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EFFECT OF DRYING METHOD ON NUTRIENT INTEGRITY OF SELECTED COMPONENTS OF PUMPKIN (*Cucurbita moschata* Duch.) FRUIT FLOUR

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ABSTRACT

Pumpkin is a multi-purpose fruit and leafy vegetable with abundant nutritional value and economic potential as a food and industrial crop. *Cucurbita moschata* is the most common, heat-tolerant, better thriver in tropical Africa, but remains under-utilised. Food preservation prolongs consumption period, diet variety and income generation for manufacturing companies. However, preservation is a central problem facing developing countries, with huge post-harvest losses of perishable commodities. Food availability that decreases just a few months after harvest limits development of high-value agri-business industries specializing in highly perishable products. Although processing and preservation treatments lead to high convenience, the subsequent nutritional loss remains a challenge. There is need to find ways of minimizing nutritional losses. Subsequently, the present study grew and subjected mature pumpkin fruits to three open solar (OSD), oven electric (OED) and enhanced solar (ESD) drying methods in an incomplete randomized block design. Dry fruit slices were milled and analysed for β-carotene, protein, zinc, iron, calcium, energy, and moisture contents. There was a significant ($P<0.05$)difference in length of time taken to dry pumpkin fruit slices using the three methods. Oven drying took shortest time of 7.25 hours to attain15.15% final moisture content (MC), while OSD took 9.5 hours to attain 14.91% MC, but these MC were above safe levels. Enhanced solar drying achieved safest 12.82% MC, but in a longer time of 13.2 hours. A significant ($P<0.05$) difference resulted in β-carotene, protein and zinc contents of the four flours. There was consistent increase ofβ-carotene and protein contents in dried flour compared to fresh fruit, while minerals and energy slightly reduced ($P>0.05$). Oven dried flour had 74.84 μ/g, while fresh fruit had 16.6 μ/gβ-carotene. Protein ranged from13.8% to 16.5% in dry flours compared to 2.6% in fresh fruit. Zinc, iron, calcium and energy decreased in dry flours compared to fresh fruit, and ranged from:9 to 44 ppm zinc, 49.5to 94.5 ppm iron, 525 to 1,116.82ppm calcium, and 3.6 to 4.2 kcal/g energy. Drying generally increases certain nutrients in reduced bulk as it did β-carotene and protein, but also reduces others as it did zinc, iron, calcium and energy through oxidation. There is need to invest in ESD as an effective method of pumpkin fruit and nutrient integrity preservation, as well as post-harvest loss prevention.

Keywords: fruit drying, β-carotene, protein, mineral nutrients, calorific value.

INTRODUCTION

Pumpkin is an angiosperm belonging to the *Cucurbitaceae* family that is characterized by climbing herbaceous vines with tendrils and large, fleshy fruits containing numerous seeds (Acquaah, 2004). Pumpkins have spread all over the tropics and subtropics (Mnzava and Mbewe, 1997). Of the seven continents, only Antarctica is unable to produce pumpkins (Halloween Online, 2007). Pumpkins occur in three common types throughout the world, namely *Cucurbita pepo*, *C. maxima* and *C.moschata* (Lee *et al*. 2003). *Cucurbita moschata* is the most heat-tolerant species and the most common in tropical Africa (Fedha *et al*., 2010).It has great economic potential as a food and as an industrial crop. It is utilized for its leaves, marrow, fruit pulp, seeds and flowers. The stem could be used as livestock feed. It has health enhancing properties (Chweya and Eyzaguirre, 1999; Mnzava and Mbewe, 1997). Pumpkin has an abundance of macro- and micro-nutrients, as well as antioxidants that boost the human body immunity against cancer and other deadly diseases (Oloyede *et al*., 2013). It has such nutritional potential unequalled to any other single crop (Encyclopedia of Foods, 2004). Pumpkin is a traditional crop with high potential to overcome undernourishment and food poverty (Ondigi *et al*., 2008), yet very little has been done to generate income from this crop even amidst favourable ecological conditions throughout East Africa (Hamisy *et al*, 2002; Muendo and Tschirley, 2004). Consequently pumpkin remains underutilized and less regarded by many households.

The aims of the food industry today are to: extend the period (shelf-life) during which a food remains wholesome by using preservation techniques that inhibit microbial or biochemical changes and allow time for distribution, sale and home storage; increase variety in the diet by providing a range of attractive flavour, colour, aroma and texture in food; provide nutrients required for health; and generate income for the manufacturing company and its shareholders (Fellows, 2009). However, preservation of agricultural produce is one of the central problems facing developing countries. Owing to the lack of and/or inadequacy of preservation methods, large quantities of urgently needed food perishes (Habwe, 2008). Even when farmers manage to achieve higher crop yields, their harvests are still at risk because of inadequate storage facilities. Most existing storage facilities cannot protect crops from destructive pests or weather-accelerated decay. Sub-Saharan Africa countries face average 35-50%

post-harvest losses, for perishable products like fruits and vegetables, of total attainable production. Food availability decreases just a few months after harvest because sellers find it difficult to store perishable commodities. The effect of poor storage facilities also limits the development of high-value agri-business industries that specialize in horticulture or other highly perishable agricultural products (Gajigo and Lukoma, 2011).

As time goes by, these problems will be aggravated by the growing dietary needs of growing populations in these countries. In Africa and Kenya in particular, these problems exist with many fruit and vegetable varieties, especially the indigenous ones, resulting in wastage during the in-season and limited supply during the off-season accompanied by high prices (Habwe, 2008; Onyango *et al*., 2006), because most locally available vegetables are seasonal and not available year-long. African indigenous vegetables cannot be marketed fast enough when they are in-season owing to their limited keeping ability (perishability). Appropriate preservation and storage methods should be performed to prolong consumption of such nutrient-rich foods all year-round (Chavasit *et al*., 2002). Processing can transform vegetables from perishable produce into stable foods with long shelf-life, thereby aid in global transportation and distribution (Onyango *et al*., 2008). Mild or minimal processing and preservation treatments lead to high convenience and nutritional value, which is advantageous to consumers and food services. Changing customs have led to the increasing use of convenience foods at home and in food outlets (Wiley, 1994). Various methods of food processing and preservation can be used today. The methods include dehydration, cold and heat treatment, fermentation, minimal processing, irradiation, additives and packaging to prevent growth of microbes such as bacteria and fungi (Masarirambi *et al*., 2010).

The biggest challenge in processing fresh produce is subsequent nutrient loss. Actual losses depend on various factors such as food type, temperature and cooking time. Nearly all food preparation and preservation methods lead to losses. Drying has been recognized as the most useful processing technique for prolonging the keeping quality of solid foods including vegetables (Dissa *et al*., 2011). Food processors and nutritionists need to find ways of minimizing nutritional losses without compromising the health of consumers. Alternatively to combat losses and improve human health, food fortification may be more widely used (Masarirambi *et al*., 2010). Physical, chemical and biochemical transformations occurring during air-drying represent one of the main problems that may lead to product quality depreciation since the maximum temperatures used in food drying are generally not high enough to inactivate enzymes (Mujumdar, 1997). Application of heat blanching to fruits and vegetables before air-drying is aimed at stopping enzymatic activity and undesirable changes to the sensory and nutritional properties during drying and storage, thereby enhancing product quality (Filho *et al*., 2010). The purpose of the present paper was to determine the effect of drying on pumpkin fruit flour nutrient contents. Three drying methods used were: open sun, oven, and enhanced solar drying. Hypotheses tested were that there was no significant difference in the time taken to dry pumpkin fruit, and in the protein, β-carotene, zinc, iron, calcium and energy contents of pumpkin flour for the three drying methods.

METHODOLOGY

Drying pumpkin fruit

Multi-purpose pumpkin fruits of one landrace were grown under uniform conditions on a plot in Chuka University. Mature fruits were harvested with intact stalk and stored on a raised shelf in an aerated room. The fruits were washed, peeled, sliced, seeds removed and discarded. The slices were cut uniformly at 2.5 cm length by 0.5 cm width. Slices weighing 250 g were blanched by dipping fast in boiling water for 1 minute. Since dipping the slices lowered the temperature of the boiling water, the timing for blanching begun after the water started boiling again. Blanched pieces were strained and cooled with running tap water for another 1 minute and wiped with absorbent paper. They were then subjected to drying while weighing every three hours until constant weight was achieved (Workneh *et al*., 2012). Three drying methods were compared to determine the most appropriate regarding drying time and effect on nutritive value. Drying methods used were open sun drying, enclosed solar drying, and oven drying, with control samples of fresh fruits preserved by freezing slices from the same batch of sliced fruits. Before freezing the pieces were wrapped in aluminum foil then put in brown paper bags to protect them from light.

An incomplete randomized block design was used in the experiments since blocks were not big enough to contain all treatments. Each drying method had four replicates. In the enhanced solar drying, the replicates were placed in separate shelves. Because the drier shelves had three compartments, one replicate had three blocks. The electric oven used had three shelves, hence held one replicate at a time, with three blocks. Open sun drying had no blocks because tables used had similar height, hence all replicates were drying at the same level.

Dried pumpkin fruit slices were ground using a Teflon-coated mill, then sieved to achieve uniformly fine powder. This was then analysed to determine nutritive value. To determine flour keeping quality, the moisture content of pumpkin powder from the different drying methods was determined. A small known weight of powder in a crucible was heated in a dry oven at 105^oC for 2 hours, then covered with aluminum foil and cooled in a desiccator for 1 hour. Percent moisture content was determined by calculating the difference between the weight (g) of sample before and after heating, divided by sample weight (g) before heating, multiplied by 100.This comparison helped establish which method achieved safest moisture level.

To determination of nutritive value, four replicates of pumpkin powder samples from each of the three drying methods and the control fresh (frozen) fruits were analysed for β-carotene, protein, zinc, iron, calcium,

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and energy contents. Beta-carotene was determined by extracting 2g of each sample using acetone. The sample was crushed using a mortar and pestle until the residue turned colourless. The extract was passed through a funnel stuffed with glass wool, and then 25ml of this extract was put in a round-bottomed flask and evaporated to dryness at about 60°C. A 1ml of petroleum ether was added into the evaporated sample to dissolve the β-carotene. The solution was then eluted using a column chromatography. For preparation of the column, slurry made from silica gel with 60-120 mesh and petroleum ether was laid in a glass column of 15cm in length fitted with glass wool at the elution point. After the slurry had settled, the column top was packed with anhydrous Na_2SO_4, and 1ml absolute ethanol was added to activate both anhydrous Na_2SO_4 and silica gel. The mixture was then eluted using petroleum ether until a volume of 25 ml had been collected. The elute absorbance was read in UV-VIS spectrophotometer (Shimadzu Pharmaspec Model 1700) at 450nm. Five standard solutions of β-carotene with concentrations between 0.4μg/g and 2.4μg/g were prepared and their absorbance read at the same wavelength and plotted against their corresponding concentrations to give a standard curve (Okalebo *et al*., 2002). Beta-carotene in samples was determined using the formula: Beta-carotene = (0.4/0.12)*(Absorbance*FV/sample weight)*DF, Where FV = final volume, DF= dilution factor.

Protein analysis was done by weighing 0.3 g sample, putting in a test tube, adding 4 ml of digestion mixture with H_2SO_4, H_2O_2 and selenium catalyst, and reagent blanks for each sample batch. These were digested for 1 hour at 110°C and 330°C to complete digestionin a digester. Mixture turning colourless indicated complete digestion then 25ml of distilled water was added and mixed well until no more sediment dissolved. The mixture was allowed to cool and made up to 50 ml using distilled water, allowed to settle and then a clear solution was taken from top to determine total nitrogen by Kjeldal method, where 25 ml NaOH were dispensedin the digested sample in a conical flask, then 25ml of boric acid added plus 3 drops of mixed indicator with 0.99g bromocressol green, 0.066g methyl red and 0.011g thymol blue in 1ml ethanol. Distillation was done to 150ml in a conical flask. The pale pink colour of the distillate turned to green. The distillate was back-titrated with 0.1M HCl until the colour changed from green to pale pink (Okalebo *et al*., 2002). The amount of HCl used was recorded andthe percentage protein determined using a conversion factor 6.25 (AOAC, 1990). Protein % = (T5-TB)×0.1×N14.007×100/[0.3×6.25 (F)], Where: T5= titration volume for sample (ml); TB=Titration volume for blank (ml); N= normality of acid; F=conversion factor for N_2 to protein.

Mineral analysis was done by weighing 10 g of dried pumpkin fruit from each drying method, milling using a chromium ball mill (Retsch Mill Model, MM 400), whose milling compartment was coated with Teflon. After each milling round, the compartment was thoroughly wiped clean using a wet cloth to avoid contamination of the next sample. The resulting whole meal flour was stored in dry clean brown envelopes. For analysis of Ca, Fe and Zn contents in the sample, 0.3g of the finely ground pumpkin flour was weighed and placed in a dry clean glass digestion tube, 4 ml of the digestion mixture with selenium-sulphuric acid mixture added and heated to 300°C in a block digester, until the digest turned colourless or pale yellow. The tubes were then removed from the block digester and cooled to room temperature. The digest was then transferred into a 100ml volumetric flask and filled to the mark with de-ionized water. After cooling, the digests were analyzed for trace metals of calcium, iron and zinc by measuring their absorbance at 422.7nm, 248.33nm and 213.86nm, respectively, using an Atomic Absorption Spectrophotometer (Shimadzu Model AA-6300, Tokyo-Japan). Standards of 2.5, 5.0, 7.5 and 10 ppm were prepared from1000 ppm standard stock solution and absorbance determined. The stock solutions were prepared from salts of calcium, iron and zinc nitrates for calcium, iron and zinc standards, respectively. The results were used to construct calibration curves with absorbance against corresponding concentration.

Determination of calorific value of the products was done using oxygen combustion bomb calorimetry, where 1 g of sample was weighed in a crucible and placed inside a stainless steel container filled with 30 bar of oxygen. The sample was ignited using a cotton thread connected to an ignition wire inside the bomb calorimeter and burned. Temperature change was monitored and recorded at 3 minutes intervals. The heat created during the burning process was determined by comparing with the heat obtained from 1 g of standard benzoic acid. The calorific value of the food sample was calculated by multiplying its temperature rise in the calorimeter by the previously determined energy equivalent from the standard and dividing by the weight of sample.

Data Statistical analysis

Incomplete randomised block design was used since blocks were not big enough to contain all treatments. The model: $Y_{ijk} = \mu+t_i+s_j+r_{jk}+e_{ijk}$: Where Y_{ijk}=the observed time used to dry for the i th treatment of the k th replicate in the j th block; μ= The general mean; t_i=Fixed effect of the i th treatment, i = 1, 2, 3; s_j= Random effect of the j thblock , j = 1, 2, 3, 4 with $s_j \sim N(0, \sigma_s^2)$;$r_{jk}$ = Random effect of the kth replicate with temperature nested within the jthblock, with $r_{jk} \sim N(0, \sigma_r^2)$; e_{ijk}= Random error, independent, identically and normally distributed, with $e_{ijk} \sim N(0, \sigma_e^2)$. Data were analysed using restricted maximal likelihood mixed model procedure in SAS version 9.3 (SAS Institute, 2004). The effects of method of drying were fixed, while effects of replicates and blocks were random, with temperature nested within blocks. As well SPSS version 16 was used.

RESULTS

Pumpkin fruit drying

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The three methods used to dry pumpkin fruit were enhanced solar drying (ESD), open sun drying (OSD) and oven electric drying (OVD). The time taken to dry the samples to constant weight was evaluated for each method. In ESD, the different shelves had great variations in terms of drying time. The highest shelf took the shortest time (11 hours) while the lowest shelf took the longest time of 16 hours. In oven drying, the different shelves varied greatly in terms of temperature and length of drying the samples. Whereas oven temperature was set at 50°C, the actual temperature of the top shelf was 52°C, middle shelf 56°C and lowest shelf 60°C. There were notable differences in time of drying, with hottest oven shelf taking 4 hours and coolest shelf taking 10 hours for samples to dry completely. Open solar drying whereby tables used were at same height, did not have much variation in drying time among the replicates. Generally, ESD took the longest time and OVD the shortest time to dry the samples (Table-1).

Table-1. Means of time taken to dry pumpkin fruit to constant weight for three drying methods.

Drying method	Average drying time (hours)*	Average moisture content (%)
Enhanced solar drying	13.27a	12.82%
Open solar drying	9.50b	14.91%
Oven drying	7.25c	15.15%

*Means followed by the same letter within a column are not significantly different at $P = 0.05$

Open sun dried samples lost moisture at a very fast rate compared to oven drying yet oven dried samples attained constant weight ahead of those dried in the open sun (Figure-1). Enhanced solar drying was gradual until a constant weight was achieved. There were significant differences (P=0.0001) between the length of time taken to dry pumpkin fruit using the three methods (Table-2).

Determination of moisture content

The dry fruit slices were milled and analysed for moisture content (MC). All four replicates from each drying method were tested. The OVD had the highest MC, ranging from 13% to 17%, while ESD had lowest ranging from 11% to 14%. The open sun drying MC ranged from 12.92% to 16.05% (Table-1).

Table-2. Least square means comparing time taken to dry pumpkin fruit to constant weight by three methods.

Drying method	Drying method	Estimate	Standard error	df	t-value	*P*-value
Enhanced solar	Open sun drying	3.7566	0.8445	15	4.45	0.0005
Enhanced solar	Oven drying	6.1134	1.0776	15	5.67	<0.0001
Open sun	Oven drying	2.3569	1.0347	15	2.28	0.0378

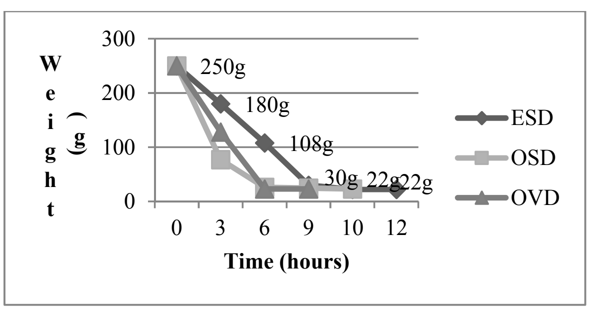

Figure-1. Trends for moisture loss rates in the three drying treatments.ESD =Enhanced Solar Drying; OSD = Open Sun Drying; OVD = Oven Drying.

Determination of nutritive value

Table-3 has means of nutritive value of pumpkin fruit subjected tothe different drying methods. There were significant differences between β-carotene, protein and zinc levels in the four treatments. Oven dried pumpkin flour had the highest levels of 74.84 µg/gβ-carotene, while fresh fruit had the least16.6 µg/g (Table-3).

Protein showed no significant difference in the three drying methods, but significantly differed between the flours and fresh fruit, where it was highest at 13.8% to 16.5% for dry flours and lowest at 2.6% for fresh fruit. Open sun and enhanced solar drying recorded higher levels while oven drying had slightly lower levels, but all the drying methods resulted in great increase in protein content. Drying pumpkin fruit realized almost 800% increase in protein (Table-3).

Zinc was significantly different among the treatments, where it was highest in fresh fruit at 44 ppm and lowest in enhanced solar drying at 9 ppm. Zinc levels reduced after fruit drying (Table-3). Enhanced solar drying recorded the highest reduction of zinc, while open sun drying preserved most of the zinc.

Analysis of iron, calcium and energy levels showed no significant (P>0.05) difference between all the treatments (Table-3).Iron ranged from 49 to 94 ppm, calcium from 525 to 2492 ppm, and energy from 3.6 to 4.2 kcal/g. As was the case for zinc, iron also showed a reduction in all the dried samples compared to the fresh fruit, with the exception of open sun drying, which had a

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negligible increase of 0.2975 ppm in the dried sample. Open sun drying showed the most preservation while enhanced solar recorded the highest losses of iron.

Calcium levels of pumpkin fruit were also reduced greatly after drying, with open sun drying recording the greatest reduction and oven dried samples showing highest preservation. Drying recorded losses of over200% of calcium from the fruit.

Energy content also showed a similar trend of reduction in the dried samples, although small and insignificant. Table-3 shows that oven drying caused the least loss while open sun drying had the highest loss in energy content.

DISCUSSION

The length of time taken to dry samples using the three methods show that enhanced solar drying was the slowest compared to open sun and oven drying. Drying in a solar drier occurs in an enclosed environment, whereas moisture evaporates faster in the open, leading to quick drying. The high rate of evaporation during drying, leads to high possibility of losing more nutrients. This has been found to be true in previous studies which reported that open air drying was first in terms of cost benefit, but poorest in terms of protection against dust, insects, microbes and nutrient retention (Eze and Chibuzor, 2008; Anyanwu and Okonkwo, 2008). Open sun drying is inconvenienced by clouds or rains where samples take longer to dry and even end up spoiling. Enhanced solar drying is more consistent in fluctuating weather conditions, since the temperatures in the drying chamber remain relatively constant as the solar drier is able to trap and retain heat from the sun even when it is cloudy. Solar drying is appropriate technology for a sustainable environment since it has potential for high quality product and is environment-friendly (Yaldiz and Ertekyn, 2001).

Moisture content contributes a lot to the food safety and shelf-life. The higher the moisture content, the less the period a food will keep before spoiling. Moisture rich foods are susceptible to attack by microbes, while low moisture levels slow down growth of microorganisms. Moisture levels of 14% and above promote fungal growth, while lower moisture levels prevent spoilage (Hoseney, 1994). The present study found that moisture content of oven and sun dried pumpkin fruit powder was above acceptable safe levels. Oven drying retains the highest moisture level in pumpkin fruit. Enhanced solar drying is slower but able to achieve complete drying. Therefore the faster a drying method is, the less effective the removal of moisture to the core of the food pieces. Oven drying retains more moisture content which will render the flour going bad sooner. The low level of moisture content in solar dried pumpkin powder enables it to be preserved for longer period. A similar study comparing three drying methods on plantain, yam and cocoyam showed similar results where solar drying retained least moisture content (Agoreyo, *et al*., 2011).

Oven drying retained the highest amounts of β-carotene followed by ESD, while OSDhad the least amount of β-carotene. Due to the fast rate of drying in the oven, less nutrients were lost by the time constant weight was achieved. In addition, the samples were still intact at the core by the time constant weight was achieved. Lower values observed in sun dried pumpkin fruit were most likely a result of the effect of the rays of the sun on the carotenoid pigments. Similar results were found in a study by Kiremire *et al*., (2010) where oven drying exhibited better retention of β-carotene, followed by solar drying and open sun retained the least β-carotene.

Table-3. Means of nutrient content of pumpkin flour from three drying methods.

Treatment	**β-carotene** (μg/g)*	**Protein** (%)	**Zinc** (ppm)	**Iron** (ppm)	**Calcium** (ppm)	**Energy** (kcal/g)
Oven dried	74.8425a	13.7850a	24.948a	66.3225a	830.23a	3.84675a
Enhanced solar	62.9875ab	16.4875a	9.058b	49.5400a	539.08a	3.76350a
Open sun	27.1750bc	16.4900a	20.995ba	94.7975a	525.43a	3.62875a
Fresh fruit	16.6150c	2.6175b	44.075c	94.5000a	1,116.82a	4.26575a
F-value	8.497	58.832	17.616	1.595	1.705	2.376
P-value	0.003	0.000	0.000	0.242	0.219	0.121

*Means followed by the same letter within a column are not significantly different at $P = 0.05$

Sun drying involves exposure of a product to solar radiation without protection against the sun's UV rays, and photo-degradation of the carotenoids with the subsequent loss of vitamin A activity. The higher levels observed in oven dried samples could be due to the fact that the method did not involve sun rays.

Studies have shown varied results on effect of drying on β-carotene. Fresh pumpkin fruit samples in the United States contained 24-84 μg/gβ-carotene, while the present study observed 13.53 μg/g. Another study in Kenya reported 518 μg/g of β-carotene in the fruit pulp of pumpkins grown in Machakos. In the later study, the β-carotene levels reduced from 518 to 262.2μg/g after drying the fruit, but the amounts in flour from fruit dried without peeling remained significantly higher even with a decrease after drying (Fedha *et al*., 2010).

Results in the present study are based on flour from pumpkin fruit which was thinly peeled and the dried pumpkin recorded between 33.38 and 83.34 µg/g of β-carotene, which was an increase from 13.53µg/g in fresh fruit. A study by Onoja (2014) on pumpkin leaves of a different landrace showed a similar trend, where drying significantly increased β-carotene levels. This was due to concentration of nutrients in the dry matter. The varied differences in β-carotene contents, even between samples of the same variety, may be attributed to the long period during which these fruits can be harvested, and some of the low levels may be due to analysis of immature fruit (Rodriguez-Amaya, 1997).

Results for protein similarly showed less amount of protein in fresh fruit compared to dried pumpkin fruit. Dried fruit had five or more times of amount detected in fresh fruit. The amount of protein in fresh fruit is comparable with a study by Fedha *et al*. (2010), which reported 4% protein. The same study showed a slight increase in protein levels in dry pumpkin fruit (4.3%). Generally, the higher nutritive values observed in dried pumpkin fruit in the present study was due to drying which increased the dry matter and level of nutrients in any given weight. This was also in agreement with a study conducted by Morris *et al*. (2004), who concluded that removal of moisture may increase the nutrient content, which was the case in all the dried samples.

Results for minerals showed that fresh fruit generally had higher levels of each of the minerals, and that drying resulted in reduced mineral levels. Energy levels also showed a similar trend, with slight reductions in the dried samples compared to fresh fruit. With the exception of zinc, these nutrient reductions were, however, not very significant.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that enhanced solar drying is a slower but consistent method since it is able to achieve safe moisture levels of dried pumpkin fruit. Open sun drying was faster because the study was done during hot weather. Oven drying, though faster and preserving more β-carotene levels is not practical in many rural set ups where electricity supply may not be accessible, and not cost effective where power is available.

The nutritive value of pumpkin flour is different from that of the fresh fruit. There is consistent increase for both β-carotene and protein in dried pumpkin fruit. On the other hand, mineral and energy contents seem to reduce in the dried samples when compared with fresh fruit. Results for this study can be explained by the fact that drying increases the nutrient density in much reduced bulk. This is, however, not usually the case for all nutrients; while great increase is recorded for some nutrients, others will be compromised. In this study, the reductions in some of the nutrients after drying were anyway not significant.

Enhanced solar drying resulted in an increase in β-carotene and protein, while oven (electric) drying preserved a great deal of the minerals, although still a reduction compared to fresh fruit. However, electric drying will not be feasible for many local households. Open sun drying is also noted to preserve a number of minerals but second to oven drying. This method may however be inconvenienced during cool or rainy seasons which may render it impossible. Drying food in open air results in a great deal of contamination with microbes and dust, which may lead to unsafe food. It is therefore concluded that enhanced solar drying is the best method for drying pumpkin fruit as it preserves relatively more nutrients and is locally feasible.

The rich nutrient potential of dried pumpkin fruit can be tapped for food at household and commercial level. Utilization of pumpkin flour based products can be a good source of vitamin A from the β-carotene and of protein, which are important nutrients for the population, especially growing children. Incorporating pumpkin flour into main meals, snacks and weaning foods can be a good avenue to promoting healthy growth and development of children. Preservation of fruits by drying will be a superb way of preventing postharvest losses when there is a lot of harvest which farmers have to take care of either by selling or consuming before it spoils. Pumpkin fruit though able to keep longer than most other fruits and vegetables, will only do so if the fruit is completely free of the slightest bruise. Sometimes this is not possible since pumpkin fruits will have insect bites or acquire small bruises during transportation after harvest. The bruises eventually cause rotting within the first few weeks after harvest. This study therefore recommends that efforts be made to create awareness among farmers on importance of investing in solar driers as a means of pumpkin fruit preservation, and to make such equipment affordable to the farmers.

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