COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH-FOOD RESEARCH INSTITUTE

THE CSIR-FRI/GTZ/MOAP DRIED FRUITS SHELF-LIFE STUDIES

Final Technical Report

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7/27/2010

The shelf-life durations of dried pineapples, papaya, mango and coconut under room (av 29 ^{o}C and 75 % RH) and chilled-room conditions (av. 19 ^{o}C and 75% RH) were 8 and 12 months, respectively. The corresponding durations for dried banana slices for both storage conditions were all 8 months.

Executive Summary

The CSIR-FRI is engaged in a collaborative project with the German Technical Cooperation (GTZ) Office in Ghana as part of the on-going Market Oriented Agriculture Programme (MOAP) of the Ministry of Food and Agriculture of Ghana. One of the activities of this CSIR-FRI/ GTZ/ MOAP collaboration has developed a cost-effective drying facility for processing fruits and vegetables. This is a tunnel dryer which operates on hot-air generated through steam which is circulated round the tunnel. As part of test-running of this dryer, samples of banana, coconut, mango, papaya and pineapple slices produced by Nature's Best Fruit Limited were dried in this dryer and the shelf-lives stabilities of the dried products assessed over a period of one year under two storage conditions. Nature's Best Fruits Limited is one of the private entrepreneur through whom the CSIR-FRI/ GTZ/ MOAP project is assessing the technical feasibilities of the technologies it is developing. The two storage conditions used were room temperature 28 ± 2ºC and chilled-room temperature 18± 2ºC all at humidity conditions of 78 ± 4% RH.

The shelf-life indices monitored over the 12 month period were the physico-chemical, microbiological and sensorial properties of the stored products.

Under the physico-chemical properties, moisture contents remained relatively stable throughout the storage period averaging from 3.13,10.89, 11.56,12.05 to 12.29 %, respectively for dried coconut, papaya, mango, banana and pineapple. The corresponding water activity values were equally stable ranging between 0.54 and 0.56. These low water contents accounts for the microbiological stability of the products throughout the storage period. The absence of coliforms, E. coli, Staph and Salmonella is an indication that good hygienic and manufacturing practices were strictly adhered to by the Nature's Best Fruits Ltd during the production of the samples.

The colours as measured using the trismulus system of all the products stored under the chilled-room condition were much brighter and more acceptable than those under the room temperature conditions. Non-enzymatic browning was much more pronounced in the banana slices than the rest of the products. There was no significant deterioration in the Vitamin A and C contents of the dried fruits. The total soluble solids (indicated by the Brix) and pH remained unchanged during the whole period of storage. The free fatty acid levels of the coconut slices even at the end of 12 month's storage were within internationally acceptable levels for commercial desiccated coconut.

A trained panel of 15 used to monitor the sensory parameters of the stored samples gave relatively high scores for taste, smell, mouth-feel, hand-feel and overall acceptability sensory parameters for the first 8 months. The results of colour parameter were consistent for the pineapple, mango, papaya and coconut samples especially under the chilled-room storage condition but slightly variable under the room temperature condition. From the 8^{th} month, the scores for the sensorial parameters started decreasing significantly especially for products under the room temperature conditions. In particular, the colour score for the dried banana slices was very low. All the dried products passed the microbial and physico-chemical and sensorial specifications by the Organic Food Production Act (www.organicGuide.com) as well as the specifications of the present importing company of Nature's Best Fruits Ltd which is the Meridian Organic Foods Company of Stuttgart, Germany. The conclusion is that the optimal shelf-life duration for dried pineapples, papaya, mango and coconut, established through this study, under the room condition (average 29 ºC and 75 % RH) was 8 months whilst that for the chilled-room temperature (average 19 ºC and 75 % RH) condition is 12 month. The shelf-life duration for dried banana slices established under both storage conditions was 8 months.

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1. INTRODUCTION

The Food Research Institute is engaged in a collaborative project with the on-going Market Oriented Agriculture Programme (MOAP) being undertaken by the Ministry of Food and Agriculture (MoFA) with funding from the German Government through its developing agency, the GTZ. The CSIR-FRI/GTZ/MOAP collaboration is aimed at developing cost-effective drying facilities for the processing of fruits and vegetables into high quality dried products especially for the export market. The project has so far designed and fabricated two types of dryers. The first of these dryers is an innovative solar dryer with a back-up hot water facility to ensure continuance of the availability of hot air during the night as well as on days with overcast weather. The second dryer is tunnel tray dryer which operates on hot air generated through steam which is circulated round the tunnel. As part of the test-running of the latter, drying of the fruits is being carried out on experimental stages. This is being done in order to set the optimal conditions temperature, air-flow and humidity, for the use of the dryer.

One other key issue about the testing of the experimental dryer was to establish how long fruits dried in these dryers will remain shelf-stable. To ascertain this, a yearlong study of the shelf-life characteristics of the dried products was started in June 2009. This is under a sub-project titled "*Shelf-life studies of dehydrated banana, coconut, mango, papaya and pineapple, packaged in high density polymeric pouches at two temperature conditions*"**.** These samples were produced by Nature's Best Fruits Limited which is the private company involved in the CSIR-FRI/GTZ/MOAP Collaborative Project. This report therefore covers the results obtained from the June 2009 to May 2010.

Fig. 1: The Developed Mobile Tunnel Dryer Used to Dry the Fruits

Operating Conditions: 68 ± 3°C for 10 h

2. MATERIALS AND METHODS

2.1 MATERIALS

The fruits being used in the study were pineapple, mango, papaya, banana and coconut. The fresh fruits were immediately peeled and sliced into appropriate sizes and dried in the newly developed tunnel dryer (Fig.1), according to methods used by Nature's Best Fruits Limited dried until the moisture content was about 8 % wet basis, suing the developed mobile dryer as shown in Fig.1. The dried products were aseptically packaged into two lots, using high density polyethylene pouches. Nature's Best Limited is the participating private entrepreneur on the CSIR-FRI/GTZ/MOAP Project.

2.2 STORAGE CONDITIONS

These were respectively stored under two temperature conditions; at ambient room temperature which averaged at 28± 2ºC and in a chilled room at average temperature of 18± 2ºC. The average relative humidity under both temperature was 78 ± 4% RH.

2.2 SAMPLING FREQUENCIES

Sampling frequency for product withdrawals during shelf-life testing was based on the principles of Taoukis et al (1997). Sampling for the physico-chemical and microbiological analysis was done initially at weekly intervals for 6 weeks and thereafter at 2-week interval until the end of September and finally at monthly intervals. Sampling for determination of total soluble solids, pH, vitamins A and C for the pineapples, papaya, banana and mango samples was done at 3-month intervals. Sampling for free fatty acids representing rancidity of these fruits as well as the dried coconut was done on twice.

2.4 ANALYSIS ON DRIED FRUITS

2.4.1 Physico-chemical Properties

The physico-chemical properties measured in the study were moisture, water activity (a_w), colour, total soluble solids (TSS), pulp pH, vitamin A and C and free fatty acids. Data obtained from the measurement of these parameters were subjected to analysis of variance (ANOVA) and least significant difference (LSD) was used to separate the means when found to be significant.

2.4.1.1 Moisture, Water Activity (a_w) and Colour,

The moisture content was determined using the electronic moisture analyzer using triplicates of 3 gm of the samples. The Water activity was measured using standard methods with a Rotronic Hygrolab 2 (Erotronic ag Ltd. USA). The colour measurements of the dried fruit samples were determined with the Minolta Chroma Meter (Model CR 310, Minolta Camera Co. Ltd. Japan), using the L* a* b* colour system. The Chroma meter was calibrated with a standard white tile (L* = 97.63 a*=-0.48 b* = +2.12). Δ**E** value defines the size of the total colour difference, but does not give information about how the colours differ. Δ**E** is defined by the following equation: $\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$ (MacDougall 1988).

2.4.1.2 Total Soluble Solids (TSS) & pH

For the determination of the TSS and pH, 10 g of pulp was crushed in a mortar in the laboratory with a pestle and mixed with 10ml of distilled water, blended into homogenized slurry of the dried fruit sample. The slurry obtained was then used to determine the TSS and pH. The TSS was determined with a refractometer (RB 32), expressed as the ºBrix, and the pH using Cyberscan 310 pH meter.

2.4.1.3 Vitamin A & C

The changes in vitamins A and C were monitored at 3 –month interval during the storage. The determination of vitamin A was by the AOAC (2000) method 992.04 whilst the 2,6-Dicholorophenol titrimetric method (AOAC, 2000) was used for the vitamin C.

2.4.1.4 Free Fatty Acids

The free fatty acid (FFA) contents of were determined at 3–month intervals to monitor the occurrence of any rancidity in the oil contained in the samples during storage especially in the dried coconut samples. The standard AOAC (2000) method was used and the results were reported as percentage lauric acid.

2.4.2 Microbiological Stati

The microbiological analyses carried out were Aerobic plate count, Mould and Yeast Count, Coliform count, E.coli count, *Staph. Aureus*, *Salmonella* spp and Listeria monocyt. All analyses are being carried using accredited methods according to Nordic Committee on Food Analysis (2006) and ISO 17025.

2.4.3 Sensory Analysis

The sensory parameters monitored were taste, colour, mouth-feel, hand-feel, smell and overall acceptability. Fifteen panelists were trained to evaluate 3 digits coded samples of both dried and un-dried using the descriptive method (Graphical scale method), described by McBride & Finlay (1989) and Larmond (1977). A 15 cm anchored horizontal scale was used for each quality attribute. The extreme left end of the 15 cm horizontal scale denoted low intensity for each quality attribute while the right end denoted high intensity (100%) based on the agreement among the panelist on the terms of quality attribute description they perceive to be of low intensity or high intensity. Each judge recorded his/her evaluation by making a vertical line at the point on the 15 cm scale that reflects his/her perception of the magnitude of that particular attribute.

Preliminary training was carried out to increase the ability of the panelists to detect the differences and familiarize themselves with test procedure, recall sensory characteristics and generate reproducible results. The training was done according to methods of Malek *et al* (1982).

After the evaluation of the quality attributes by the panelists, data were compiled by measuring the intensity of likeness of the panelists by using a ruler and dividing the value by 15cm which was the length of the horizontal line. The value was then converted into percentage. The data was arcsine transformed before results were retransformed back to their original scales for presentation in graphs. Graphical presentations and statistical analysis were done by using Excel (windows 2007). Correlation analysis was by using Genstat version 9.2 and was conducted at a level of significance of ($p \leq 0.05$).

2.4.3.1 Taste

The taste was evaluated by the panelists by tasting a piece of the dried fruit. The extreme left end of the scale denoted very sour (low intensity) and the right end denoted very sweet (high intensity).

2.4.3.2 *Colour*

The panelists agreed on the colour description dark brown (indicating extreme browning) as low intensity scale and light brown yellow as high intensity scale.

2.4.3.3 *Mouth- and Hand-feel (firmness)*

Mouth- and hand-feel were used as indices of the firmness or texture. It was evaluated by the panelist taking a piece of the dried and pressing between the first and fore-fingers and then biting with the incisors. The low intensity was denoted soft and/or soggy while high intensity was denoted by very firm and/or crispy.

2.4.3.4 *Smell*

Smell was based on the intensity of the stimulation, perceived when the sample approached the nose. The panelist is so doing tried to perceive any foul smell indicating moldiness and or rancidity. The description very foul and/or presence of rancidity denoted low intensity scale while high intensity was denoted by very nice.

2.4.3.5 Overall acceptability

The overall acceptability was evaluated by the panelists based on the taste, colour, mouth- and hand-feel and smell. The low intensity scale was denoted by poor and the high intensity was denoted by excellent.

2.5 DETERMINATION OF THE WATER VAPOUR PERMEABILITY RATES OF THE PACKAGING MATERIALS

The permeability, K/x of the packaging material was determined according to the methods of explained by Johnson (2008). Approximately 60 g potions of silica gel desiccant were dried under vacuum at 20 mm Hg at 70 ^{o}C for 24 h. The dried silica gel was immediately transferred into pouches of polyethylene heat sealed and weighed. The pouches containing the silica gel were suspended in a desiccator and kept in an environmental chamber at 37 ^{o}C and 75 % RH. The increase in weight of the pouches, as a result of water transmission was monitored daily for 10 days. The increase in weight was used to calculate the water vapour transmission rate (WVTR) of the film using the principles of Tubert & Iglesias (1985).

2.6 STATISTICAL ANALYSIS

Analysis was carried out in duplicates for moisture, microbial load, vitamins C and vitamin A and the result obtained was statistically analyzed using ANOVA. Statistical package used was the Stat graphics (Centrion edition).

3. RESULTS

Throughout the storage period, the two key shelf-life indices of moisture content and water activity of all the samples remained relatively stable. The moisture contents averaged from 3.13, 10.89, 11.56, 12.05 to 12.29 for dried coconut, papaya, mango, banana and pineapple, respectively. The respective corresponding average water activity values were 0.54, 0.55,0.56,0.56 and 0.56. Water activity represents the amount of available moisture in the food that can influence chemical, enzymatic and microbiological activities (Brennan, 1994).

The water vapour film permeability rate was estimated to be 9 $g/m^2/m^2$/day at 75% RH. This represents the usual water transmission rates high density polyethylene. This was able to hold in check adverse water transmission into the stored products. With the exception of the increased non-enzymatic browning of the banana slices, all other products gave only slight browning colouration. Fig. 2 shows that the colour of the dried pineapples changed only slightly, as indicated by the lightness colour value which averaged around 71.2 under room and 69.7 under chilled temperature conditions during the course of the 1 year storage. This trend is in contrast with that of the dried banana as indicated in Fig.2, where the lightness colour values changed from the initial 71.6 to 61.8 for room and 63.0 for chilled room storage conditions. Fig. 3 indicates the main factor responsible for the reduced colour (or browning) in the banana was due to the increased value of the a_w.

Fig.2 Lightness colour (Lg) and Water Activity (Aw) Profiles of Dried Pineapple Stored at Room (RT) and Chilled (CT) Temperature conditions

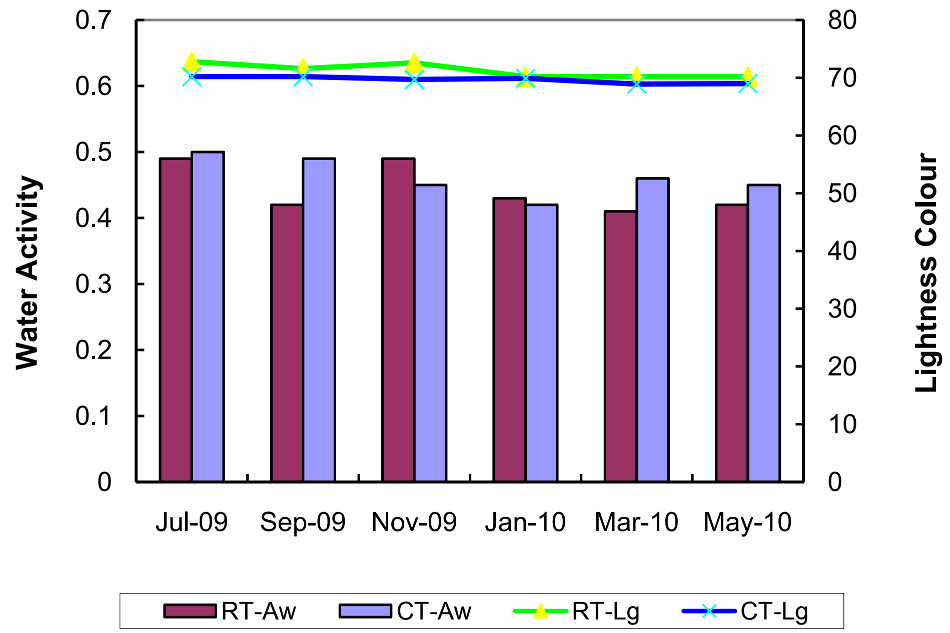
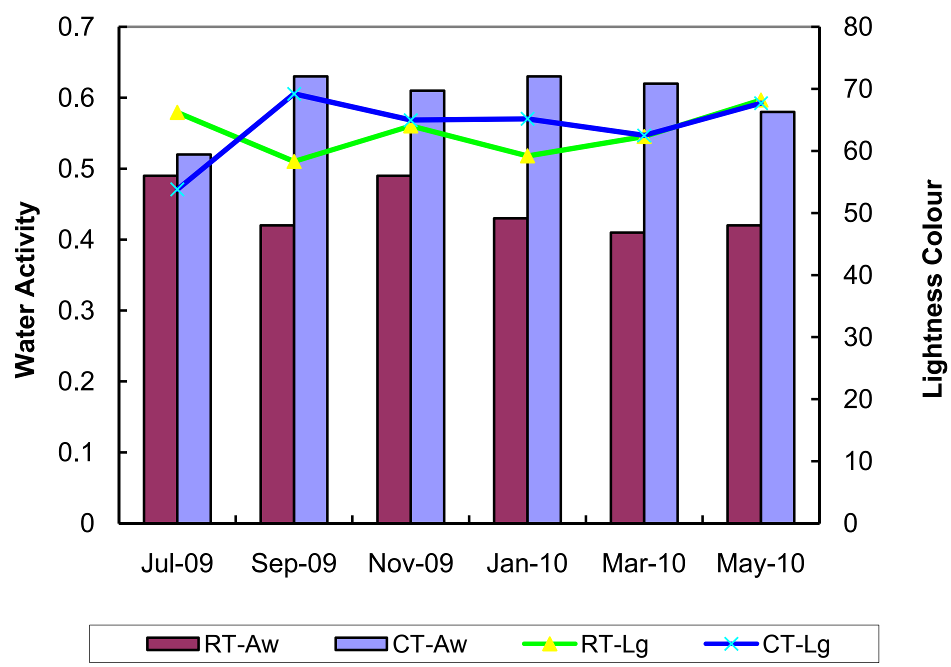


Fig. 3 Lightness (Lg) and Water Activity(Aw) Profiles of Dried Banana Stored at Room (RT) and Chilled(CT) Temperatures Conditions



Tables 1 and 2 indicate that overall there were no significant deteriorations in the TSS, pH, vitamins A and C of the dried fruits during storage for 12 months under the two environmental conditions. Vitamin C is an important anti-oxidant that helps protect the body to fight against cancers, heart diseases and stresses. It is part of the cellular chemistry that provides energy and for making the collagen protein involved in the building and health of cartilage, joints, skin, and blood vessels. Additionally, vitamin C helps in maintaining a healthy immune system, it aids in neutralizing pollutants, is needed for antibody production, acts to increase the absorption of nutrients (including iron) in the gut. Mugalo et al (1994) studying the shelf- stability of powdered non-alcoholic banana manufactured by sun-drying and oven-drying recorded nutrient losses during three months in transparent polythene bags reached 93, 93 and 70% in sundried samples and 84, 99 and 55% in oven-dried samples, respectively, when compared to the fresh banana. The almost stable form of the vitamin C is very significant. This is because the vitamins are the most important nutrients one gets from eating fruits.

Table 1: Values of TSS, pH, FFA, Vitamin A and C of dried pineapples, papaya, mango and banana stored under room temperature (28± 2^{o}C and 78 ± 4% RH) conditions

Month	Pineapple					Papaya					Mango					Banana				
	TSS	pH	Vit A	Vit C	FFA	TSS	pH	Vit A	Vit C	FFA	TSS	pH	Vit A	Vit C	FFA	TSS	pH	Vit A	Vit C	FFA
0	48	3.8	0	15	n.a	45	4.2	0	62	n.a	30	4.1	151	28	n.a	42	4.8	0	12	n.a
3	42	3.8	0	15	n.d	33	4.2	0	60	n.d	29	4.1	146	23	n.d	39	4.7	0	9	n.d
6	39	3.8	0	14	n.a	26	4.2	0	56	n.a	28	4.1	140	19	n.a	39	4.8	0	9	n.a
9	36	3.8	0	13	n.d	24	4.2	0	56	n.d	20	4.1	135	15	n.d	32	4.8	0	8	n.d
12	34	3.8	0	13	0.0	24	4.0	0	56	0.0	20	4.1	132	12	0.0	27	4.8	0	8	0.0

Legend: TSS= Total Soluble Solids (^{0}Brix), Vit A= Vitamin A (in µg/100 g dried weight), Vit C= Vitamin C (in mg/100mg of dried weight), FFA= Free Fatty Acids (in % lauric acid) n.d=not determined ; n.a = not available/detected

Table 2: Values of TSS, pH, FFA, Vitamin A and C of dried pineapples, papaya, mango and banana stored under chilled temperature (18 ± 2^{o}C and 78 ± 4% RH) conditions

Month	Pineapple					Papaya					Mango					Banana				
	TSS	pH	Vit A	Vit C	FFA	TSS	pH	Vit A	Vit C	FFA	TSS	pH	Vit A	Vit C	FFA	TSS	pH	Vit A	Vit C	FFA
0	48	3.8	0	15	n.a	45	4.2	0	62	n.a	30	4.1	151	28	n.a	42	4.8	0	12	n.a
3	42	3.8	0	15	n.d	34	4.2	0	60	n.d	25	4.1	151	23	n.d	39	4.7	0	9	n.d
6	39	3.8	0	12	n.a	22	4.2	0	58	n.a	24	4.1	145	20	n.a	39	4.8	0	8	n.a
9	36	3.8	0	11	n.d	22	4.2	0	56	n.d	20	4.1	140	18	n.d	37	4.8	0	8	n.d
12	35	3.8	0	11	0.0	22	4.0	0	53	0.0	20	4.1	135	15	0.0	36	4.8	0	8	0.0

Legend: TSS= Total Soluble Solids (^{0}Brix), Vit A= Vitamin A (in µg/100 g dried weight), Vit C= Vitamin C (in mg/100mg of dried weight),

FFA= Free Fatty Acids (in % lauric acid) n.d=not determined ; n.a = not available/detected

Table 3: Free Fatty Acid Contents of Dried Coconut Slices during storage under two conditions

Storage Month	% Free Fatty Acid Content (as lauric acid)	
	28± 2^{o}C and 78 ± 4% RH	18± 2^{o}C and 78 ± 4% RH
0	**n.a**	**n.a**
6	**o.1**	**0.2**
12	**0.2**	**0.4**

n.a = not available/detected

There was very little evidence of rancidity in the stored dried coconut slices as indicated by the free fatty acid results in Table 3. This is very significant because, the permissible levels for desiccated coconut in international trade is between 0.1 to 0.4% according to the www.indiamart.com

Table 4: Aerobic Plate Counts (at 30 ^{o}C / 72 h cfu/g NMKL 86 2006) of Dried Fruits Stored at Room Temperature Condition, 28± 2^{o}C and 78 ± 4% RH

Aerobic Plate Count (at 30^{o}C / 72 h cfu/g NMKL 86 2006)						
Sampling Date	**Pineapple**	**Papaya**	**Mango**	**Banana**	**Coconut**	
Initial (3/6/09)	1.3 x 10^{3}	510	540	360	6.1 x 10^{4}	
10/6/09	560	420	340	280	6.4 x 10^{4}	
17/6/09	370	420	260	140	1.8 x 10^{4}	
24/6/09	560	390	5.6 x 10^{3}	280	3.6 x 10^{3}	
1/7/09	90	420	190	280	330	
8/7/09	50	240	1.2 x10^{3}	90	1.7 x 10^{4}	
15/7/09	80	340	510	160	6.2 x 10^{3}	
29/8/09	1.3 x 10^{3}	260	1.6 x 10^{3}	170	2.1 x10^{4}	
12/8/09	230	9.2 x 10^{3}	30	330	4.0 x 10^{3}	
26/8/09	560	350	10	1.8 x 10^{3}	6.1 x 10^{4}	
9/9/09	120	130	170	20	330	
23/9/09	230	440	450	90	2.2 x 10^{3}	
30/10/09	1.2 x 10^{3}	450	520	80	1.4 x 10^{4}	
30/11/09	3.1 x 10^{3}	2.5 x 10^{3}	320	280	2.1 x 10^{4}	
28/12/09	370	350	100	140	6.4 x10^{4}	
31/1/10	240	7.1 x 10^{3}	2.3 x 10^{3}	2.3 x 10^{3}	540	
28/2/10	340	440	5.3 x 10^{3}	100	2.3 x 10^{4}	
30/3/10	1.7 x 10^{3}	230	2.3 x 10^{3}	150	6.3 x 10^{3}	
29/4/10	350	2.3 x 10^{3}	670	560	3.5 x 10^{4}	
27/5/10	6.2 x 10^{3}	180	120	1.6 x 10^{3}	4.9 x10^{5}	

Table 5: Aerobic Plate Counts (at 30 °C / 72 h cfu/g NMKL 86 2006) of Dried Fruits Stored at Chilled Condition, 18± 2°C and 78 ± 4% RH

Aerobic Plate Count (at 30 °C / 72 h cfu/g NMKL 86 2006)						
Sampling Date	**Pineapple**	**Papaya**	**Mango**	**Banana**	**Coconut**	
Initial (3/6/09)	1.3×10^3	510	540	360	6.1×10^4	
10/6/09	240	234	260	640	456	
17/6/09	320	350	390	750	560	
24/6/09	250	420	190	350	4.8×10^3	
1/7/09	240	120	175	390	2.3×10^3	
8/7/09	350	440	410	310	4.7×10^3	
15/7/09	240	240	440	310	5.3×10^3	
29/8/09	150	320	370	440		
12/8/09	230	450	345	560	3.8×10^3	
26/8/09	260	2.0×10^3	310	240	3.2×10^3	
9/9/09	390	310	750	170	2.3×10^3	
23/9/09	340	1.8×10^3	1.0×10^3	140	330	
30/10/09	450	750	1.8×10^3	156	310	
30/11/09	530	140	2.5×10^3	145	3.2×10^3	
28/12/09	450	710	560	345	230	
31/1/10	310	560	720	540	349	
28/2/10	67	420	420	50	2.1X 103	
30/3/10	54	2.8×10^3	140	450	2.3×10^3	
29/4/10	35	1.0×10^3	230	64	2.3 X 104	
27/5/10	30	2.6×10^3	120	50	2.0×10^4	

Over the 12 months storage period, all the dried samples remained microbiologically stable under the two storage conditions (Tables 3 and 4). Correspondingly, the mould and yeast counts of all samples for the samples were also almost negligible for the period. There were no evidence of Coliforms, E. coli, *Staph aureus*, Salmonella spp and Listeria spp. These results are in line with the very low moisture contents and the water activities recorded for the period. Jay (1992) has explained that through drying microorganisms and enzymes are deprived of the water essentially needed for active growth and multiplication. This is shown by the almost constant values of the water activity and aerobic plate counts as given in both tables.

Tables 6 through to Table 10 give the results of the monitoring of the sensory attributes of the dried fruits by the trained panelist at 3-month interval over the 12 month storage period. As indicated almost all the dried fruits, with the exception of the banana fruits, were acceptable up

8 month. This is indicated by the comparable scores ($P < 0.05$) for taste, smell, mouth feel, taste and overall acceptability, except for colour. It was after the 8 month that there was significant drop in the overall acceptability. The respective scores for the dried banana samples under the two conditions were variable. These results are correlated with the profile of lightness parameter monitored for the banana in particular (as shown in Fig 4 & 5).

Table 6: Mean Ratings for Acceptability of Dried Mango Stored at Chilled Condition (18± 2^{o}C) and Room Condition (28± 2^{o}C) all at av. 78 ± 4% RH

Storage Time (Month)	**Mean Ratings at Chilled Condition (18± 2^{o}C and 78 ± 4% RH)**					
	Taste	**Colour**	**Mouth-Feel**	**Hand-Feel**	**Smell**	**Overall Acceptability**
0 (initial)	7.9	7.9	7.8	7.5	7.9	7.5
4	7.5	7.4	7.5	6.9	7.5	7.4
8	7.1	6.5	7.6	6.9	7.5	7.2
12	6.9	6.5	7.1	7.1	7.2	6.2
	Mean Ratings at Room Condition (28± 2^{o}C and 78 ± 4% RH)					
Storage Time (Month)	**Taste**	**Colour**	**Mouth-Feel**	**Hand-Feel**	**Smell**	**Overall Acceptability**
0 (initial)	7.9	7.9	7.8	7.5	7.9	7.5
4	7.5	6.9	7.5	7.3	7.2	7.2
8	7.8	6.5	7.1	7.3	7.8	7.2
12	7.1	6.5	7.1	7.1	6.8	6.3

Each sample was evaluated by 15 trained panelists. A 9-point hedonic scale was used for acceptability with mean ratings of 1= dislike extremely, 5= neither like nor dislike and 9= like extremely

Table 7: Mean Ratings for Acceptability of Dried Papaya Stored at Chilled Condition (18± 2^oC) and Room Condition (28± 2^oC) all at av. 78 ± 4% RH

Storage Time (Month)	Mean Ratings at Chilled Condition (18± 2^oC and 78 ± 4% RH)					
	Taste	**Colour**	**Mouth-Feel**	**Hand-Feel**	**Smell**	**Overall Acceptability**
0 (initial)	7.9	7.9	7.8	7.5	7.9	7.5
4	7.5	7.4	7.5	6.9	7.3	7.4
8	7.1	6.5	7.6	6.9	7.2	7.2
12	6.9	6.5	7.1	7.1	7.2	6.8
	Mean Ratings at Room Condition (28± 2^oC and 78 ± 4% RH)					
Storage Time (Month)	**Taste**	**Colour**	**Mouth-Feel**	**Hand-Feel**	**Smell**	**Overall Acceptability**
0 (initial)	7.9	7.9	7.8	7.5	7.9	7.5
4	7.5	6.9	7.5	7.3	7.2	7.2
8	7.8	6.5	7.1	7.3	6.8	7.2
12	7.1	6.5	7.1	7.1	6.8	6.5

Each sample was evaluated by 15 trained panelists. A 9-point hedonic scale was used for acceptability with mean ratings of 1= dislike extremely, 5= neither like nor dislike and 9= like extremely

Table8: Mean Ratings for Acceptability of Dried Pineapple Stored at Chilled Condition (18± 2^oC) and Room Condition (28± 2^oC) all at av. 78 ± 4% RH

Storage Time (Month)	Mean Ratings at Chilled Condition (18± 2^oC and 78 ± 4% RH)					
	Taste	**Colour**	**Mouth-Feel**	**Hand-Feel**	**Smell**	**Overall Acceptability**
0 (initial)	7.9	7.9	7.8	7.5	7.4	7.5
4	7.5	7.4	7.5	6.9	7.3	7.4
8	7.1	6.5	7.6	6.9	6.8	7.2
12	6.9	6.5	7.1	7.1	6.8	5.6
	Mean Ratings at Room Condition (28± 2^oC and 78 ± 4% RH)					
Storage Time (Month)	**Taste**	**Colour**	**Mouth-Feel**	**Hand-Feel**	**Smell**	**Overall Acceptability**
0 (initial)	7.9	7.9	7.8	7.5	7.4	7.5
4	7.5	6.9	7.5	7.3	7.2	7.2
8	7.8	4.5	7.1	7.3	6.8	7.0
12	7.1	3.4	7.1	7.1	6.8	4.3

Each sample was evaluated by 15 trained panelists. A 9-point hedonic scale was used for acceptability with mean ratings of 1= dislike extremely, 5= neither like nor dislike and 9= like extremely

Table 9: Mean Ratings for Acceptability of Dried Banana Stored at Chilled Condition (18± 2^{o}C) and Room Condition (28± 2^{o}C) all at av. 78 ± 4% RH

Storage Time (Month)	Mean Ratings at Chilled Condition (18± 2^{o}C and 78 ± 4% RH)					
	Taste	Colour	Mouth-Feel	Hand-Feel	Smell	Overall Acceptability
0 (initial)						
4	7.5	7.9	7.5	6.9	7.3	7.4
8	7.1	6.5	7.6	6.9	6.8	6.2
12	6.9	4.5	5.8	7.1	6.8	5.1
	Mean Ratings at Room Condition (28± 2^{o}C and 78 ± 4% RH)					
Storage Time (Month)	Taste	Colour	Mouth-Feel	Hand-Feel	Smell	Overall Acceptability
0 (initial)						
4	7.2	7.5	7.5	7.3	7.2	7.2
8	6.8	4.2	6.1	7.3	6.8	5.8
12	6.1	3.2	6.2	7.1	6.8	3.3

Each sample was evaluated by 15 trained panelists. A 9-point hedonic scale was used for acceptability with mean ratings of 1= dislike extremely, 5= neither like nor dislike and 9= like extremely

Table 10: Mean Ratings for Acceptability of Dried Coconut Stored at Chilled Condition (18± 2^{o}C) and Room Condition (28± 2^{o}C) all at av. 78 ± 4% RH

Storage Time (Month)	Mean Ratings at Chilled Condition (18± 2^{o}C and 78 ± 4% RH)					
	Taste	Colour	Mouth-Feel	Hand-Feel	Smell	Overall Acceptability
0 (initial)	7.9	7.9	7.8	7.5	7.9	7.5
4	7.5	7.9	7.5	6.9	7.3	7.4
8	7.1	6.5	7.6	6.9	6.8	6.2
12	6.9	4.5	5.8	7.1	6.8	5.1
	Mean Ratings at Room Condition (28± 2^{o}C and 78 ± 4% RH)					
Storage Time (Month)	Taste	Colour	Mouth-Feel	Hand-Feel	Smell	Overall Acceptability
0 (initial)	7.9	7.9	7.8	7.5	7.9	7.5
4	7.2	7.5	7.5	7.3	7.2	7.2
8	6.8	4.2	6.1	7.3	6.8	5.8
12	6.1	3.2	6.2	7.1	6.8	3.3

Each sample was evaluated by 15 trained panelists. A 9-point hedonic scale was used for acceptability with mean ratings of 1= dislike extremely, 5= neither like nor dislike and 9= like extremely

Figure 4: Pictures showing dried fruits stored under chilled room temperature at 8 months' storage

Air-dried pineapple fruits at 8 months storage under at 18 ± 2 ^{o}C and 78 ± 4 % RH

Air-dried mango fruits at 8 months' storage under at 18 ± 2 ^{o}C and 78 ± 4 % RH

Air-dried banana fruits at 8 months storage under at 18 ± 2 ^{o}C and 78 ± 4 % RH

Air-dried desiccated coconut fruits at 8 months storage under at 18 ± 2 ^{o}C and 78 ± 4 % RH

Figure 5: Pictures showing comparison of dried fruits stored under room temperature and chilled room temperature at 8 months' storage

Air-dried pineapple fruits: Left: Under room condition   Right: Under chilled room condition

Air-dried banana fruits: Left: Under room condition   Right: Under chilled room condition.

As shown in the two sets of pictures in Figures 4 and 5, there is excessive non-enzymatic browning of the dried pineapple and banana samples under the room conditions. This will certainly be unacceptable to consumers as indicated by the panel scores in Tables 8 and 9.

Air-dried mango fruits: Left: Under room condition   Right: Under chilled room condition.

Air-dried mango fruit and Coconut slices under chilled room condition.

Figure 6: Pictures showing dried mango stored under room temperature at 12 months' storage

This picture shows that the colour of the dried mango to be fading at the 12 month storage

4. DISCUSSION

This shelf-life study was on processed organic fruit and coconut products produced by Nature's Best Fruits Limited. The shelf-stable of almost all the products especially for the first 8 month is proof of the fact that the drying conditions of 68 ±3 ^{o}C for 10 h in the developed tunnel dryer was adequate enough for obtaining internationally commercial acceptable products. The very low moisture contents and water activities monitored for the samples are ample proofs that the sealed high density polyethylene pouches used were able to serve as good moisture barriers for the whole period of storage. The increased non-enzymatic browning in the banana samples could have been reduced by using a number of pre-treatment methods (Abano, 2010) during the processing prior to air-drying. Taoukis et al (1988) consider non-enzymatic browning to be one of the key deteriorative indices of dry foods in storage. Non-enzymatic browning occurs through several mechanisms, one of which is the Maillard reaction. The Maillard reaction is caused by carbonyl groups of the reducing sugars present in the fruits reacting with amino groups of the proteins and amino acids, followed by a series of other complicated reactions. Maillard-type browning can be undesirable in fruits because it not only adversely affect the colour but can also impart a bitter taste to the fruits. Non-enzymatic browning can occur because as the dry foods slowly gains moisture, its a_w increases and will eventually reaches the value maximum browning which is around aw 0.5 to 0.6 (Taoukis *et al*, 1988). However, here is a growing demand for organically certified products that are also low in sugar (natural levels). can be attributable to several factors. This effect is well known in unblanched and untreated dried banana (Ihekoronye & Ngoddy, 1985). Indeed anecdotal evidence indicates that a darker colour may ever be preferred by those preferring organic material as it indicates the untreated product (www.organicGuide/blog/just-food/organic-dried fruits). The Celebes Corporation (www.celebes.com) of the Philippines manufactures several types of organic products which include banana chips. There are several methods for minimizing the formation of non-enzymatic browning in dried foods during storage. These include blanching, osmo-dehydration and the use of sulphuring reagents (Brennan, 1994). Given the increasing concerns consumers have towards the use of additives in food products, initial sulphuring of the banana slices to minimize the occurrence of non-enzymatic browning might not be popular. Osmo-dehydration which could be a possible option might also be unpopular. This is because in osmo-dehydration, the banana slices would have to be osmo-dried initially in concentrated sugar solution before the drying in completed in the oven. This two-stage drying is not likely to be acceptable for health

Like other food additives, there is a growing resistance among consumers towards the use of excess sugar in food products. Blanching would seem to be the best option Nature Best's Fruit Company could use. There are two main forms of blanching, hot water blanching and steam blanching. The latter is recommended because it is known to result in less leaching of the vitamins (Ihekoronye & Ngoddy, 1985). Steam blanchers make use of saturated steam at atmospheric or at low positive pressure, up to 150 kN m-2. For the company to use steam blanching of the fruits prior to drying, there will be the need to experimentally determine the correct blanching times for the various types of fruits. The CSIR-Food Research Institute should be able to assist the company to arrive at the correct blanching times. The absence of the *Staph aureus*, E*. coli*, *Coliforms*, *Samonella* spp and *Listeria* spp are indications that good hygienic and good manufacturing practices were strictly adhered to during the production of the dried fruits samples. This is because all these microorganisms are considered the main microbial indicators of the safety of any food. *Staph aureus* is a food-poisoning microorganism usually found in the nasal cavity, on the skin, and wounds and can easily be transmitted either directly or through cross-contamination during food processing. The presence of *E. coli* is an indication of feacal contamination which may get onto the food either direct human contact or through the water used in processing or through cross-contamination. Salmonella and Listeria are also food poisoning microorganisms which use the intestinal tracts of animals as their primary habitats. The non-detection of these microorganisms in the dried samples all through the storage period is also an indication of the use of GMPs and GHPs during the production of the dried fruits. It is noteworthy Nature's Best Fruits Company's production practices results in safe foods. Food safety is now a very big issue in international trade. Consumers all over the world are increasingly demanding foods sold to them are safe and would not pose any problems with their health. The most desirable quality that must be associated with a food product is the freedom from infectious organism. While it may not be possible to achieve a zero tolerance for all such organisms under GMPs, the production of foods with the lowest possible numbers of micro-organisms should be the goal. The classical approach to ensuring low microbial counts has been to rely heavily on microbiological determinations of both the raw and end-products. Unfortunately, this approach is usually not very reliable because it takes a long time for one detect any microbiological. The new approach is the use of the principles based Hazard Analysis Critical Control Points (HACCP). HACCP is a system that leads to the production of microbiologically safe foods by analyzing for hazards of the raw materials- those that may appear throughout processing and those that occur from consumer abuse. The HACCP is one system most external food auditors recommend for establishments like Nature's Best Fruits Company which is targeting the export markets in Europe and the Americas.

4. Conclusions

Overall, this study has established that pineapple, papaya, mango and coconut dried in the newly developed mobile tunnel dryers, packaged in transparent polyethylene pouches can remain shelf-stable and organolectically acceptable up to the 8 month when stored under room (average 29 ^{o}C and 75 % RH) and up 12 months under chilled-room (average 19 ^{o}C and 75 % RH) condition. This means that all the dried products passed the microbial and physico-chemical and sensorial specifications of the Organic Food Production Act (www.organicGuide.com) as well as the specifications of the present importing company of Nature's Best Fruits Ltd which is the Meridian Organic Foods Company of Stuttgart, Germany.

5. References

Abano, E.E. (2010) Assessments of drying characteristics and physico-organoleptic properties properties of dried pineapple slices under different pre-treatments. *Asian J. Agric Res.,* **4**: 155 - 161

AOAC (2000) *Official Methods of Analysis,* 17th edition. Association of Official Analytical Chemists, Washington D.C.

Brennan, J.G. (1994) *Food Dehydration: a dictionary and guide.* Butterworth-Heinemann pp.189

Fennema, O. R. (**1996)**. *Food Chemistry*, Marcel Dekker, Inc. New York, Basel pp. 182, 191-193, 195,196,198-199,201-204.

Ihekoronye, A. L. and Ngoddy, P. O. (1985). *Integrated Food Science and Technology for the Tropics*. Macmillan Publishers Ltd. London. pp10-89

Jay, J. M., **(1987)** Modern Food Microbiology (3rd edition) Van Nostrand Reinhold Company, New York.pp40-44.

Johnson, P.N.-T. (1996) Dehydration characteristics of plantain (*Musa AAB*). Ph.D. Thesis). The University of Reading, U.K.

Johnson, P-N.T. (2008) *Guide to Food Packaging & Packaging Materials*. Col-DB Pub., Accra pp.88

Labuza (1984) Interpretation of sorption data in relation to the state of constituent water. In: Water relations In: *Foods* ed R. Duckworth pp 155-172 New York. Academic Press.

Lamond, E. (1977) Laboratory Methods for Sensory Evaluation of Foods. Canada Dept of Agric Publication. Ottawa. Pp 1637.

Malek, D.M, Schmitt, D.J and Munroe, J.H. (1982) A rapid system for scoring and analyzing sensory data. *J. American Society of Brewing Chemists*., **40**: 133 -136.

McBride, R. L. and Finlay, D.C. (1989) Perception of taste mixtures by experienced and novice assessors. *J. Sens. Stud*., **3**: 237 -248

MacDougall, D.B. (1988) Colour vision and appearance measurement. In: Sensory Analysis of Foods. 2nd ed. J.R. Piggot pp 103- 130 London: Eleseveir App Sci.

Mugalo, J.K., Lyimo, M.H & Keisy, F.L (1994) Production and storage stability of non-alcoholic banana beverage powder. *Plant Foods for Human Nutrition,* 45, 2, 155 -163

Taoukis, P.S.,El meskine, A. and Labuza T.P.(1988) Moisture transfer and shelf-life of packaged foods. In: *Food and Packaging Interactions* ed by J.H. Hotchkiss pp 243 -261 Symposia Series American Chemical Society, Washington.

Tubert, A.H & Iglesias, H.A. (1986) Water sorption isotherms and prediction of moisture gain during storage of packaged cereal crackers *Lebensm-Wiss.u-Technol.,* **19**, 365 -368.

www.organicGuide.com

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www.indiamart.com