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Formulation and quality assessment of snacks made from dried mango, pineapple and banana fruits

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Abstract

The purpose of this study was to develop snacks based on electrical cabinet and tunnel solar dried mango (*Mangifera indica* cv. Dodo), pineapple (*Ananas comonsuss* cv. Smooth cayenne) and bananas (*Musa acuminate* cv. Kisukari). The developed snacks include; dried fruits and fruit leather. The products were assessed for their safety, nutritional and shelf-life stability, whereby a factorial design was used to determine their effects on proximate, vitamin A and C, water activity and microbial load. The results showed significant differences ($p<0.05$) in proximate composition, vitamins (A and C), microbial load and water activities. Most of the samples dried by solar tunnel dryer had higher proximate composition as compared to electrical dryer. It was also observed that samples dried by solar tunnel dryer had higher content of vitamin A and C than the samples which were dried by electrical cabinet dryer. However, from the results there were insignificant differences ($p>0.05$) on minerals for both drying methods in which potassium was the most abundant mineral while iron was the least abundant mineral. All the developed snakes at different processing methods were observed to have shelf-life stability for the four months studied in all samples. In general, solar tunnel drying method was the best technique as it retained most of the required nutrients compared to an electrical cabinet drier and it was observed to have a minimal running cost which can be affordable by small scale producers in developing countries.

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Introduction

Fruits play an important role in human nutrition and health, particularly as sources of vitamin C, thiamine, niacin, pyridoxine, folic acid, minerals, phytochemicals and dietary fiber (Wargovich, 2000). Other vital nutrients supplied by fruits and include; riboflavin, zinc, calcium, potassium and phosphorus. The health benefit of fruits is associated with the presence of these valuable nutrients. The distribution of antioxidant capacity in fruits varies greatly depending on the type of fruit and location of the fruit itself (Runyogote *et al.*, 2021). With this variation of some nutritional contents in fruits it is better to consume a variety of them rather than limiting consumption to a few with the highest antioxidant capacity (Kalt, 2002). However, despite these merits, fruits are seasonal and highly perishable leading to enormous post-harvest losses. Lack of handling and processing knowledge and facilities are among many factors for their greater losses. Only less than 10% of the produced fruits are being processed in the country leading to both nutrition and economic losses (MACF, 2009).

The market for dehydrated fruits is important for most countries worldwide (Funebo and Ohlsson, 1998). Dehydration is one of the techniques that offers a means of preserving foods in a stable and safe condition as it reduces water activity and extends shelf-life much longer than that of fresh fruits. Different foods such as cereals, fruits and vegetables, may be dried using different methods depending on the purpose of drying and the availability of technology. The drying methods available range from those harnessing solar energy as a source of energy to modern mechanical and electrical methods using fuel and electricity as sources (Makanjuola *et al.*, 2013). Open sun drying is the oldest and most common method that has been used in preservation of agricultural produces in developing countries. However, the methods have been associated with in-built quality problem due to environmental and biological effect. Solar drying seems to be the best alternative as it produces product quickly and in hygienic manner with substantial retention of valuable nutrients (Mongi, 2013). Furthermore, solar drying is seen as a means of providing opportunities for value addition and income generation from marketing produce in local, regional and inter-national markets. Therefore, the study was carried out to formulate snacks based on solar and electrical dried banana, pineapple and mango fruits in Tanzania.

Material and methods

Research areas

The study was conducted in Morogoro Municipal Council. All drying activities were done at Danida project premises, Sokoine University of Agriculture (SUA) while laboratory analysis was done at the Department of Food Science and Technology laboratory.

Materials

Mango (*Mangifera indica*), banana (*Musa* sp.*)* and pineapples (*Ananas comosuss*) were purchased from Morogoro Municipal Market. Analytical grade reagents, chemicals and equipment for chemical and microbiology analysis were purchased from Py-rex East Africa suppliers and some obtained from Food science and Horticulture laboratories at SUA.

Research design

A purposive sampling procedure was used to collect a variety of each fruit (Mango cv. Dodo, banana cv. Kisukari and pineapple cv. Smooth cayenne) from Morogoro Municipal market in order to obtain fruits with better characteristics. A total of 360 samples were collected (i.e.120 Mangoes, 60 pineapples and 180 bananas) and subjected to two drying methods (solar tunnel and electrical cabinet dryers) and dried products were used to develop different snacks formulation. Factorial designs were used in the study and the principal factors were snack type and dryer type (solar tunnel and electrical cabinet dryers). For dried fruit products 7 x 2 factorial

design was used while for fruit leather products 5 x 2 factorial design was applied. The effect of these factors on proximate, vitamin A and C, water activity and microbial load were determined.

Drying procedures

Fresh mature ripe fruits samples were washed, peeled and sliced to 6 mm thick for pineapple and 9 mm thick for banana and mango, each sample was divided into 3 portions that were subjected in equal loading density of 3 kg/m^3 to either solar drying tunnel with temperature ranging from 60-80^{0}C for about 2 days or cabinet electrical dryer with constant drying temperature of 60 -70°C for 10 hours as indicated in Fig. 1. The solar tunnel dryer temperatures were determined during drying process but observed during drying period. Samples were offloaded from dryers after predetermined moisture levels which ranged from 13-17%. The dried pieces of fruits were packed in polyethylene bags and stored at 4°C waiting for analysis (Mongi, 2013).

Fig. 1. General flow diagram for fruit drying (Modified from King'ori *et al*., 1999)

Product formulation

Mixed dried fruits

Several formulations were developed with different ratios of mixed dried fruits and pre-tested for sensory parameters including color, texture, aroma, taste and general acceptability using a consumer panel of 20. The most liked ratio was 1:1 and hence opting for this ratio for further investigation as indicated in Table 1. The developed snacks were packed into plastic bags and stored at room temperature prior to analyses.

Table 1. Different formulation of mixed dried fruits

Fruit blends	Fruit ratios		
	Banana	Pineapple	Mango
Banana	1	0	0
Pineapple	0	1	0
Mango	0	0	1
Mango: Pineapple	0	1	1
Mango: Banana	1	0	1
Banana: Pineapple	1	1	0
Mango: Banana: Pineapple	1	1	1

Fruit leather

Fresh mature ripe fruits were washed, peeled, cut into small pieces and blended (Table 2) to obtain the fruit puree. The obtained fruit puree was dried by tunnel and cabinet dryers to obtain the fruit leather. The developed snacks were packed into plastic bags and stored at room temperature prior to analyses.

Table 2. Different formulation and rations of fruits leather developed

Fruit blends	Fruit ratios		
	Banana	Pineapple	Mango
Mango	0	0	1
Mango: Banana	1	0	1
Mango: Banana	3	0	7
Mango: Pineapple	1	1	0
Mango: Pineapple	3	7	0

Proximate analysis

Determination of moisture content

The moisture content was determined according to standard oven drying method explained by AOAC (1995). The sample was first weighed (W_1) transferred into a pre-weighed crucibles (W_2) and oven dried at 110^{0}C for overnight. After this the crucibles with contents were cooled in a desiccator and re-

weighed (W_3). The amount of moisture in percentage was calculated as follows:

$$\%\ \text{Moisture content} = \frac{W1 - (W3 - W2)}{W1} \times 100$$

Determination of protein content

Kjeldahl procedure was used for the determination of protein (AOAC, 1995) using block digestion and steam distillation (Kjeltec ™ 8200 Auto distillation unit 2012). About 0.25g of dried fruit sample was weighed and transferred into a digestion flask in which approximately 2g of catalyst mixture ($CuSO_4$, K_2SO_4) were added followed by approximately 6 ml of concentrated sulphuric acid. The contents of the flask were digested by heating in a fume chamber for about 1hour to allow the nitrogen held in the heterocyclic ring to be released. The content was connected to the nitrogen distillation unit containing 80 ml distilled water and 50 ml of 40% v/w NaOH, which convert ammonium (NH_4^+) into ammonia (NH_3) thereafter steam distilled into a flask containing 30 ml boric acid solution with mixed indicators (bromocresol green and methyl red). Distillation was allowed to proceed until 100-150 mls were collected. The distillate was titrated with 0.1N HCl until color change from blue to dirty green or orange endpoint was observed, the volume of acid used for neutralization was noted. The percentage of crude protein was calculated as follows:

% Nitrogen= {(1.401× (titre-blank)mls × Concentration of acids in molarity)/(sample weight (g)}

% crude protein=% N×conversion factor

A conversion factor of 6.25 was used to convert nitrogen into protein

Determination of fat/ lipid

The fat content was determined by solvent extraction method as described in standard method (AOAC, 1995) using Soxtec™ 2055 (manufacturer). About 3 g of dried fruit sample was weighed and then transferred into extraction thimble and covered with defatted cotton wool. The thimble support holder was used to insert the thimbles into the extraction unit, then the cup holder was used to insert the extraction cup containing 70 ml of solvent (40- 60°C petroleum ether) and extraction proceeded for about 2 hours. The extraction process involved three stages boiling (15 minutes), rinsing (45 minutes) and recovery (10 minutes). The cup containing extracted fat was dried in an oven at 105^{0}C for 30min, cooled in desiccator and weighed. The percentage fat was calculated as follows:

$$\%\ \text{Fat} = \frac{\text{Weight of lipid (g)}}{\text{Weight of sample (g)}} \times 100$$

Determination of ash

The ash content was determined by heating a sample in a muffle furnace as described in standard method (AOAC, 1995). About 5 g of sample was weighed in a pre- weighed crucible and transferred to a furnace at 550^{0}C and left overnight. The crucible was then cooled in a desiccator. The ash was weighed and expressed as percentage of the original sample weight on dry weight basis. The percentage ash was calculated as follows:

$$\%\ \text{Ash} = \frac{\text{Weigh of ash}}{\text{Weight of sample}} \times 100$$

Determination of crude fiber

Crude fiber was determined using dilute acid and alkali hydrolysis as described by AOAC (1995) using Fibertec 2010. The Weende method was used whereby about 1g of the sample was accurately weighed into glass crucible and about 200 ml of boiled 1.25% H_2SO_4 was poured into the flask and then the mixture was boiled for exactly 30 minutes under reflux condenser. The insoluble matter was washed with boiling water 3-4 times until the residue was free from acid. About 200 ml of 1.25% boiling potassium hydroxide solution was added into the residue and then heated for 30 minutes under reflux condenser. The residue was filtered, washed with boiling water and then crucible was transferred to the cold extraction unit and washed with acetone. After digestion, the residues were dried at 105°C

for 5 hours in an air convection oven, cooled in a desiccator to a constant weight and weighed. The residue was incinerated in an electric furnace at 525°C for about 3 hours until all the carbonaceous matter was burnt. The crucible was left to cool down to below 250°C then removed from the furnace and transferred to the desiccator, cooled to room temperature and weighed. Percentage crude fiber was calculated as follows:

$$\%\text{Crude fibre content} = \frac{(B - C)}{A} \times 10$$

Where; A is the weight of sample (g), B is the weight of crucible with dried residue after digestion (g) and C is the weight of crucible with ash (g)

Determination of carbohydrate

The carbohydrate content was determined by a difference method as follows:

% Cabohydra=100-(% Moisture content +% Crude fibre+ % ash content+% lipid+% protein)

Mineral analysis

The ash content was used for analysis of minerals according to the AOAC (1995) procedures. The mineral content was determined by the use of Unicam 919 Atomic Absorption Spectrophotometer (AAS UNICAM 919). Test portions were dried and then ashed at 450°C under a gradual increase (about 50^0C/hr) in temperature.

The residue was dissolved in 0.1 N HNO_3 left to dissolve then filtered using a whatman filter paper No.1. The analytes were analysed by flame procedures. The set instrument was as per the previously established optimum condition / as per the guidelines given in the instruction manual. The absorbance of sample and standard solutions was determined. The standard conditions for Atomic Absorption Spectrophotometer (Element wavelength flame-gases) were: zinc 319.9nm, iron 248.8nm, potassium 766.5nm, calcium 422.7nm, sodium 587.0nm and phosphorus 840.0nm.

The Standard curve plot (Appendix 6-10) of absorbance against the known concentration of standard solutions (0.5, 1, 1.5, 2. 0, 2 .5 and 3.0 ppm) was used to determine the concentration of minerals in samples and expressed as in the following formula.

Mineral content (mg/100g)=(Reading value in ppm ×dilution factor×100)/(Sample weight (g))

Vitamin A and C determination

Beta carotene determination (Precursor of vitamin A)

Beta carotene determination was done according to Delia and Mieko (2004), about 1g of fruit sample was weighed, transferred into a motor and pestle, ground to facilitate the extraction procedure and about 1.5g of celite was added to aid in grinding process. The mixture was ground with 50 ml of acetone (acetone refrigerated at 4^0 C for 2 hours prior to use). The extraction was repeated until the sample from the mortar was devoid of color (clear). About 50 ml of petroleum ether was put in a separating funnel (250 – 500 ml capacity) and the acetone was added. Distilled water was added slowly along the neck without shaking to avoid emulsion formation (water stones) in the carotenoid extracts. The two phases were then left to separate for 30 minutes and the lower aqueous layer was discarded, the sample was washed 3-4 times with distilled water (approximately 200 ml was used) each time to remove residual acetone that was used in the extraction process, the last phase washing was done to ensure that no any amount of the upper phase was discarded. The washed samples were then passed through anhydrous sodium sulphate to make it free from any trace of water. The dried carotene extracts was then collected into a clean and dry volumetric flask. The extract was then read under UV-Visible Spectrophotometer (Wagtech, CECIL 2021) at a wavelength of 450nm to obtain its absorbance. After obtaining

the absorbance beta carotene concentration was calculated using the equation of the standard.

Determination of ascorbic acid (Vitamin C)

Vitamin C (Ascorbic acid) was determined based on the oxidation reduction reaction principle through the following procedures. 5g of the homogenized fruit sample was weighed. Using a motor and pestle fruit juice was extracted using 10 mls portions of 10% TCA and the extract was collected into a volumetric flask. The diluted sample extract was then filtered using Whatman filter paper No.1. 10mls of a clear filtrate was pipetted into 250ml Erlenmeyer flask and then a blank solution was prepared by taking 10mls of 10% TCA solution into 250ml Erlenmeyer flask. Then the burette was filled with standard Indophenols solution adjusted to zero meniscus. Slowly the content was titrated with standard solution of indophenol until faint pink color was obtained which persisted for 10 seconds (Tomohiro, 1990). The volume of Indophenol solution used to oxidize the ascorbic acid present in the sample extract and in the blank solution was recorded. Then the vitamin C content in the fruit sample extract was calculated using the formula indicated below.

Vitamin C content in mg/100g of the sample $= \frac{(A-B)*C*V*100}{D*S}$

Whereby; A is the volume in ml of the Indophenol solution used for sample, B is the volume in ml of the Indophenol solution used for blank, C is the mass in mg of ascorbic acid equivalent to 1.0ml indophenols solution, S is the mass of sample in (g) taken for analysis, V is the total volume of extract in milliliters and D is the volume of sample filtrate in milliliters taken for analysis

Water activity determination

Water activity was determined by the Labswift-water activity analyzer as described by Novasina (2010). The chopped samples were filled into the sample dish (three quarters of its volume) then put into the measurement chamber and closed. The analyzer button was pressed there after the results were read when the stable value was displayed.

Determination of shelf life

Shelf life was determination by assessment of microbial loads (in the 2nd and 4th months) of dried fruit samples from two drying methods (solar tunnel and electrical cabinet electrical dryers) packed in polythene bags and stored at room temperature for four months. The effect of these factors on microbial load was assessed and compared. Samples were taken for evaluation in an interval of two months.

Microbiological analysis (Total count, fungi and coliform)

Total bacterial count

Total number of microorganisms were analyzed according to the ISO 4833 (2003) procedures. About 12 ml to 15 ml of the plate count agar (PCA) at 44 °C to 47 °C was poured into each Petri dish and carefully the inoculum was mixed with the medium by rotating the Petri dishes and the mixture was allowed to solidify by leaving the Petri dishes standing on a cool horizontal surface. After complete solidification prepared dishes were inverted and placed in the incubator at 30 °C ± 1 °C for 72 h. After the specified incubation period the colonies were counted. The counted number of colonies forming units (CFU) per gram were calculated using the following formula;

$$CFU/g = \frac{\sum C}{(n1 + n2)d}$$

Where; ∑C is the sum of colonies counted on the dishes retained, n1 is the number of dishes retained in the first dilution, n2 is the number of dishes retained in the second dilution, d is the dilution factor corresponding of the first dilution.

Coliform

Coliform was determined according to the ISO 7251 (2005) procedures. This method is based

on MPN procedures using the lauryl sulphate tryptose Brilliant-Green lactose bile broth each being incubated at 37°C for 24-48 hours. Fecal coliform (*E. coli*) EC broth was used, incubated at 44°C for 48 hours. On confirmation for the presence of E. Coli KOVACS reagent was used.

Fungi (yeast and molds)

Yeast and moulds were determined according to ISO 6611 (2004) procedures. About 15 ml of the medium containing chloramphenicol previously melted and maintained at 45°C in the water bath into each petri dish was carefully mixed with the inoculum. The Petri dishes were rotated and allowed the mixture to solidify by leaving the Petri dishes to stand on a cool horizontal surface. The prepared dishes were inverted and placed them (while keeping in an upright position) in the incubator set at 25°C for 5 days. The colonies were counted on each dish distinguishing between colonies of yeasts and colonies of moulds on the basis of their morphological characteristics. The counted number of colonies forming units (CFU) per gram were calculated using the following formula;

$$CFU/g = \frac{\sum C}{(n1 + n2)d}$$

Where; ∑C is the sum of colonies counted on the dishes retained, n1 is the number of dishes retained in the first dilution, n2 is the number of dishes retained in the second dilution, d is the dilution factor corresponding of the first dilution.

Statistical data analysis

The data were analysed by using R statistical package (R Development Core Team, Version 3.0.0, Vienna, Austria) for Analysis of Variance to determine the significant ($p<0.05$) variations between the main factors. Mean was separated by Turkey's Honest Significant difference ($p<0.05$). Results were expressed as mean ± SD and presented in tabular and graphical forms.

Results and discussion

The developed products are dried fruits and fruit leather which are shown in Fig. 2 and Fig. 3 respectively.

Fig. 2. Dried fruits (mango, banana and pineapples)

Fig. 3. Fruit leather (made from mango, banana and pineapples)

Table 3. The effect of drying methods on proximate composition (g/100g) of each dried product

Products	Dryer	Moisture	Ash	Protein	Fat	Fiber	Carbohydrate
BP	Electrical	12.9±0.2^{b}	6.7±0.2^{a}	2.0±0.2^{b}	0.0±0.0^{b}	4.3±0.2^{a}	74.1±0.4^{a}
	Tunnel	14.8±0.3^{a}	5.4±0.3^{b}	2.9±0.3^{a}	0.3±0.2^{a}	3.9±0.4^{b}	72.7±0.8^{b}
BT	Electrical	13.2±0.3^{b}	4.0±0.5^{a}	2.3±0.0^{a}	0.1±0.0^{a}	3.1±0.1^{b}	77.4±0.0^{a}
	Tunnel	14.1±0.2^{a}	3.7±0.2^{b}	2.2±0.3^{b}	0.0±0.0^{b}	4.3±0.3^{a}	75.7±0.2^{b}
MB	Electrical	13.3±0.1^{b}	6.4±0.2^{a}	4.0±0.3^{a}	0.6±0.2^{a}	5.2±0.3^{a}	70.5±0.5^{a}
	Tunnel	15.2±0.6^{a}	6.1±0.1^{b}	2.0±0.3^{b}	0.2±0.1^{b}	4.6±0.6^{b}	71.9±1.2^{b}
MD	Electrical	13.6±0.0^{b}	6.1±0.1^{ba}	3.8±0.0^{a}	0.0±0.0^{a}	4.1±0.3^{a}	72.3±0.5^{b}
	Tunnel	14.1±0.2^{a}	6.4±0.2^{a}	3.4±0.2^{b}	0.0±0.0^{a}	2.2±0.2^{b}	73.9±0.8^{ab}
MP	Electrical	13.0±0.2^{b}	6.3±0.4^{b}	3.3±0.4^{b}	0.3±0.1^{b}	2.0±0.2^{b}	75.1±0.6^{a}
	Tunnel	14.1±0.2^{a}	6.4±0.2^{a}	3.8±0.2^{a}	0.4±0.0^{a}	2.4±0.1^{a}	72.9±0.1^{b}
PS	Electrical	12.8±0.3^{b}	2.8±0.2^{a}	2.0±0.0^{a}	0.1±0.0^{b}	3.9±0.2^{a}	78.5±0.1^{b}
	Tunnel	13.3±0.1^{a}	2.0±0.1^{b}	2.0±0.0^{a}	0.2±0.0^{a}	3.7±0.1^{b}	78.9±0.1^{a}
MBP	Electrical	14.1±0.4^{b}	6.8±0.2^{a}	3.4±0.1^{a}	0.2±0.0^{b}	2.7±0.1^{b}	72.8±0.1^{a}
	Tunnel	16.1±0.2^{a}	6.5±0.3^{b}	3.1±0.5^{b}	0.3±0.1^{a}	4.1±0.3^{a}	69.9±0.8^{b}

Data presented as arithmetic means ± SD (n = 2). Means in each column for each product with different superscript letters are significantly different at $p<0.05$. Key ; BP is mixed banana and pineapple, MB is mixed mango and banana, BT is dried banana, MD is dried mango, MP is mixed mango and pineapple, PS is dried pineapple and MBP is mixed mango, banana and pineapple.

Proximate composition

The effect of products on proximate composition in different formulations within the drying methods is shown in Table 3. The results showed that among the formulations MBP had highest moisture content in both electrical cabinet and solar tunnel dryers compared to other products. MD had no fat content in each dryer type. PS and MBP formulations had the same contents of protein and fat in each drying methods while PS had the highest value of carbohydrate with respect to other products (Table 3). Moreover, the results show significant ($p<0.05$) variations in the moisture content in each drying methods with the solar tunnel dryer having the highest value of moisture content in all formulations.

Table 4. The effect of drying methods on proximate composition (g/100g) of each fruit leather

Products	Dryer type	MC	Ash	Protein	Fat	Fiber	Carbohydrate
BMS	Electrical	13.9±0.1^{b}	3.2±0.1^{a}	2.7±0.1^{b}	0.0±0.0^{a}	4.9±0.2^{a}	73.8±0.0^{b}
	Tunnel	15.4±0.1^{a}	3.1±0.1^{b}	3.2±0.1^{a}	0.1±0.0^{a}	4.8±0.1^{b}	74.9±0.0^{a}
MBL	Electrical	14.5±0.4^{b}	3.8±0.1^{a}	2.4±0.4^{a}	0.1±0.0^{b}	3.6±0.0^{a}	75.6±0.0^{b}
	Tunnel	15.0±0.2^{a}	3.2±0.5^{b}	3.4±0.2^{a}	0.2±0.0^{a}	2.7±0.2^{b}	75.7±0.6^{a}
ML	Electrical	15.1±0.3^{b}	2.7±0.2^{b}	3.1±0.0^{a}	0.0±0.0^{a}	3.2±0.5^{a}	75.8±0.4^{a}
	Tunnel	17.3±0.1^{a}	3.4±0.1^{a}	3.5±0.0^{b}	0.0±0.0^{a}	2.5±0.1^{b}	73.3±0.3^{b}
MPL	Electrical	13.8±0.1^{a}	2.1±0.2^{a}	2.4±0.0^{a}	0.0±0.0^{b}	1.8±0.0^{b}	79.8±0.1^{a}
	Tunnel	14.7±0.4^{b}	2.1±0.1^{a}	2.5±0.4^{b}	0.3±0.1^{a}	3.0±0.3^{a}	77.8±0.3^{b}
PMD	Electrical	16.6±0.0^{b}	2.7±0.2^{b}	2.4±0.2^{b}	0.0±0.0^{a}	3.5±0.4^{b}	74.8±0.3^{a}
	Tunnel	16.9±0.3^{a}	2.9±0.5^{a}	3.9±0.1^{a}	0.0±0.0^{a}	5.4±0.3^{a}	70.8±0.2^{b}

Data presented as arithmetic means ± SD (n = 2). Means in each column for each product with different superscript letters are significantly different at $p<0.05$. Key: Mixture of banana and mango leather (BMS), mixture of mango and banana leather (MBL), mango leather (ML), mixture of pineapple and mango leather (MPL) and mixture of mango and pineapple leather (PMD).

The effect of drying methods on proximate composition (g/100g) of each fruit leather is shown in Table 4. The results showed a significant difference ($p<0.05$) in proximate composition among the fruit leather products analyzed. The significantly highest moisture content was found in product ML for electrical dryer while sample MPL had the lowest moisture content with the electrical dryer. Product PMD and ML were observed not to contain fat content in all drying methods and on the other hand, sample MPL had the highest content of

carbohydrate while sample BMS had the highest content of fiber (Table 4). The effect of drying method on proximate composition was significant ($p<0.05$). All products dried by solar tunnel dryer had the highest moisture content compared to those dried by the electrical cabinet dryer.

Data presented as arithmetic means ± SD (n = 2). Means in each column for each product with different superscript letters are significantly different at $p<0.05$. Key: Mixture of banana and mango leather (BMS), mixture of mango and banana leather (MBL), mango leather (ML), mixture of pineapple and mango leather (MPL) and mixture of mango and pineapple leather (PMD).

The results indicate the significant variations in proximate composition among the formulated products by different dryers. The variations might have been caused by different reactions and behavior during drying which resulted into different values between the varieties within the fruit (Perera, 2005). The moisture content values observed in this study are in line with that reported by Ajay *et al.* (2009) that, depending on the agricultural product, water content of properly dried food product vary from 5-25% with successful drying. The decrease in protein content was caused by degree of heat applied. This means that, as the temperature increases protein undergoes denaturation and interacts with other food components, which may cause changes in solubility, texture and nutritive values (Damodaran, 2008). These findings agree with the reports of Morris *et al.* (2004); Eze and Agbo (2011) that, nutritional losses during drying occur to great extent due to application of heat, thereby decreasing the concentration of some nutrients especially protein. Although most of fruits and vegetables contain only small quantities of lipids, may undergo enzymatic hydrolysis in the initial phase of drying and autoxidation reaction of unsaturated fatty acids, producing hydro-peroxides, ketones and acids, which may cause rancid and objectionable odors (Perera, 2005).

Furthermore, the results show that, solar drying has no effects on crude fiber content of dried fruits and vegetables. This might be due to the fact that fiber is relatively insensitive to thermal processing, so its content is very similar in fresh and dried fruits and vegetables (Barret, 2007). The results also suggest that, the methods applied and varieties have varied effects on retention of some proximate composition values during drying due to different drying conditions and modes of operations such as drying air temperature, air flow rate and drying rates that could be associated with these differences (Mongi, 2013).

Vitamin, minerals and water activity

Table 5 shows the effect of drying methods on beta carotene concentration (µg/100g), Vitamin C (mg/100g) and water activity of each dried product. The results showed significant differences ($p<0.05$) in all dried products. Sample MD had the highest concentration of beta carotene in both the two drying methods (electrical cabinet and solar tunnel dryers) compared to all other products whereas pineapple dried by solar tunnel was observed to contain the least concentration of beta carotene among other dried products (Table 5). Dried pineapple had the highest content of vitamin C for both drying methods (Solar tunnel and electrical cabinet dryers) followed by mango mixed with banana, while dried banana had the lowest content of vitamin C (Table 5).

The higher water activity was observed in the samples dried by the solar tunnel dryer than those samples dried by electrical cabinet dryer (Table 5) this was due to the efficiency and the constant set of temperature range of the electrical cabinet dryer throughout the drying period.

Table 5. The effect of drying methods on beta carotene concentration (µg/100g), vitamin C (mg/100g) and Water activity on each dried product

Products	Dryer type	Beta carotene	Vitamin C	Water activity
BP	Electrical	2.2±0.0^{b}	29.3±2.7^{b}	0.40±0.0^{b}
	Tunnel	2.3±0.0^{a}	31.4±1.3^{a}	0.42±0.0^{a}
BT	Electrical	0.7±0.2^{b}	24.3±1.4^{b}	0.40±0.0^{b}
	Tunnel	1.8±0.1^{a}	25.6±1.3^{a}	0.46±0.0^{a}
MB	Electrical	17.0±3.4^{b}	29.6±1.3^{b}	0.40±0.0^{b}
	Tunnel	18.1±1.8^{a}	31.7±1.3^{a}	0.45±0.0^{a}
MD	Electrical	37.7±5.0^{b}	27.0±0.0^{b}	0.40±0.0^{b}
	Tunnel	55.2±6.1^{a}	28.2±1.4^{a}	0.54±0.0^{a}
MP	Electrical	14.6±2.1^{b}	28.2±1.3^{b}	0.41±0.0^{b}
	Tunnel	18.1±3.5^{a}	29.3±2.7^{a}	0.44±0.0^{a}
PS	Electrical	0.4±0.0^{b}	30.6±1.4^{b}	0.42±0.0^{b}
	Tunnel	0.6±0.0^{a}	32.2±1.4^{a}	0.43±0.0^{a}
MBP	Electrical	7.4±4.3^{b}	27.9±0.0^{b}	0.42±0.0^{b}
	Tunnel	10.1±3.0^{a}	30.5±1.4^{b}	0.46±0.0^{a}

Data presented as arithmetic means ± SD (n = 2). Means in each column for each product with different superscript letters are significantly different at $p<0.05$. Key ; BP is mixed banana and pineapple, MB is mixed mango and banana, BT is dried banana, MD is dried mango, MP is mixed mango and pineapple, PS is dried pineapple and MBP is mixed mango, banana and pineapple.

Table 6. The effect of drying methods on beta carotene concentration (µg/100g), vitamin C (mg/100g) and water activity on each fruit leather product

Products	Dryer type	Beta carotene	Vitamin C	Water activity
BMS	Electrical	6.4±0.0^{a}	28.2±1.3^{b}	0.47±0.0^{a}
	Tunnel	7.1±0.0^{a}	31.4±0.4^{a}	0.46±0.0^{b}
MBL	Electrical	9.3±0.0^{b}	20.4±1.3^{b}	0.43±0.0^{a}
	Tunnel	9.5±0.0^{a}	30.2±1.3^{a}	0.42±0.0^{b}
ML	Electrical	37.6±0.2^{b}	18.1±0.0^{b}	0.51±0.0^{b}
	Tunnel	37.8±0.1^{a}	20.1±1.3^{a}	0.52±0.0^{a}
MPL	Electrical	13.3±0.0^{b}	32.1±2.7^{a}	0.41±0.0^{b}
	Tunnel	18.1±0.0^{a}	27.1±1.3^{b}	0.44±0.0^{a}
PMD	Electrical	15.0±0.0^{b}	30.2±1.3^{b}	0.58±0.0^{a}
	Tunnel	15.1±0.0^{a}	31.6±2.7^{a}	0.53±0.0 ^{b}

Data presented as arithmetic means ± SD (n = 2). Means in each column for each product with different superscript letters are significantly different at $p<0.05$. Key: Mixture of banana and mango leather (BMS), mixture of mango and banana leather (MBL), mango leather (ML), mixture of pineapple and mango leather (MPL) and mixture of mango and pineapple leather (PMD).

The effect of drying methods on beta carotene concentration (µg/100g), vitamin C content (mg/100g), and water activity of each fruit leather product is shown in Table 6. The results indicated significant differences ($p<0.05$) in all products. Mango leather had the highest content of beta carotene concentration in all two drying methods (Solar tunnel electrical cabinet dryers) while banana mango leather was observed to contain the least concentration of beta carotene among other fruit leather products (Table 6). Fruit leather products dried by the solar tunnel dryer had the higher concentration of beta carotene than the electrical cabinet dryer in all products.

This was due to the amount of heat being higher in electrical cabinet dryer than that of the solar tunnel dryer. Sample PMD had the highest content of vitamin C in both drying methods (Solar tunnel and electrical cabinet dryers) to all other products while sample ML had the lowest content of vitamin C (Table 6). The effect of drying methods on vitamin C was also significant ($p<0.05$) in which fruit leather products dried by the tunnel dryer had the higher contents of

vitamin C in all samples except sample MPL Which was observed to have higher content of vitamin C in the electrical dryer. Sample PMD had the highest water activity in both drying methods among all samples. The tunnel dryer had higher water activity in most of the sample with the exceptional of sample PMD (Table 6).

The significant difference of beta carotene concentration observed in different product is caused by the oxidative degradation of β-carotene as a result of thermal treatment at different temperatures. Borsarelli and Mercadante (2010) show a simplified mechanism of the overall changes occurring in carotenoids during heating. The degradation of β-carotene decreases the nutritional value of vitamin A and its activity as an antioxidant, and causes significant loss of the natural flavor and chromophores in foods. Ultimately, the food products are less acceptable to consumers. In food industries β-carotene can also be added to some commercial fruits and vegetables beverages (Rodrıguez-Comesana *et al.,* 2002). Thus, in order to maintain the high quality of nutrition and flavor of products, it is particularly important to protect β-carotene during processing and storage. Generally, vitamin A is essential for growth and development, immune system and vision. Krinsky and Jonson (2005) reported that β-carotene is an important chain-breaking antioxidant which scavenges lipid oxide radicals. However, pro-oxidant actions in this context of lipid peroxidation have also been described as an exposure of β-carotene to oxidizing conditions in high oxygen levels leading to increased markers of lipid peroxidation (El-Agamey *et al.,* 2004).

The differences in vitamin C degradation between the drying methods could be influenced by temperature, dying kinetics and water activity. The higher temperature in the tunnel dryer inactivated the ascorbic acid oxidase and offered vitamin protection towards enzymatic oxidation (Leong and Oey, 2012). In addition to enzymatic in-activation the shorter drying time in the tunnel dryer than the cabinet dryer reduced the exposure time to oxidizing agents that resulted into relatively lower vitamin C degradation in its samples. This is in agreement with Santos and Silva (2008) who reported that, the longer the drying period (low temperature, high relative humidity, thick product), the lower the retention of ascorbic acid. This was further supported by Methakhup (2003) who found the rate of ascorbic acid oxidation was pH dependent, showing a maximum at pH 5.0 and minimum at pH range of 2.5 to 3.0. Leaching is another important factor that could have led to loss of vitamin C along with the water activity during the preparation and drying process (Kirimire, 2010). Moreover, the relatively higher moisture content in the solar tunnel dried samples than in the electrical cabinet dried samples could have contributed to their relatively higher vitamin C degradation. Vitamin C stability is reduced in aqueous state than in the dry state (Kirimire, 2010). Vitamin C retention is also improved by all drying processes under an inert atmosphere, which reduces the presence of O_2 as evidenced in tunnel dried samples. Similar effect of the drying methods in vitamin C were also reported in mango (Kabasa *et al.,* 2004), vegetables (Kirimire, 2010) and tomato (Perumal, 2009).

Physically, vitamin C functions as an effective water-soluble antioxidant that readily scavenge reactive oxygen species (ROS) and also a factor in numerous physiological reactions, including the post-translational hydroxylation of proline and lysine in collagen and other connective tissue proteins, collagen, collagen gene expression, synthesis of norepinephrine and adrenal hormones, activation of many peptide hormones, and synthesis of carnitine (Johnstone *et al.,* 2007). Also, it is apparently shown that, one would need to consume large quantities of dried fruits and vegetables to meet RDA of 75 and 90 mg/day for women and men respectively and 45mg/day for children 9-12 years old (USDA,

2010). Moisture loss or uptake is one of the most important factors that control the shelf life of foods. As water activity in a foodstuff decreases, the number and growth of microbial species able to grow in that environment also decreases (Idah and Aderibighe, 2007). From the results it has been observed that all the products developed had the water activity >0.6 This means that, below this limit no microbial proliferation can occur, browning is minimized and the product becomes safe and stable. On the other hand, reduction of water activity in final product is a very important factor to ensure the stability of the dried foods which means final product with low water activity is safe from enzymatic spoilage because active water is not available for microbial growth (Chieh, 2006). Therefore, dried products having the moisture content of 20% and a water activity of 0.7 or bellow tend to be resistant to microbial deterioration (UNIDO, 2001).

Table 7. The effect of drying methods on mineral content (mg/ 100 g) of each dried product

Products	Dryer type	Ca	Na	Fe	P	K
BP	Electrical	91.7±3.4^a	62.4±0.4^a	2.4±0.2^a	43.9±0.3^a	725.9±7.5^a
	Tunnel	96.2±3.0^a	63.5±0.1^a	2.2±0.0^a	44.6±0^a	761.9±7.3^a
BT	Electrical	85.1±3.4^a	60.4±0.3^a	2.4±0.0^a	46.8±0.3^a	811.7±7.3^a
	Tunnel	90.2±3.4^a	61.5±0.3^a	2.4±0.0^a	42.7±0.0^a	729.4±7.3^a
MB	Electrical	84.5±3.8^a	60.7±0.7^a	2.2±0.0^a	42.5±0.3^a	708.8±7.3^a
	Tunnel	81.7±3.0^a	60.2±0.0^a	2.0±0.3^a	42.3±0.0^a	703.6±7.3^a
MD	Electrical	76.1±3.4^a	60.8±0.3^a	2.3±0.0^a	42.0±0.3^a	650.2±7.3^a
	Tunnel	83.0±3.4^a	60.6±0.3^a	2.2±0.0^a	43.5±0.3^a	590.5±6.5^a
MP	Electrical	93.8±3.4^a	59.1±0.3^a	2.2±0.0^a	42.3±0.0^a	739.7±7.3^a
	Tunnel	108.2±3.4^a	61.5±0.3^a	2.2±0.0^a	42.7±0.0^a	654.2±7.3^a
PS	Electrical	105.8±3.0^a	60.9±0.3^a	2.3±0.0^a	42.3±0.0^a	626.5±7.3^a
	Tunnel	98.6±3.4^a	60.1±0.1^a	2.1±0.0^a	43.9±0.3^a	631.7±7.3^a
MBP	Electrical	55.7±3.4^a	59.2±0.1^a	2.2±0.0^a	42.0±0.3^a	796.3±7.5^a
	Tunnel	54.9±3.4^a	59.7±0.4^a	2.2±0.0^a	41.8±0.0^a	744.9±7.3^a

Data presented as arithmetic means ± SD (n = 2). Means in column of each product with different superscript letters are significantly different at $p<0.05$. Key ; BP is mixed banana and pineapple, MB is mixed mango and banana, BT is dried banana, MD is dried mango, MP is mixed mango and pineapple, PS is dried pineapple and MBP is mixed mango, banana and pineapple.

Minerals

The effect of drying methods on mineral content (mg/ 100 g) of each dried product is shown in Table 7. There were no significant ($p>0.05$) differences in mineral content between samples dried by both methods (Electrical cabinet dryer and solar tunnel dryer). Potassium was the most abundant mineral while iron was least abundant of all minerals (Table 7). The variations in the drying methods were also insignificant ($p>0.05$) this is due to their stability on heat.

The effect of drying methods on mineral content (mg/ 100 g) of each fruit leather has been indicated in Table 8. The results show that there are no significant differences ($p>0.05$) in mineral content within the sample. Potassium had the highest values while iron had the lowest mineral contents. The variation in the dryer type was insignificant at ($p>0.05$).

Potassium was the most abundant mineral while iron was the least available mineral in all of the dried and fruit leather samples. This is comparable to the findings obtained in other studies in various fruits and vegetables example apples (Lowor and Adyente-Badu, 2009), vegetables (Iqbal *et al.*, 2006) and Amaranthus (Mepba *et al.,* 2007). There were slightly variations in the mineral contents with the exceptional of phosphorous and iron. The observed variation might have resulted from species, variety, genetic, geographic, climatic, environmental condition, agronomic factor and seasonal variations (Gul and Safdar, 2009; Adepoju, 2012). The observed insignificant

differences in all mineral contents between the drying methods indicate that, solar drying and electrical cabinet temperatures had little or no effect on mineral contents of the dried products as well as the fruit leather. Most minerals have fairly low volatility at high temperatures of up 550-600oC which means, the solar drying and electrical cabinet air temperatures are of little consequences for their contents (Nielsen, 2010). Fruits are important sources of minerals in human diet which are important for vital body functions such as acid base and water balance. Potassium is necessary for bone health, energy metabolism and maintenance of the electrochemical balance that allows nerve cells to transmit impulses and muscles to contract (Dickinson, 2002). The findings revealed that, one would need to consume 574-642g of dried mango, 386-422 g of dried banana, 918-920 g of dried pineapple to meet the RDA of 470g/day set by USDA (2010). It has also been reported that, fruits are generally poor sources of iron (Mepba *et al.*, 2007) which suggests consumption of large quantities of fruits will meet the Recommended Daily Allowance (RDA) of 45 mg/day.

Table 8. The effect of drying methods on mineral content (mg/ 100 g) of each fruit leather

Products	Dryer type	Ca	Na	Fe	P	K
BMS	Electrical	67.3±3.8^a	60.3±0.1^a	2.1±0.0^a	42.0±0.3^a	667.3±7.3^a
	Tunnel	65.6±3.4^a	62.4±0.1^a	2.3±0.2^a	43.0±0.3^a	659.1±7.3^a
MBL	Electrical	55.1±3.4^a	61.4±0.1^a	2.4±0.4^a	41.6±0.3^a	657.9±7.3^b
	Tunnel	56.3±3.4^a	60.5±2.3^a	2.3±0.2^a	42.0±0.3^a	664.8±8.9^a
ML	Electrical	55.8±2.0^a	63.3±0.1^a	2.1±0.0^a	42.3±0.0^a	6840.5±7.3^a
	Tunnel	59.3±3.4^a	58.9±0.0^a	2.4±0.0^a	41.8±0.0^a	688.3±7.3^a
MPL	Electrical	57.7±2.0^a	63.4±0.3^a	2.2±0.0^a	42.3±0.0^a	689.3±7.3^a
	Tunnel	56.6±3.4^a	59.6±0.3^a	2.2±0.0^a	42.5±0.3^a	708.8±7.3^a
PMD	Electrical	69.8±3.4^a	59.6±0.3^a	2.2±0.0^a	42.3±0.0^a	679.9±7.3^a
	Tunnel	65.7±3.4^a	61.6±0.4^a	2.2±0.0^a	43.5±0.3^a	688.3±7.3^a

Data presented as arithmetic means ± SD (n = 2). Means in each column for each product with different superscript letters are significantly different at $p<0.05$. Key: Mixture of banana and mango leather (BMS), mixture of mango and banana leather (MBL), mango leather (ML), mixture of pineapple and mango leather (MPL) and mixture of mango and pineapple leather (PMD).

Shelf life of the developed product

Microbial load

Dried fruits

The effect of drying methods and storage time on microbial quality of dried fruits is shown in Fig.4-6. The results show significant variations ($p<0.05$) in microbial load between drying methods. Samples dried by tunnel dryer had lower total bacterial count, moulds and yeast than the samples dried by electrical cabinet dryer. The effect of storage time on microbial load was also significant ($p<0.05$). The fourth month storage time resulted into higher microbial load in sample BTE (Total bacterial count), BTG, MDE, MDG, and PSE while sample PSG, MDE (moulds) and BTE (Yeast) no microbial loads were seen (Fig. 4-6).

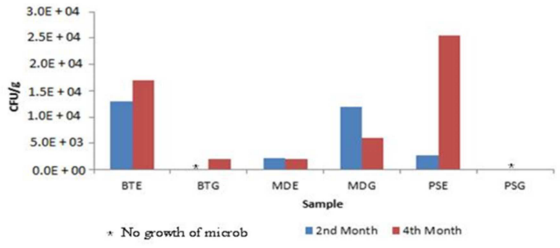

Fig. 4. Effects of drying methods on total bacterial count (cfu/g) in dried fruits

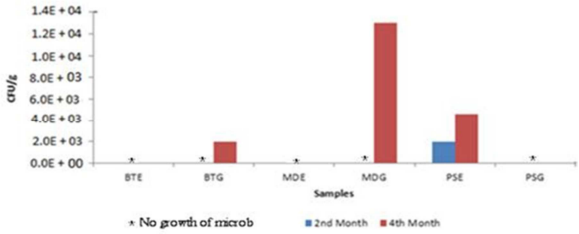

Fig. 5. Effects of drying methods on moulds (cfu/g) in dried fruits

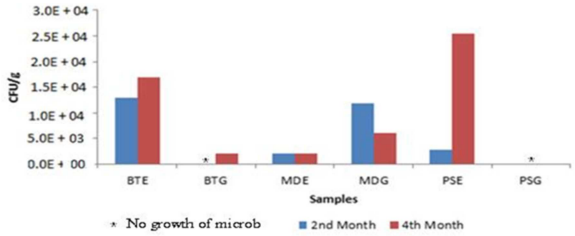

Fig. 6. Effects of drying methods on yeast (cfu/g) in dried fruits

Mixed dried fruits

The effect of drying methods and storage time on microbial quality of mixed dried fruits is shown in Fig.7-9. The results indicated significant variations ($p<0.05$) in microbial load between drying methods. Samples dried by solar tunnel dryer had higher total bacterial count, moulds and yeast than the samples dried by electrical cabinet dryer this was due to the electrical cabinet dryer being constructed inside the house unlike the solar tunnel dryer which was in an open space, in which its hygienic condition could have been compromised by the external features like the blowing of wind. The fourth month storage time resulted into higher microbial loads with the exception of samples MBE (moulds and yeast), BPE (moulds), MBG (moulds) and MPE (moulds) which showed no microbial growth.

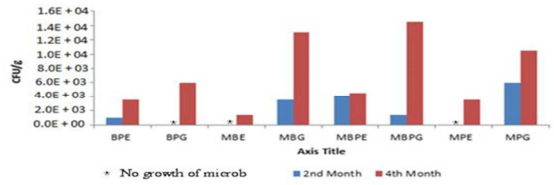

Fig. 7. Effects of drying methods on total bacterial count (cfu/g) in mixed dried fruits

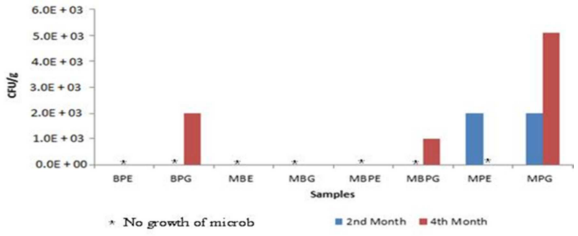

Fig. 8. Effects of drying methods on moulds (cfu/g) in mixed dried fruits

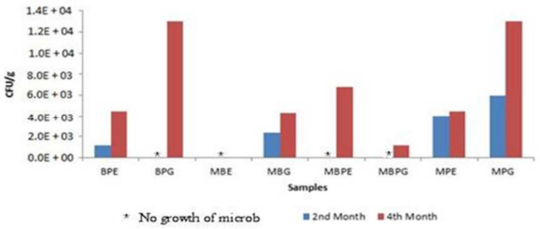

Fig. 9. Effects of drying methods on yeast (cfu/g) in mixed dried fruits

Fruit leather

The effect of drying methods and storage time on microbial quality of fruit leather is shown in Fig. 10-12. The results had significant variations ($p<0.05$) in microbial load between drying methods. The fourth month storage time had higher microbial loads (Fig. 10-12).

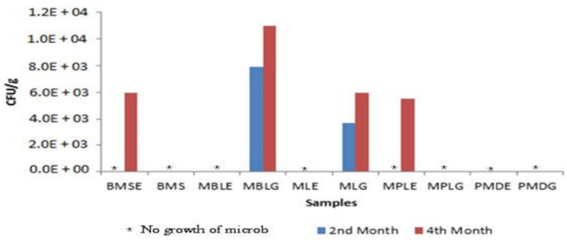

Fig.10. Effects of drying methods on total bacterial count (cfu/g) in fruit leather

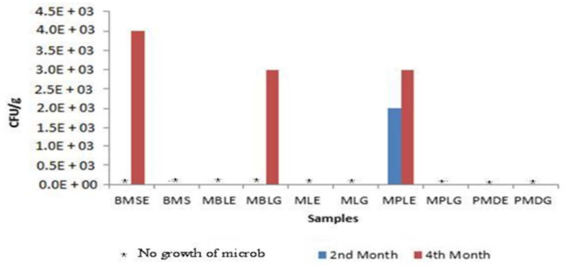

Fig. 11. Effects of drying methods on moulds (cfu/g) in fruit leather

In all samples no coliforms were observed and this signifies that all snacks formulated were safe for consumption since coliforms are commonly used as the indicators of unsanitary conditions in the food processing unit (Jayaraman and Das-Gupta, 2006). Removal of water activities increases the solute concentration of the food system and thus reduces the availability of water

for microorganisms to grow. The recommended maximum limit of water activity for specific microorganisms to grow as reported by Perumal (2009), include; fungi the limit is below aw = 0.7 (20% moisture content) while most yeast and bacteria are inhibited at water activity below aw = 0.8 and 0.9 respectively. For complete microbiological stability, water activity of the system should be below 0.6, where below this value, most microbial growth especially bacterial is impended with the exception of xerophillic moulds and osmophillic yeast which can thrive at water activity of 0.61 (Jayaraman and Das-Gupta, 2006).

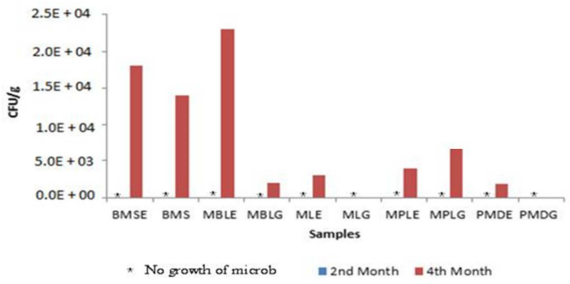

Fig. 12. Effects of drying methods on yeast (cfu/g) in fruit leather

Moreover, the survival, number and type of microorganisms during and after drying depends on the initial microbial quality of fresh produce, pH and composition, pre-treatments, drying time, methods of drying, moisture content of the final product and the good manufacturing practices (GMP) and general hygienic practices during processing and drying (Sagar and Suresh, 2010). Also, the interaction of some factors such as water activity, temperature-time combination, pH, oxygen, carbon dioxide and chemical preservatives have an important effect on the inhibition of microbial growth during drying period (Fellows, 2009).

Generally, the results have shown the potential of drying in extending shelf life of the developed product and thus minimizing the post-harvest losses. However, drying alone does not kill the microorganisms (Barbosa-Canovas and Vega-Mercado, 1996). Therefore, in order to come up with shelf-life stable dried product good hygienic practices should be followed including adequate training on GMPs and GHP to food handlers and processors coupled with effective applications of hazard analysis critical control point (HACCP) in the production chain to advocate safe end products.

Conclusion

The study has shown that both drying methods had substantial levels of required nutrients one will need for health life. It was also observed that the use of drying technology in agricultural sector to conserve seasonal fruits could be the best alternative approach to ensure the availabilities of fruits yearly in developing countries. Therefore, in order to come up with safe and good finished dried products, good manufacturing practices, good hygienic practices, HACCP system, choice of drying methods and operations that will retain required nutrients should be considered in the production chain for higher consumer acceptability and economical point of view.

The developed products (snacks) had the acceptable range of moisture content and water activity which allowed the products to be shelf life stable throughout the study period of four months. Furthermore, the absence of coliforms was an indicative of sanitary conditions that contributed to the shelf-life stability of the developed products. Therefore, in view of these results, it can be concluded that solar tunnel dryer is the best drying technology for agriculture produces in developing countries due to its economic use, retention of the nutrients and prolonging shelf life of dried products.

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