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SOLAR DRYING OF EGYPTIAN LIME FRUITS FOR DOMESTIC USAGE

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ABSTRACT

Egyptian lime fruits (*Citrus aurantifolia*) were dried during the high production season, i.e. September of 2006 using a simple solar dryer. The dried lime fruits were incorporated in making lime juice and in baking cakes. The physico-chemical and organoleptic evaluation of the products were studied. Peeled and lobed lime fruit (PL) was used as control-1. The PL was treated by blanching for 2-3 min. in 25 % sucrose solution (PLS) and also, by blanching for 2-3 min. in 25% sucrose + 0.06 % sodium meta-bisulphite (PLSS). In addition, whole seedless lime puree (WP) was used as control-2. The WP was treated by adding 25% sucrose (WPS) and in addition by adding 25% table sugar + 0.06% sodium meta-bisulphite (WPSS). The WPS and WPSS treatments were heated for 2-3 min. at 80°C. The organoleptic evaluation of lime juices prepared from the different dried lime fruit products gave high quality score except for WP samples. Also, addition of dried lime puree (WP, WPS and WPSS) in baking the cakes at levels of 5, 7 and 10% resulted in the improvement in both the physical measures of the baking quality of cake and in the overall acceptability score of organoleptic parameters. The study shows the positive possibility of drying the Egyptian lime fruits using the solar drying technique during the high season for making juice and baking cake throughout the year. The dried lime purée might be used as the common apricot purée.

Keywords: Lime puree, dried citrus, solar drying.

INTRODUCTION

Citrus fruits are considered as one of the most important fruits cultivated in Egypt. Egyptian lime fruits (*Citrus aurantifolia*) are acidic citrus fruits representing significant quantity of the total citrus production (El-Saidawy, 1997) and have been cultivated in Egypt since the sixteenth century (Mattuk *et al.*, 1997).

Lime fruits and other citrus fruits contain amounts of different constituents and are thought to have some health benefits. They contain a terpene called limonene which gives the characteristic of lemon smell and taste. Lemons contain significant amounts of citric acid; this is why they have a low pH and a sour taste. They also contain Vitamin C which is essential to human health (El-kady, 1996). In addition, lime fruits contain unique flavonoid compounds that have antioxidant and anti-cancer properties. These flavonoids have been shown to stop cell division in many cancer cell lines (Kawaii *et al.*, 1999). Moreover, the inclusion of lime juice during the main meal of the day was

reported to have protective activity against the contraction of cholera (Mata *et al.*, 1994).

Fruit leathers are made by pouring puréed fruit onto a flat surface for drying. When dried, the fruit is pulled from the surface and rolled. It gets the name "leather" from the fact that when the puréed fruit is dried, it is shiny and has the texture of leather. A variety of fruits can be used for leathers. Some favorites include apples, apricots, bananas, peaches, pears, plums. They can be used singly or in combinations (Baker, 1997).

Lemon slices were dried using the closed-type solar dryer and were compared with hot air drying at 60°C and were generally found to have better general levels of quality in terms of sensory parameters (Chen *et al.*, 2005).

In Egypt, lime fruits had a wide variety of application including refreshing, pharmaceutics purposes and also with meals as flavor enhancer.

The main season of lime fruits begins approximately in August and lasts till November which is more or less a short season. Accordingly, lime price in the fresh market suffers significant fluctuation.

Therefore, the aim of this study was to seek for a simple drying method for preserving the lime fruits. Moreover, domestic way for the utilization of the dried lime will be studied and evaluated.

MATERIALS AND METHODS

Lime fruits, i.e., *Citrus aurantifolia* used in this study were obtained from a private farm in Ahmed Oraby area, Esmailia road, Cairo, Egypt. The fruits were fully mature (sufficiently ripe) with the bright yellow stage, free from deterioration. Fruits were refrigerated at 5°C for 24 hr. then, cleaned with running water then treated as follows:

1- Peeled and lobed lime fruit (control 1) = PL
2- Peeled and lobed lime fruit, blanched 2-3 min. in 25% sucrose solution = PLS
3- Peeled and lobed lime fruit, blanched 2-3 min. in 25% sucrose solution + 0.06 % sodium meta-bisulphite = PLSS
4- Seedless whole lime fruit purée (control 2) = WP
5- Seedless whole lime fruit purée with 25% sucrose and heated at 80°C for 2-3 min. = WPS
6- Seedless whole lime fruit purée with 25% sucrose + 0.06% sodium meta-bisulphite and heated for 2-3 min. at 80°C = WPSS

Whole lime fruit purée was prepared by cutting the whole fruits into small pieces then the seeds were removed. The small lime pieces were blended until smooth product was obtained.

PL, PLS and PLSS were drained well then, placed in a single layer over the drying trays of the solar dryer. WP, WPS and WPSS samples were spread over plastic sheets in 0.5 cm thickness and placed in drying trays of the solar dryer.

The solar dryer used was a direct cabinet type with natural air circulation which are used generally for drying agricultural products especially fruits and vegetables and was described earlier by Yousef & Medany (2007). The drying experiments were conducted for 60-72 hrs. of September 2006.

The temperature ranged between 22 and 32°C outside the dryer and it was found in earlier studies that temperature inside the solar dryer was higher than the outside temperature by 6 to 11°C according to the time of the day (Yousef & Medany, 2007).

The dried lime lobe and purée samples were packed in polyethylene bags and refrigerated for 2 days. Quantities and percentages of the different parts of lime fruits and dehydrated products were calculated and tabulated in Table 1.

Table 1. Quantities and percentage of the different parts of lime fruits and dehydrated products

Components	Sample weight, g	Percentage, %
Fresh fruits		
Whole lime fruits	1000	100
Peel	165	16.5
Seeds	12.5	1.25
Fresh PL	835	83.5
Fresh WP	987.5	98.75
Dehydrated products		
Dried PL	186.3	18.63
Dried WP	114.4	11.44

Seeds were removed from PL, PLS and PLSS dried samples and then blended to smooth powder. While, dried WP, WPS, and WPSS were cut into small pieces (0.5 x 0.5cm). Afterwards the dried lime samples were used in baking the cakes and for juice preparation.

Preparation of lime juice

Each dried PL, PLS and PLSS powders at the levels of 1, 2 and 3% were soaked in tap water for 15 min, then the lime juice was evaluated. In addition, 2, 3, 4% of each dried WP, WPS and WPSS paste were soaked for 3 hrs and blended before evaluating the lime juice. Sucrose was added to lime juice till a final concentration of 18% was reached.

Preparation of lime cake

The basic formula of cake consists of 100 g wheat flour (72% extraction), 55 g butter, 55 g fresh egg, 100 g sucrose, 40 ml fresh milk, 3 g baking powder, 0.2 g vanillia (Abd- Elkader, 1995). Small pieces of 5, 7 and 10% of the different dried whole lime purée (WP, WPS and WPSS) and 3, 6, and 9% of the different dried powder lobe (PL, PLS and PLSS) estimated on the amount of wheat flour were added to this formula.

Analytical methods

Moisture content of lime samples was determined using an oven air dryer at 105°C according to the A.O.A.C (1995). Total acidity was measured as ascorbic acid and total soluble solids (T.S.S.) were determined by a Carl Zeiss refractometer at 20°C (Ranganna, 1995). The pH value was determined directly using a Beckman glass electrode pH meter at 25°C. The ascorbic acid content was determined using the 2, 6 dichlorophenol indophenol titration method (A.O.A.C., 1980).

Rehydration ratio of the dry lime samples was determined according to Ranganna (1995). Two to ten grams of the dried materials were placed in 80-150 ml of distilled water and boiled for 5 min, dumped into a 7.5 cm Buchner funnel covered with a coarsely porous then, filtered with Whatman paper No. 4 and the rehydrated samples were weighted.

Rehydration ratio = B/A

A= weight of dehydrated samples

B= weight of rehydrated samples

Determination of color

Dried lime fruit samples were evaluated for color using Hunter lab color. (model D25) according to Hunter (2005). The Hunter color values were measured based on three parameters, the L*, a*, and b* type of scales simulate this as:

1) L* (lightness) from 0 for black (darker) color to 100 for white (lightness) color.
2) a* (red-green) from (-a) for greens to (+a) for redness.
3) b* (blue-yellow) from (-b) for blueness to (+b) for yellowness.

Physical characteristics of cake

After baking and cooling for one hour at room temperature, cake weight (g) and cake volume (cm^3) were measured following the seed displacement method described by Griswold (1962). Specific volume of baked cake was calculated as follows:

Specific volume = Cake volume (cm^3)/ cake weight (g).

Organoleptic evaluation

Lime juice and cake samples were organoleptically evaluated by ten members from Bread and Dough Technology Research Department, Food Technology Research Institute, Agric. Res. Center. Lime juices were evaluated for their taste, odor, color, bitterness and acceptability. Cake samples were left at room temperature after baking and were evaluated for their shape, volume, crust color, graining of crumb, texture, crumb color, taste and odor for cake. (Griswold, 1962).

Statistical analysis

Ten replicates for each of the different treatments of both cake and lime juice prepared from peeled and lobed lime fruits and seedless whole lime fruits were statistically analyzed as a complete randomized block according to Snedicor (1980). Values of different characters were arranged using the least significant difference (L.S.D) using SAS® software package.

RESULTS AND DISCUSSION

1- Some physicho-chemical characteristics of lime products

Physico-chemical characteristics of the fresh and dried lime fruits samples are given in Table 2. The pH values were 1.9 and 2.3 for the fresh samples of lobes and whole lime purée respectively. On the other hand, it could be noticed that addition of sugar and sulfur dioxide had no effect on the pH values of both lobe and purée of lime fruits. Also, total acidity measured as citric acid was found to be 7.71 and 6.00% for PL and WP, samples respectively. It could be noticed that dried samples had lower acidity than the

fresh samples. The low acidity of lime puree as compared with that of the lobe may be due to the low concentration of acids in the peel. These findings are in agreement with those reported by El-kady (1996).

Moisture content of whole fresh lime purée (WP) and lobe (PL) are 84.37 and 87.03%, respectively. Addition of sugar decreased the moisture content of fresh lime fruits, but increased the moisture content in the dried products. Fresh whole lime fruit (WP) contained higher ascorbic acid content which reached 50.45 mg/100g, as compared with PL which contained 45.90 mg/100g. On the other hand, dehydration caused appreciable decrement in ascorbic acid content in all treatments. Loss in vitamin C as a result of heat processing either due to blanching or to the drying heat was reported (Roiz, 1997).

Table 2. Some physico-chemical characteristics of fresh and dehydrated lime fruits

Treatments	Physico-chemical characteristics					
	pH value	Total acidity, g citric/100 ml	Moisture content, %	Ascorbic acid, mg/100g*	T.S.S., %	Rehydration ratio
Fresh PL	1.93	7.71	87.03	45.90	9	n.d
Fresh PLS	1.90	7.30	86.75	23.70	13	n.d
Fresh PLSS	1.90	7.85	83.04	23.10	13	n.d
Fresh WP	2.30	6.00	84.37	50.45	11	n.d
Fresh WPS	2.30	5.60	55.98	18.00	40	n.d
Fresh WPSS	2.25	5.80	55.76	18.40	40	n.d
Dried PL	2.36	4.43	4.19	10.08	n.d	6.45
Dried PLS	2.33	4.32	4.45	9.10	n.d	4.97
Dried PLSS	2.34	4.21	4.87	9.67	n.d	5.24
Dried WP	2.55	3.29	8.60	11.89	n.d	4.30
Dried WPS	2.57	3.51	11.16	5.38	n.d	3.42
Dried WPSS	2.54	3.55	11.98	6.21	n.d	2.51

n.d = not determined
* on dry weight bases

The total soluble solids of fresh PL and WP were 9 and 11% respectively. The addition of sugar increased the TSS which reached 13% for fresh PLS and PLSS while recorded 40% for fresh WPS and WPSS samples.

2- Effect of solar drying on lime products

The effect of drying on lime fruit lightness (L^*), redness (a^*) and yellowness (b^*) were evaluated and presented in Table 3. The solar drying had significant effect on the L^*, a^* and b^* values, which reflected the degree of browning during drying. These findings were in agreement with those reported by Rahman *et al* (2005) who dried meat with different methods.

Table 3. Effect of solar drying on color of lime fruits

Treatments	*L**	*a**	*b**
Fresh PL	46.67	-5.29	12.21
Fresh PLS	41.16	-0.64	9.48
Fresh PLSS	44.64	4.17	11.10
Fresh WP	54.49	-2.74	21.89
Fresh WPS	43.78	1.63	16.53
Fresh WPSS	47.00	-1.44	28.65
PL	35.00	6.24	11.93
PLS	33.55	4.22	10.49
PLSS	38.11	5.86	14.03
WP	44.56	6.93	24.00
WPS	42.49	7.32	21.53
WPSS	46.79	7.40	27.24

L* **(lightness) from 0 for black (darker) color to 100 for white (lightness) color.**
a* **(red-green) from (-*a*) for greenness to (+*a*) for redness.**
b* **(blue-yellow) from (-*b*) for blueness to (+*b*) for yellowness.**

Generally, *L** and *b** values indicated that the dried samples were darker-yellow in color than the fresh samples which were lighter-yellow in color in both of the peeled and lobed lime fruit (PL) and seedless lime fruit puree (WP). Also, the results showed that addition of sugars to either PL or WP samples caused the PLS and WPS samples to be darker-yellow in color as compared with either PL or WP samples, which were lighter-yellow in color. Moreover, addition of sodium meta-bisulphite to either WPS or LPS samples resulted in the lightest-yellow dried lime samples (WPSS and LPSS). In the same trend, El-Kady (1996) in his studies added sodium meta-bisulphite to protect ascorbic acid and prevent the formation of brown color.

Organoleptic evaluation of lime juice prepared from the different dried lime fruit products is presented in Table 4. Lime juices prepared from PL, PLS, PLSS, WPS and WPSS have good score for taste, odor, color, bitterness and acceptability. Lime juice prepared from WP gave however, inferior grade. From these data, it could be concluded that the addition of sugars in lime puree has improved the organoleptic properties of lime juices.

Table 4. Organoleptic evaluation of lime juice prepared from dried lime fruit

Lime juice samples	Organoleptic characteristics of lime juice				
	Taste (10)	Odor (10)	Color (10)	Bitterness (10)	Acceptability (10)
PL					
3 %	7.7[a]	7.1[a]	7.6[a]	7.1[a]	8.0[a]
6 %	7.8[a]	7.3[a]	8.1[a]	6.6[a]	7.1[a]
9 %	7.8[a]	7.8[a]	7.7[a]	7.1[a]	7.8[a]
PLS					
3 %	7.2[a]	6.5[b]	6.9[a]	6.4[a]	6.9[a]
6 %	7.1[a]	7.0[a]	7.9[a]	7.0[a]	7.4[a]
9 %	7.5[a]	7.0[a]	7.8[a]	6.8[a]	7.6[a]
PLSS					
3 %	7.0[a]	6.9[a]	6.7[b]	6.1[a]	7.0[a]
6 %	7.1[a]	7.1[a]	6.9[a]	6.3[a]	6.6[b]
9 %	7.1[a]	7.3[a]	6.5[b]	6.4[a]	7.0[a]
WP					
5 %	6.3[b]	6.3[b]	6.1[b]	5.8[b]	6.5[b]
7 %	6.5[b]	6.5[b]	5.8[c]	5.5[b]	6.2[b]
10 %	6.5[b]	6.4[b]	5.8[c]	5.4[b]	6.4[b]
WPS					
5%	6.9[a]	6.2[b]	7.0[a]	6.2[a]	6.9[a]
7 %	6.9[a]	6.6[b]	7.9[a]	6.5[a]	6.9[a]
10 %	6.9[a]	6.8[a]	7.6[a]	6.5[a]	6.9[a]
WPSS					
5%	7.0[a]	6.9[a]	7.1[a]	6.1[a]	6.9[a]
7%	7.3[a]	7.2[a]	7.4[a]	6.7[a]	6.9[a]
10 %	7.3[a]	7.0[a]	7.8[a]	6.9[a]	7.1[a]
LSD < 0.05	1.0814	1.1512	1.2639	1.3357	1.1558

a, b and c means in the same column within the same item followed by different superscripts differ significantly at $P< 0.05$.

3- Effect of using dried lime products in baking cakes

Results of incorporating the different treatments of peeled and lobed dried powder lime fruits at levels of 3, 6 or 9 % and 5, 7 or 10% of dried seedless lime puree on the physical characteristics of baking quality of cake are shown in Table 5. Addition of dried lime puree at any of the tested levels resulted in improved measures of the baking quality of cake. The specific volume was improved, as reaching 2.39 cm^3/g for 5% WP treatment and 2.59 cm^3/g for both 7 and 10% of WPS treatments.

The effect of adding dried lime fruit samples on the organoleptic properties of cake is shown in Table 6. Addition of WPS and WSS treatments at the different tested levels to cake resulted in increasing the overall acceptability score of organoleptic qualities. However, there are no significant differences between cakes supplemented with dried purée samples at the three tested levels on the overall organoleptic properties. Whereas, there are significant differences when dried lime peeled and lobed samples were added at all the tested levels. From these data, it might be concluded that the different dried puree supplementation at the three tested levels have

improved baking quality without any negative effect on the organoleptic evaluation.

It could be concluded that solar drying of lime fruits at the production season, as a simple preservation method, would provide both national and international markets with this fruit products all the year round. Moreover, the most common domestic usages, i.e., refreshing beverage and baking, have benefited from the dried lime fruit products. These results would open an avenue for the utilization of the dried lime purée resembling that of the common dried apricot purée.

Table 5. Physical-characteristics of cake supplemented with different dried products of lime fruits

Cake samples	Weight, g	Volume, cm^3	Specific volume, cm^3/g
mixed with			
3 % PL	292.31	615	2.10
6 % PL	314.59	630	2.00
9 % PL	326.08	580	1.78
mixed with			
3 % PLS	311.48	660	2.12
6 % PLS	313.19	620	1.98
9 % PLS	320.31	580	1.81
mixed with			
3 % PLSS	306.88	720	2.35
6 % PLSS	311.73	630	2.02
9 % PLSS	326.90	610	1.87
mixed with			
5 % WP	300.84	720	2.39
7 % WP	301.63	760	2.52
10 % WP	303.09	750	2.47
mixed with			
5 % WPS	312.07	800	2.56
7 % WPS	309.42	800	2.58
10 % WPS	312.80	810	2.59
mixed with			
5 % WPSS	308.28	750	2.43
7 % WPSS	309.51	770	2.49
10 % WPSS	309.66	780	2.52

Table 6. Organoleptic evaluation of cake supplemented with different levels of dried lime fruits

Cake samples	Organoleptic characteristics of cake								Overall acceptability (100)
	Shape (10)	Volume (15)	Crust color (5)	Graining of crumb (10)	Texture (15)	Crumb color (5)	Taste (20)	Odor (20)	
Mixed with									
3 % PL	7.67^{b}	12.33^{b}	3.22^{b}	7.89^{b}	12.58^{a}	3.78^{b}	15.00^{b}	15.22^{b}	77.69
6 % PL	7.56^{b}	12.56^{a}	3.44^{b}	8.22^{a}	12.11^{b}	4.00^{a}	16.33^{a}	16.56^{a}	80.78
9 % PL	8.22^{a}	12.78^{a}	3.56^{b}	8.22^{a}	11.89^{b}	3.67^{b}	14.22^{b}	15.11^{b}	77.67
Mixed with									
3 % PLS	8.44^{a}	12.89^{a}	4.00^{a}	8.11^{a}	12.56^{a}	4.00^{a}	15.89^{a}	16.78^{a}	82.67
6 % PLS	8.11^{a}	12.89^{a}	4.00^{a}	8.33^{a}	13.00^{a}	4.00^{a}	17.22^{b}	15.89^{b}	83.44
9 % PLS	8.11^{a}	13.11^{a}	3.78^{b}	8.89^{a}	12.44^{a}	4.33^{a}	16.67^{b}	16.00^{b}	83.33
Mixed with									
3 % PLSS	8.56^{a}	11.67^{b}	3.67^{b}	8.67^{a}	12.89^{a}	4.33^{a}	17.56^{a}	16.56^{a}	83.91
6 % PLSS	7.78^{a}	12.22^{b}	3.11^{b}	7.33^{b}	12.00^{b}	3.78^{b}	15.56^{a}	16.56^{a}	78.34
9 % PLSS	7.33^{b}	12.33^{b}	3.22^{b}	8.22^{a}	12.44^{a}	4.00^{a}	14.33^{a}	16.11^{a}	77.98
Mixed with									
5 % WP	8.89^{a}	13.22^{a}	4.33^{a}	8.33^{a}	13.11^{a}	4.33^{a}	16.11^{a}	17.11^{a}	85.43
7 % WP	8.56^{a}	13.56^{a}	4.11^{a}	8.67^{a}	12.56^{a}	4.33^{a}	15.56^{a}	16.89^{a}	84.24
10 % WP	8.33^{a}	13.22^{a}	4.11^{a}	9.00^{a}	13.33^{a}	4.00^{a}	14.44^{a}	16.78^{a}	83.21
Mixed with									
5% WPS	7.44^{b}	13.00^{a}	3.22^{b}	7.44^{b}	13.78^{a}	4.33^{a}	18.00^{a}	17.22^{a}	84.43
7 % WPS	8.11^{a}	12.89^{a}	4.00^{a}	8.22^{a}	13.33^{a}	4.44^{a}	16.33^{a}	17.00^{a}	84.32
0 % WPS	9.00^{a}	14.11^{a}	4.44^{a}	8.89^{a}	13.56^{a}	4.67^{a}	16.44^{a}	18.22^{a}	89.33
Mixed with									
5% WPSS	8.78^{a}	13.33^{a}	4.11^{a}	8.44^{a}	14.00^{a}	4.67^{a}	18.33^{a}	18.33^{a}	89.99
7% WPSS	8.33^{a}	13.56^{a}	4.22^{a}	8.44^{a}	13.56^{a}	4.00^{a}	17.44^{a}	18.22^{a}	87.77
10 % WPSS	8.00^{a}	13.11^{a}	3.78^{a}	9.00^{a}	13.67^{a}	4.56^{a}	17.11^{a}	18.11^{a}	87.34
LSD < 0.05	1.2504	1.7246	0.6838	1.0883	1.6702	0.6848	2.5078	2.3182	

a and b .... means in the same column within the same item followed by different superscripts differ significantly at P< 0.05.

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استخدام الطاقة الشمسية فى تجفيف الليمون المصرى للاستخدام المنزلى البسيط

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تم تجفيف ثمار الليمون البلدى البنزهير فى شهر سبتمبر لموسم إنتاج عام 2006 باستخدام مجفف شمسى بسيط الصنع. استخدم الليمون المجفف لعمل عصير الليمون ولتدعيم الكيك. اجريت بعض التقديرات الفيزوكيميائية والتقييم الحسى للمنتج المجفف. وكانت منتجات الليمون المجففة كالتالى: فصوص ليمون بدون قشر(PL) وهى العينة القياسية الأولى (الكنترول-1). ولقد تم معاملة الفصوص بالسلق فى محلول 25% سكر لمدة 2-3 دقائق (PLS) وأيضا السلق فى محلول 25% سكر و 0.06 % صوديوم ميتا بيسلفيت (PLSS). وكانت العينة القياسية الثانية (الكنترول-2) WP عبارة عن ليمون كامل بدون بذور ومفروم لعمل عجينة الليمون. ثم عوملت العينة WP بإضافة 25% سكر للعجينة (WPS) وفى معاملة أخرى تم إضافة 25% سكر و0.06 % صوديوم ميتا بيسلفيت (WPSS) وتم تسخين المعاملتان WPS و WPSS على 80°م لمدة 2-3 ق. عصير الليمون المجهز عن طريق المنتجات المجففة لثمار الليمون أعطت كلها نتائج جيدة فى الصفات الحسية ما عدا عجينة الليمون المجففة بدون معاملة (WP) وعند إضافة السكر لعجينة الليمون أدى إلى تحسين الصفات الحسية لعصير الليمون. ولقد أدى إضافة عجينة الليمون المجففة إلى الكيك إلى تحسين جودة صفات الكيك وأيضا القياسات الحسية له. أوضحت هذه الدراسة إمكانية استخدام المنتج المجفف لثمار الليمون فى أى وقت خلال العام. وأظهرت هذه الدراسة إمكانية استخدام شرائح عجينة الليمون المجففة كشرائح عجينة المشمش المعروفة والمستخدمة من أزمنة طويلة.