0.51	0.10 ± 0.11	1.06 ± 0.08	0.83 ± 0.10
	Fresh fries	857 ± 0.32	49.51 ± 0.20	39.45 ± 0.63	4.74 ± 0.14	3.09 ± 0.77	1.22 ± 0.18	1.99 ± 0.18
	Frozen fries	815 ± 0.44	54.94 ± 0.23	33.81 ± 0.71	3.81 ± 0.80	4.90 ± 0.10	1.20 ± 0.01	1.45 ± 0.04

Carbohydrate= 100-(%moisture content + % crude fat + %crude fibre + %crude fat + % ash);
Energy (KJ/100g) = (%protein) + (%fat) + (%carbohydrate).

Effect of processing and frozen storage on the chemical composition of potatoes

Processing and frozen storage had significant (P≤0.05) impact on proximate composition of potatoes (Table 3).

Carbohydrate content: Carbohydrate levels differed significantly (P≤0.05) in raw tubers and the processed potatoes among cultivars but not within the same cultivar. Total carbohydrates in raw tubers ranged from 85.31 % in Kenya Karibu to 88.72 % in Kenya Sifa. The potato has lower average carbohydrate content than other roots and tubers such as sweet potato and cassava (Woolfe, 1987) Boiled tubers did not have significant (P>0.05) difference in carbohydrate contents compared to raw tubers when looking at tubers of the same variety. Carbohydrate levels, however, reduced significantly (P≤0.05) in fresh and frozen fries. Similar reductions have been explained to result from reaction of reducing sugars that are part of carbohydrates with amino acids during non-enzymatic browning (Woolfe, 1987; Ramasawmy *et al*., 1999).

Crude protein: The variety had significant (P≤0.05) effect on crude protein content of raw tubers ranging from 6.68 to 8.65 % in clone 391691.96 and Dutch Robyjn, respectively. The potato protein at an average of 2 % (FWB) is closely comparable to that of most other root and staples, with the exception of cassava, which has only half of this amount (Woolfe, 1987). It is also comparable, on a dry basis (8.4 %), with that of the cereals such as corn (9.5 %), rice (6.8 %) and sorghum (10.9 %). The levels of crude protein differed significantly (P≤0.05) in boiled tubers, fresh and frozen French fries among the cultivars. There was no significant (P>0.05) effect of boiling and frying on crude protein content when compared with raw tubers for each cultivar. This is in agreement with the findings of Toma *et al*. (1978). Freezing, however, significantly (P≤0.05) reduced crude protein content in all the cultivars with losses ranging from 4.5 % in cv. Tigoni to 14.7 % in cv. Kenya Sifa. This indicates that retention rates are in the range of 85.3 - 95.5%, similar to the 81 to 85 % reported by Augustin *et al.* (1979).

Crude fat content: The crude fat content in raw tubers ranged from 0.38 to 0.53 % in cv. Kenya Karibu and cv Kenya Sifa, respectively. There was no significant (P>0.05) difference in the crude fat content of raw and boiled tubers among the cultivars in both harvests. The ranges above compare well with the findings of Gilliard (1973) who found values of 0.4 to 0.65 % on dry weight basis in 23 potato varieties. Although this range is too low to have any nutritional significance, it nevertheless contributes towards potato palatability, enhances tuber cellular integrity and resistance to bruising and plays a part in reducing enzymic darkening in tuber flesh (Woolfe, 1987). Approximately 75 % of the fatty acids of the potato lipids are polyunsaturated linoleic and linolenic acids that contribute to production of both desirable flavour characteristics in cooked tubers and undesirable 'off' flavours in processed products (Woolfe, 1987). Boiling did not have a significant (P>0.05) effect on the fat content of potato tubers. Frying of potatoes, however, increased fat content significantly (P≤0.05) ranging from 6.4 % in variety Dutch Robyjn to 9.82 % in variety Desiree. Moreover, frozen fries had higher levels of fat content compared to fresh fries. These findings agree with those of Greenfield *et al*. (1984) and Melton *et al*. (2001). Many factors have been reported to affect fat uptake into French fries, including oil quality, frying temperature and duration, product shape, moisture content, solid content, gel strength, and proteins (Pinthus *et al*., 1995). In the present study, the potato cultivar had significant (P≤0.05) effect on fat uptake by the French fries. The different cellular structures may have affected fat uptake by influencing either the loss of moisture or damage done to original anatomy during processing.

Crude fibre content: Crude fibre content of raw tubers differed significantly (P≤0.05) among the cultivars. Variety Tigoni (2.48 %) had the highest levels while Desiree (1.79 %) had the lowest levels in raw tubers. The reduction of crude fibre content was not significant (P>0.05) after boiling, frying or freezing when compared to raw potatoes. The results compare well with the findings of Jones et al. (1985) who observed little change of fibre content in flesh of baked, roasted or French fried Sebago variety potatoes on a dry weight basis.

Total ash content: Variety had a significant effect (P≤0.05) on the ash content of raw tubers and their processed forms. The ash contents differed significantly (P≤0.05) in the raw tubers with the varieties Desiree (3.69 %) and Kenya Karibu (3.65 %) having the highest values while varieties Tigoni (2.76 %) and Kenya Sifa (2.12 %) had low levels. The ash content of potatoes is about 1 % (FWB) and 3.5 % (DWB) and contains some important minerals and trace elements essential to various body structures and functions (True *et al*., 1978; Burton, 1989). Large variations in ash content such as those observed in the present study have been attributed to variety, soil type and fertilizer application (True *et al*., 1978; Woolfe, 1987).

Table 3: Proximate composition (% dry weight basis) of potatoes as affected by processing and frozen storage.

	Carbohydrate content				Crude protein content				Crude fat content				Crude fibre content				Total ash content			
Cultivar	Raw tubers	Boiled tubers	Fresh fries	Frozen fresh	Raw tubers	Boiled tubers	Fresh fries	Frozen fresh	Raw tubers	Boiled tubers	Fresh fries	Frozen fresh	Raw tubers	Boiled tubers	Fresh fries	Frozen fresh	Raw tubers	Boiled tubers	Fresh fries	Frozen fresh
393385.39	88.67a	88.72a	81.74a	76.65a	6.68c	7.16b	6.15d	6.94b	0.49a	0.51a	8.77e	11.77e	2.01c	1.87d	2.22ab	2.01c	2.01c	1.87d	2.22ab	2.01c
391691.96	85.83c	86.24bc	77.22c	73.66d	8.40a	8.31b	8.20a	7.67a	0.45a	0.48a	9.45e	13.45d	2.26b	2.11c	2.01b	2.12bc	2.26b	2.11c	2.01b	2.12bc
393385.47	87.08b	87.50b	80.65a	77.38a	7.72b	7.03c	7.30b	6.79b	0.44a	0.53a	7.44f	10.85f	1.98c	1.83d	1.95b	1.88de	1.98c	1.83d	1.95b	1.88de
Desiree	86.15bc	86.26bc	77.17c	72.40e	7.94b	8.08b	7.61b	7.03b	0.45a	0.51a	9.82e	15.33b	1.79c	1.72e	1.85c	1.85de	1.79c	1.72e	1.85c	1.85de
Dutch Robyjn	85.74c	86.11bc	80.67a	77.35a	8.65a	8.19b	8.17a	7.81a	0.40a	0.38a	6.40f	10.38f	2.23b	1.98d	2.05b	1.83de	2.23b	1.98d	2.05b	1.83de
Kenya Karibu	85.31c	85.50d	77.21c	75.10c	8.38a	8.26a	8.23a	7.91a	0.38a	0.37a	8.58e	13.00d	2.29b	2.31b	2.10b	2.06c	2.29b	2.31b	2.10b	2.06c
Kenya Sifa	88.72a	88.44a	79.74b	76.35a	6.74c	7.31c	6.65c	5.75d	0.53a	0.51a	9.01e	13.11d	1.90c	1.76e	2.07b	2.06c	1.90c	1.76e	2.07b	2.06c
Tigoni	87.11b	86.4	80.04a	76.21b	7.26c	7.76b	7.08d	6.94b	0.46a	0.34a	7.61f	11.13f	2.48b	2.29b	2.43a	2.07c	2.48b	2.29b	2.43a	2.07c
CV (%)	0.57	0.54	1.08	0.8	5.14	5.32	3.2	4.26	23.62	27.52	7.55f	4.19	7	5.23	13.1	5.59	7	5.23	13.1	5.59
LSD ($P \leq 0.05$)	0.74	0.7	1.26	0.9	n.s	n.s	0.34	0.41	n.s	n.s	1.15	0.89	0.24	0.16	0.43	0.17	0.24	0.16	0.43	0.17

Results (dry basis) are means of two determinations. Means with the same letters within the same column are not significantly different at 5 %level of significance

Table 4: Average contents (mg/100 g) of phosphorus, potassium, sodium and calcium in raw and processed potato tubers.

	phosphorus				potassium				sodium				calcium			
Cultivar	Raw tubers	Boiled tubers	Fresh fries	Frozen fresh	Raw tubers	Boiled tubers	Fresh fries	Frozen fresh	Raw tubers	Boiled tubers	Fresh fries	Frozen fresh	Raw tubers	Boiled tubers	Fresh fries	Frozen fresh
Dutch Robyjn	207a	187a	206a	203a	2082a	1807a	1832a	1813a	315b	311b	312b	308b	42f	38f	37e	34e
Kenya Karibu	200a	177a	196a	196a	1802b	1529b	1552b	1534b	202f	200g	201g	198g	92a	89a	92a	89a
391691.96	174b	151b	171b	170b	981f	705f	730f	711f	216e	212f	214f	210f	80b	75b	61b	58b
Desiree	151c	128c	148c	147c	779g	507g	529g	509g	301c	296d	299d	296d	62c	57c	61b	58b
393385.39	145c	122c	142c	141c	697h	419h	442h	423h	191g	187h	188h	186h	37g	32g	36f	31f
Kenya Sifa	143c	121c	140c	139c	1533d	1258d	1282d	1263d	303c	300c	300c	298c	52d	47d	51c	48c
Tigoni	142c	120c	140c	138c	1009e	733e	758e	737e	290d	288e	288e	285e	43e	39e	42d	39d
393385.47	132c	110c	130c	128c	1726c	1450c	1475c	1456c	322a	317a	318a	316a	37g	32g	35f	31f
CV (%)	7.42	8.74	7.62	7.62	0.14	0.17	0.05	0.09	0.56	0.46	0.21	0.23	0.45	1.29	0.97	0.89
LSD ($P \leq 0.05$)	18.05	18.35	18.23	18.06	2.85	2.68	0.75	1.45	2.25	1.84	0.84	0.92	0.37	0.99	0.75	0.65

Results (dry basis) are means of three determinations. Means with the same letters within the same column are not significantly different at 5% level of significance.

Among the boiled tubers, variety had significant (P≤0.05) effect on the ash content. Variety Desiree had the highest levels (3.14 %) while Tigoni had the lowest levels (2.23 %). Using raw tubers as the reference point, boiling had significant effect (P≤0.05) on the ash content resulting to lower levels in all the cultivars. Such decrease has been attributed to leaching of the minerals in the cooking water (Burton, 1989).

Ash content levels varied significantly (P≤0.05) in the freshly prepared French fries among the cultivars. Variety Kenya Karibu had the highest levels (3.68 %) while clone 393385.39 had the lowest (2.70 %). There was no significant (P>0.05) change in ash content of freshly prepared French fries indicating that frying does not cause mineral leaching as much as boiling. Among the tubers that were fried and frozen, there was significant difference in the ash content (P≤0.05) with the highest mean exhibited by Kenya Karibu (3.67 %) while clone 391691.96 had the lowest (1.89 %). This shows that clone 391691.96 was greatly affected by freezing within its structures

Effect of processing on mineral composition: There is very little literature that covers this area as few researchers have ventured into similar studies (Woolfe, 1987). The tubers analysed had considerable amounts of calcium, potassium, sodium and phosphorus that were significantly (P≤0.05) affected with processing (Table 4). Processing had significant (P≤0.05) effect on zinc, iron, magnesium and manganese (Table 5).

Phosphorus: Phosphorus levels in raw tubers differed significantly (P≤0.05) among cultivars. The levels ranged from 132 mg/100 g in clone 393385.47 to 207 mg/100 g in Dutch Robyjn. Values reported for phosphorus in potato tubers vary with varieties, cultural practices and location of the study. Woolfe (1987) reported a range of 27-89 mg/100 g (fresh weight basis) while Burton, (1989) reported range of 150-300 mg/100 g (dry weight basis). The range in the present study compares more closely to the values reported by Burton (1989). On boiling tubers, phosphorus content significantly (P≤0.05) reduced with percent losses ranging from 9.7 % in cv. Tigoni to 16.7 % in cv. Dutch Robyjn. The losses due to leaching on boiling can be reduced by retaining the skin (True *et al*., 1979). Though there was reduction in the levels of phosphorus in the fresh and frozen fries, the reduction was not significant (P>0.05). Thus freezing did not have any adverse effect on the mineral content.

Potassium: The raw tubers had high amounts of potassium ranging from 697 mg to 2082 mg per 100 g of dry weight basis. The levels of potassium differed significantly (P≤0.05) with processing among cultivars with variety Dutch Robyjn having highest level (2082 mg/100 g) while clone 393385.39 had the lowest (697 mg/100 g). This level compares to those documented by Burton (1989). Significant (P≤0.05) losses of potassium occurred in boiled tubers (13.2-39.89 %), fresh fries (12.1-36.6 %) and frozen fries (12.92-39.3 %). The losses were more pronounced on boiled tubers and frozen fries but they pose no danger of deficiency since the retained amounts are still substantial and the mineral is also available in other foods (Woolfe, 1987; Burton, 1989).

Sodium: Sodium levels in raw tubers differed significantly (P≤0.05) among cultivars. The levels ranged from 191 mg/100 g in clone 393385.39 to 322 mg/100 g in clone 393385.47. This compares well with the range of 20 mg to 300 mg per 100 g (dry weight basis) that was reported by Burton (1989) and Imungi (1987). Though there was reduction in the levels of sodium in boiled, fresh and frozen fries, the reductions were not significant (P>0.05). Similar results were reported by True *et al*., (1979) and Woolfe (1987).

Calcium: Calcium levels varied significantly (P≤0.05) with processing in all cultivars. The range of 37 - 92 mg per 100 g in the raw tubers (dry basis) compares closely to that reported by Burton (1989). The calcium values in fresh French-fries did not significantly (P>0.05) differ when compared to raw tubers while boiling and freezing significantly (P≤0.05) reduced levels of calcium. Boiling losses ranged from 8.27 % in clone 393385.39 to 13 % in Dutch Robyjn. On freezing, there was significant (P≤0.05) reduction with losses ranging from 7.88 % in 393385.39 to 12.43 % in Dutch Robyjn. This translates to high retention (92.22-87.57 %) making it feasible to process and freeze-store chips without significant losses.

Zinc: Zinc levels differed significantly (P≤0.05) among the cultivars in raw tubers. The levels ranged from 1.77 mg/100 g in Tigoni to 2.90 mg/100 g in Dutch Robyjn (table 12). The levels of zinc in the study compares well with those reported by Woolfe (1987) and Burton (1989). Levels of zinc did not significantly (P>0.05) differ for French fries compared to the raw tubers. On boiling zinc content significantly (P≤0.05) reduced with losses ranging from 8.27 % in clone 393385.39 to 13 % in Dutch Robyjn. Likewise, the levels significantly (P≤0.05) reduced in frozen stored French fries with losses ranging from 7.85 % in cv. 393385.39 to 12.44 % in Dutch Robyjn. Retention rate of 92.25-87.56 % enables taking the advantages of processing without adverse losses of this mineral, which is required by body enzymes for synthesis and metabolism (FAO/WHO, 1996).

Table 5: Average contents (mg/100 g dry weight basis) of zinc, iron, magnesium and manganese.

	Zinc				Iron				Magnessium				Manganese			
Cultivar	Raw	Boiled	Fresh	Frozen	Raw	Boiled	Fresh	Frozen	Raw	Boiled	Fresh	Frozen	Raw	Boiled	Fresh	Frozen
Dutch Robyjn	2.90a	2.58a	2.77a	2.67a	3.77d	3.43e	3.76e	3.43d	138b	131b	137b	132b	3.25ab	2.48e	3.23ab	3.02ab
391691.96	2.87b	2.57a	2.74b	2.58b	2.74f	2.66g	2.88g	2.41f	67h	60f	66h	61h	2.77c	2.52d	2.75c	2.54c
Kenya Sifa	2.78c	2.52ab	2.65c	2.55b	4.31b	4.25b	4.32c	3.95b	116d	103d	115d	110d	3.22ab	3.18b	3.19ab	2.98ab
Kenya Karibu	2.76d	2.51ab	2.63d	2.54b	4.31b	4.12c	4.45b	4.00a	153a	145a	152a	146a	3.61a	3.36a	3.59a	3.38a
393385.39	2.66e	2.44b	2.55e	2.45c	2.65g	2.53h	2.72h	2.33g	88f	81e	88f	82f	2.16d	1.90g	2.14d	1.93d
393385.47	1.93f	1.70c	1.81f	1.72d	3.89c	3.55d	3.88d	3.47c	111e	104d	110e	105e	2.98cb	2.71c	2.96cb	2.75cb
Desiree	1.78g	1.55d	1.66g	1.56e	4.54a	4.32a	4.55a	3.99a	120c	113c	118c	114c	2.80c	2.53d	2.77c	2.56c
Tigoni	1.77g	1.54d	1.65g	1.55e	3.57e	3.21f	3.64f	3.21e	85g	77e	84g	78g	2.35d	2.11f	2.33d	2.12d
CV (%)	0.4	2.8	0.61	1.55	4.7	8.8	2.9	4.6	0.32	0.34	0.46	0.54	9	5.2	9.9.06	9.77
LSD (P≤0.05)	0.01	0.09	0.02	0.05	0.026	0.044	0.02	0.02	0.53	0.53	0.75	0.84	0.39	0.02	0.39	0.4

Results (dry basis) are means of three determinations; Means with the same letters within the same column are not significantly different at 5%level of significance.

Iron: Iron content differed significantly (P≤0.05) among the cultivars in raw tubers ranging from 2.65 mg/100 g in clone 393385.39 to 4.54 mg/100 g in Desiree. The range in the study compares well with values reported by Imungi (1987) and Burton (1989). Levels of iron did not significantly (P>0.05) differ for fresh French fries compared to the raw tubers. Boiling significantly (P≤0.05) reduced levels of iron with losses ranging from 2.6 % in cv. Kenya Sifa to 10.8 % in cv. Tigoni. This translates to about 90.2 - 97.4 % retention of iron content among the cultivars after boiling. The loss due to leaching was described by Woolfe (1987) as nutritionally insignificant. Freezing significantly (P≤0.05) reduced iron content with losses ranging from 7.62 % in cv. Kenya Karibu to 10.56 % in cv. Tigoni. Freezing of water in cells of potato chips may have caused damage resulting to leaching of minerals in frying oil. Woolfe (1987) assumed without any reported analysis that there would be losses during peeling and slicing of chips in preparation of frozen French fries. The present study shows that losses due to frozen storage compares with those due to boiling with substantial retention level of 89.44-92.38 %, which allows the technology to be embraced.

Magnesium: The amount of magnesium in the raw tubers of the 8 cultivars ranged between 67 mg in clone 391691.96 to 153 mg in variety Kenya Karibu per 100 g (dry basis). This compares to the range of 45.9 to 216.5 mg per 100g (dwb) reported by Burton (1989). The levels of magnesium differed significantly (P≤0.05) with processing among the cultivars. Boiling significantly reduced (P≤0.05) magnesium content with percent losses ranging from 5.07 % in Desiree to 11.2 % in Dutch Robyjn. Similar results have been reported by True *et al*. (1979) and Woolfe (1987). Likewise, freezing significantly (P≤0.05) reduced the levels of magnesium with average losses ranging from 4.3 % in cv. Dutch Robyjn to 8.95 % in clone 391691.96. The high retention rate 91.05 - 95.6 % means that mineral would be adequate in frozen chips.

Manganese: Manganese levels in raw tubers differed significantly (P≤0.05) among the cultivars ranging from 2.16 mg/100 g in clone 393385.39 to 3.61 mg/100 g in Kenya Karibu. The range in the study compares well with values reported by True *et al*. (1978) and Burton (1989). Levels of manganese did not significantly (P>0.05) differ in fresh French fries compared to the raw tubers. Boiling, however, significantly (P≤0.05) reduced manganese content with losses ranging from 6.9 % in cv. Tigoni to 12 % in cv. Dutch Robyjn. This translates to about 88 - 93.9 % retention of manganese among the cultivars after boiling. Freezing significantly (P≤0.05) reduced manganese content with losses ranging from 6.4 % in cv. Tigoni to 10.65 % in cv. Dutch Robyjn translating to 89.35 - 93.6 % retention, which is adequate to meet requirements (Woolfe, 1987).

CONCLUSIONS: The study succeeded in establishing that local cultivars in Kenya could be suitable for boiling and processing into freshly prepared and frozen French fries without adverse effects to nutritional compositions. The proximate and mineral composition of the varieties Tigoni, Desiree, Kenya Karibu, Kenya Sifa and Dutch Robyjn, and the clones 391691.96, 393385.47 and 393385.39 were found to be closely comparable to those reported in literature. This finding provides adequate nutritional information on raw and processed potato products from Kenya that has not been adequately addressed.

Potato has been considered to be a rich source of energy and to provide to provide negligible amounts of protein and minerals. It has been shown here that, by itself, it is a poor source of energy unless fried, but that it contains good amount of minerals and trace element. Frying alone did not have any adverse effect on proximate chemical and mineral composition of the potatoes. The rates of retentions of these constituents were considerably higher and thus processing of frozen French fry technology in Kenya is worth consideration. The study indicates that the benefits of this technology can be harnessed without adverse effect on nutritional quality. Local potatoes can then be used not only as boiled or fresh fries but also frozen fries with increased shelf life.

Potato being a major food crop in Kenya, only second to maize is largely consumed by a large number of the population especially in the potato growing areas and urban centres where French fries is the major form of consumption. The nutritional information in this study, therefore, gives adequate and necessary information that consuming potatoes will supply adequate nutrients required by the body. This information is essential not only to consumers but processing industries as it is useful for labelling purposes.

Variety Tigoni generally has high yield and is grown by many farmers in Kenya. It, however, greens so fast on exposure to light. This may pose great loss to farmers and processors who have no prior knowledge. This challenge was overcome by dark storage of all the tubers. More work may be done by breeders to produce variety as high yielding as Tigoni but that has good keeping quality.

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