



**PHYSICAL AND BIOCHEMICAL CHARACTERISATION OF LOQUAT FRUIT
(*ERIOBOTRYA JAPONICA LINDL.*) VARIETIES IN SOUTHERN LEBANESE AREAS**

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ABSTRACT: The objective of this study was to investigate the physical and biochemical characteristics of loquat (*Eriobotrya japonica* Lindl.) in order to help selecting the appropriate cultivar for a better fresh fruit consumption. For this reason, the soluble solid content or titratable acidity expressed as malic acid and its pH were measured to complement the profile of 20 accessions of nine commercial varieties whereof three of them were native to Lebanon (Ahmar, Baladi, Sukkary) while the other six were introduced from other countries (Argelino, Espani, Eustrali, Faransi, Tanaka and Turki). Samples were collected from three districts in the Southern side of Lebanon (Chouf, Jezzine and Saida). Fruits were harvested at full ripen maturity and analyzed without delay. Seventeen different parameters (weight, length, circumference, shape, color, firmness and seed number, seed shape, seed weight, ...) created the identity card for loquat varieties in the country. Fruit quality traits were used to clarify groupings among the twenty accessions. The soluble solid content (SSC) varied between 8.06° B (Argelino Jin2) and 16.02° B (Sukkary Gh₁). The titratable acidity, expressed as acid malic ranged from 0.06 (Eustrali Be₄) to 0.39 (Baladi A₁). The pH of the fruit varied from 3.62 (Turki AQ₁) to 5.15 (Sukkary Gh₁). Such related data collection created the identity card of the varieties in the country and could help the growers to better select the right cultivar, for fresh fruit consumption and for industrial processing.

Key words: Loquat, Fruit, Physical traits, Biochemical traits, quality

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INTRODUCTION

Loquat (*Eriobotrya japonica* Lindl.) from Rosaceae family is considered the first colourful attractive edible fruit after winter and is mainly produced on the Lebanese coast. It is used worldwide for medicinal and for landscape (as a decorative tree) purposes especially near houses rather than for commercial purposes [1]. The prices of the fruits start high in early spring, decrease at peak production and increase after May because of new fruits are produced at higher elevation, with a good economic impact on farmers of Bekaa area. After May, the loquat fresh fruits disappear. According to its propagation, loquat bears different names and varieties are described by regional knowledge. In this study, the word “accession” is used for a variety collected in specific location, while “cultivar” is used for a specific variety regardless of the collection place. Studies on loquat are very recent in Lebanon, despite its cultivation for more than 200 years [2].

Varieties of loquat are given local names by farmers throughout the country such as Ahmar, Baladi and Saidaoui [3]. Last publication recorded 8 varieties grown in Lebanon and studied in depth the botanical characteristics of their trees, leaves and fruits while the biochemical characterization was initiated in this study [4]. The present study focused on the fruit morphology to differentiate between cultivars and on biochemical attributes to save longer our local varieties by implementing previous work done by collecting loquat varieties studied in Lebanon and by analysing the physical and biochemical composition of each variety [5]. The objectives of this study were (1) to review the physical characteristics of the loquat fruit studied previously, (2) to assess some physical and biochemical characteristics of 20 accessions and assess their similarities and differences in terms of taste, color and size, (3) to attempt to clarify the confusion of local common name of varieties, (4) to compare the Lebanese grown varieties with varieties in the region, (5) to illustrate the varieties and their names with pictures and collected data. Varieties of loquat are given local names by farmers throughout the country such as Ahmar, Baladi and Saidaoui [3]. Last publication recorded 8 varieties grown in Lebanon and studied in depth the botanical characteristics of their trees, leaves and fruits while the biochemical characterization was initiated in this study [4]. The present study focused on the fruit morphology to differentiate between cultivars and on biochemical attributes to save longer our local varieties by implementing previous work done by collecting loquat varieties studied in Lebanon and by analysing the physical and biochemical composition of each variety [5]. The objectives of this study were (1) to review the physical characteristics of the loquat fruit studied previously, (2) to assess some physical and biochemical characteristics of 20 accessions and assess their similarities and differences in terms of taste, color and size, (3) to attempt to clarify the confusion of local common name of varieties, (4) to compare the Lebanese grown varieties with varieties in the region, (5) to illustrate the varieties and their names with pictures and collected data.

MATERIALS AND METHODS

Description of sites

The present study covered three Southern districts of Lebanon (Saida, Chouf and Jezzine) covering where loquat trees are found. The regions selected were from 30 m above sea level (Aalman to Babliye area) on the coastal area, and up to 360 m above sea level (Lebaa area) (Fig 1 and Table 1).

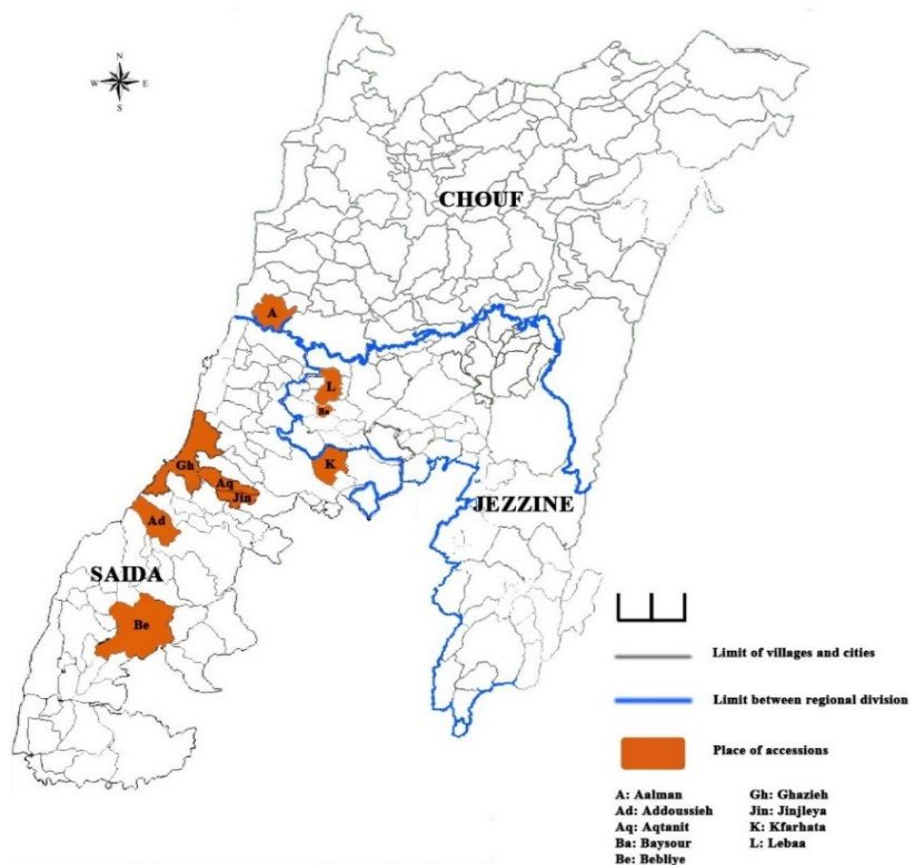


Figure 1: Map of accessions and related locations (Saida, Chouf and Jezzine areas).

Collection of samples of numbers cultivars

One to two kilograms (kg) of each of the 20 accessions were collected from 10 commercial fields. Three accessions were picked from Chouf, thirteen from Saida and four from Jezzine. The fruits were harvested by hand, collected in bags and labeled with the identity of the accessions (place, farmer, variety, date). Fruits were put in cold storage overnight. The measurements were done next day at the food technology and in the animal science respective laboratories of the Faculty of Agriculture at the Lebanese University. The fruits of each accession were sorted visually by size and color and then further by weight to create homogeneous lots for accurate measurements.

Measurements

The sample size for measurement of each accession was 4 fruits depending on availability. Each fruit was measured for its physical and biochemical traits. The studied traits are divided into sixteen quantitative variables and four qualitative variables.

Physical and biochemical traits of harvested fruits grown in these areas were studied and correlation between selected accessions and locations was estimated.

Weight: fruits were laid on the scale after zeroing it to get an accurate measure. Also the seeds of each fruit were weighed together. The edible part (flesh and skin) weight was calculated by subtracting the weight of seeds from the weight of fruit.

Length and Circumference: Both were measured by a gradual tape. Length was taken from the peduncle base to the center of blossom end. The circumference of the fruit was measured horizontally around the center of fruit.

Color of skin and flesh: The color of the skin and the flesh were described subjectively by sight relying on the European Loquat List Descriptor RESGEN29 and objectively by measuring two sides of the fruit around the midpoint on the surface by a colorimeter ((ADCI -60-C Automatic Color Difference Meter (Beijing CTK Instrument Technology Co. Ltd.). A luminary transference arrives on the studied object and gives the three components Hunter Lab: lightness L*(brightness, 100 = white, 0 = black), redness a* (+, red; -, green) and yellowness b*(+, yellow; -, blue). The Chroma (C) of the skin (S) and of the flesh (F) was calculated according to CIE lab formula [6]:

$$\text{Chroma: } C_{ab}^* = \sqrt{a^{*2} + b^{*2}}$$

Firmness of skin and flesh: The fruit firmness was determined using a Setamatic TM (STANPHOPE SETA) penetrometer with a cylindrical weight of 50g and a 90° angle. The 50g mass was added to force the penetrometer to penetrate into the skin and have interpretable measures and avoid having zero values. All replicate of each accession were measured on two sides of fruit with skin and flesh. It is expressed in millimeter (mm) of how deep the needle perforated the fruit. **Fruit and seed morphology** were described using the European Loquat List Descriptor RESGEN29 by European Minor Fruit Tree Species Database (EMFTSD).

The number of seeds and their weights were also recorded.

Biochemical measurements

Solid Soluble Content: 1 drop of juice was put on the refractometer prism (Convex (CEDEX, CETI. OSI BP 124-78312 MAUREPAS) to measure the soluble solid content (SSC) present in each fruit of each cultivarin °Brix.

pH: After buffering, the electrode is put in contact with the juice sample. The electrode is rinsed with distilled water and dried after each measure.

Titrateable acidity: 10 ml of filtrated juice are used and put in an Erlenmeyer flask and 3-4 drops of phenolphthalein are added to juice. NaOH is filled with the gradual burette at 0.1N. The titration is done against the juice, till the color transformation from orange to pink-red. The titrateable acidity expressed as Malic acid was calculated by the following formula as reported previously [7]:

$$\% \text{ Acid} = \frac{(\text{ml NaOH used}) (0.1) (0.067)}{(\text{Weight of sample}) (10\text{ml})}$$

Statistical Analysis

Data were recorded for one time at mature harvest with four replications of each accession composed from four fruits. The Principle Component Analysis (PCA), Cluster Analysis and ANOVA statistical test was performed using the STATISTICA Six Sigma Software (STATISTICA, 2008).

To look for significant effects associated with varietal parameters within all accessions, one-way ANOVA analysis was performed on %TA, SSC, pH data sets, and means were compared by the Bonferroni test, considering a significance level of $p < 0.05$.

Data sets used for PCA were obtained by first averaging replicate determinations and then applying auto scaling as a pretreatment, by merging the same data sets used for PCA. The PCA is used to show the correlation between studied data. Several PCs were created from the input data, and each PC explains a percentage from the total variance. The first PC gathers inputs with the highest percentage effect, the following PCs will gather the remaining inputs with the less effect (Narasimhan, 2006).

The Cluster Analysis regroups the studied accessions according to the components of each one, showing similarities among a number of characters that are unique for this group in the function of Euclidean distance. This distance informs the similarities and the differences by quality traits.

RESULTS AND DISCUSSIONS

Description of sites

The present study covered the loquat fruits on some varieties grown in the Southern 3 districts (Saida, Choufand Jezzine) of Lebanon (Figure 1), which gathers most of the loquat production of Lebanon [8]. The selected accessions and their locations are listed in the Table 1 and Figure 1. The measurements of physical and biochemical parameters, were taken on nine commonly named varieties from 20 accessions. Some of the physical traits have been previously studied as a part of botanical characterization of the tree and its fruits and all its components [4].

The mean, minimum, maximum calculated for each trait (size, shape, color, firmness) to show the range of variability was calculated (Table 2). Values showed a large intervals for fruit and seeds weight of fruit and the edible part, while narrow variability was found in firmness, number of seeds, Chroma (CF, CS), Lightness (L^*S , L^*F) and Size (weight, length, and circumference) in addition to %TA, SSC, pH which will be discussed later.

Size: The mean value with the standard deviation of quantitative variables of fruit (weight, length, circumference) and the qualitative variable of fruit (shape) were shown in Table 3. The fruits of the twenty accessions were divided into three weight groups: The small fruits were mainly from Baladi accessions and Argelino; they weighed less than 32g. The medium size fruits were mainly Faransi, Ahmar, Tanaka and Turki accessions. The large ones were Eustrali and Espani. This distribution was in agreement with the work done by Chalak et al [4]. The average weight of Ahmar accession, a local variety, was 39.38 ± 3.26 g; higher than the average Baladi (26.05 ± 1.56 g) or the one of Sukkary (25.35 ± 2.36 g). Ahmar showed less fruits per cluster (2-3 fruits per cluster) however bigger ones. The reason for this difference could be orchard management of this specific field or natural thinning or low fruit set. The present study showed that the number and weight of seeds per fruit are not always correlated with the overall weight of the fruit while other researchers found that the weight of fruit is directly correlated with the number of seeds and weight of flesh, [10-11-24]. *Argelino Jin2* a variety newly introduced to the Lebanese orchards, was described as small (32g) in this study while the same one grown in Pakistan was almost double in weight (65g) [12]. This difference can be due to climatic conditions and orchard management. The length and the circumference were proportional to each other and positively correlated to the weight: The highest length and circumference appeared in *Eustrali Be4* (11.50 ± 0.53 cm, 17 ± 0.38 cm), and the lowest in *Baladi A1* and *Baladi Gh2* (5 ± 0.0 cm, 10 ± 0.46 cm) respectively.

Shape: A large variability was recorded in the fruit shape. The different possible shapes of the varieties in this study were presented (Table 3) according to European Loquat List Descriptor RESGEN29 and Figure 2 illustrated the actual fruits of each accession. The shape, color and size are criteria for commercial preference [13]. The round shape was the most known, because the Baladi is the more spread in the market, and the earliest to mature [5]. Faransi and the Turki are similar to Baladi in shape with some variability. The Eustrali and Espani have bigger pear shape obovate fruits, which is not highly marketable in Lebanon.

Color: The color of loquat fruit is a visible marker which is related to the abundant content of carotenoids in peel and flesh of the fruit [14]. Figure 2 presented a compilation of photographs showing the colors of each accession from different angles. Table 4 below classified the accessions visually according to the color of their flesh and skin. The yellow fleshed accessions e. g. Eustrali, Espani, Faransi and Sukkary were less present in the orchard visited, this could be due to consumer preference oriented towards more colorful fruits. The color orange was more intense in *Faransi Aq3* mainly, followed in intensity by the *Ahmar Be2* and less in others which could be due to the variability in pigment concentration present. L^* and C of the skin were positively correlated in most of accessions.

The lowest CS was on *Sukkary Gh1* (45.11 ± 4.77) and the highest is *Eustrali Be4* (55.9 ± 10.78). This can be explained by the over ripening of *Sukkary Gh1* and not full ripening of *Eustrali Be4* at the time of harvest, because the chroma of fruit decrease with the ripening of fruit [15]. Other significance was not presented between accessions. L*S and CS and the texture of the skin were affected by the sunlight exposure and water content. The large number of present accessions were orange fleshed (e. g. Ahmar, Argelino, Baladi, Tanaka, Turki) and the yellow fleshed were mainly Faransi and Sukkary while other reporters described Baladi, Turki and Faransi as orange yellow [4].

Firmness : The fruit firmness is a criterion of fruit ripeness and perishability. The range of firmness of skin was very small among accessions, while the firmness of flesh was significantly different than skin firmness. In the different Baladi accessions firmness showed some differences on flesh and skin e. g. *Baladi A1*, *Baladi A2* and *Baladi Be3*; while all Faransi and Turki accessions were very firm skin where 0 mm penetration of the rod was observed. Concerning the flesh firmness, the softest was the Baladi accessions showing significant difference between *Baladi Be3* and *Baladi A2*, and the firmest in flesh were Tanaka and Argelino. Some of the fruits of Baladi, Sukkary in coastal villages represented softer fruits, while the fruits of Baladi at higher elevation showed higher firmness. This difference could be due to the stage of ripening.

A firm flesh is an indicator of low eating quality, but the firm fruits are wanted to prevent the fruits from physical damages during postharvest handling [16]. In Lebanon, loquat fruits are not harvested at fully ripe stage which is the optimum eating quality but rather at edible ripe stage, to make sure that the fruits have a longer shelf life during handling in the local and export market. Tanaka and Argelino were the firmest among the fruits assessed in the present study which confirmed Morton's results in 1987 [17]. The reason of this high firmness can also be due to low rain in May month, especially that Tanaka and Argelino were late varieties [18]. Tanaka was also reported to have a thin skin and a soft fruits [19].

Table 1: Varieties collected and sites of accessions

District	Village	Elevation(m)	Latitude Longitud (°)	Varieties per accession
Chouf	Aalman (A)	150	33. 588986 35. 412787	BaladiA1 BaladiA2 Espani A3
Jezzine	Baysour (Ba)	324	33. 536471 35. 448128	Turki Ba1
	Lebaa (L)	325	33. 5489 35. 4528	Baladi L1 Faransi L2 Faransi L3
Saida	Adoussieh (Ad)	55	33. 481363 35. 326636	Turki Ad1
	Aaqtanit (Aq)	137	33. 490797 35. 378867	Faransi Aq2 Faransi Aq3 TurkiAq1 Turki Aq4
	Bebliye (Be)	200	33. 4211 35. 3428	Ahmar Be2 Baladi Be3 Faransi Be1 Eustrali Be4
	Ghazieh (Gh)	30	33. 518041 35. 365092	Baladi Gh2 Sukkary Gh1
	Jinjleya (Jin)	327	33. 483408 35. 392279	Argelino Jin2 Tanaka Jin1

The seeds: The number of seeds per fruit (Table 2) ranged from 1 to 5 in all accessions. The size and the weight of seeds affected the whole fruit weight. Baladi (A1, A2, Be3, L1) accessions contained one seed while all other Baladi accessions showed two to three seeds [4]. The number of seeds can be affected by the extent of pollination, especially that the weather in fall 2014 was unusually cold for the period, which could have affected pollinator activities. The Faransi accessions showed a range of seeds number, which was mostly in agreement with other publications [4]. The seed number is an important factor in the quality of loquat, where the superior quality is in the fewer seeded varieties [17]. Table 5 below grouped the accessions according to their number of seeds.

The seeds weight represented a percentage of the whole fruit weight. Table 6 showed that the majority of the accession had seeds weighing from 5 to 10g. The present study showed that the number of seeds does not reflect the total weight of seeds (Table 6), because some accessions contained several seeds (e. g. *Faransi Be1*, <7g) that were lighter than the one seeded (e. g. *Baladi L1*, 7-10g).

The shape of seeds seemed to affect the number of seeds. Table 7 showed the accessions grouping by shape of seeds. The elliptical was the chief shape mainly observed in Turki, Faransi, Espani and Eustrali, Tanaka contained a variety of big and small seeds. In addition to the shape of the seed itself, special characters appeared (Figure 3) in two accessions: On the *Sukkary Gh1* creamy stripes and on that of *Faransi Aq3* creamy dots were observed on the seed skin. This morphological character on the seed of "Itali" variety was found recorded in North of Lebanon [5].

Table 2: The mean value, maximum, minimum and the standard deviation of studied parameters.

Traits	Mean	Minimum	Maximum	Std. Dev.
Weight	44.40	19.61	104.18	20.29
L*S	61.92	56.29	70.00	3.23
CS	50.50	45.11	55.95	3.15
Length	6.90	4.75	11.50	1.50
Circumference	12.87	10.00	17.00	1.79
Firmness of skin	0.09	0.00	1.08	0.24
Firmness of pulp	1.02	0.15	2.78	0.85
L*F	59.83	52.40	67.77	4.42
CF	46.72	39.35	56.98	4.69
%TA	0.17	0.06	0.39	0.07
SSC	11.19	8.06	16.03	2.50
Number of seeds	2.89	1.25	5.25	0.91
Weight of seeds	7.73	3.70	12.93	2.44
WF-WS	36.75	14.40	92.14	18.37
pH	4.08	3.62	5.15	0.40

Table 3: Physical characteristics of fruit of 20 accessions (Means± Standard Deviation)

Accessions	Shape	Weight (g)	Length (cm)	Circumference (cm)
Ahmar Be2	Obovate	39.38±3.26	6.25 ±0.46	12.63±0.44
Argelino Jin2	Round	29.97±1.92	5.50±0.00	11.50±0.53
Baladi A1	Round	19.61±0.42	5.00±0.00	10.00±0.00
Baladi A2	Round	25.80±0.52	6.00±0.00	11.00±0.00
Baladi Be3	Round	29.22±0.83	5.75±0.27	11.50±0.38
Baladi Gh2	Round	22.78±4.23	4.75±0.46	10.25±0.46
Baladi L1	Obovate	32.83±1.81	6.38±0.58	11.75±0.46
Espani A3	Obovate	84.72±8.90	9.30±0.44	15.38±0.44
Eustrali Be4	Elliptic	104.18±8.56	11.50±0.53	17.00±0.38
Faransi Aq2	Obovate	46.11±2.69	7.38±0.44	13.38±0.69
Faransi Aq3	Round	45.71±3.11	6.75±0.27	13.50±0.53
Faransi Be1	Obovate narrow	42.35±2.94	6.75±0.46	13.25±0.27
Faransi L2	Elliptic	42.64±0.74	6.88±0.23	13.00±0.00
Faransi L3	Elliptic	44.28±5.97	6.63±0.58	13.43±0.40
Sukkary Gh1	Elliptic	25.35±2.36	6.25±0.46	10.25±0.46
Tanaka Jin1	Elliptic	50.92±4.69	7.38±0.44	13.50±0.53
Turki Ad1	Obovate	49.30±4.20	6.75±0.89	13.63±0.44
Turki Aq1	Round	48.16±4.28	7.13±0.79	14.38±0.58
Turki Aq4	Elliptic	50.02±3.48	7.88±0.58	13.75±0.57
Turki Ba1	Obovate	54.74±8.03	7.88±0.23	14.25±0.60

Table 4: Color characteristics (Color, Lightness (L*), Chroma(C)) of 20 accessions

Accession	Subjective S color	L*S	CS	Subjective F color	L*F	CF
Ahmar Be2	orange deep	65.79	55.95	Orange	61.51	52.10
Argelino Jin1	orange	62.08	49.28	Orange	55.87	45.41
Baladi A1	orange	60.29	54.11	Orange	58.71	45.71
Baladi A2	orange	60.56	50.84	Orange	64.98	47.52
Baladi Be3	yellow	61.81	48.75	Yellow	59.52	50.80
Baladi Gh2	orange deep	62.70	49.07	Orange	67.77	56.98
Baladi L1	orange	58.81	45.11	Orange	60.70	42.50
Espani A3	yellow orange	61.78	50.13	yellow-orange	58.04	44.94
Eustrali Be4	yellow	66.33	52.73	Yellow	57.26	42.81
Faransi Aq2	yellow	62.27	46.50	Yellow	53.33	39.35
Faransi Aq3	orange	64.95	45.29	Orange	57.20	53.01
Faransi Be1	yellow	70.00	54.46	Yellow	64.75	44.89
Faransi L2	yellow	56.29	50.35	Yellow	65.22	50.86
Faransi L3	yellow	62.79	47.76	yellow pale	64.36	43.13
Sukkary Gh1	yellow	57.28	52.73	pale yellow	52.40	39.95
Tanaka Jin1	orange	58.44	49.89	Orange	52.53	48.28
Turki Ad1	orange	60.88	51.44	Orange	60.98	43.45
Turki Aq1	yellow	63.47	53.80	Yellow	65.22	42.76
Turki Aq4	orange	60.64	57.33	yellow-orange	52.53	50.63
Turki Ba1	orange	57.57	55.95	Orange	61.46	49.65

Table 5: Grouping of varieties according to their seeds number

Number of seeds	Accession
1	Baladi L1, Baladi A1, Sukkary Gh1, Baladi Be3, Baladi A2
2	Turki Ad1
3	Ahmar Be2, Argelino Jin2, Espani A3, Faransi L2, Faransi L3, Faransi Aq2, Faransi Aq3
4	Faransi Aq3, Turki Ba1, Baladi Gh2, Eustrali Be4, Tanaka Jin1, Turki Aq1, Turki Ba1
5	Faransi Be1

Table 6: Grouping of accessions according to seeds weight

Weight of seeds in g	Accession
<5	Sukkary Gh1, Baladi A2
5-7	Argelino Jin2, Baladi Gh2, Baladi A1, Baladi L1, Faransi Aq2, Faransi L2
7-10	Ahmar Be2, Baladi Be3, Faransi Be1, Faransi Aq3, Faransi Be1 Faransi L3, Tanaka Jin1, Turki Ad1, Turki Aq1, Turki Aq4, Turki Ba1
>10	Espani A3, Eustrali Be4

Table 7: Grouping of accessions according to seed shape

Shape of seeds	Varieties
Round	Baladi A1, Baladi A2
Elliptical	Ahmar Be2, Baladi, Gh2, Espani A3, Eustrali Be4, Faransi Aq2, Faransi Aq3, Faransi L2, Faransi L3, Faransi Be1, Sukkary Gh1, Tanaka Jin1, Turki Ad1, Turki Aq1
Elliptical narrow	Turki Ba1
Obovate	Argelino Jin2, Baladi Be3 Baladi L1, Turki Aq4

Table 8: Biochemical parameters of 20 accessions (Mean ±Standard Deviation)

Accessions	%TA Means ±SD		SSC(Brix) Means ±SD		pH Means ±SD	
	Ahmar Be2	0.20	±0.03c	12.65	± 1.19b	3.91
Argelino Jin2	0.30	± 0.12b	8.06	± 2.36c	3.77	± 0.32c
Baladi A1	0.39	± 0.15a	13.63	± 1.03b	4.38	± 0.24b
Baladi A2	0.24	± 0.07bc	11.69	± 1.46b	4.48	± 0.73b
Baladi Be3	0.18	± 0.07c	13.00	± 0.73b	4.36	± 0.40b
Baladi Gh2	0.15	± 0.02c	15.63	± 0.44a	4.80	± 0.30ab
Baladi L1	0.13	± 0.03d	13.63	± 1.03b	4.38	± 0.24b
Espani A3	0.08	± 0.02e	8.55	± 0.52c	3.69	± 0.11c
Eustrali Be4	0.06	± 0.01e	9.03	± 0.76c	3.83	± 0.12c
Faransi Aq2	0.20	± 0.02c	8.55	± 0.98c	3.75	± 0.15c
Faransi Aq3	0.14	± 0.02d	9.50	± 0.65c	3.90	± 0.31c
Faransi Be1	0.18	± 0.03c	13.24	± 1.84b	4.04	± 0.52c
Faransi L2	0.14	± 0.07d	11.69	± 0.51b	4.10	± 0.34c
Faransi L3	0.17	± 0.01c	11.88	± 1.79b	4.05	± 0.35c
Sukkary Gh1	0.10	± 0.02d	16.03	± 0.38a	5.15	± 0.04a
Tanaka Jin1	0.17	± 0.04c	11.63	± 1.27b	3.81	± 0.20c
Turki Ad1	0.14	± 0.03d	9.10	± 0.76c	3.74	± 0.15c
Turki Aq1	0.18	± 0.03c	8.10	± 0.83c	3.62	± 0.38c
Turki Aq4	0.11	± 0.03d	9.05	± 0.79c	4.03	± 0.32c
Turki Ba1	0.14	± 0.04d	9.25	± 0.46c	3.88	± 0.51c

Table 9: Varieties main characteristics that may be useful to farmers and consumers

Variety	Size	Shape	Color	Sweet	Acid	Flavor
Ahmar	Medium	Elliptic	Orange	++	++	+++
Argelino	Small	Obovate	Orange	+	+++	+
Baladi	Small	Round	Orange	+++	++	+++
Espani	Big	Elliptic	Yellow-Orange	-	-	+
Eustrali	Big	Elliptic	Yellow	-	-	+
Faransi	Medium	Elliptic	Yellow-Orange	++	+	++
Sukkary	Small	Elliptic	Yellow	+++	+	+++
Tanaka	Medium	Elliptic	Orange	++	++	++
Turki	Medium	Elliptic	Orange	++	+++	+

(-: Very low or absent +:Moderate ++: High +++: Very high)

Table 9: Varieties main characteristics that may be useful to farmers and consumers

Variety	Size	Shape	Color	Sweet	Acid	Flavor
Ahmar	Medium	Elliptic	Orange	++	++	+++
Argelino	Small	Obovate	Orange	+	+++	+
Baladi	Small	Round	Orange	+++	++	+++
Espani	Big	Elliptic	Yellow-Orange	-	-	+
Eustrali	Big	Elliptic	Yellow	-	-	+
Faransi	Medium	Elliptic	Yellow-Orange	++	+	++
Sukkary	Small	Elliptic	Yellow	+++	+	+++
Tanaka	Medium	Elliptic	Orange	++	++	++
Turki	Medium	Elliptic	Orange	++	+++	+

(-: Very low or absent +:Moderate ++: High +++: Very high)

Biochemical Characteristics

The loquat spread and grown on the Lebanese coast offered a variety of biochemical characteristics. The preliminary biochemical analysis of the selection of loquat fruits was done for the first time in Lebanon. Similar characterisations were reported previously on five loquat genotypes in the Mediterranean coastal region [8-9].Table 8 showed the results of measured biochemical parameters.

pH: One of the internal parameters of the physiological characteristics, related to the presence of acid-base rate is the pH. All accessions were considered to have weak acidity because their pH ranges between 3 and 6. The lowest pH was found in *Turki Aq1* (3.62±0.38) and the highest in *Sukkary Gh1* (5.15±0.04). The pH did not seem to be correlated with the %TA because the %TA value (0.14) was observed in *Faransi Aq3*, *Faransi L2*, *Turki Ad1* and *Turki Ba1* while their pH was 3.90, 4.10, 3.74 and 3.88 respectively. The *Bonferroni test* showed a significant difference between Baladi and Sukkary (P<0.05) while all other accessions were not significantly different.

Titrate acidity: The percent TA was expressed by the Malic acid concentration, which was the highest organic acid present in the loquat [12]. The %TA in *Espani A3* and *Eustrali Be4* was inversely correlated to pH. *Argelino Jin2* acidity was significantly different than that of *Eustrali*, *Sukkary*, *Tanaka*, *Turki*, *Espani* and *Faransi* which can be a cause of variety and/or a management problem. The high quality of loquat fruit has been reported to have moderate titrate acid (TA) from 0.3 to 0.6% [16]. The decrease in acidity up to a certain extent was a sign of ripening and one of the qualitative traits that makes the loquat fruit attractive to the consumer. [20]. Among the accessions of this study, *Baladi A1* and *Argelino Jin2* had the highest concentration of malic acid which is comparable to [16] while other accessions contained less acid due to varietal characteristics, degree of ripeness, or orchard management. Also, in [20], the values recorded for *Turki* and *Baladi* before storage were similar to the same varieties in the present study. The one way ANOVA recorded that the %TA is inversely proportional to the SSC in *Baladi* while SSC and TA are not correlated in *Turki*. In *Ahmar Be2*, SSC and TA were high, this is the only exception: this high level in both characters, gave to the variety a special taste and flavor. All %TA values were reported previously to be higher from the ones studied in this document [23].

Solid Soluble Content: The highest SSC was present with high significance in the *Sukkary Gh1* (16.02 ± 0.38 ° Brix). Its name is also an indicator of sweetness ("sukkary" means sugary in Arabic). The *Baladi* ranged from 11 to 13 °Brix, except for *Baladi Gh2* (15.63 ± 0.44 ° Brix) which could be due to extra ripening of the small fruit size. The SSC in *Baladi* was the highest maybe because the organic acids were rapidly used for sugar formation [20]. The lowest SSC was present in *Argelino Jin2* (8.09 ± 2.36 ° Brix) which was significantly different from other accessions, this could be due to the large amount of water content in the fruit. *Tanaka Jin1* (11.63 ± 1.27 ° Brix) was similar to the rate mentioned by the European loquat Descriptor List. The SSC was higher in low rainfall years, and it decreased with the increase in fruit weight [18]. Lowest SSC was showed in *Otavani* 8.95 °Brix [21], while in this study, less than this rate was present in *Argelino Jin2*, *Turki Aq1*, *Faransi Aq2* and *Espani A3*. The SSC of 'Sayda' (13.63 °Brix) was reported to have similar to *Baladi A1* and *Baladi L1* accessions [22].

Distance between biochemical parameters

All accessions were represented in the bi-plot of PCA (Figure 3) for biochemical parameters (SSC, %TA and pH). The PC1 in this bi-plot represented 62.53% of total variance showing principally the SSC in addition to the pH with minor effect, and the PC2 which represented 33.11% of total variance showed only the % TA. The *Baladi* accessions were all positively correlated with PC1 representing high sugar content where the highest was the *Baladi Gh2* (15.63 ± 0.44 °Brix) significantly different from *Baladi A1*, *Baladi A2*, *Baladi Be3*, *Baladi L1* with SSC between 11°B and 13°Brix. The lowest SSC was grouped in the negative part of PC1 axis e. g. *Turki Aq1*, *Faransi Aq2*, *Espani A3*, *Eustrali Be4*, *Turki Ba1*. All *Turki* accessions and the two *Faransi Aq2* and *Aq3* had low SSC, which drove us to think that *Turki* and *Faransi* were the same in Aqtanit orchard. However this resemblance could be due to the influence of the orchard. The *Baladi A1* and *Argelino Jin2* were grouped in the positive part of the PC2, which means they have high acidity. However the majority of all the accessions were turning around the axis, except for *Sukkary Gh1*, *Espani A3*, *Eustrali Be4*, *Turki Aq4* that have lower acidity. We obtained a group of accessions closely related in their sugar-acid content (Figure 3). However, our discriminant accessions appeared as followed:

Sukkary Gh1 and *Baladi Gh2* were the sweet, with low acidity content

Baladi A1 had high sugar content (13.63 ± 1.03 °Brix) with the highest level of %TA (0.39 ± 0.15) among all varieties.

Argelino Jin2 was characterised by low sugar content and high %TA (0.30 ± 0.12)

The lowest sugar and acid was recorded in *Espani A3* and *Eustrali Be4*.

It was observed that the SSC was positively correlated with the pH in all accessions, while the %TA was changeable and only in *Sukkary* it is inversely proportional.

Parameters analysis

All parameters had their effects on all accessions, which made them distinct from each other. To know the influence of each parameter on the accessions, a PCA was performed to reveal the correlation between parameters on accessions. Figure 4 illustrated the effect of parameters on accessions through a Bi-plot on the first two PC axes for quantitative and qualitative parameters (shape) where PC1 represented the majority of the parameters which included size, firmness, shape, sugar, acid, weight of seed and number of seed and color, with a 95.19 % of total variance, while PC2 represented a differentiation for 2 parameters only (weight of fruit and its edible parts) with a 4.20% of total variance.

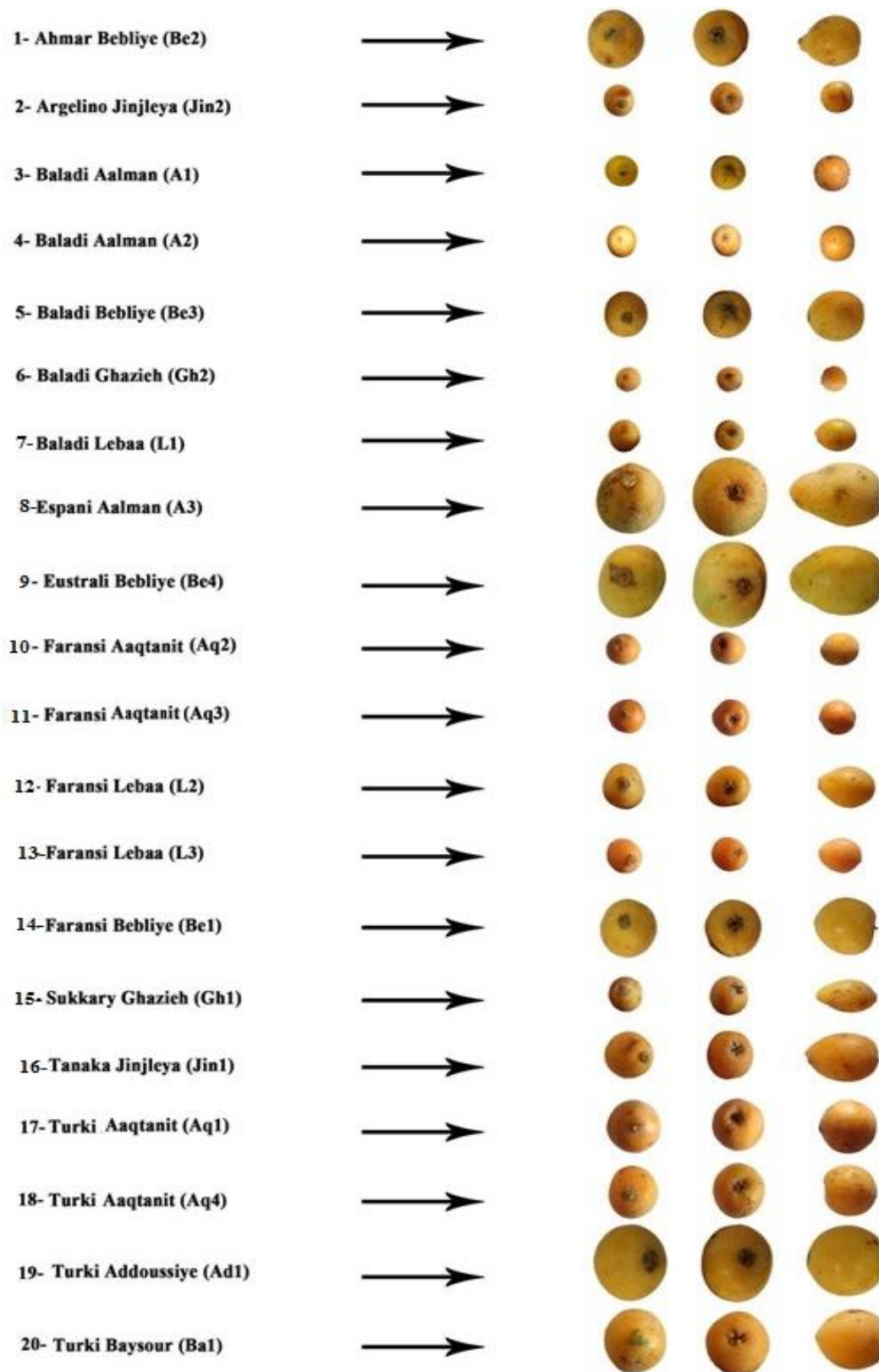


Figure 2: Photograph of orientation of loquat 20 accessions



Figure 3: On the *Sukkary Gh1* creamy stripes and on *Faransi Aq3* creamy dots were observed on the seed skin

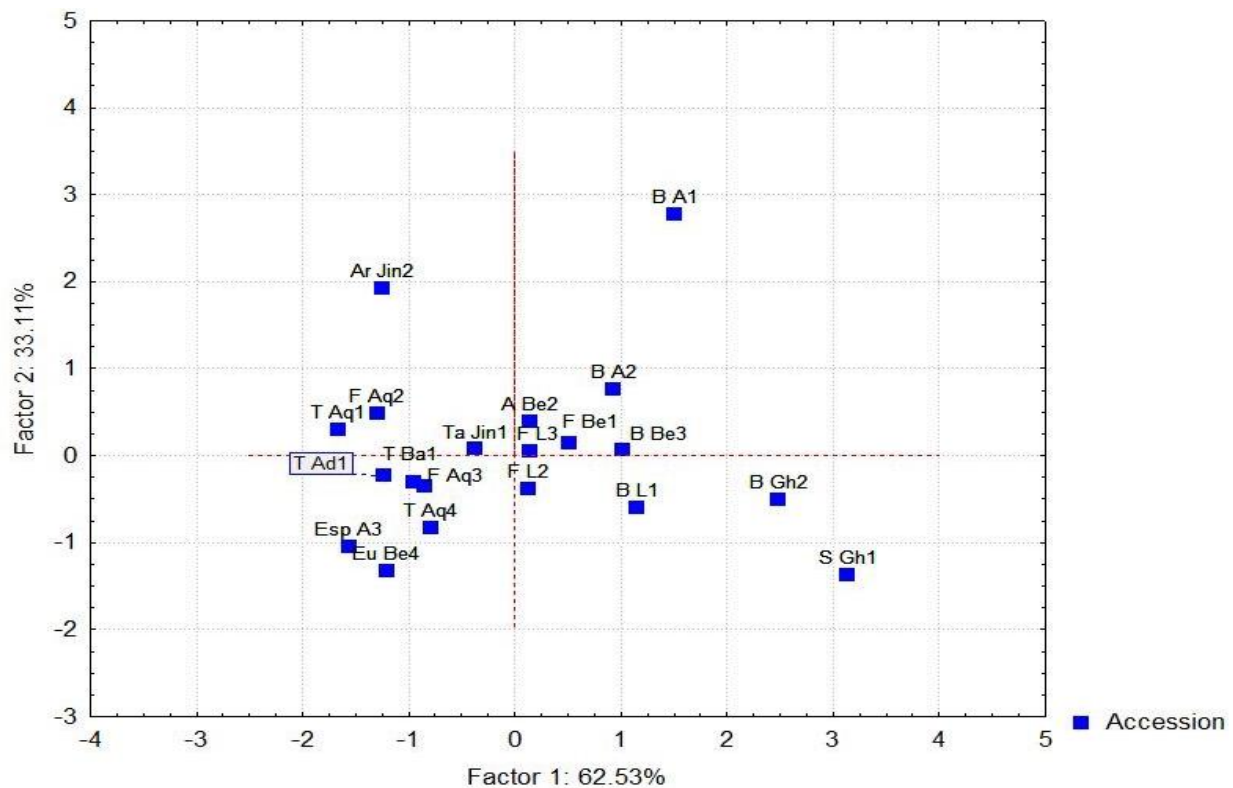


Figure 4: Biplot on the first tow PC axes for loquat accessions based on studied biochemical traits.

(A: Ahmar, Arg: Argelino, B:Baladi, Esp: Espani, Eu: Eustrali, F: Faransi, Su : Sukkary, T :Turki, Ta : Tanaka, A :Aalman, Ad : Addoussieh, Aq: Aqtanit, Ba : Baysour, Be :Bebliye, Gh: Ghazieh, Jin: Jinjleya, L: Lebaa).

The bi-plot (Figure 4) showed that all parameters related to the morphological and biochemical aspects were grouped in the positive part of PC1 which means they were strongly discriminant. It was therefore noted that, on one hand and in addition to the morphological characteristics studied also [4], that the fruit internal composition (SSC, %TA and pH). On the other hand, the color of the fruit, here measured as Chroma (C) and L* of skin and flesh, showed in PC1 an inverse relation with the other parameters of the group. This finding was similar to measurements reported on *Passiflora* spp. [15]. Chromatic parameters were located on the negative side of PC1, which indicated that the lower the chromatic parameters, the higher the biochemical and other physical parameters. Chroma described the vividness or the dullness of the skin or the flesh, while L* showed the luminous density of the color balanced between the white and the black. Only the weight of the whole fruit and the fruit edible part (Weight of fruit - Weight of seed) were completely separated to PC2; this showed that the effect of weight played an important role not only on the morphology but also on the biochemical composition of the loquat because it was highly influenced by cultural practices and agro-climatic conditions. The biochemical parameters are inversely proportional with the weight of fruit [18]. The study showed that for example in *Eustrali Be4* and *Espani A3* the higher the weight ($104,18 \pm 8.56$ g and 84.72 ± 8.90 g), the lower the SSC ($9.03 \pm 0.76^\circ$ Brix and $8.55 \pm 0.52^\circ$ Brix) and %TA (0.06 ± 0.01 and 0.08 ± 0.02) respectively. The fruit size is an important aspect for the market especially that when the consumer selects the fruit based on appearance he gets disappointed by the taste most of the time. In Lebanon, according to the traders met during this study the bigger fruit is more marketable. The edible part of the fruit is also a parameter that significantly distinct the different accessions and it is also a characteristic that attract the consumer, since the loquat is known to have a lot of seeds as compared to the volume of the fruit [23]. This PCA showed also that on one hand the color and the weight were inversely proportional and on the other hand the color and the biochemical parameters were inversely proportional (Figure 4). This could be interpreted as when the fruit is large its color chroma and its biochemical components are less intense. We noticed that the weight of seed (WS) was not affecting the biochemical parameter in the PCA but it had an effect on weight of the whole fruit. However, it appeared that the higher the WS, the lower the edible part. Environmental factors that may influence performance of a given genotype from location to location include soil, moisture, temperature, light intensity, humidity, rainfall, photoperiod, and cultural practices. These factors may play a role in gene regulation, which in turn can affect the expression of the genes controlling the trait of interest and ultimately result in different phenotypic expression among locations.

Distance between Accessions

The dendrogram of accession illustrated the cluster analysis (Figure 5) and was based on the most discriminant 17 physical and biochemical qualitative and quantitative characters here studied, have permitted to divide the 20 accessions into six clusters with Euclidean distance 12.

Cluster I was formed only of *Sukkary Gh1*, which was a local variety, distinguished by the highest sugar content (SSC= $16.02 \pm 0.38^\circ$ Brix), highest pH (5.15 ± 0.04), possessing one seed and elongate shape.

Cluster II was formed only of *Baladi Gh2*, identified by its highest SSC ($15.63 \pm 0.44^\circ$ Brix) among the Baladi accessions of the present study.

Cluster III was formed of *Argelino Jin2*, *Baladi A1*, *Baladi A2* and *Baladi L1*. They seemed to be similar in shape and size having similar length (~ 5-6cm) and circumference (~11-12cm).

Cluster IV was formed of *Baladi Be3* alone. It is a local variety which is distinguished by its round shape and the highest weight of seeds compared to other Baladi accessions.

Cluster V was divided into two sub-groups:

Sub Cluster V' was formed of *Ahmar Be2*, *Faransi Be1*, *Faransi L2* and *Faransi L3*. It grouped all "French" accessions with the local Ahmar as they have similar weight (~ 40g), close L* values (~ 60), Length (~ 6 cm), circumference (~ 13cm), firmness of skin (0 mm), similar SSC (from $11.88 \pm 1.79^\circ$ Brix to $13.24 \pm 1.84^\circ$ Brix). The Ahmar variety was older than the Faransi and they were both different in shape and in color, and similar in other quality parameters. Sub Cluster V'' was formed of seven accessions grouping all Turki accessions with Tanaka and two Faransi of Aaqtanit. They were distinguished by a similar sizes: Length (~7cm), and circumference (~13-14cm), L* values (~ 60) and SSC (~ 10° Brix). Having studied all the accessions, there seemed to be confusion in their common names. *Faransi Aq2* and *Aq3* seemed to be the same variety as Turki Aq1 and Aq4.

However there was a possibility that this resemblance was also due to the regional influence [12] and cultural practices management [12]. Tanaka Jin1 was included in this Sub Cluster V'' however, because it has been imported and possessed a label, it cannot be confused with the other members of the V''.

Cluster VI was formed from the biggest loquat fruits accessions. *Espani A3* and *Eustrali Be4*, as their weight was the highest ($84.72\pm 8.90\text{g}$, $104.18\pm 8.56\text{g}$), high seeds weight (10.37 ± 1.18 - $12.9\pm 0.74\text{g}$) and high edible part ($74.35\pm 8.84\text{g}$ - $92.14\pm 9.60\text{g}$). Large fruits such as *Eustrali* and *Espani* were similar to 'Mizuho' (100g) in Australia (RFCA, 1996) and 'Jiefangzhong' (172g) in China [11]. The weight of fruit was affected by the presence and absence of pollinator insects; thus the more the seeds, the more 'flesh', and thus weight [11]. Additionally, they were the lowest in malic acid concentration (0.06 ± 0.01 , 0.08 ± 0.02) and the lowest in the SSC ($9.03\pm 0.76^\circ\text{Brix}$, $8.55\pm 0.52^\circ\text{Brix}$) respectively.

To take an idea about the present cultivated varieties in Lebanon according the result of this study, the Table 9 illustrated the useful main characteristic in the market.

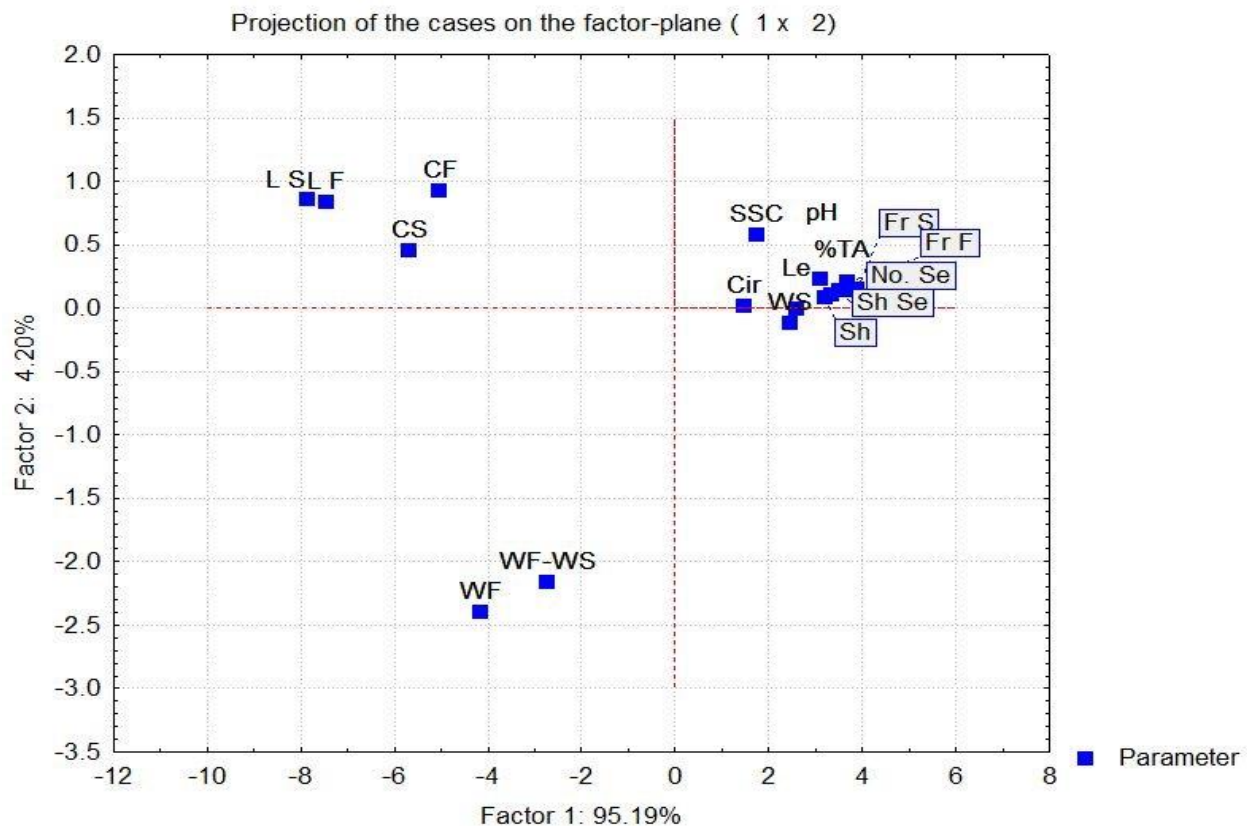


Figure 5: Biplot on the first two PC axes for studied parameters

(CS: Chroma of Skin; CF: Chroma of Flesh, Cir: Circumference; FrS: Firmness of Skin; FrF: Firmness of Flesh; LS: Lightness of Skin; LF: Lightness of Flesh; No. Se: Number of Seed; pH: pH; SH: Shape; Sh Se: Shape of Seed; SSC: Solid Soluble Content; %TA: Titratable Acidity expressed in Malic Acid rate)

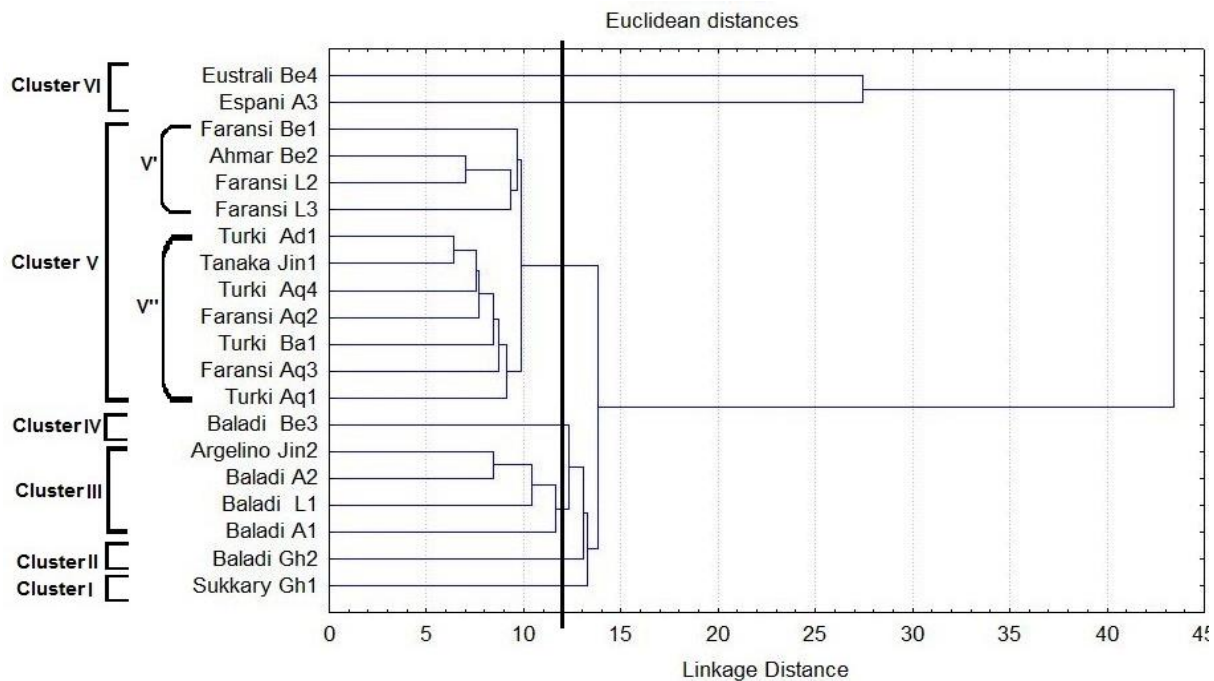


Figure 6: Dendrogram for the 20 loquat studied accessions clustered using Euclidean distance based on all 17 parameters

CONCLUSIONS AND RECOMMENDATIONS

In this study, the physical traits and biochemical attributes were examined for 20 accessions belonging to nine loquat varieties growing in Chouf, Saida and Jezzine, with the perspective of improving the fruit quality commercialized in the Lebanese and regional markets.

Baladi the most common variety found in Lebanon showed a great variability in quality traits. Nevertheless this traditional variety was the best in terms of sugar content and fruit color, while the largest fruits were found in Eustrali and Espani varieties regardless of the taste. The French variety was distinguished by its fruit taste and color. Based on the above conclusions, varieties can be appropriately chosen for commercialization upon market and consumers demand.

Our results suggest a pilot loquat orchard be established to include all available varieties growing in Lebanon to unify all data in one place. The genotypes which are dispersed in several places with different management, should be collected in a uniform plantation to increase its organoleptic importance and the right difference between genotypes, as it is an important crop in the local and export market. This is done for olive and citrus at the Lebanese Agricultural Research Institute (LARI). To certify the already studied botanical and physiological characteristics, a molecular analysis should be done to show the genetic distances and the clear discrimination. In order to protect these varieties in the country and to provide more information and studies about *E. japonica* Lindl. in Lebanon, to keep our rank in the world as the third producer of loquat after China and Spain (Noun, 2012), research and studies should focus more on the Lebanese loquat production and continue its role as spreader in the Mediterranean Basin reaching India (Demir, 1987; Morton 1987; Uzun *et al.*, 2012). It is important to note that in addition to the genotypic traits, the phenotype is also influenced by the right orchard management giving good quality fruits. To improve some new technologies for good yield with special quality, fertilization, irrigation and protection program must be modified to enhance the inherent quality traits of the variety. To increase its presence longer in the market, new storage methods can lead this crop to have a better commercial potential.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Samih Alhadj, for overall guidance and to Dr. Ali Ismail for facilitating our work in the Food Technology, Department laboratory. The authors would also thank Dr. Rabih Roumouz for making available the equipment of the animal production laboratory and to thank Mr. Ghassan AbdelMenhem, Mrs. Claudine Lahoud Roumouz for their assistance in measurements taken in their respective laboratories.

Conflict of interest statement

We declare that we have no conflict of interest.

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