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# Chemical and Microbiological Characterization of Egyptian Cultivars for Some Spices and Herbs Commonly Exported Abroad

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## Abstract

**The present study highlighted some chemical, nutritional, microbiological and essential oil characteristics of the Egyptian traditional cultivars for seeds of cumin (*Cuminum cyminum*) and coriander (*Coriandum sativum*) spices as well as for basil whole herb (*Ocimum basilicum*) collected from different Egyptian export centers as being ready for export. The found values for humidity in dry seeds of cumin (7.4%) and coriander (6.4%) as well as total ash and ash insoluble in acid (in cumin 7.7% and 0.74%, but in coriander 5.3% and 0.55%, respectively) were lower than the maximum limits indicated by the Egyptian Specification Standards (ES) and by International Standards Organization (ISO) for cumin and coriander seeds. Analysis of essential minerals in seed spices and herbs indicated that they were are rich in K, Ca, Na, Fe and Zn. Total bacterial count was low content in seeds of cumin and coriander as well as fresh whole basil herb. The microbiological load in all tested seed spices and herbs was found lower than those indicated by the ES and ISO for cumin and coriander seeds. Yields in hydro-distilled essential oils (EOs) were the highest in cumin seeds (3.762%), while both coriander and basil herb had lower amounts (0.285% and 0.686%, respectively). EOs contents were found higher than the maximum limits for cumin (1.5% - 2.5% on dry weight basis), but the within the limits for coriander (0.1% - 0.5% on dry weight basis) as indicated by the ES and ISO for cumin and coriander seed oils. Gas chromatography of extracted EOs from seeds of cumin and coriander as well as basil herbs indicated the presence of 41, 35 and 47 compounds, respectively, where cuminaldehyde was the major component in cumin volatiles, but was linalool in volatiles of both coriander seeds and basil herbs. EOs of basil herbs grown in Egypt, were of the high linalool-chemotype which were characterized by high contents of linalool and relatively lower amounts of eugenol. However, the major compounds in the**

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**three tested EOs from seeds or herbs grown in Egypt are in accordance with literature reports from different parts of the world. Volatile oil components in EOs of the three tested Egyptian spices and herbs were classified into groups, based on the relative area (%). The proportion of the major and the other main components in EOs from seeds of cumin and coriander cultivars were within the ranges indicated by both the ES and ISO for cumin seed oils (cuminaldehyde between 15% - 46%) and for coriander seed oils (linalool between 65% - 78%). No Egyptian Specification Standards are established yet for fresh basil herbs and for basil oil of Linalool chemotype, but only present for basil oil of methylchavicol-chemotype.**

## Keywords

**Cumin, Coriander, Basil, GC-Fractionation, Chemical, Physical, Microbiological Analysis, Spices, Herbs**

## 1. Introduction

Spices and herbs, commonly known as aromatic plants, are an important group of agricultural commodities being used by many civilizations all over the world to add flavor, taste, nutritional values and increase shelf life to food as well as to heal various physical, mental, emotional problems and to restore human health [1]. However, each spice or herb is characterized by a peculiar quail-quantitative composition for its essential oil and all of these oils contain compounds with established biological activity [2]. Cumin (*Cuminum cyminum*, family Umbelliferae) is among the large number of spices used to flavor foods and beverages in the world, especially India and Mediterranean regions, and occupies a place of prominence [3]. Cumin seeds possess an aromatic odor and have a spicy and bitter taste and largely used in the Egyptian kitchen and is locally known as "Kammoun" [4]. Coriander (*Coriandum sativum* L., family Apiaceae) is among many of the aromatic plants that actually gathered when they have finished flowering, with the leaves being referred to as an herb, and the dried seeds as a spice [5]. Although plant can be grown throughout the year, coriander is processed to increase its palatability, profitability and facilitate international trade where processing of fruits and leaves of coriander is the best way to preserve this herb [1].

Basil (*Ocimum basilicum* L., Lamiaceae family) or sweet basil is one of the most important well-known herbs to many cultures [6], and is a very versatile and popular annual herb with abundantly aromatic leaves which are used fresh or dried [7]. Basil is called as "reyhan" in Turkish [8]. The word "Reyhan" has been mentioned in two suras, Ar-Rehman and Al-Waqia (once in each) of the holy Qura'n [9]. In fact, basil is multipurpose plant species used as a decorative, seasoning, medicinal plant and used to relish many kinds of foods [10] [11].

Besides being used as spices and herbs in Egyptian trade, cumin, coriander and basil are widely cultivated for export abroad due to the continuous and increased demands for their products and their distinguished economic importance throughout the world [12]. They are greatly valued as medicinal plants and have attracted enormous attention of researchers worldwide to experimentally validate their pharmacological activities and the therapeutic use as they have documented in several indigenous healing systems [13].

Therefore, the present study was lunched to highlight some chemical, nutritional and microbiological characteristics for seeds and essential oils for the Egyptian traditional cultivars of cumin and coriander spices as well as for basil herb collected from different Egyptian export centers as being ready for export.

## 2. Material and Methods

### 2.1. Materials

Cumin seeds (*Cuminum cyminum*) and coriander seeds (*Coriandum sativum*) were obtained from an Egyptian local store market for bulk and retail spices commerce and their export (Harraz market for Seeds and Pesticides, Bab El-Khalksquare, Cairo, Egypt).

Basil herbs (*Ocimum basilicum*) were obtained from Egyptian Baladi basil cultivar which is a hybrid between native and American basil types at ratio of 2:1. Such cultivar was grown a private farm (run with organic plantation system) at Abshoway Village in El-Fayoum Governorate, Egypt.

### 2.2. Preparation of Spices and Herbs

Spices of cumin and coriander seeds were already prepared into dry seed form in the same aforementioned purchasing place, as usually practiced in Egypt for the preparation of dry spices for export abroad. Basil plants were cultivated, collected and the aerial parts of herbs were harvested at the start of flowering period and prepared in the aforementioned private farm under strict managing and precaution as usually practiced for the preparation of green basil herbs. Seeds were ground to powder form and sieved while basil herbs were minced into very small pieces.

### 2.3. Analytical Methods

#### 2.3.1. Determination of Chemical Composition of Spices and Herbs

Moisture, crude protein, ether extract, total ash, insoluble ash in acid, crude fibers were determined as described by A.O.A.C. methods [14]. Total carbohydrates were determined by difference [15].

#### 2.3.2. Determination of Essential Minerals

a) Method of digestion for mineral analysis: Digestion of dry seed spices and fresh herbs for mineral analysis by photometric and colorimetric was performed according to A.O.A.C. methods [14].

b) Flame photometric determination: The concentration of potassium, calcium and sodium in digested ashes of the fresh and dry spices and herbs according to methods described previously by Brown and Lillel and [16].

c) Spectrophotometric determination of phosphorus: Determination was performed according to the method of Murphy and Riley [17].

d) Atomic absorption spectrophotometeric determination: Iron, zinc, manganese, cupper and magnesium were determined in ashed samples of dry seed spices and fresh herbs using atomic absorption Spectrophotometer (Model AA 4000) according to A.O.A.C. method [14].

### 2.4. Determination of Microbiological Characteristics

The microbiological examinations of dried seed spices and fresh herbs samples included the determination of total aerobic counts, total anaerobic bacteria, yeast and mold counts, and *Coliform* group which were determined according to APHA [18], while detection for *Salmonella sp.* was performed according to IAEA [19].

### 2.5. Chemical Characterization of Essential Oils

a) Methods for extraction of essential oils: The essential oils of dried cumin and coriander seeds and fresh basil herbs were extracted through hydro distillation by using a Clevenger type apparatus according to El-Ghorab *et al.* [20].

b) Determination of yield in essential oils: Percentage of volatile oil extracted was calculated on fresh and dry weight basis in replicate distillations from the tested spices and herbs according to the following Equation:

$$\text{Volatile oil (\%)} = \frac{\text{Weight of volatile oil recovered in the receiver}}{\text{Weight of sample}} \times 100\%$$

The volatile oil was removed from the receiver with ether and dried overnight using anhydrous sodium sulphate before removing the ether. The obtained volatile oil was stored in the dark at a temperature of −18˚C until requiring for analysis.

c) Gas chromatography of essential oils:

1) Apparatus and conditions for separation

Volatile compounds in essential oils of dried cumin and coriander seeds and fresh basil herbs were identified by comparison with kovats gas chromatographic retention index [21] and by the mass spectral fragmentation pattern of each GC component compared with authentic compounds. Agas chromatograph (Hewlett Packard model 6890) equipped with a DB5 capillary column (30 m × 0.25 mm i.d. × 0.25 µm df.), FID detector was used. The analysis was carried out under the following conditions: injector temperature 200˚C and detector temperature 250˚C. The column was programmed from 35˚C to 220˚C at 30˚C/min and held for 40 min. The heliumcarrier gas flow rate was 29 cm/sec. Injections were in the split less mode.

2) Identification and quantitation

Kovat's indices were determined by co-injection of the sample with a solution containing homologous series of n-hydrocarbons ($C_6$-$C_{26}$) under the same conditions as described above. The separated components were identified by matching with N1ST mass-spectral library data, and by comparison of Kovat's indices with those of authentic components and with published data of Adams *et al*. [22]. The quantitative determination was carried out based on peak area integration.

## 3. Results and Discussion

### 3.1. Comparative Chemical Composition of Tested Spices and Herbs

The fresh basil leaves showed the highest moisture content, which reached to 80.35 ± 0.12, compared to samples of cumin and coriander seeds (7.44 ± 0.13 and 6.47 ± 0.16, respectively) (**Table 1**). Moisture values for dry cumin seeds and coriander as collected from the Egyptian export centers were found to be lower than the maximum humidity limits for cumin seeds (9% - 13% according to quality grades) and for coriander (9%) which were indicated by the Egyptian Specification Standards for dry seeds of cumin and coriander (ES: 1930/2008 and ES: 2095/2005, respectively) and by International Standards Organization [(ISO: 9301/2003) and (ISO: 3516/1997), respectively]. No Egyptian Specification Standards or International Standards Organization is established yet for fresh basil herbs.

With regard to cumin dry seeds, although higher moisture values were reported of 7% - 22% [23] and of 12.8% [24], the maximum humidity in cumin seeds must be no more than 9%, which confirm with the International Standards Specifications [25].

The found moisture values for coriander seeds were comparable to values of 6.65% [26] and 6.2% [5]. Various studies abroad indicated that moisture content of fresh whole basil herbs was found to be in the range of 80% - 88.25%, which is consistent or slightly higher than that found in the present results [27] [28].

The second major component of all samples was carbohydrates content. On as is basis, coriander seeds showed the highest total carbohydrates (62.32%) followed by cumin (55.58%). In contrast, when calculation was made in dry weight basis, fresh whole basil herbs showed the highest total carbohydrates (68.07%). The found carbohydrates values were higher than those reported in literature for cumin seeds of 48.01% [29] for coriander seeds of 24.0% [30] or 52.10% [31] and whole fresh basil of 7.0% [32], of 7.02% [33], of 6.6% [34] and of 9.3% [27].

Protein content, on both fresh weight and dry weight basis, was the highest in cumin seeds (18.40% and 19.88%, respectively), followed by coriander seeds (15.39% and 16.46%, respectively) while fresh basil herb showed the lowest content (1.78% and 9.04%, respectively). The found protein content values were comparable to those reported in literature for cumin seeds of 19% [35], 18.7% [24] and of 17.7% [29], but higher (15.7%) than that reported others [36].

**Table 1.** Comparative chemical composition of some spices and herbs collected from different Egyptian export centers (as ready for export).

| Component | Cumin seeds | | Coriander seeds | | Whole fresh basil herb | |
|---|---|---|---|---|---|---|
| | On wet weight | On dry weight | On wet weight | On dry weight | On wet weight | On dry weight |
| Moisture | 7.44 ± 0.13* | - | 6.47 ± 0.16 | - | 80.35 ± 0.12 | - |
| Crude protein | 18.40 ± 0.16 | 19.88 ± 0.20 | 15.39 ± 0.18 | 16.46 ± 0.20 | 1.78 ± 0.03 | 9.04 ± 0.12 |
| Ether extract | 11.44 ± 0.20 | 12.36 ± 0.23 | 10.84 ± 0.12 | 11.59 ± 0.15 | 1.08 ± 0.03 | 5.50 ± 0.15 |
| Crude fibers | 21.82 ± 0.13 | 23.57 ± 0.13 | 27.23 ± 0.14 | 29.11 ± 0.20 | 2.89 ± 0.08 | 14.71 ± 0.29 |
| Total ash | 7.14 ± 0.10 | 7.71 ± 0.10 | 4.98 ± 0.18 | 5.33 ± 0.18 | 3.42 ± 0.11 | 17.39 ± 0.46 |
| Ash (insoluble in acid) | 0.69 ± 0.18 | 0.74 ± 0.19 | 0.51 ± 0.12 | 0.55 ± 0.13 | 0.10 ± 0.03 | 0.52 ± 0.15 |
| Total carbohydrate** | 55.58 | 60.05 | 62.32 | 66.62 | 13.37 | 68.07 |

*Mean of triplicate determination ± standard deviation. **Total carbohydrate calculated by difference.

However, protein values were found higher than those reported by many researchers for coriander seeds of 11.49% [37], 11% [38], 11.75% [26], 12.58% [5] and 12.58% [1] as well as for basil herb either on dry weight basis of 22.2% [39] or on fresh weight basis of 3.3% [32], 3.16% [33], 3.8%, [34] and 4.2% [28].

With the same trend of protein, cumin seeds had the highest ether extract content, on both fresh weight and dry weight basis (11.44% and 12.36%, respectively), followed by dried coriander seeds (10.84% and 11.59%, respectively) while fresh basil herb showed the lowest content (1.08% and 5.50%, respectively). Comparable literature values to those found in the present study for ether extract were reported for cumin seeds of 10% [35] [40], for coriander seeds of 9.8% [26] or 9.12% [1] and for whole basil herbs on fresh basis of 1.2% [32] or 1.05% [33].

Crude fiber content data, on both fresh weight and dry weight basis, indicated that dry coriander seeds exhibited the highest values (27.23% and 29.11%, respectively) followed by cumin seeds (21.82% and 23.57%, respectively) while fresh basil herbs had the lowest content (2.89% and 14.71%, respectively).

High amounts of fibers than those found inseeds of the Egyptian cumin cultivar were reported in Pakistani cultivars of 37.2% [36] depending upon the varieties. The found crude fibers values for seeds of the tested coriander cultivar compared well with those reported of 28.43% for Italian cultivars [37] or nearly 30% [38]. In contrast, higher value (37.14%) for Indian cultivars was found [1].

Crude fibers contents in the tested whole basil herbs, on fresh basis, were found (2.89%) higher than those reported of 2.0% [32] or of 1.0 % [34], but lower on dry basis (14.71%) than of 19.07% [27] or 33.3% [39].

Total ash content data, on fresh weight basis, indicated that dry cumin seeds had the highest values (7.14%) followed by coriander seeds (4.98%) while fresh basil herbs exhibited the lowest content (3.42%), but when calculation was made on dry weight basis the fresh basil herbs showed the highest total ash value (17.39 %) followed by cumin seeds (7.71%), while coriander seeds showed the lowest content (5.33%).

In contrast, ash insoluble in acid content showed different results, on both fresh weight and dry weight basis, where cumin had the highest values (0.69% and 0.74%, respectively) followed by coriander (0.51% and 0.55%, respectively) while fresh basil herb showed the lowest content (0.10% and 0.52%, respectively).

The found total ash and as hinsoluble in acid values were found lower than the maximum limits indicated for dry cumin seeds (8.5% - 12% and 1.5% - 4% according to quality grades, respectively) by the Egyptian Specification Standards (ES: 1930/2008) and by the International Standards Organization (ISO: 9301/2003) and those indicatedfordry coriander seeds (7% and 1.5% for all quality grades, respectively) by the Egyptian Specification Standards (ES: 2095/2005) and by the International Standards Organization (ISO: 2255/1996).

Moreover, values found for total ash and ash insoluble in acid were lower than those reported for dry cumin seeds by others of 9.5% total ash and a maximum 2% acid insoluble ashes [25] as well as that value reported for coriander seeds grown in India [31] of 14.02%. In contrast, the found values for total ash in basil herbs consisted well with those indicated in literature of 3.32% [27], but lower than those reported on fresh weight basis of 2.0% [32] and of 1.8% [34] and higher than those reported by others of 10.18% [39] or 8.7% [41] on dry weight basis.

It should be mentioned that the chemical composition of the various spices and herbs were reported to vary significantly according to the variety and species in plant herb, cultivation practices, plantation season, number and time of cuts, plant development stage and the climatic conditions [30].

### 3.2. Comparative Content in Essential Minerals of Tested Spices and Herbs

In recent years, there has been a growing interest in monitoring element contents of the spices and herbs. Analysis of essential mineral (**Table 2**) indicated that the first major macro essential element in both seed spices was K, but was Ca in basil herb, while Fe was the first major micro essential element in both seed spices and basil herb. However, in cumin seeds, the level of macro essential elements felt in magnitude of the order: K > P > Mg > Ca > Na but the level of micro essential elements was Fe > Mn > Zn > Cu. In coriander seeds, the level of macro essential elements felt in magnitude of the order: K > P > Na > Ca > Mg but the level of micro essential elements was Fe > Zn > Mn > Cu. In contrast, the level of macro essential elements in basil herb felt in magnitude of the order: Ca > K > Mg > P > Na, but the level of micro essential elements was Fe > Mn > Zn > Cu. Literature reports about mineral content in cumin seeds [42] in coriander [31] [37] [43] and in basil [44] are in accordance with the obtained data that the three tested spices and herbs are rich in K, Ca, Na, Fe and Zn. Thus, they could be considered as sources of fairly good amounts of these minerals. Moreover, it was stated that these spices and herbs are rich source of iron and zinc compared to other cereals [3].

**Table 2.** Essential minerals composition of some spices and herbs previously collected from different Egyptian export centers as ready for export.

| Component | Cumin seeds | | Coriander seeds | | Whole fresh basil herb | |
|---|---|---|---|---|---|---|
| | On wet weight | On dry weight | On wet weight | On dry weight | On wet weight | On dry weight |
| Macro elements (g/100g) | | | | | | |
| K | 3.25 ± 0.35 | 3.51 ± 0.52 | 3.71 ± 0.30 | 3.97 ± 0.26 | 0.96 ± 0.30 | 4.88 ± 0.82 |
| Na | 0.10 ± 0.10 | 0.11 ± 0.01 | 0.24 ± 0.06 | 0.26 ± 0.13 | 0.06 ± 0.00 | 0.31 ± 0.08 |
| Ca | 0.20 ± 0.03 | 0.22 ± 0.02 | 0.18 ± 0.02 | 0.19 ± 0.04 | 1.23 ± 0.68 | 6.25 ± 1.41 |
| Mg | 0.21 ± 0.05 | 0.23 ± 0.05 | 0.15 ± 0.04 | 0.17 ± 0.03 | 0.28 ± 0.02 | 1.42 ± 0.02 |
| P | 0.52 ± 0.01 | 0.56 ± 0.01 | 0.73 ± 0.02 | 0.78 ± 0.02 | 0.16 ± 0.01 | 0.81 ± 0.05 |
| Micro elements (mg/100g) | | | | | | |
| Fe | 330 ± 8.16 | 357 ± 7.24 | 369 ± 9.20 | 394 ± 8.05 | 141 ± 2.20 | 718 ± 13.70 |
| Mn | 65 ± 2.10 | 70 ± 2.22 | 53 ± 1.14 | 57 ± 1.15 | 49 ± 1.15 | 249 ± 3.71 |
| Zn | 64 ± 1.30 | 69 ± 1.13 | 80 ± 1.25 | 85 ± 2.28 | 24 ± 1.26 | 122 ± 1.13 |
| Cu | 30 ± 1.20 | 33 ± 1.34 | 32 ± 1.01 | 34 ± 1.02 | 10 ± 0.89 | 51 ± 1.45 |

### 3.3. Comparative Microbiological Characteristics of Spices and Herbs

Data in **Table 3** showed that total bacterial count was low content in seeds of cumin and coriander as well as-fresh whole basil herb, where its log number was 3.72, 3.73 and 3.78, respectively. However, anaerobic bacteria, moulds and yeasts and Coliform group were of higher content. The log number of anaerobic bacterial count was: 3.65, 3.55 and 3.47 incumin, coriander and basil, respectively, for moulds and yeasts were: 2.97, 2.39 and 2.39, respectively. In addition, the log number of Coliform group count was: 3.00, 3.14 and 3.32, respectively. On the other hand, the three tested seed spicesand herbs (cumin, coriander and basil) were nil from Salmonella spp. bacteria. The microbiologicalload in all tested seed spices and herbs were lower than those indicated by the Egyptian Specification Standards (ES: 1930/2008 and ES: 2095/2005) as well as by the International Standards Organization (ISO: 9301/2003 and ISO: 2255/1996) for cumin and coriander seeds, respectively.

### 3.4. Comparative Yield in Essential Oils Extracted from Spices and Herbs

Yields of the different essential oils (EOs), extracted by hydro distillation (**Table 4**) showed that, on dry weight basis, cumin seeds had the highest amount of volatiles (3.762% ± 0.18%), while both coriander and basil samples had lower amounts (0.285% ± 0.01% and 0.686% ± 0.03%, respectively).

Furthermore, EOs contents of the tested cumin seeds are in the range reported in literature in Bulgaria of 5.3% [45], in China of 2.608% to 4.062% [46] and in Pakistan of 2.52% ± 0.11% [36]. However, it is higher than the maximum limits (1.5% - 2.5% on dry weight basis according to quality grades) as indicated by the Egyptian Specification Standards (ES: 1930/2008) and by the International Standards Organization (ISO: 9301/2003) for cumin seed oil. Moreover, it is higher than other cultivars grown in different locations in Iran of 1.4% - 2.2% [47], in Turkey of 1.4% to 2.8% [48], in Tunisia of 1.6% [49], in India of 1.21% or 1% [50] [51].

Results indicated that EOs content of coriander seeds cultivar grown in Egypt is higher and/or comparable to many varieties or cultivars grown in different locations (in India of 0.5% - 1% [52], in Pakistan of 0.15% [53] and 0.03% to 2.7% [5], in Iran of 0.1% to 0.36% [54], in Bulgaria of 0.1% - 0.5% [30], in Argentina of 0.40% [55], in Turkey between 0.03% and 2.6% [56]). However, it is within the limits (0.1% - 0.5% on dry weight basis according to quality grades) indicated by both the Egyptian Specification Standards (ES: 2095/2005) and by International Standards Organization (ISO: 2255/1996) for coriander seeds.

The found EOs content of whole basil herbs from the cultivar grown in Egypt, was sometimes either higher or comparable to many varieties or cultivars grown in different locations (in Turkey of 0.15% - 1.59% [57], in India of 0.2% in stems to 1.2% in leaves on a fresh weight basis [58], in Algeria of 0.4% [59], in Iran of 0.5% [60], in Pakistan of 0.5% to 0.8% [61], in Sudan of 0.33% to 0.47% in fresh leaves [62], in Romania 0.2% and 1%

**Table 3.** Comparative microbiological characteristics of some spices and herbs previously collected from different Egyptian export centers as ready for export (as is basis).

| Microbiological examination | | Cumin seeds | Coriander seeds | Whole fresh basil herb |
|---|---|---|---|---|
| Total bacterial count | No. | $5.3 \times 10^3$ | $5.4 \times 10^3$ | $6.1 \times 10^3$ |
| | Log No. | 3.72 | 3.73 | 3.78 |
| Anaerobic bacterial count | No. | $4.6 \times 10^3$ | $3.6 \times 10^3$ | $5.5 \times 10^3$ |
| | Log No. | 3.65 | 3.55 | 3.47 |
| Moulds and yeasts | No. | $9.5 \times 10^2$ | $2.5 \times 10^2$ | $2.5 \times 10^2$ |
| | Log No. | 2.97 | 2.39 | 2.39 |
| Coliform group count | No. | $1.0 \times 10^3$ | $1.4 \times 10^3$ | $2.1 \times 10^3$ |
| | Log No. | 3.00 | 3.14 | 3.32 |
| *Salmonella* spp. | No. | - | - | - |
| | Log No. | - | - | - |

(-): Not detected.

**Table 4.** Comparison of yield of essential oils extracted from some spices and herbs previously collected from different Egyptian export centers as ready for export (on as is and dry basis).

| Spices and herbs | Essential oils extracted (%) | |
|---|---|---|
| | Before dried | After dried |
| Cumin seeds | 3.52 ± 0.17 | 3.762 ± 0.18 |
| Coriander seeds | 0.27 ± 0.01 | 0.285 ± 0.01 |
| Whole fresh basil herb | 0.14 ± 0.01 | 0.686 ± 0.03 |

[63], of 0.171% in Omani basil [64]).

It should be mentioned that yields of EOs extracted from spices and herbs were found to vary, not only with varieties, season, cuttings and agricultural practices, but also according to parts of herbs(whole, flowers, leaves and stems for basil herbs [65] [66] and for seed spices [67].

## 3.5. Comparative Composition of EOs Extracted from Spices and Herbs

Chemical identification of the oil constituents dry seeds of cumin and coriander as well as fresh whole basil herbs collected from different Egyptian export centers as being ready for export abroad was conducted using gas chromatography (GC) based on their retention indices (RI). The volatile oil components in EOs of the three tested Egyptian spices and herbs were classified into groups, based on the relative area %.

### 3.5.1. GC Identification of Essential Oil Composition of Cumin Seeds

GC chromatograms indicated the presence of 41 compounds, which accounted for 98.78% of EOs hydro-distilled from seeds of the cumin cultivar grown in Egypt (**Table 5**). The major compounds in cuminessential oil were cumin aldehyde (35.25%), tetradecene (12.25%), $\gamma$-terpenene (12%), $\beta$-ocimene (9.72%), p-mentha-2-en-ol (9%), $\alpha$-terpinyl acetate (5.32%), $\alpha$-terpinolene (3%), Lmonine (0.5%), myrcene (0.2%), $\beta$-pinene (0.9%) and $\alpha$-pinene (0.19%).

Results indicated that the major component and also its proportion in the tested cumin Eos resembled those values found by various investigators in different locations in the world e.g., of 36.31% in Chinese cultivars [68] [40], 36% in Bulgarian cultivar [45], 39.48% in Tunisian variety [4]. However, there were differences in proportion of the major component (of 22.76% in Chinese cultivar [69], 27.7% in Pakistani cultivar [36], 30.2% [70]) and in number of separated compounds in GC chromatograms (21 components in Tunisian cultivar [4], 19 components [70] or 38 compounds [71]) and also the identity of major component (as found in china [69], in Tunisia

**Table 5.** Effect of storage conditions on gas chromatographic profile of essential oils extracted from dried seeds of Egyptian cultivar of cumin (*Cuminum cyminum*) stored for six months before exportation abroad (as is basis).

| Peak No. | Compounds | KI | % Area | Method of identification | Type of component |
|---|---|---|---|---|---|
| 1 | *α*-pinene | 939 | 0.19 | KI & MS | M |
| 2 | Sabinene | 976 | 0.12 | KI & MS | M |
| 3 | *β*-pinene | 980 | 0.9 | KI & MS | M |
| 4 | Octanone <2-> | 987 | 0.07 | KI & MS | LOC |
| 5 | Myrcene | 991 | 0.2 | KI & MS | M |
| 6 | Octanol <2-> | 995 | 0.35 | KI & MS | LOC |
| 7 | *α*-phellandrene | 1005 | 0.82 | KI & MS | M |
| 8 | Limonene | 1031 | 0.5 | KI & MS | M |
| 9 | 1, 8-cineole | 1033 | 0.49 | KI & MS | LOC |
| 10 | (E)-*β*-ocimene | 1042 | 9.72 | KI & MS & ST | M |
| 11 | *γ*-terpenine | 1064 | 12 | KI & MS & ST | M |
| 12 | Para cymene | 1089 | 0.1 | KI & MS | M |
| 13 | *α*-terpinolene | 1096 | 3 | KI & MS & ST | LOC |
| 14 | 3 linalool | 1098 | 0.10 | KI & MS & ST | LOC |
| 15 | cis-sabinene hydrate | 1104 | 0 | KI & MS | LOC |
| 16 | p-menth-2-en-1-ol | 1130 | 9 | KI & MS & ST | LOC |
| 17 | Terpin-4-oL | 1177 | 0.1 | KI & MS & ST | LOC |
| 18 | Cumin aldehyde | 1239 | 35.25 | KI & MS & ST | LOC |
| 19 | Geraniol | 1254 | 0.63 | KI & MS | HOC |
| 20 | Phellandral | 1273 | 0 | KI & MS | HOC |
| 21 | 2-caren-10-al | 1281 | 1.32 | KI & MS | HOC |
| 22 | Methyl geranate | 1326 | 0.24 | KI & MS | HOC |
| 23 | *α*-Terpinyl acetate | 1344 | 5.32 | KI & MS | HOC |
| 24 | Tetradecene <1-> | 1392 | 12.25 | KI & MS & ST | S |
| 25 | *β*-caryophyllene | 1467 | 0 | KI & MS | S |
| 26 | Carotol | 1549 | 0.1 | KI & MS | HOC |
| 27 | Germacrene-D-4-ol | 1573 | 0.25 | KI & MS | HOC |
| 28 | Humulene epoxide II | 1604 | 0 | KI & MS | HOC |
| 29 | Dill apiole | 1624 | 0 | KI & MS | HOC |
| 30 | Cubenol | 1639 | 0 | KI & MS | HOC |
| 31 | Acetocyclohexanedione | 1713 | 0.22 | KI & MS | HOC |
| 32 | Sesquilavandulyl acetate <E-> | 1740 | 0 | KI & MS | HOC |
| 33 | *α*-sinensal | 1751 | 0 | KI & MS | HOC |
| 34 | Ethyl tetradecanoate | 1795 | 0 | KI & MS | HOC |
| 35 | Bisabolol acetate <epi-alpha-> | 1805 | 0 | KI & MS | HOC |
| 36 | *α*-vetivone | 1830 | 0 | KI & MS | HOC |
| 37 | Farnesyl acetate <E-E> | 1838 | 0.05 | KI & MS | HOC |
| 38 | Laurenene <epi-> | 1892 | 0.15 | KI & MS | S |
| 39 | Occidol acetate | 1967 | 0 | KI & MS | HOC |
| 40 | Manoyl oxide | 1987 | 0.63 | KI & MS | HOC |
| 41 | Phynyl ethyl anthranilate-2- | 2110 | 4.70 | KI & MS | HOC |
| | Chemical classes | | | | |
| | Monoterpene (M) | M | 24.55 | | |
| | Light oxygenated compound (LOC) | LOC | 48.37 | | |
| | Heavey oxygenated compound (HOC) | HOC | 13.46 | | |
| | Sesqterpene (S) | S | 12.40 | | |

[59] and in Iran [51]).

However, the name and proportion of the major and other main components in cumin EOs were within the ranges indicated by both the Egyptian Specification Standards (ES: 2034/2007) and by International Standards Organization (ISO: 9301/2003) for essential oils of cumin seeds (cumin aldehyde between 15% - 46% of oil and other components, with the exception of the proportion of $\beta$-pinene).

The volatile oil components in EOs from the tested Egyptian cultivar were classified into four groups (based on the relative area %), viz. mono terpenes [M] (24.55%), lightly oxygenated compounds [LOC] (48.37%) sesquiterpenes [S] (12.4%), and heavily oxygenated compounds [HOC] (13.46%). The LOC and M were found in higher amounts in comparison with HOC and S, respectively. The most significant compounds in LOC and M were cumin aldehyde and g-terpinene, respectively, while S and HOC were tetradecene and $\alpha$-terpinyl acetate, respectively. However, different groups for volatile components than those found in EOs of the Egyptian cultivar were reported in literature [72].

### 3.5.2. Identification of Essential Oil Composition of Coriander Seeds

GC Chromatograms revealed the presence of 35 peaks in Eos hydro-extracted from the tested coriander cultivar grown in Egypt of which nineteen compounds constituted 99.97% OF EOs. The major constituents were: trans-linalool (72.6%), sabinene hydrate (4.53%), $\alpha$-Pinene (3%), ethylhexanoic acid <2-> (5.19%), p-cymen-8-ol (4.51%), nerol (1.1%), caryophyllene <9-epi-E> (2.71%) a-thujene (3.28%), camphor (0.27%) and Limonine (0.13%). In addition, the coriander seeds essential oil also contained considerable amounts of various minor constituents whose contribution was <0.7% (**Table 6**).

Results indicated that major compounds identified in Eos from seeds or tested coriander cultivar grown in Egypt are in accordance with the findings on various investigators for cultivars from different parts of the world, e.g., 68.14% in Argentina [55], 68.00% in Russian [73], 70.5% in Korea [74], 75.30% in India [75], 65% to 70% in Pakistan [53]. In contrast, there were reported differences inlinalool proportion [54.57% in Cuba [76], 87.54% in India [77], of 63.9% - 66.2% in Canada [78], of 37.65% in Bangladesh [79], of 58.22% [80] in Brazil, of 53.79% [81] in South Korea, of 55.59% in Pakistan [5], and in the number of separated compounds in GC chromatograms (35 compounds in Cuba [76], 24 components in India [82] and 53 compounds in Bangladesh [79]).

However, the major component and the other main components in EOs of seeds of the tested coriander cultivar were within the ranges for Linalool (between 65% - 78% of oil) and other components as indicated by both the Egyptian Specification Standards (ES: 2037/2007)and by International Standards Organization (ISO: 3516/1979) for coriander oil seeds. Regarding the groups of chemical constituents, EOs of the Egyptian coriander seeds mainly consisted of light oxygenated compounds (88.93%), followed by monoterpene hydrocarbons (8.27%), sesquiterpene hydrocarbons (2.7%) and heavy oxygenated compounds (0.06). Linalool was the main light oxygenated compounds, while thujene (3.28%) was the major monoterpene.

In agreement to the found results about groups of chemical constituents in EOs of the Egyptian coriander seeds, it was stated that EOs of seeds from Indian cultivar of coriander rich in oxygenated monoterpenes, while the oxygenated monoterpenes, monoterpene hydrocarbon amounted to 80.47%, 6.45%, respectively [77]. Furthermore, EOs of seeds from Pakastani cultivar of coriander mainly comprised of oxygenated monoterpene hydrocarbons (80.83%), followed by monoterpene hydrocarbons (8.00%), sesquiterpene hydrocarbons (0.47%) and oxygenated sesquiterpene hydrocarbons (0.35%) [53]. In contrast, the presence of sesquiterpene hydrocarbons at a concentration over 13% in EOs of coriander seeds has been detected [83].

### 3.5.3. Identification of Essential Oil Composition of Whole Basil Herbs

GC Chromatograms of essential oils from Egyptian cultivar of basil whole herb revealed that forty seven compounds, representing 99.08% of the GC profile, were identified, where the major identified constituents (**Table7**) were: linalool (54.01%), Kessane (10.02%), Germacrene D (4.4%), Terpin-4-ol (2.19%), Eugenol (1.75%), $\beta$-selinene (4.4%), Cadina-1, 4-diene (1.54%), $\alpha$-cadinene (0.84%), elmicine (1.46%), caryophyllene oxide (1.66%), viridiflorol (1.19%), humuleneepoxide II (2.44%), 10-epi-g-eudesmol (4.01%) and $\alpha$-sinensal (3.09%).

The EOs of basil herbs grown in Egypt, were of the high Linalool-chemotype which are characterized by high contents of linalool and relatively lower amounts of eugenol (in the present they were 54.01% and 1.75%, respectively). It has been always reported that basil oils have very variable chemical composition [65]. On this basis of the oil composition, basil accessions were divided into seven groups: 1) high-linalool chemotype, 2) linalool-eugenolchemotype, 3) methyl chavicolchemotype and no linalool 4) methyl chavicol-linalool chemotype,

**Table 6.** Gas chromatographic characteristics of essential oils extracted from dried seeds of coriander (*Coriandum sativum*) previously collected from different Egyptian export centers as ready for export (as is basis)*.

| Peak No. | Compounds | KI | % Area | Method of identification | Type of component |
|---|---|---|---|---|---|
| 1 | $\alpha$-pinene | 939 | 3 | MS & KI | M |
| 2 | $\alpha$-thujene | 995 | 3.28 | MS & KI | M |
| 3 | $\beta$-pinene | 980 | 0.1 | MS & KI | M |
| 4 | (delta3) $\delta$3-carene | 1012 | 0.65 | MS & KI | M |
| 5 | P-cymene | 1026 | 0.2 | MS & KI & ST | M |
| 6 | Limonene | 1031 | 0.13 | MS & KI & ST | M |
| 7 | (Z)-$\beta$-ocimene | 1041 | 0.7 | MS & KI & ST | M |
| 8 | $\gamma$-terpinene | 1061 | 0.21 | MS & KI & ST | M |
| 9 | Sabinene hydrate trans | 1097 | 4.53 | MS & KI & ST | LOC |
| 10 | Linalool | 1098 | 72.6 | MS & KI & ST | LOC |
| 11 | Ethyl hexanoic acid <2-> | 1129 | 5.19 | MS & KI & ST | LOC |
| 12 | Camphor | 1151 | 0.27 | MS & KI & ST | LOC |
| 13 | Borneol | 1168 | 0.32 | MS & KI | LOC |
| 14 | P-cymen-8-ol | 1184 | 4.51 | MS & KI & ST | LOC |
| 15 | Geranial | 1275 | 0.18 | MS & KI | LOC |
| 16 | Nerol | 1228 | 1.1 | MS & KI & ST | LOC |
| 17 | Carvacrol | 1301 | 0.23 | MS & KI | LOC |
| 18 | Geranyl acetate | 1379 | 0 | MS & KI | HOC |
| 19 | Humulene <alpha-> | 1464 | 0 | MS & KI | S |
| 20 | Caryophyllene <9-epi-(E)-> | 1471 | 2.71 | MS & KI | S |
| 21 | Geranylisobutyrate | 1514 | 0 | MS & KI | HOC |
| 22 | Caryophyllene-oxide | 1589 | 0.06 | MS & KI | HOC |
| 23 | Ethyl tetradecanoate | 1793 | 0 | MS & KI | HOC |
| 24 | Bisabolol acetate <epi-alpha-> | 1803 | 0 | MS & KI | HOC |
| 25 | Santalol acetate <(z)-epi-beta-> | 1807 | 0 | MS & KI | HOC |
| 26 | Vetivone <alpha> | 1836 | 0 | MS & KI | S |
| 27 | Farnesyl acetate <E-E> | 1841 | 0 | MS & KI | HOC |
| 28 | Laurenene <epi-> | 1891 | 0 | MS & KI | S |
| 29 | Isophytol | 1941 | 0 | MS & KI | HOC |
| 30 | Phytol | 1956 | 0 | MS & KI | HOC |
| 31 | Occidol acetate | 1970 | 0 | MS & KI | HOC |
| 32 | Manoyl oxide | 1987 | 0 | MS & KI | HOC |
| 33 | Laurenan-3-one | 2104 | 0 | MS & KI | HOC |
| 34 | Phynyl ethyl anthranilate-2- | 2117 | 0 | MS & KI | HOC |
| 35 | Incensole | 2155 | 0 | MS & KI | HOC |
| | Chemical classes | | | | |
| | Monoterpene (M) | M | 8.27 | | |
| | Light oxygenated compound (LOC) | LOC | 88.93 | | |
| | Heavey oxygenated compound (HOC) | HOC | 0.06 | | |
| | Sesqterpene (S) | S | 2.71 | | |

**Table 7.** Gas chromatographic characteristics of essential oils extracted from green whole basil herb (*Ocimum basilicum*) previously collected from different Egyptian export plantation centers as ready for export (as is basis)*.

| Peak No. | Compounds | KI | % Area | Method of identification | Type of component |
|---|---|---|---|---|---|
| 1 | Myrcene | 994 | 0.08 | KI & MS | M |
| 2 | 1,8 cineol | 1033 | 0.62 | KI & MS | LOC |
| 3 | (Z)-*β*-ocimene | 1038 | 0.14 | KI & MS & ST | M |
| 4 | *γ*-terpinene | 1057 | 0.06 | KI & MS & ST | M |
| 5 | Linalool | 1098 | 54.01 | KI & MS & ST | LOC |
| 6 | Limonene oxide | 1130 | 0.09 | KI & MS & ST | LOC |
| 7 | Camphor | 1150 | 0.04 | KI & MS & ST | LOC |
| 8 | Borneol | 1167 | 0.07 | KI & MS & ST | LOC |
| 9 | Terpinen-4-ol | 1177 | 2.19 | KI & MS & ST | LOC |
| 10 | Nerol | 1231 | 0.82 | KI & MS & ST | LOC |
| 11 | Exo-fenchyle acetate | 1237 | 0.04 | KI & MS | LOC |
| 12 | Geraniol | 1255 | 0.05 | KI & MS | LOC |
| 13 | Geranial | 1268 | 0.26 | KI & MS | LOC |
| 14 | Thymol | 1292 | 0.9 | KI & MS | LOC |
| 15 | Carvacrol | 1298 | 0.64 | KI & MS | LOC |
| 16 | Eugenol | 1358 | 1.75 | KI & MS & ST | LOC |
| 17 | *β*-caryophyllene | 1421 | 0.09 | KI & MS | S |
| 18 | *β*-gurjunene | 1434 | 0.28 | KI & MS | S |
| 19 | *α*-humulene | 1451 | 0.03 | KI & MS | S |
| 20 | cis-muurola-4(14)5-diene | 1465 | 0.43 | KI & MS | S |
| 21 | Germacrene D | 1476 | 0.8 | KI & MS | S |
| 22 | *β*-selinene | 1483 | 4.4 | KI & MS | S |
| 23 | *α*-muurolene | 1502 | 0.21 | KI & MS | S |
| 24 | *γ*-cadinene | 1514 | 0.41 | KI & MS | S |
| 25 | 7 epi-*α*-salinene | 1517 | 0.61 | KI & MS | S |
| 26 | *δ*-cadinene | 1521 | 0.25 | KI & MS | S |
| 27 | Kessane | 1528 | 10.02 | KI & MS | S |
| 28 | Cadina-1,4-diene | 1532 | 1.54 | KI & MS | S |
| 29 | *α*-cadinene | 1538 | 0.84 | KI & MS | S |
| 30 | Elemicine | 1553 | 1.46 | KI & MS | S |
| 31 | Germacrene-B | 1557 | 0.4 | KI & MS | S |
| 32 | Germacrene-D-4-ol | 1574 | 0.65 | KI & MS | HOC |
| 33 | Spathulenol | 1579 | 0.01 | KI & MS | HOC |
| 34 | Caryophyllene oxide | 1582 | 1.66 | KI & MS | HOC |
| 35 | Viridiflorol | 1597 | 1.19 | KI & MS | HOC |
| 36 | Humulene epoxide II | 1606 | 2.44 | KI & MS | HOC |
| 37 | 10-epi-*γ*-eudesmol | 1618 | 4.01 | KI & MS | HOC |
| 38 | Dill apiole | 1622 | 1.15 | KI & MS | HOC |
| 39 | *γ*-eudesmol | 1630 | 0.42 | KI & MS | HOC |
| 40 | Cadinol, epi-*α* | 1642 | 0.08 | KI & MS | HOC |
| 41 | *α*-cadinol | 1662 | 0.12 | KI & MS | HOC |
| 42 | *α*-bisabolol | 1686 | 0.2 | KI & MS | HOC |
| 43 | *β*-sinensal | 1695 | 0.07 | KI & MS | HOC |
| 44 | Sesquilavandulyl acetate <E-> | 1747 | 0.29 | KI & MS | HOC |
| 45 | *α*-sinensal | 1766 | 3.09 | KI & MS | HOC |
| 46 | Ethyl tetradecanoate | 1770 | 0.02 | KI & MS | HOC |
| 47 | Phytol | 1950 | 0.15 | KI & MS | HOC |
| | Chemical classes | | | | |
| | Monoterpene (M) | M | 0.28 | | |
| | Sesqterpene (S) | S | 21.77 | | |
| | Light oxygenated compound (LOC) | LOC | 61.48 | | |
| | Heavey oxygenated compound (HOC) | HOC | 15.55 | | |

5) methyl eugenol-linalool chemotype, 6) methyl cinnamate-linalool chemotype, and 7) bergamotenechemotype [84].

The obtained findings for the Egyptian basil cultivar that linalool was the main component and also having the highest proportion are in good agreement with various literature reports about Linalool-chemotype cultivars grown in different parts of the world where Linalool was the main compound and of high content (54% - 60%) in EOs of different basil types or cultivars (from Italy [10], from Bangladesh [85], from Bulgaria [86], from Spain [87] and from Pakistan [61]).

Lower or higher linalool percentage than that found in EOs from the Egyptian basil cultivar were reported in literature for Linalool-chemotype basil oil [of 49.7% in Brazilian basil cultivars [88], of 71.4% in Bulgarian cultivar [89], of 41.2% in Turkish basil [90], of 43.8% in Algerian cultivar [59], of 44.18% in an Egyptian cultivar [91], 69.9% for Omani basil [64]. Moreover, the number of components isolated in GC chromatograms from EOs of the Egyptian basil cultivar (47 components) was either lower number (29 compounds in Pakistan [61], 33 components [92]) or higher number (59components in Algeria [59] and 75 in Omani basil [64]).

The major component, its proportion and proportion of the other main components in EOs of the tested fresh basil herb cultivar were found different than those indicated by the Egyptian Specification Standards (ES: 1359/2007) and by International Standards Organization (ISO: 11043/1998) for basil oil of methyl-chavicol type. No specifications are present yet for basil oil of Linalool-chemo type.

Regarding the groups of chemical constituents, the majority of compounds in EOs from whole basil herbs grown in Egypt were light oxygenated monoterpene compounds (LOC) (61.48%), sesquiterpene (S) (21.34%) and heavy oxygenated compounds (HOC) (15.98%). Monoterpenes (0.28%) were also present. The found results for classified chemical groups in Egyptian basil cultivar volatile oils compared well with literature reports that the oxygenated compounds were also the major constituent in Turkish *basilicum* volatile oils [93]. Pakistani basil EOs mainly consisted of oxy-genated monoterpenes followed by sesquiterpenes hydrocarbons and oxygenated sesquiterpenes [61]. In addition, basil oil was found richer in oxygenated monoterpenes (49.15%), where linalool representing the most important compound in the genus [63].

In addition, it was stated that *s*weet basiloil is mainly composed of monoterpenes, sesquiterpenes and phenylpropanoids [94]. The presence of monoterpene hydrocarbons, oxygenated monoterpene, sesquiterpene hydrocarbons, oxygenated sesquiterpene, etc. in basil oils was ensured [9]. In fact, basil volatiles were characterized by the prevalence of oxygenated monoterpenoid compounds, being the main constituent's linalool, eugenol and eucalyptol [95].

The observed differences in the identity of major components, their proportion and in group classification of these components between results of the three tested Egyptian cultivars of spices and herbs and those in literature reports could be attributed to various reasons and factors. For example, geographic origin and region of the tested spices and herbs including plant part, harvest time, extraction method, type of cultivar, storage conditions, climatic effects on the plants eventually affects the chemical composition [61] [70].

## 4. Conclusion

The tested seed spices and basil herbs and their extracted EOs, commonly cultivated and exported abroad in Egypt as collected from the export centers were chemically, microbiologically and chromatographically characterized. Their characteristics were compared with those cultivated in different parts of the world and also to the Egyptian Standards and International Specifications (ISO) for seeds and EOs of cumin and coriander seeds as well as for basil herb and were found to be within the limits for these specifications.

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