Fruits, 2015, vol. 70(2), p. 77-90

DOI: 10.1051/fruits/2014048

FRUITS

Available online at:
www.fruits-journal.org

ORIGINAL ARTICLE

Impact of drying methods on the nutrient profile of fruits of *Cordia africana* Lam. in Tigray, northern Ethiopia

Sarah Tewolde-Berhan[1,2*], Siv Fagertun Remberg[2], Kebede Abegaz[3], Judith Narvhus[2], Fetien Abay[1] and Trude Wicklund[2]

[1] Department of Land Resources and Environmental Protection/Department of Crop and Horticultural Sciences, Mekelle University, P.O. Box 231, Mekelle, Ethiopia
[2] Department of Chemistry, Biotechnology and Food Science/ Department of Plant and Environmental Sciences, University of Life Sciences, P.O. Box 5003, NO-1432 Aas, Norway
[3] School of Human Nutrition, Food Science and Technology, Hawassa University, P.O. Box 5, Hawassa, Ethiopia

Received 2 April 2014 – Accepted 10 December 2014

Abstract – Introduction. *Cordia africana* Lam. is a tree that produces small fruits eaten in Ethiopia and other parts of Africa. The fresh fruit are sold in the market place in open bowls and, traditionally, the fruit is dried on the tree like dates. **Materials and methods.** Modern methods of processing the fruit were studied. Some of the changes in the nutrient content and chemistry of the fruit were measured using standard methods. **Results and discussion.** In the fresh fruit, the traditional method of handling collected 7.6 g dust kg^{-1}. The TP (total phenols measured with Folin Ciocalteu's reagent) contents varied significantly between the processing methods. Using a solar dryer, the fruit dried within 5 days while the on-tree drying process took 63 days. The taste of the fruit from the direct solar dryer was less preferred to those dried on the tree. The TP values were found to be good in the dried fruits with 200 g fruit being enough to meet the daily requirement. In addition, the vitamin A and vitamin C levels were still good after drying and storage. For both fresh and dried fruits the organic acid and basic sugar profile did not show a very clear picture, as the difference in rainfall and evaporation rates between the two years of the study influenced these parameters. The headspace gas chromatography (HSGC) gave 20 volatile organic compounds and the coupled mass spectrometry (HSGC-MS) gave 39 volatile organic compounds. **Conclusion.** The dried fruit of *Cordia africana* could be used to partially meet the daily nutritional requirements of households in Ethiopia.

Keywords: Ethiopia / Tigray / *Cordia africana* / fresh fruit / dried fruit / phenolic compounds / nutritional value

Résumé – Impact du mode de séchage sur le profil nutritionnel des fruits de *Cordia africana* Lam. de la région du Tigray, au Nord de l'Éthiopie. Introduction. *Cordia Africana* Lam. est un arbre qui produit de petits fruits couramment consommés en Ethiopie et dans plusieurs pays d'Afrique. Les fruits frais sont commercialisés sur les marchés dans des récipients ouverts et traditionnellement, ils sont vendus séchés sur l'arbre comme des dates. **Matériel et méthodes.** Des méthodes modernes de transformation des fruits ont été étudiées. Les modifications nutritionnelles et biochimiques des fruits ont été mesurées par des méthodes standard. **Résultats et discussion.** La pratique traditionnelle de collecte traite 7.6 g de poussière par kg de fruits frais. Les teneurs en phénols totaux (TP), mesurés par réactif de Folin Ciocalteu, ont varié de façon significative selon le mode de transformation des fruits. Avec un séchoir solaire, les fruits ont séchés en 5 jours alors que le processus naturel sur l'arbre a pris 63 jours. Le goût des fruits issus directement du four solaire s'est avéré moins apprécié que celui des fruits séchés sur l'arbre. Une masse de 200 g de fruits secs a été mesurée correspondant aux besoins journaliers en TP. De plus, les teneurs en vitamine A et en vitamine C sont restées élevées après séchage et stockage. Les profils en acides organiques et en sucres de base n'ont pas montré d'évolution claire dans la mesure où les différences annuelles de pluviométrie et d'évaporation ont joué sur ces paramètres. La chromatographie en phase gazeuse par espace de tête (HSCG) nous a fourni 20 composés organiques volatils et par couplage au spectrographe de masse (HSGC-MS) a révélé 39 composés organiques volatils. **Conclusion.** Les fruits séchés de *Cordia africana* pourraient être utilisés pour satisfaire une partie des besoins nutritionnels des ménages en Ethiopie.

Mots clés : Éthiopie / Tigray / *Cordia africana* / fruits séchés / composés phénoliques / valeur nutritionnelle

* Corresponding author: saratbge@gmail.com

1 Introduction

The fruit of *Cordia africana* are widely eaten in most parts of Ethiopia and other countries in Africa [1–4]. During the study it was found that the fruit is used both fresh as well as after being dried and stored. The tree produces a lot of fruit during the dry season when other fruits can only be produced where there is irrigation and the stores of basic food crops in households are running low. *Cordia* is also known to produce fruit in drought years as the tree has deep roots. The fruit was found to be a very good source of total phenol antioxidants. In addition, it is a good partial source of nutritionally important iron and vitamin A, as well as some protein, calcium, copper, potassium, magnesium, manganese, phosphorus, and vitamin C [5, 6]. Traditionally, the fresh fruit is collected, sorted and cleaned by hand and spread out on plastic flat-bottomed bowls in the sun before and during selling. This marketing of the fresh fruit is only at a small scale in some local markets. The dried fruit is mainly stored to be consumed at household level and is seldom sold. Sun-drying of fruit is an old traditional method of preservation found all over the world [7]. Traditionally, the *Cordia* fruit are also dried on the tree like dates [8, 9]. The process of drying fruits on trees has not been studied in detail except for the study done on dates. Thus the investigation of the actual drying process was found to be important. In addition, it was thought that it may be more nutritious and economical to dry the fruit in cabinet direct solar dryers [10, 11]. Thus a comparison of the two processes was undertaken.

The improvement of the marketing of this fruit is important in that it can contribute to the improvement of overall nutrition of the Ethiopian population while also increasing the income of local producers and processors. To improve marketing of the fruit and securing food safety, the processing, packaging, and market chain also needs improvement [12–20]. To look at the improvement potential in post-harvest handling, processing methods that included collection, sorting, washing, air drying under shade, and storage in clean ventilated, i.e. not sealed containers was compared to the traditional processing method.

The objective of this study was to compare the effects of modern and traditional *Cordia africana* fresh and dried fruit processing methods as related to time, visual presence of micro-organisms, physical parameters, moisture, vitamins A and C, antioxidant levels and organic acid profiles.

2 Materials and methods

2.1 *Cordia africana* fruit sampling strategy

Five *Cordia africana* trees were selected and marked. All the processing tests were undertaken on the fruits of these five trees.

2.1.1 Fresh fruit

Fruit were collected from all five trees. These were then divided into three groups. The first group was frozen immediately. The second group was washed; air dried, and laid out in the shade for seven days to represent what would happen to the fruit if they were sold in shops, which will be referred to as modern in this paper. After seven days they were frozen. The third group was given to a traditional fruit merchant to process. She washed the fruit; air dried them and laid them out in plastic flat-bottomed bowls on the floor in the market. The fruit were thus exposed to the sun, wind, dust and handling during the day and were taken back into the house to stay overnight for seven days. After seven days the fruit were taken from the traditional fruit merchant and frozen. All the fruit collected initially as fresh were frozen until processed for analysis.

2.1.2 Dried fruit

From each tree, ten bunches were selected. From these ten bunches, the fruit from five bunches were taken for direct drying in a solar dryer while the fruit of the other five bunches were left to dry on the trees. On each of the ten bunches ten fruits were marked with thread tied around the fruit stalk. Each of the fruit for direct drying in the solar dryer was measured daily. Each fruit left on the trees to dry was measured every other day. The vertical and diagonal dimensions were measured and the colour was recorded. Each time a measurement was taken; two fruits were removed to determine their moisture content as representative of the moisture content of the bunch. This process of taking measurements of drying fruit was carried out in 2010 and again in 2012.

2.2 Analytical methods

For each tree, the size, colour, weight, moisture and ash were determined from individual fruits selected from the fruit bunches, while TP (total phenol), FRAP (ferric reducing activity power), and vitamin A and C, and organic acid profile values were determined from the homogenized samples. For homogenization first the fruit cap was removed followed by the removal of the fruit skin. The remaining sticky flesh was dissolved in a specified amount of water (50−150 mL depending on the number of fruit collected and fruit flesh size) and blended with an egg whisk. When the stone had been separated from the flesh, the stone was removed. The previously separated skin was put back into the dissolved fruit flesh and blended to produce a homogenized fruit pulp paste. As the homogenisation process involved dilution, TP, FRAP and vitamin A and C, and organic acid profile values were calculated back to discount for the dilution.

2.2.1 Physical description of the fruit

Size: the size, in cm, was measured for both diagonal and vertical dimensions of the fruit [21]. This was done using a micro-calliper.

Colour (L*a*b): the colour was initially measured using a colour chart from the Natural Colour Systems [22]. The Natural Colour Systems colours were then converted to the CIE L*a*b* colour [23, 24] reading using a Minolta colour meter.

Hardness: the hardness was measured using personal judgment, and hardness classes of Medium, Soft, and Hard were set.

2.2.2 Physico-chemical properties

Moisture content (%) was determined following the AOAC 934.06 standard [25] Vitamin C (mg 100 g^{-1}) was measured following AOAC 967.21 standard with the metaphosphoric acid–acetic acid solution replaced by 0.1% oxalic acid [26,27] Vitamin A (μg 100 g^{-1}) was measured using the method where trans-β-carotene was extracted one time with ethanol: hexane (4:3 v/v) and two times with hexane. The determination was carried out by rp-HPLC with UV/DAD detection (450 nm). For quantification a 3-point calibration curve was used. The calibration standards used were pure compounds from Sigma, purity > 98%. The purity of the standards for each calibration was determined by a series of spectrophotometric measurements (UV 340/455/483 nm) method described in DIN EN 12823-2:2000 [28–30].

Ferric Reducing Activity Power (FRAP) (μmol L^{-1}): 3 g of the homogenate was extracted in 30 mL methanol, centrifuged and the supernatant was mixed with acetate buffer, TPTZ and iron trichloride, incubated for 10 min and the absorbance was measured at 595 nm. Standards were prepared using Trolox to which readings were compared, following the Konelab 30i outline and method [31,32].

Total Phenols (TP) (mg GAE 100 g^{-1}): 3 g of the homogenate was extracted in 30 mL methanol, centrifuged and the supernatant was mixed with Folin Ciocalteu's reagent and 7.5% (w/v) sodium carbonate, then incubated for 15 min, after which it was measured at 765 nm. Standards were prepared using Gallic acid to which readings were compared. For the analysis the Konelab 30i outline and method was followed [31,32].

Basic sugars and organic acids were analysed by High Pressure Liquid Chromatography (HPLC) (in ppm): 1 g samples were prepared by mixing them with 2.5 mL ultra-pure water, 0.2 mL 1N H_2SO_4 and 8.0 mL acetonitrile (Merck KGaA, Darmstadt, Germany). The mixture was shaken by hand and then by a rotary mixer for 30 min. After mixing the sample was centrifuged at ca. 1,500 *g* for 15 min. The supernatant was then filtered through a filter with 0.2 μL pore size and filled directly into the sample vial and sealed with a plastic cap. Separation of organic acids and carbohydrates was achieved by injection of 25 μL of the filtered sample onto an Aminex HPX-87H HPLC column (Bio-Rad Labs., Richmond, CA, USA), at 32 °C. For the mobile phase, H_2SO_4 (5 mM) at a flow rate of 0.4 mL min^{-1} was used. The detection of organic acids and basic sugars was made using a UV detector set at 210 nm and a refractive index detector respectively (Perkin Elmer, Norwalk, CT, USA). Quantification was done through comparisons of retention times against those of standards made of known concentration mixed in ultra-pure water [33,34].

Volatile organic compounds: were detected by Headspace Gas Chromatography (HSGC) (in ppm) from 10 g samples weighed into a headspace vial and sealed with a Teflon coated septum and aluminium ring. Samples were equilibrated at 50 °C for 45 min in a Hewlett Packard HP 7694 headspace sampler and a sample of 1.0 mL headspace gas was injected into the GC using nitrogen as a carrier gas at a flow rate of 5 mL min^{-1}. The headspace manifold was set at 60 °C. Separation of the volatile compounds was achieved using a CP-Sil 5 CB column, 25 m long, 0.53 mm internal diameter and 5 μm film thickness and applying a GC temperature program of: 53 °C 1 min; increased at 15 °C min^{-1} to 70 °C, 2 min; then increased at 22 °C min^{-1} to 130 °C, 3 min. External calibration curves with standard solutions were used to identify and quantify the compounds [33].

Volatile organic compounds were analyzed by Headspace Gas Chromatography Mass Spectrometry (HSGCMS): samples were prepared in the same way as for the HSGC. Volatiles were sampled dynamically using a Teledyne Tekmar HT3™ Static/Dynamic Headspace System with HT3 Teklink v. 1.2.1104 software (Teledyne Tekmar, Mason, OH). Vial conditions were 50 °C with a preheating time of 5 min and mixing set at five. Then a Helium flow of 50 mL min^{-1} for 10 min was used to trap the volatiles on Tenax® GR 60/80 mesh size (Supelco Analytical, Bellefonte, PA) kept at 25 °C. Dry purge flow was 75 mL min^{-1} for 2 min at 25 °C. Desorption was performed at 280 °C with a gas flow of 75 mL min^{-1} for 5 min with a transfer line temperature of 100 °C. Separation was performed using a 6890N Network GC System (Agilent Technologies, Waldbronn, Germany) fitted with a DB-WAXETR 30 m × 0.25 mm × 0.50 μm capillary column (Agilent Technologies) with 1 mL min^{-1} helium as carrier gas. Temperature programme was 30 °C for 10 min, then 1 °C min^{-1} to 40 °C, 3 °C min^{-1} to 70 °C and 6.5 °C min^{-1} to 230 °C followed by 5 min hold-time. Detection was by a 5975 Inert XL Mass Selective Detector (Agilent Technologies) with the following conditions; electron ionization mode (70 eV) with ion source temperature at 200 °C scanning continuously the range 33 to 300 m/z. The GC/MS used MSD ChemStation D.02.00.275 software and the volatile compounds were identified using NIST MS Search 2.0 (Agilent Technologies), using retention times and with authentic single reference compounds. Performance of the system was verified with blanks and standards [35].

3 Results and discussion

3.1 Physical characteristics

3.1.1 Fresh fruit

The fresh fruit once processed was divided in to two groups based on how they were processed by modern and traditional methods. At the end of the seventh day both modern and traditionally processed fruits showed no visible signs of microbial presence. Though the fruit in both cases appeared similar, the traditionally processed fruits had a lot of dust on and with them. With simple shaking, the dust was removed and per kilogram of fruit there was an average of 7.6 g dust. This was not surprising considering that they were laid out in dusty streets in the markets. The overall physical characteristics measured are presented in *table I*.

On day seven, the processed fruits were significantly different in diameter compared to the fresh fruit off the trees. In a

Table I. Basic physical characteristics of the fresh fruit just after collection and seven days after processing with the modern and traditional methods.

Processing method	Statistical variables	D1 (cm)	D2 (cm)	AD (cm)	L*	a*	b*	Hardness	M%
Day 1 fresh fruit (FF)	Mean	1.18	1.18	1.18	41.50	–1.63	44.06	M	57.87
	SE Mean	0.02	0.02	0.02	0.77	1.18	0.54	M	1.38
	Minimum	1.13	1.14	1.13	39.78	–4.26	42.64	M	53.49
	Median	1.17	1.15	1.16	41.29	–2.12	44.21	M	58.18
	Maximum	1.25	1.27	1.26	43.81	2.03	45.61	M	61.90
Day 7 traditional processing (FT)	Mean	1.07	1.27	1.17	33.51	9.27	37.05	M	49.65
	SE Mean	0.03	0.01	0.02	1.50	0.78	2.27	M	2.15
	Minimum	0.98	1.25	1.11	29.64	6.39	31.29	M	42.78
	Median	1.08	1.26	1.17	34.74	9.65	39.07	M	50.02
	Maximum	1.14	1.32	1.22	36.70	10.83	42.03	M	55.97
Day 7 modern processing (FM)	Mean	1.19	1.33	1.26	32.29	8.46	35.82	M	55.02
	SE Mean	0.04	0.03	0.03	1.17	0.50	1.82	M	1.35
	Minimum	1.11	1.26	1.18	28.93	6.94	30.53	M	51.88
	Median	1.13	1.33	1.23	32.12	8.79	35.38	M	55.25
	Maximum	1.31	1.40	1.35	35.34	9.93	40.50	M	57.98
ANOVA and significance Tukey's grouping			**FF A FM B FT B		**FF A FM B FT B	**FF A FM B FT B	*FF A FM B FT B		*FF A FM B FT B

* 5% level of significance and ** 1% level of significance. Different letters per column mean significant differences.

Table II. Summary of the parameters measured in the direct solar drying process from fruit removed from the trees when fresh.

Variable	Nr days	Mean	SE Mean	Minimum	Median	Maximum
D1 (cm) 1st	5	1.14	0.02	0.80	1.13	1.59
D2 (cm) 1st	5	1.23	0.01	0.94	1.24	1.54
AD (cm) 1st	5	1.19	0.01	0.89	1.16	1.56
L* 1st	5	25.91	0.97	13.06	24.31	47.90
a* 1st	5	3.31	0.32	–5.96	3.52	14.27
b* 1st	5	22.20	1.51	1.35	20.17	53.85
Hardness 1st	5	Soft			Soft	
M% 1st	5	49.90	0.67	31.66	50.42	66.94
D1 (cm) 2nd	5	1.06	0.01	0.85	1.06	1.41
D2 (cm) 2nd	5	1.24	0.01	1.07	1.25	1.45
AD (cm) 2nd	5	1.15	0.01	0. 96	1.14	1.43
L* 2nd	5	24.30	0.81	12.89	19.03	44.29
a* 2nd	5	7.21	0.17	2.25	7.39	11.85
b* 2nd	5	21.39	1.41	0.82	12.16	53.34
Hardness 2nd	5	Soft			Soft	
M% 2nd	5	44.04	1.08	11.66	45.06	64.59

similar manner the processed fruits were significantly different in colour from the fruit fresh off the tree, with the colour being darker with less green, less yellow, more red and more blue on the seventh day. The traditionally processed fruits were significantly drier compared to the fresh fruits off the trees, however there was no significant difference between fruit fresh from the tree and the modern processed fruit with respect to the other parameters. All the noted significant changes can be explained by the drying process of the fruit. The values from the fresh fruit off the tree are consistent with a study looking at more trees in the region) [6].

3.1.2 Dried fruit

The fruits dried directly in the solar dryer grew mould as the weather was unusually moist and the fruits were stored in plastic bags. A second drying was undertaken and the fruits were dried further than in the first trial and were stored in paper bags. The measurements from both drying trials are presented in *table II*. The number of days the fruits dried in the second drying was the same but the moisture content was lower as the fruits were collected later in the season. During the second drying the fruit size became smaller, the colour darker with

Table III. Summary of the parameters measured in the drying process with the fruits left on the trees.

Variable	Nr days	Mean	SE Mean	Minimum	Median	Maximum
D1 (cm)	65	1.13	0	0.85	1.13	1.38
D2 (cm)	65	1.29	0	1.03	1.29	1.50
AD (cm)	65	1.21	0	0.99	1.20	1.42
L*	65	30.94	0.28	13.51	30.60	74.09
a*	65	8.73	0.16	–11.48	9.78	16.30
b*	65	32.81	0.41	1.66	33.58	82.17
Hardness	65	Soft			Medium	
M%	65	51.56	0.32	16.30	53.25	69.51

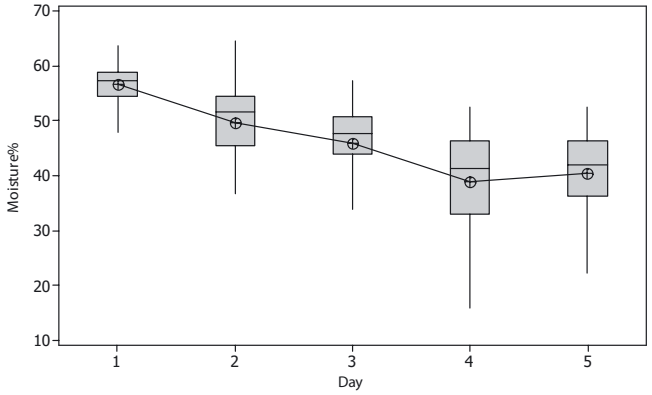

Figure 1. Moisture content of *Cordia africana* fruit during the first 5 days in the solar dryer. Mean and rage box plot summarized per tree, bars represent SD (n = 250 fruits from 5 trees).

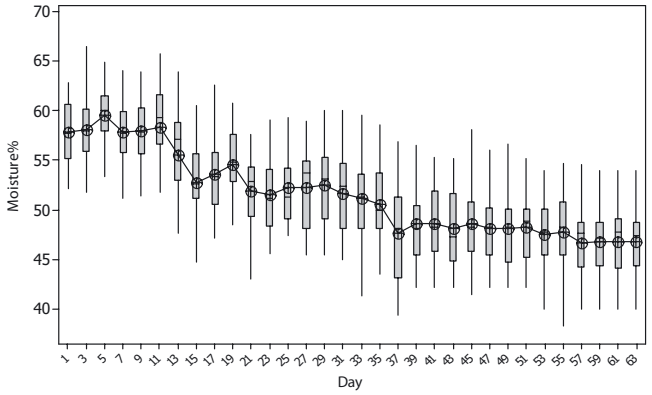

Figure 2. Moisture content of *Cordia africana* fruit over 63 days of drying on the tree. Mean and rage box plot summarized per tree, bars represent SD (n = 250 fruits from 5 trees).

Table IV. Time series summary of the parameters measured in the solar dryer and tree drying processes.

Variable	Drying method	Day of record	Mean
Diagonal diameter cm	Dryer	1	1.20
	Tree	1	1.18
	Dryer	5	1.01
	Tree	63	0.98
Vertical diameter cm	Dryer	1	1.25
	Tree	1	1.17
	Dryer	5	1.22
	Tree	63	1.24
Average diameter cm	Dryer	1	1.23
	Tree	1	1.18
	Dryer	5	1.12
	Tree	63	1.11
L*	Dryer	1	36.06
	Tree	1	41.50
	Dryer	5	16.74
	Tree	63	23.67
a*	Dryer	1	3.85
	Tree	1	–1.63
	Dryer	5	5.47
	Tree	63	9.77
b*	Dryer	1	39.56
	Tree	1	44.06
	Dryer	5	7.86
	Tree	63	20.77
Hardness	Dryer	1	Medium
	Tree	1	Medium
	Dryer	5	Hard & dry
	Tree	63	Hard & dry
Moisture %	Dryer	1	56.70
	Tree	1	57.87
	Dryer	5	40.40
	Tree	63	46.82

more red/magenta colour, and less yellow colour in it. All these differences can be explained by the fact that the fruits used in the second drying were collected later in the fruiting season.

The summary of the data from the fruit drying process on the trees is presented in *table III*. The drying process on the tree took 63 days with measurements taken on 33 days. The average values presented in the table only give the overall picture; the changes that occurred through time can be seen in the minimum and maximum values. They are however better represented in the time series analysis, shown in the following box plot of the moisture content (*figures 1-2*, *table IV*). The long time it takes for the fruit to dry on the trees leaves them exposed to bird and insect attack, incidental rain causing fungal and other microbial growth. Thus considering the physical parameters only, the direct drying in the solar dryer gave better dried fruit.

The time series data were collected over 5- and 63-day intervals. The information from the basic parameters measured is therefore, summarised and compared in *table IV*. Time series summary of the parameters measured in the solar dryer and tree drying processes.

Table V. Total phenol, ferric reducing antioxidant power, vitamin C and vitamin A values of fresh and dried processed fruit of *Cordia africana* with a one way ANNOVA comparison of means, fresh (FW) and dry weight (DM) basis; fresh fruit (FF), fresh fruit modern on day 7 (FM), fresh fruit traditional on day 7 (FT), 2012 solar dryer dried fruit (NDM), 2012 dried fruit traditional (NDT), 2010 solar dryer dried fruit (ODM), 2010 dried fruit traditional (ODT).

Component analyzed	Fruit treatment	Mean DW	Mean FW	Tukey's grouping DW	$P \leqslant$	Sign.
Total Phenol value	FF	69.16 ± 0.13	31.32 ± 0.82	A	0.000	*
(mg GAE 100 g^{-1} FW)	FM	60.57 ± 1.21	30.61 ± 0.69	B		
	FT	52.60 ± 1.13	30.35 ± 0.48	C		
	NDM	33.44 ± 0.30	32.07 ± 0.27	D		
	NDT	31.22 ± 1.06	29.68 ± 0.97	D		
	ODM	57.35 ± 1.91	53.09 ± 0.85	BC		
	ODT	60.74 ± 1.59	53.93 ± 1.25	B		
FRAP value	FF	55.94 ± 1.45	24.32 ± 0.93	B	0.000	*
(μmol L^{-1})	FM	58.86 ± 0.14	27.71 ± 1.46	B		
	FT	58.60 ± 1.65	28.59 ± 0.84	B		
	NDM	30.49 ± 0.67	29.24 ± 0.67	C		
	NDT	31.12 ± 0.04	29.71 ± 0.06	C		
	ODM	58.05 ± 0.20	54.45 ± 0.81	B		
	ODT	68.27 ± 0.85	60.54 ± 0.82	A		
Vitamin C	FF	21.87 ± 2.14	7.65 ± 0.31	A	0.000	*
(mg 100 g^{-1})	FM	16.86 ± 0.55	6.87 ± 0.29	A		
	FT	18.82 ± 0.75	6.77 ± 0.23	A		
	NDM	8.04 ± 0.90	7.86 ± 0.77	B		
	NDT	6.52 ± 1.15	6.58 ± 1.26	B		
	ODM	7.31 ± 0.79	6.84 ± 0.86	B		
	ODT	6.21 ± 0.78	5.51 ± 0.68	B		
Vitamin A	FF	1,768.0 ± 142.0	212.0 ± 28.8	A	0.000	*
(μg 100 g^{-1})	FM	2,713.0 ± 490.0	229.3 ± 34.9	A		
	FT	2,651.0 ± 496.0	237.8 ± 45.3	A		
	NDM	304.6 ± 37.6	49.7 ± 7.9	B		
	NDT	279.6 ± 30.7	48.0 ± 5.2	B		
	ODM	518.6 ± 94.3	61.2 ± 10.2	B		
	ODT	372.4 ± 73.4	42.2 ± 8.4	B		

* Significant at 1%. P is the confidence interval. $N = 35$ composite fruit samples.

Overall, the drying process on the tree took 13 times longer than that in the solar dryer, exposing the fruit to rain, dust, and insect and bird attack. The overall physical parameters were similar. However, a simple taste test involving 15 people, lab attendants and students showed that the fruit dried on the trees had a preferable taste from the third month after the drying process had started. When the same test was undertaken a year after the drying process fruit dried by both methods had similar taste. For this reason further analysis on the aroma compounds and basic sugar profile was undertaken to describe this difference.

3.2 Chemical characteristics

Both dried and fresh fruits were collected, processed and analysed. The ferric reducing antioxidant power (FRAP), total phenols (TP), vitamin C and vitamin A amounts were measured. The summarised results of these measurements and the comparison of means on a dry matter basis are presented in *table V*. The dry matter mean was used to give a similar basis for comparison as the fruit were both fresh and dry.

The fresh fruit processing did not show any significant difference with respect to the FRAP and vitamins tested, while it varied significantly for the total phenol values. Looking at the dried fruit, the same pattern can be seen for the vitamins, while the FRAP and TP values varied significantly. Both results show that the TP and FRAP varied significantly across the different processing methods used. The results are however offset by the fact that 2010 was an exceptionally wet year, while 2012 was a relatively drier one. The monthly rainfall for April and May was 79.4 and 29.9 in 2010 and 37 and 20.6 mm per month in 2012 respectively. During the same time the average daily evaporation rate was 9.6 and 9.18 in 2010 and 9.12 and 10.18 mm per day in 2012. This gave an average deficit of 227.05 mm per month for 2010 and 260.7 mm per month for 2012. This can be seen in the fact that the fruits stored for two years had more antioxidants in the TP and FRAP

Table VI. HPLC, HSGC organic acid, basic sugar and volatile organic compounds in the profile of fresh and dried processed fruit of *Cordia africana* with a one way ANOVA comparison of means; fresh fruit (FF), fresh fruit modern on day 7 (FM), fresh fruit traditional on day 7 (FT), 2012 solar dryer dried fruits (NDM), 2012 dried fruit traditional (NDT), 2010 solar dryer dried fruits (ODM), 2010 dried fruit traditional (ODT).

Component analysed		Fruit treatment	Mean dry weight	Mean fresh weight	Tukey's grouping DW	$P \leqslant$	Sign.
Sugars HPLC (ppm)	Maltose	FF	170,864 ± 15,475	94,335 ± 10,405	B	0.000	**
		FM	334,783 ± 61,797	156,397 ± 29,756	A		
		FT	407,231 ± 42,674	155,100 ± 14,618	A		
		NDM	87,017 ± 2,537	8,560 ± 383	C		
		NDT	66,478 ± 24,424	8,043 ± 3,187	C		
		ODM	179,555 ± 29,545	19,111 ± 3,619	B		
		ODT	62,874 ± 15,716	8,373 ± 2,174	C		
	Glucose	FF	85,496 ± 17,537	46,567 ± 8,543	C	0.000	**
		FM	169,294 ± 34,021	79,391 ± 17,120	AB		
		FT	114,380 ± 21,280	43,637 ± 8,136	BC		
		NDM	47,267 ± 10,772	4,510 ± 759	C		
		NDT	70,952 ± 5,930	8,312 ± 745	C		
		ODM	80,700 ± 9,868	8,685 ± 1,809	C		
		ODT	229,570 ± 13,234	30,997 ± 2,764	A		
Organic acid HPLC (ppm)	Citric acid	FF	21,335 ± 2,490	11,822 ± 1,710	B	0.000	**
		FM	49,181 ± 4,426	22,867 ± 2,117	A		
		FT	47,336 ± 7,365	18,022 ± 2,784	A		
		NDM	7,959 ± 2,043	783 ± 196	C		
		NDT	7,792 ± 879	911 ± 100	C		
		ODM	21,826 ± 2,277	2,313 ± 355	B		
		ODT	23,324 ± 2,170	3,127 ± 306	B		
	Acetic acid	FF	22,846 ± 6,743	12,551 ± 3,901	AB	0.023	*
		FM	38,675 ± 13,175	17,878 ± 6,026	AB		
		FT	38,727 ± 11,274	15,017 ± 4,322	AB		
		NDM	11,145 ± 2,853	1,073 ± 263	C		
		NDT	19,698 ± 6,031	2,372 ± 814	BC		
		ODM	42,204 ± 7,947	4,582 ± 1,081	AB		
		ODT	51,345 ± 6,024	6,900 ± 909	A		
Volatile org compounds HSGC (ppm)	Acetaldehyde	FF	178,9 ± 18,10	99,1 ± 12,60	A	0.000	**
		FM	206,4 ± 16,50	96,20 ± 8,83	A		
		FT	165,8 ± 16,10	63,68 ± 6,95	A		
		NDM	14,43 ± 1,52	1,422 ± 0,18	B		
		NDT	28,07 ± 3,26	3,302 ± 0,43	B		
		ODM	24,43 ± 4,08	2,637 ± 0,58	B		
		ODT	26,40 ± 4,55	3,483 ± 0,54	B		
	Diacetyl	FF	2,250 ± 0,885	1,273 ± 0,533	B	0.002	**
		FM	3,696 ± 0,700	1,705 ± 0,295	AB		
		FT	7,240 ± 2,590	2,800 ± 1,070	A		
		NDM	2,773 ± 0,214	0,275 ± 0,031	AB		
		NDT	0,931 ± 0,336	0,111 ± 0,039	B		
		ODM	1,007 ± 0,346	0,106 ± 0,037	B		
		ODT	0,659 ± 0,314	0,088 ± 0,043	B		

* Significant at 5%. ** Significant at 1%. P is the confidence interval. $N = 35$ composite fruit samples.

measurements than the freshly dried fruits. As would be expected per dry matter comparison the fresh fruit had significantly higher vitamin C and vitamin A levels [26, 36]. However, the dried fruit still had a good content of vitamin C even after two years of storage; consumption of just 967 g would meet the daily intake requirement [37]. The vitamin A though further reduced can still be used as a partial source, but a kilo of fruit would need to be consumed to meet the daily intake requirement. The TP values were also good in that eating 200 g or more of dried fruit would meet the American and European dietary standards [38, 39].

The tastes of the processed fruit were compared by a simple untrained panel and using organic acid and basic sugar profiling. The panellists found the taste of the on-tree dried fruits to be preferable in the short term; however this difference was not noticeable after a year of storage. For this reason a comparison was undertaken using basic sugars, organic acids and volatile organic compounds using HPLC, HSGC and HSGCMS. The results are briefly presented in *table VI*, with the details in *tables VII* and *table VIII*.

In the HPLC maltose, glucose, fructose, citric acid, succinic acid and acetic acid were identified and their quantities

were measured. In the HSGC 17 volatile organic compounds were identified and their quantities were measured (*tables VII*). Comparing the dried and fresh fruit, only five compounds 3-metyl-1-butanol, acetoin, 2-metyl-butanal, 2-metyl-propanal and acetaldehyde were significantly different in concentration as compared to the dried fruit. In addition, 2-butanone and 2-butanol are found only in the fresh fruit. The comparison of the dried fruits is again offset by the rainfall difference between the years. Looking at the basic sugars, it is interesting to note that the sugar level in the on-tree dried fruit is consistently as high as that of the fresh fruit for the sample of 2010 for fructose and glucose. In contrast for maltose it is the solar dryer dried fruit that resembles the fresh fruit. The ethanol content in all forms of the fruit was consistently very high, though it varied significantly with almost all the processing methods. With the HSGCMS only volatile organic compounds were collected and 39 compounds were identified: the results are presented in *table VIII*. The compounds identified by HSGCMS were checked in the literature and pentane, 2-bromo and dextroamphetamine were not found in literature on fruit. Paired *t*-test, one way ANOVA, and cluster analysis tests undertaken for identifying significance of the presence and absence of the compounds showed no significant differences. Twenty one out of the 39 compounds were found in only one of the fruit categories. Twelve of them are in common with the HSGC analysis, while 27 were only identified with the HSGCMS method and 8 were identified only in the HSGC method.

4 Conclusion

The results of our research showed that the fresh fruit processing and marketing process need to be improved as the fruit processed by the traditional method were found to contain dust, though vitamin C and A levels did not change significantly from that of the fresh and solar dryer processed fruits. The direct drying process using the solar dryer saved a lot of time and kept the fruits clean and safe from insect and bird attack. However, the taste of the fruit was not the same until it had been stored for a whole year. Acceptability and cost factors need to be studied and considered for the promotion of the use of direct drying with a solar dryer. The processing method did not have any significant effect on the TP, vitamin C and A levels of the dried fruit. Even though the drying process reduced the TP and vitamin C levels, the content was still high enough for the dried fruit to be considered a good sources of these nutrients. The FRAP and TP value comparisons were offset by the difference in rainfall in the two years where sampling was undertaken. The basic sugar, organic acid and volatile organic compound comparisons showed that the fresh and dried fruit varied significantly from each other. Looking at the dried fruit, the difference again was offset by the rainfall variation in the years when the study was carried out The HSGC and HSGCMS gave 12 similar compounds. In conclusion, the fresh fruit processing and marketing process needs improvement. The dried fruit were found to still be nutritious, thus drying is a very good method for processing and preserving fruits. The use of the solar dryer saved time and kept the fruit in a better condition, however the taste needed time to mature and this needs further study before promotion.

Acknowledgements. The authors would like to thank NUFU (The Norwegian Programme for Development, Research and Education), Mekelle University, University of Life Science, and Sokoine University for the collaborative project that made this study possible. The authors would also like to thank the lab staff in Mekelle University and the University of Life Science for their guidance and teaching and working long hours.

References

[1] Kebu B., Fassil K., Ethnobotanical study of wild edible plants in Derashe and Kucha Districts, South Ethiopia, *J. Ethnobiol. Ethnomed*. 2 (2006) 53–61.

[2] Addis G., Urga K., Dikasso D., Ethnobotanical study of edible wild plants in some selected districts of Ethiopia, Human Ecology. 33 (2005) 83–118.

[3] ICRAF, *Cordia africana*, A tree species reference and selection guide, World agroforesrty centre database, ICRAF, Nairobi, 2008.

[4] Fentahun M., Hager H., Exploiting locally available resources for food and nutritional security enhancement: wild fruits diversity, potential and state of exploitation in the Amhara region of Ethiopia, Food Sec. 1 (2009) 207–219.

[5] Tewolde-Berhan S., Remberg S.F., Abegaz K., Narvhus J.A., Abay F., Wicklund T., Ferric reducing antioxidant power and total phenols in *Cordia africana*, Afr. J. Biochem. Res. 7 (2013) 215–224.

[6] Tewolde-Berhan S., Remberg S.F., Abay F., Abegaz K., Narvhus J.A., Wicklund T., Nutritional composition of *Cordia africana (Lam.)* fruit in different agroecology and land uses in northern Ethiopia, Fruits Sumitted. (Unpublished).

[7] Ibrahim D., Sun drying of figs: an experimental study, J. Food Eng. 71 (2005) 403–407.

[8] Barreveld W.H., Date Palm Products, FAO, Rome, 1993.

[9] Falade K.O., Abbo E.S., Air-drying and rehydration characteristics of date palm (Phoenix dactylifera L.) fruits, J. Food Eng. 79 (2007) 724–730.

[10] Mongi R.J., Bernadette N., Chove B., Wicklund T., Descriptive sensory analysis, consumer liking and preference mapping for solar dried mango cv Dodo, Food Sci. Qual. Manag. 16 (2013) 16–23.

[11] Sharma A., Chen C.R., Vu Lan N., Solar-energy drying systems: A review, Renew. Sust. Energ. Rev. 13 (2009) 1185–1210.

[12] Huang J., Wu Y., Zhi H., Rozelle S., Small holder incomes, food safety and producing, and marketing China's fruit, Appl. Econ. Perspect. Policy 30 (2008) 469–479.

[13] Markelova H., Meinzen-Dick R., Hellin J., Dohrn S., Collective action for smallholder market access, Food Polcy 34 (2009) 1–7.

[14] Fischer E., Qaim M., Smallholder farmers and collective action: What determines the intensity of participation? Proceedings of the german development economics conference, Berlin, 2011.

[15] Ton G., Challenges for smallholder market access: a review of literature on institutional arrangements in collective marketing, Stewart Postharvest Review. 4 (2008) 1–6.

[16] Berdegué J.A., Balsevich F., Flores L., Reardon T., Central American supermarkets' private standards of quality and safety in procurement of fresh fruits and vegetables, Food Policy 30 (2005) 254–269.

[17] Cadilhon J.-J., Moustier P., Poole N.D., Tam P.T.G., Fearne A.P., Traditional vs. modern food systems? Insights from vegetable supply chains to Ho Chi Minh City (Vietnam), Dev Policy Rev. 24 (2006) 31–49.

[18] Shepherd A., The implications of supermarket development for horticultural farmers and traditional marketing systems in Asia; Rome, FAO. (2005).

[19] Feyssa D.H., Njoka J.T., Asfaw Z., Nyangito M.M., Seasonal availability and consumption of wild edible plants in semi-arid Ethiopia: Implications to food security and climate change adaptation, J Hort For. 3 (2011) 138–149.

[20] Teklehaimanot G., Haile M., Women in backyards: Root crop production and biodiversity management in backyards, Oslo, 2007.

[21] Bertin N., Causse M., Brunel B., Tricon D., Génard M., Identification of growth processes involved in QTLs for tomato fruit size and composition, J Exp. Bot. 60 (2009) 237–248.

[22] Hård A., Sivik L., NCS-natural color system: A swedish standard for coloer notation, Color Research & Application. 6 (1981) 129–138.

[23] Osorio D., Vorobyev M., Colour vision as an adaptation to frugivory in primates, Proceedings of the Royal Society of London. Series B: Biol. Sci. 263 (1996) 593–599.

[24] Özkan M., Kirca A., Cemeroğlu B., Effect of moisture content on CIE color values in dried apricots, Eur. Food Res. Technol. 216 (2003) 217–219.

[25] Horwitz W., Latimer G.W., Official methods of analysis of AOAC International. AOAC International, Gaithersburg, Md., 2005.

[26] Eleyinmi A.F., Ilelaboye N.O.A., Aiyeleye F.B., Akoja S.S., Effect of different pre-drying operations on some nutritionally valuable minerals, ascorbic acid and rehydration index of Capsicum specie, Trop. Agr. Res. Extension 5 (2002) 57–61.

[27] Hernández Y., Lobo M.G., González M., Determination of vitamin C in tropical fruits: A comparative evaluation of methods, Food Chem. 96 (2006) 654–664.

[28] J. BLAKE C., Committee on food nutrition: Fat-soluble vitamins, J. AOAC Int. 90 (2007) 18B–25B.

[29] Szpylka J., W. Devries J., Determination of β-carotene in supplements and raw materials by reversed-phase high pressure liquid chromatography: Collaborative study, J. AOAC Int. 88 (2005) 1279–1291.

[30] Bernhardt S., Schlich E., Impact of different cooking methods on food quality: Retention of lipophilic vitamins in fresh and frozen vegetables, J. Food Eng. 77 (2006) 327–333.

[31] Zargar M., Azizah A.H., Roheeyati A.M., Fatimah B., Jahanshiri F., Pak-Dek M.S., Bioactive compounds and antioxidant activity of different extracts from Vitex negundo leaf, J. Med. Plants Res. 5 (2011) 2525–2532.

[32] Volden J., Borge G.I.A., Bengtsson G.B., Hansen M., Thygesen I.E., Wicklund T., Effect of thermal treatment on glucosinolates and antioxidant-related parameters in red cabbage (*Brassica oleracea* L. ssp. *capitata* f. rubra), Food Chemistry. 109 (2008) 595–605.

[33] Narvhus J., Østeraas K., Mutukumira T., Abrahamsen R., Production of fermented milk using a malty compound-producing strain of *Lactococcus lactis* subsp. *lactis* biovar. *diacetylactis*, isolated from Zimbabwean naturally fermented milk, International journal of food microbiology. 41 (1998) 73–80.

[34] Kelebek H., Selli S., Canbas A., Cabaroglu T., HPLC determination of organic acids, sugars, phenolic compositions and antioxidant capacity of orange juice and orange wine made from a Turkish cv. Kozan, Microchem. J. 91 (2009) 187–192.

[35] Volden J., Bjelanovic M., Vogt G., Slinde E., Skaugen M., Nordvi B., Egelandsdal B., Oxidation progress in an emulsion made from metmyoglobin and different triacylglycerols, Food Chemistry. 128 (2011) 854–863.

[36] Mac Carthy D. (Ed.), Concentration and drying of foods, Elsevier Appl. Sci., London, 1986.

[37] Food and Drug Administration U.S., 14. Appendix F: Calculate the Percent Daily Value for the Appropriate Nutrients: Guidance for Industry: A Food Labeling Guide, FOOD, U.S. Food and Drug Administration, Silver Spring, US, 2011.

[38] Chun O.K., Kim D.-O., Smith N., Schroeder D., Han J.T., Lee C.Y., Daily consumption of phenolics and total antioxidant capacity from fruit and vegetables in the American diet, J. Sci. Food Agric. 85 (2005) 1715–1724.

[39] Hervert-Hernández D., García O.P., Rosado J.L., Goñi I., The contribution of fruits and vegetables to dietary intake of polyphenols and antioxidant capacity in a Mexican rural diet: Importance of fruit and vegetable variety, Food Research International. 44 (2011) 1182–1189.

Cite this article as: Sarah Tewolde-Berhan, Siv Fagertun Remberg, Kebede Abegaz, Judith Narvhus, Fetien Abay, Trude Wicklund. Impact of drying methods on the nutrient profile of fruits of *Cordia africana* Lam. in Tigray, northern Ethiopia. *Fruits* 70 (2015) 77–90.

Table VII a. HPLC, HSGC organic acid, basic sugar and volatile organic compounds profile of fresh and dried processed fruit of *Cordia africana* with a one way ANOVA comparison of means; fresh fruit (FF), fresh fruit modern on day 7 (FM), fresh fruit traditional on day 7 (FT), 2012 solar dryer dried fruits (NDM), 2012 dried fruit traditional (NDT), 2010 solar dryer dried fruits (ODM), 2010 dried fruit traditional (ODT).

Component analysed		Fruit treatment	Mean dry weight	Mean fresh weight	Tukey's grouping DW	$P \leqslant$	Sign.
Sugars HPLC (ppm)	Maltose	FF	170,864 ± 15,475	94,335 ± 10,405	B	0.00	**
		FM	334,783 ± 61,797	156,397 ± 29,756	A		
		FT	407,231 ± 42,674	155,100 ± 14,618	A		
		NDM	8,7017 ± 2,537	8,560 ± 383	C		
		NDT	66,478 ± 24,424	8,043 ± 3,187	C		
		ODM	179,555 ± 29,545	19,111 ± 3,619	B		
		ODT	62,874 ± 15,716	8,373 ± 2,174	C		
	Glucose	FF	85,496 ± 17,537	46,567 ± 8,543	C	0.00	**
		FM	169,294 ± 34,021	79,391 ± 17,120	AB		
		FT	114,380 ± 21,280	43,637 ± 8,136	BC		
		NDM	47,267 ± 10,772	4,510 ± 759	C		
		NDT	70,952 ± 5,930	8,312 ± 745	C		
		ODM	80,700 ± 9,868	8,685 ± 1,809	C		
		ODT	229,570 ± 13,234	30,997 ± 2,764	A		
	Fructose	FF	131,242 ± 22,720	71,954 ± 11,839	BC	0.00	**
		FM	241,071 ± 48,077	113,035 ± 24233	AB		
		FT	169,569 ± 26,340	64,984 ± 10,756	ABC		
		NDM	66,960 ± 10,080	6,441 ± 583	C		
		NDT	82,112 ± 8,699	9,608 ± 1,011	C		
		ODM	126,250 ± 20,901	13,713 ± 3,314	C		
		ODT	253,211 ± 13,403	34,081 ± 2,621	A		
Organic acid HPLC (ppm)	Citric acid	FF	21,335 ± 2,490	11,822 ± 1,710	B	0.00	**
		FM	49,181 ± 4,426	22,867 ± 2,117	A		
		FT	47,336 ± 7,365	18,022 ± 2,784	A		
		NDM	7,959 ± 2,043	783 ± 196	C		
		NDT	7,792 ± 879	911 ± 100	C		
		ODM	21,826 ± 2,277	2,313 ± 355	B		
		ODT	23,324 ± 2,170	3,127 ± 306	B		
	Succinic acid	FF	13,501 ± 3,036	7,379 ± 1,579	B	0.00	**
		FM	28,904 ± 4,202	13,393 ± 1,875	B		
		FT	62,238 ± 12,142	23,431 ± 4,211	A		
		NDM	9,615 ± 1,341	945 ± 131	C		
		NDT	8,371 ± 1,000	974,3 ± 99,5	C		
		ODM	26,943 ± 3,467	2,890 ± 544	B		
		ODT	23,154 ± 1,396	3,118 ± 267	B		
	Acetic acid	FF	22,846 ± 6,743	12,551 ± 3,901	AB	0.023	*
		FM	38,675 ± 13,175	17,878 ± 6,026	AB		
		FT	38,727 ± 11,274	15,017 ± 4,322	AB		
		NDM	11,145 ± 2,853	1,073 ± 263	C		
		NDT	19,698 ± 6,031	2,372 ± 814	BC		
		ODM	42,204 ± 7,947	4,582 ± 1,081	AB		
		ODT	51,345 ± 6,024	6,900 ± 909	A		

* Significant at 5%. ** Significant at 1%. *P* is the confidence interval. *N* = 35 composite fruit samples.

Table VII b. HPLC, HSGC organic acid, basic sugar and volatile organic compounds profile of fresh and dried processed fruit of *Cordia africana* with a one way ANOVA comparison of means; fresh fruit (FF), fresh fruit modern on day 7 (FM), fresh fruit traditional on day 7 (FT), 2012 solar dryer dried fruits (NDM), 2012 dried fruit traditional (NDT), 2010 solar dryer dried fruits (ODM), 2010 dried fruit traditional (ODT).

Component analysed		Fruit treatment	Mean dry weight	Mean fresh weight	Tukey's grouping DW	$P \leqslant$	Sign.
Volatile organic compounds HSGC (ppm)	Acetaldehyde	FF	178,9 ± 18,10	99,10 ± 12,60	A	0.00	**
		FM	206,4 ± 16,50	96,20 ± 8,83	A		
		FT	165,8 ± 16,10	63,68 ± 6,95	A		
		NDM	14,43 ± 1,52	1,42 ± 0,18	B		
		NDT	28,07 ± 3,26	3,30 ± 0,44	B		
		ODM	24,43 ± 4,08	2,64 ± 0,58	B		
		ODT	26,40 ± 4,55	3,48 ± 0,54	B		
	Ethanol	FF	6,27 ± 341,00	3,45 ± 236,00	A	0.00	**
		FM	3,61 ± 345,00	1,68 ± 175,00	B		
		FT	1,63 ± 330.00	631,00 ± 145,00	C		
		NDM	211,20 ± 20,50	20,60 ± 1,67	D		
		NDT	75,60 ± 16,30	8,77 ± 1,69	E		
		ODM	20,63 ± 6,47	2,19 ± 0,70	F		
		ODT	30,60 ± 3,00	4,09 ± 0,38	EF		
	Aceton/ Acrolein	FF	5,330 ± 2,450	2,940 ± 1,380	A	0,025	*
		FM	0,726 ± 0,190	0,334 ± 0,084	BC		
		FT	0,836 ± 0,085	0,323 ± 0,042	B		
		NDM	0,772 ± 0,193	0,074 ± 0,178	BC		
		NDT	0,328 ± 0,089	0,040 ± 0,013	C		
		ODM	0,661 ± 0,065	0,070 ± 0,011	BC		
		ODT	0,834 ± 0,065	0,112 ± 0,011	B		
	2-metyl-propanal	FF	1,810 ± 0,412	1,009 ± 0,252	A	0.000	**
		FM	1,953 ± 0,412	0,912 ± 0,198	A		
		FT	2,589 ± 0,423	0,986 ± 0,151	A		
		NDM	0,278 ± 0,023	0,028 ± 0,004	B		
		NDT	0,189 ± 0,035	0,022 ± 0,004	B		
		ODM	0,266 ± 0,039	0,028 ± 0,004	B		
		ODT	0,177 ± 0,029	0,023 ± 0,003	B		
	Diacetyl	FF	2,250 ± 0,885	1,273 ± 0,533	B	0.002	**
		FM	3,696 ± 0,700	1,705 ± 0,295	AB		
		FT	7,240 ± 2,590	2,800 ± 1,070	A		
		NDM	2,773 ± 0,214	0,275 ± 0,031	AB		
		NDT	0,931 ± 0,336	0,110 ± 0,039	B		
		ODM	1,007 ± 0,346	0,106 ± 0,037	B		
		ODT	0,659 ± 0,314	0,088 ± 0,043	B		
	2-butanone	FF	0,0484 ± 0,048	0,028 ± 0,028	B	0.000	**
		FM	0,307 ± 0,075	0,144 ± 0,036	A		
		FT	0,283 ± 0,098	0,107 ± 0,039	A		
		NDM	0,000 ± 0,000	0,000 ± 0,000	B		
		NDT	0,000 ± 0,000	0,000 ± 0,000	B		
		ODM	0,000 ± 0,000	0,000 ± 0,000	B		
		ODT	0,000 ± 0,000	0,000 ± 0,000	B		

* Significant at 5%. ** Significant at 1%. *P* is the confidence interval. *N* = 35 composite fruit samples.

Table VII c. HPLC, HSGC organic acid, basic sugar and volatile organic compounds profile of fresh and dried processed fruit of *Cordia africana* with a one way ANOVA comparison of means; fresh fruit (FF), fresh fruit modern on day 7 (FM), fresh fruit traditional on day 7 (FT), 2012 solar dryer dried fruits (NDM), 2012 dried fruit traditional (NDT), 2010 solar dryer dried fruits (ODM), 2010 dried fruit traditional (ODT).

Component analysed		Fruit treatment	Mean dry weight	Mean fresh weight	Tukey's grouping DW	$P \leqslant$	Sign.
Volatile organic compounds HSGC (ppm)	2-butanol	FF	0,00 ± 0,00	0,00 ± 0,00	B	0.00	**
		FM	0,22 ± 0,08	0,10 ± 0,04	A		
		FT	0,26 ± 0,10	0,10 ± 0,04	A		
		NDM	0,00 ± 0,00	0,00 ± 0,00	B		
		NDT	0,00 ± 0,00	0,00 ± 0,00	B		
		ODM	0,00 ± 0,00	0,00 ± 0,00	B		
		ODT	0,00 ± 0,00	0,00 ± 0,00	B		
	Ethyl acetate	FF	1,0190 ± 0,1580	0,5595 ± 0,0878	A	0.00	**
		FM	0,5397 ± 0,0678	0,2506 ± 0,0309	BC		
		FT	0,2508 ± 0,0670	0,0946 ± 0,0239	CD		
		NDM	0,6704 ± 0,0323	0,0661 ± 0,0043	B		
		NDT	0,1158 ± 0,0586	0,0142 ± 0,0076	D		
		ODM	0,0524 ± 0,0214	0,0060 ± 0,0025	D		
		ODT	0,1242 ± 0,0224	0,0167 ± 0,0032	D		
	2-metyl-1-propanol	FF	1,181 ± 0,131	0,645 ± 0,065	AB	0.002	**
		FM	1,226 ± 0,303	0,571 ± 0,144	AB		
		FT	2,552 ± 0,577	0,993 ± 0,258	A		
		NDM	0,252 ± 0,047	0,025 ± 0,005	B		
		NDT	0,386 ± 0,069	0,044 ± 0,007	B		
		ODM	0,000 ± 0,000	0,000 ± 0,000	B		
		ODT	0,925 ± 0,660	0,129 ± 0,094	AB		
	3-metyl-butanal	FF	1,739 ± 0,608	0,977 ± 0,359	A	0.000	**
		FM	1,449 ± 0,382	0,675 ± 0,180	AB		
		FT	1,802 ± 0,375	0,686 ± 0,137	A		
		NDM	0,5145 ± 0,042	0,05117 ± 0,006	ABC		
		NDT	0,1408 ± 0,033	0,01667 ± 0,004	BC		
		ODM	0,2915 ± 0,053	0,03033 ± 0,006	BC		
		ODT	0,1595 ± 0,018	0,02128 ± 0,002	C		
	2-metyl-butanal	FF	3,297 ± 0,815	1,828 ± 0,486	A	0.00	**
		FM	3,222 ± 0,699	1,506 ± 0,337	A		
		FT	3,707 ± 0,378	1,420 ± 0,147	A		
		NDM	0,488 ± 0,048	0,048 ± 0,007	B		
		NDT	0,375 ± 0,105	0,044 ± 0,012	B		
		ODM	0,444 ± 0,636	0,045 ± 0,006	B		
		ODT	0,338 ± 0,061	0,045 ± 0,007	B		
	2.3-pentadione	FF	1,943 ± 0,721	1,031 ± 0,355	AB	0.001	**
		FM	2,528 ± 0,856	1,179 ± 0,401	A		
		FT	0,779 ± 0,167	0,298 ± 0,063	ABC		
		NDM	0,192 ± 0,123	0,018 ± 0,011	BC		
		NDT	0,410 ± 0,151	0,048 ± 0,017	BC		
		ODM	0,084 ± 0,055	0,009 ± 0,006	C		
		ODT	0,217 ± 0,103	0,028 ± 0,014	BC		

* Significant at 5%. ** Significant at 1%. P is the confidence interval. $N = 35$ composite fruit samples.

Table VII d. HPLC, HSGC organic acid, basic sugar and volatile organic compounds profile of fresh and dried processed fruit of *Cordia africana* with a one way ANOVA comparison of means; fresh fruit (FF), fresh fruit modern on day 7 (FM), fresh fruit traditional on day 7 (FT), 2012 solar dryer dried fruits (NDM), 2012 dried fruit traditional (NDT), 2010 solar dryer dried fruits (ODM), 2010 dried fruit traditional (ODT).

Component analysed		Fruit treatment	Mean dry weight	Mean fresh weight	Tukey's grouping DW	$P \leqslant$	Sign.
Volatile organic compounds HSGC (ppm)	Acetoin	FF	167,23 ± 7,97	92,28 ± 7,21	A	0.00	**
		FM	142,60 ± 20,70	66,60 ± 10,50	A		
		FT	164,30 ± 10,00	62,58 ± 2,16	A		
		NDM	33,45 ± 3,95	3,30 ± 0,44	B		
		NDT	8,07 ± 2,78	0,94 ± 0,32	C		
		ODM	10,87 ± 4,10	1,17 ± 0,44	C		
		ODT	7,03 ± 2,83	0,89 ± 0,35	C		
	3-metyl-1-butanol	FF	3,022 ± 0,682	1,680 ± 0,410	B	0.000	**
		FM	3,078 ± 0,500	1,439 ± 0,255	B		
		FT	5,831 ± 0,719	2,222 ± 0,254	A		
		NDM	0,520 ± 0,094	0,050 ± 0,006	C		
		NDT	0,377 ± 0,132	0,042 ± 0,015	C		
		ODM	0,243 ± 0,119	0,027 ± 0,013	C		
		ODT	0,107 ± 0,107	0,013 ± 0,013	C		
	2-metyl-1-butanol	FF	2,447 ± 0,694	1,327 ± 0,351	BC	0.000	**
		FM	3,027 ± 0,762	1,421 ± 0,381	AB		
		FT	5,380 ± 1,340	2,087 ± 0,587	A		
		NDM	0,284 ± 0,064	0,027 ± 0,005	BC		
		NDT	0,658 ± 0,165	0,075 ± 0,017	BC		
		ODM	0,353 ± 0,077	0,037 ± 0,008	C		
		ODT	0,708 ± 0,044	0,095 ± 0,008	BC		
	Hexanal	FF	0,2625 ± 0,0478	0,1453 ± 0,0274	A	0.0000	**
		FM	0,3116 ± 0,0325	0,1447 ± 0,0150	A		
		FT	0,1031 ± 0,0134	0,0396 ± 0,0058	B		
		NDM	0,0435 ± 0,0106	0,0044 ± 0,0011	B		
		NDT	0,0247 ± 0,0034	0,0029 ± 0,0005	B		
		ODM	0,0475 ± 0,0086	0,0051 ± 0,0011	B		
		ODT	0,0374 ± 0,0063	0,0050 ± 0,0010	B		

* Significant at 5%. ** Significant at 1%. P is the confidence interval. $N = 35$ composite fruit samples (5 replicas × 7 treatments)..

Table VIII. Percentile frequency distribution of the HSGCMS volatile organic compound occurence profile of fresh and dried processed fruits of *Cordia africana;* fresh fruits (FF), fresh fruit modern on day 7 (FM), fresh fruit traditional on day 7 (FT), 2012 solar dryer dried fruits (NDM), 2012 dried fruit traditional (NDT), 2010 solar dryer dried fruits (ODM), 2010 dried fruit traditional (ODT).

Aroma compound	Fruit processing code						
	FF	FM	FT	NDM	NDT	ODM	ODT
Amine (2-Aziridinylethyl)	60	60	60				
1.3 – Butane diamine							20
1-Butanol, 2-methyl	40	40	80		80	20	60
1-Butanol, 3-methyl	40	40		60			20
1-Hexanol, 2-ethyl							20
1-Pentanol, 2-amino	40						
1-Pentanol, 4-amino					20	40	20
1-Propanol, 2-amino							20
1-Propanol, 2-methyl		60	40				
1-Propanol, 4-amino							20
2,3-Butanedione				20			
2-Butanone, 3-hydroxy	80	20	80	20	60		
2-Propenal	40						
3-Furaldehyde							20
3- Pyridinecarboxaldehyde, O-acetyloxime, (E)						20	
Acetaldehyde	80	80	80	80	100	100**	100**
Acetic acid	40	80	60	60	40	60	100
Acetone				20			
Ammonium Oxalate					20		
Butanal							20
Butanal, 2-methyl	40	20	20	60	40	60	100
Butanal, 3-methyl	20	20		60	20	100	100
Cyclobutanol				20			
Cyclohexanone, 3-hydroxy	20						
Dextroamphetamine *					20	20	
Ethyl acetate	80	80	80	80	60		40
Ethylalchohol	80	80	80	60	60		
Ethylhydrogen oxialate	80	20					
Ethyne, fluoro				20	40	60	100
Hexanal		20					
Hydroperoxide, hexyl	60	60	60		20		
O-Methylisourea hydrogensulfate		20			40		
Oxirane, (1-methylbutyl)					40		
Oxirane, 2,2 – dimethylpropyl							20
Pentanal						20	
Pentane, 2-bromo *	20						
Phenol							20
Propanal, 2-methyl	40	60	40	80	60	100	80
Styrene			40				

* Compounds not found in literature on fruit. ** Has more than one occurence per fruit composite sample.