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EFFECTS OF VEGETABLE DRYING TECHNIQUES ON NUTRIENT CONTENT: A CASE STUDY OF SOUTH-WESTERN UGANDA

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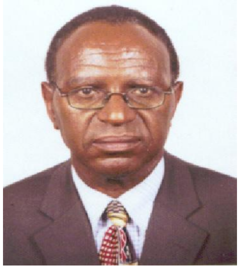

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ABSTRACT

Micronutrient deficiencies are high in Uganda. To the rural poor, the most compelling and long- term strategy to address this problem is dietary diversity. However, post-harvest losses and seasonal variability within key foods still hamper the community-based efforts to supply local food sources throughout the year. Vegetables are important in most of the daily diets and can be used to alleviate most of the micronutrient deficiencies. Vegetables are only available during the rainy season in rural areas. Therefore, it is necessary to preserve them and use them during the dry season when they are scarce. The objective of this study was to establish food preservation methods that could easily be adopted for preservation of vegetables in order to even out the imbalance of supplies between the rainy and the dry season. In order to achieve the objective, first, a survey was carried out in South Western Uganda, to identify the traditional methods of preservation of food plants. Then, the traditional methods were compared with other methods that can be used for drying vegetables, with respect to retention of nutrients after drying to determine the best method applicable to a rural setting. Sun drying was identified as the only traditional method of preserving foodstuffs in Rukungiri district. The method was cited by all households (n=116) in the drying of grains legumes and cereals such as maize, millet and sorghum. Apart from sun drying, two other methods are applicable to the rural setting; namely oven drying and solar drying. The effects of sun drying, solar drying and oven drying on the nutrient composition of selected vegetables were assessed by proximate analyses and compared with the nutrient content of the fresh vegetables. The results showed that some nutrients were lost during the drying process but in general, the nutrient content remained high. With respect to retention of the nutrient content in vegetables, solar drying was found to be the best of the three methods. Based on this study, solar drying is recommended as a method for vegetable preservation.

Key words: Vegetables, Preservation, Drying, Nutrients, Uganda

INTRODUCTION

Vegetables and fruits are the major sources of micronutrients, especially among the rural poor in Uganda. In particular, leafy vegetables can easily be accessible to every household with minimum effort and various studies have established them as a rich source of the highly needed body micronutrients [1,2,3]. Leafy vegetables have unique advantages within the farming systems, in that they grow quickly and many are disease and drought resistant because they are adapted to local conditions. Unfortunately, vegetables and fruits face high postharvest losses (30 – 40%) leading to high nutritional and economic losses [4]. Therefore, it is necessary to study and identify appropriate methods of processing and preserving them in order to minimize losses. In view of the fact preservation techniques for food and nutrients have not taken root in most communities and also because the techniques used for preservation have not been studied well, malnutrition remains rife in Uganda.

According to the Uganda Demographic and Health Survey Report of 2007, 20.4% of children in Uganda below 5 years of age suffer from vitamin A deficiency (VAD), 73% suffer from Iron Deficiency Anaemia (IDA) and 60% suffer from various Iodine Deficiency Disorders (IDD)[5]. The survey also established that one out of every five women of reproductive age suffers from vitamin A deficiency while 41% suffer from iron deficiency anaemia. The prevalence of micronutrient-related disorders among Ugandans, especially the rural poor, can be addressed by fortification, supplementation, dietary diversification and public health awareness. Dietary diversification can provide the nutrients largely from careful selection of fruits and vegetables by communities alongside proper nutrition awareness and social marketing. The fruits and vegetables could be sourced domestically or gathered from the wild in areas where they have not been domesticated.

A number of studies have been carried out on nutrient composition to understand the quality and quantity of macro- and micronutrients and anti-oxidation activity of some wild edible plants in the region, as one way of establishing the overall contribution of the plants to the local food systems [6,7]. In many of these studies, wild edible plants have exhibited consistently high mineral values and the potential to contribute useful amounts of amino acids and fatty acids to the diets. In one of the studies, which was carried out on selected West African food plants, wild edible plants exhibited higher mineral values compared to cultivated species [7]. In addition, fruits and vegetables as well as nuts also contain an abundance of phenolic compounds, terpenoids and other natural antioxidants that have been associated with protection from and/or treatment of chronic illnesses such as heart disease, cancer, diabetes and hypertension [8]. Fruits and vegetables, whether domestic or wild, help to diversify diets and lead to desirable nutritional and health outcomes.

In spite of the fact that diverse diets have been associated with increased longevity and protection against chronic diseases [9,10], the lack of dietary diversity is particularly a severe problem among the poor populations in developing countries.

This has been attributed to the fact that the diets in such countries are mainly based on starchy staples with little or no animal products, fruits and vegetables [11].

Sub-Saharan Africa region is reported to have the world's lowest intake of micronutrient-rich fruits and vegetables with the mean consumption being less than half the WHO recommended daily intake of 400g per capita per day in most countries [12]. Low consumption of fruits and vegetables is the main contributor to micronutrient deficiencies, especially in populations with a low intake of nutrient-dense animal sources and dietary products. In particular, school children in sub-Saharan Africa are at increased risk of micronutrient deficiencies because of the low meal frequency, lack of diversity, reduced maternal attention, and parasitic infections, such as hookworms and schistosoma [13]. Nutritional deficiencies, particularly deficiencies of iron, iodine, and vitamin A, are documented to be the major problems for school-age children in low income countries. Yet, deficiencies of iron, vitamin A, iodine and zinc have far-reaching consequences on growth, development and health, contributing to impaired immunity and cognitive function, growth failure, increased morbidity and mortality [14]. Ideally, the prevalence of micronutrient-related disorders can be addressed by fortification and supplementation but this has to be subsidized because it can be expensive and hence financially inaccessible to the rural population who form the majority of the micronutrient deficiency victims.

The current retail prices based on the recommended dosage for selected food supplements that are being aggressively marketed in Uganda are shown in Table 1[15]. It is obvious from the prices that neither the people in rural communities nor the majority of urban dwellers can afford to supplement their diet through the purchase of food nutrients on a routine basis. Regular consumption of fruits and vegetables can provide the required nutrients to the same population. However, evening-out seasonality of fruits and vegetables through preservation will greatly improve availability and utilisation. By using appropriate preservation methods to avail fruits and vegetables throughout the year together with systematic promotion of their cultivation and consumption, it is possible to alleviate the above nutrient deficiencies and associated public health problems.

Uganda is endowed with many varieties of indigenous food plants and about 160 species of local vegetables have been reported from various districts and regions of Uganda [2]. Twenty-two of the species are very common in all districts and regions. In the survey carried out in South-western Uganda (Rukungiri), 39 species of food plants belonging to 24 families were identified and classified according to five broad categories namely; vegetables, fruits, roots / tubers, pulses and cereals [16]. Consumption of vegetables was found to be seasonal among the poor rural communities. Poor consumption is partly attributed to the fact that farming in Uganda is mostly small scale and rain-fed. It was established that there is limited production and collection from the wild of vegetables in rural areas leading to severe relish shortage, especially in the dry season and hence contributing to household food insecurity. The relish shortage is further exacerbated by high postharvest losses due to poor and inefficient preservation techniques.

In order to increase consumption of leafy vegetables, it is necessary to preserve them during the rainy season when they are plenty, so that they can be used in lean seasons when they are scarce. In this way, they will contribute to household food security and nutritional quality, by broadening the food base.

The ultimate aim of this study was to explore the possibility of evening out the seasonality of vegetable availability so as to ensure a year-round supply of micronutrient-rich vegetables to mostly the rural poor who are in dire need of those nutrients. During the course of the study vegetable-drying methods applied in Rukungiri district were documented. The methods were then simulated in the laboratory and the nutrient content of three (fresh and dried) *Amaranthus* varieties was determined in order to assess the effect of the drying techniques on nutrient content of the dried product. The objective of this paper is to report the methods used in drying vegetables in south western Uganda and to recommend those methods that do not deplete the nutrient contents of the vegetables during the process of drying.

MATERIALS AND METHODS

To document drying methods among other research objectives, a household baseline survey was carried out in Rukungiri district in South-western Uganda. The study covered a total of 116 households from eleven sub-counties: Bugangari, Buyanja, Bwambara, Kagunga, Kambuga, Kanyantorogo, Kebisoni, Kihihi, Ruhinda, Nyakagyeme and Nyarushanje. A structured questionnaire was used to obtain data on all the traditional plants used as food and the methods used for preserving them. The three methods of drying- traditional open-sun drying, solar drying and oven drying which were cited in the study were later simulated in the laboratory at Makerere University, Kampala. To establish the effect of drying techniques on nutrient content in vegetables, amaranthus species were selected because they are the most prevalent vegetables in south western Uganda. The samples of *Amaranthus hybridus*, *Amaranthus blitum* and *Amaranthus cruentus* – were separately subjected to traditional sun drying, solar drying and oven drying as described below. Other samples of the three *Amaranthus* varieties were used for proximate analyses on crude protein, crude fat, dietary fibre and micro nutrient determination of β-carotene, vitamin C and minerals (calcium, iron phosphorus, magnesium and potassium).

SAMPLE TREATMENT AND PREPARATION

Sun Drying

One kilogram of each sample was used for the experiment. The three varieties of Amaranthus were washed and evenly spread on a tray and left to dry in the sunshine for at least seven hours per day for four days until the vegetables were brittle and considered to be dry.

Oven drying

Four hundred grams of each sample were washed in ordinary tap water and drained. The vegetables were then packed in envelopes which were punched with holes to

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allow for moisture escape. The envelopes were placed in the oven (Hot box oven, size 2) at 65°C and left to dry overnight after which they were placed on shelves to cool.

Solar drying

One kilogram of each sample was separately dried in a solar dryer at Kawanda Agricultural Research Institute. The solar dryer used aluminium foil as a reflectant and to prevent rain or condensation from dampening the products the drier was covered with plastic roofing. The samples were turned twice a day for two days and then removed from the dryer.

Nutrient content analyses

Moisture content determination was carried out following procedures described by Kirk and Sawyer [17]. To determine crude protein content, the Kjeldahl method as described by Kirk and Sawyer [17] and AOAC [18] was followed using 1g of macerated samples.

The Soxhlet method [18] was followed using Soxtec equipment for determination of crude fat content while dietary fibre was determined using Acid Detergent Fibre (ADF) solution following procedures outlined by Kirk and Sawyer [17].

β-carotene was determined following procedures outlined by Ritter and Purcell [19] while the contents of Calcium, Iron, Magnesium, Potassium, Phosphorus, Sodium and vitamin C were determined following procedures described by Kirk and Sawyer [17].

Statistical data analysis

The statistical data analysis was based on the means calculated from the data. The raw data collected were analysed using a one way Analysis Of Variance (ANOVA) to find out whether there was any statistically significant variation in the means ($p = 0.05$). The statistical program used was Genstat Version 5, Release 3.2 (Lawes Agricultural Trust Roth Amsted experimental Station, USA).

RESULTS

A structured questionnaire was used to obtain data on all the traditional plants used as food and the methods used for preserving them. Most of the respondents to the questionnaire were familiar with sun drying as a method of preserving cereals such as millet and sorghum and other grains. However, the majority of the households were not aware that vegetables and fruits could be preserved through drying. Proximate analyses were carried out on dried samples to establish the retained nutrient content. For the control experiment, fresh vegetables were analysed for the same parameters. The results obtained for nutrient retention following drying by a variety of methods are tabulated in Tables 2, 3 and 4.

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The results in Table 2 show the variation of ten dietary parameters with drying methods for the green leafy vegetable *A. dubius.* The results revealed that all the nutrients experienced losses but the losses varied from one nutrient to another depending on the treatment employed. Beta-carotene was found to be very susceptible to sun drying with 86.5 % loss.

Open-air sun drying method resulted in the greatest losses in β-carotene and vitamin C contents (58 and 84%, respectively)**.**

A. hybridus (Table 3) and *A. cruentus* (Table 4) followed a similar trend with respect to nutrient retentions but the percentage retentions were different in all the three vegetables studied. Minerals were generally stable having registered the lowest losses and highest retentions in all the three drying techniques. Sodium was one of the minerals that registered losses exceeding 30% probably due to the fact that it is highly water-soluble.

DISCUSSION

Beta-carotene was found to be susceptible to drying. Sun drying proved to be the most destructive of all the three drying methods tested in this study. The method resulted in 86.5 % nutrient loss which was in conformity with results reported by an earlier study [20].

Pro-vitamin A and vitamin C are especially prone to oxidative destruction in the presence of heat, light, oxygen, enzymes, moisture and metal ions [21]. In particular UV-radiation catalyses β-carotene oxidation leading to loss of vitamin activity [22], In this study sodium was one of the minerals that registered losses exceeding 30% but on the whole, the minerals were not severely lost. This confirms the observations highlighted by previous studies [23].

During food processing/preservation, there is a high risk that the highly susceptible double bonds of carotenoids will undergo oxidation, especially through a free radical process, which is normally minimised by the presence of water [24].

Drying techniques also involve subjecting the vegetables to heat, light and oxygen, all of which accelerate the rate of carotenoid oxidation. Therefore, techniques that expose the vegetables to such conditions for long periods will result into higher losses. This could partly explain why sun drying resulted in severe losses to β-carotene. In previous studies on traditional methods of drying vegetables in Africa, excessive losses of β-carotene was attributed to photo-oxidation in addition to other factors [25].

Comparison of the nutrients of fresh vegetables with the vegetables dried by the different methods shows that, of the three drying technologies (sun drying, solar drying and oven drying), oven drying generally seemed better, especially with regard to beta- carotene retention followed by solar drying. This suggests that the loss in β-carotene is a function of, among others, the drying conditions as observed in earlier studies [26]. Since sun drying involves exposure of the product to the solar radiation for a long period without protection against the sun's UV rays, photodegradation of the carotenoids with the subsequent loss of vitamin A activity, is likely to occur through oxidation, isomerisation and/or free radical formation. Loss in β -carotene of up to 96.4% was encountered in *A. cruentus* (Table3) as a result of sun- drying.

The difference in losses caused by the different drying processes could be attributed to the length of exposure to light, oxygen, heat and other accelerating factors. Since sun dried vegetables took more time in light than solar dried ones, it could explain why more β -carotene loss took place in sun-dried vegetables than solar dried ones.

Vitamin C is a highly soluble compound that occurs in two forms; the reduced ascorbic acid (L-ascorbic acid and the oxidised dehydro-ascorbic acid). It is only the reduced isomer that has vitamin activity but both forms are biologically active. In foods, L-ascorbic acid is reversibly oxidised to dehydro-ascorbic acid and further oxidation leads to the irreversible formation of physiologically inactive diketogulonic acid [27].

The mechanism of degradation for vitamin C is influenced by temperature, salt and sugar concentrations, pH, enzymes, metal catalysts and the presence of oxygen [28]. All the drying methods used in the study yielded significant losses in vitamin C ($p \leq 0.05$) and this could be attributed to the fact that vitamin C is highly prone to oxidative destruction in the presence of heat, light, oxygen, enzymes, moisture and metal ions [29].

Traditional sun drying registered the highest loss of vitamin C in all dried samples probably because it exposed the vegetables to direct UV light more than the other methods which were simulated. UV light plays a significant role in the oxidation of vitamin C to the less stable dehydro-ascorbic acid which is in turn oxidised to other compounds. Osborne and Voogt [27] have reported reduced stability of vitamin C in aqueous state than in the dry state. This could explain why there was more loss of vitamin C in traditional sun drying than in solar drying. In traditional sun drying, vegetables with a high moisture level are dried at low temperatures and, therefore, are exposed for a long time. Leaching is another important factor that could have led to loss of soluble minerals as well as vitamin C along with the water during the drying process.

CONCLUSION

Although the statistical analysis of the results shows significant losses in minerals as a result of drying, the amount of nutrients retained could be valuable especially in communities that have limited alternative sources of these micronutrients.
Drying of fruits and vegetables should be encouraged as a way of ensuring year round supply of micronutrients to at-risk communities and groups in the region. Fruits and vegetables could be preserved when they are in season and fed to children, for

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example, who are singled out as being at high risk. The use of solar dryers should be encouraged in drying of fruits and vegetables. Being a costly facility, women for example can be mobilised to form associations and through those small groupings soft loans can be advanced by micro finance institutions to purchase solar driers. Solar drying of β -carotene–rich fruits and vegetables is also recommended by FAO/ILSI as an appropriate low-level technology for preserving foods [7]. Such food-based approaches remain the only affordable approaches of mitigating malnutrition in the developing countries, like Uganda where the majority of the people cannot afford marketed nutrient supplements and fortified foods.

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Table 1: Calculated costs of marketed nutrients

Food supplement	Monthly Cost (USD)
Vitamin A	4.03
Vitamin B	14.47
Vitamin C	6.2
Carotenoid complex	17.76
Fibre tablets	14.9

Source [15]

Table 2: Percentage nutrient retentions in *A. dubius (doodo)* dried by different methods

Parameter	Oven-dried	Solar dried	Traditionally sun-dried
Calcium (%)	91.8	93.8	80.5
β-carotene (%)	24.2	20.5	13.5
Dietary fibre (%)	97.5	93.2	99.6
Iron (%)	87.8	85.3	72.7
Magnesium (%)	84.0	86.2	84.9
Phosphorus (%)	80.5	85.2	87.2
Potassium (%)	75.9	87.5	93.2
Protein (%)	77.0	76.4	66.9
Sodium (%)	62.7	72.0	74.7
Vitamin C (%)	36.6	71.4	27.9

Table 3: Percentage nutrient retentions in *A. hybridus (omuriri)* dried by different methods

Parameter	Oven-dried	Solar-dried	Traditionally sun-dried
Calcium (%)	94.7	91.8	95.6
β-carotene (%)	21.6	23.6	8.3
Dietary fibre (%)	72.0	79.2	91.5
Iron (%)	69.9	61.2	72.5
Magnesium (%)	84.4	84.0	86.9
Phosphorus (%)	94.0	91.6	88.8
Potassium (%)	89.9	87.1	65.9
Protein (%)	51.7	57.1	87.3
Sodium (%)	81.1	68.8	86.1
Vitamin C (%)	73.7	31.0	22.4

Table 4: Percentage nutrient retention in *A. cruentus* (omuriri) dried by different methods

Parameter	Oven-dried	Solar-dried	Traditionally sun-dried
Calcium (%)	87.6	93.6	96.1
B-carotene (%)	41.6	28.2	3.6
Dietary fibre (%)	82.9	75.3	78.0
Iron (%)	56.3	88.7	88.1
Magnesium (mg)	91.7	85.3	71.9
Phosphorus (mg)	82.6	81.7	86.7
Potassium (%)	96.8	73.6	83.4
Protein (%)	55.1	48.9	63.3
Sodium (%)	75.1	73.3	68.7
Vitamin C (%)	57.4	58.5	49.7

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