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Effect of New Solar-Drying Designs for Chamomile Essential Oil Yield and Its Chemical Constituents in Egypt

[25]

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Abstract

Egyptian medicinal and aromatic plants (MAPs) sector suffers from poor drying conditions of the product in terms of quality and safety standards, lack of professional advisory services, in addition to a high undeveloped value chain. Four designs were established in this study and focused on different methods for chamomile drying, the results of the 8/9/2 (B) design of the solar-assisted stack dryer were a masterpiece and promising for drying chamomile plant. The results of volatile oil extraction showed that an increased yield of volatile oil extraction by 30 % compared with traditional drying methods (control). GC-MS analysis indicated the essential oil chemical composition for the new drying method, were found to be the main active compound Bisabolol oxide A which were 54% in 8/9/2 (B) design of the solar-assisted stack dryer compared with the control which was 38.36% in control. The study method was promising and distinctive because it increases the yield of volatile oil extraction, maintains chemical structure compared with the control.

Keywords: Chamomile; Solar-assisted stack dryer; Volatile oil; GC-MS; Traditional drying methods

1 Introduction

Medicinal and aromatic plants (MAPs) are one of the most important export crops in Egypt, as they occupy the first rank in terms of the ratio of export production, where approximately 90% of production is exported. The United States, European Union, and Arab countries are the largest importers of Egyptian medicinal and aromatic plants (Lange 2006). Dry herbs have awesome significance, not as they were for culinary purposes, but too for medical uses (Hedrick 1972). Herbs, spices, medicinal and aromatic plants from family Lamiaceae like peppermint (*Menthapiperita*), sweet basil (*Ocimumbasilcum L.*), and rosemary (*Rosmarinus officinalis L.*), are cosmopolitan in Egypt. These plants are used as spasmolytic, stomachic, carminative, and expectorant agents in folk medicine and in official medicine. Other benefits may well be applied because of ethereal oils in therapeutic purposes owing to their antimicrobial (bactericidal and fungicidal) effects on some pathogenic microorganisms (Stefanini et al 2001, Klaus et al 2008). Chamomile (*Matricaria recutita L.*) (Family Asteraceae), is a well-known medicinal plant in folk medicine cultivated all over the world. Chamomile oil is widely employed in the pharmaceutical, cosmetic, and food industries. The pharmacological effect of chamomile oil for its spasmolytic, antimicrobial, and disinfection properties (Brunke et al 1992, Grgesina et al 1995). In Egypt, natural sun drying is one of the most common ways to keep agricultural products safe. The moisture is carried away by the wind as it blows above the product. It is affected by drying conditions, types of dryers, and characteristics of materials to be dried. The drying curve of dryers will give information on the time necessary for a product to be dried under certain conditions (Senadeera et al 2003, Ramaswamy and Marcotte 2005, Giri and Prasad 2007). Generally, the preservation factor in drying is to reduce the degree of moisture contained to the extent that it inhibits the activity of microorganisms and enzymes and reduces chemical reactions that lead to corruption (Ajay et al 2009). Many researchers have established the positive effect of low temperature drying in conjunction with low relative humidity (RH) in improving the product quality (Adapa et al 2002, Alves-Filho 2002, Sosle et al 2003). Modern methods for designing air drying operations depend on the mathematical description of plant moisture movement during the process (Hernandez et al 2000). This study focused on the improvement of the basic farmers' drying technology as direct sun drying in the open air. A properly designed solar dryer, which used low cost, environmental materials, can alleviate the drawbacks related to open sun drying and improve the quality standard of the dried product considerably. The drying kinetics factors (airflow, air velocity, pressure, temperature, and relative humidity) were determined. The essential oils of drying samples were extracted; their biological activities were determined and compared with controls.

2 Materials and Methods:

2.1 Plants

Fresh plant was used in drying trials; chamomile (*Matricaria chamomilla*) was purchased from SEKEM company, El-Sharkia governorate, Egypt.

2.2 Stack dryers for small-scale map growers in Egypt

Different designs for forced ventilation stacks have been developed and the required fan size in terms of air flow rate and pressure has been estimated.

2.2.1 Basic design (Design 1)

Ten single stacks (10 boxes in height, =layers) were located in a row. Two rows were situated in parallel without space in-between. The stacks were covered with a plastic film and the air was sucked out through the boxes in cross-flow made by the radial vacuum fan. The design was similar to the forced air cooling of vegetables as shown in **(Fig 1)**. The height of the stacks and the length of the rows are variable, the design is highly flexible. Furthermore, the capacity of the dryer depends on several variables such as drying rate, bulk density, moisture content, temperature, as well as saturation deficit of the drying air.

2.3 Design of solar-assisted stack dryer

The trials of drying of medicinal and aromatic plants during winter had revealed a low drying rate; the temperature of drying air was increased by incorporating a solar collector section. The dryer was placed on a layer of MAP stalks for heat insulation from the ground. The collector section at the entrance of the stack dryer was built with empty boxes. Several layers of black shading net serve as absorber. Empty boxes serve as top- and bottom layer of the stack dryer to create an air gap between the plastic foil and the drying material showed in supplementary data. Three sizes of over-flow stack dryers have been constructed and tested. The size is expressed following code: #layers/#stacks/#rows. The sizes were 1/9/2, 5/5/2 and 8/9/2. The limiting factor for the larger sizes was the number of available boxes on site.

Fig 1. Basic design (Design 1)

2.3.1 1/9/2 design of solar-assisted stack dryer (Design 2)

The 1/9/2 stack dryer was a version with one layer of filling, drying boxes with 9 stacks in a row and two rows in parallel. Two empty stacks have been added as a solar collector. Open dryer at the end of drying and closed dryer. The experimental set- miniature data loggers (L1-L3) for measuring T and RH have been placed at the inlet of the up includes three collector segment and at the inlet and outlet of the dryer segment as showed in **(Fig 2)**. Three miniature data loggers (L1-L3) were placed at the inlet of the collector segment and at the inlet and outlet of the dryer segment.

2.3.2 5/5/2 design of solar-assisted stack dryer (Design 3)

The 5/5/2 stack dryer was a version with five layers of filling, drying boxes with five stacks in a row and two rows in parallel. Five empty stacks have been added as solar collectors. Three miniature data loggers (L1-L3) for measuring T and RH have been placed at the outlet of the dryer segment and six (L4-L9) have been placed at the inlet **(Fig 3)**. Ambient T and RH have been measured by a further logger L10 and by logger with display D1. At the start and towards the end of drying air velocity (Q) and static pressure (P) have been measured by handheld devices at the inlet of the collector segment, the inlet and the outlet of the dryer, where (Q) has been measured at the top, middle and bottom position for left and right row. Air flow (V) has been measured by Heavy Duty Pitot Tube Anemometer and Differential Pressure Manometer (Model HD350).

2.3.3 8/9/2 design of solar-assisted stack dryer (Design 4)

The 8/9/2 stack dryer was a version with eight layers of filling, drying boxes with 9 stacks in a row and two rows in parallel between each two layers of drying boxes a layer of empty boxes was placed to allow sufficient air ventilation. Two empty stacks have been added as a solar collector and another two empty stack as a head unit to attach the fan. This construction was allowed to open the middle part of the dryer conveniently to handle the drying boxes. Three miniature data loggers (L5-L6) for measuring T and RH have been placed at the outlet of the dryer segment and three (L7-L9) have been placed at the inlet **(Fig 4)**. Ambient T and RH have been measured by a further logger L3 and by logger with display D1. At the start and towards the end of drying air velocity (Q) and static pressure (P) have been measured by handheld devices at the inlet of the collector segment, the inlet and the outlet of the dryer, where (Q) has been measured at the top, middle and bottom position. Air flow (V) has been measured by Heavy Duty Pitot Tube Anemometer.

Fig 2. 1/9/2 design of solar-assisted stack dryer (Design 2)

Fig 3. 5/5/2 design of solar-assisted stack dryer (Design 3)

Fig 4. 8/9/2 design of solar-assisted stack dryer (Design 4)

2.4 Operation time and energy consumption

The drying chamomile could be started for 10 hours daily for 8 days with a break in-between opening the dryer, mixing the drying material and inversing the vertical position of the layers. The energy consumption was 240 kWh for chamomile with stack dryer designs 1/9/2, 5/5/2, 8/9/2 (A) and 300 kWh for 8/9/2 (B) design with extra 2 workdays.

2.5. Essential oil extraction and determination

The volatile oils were extracted from fresh and dried chamomile by using a hydro-distillation Clevenger apparatus method. Samples from fresh and dried plants (100 g) were cut into small parts and suspended in 1250 ml of distilled water. The mixture was kept boiling for four hours. The extracted essential oils were dried over anhydrous sodium sulfate to remove all the water and then stored in dark-sealed-vial at 4 °C for further tests. The extracted oil percentage was calculated, according to (Guenther, 1975) using the following equation 1:

$$X0 = \rho 0 \times V0 \times WL \qquad \text{(Equation 1)}$$

Where:
X0 - Percentage of the volatile oil, %, ρ0 - Density of the volatile oil, (g/cm3), V0 - Volume of the volatile oil, (cm3), WL - Weight of sample, (100 g).

2.6. Chemical composition of essential oil by GC-MS analysis

The gas chromatography-mass spectrometry (GC-MS) analysis of the chamomile volatile oil samples was loaded by utilizing the gas chromatography-mass spectrometry device. The GC Ultra Gas Chromatographs TRACE (THERMO Scientific Corp., USA), coupled by a THERMO mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer). The gas chromatography-mass spectrometry system was equipped with a TR-5 MS column (30 m x 0.32 mm i.d., 0.25 μm film thickness). The analysis was loaded by using a stable gas it was a helium gas, as the helium at a flow-rate of 1.3 ml/min and a split ratio of 1:10 using the following temperature program was: 60°C for 1 min; rising at 4.0 °C/min to 240°C and wait for 1min. The injector and detector were put at 200 °C. Samples were diluted (1:10 hexane, v/v) of 1 μL of the mixtures was always injected. Mass spectra were reached by electron ionization (EI) at 70 eV, using a spectral range of m/z 40-450. Chemical constituent of the EOs under investigations was characterized by Automated Mass spectral Deconvolution and Identification (AMDIS) software (www.amdis.net), retention indexes (relative to *n*-alkanes C_8-C_{22}), comparison of the mass spectrum with authentic (if available), and Wiley spectral library collection and NSIT library database (Gaithersburg, MD, USA; Wiley, Hoboken, NJ, USA).

3 Results and Discussion

3.1 Stack dryers for small-scale map growers in Egypt

3.1.1 Basic design

The basic design was not adjustable enough drying for the reason that plants still green in the bottom and the middle of the boxes, there was a black spots regards to enzymatic and microorganism activity, the first level on the top was dry, conversely the plants burned because of the direct exposure to the sun. The result was not accepted in drying medicinal and aromatic plants, which selected in our trial. Meanwhile, additional designs were developed enough drying and avoid the drawbacks to meet the farmer's needs.

3.1.2 1/9/2 Solar-assisted design

The fans were not operated during the night as not much evaporation was to be expected from the semi-dry material and relative humidity was high at night, and it will raise the moisture ratio of plants. The air flow rate was indicated that the very important factor in the 1/9/2 solar-assisted design and operation of low-temperature drying systems regardless of whether natural air or heated air was used.

The obtained results of 1/9/2 design solar-assisted stack dryer was succeeded in chamomile, which we were selected in our experiments, nevertheless 1/9/2 design had a problem, it took a little number kilograms of plants (every box take 2.5 kg of fresh plants maximum, and 1/9/2 design of solar-assisted stack dryer had 18 boxes, so the drying batch 45 kg of fresh plant), accordingly, a newly developed design needed to possess a much bigger design meets the farmer's needs for production. In general, the physical properties measurements of solar-assisted stack dryer designs differ from one to another depending on layers, stacks, rows, environment, season, nature of plants, and the moisture content (Pierce and Thompson 1980).

3.1.3 5/5/2 solar-assisted design

The results of the 5/5/2 design dryer were adequate in drying chamomile, which nominated in the trial, however, the design contains a problem, it obtained a bit number of kilograms of plants (every box 2.5 kg of fresh plants maximum, and 5/5/2 design have 50 boxes, that the drying batch 125 kg of fresh plant), The study focused on a new drying model that took larger quantities than the current one.

3.1.4 8/9/2 (A&B) solar-assisted design

The layers, stacks, rows, environment, season, nature of plants, and the moisture content effect on solar-assisted stack dryer.

3.2. Essential oil extraction of testing samples Essential oil extraction of testing samples

The average yield of essential oil extraction of testing samples/100 g dried chamomile, and mint was determined. The control samples were 0.7 ± 0.01 ml in chamomile, and 0.6 ± 0.01 ml in mint **(Fig 5)**. In case of designs, the samples were taken from 8/9/2 (B) design since it was achieved the lowest moisture content with the highest mass production of all designs. The average of essential oil extracted from 8/9/2 (B) design of chamomile samples was 1 ± 0.01 ml, and in mint was 0.9 ± 0.01 ml. This means that increasing yield of essential oil extraction by 30 % by using 8/9/2 (B) design compared with traditional drying methods (control).

3.3 Chamomile essential oil chemical constituents Chamomile essential oil chemical constituents

From the data showed in **Table 1**, results indicated that the percentage of a total of the 38 chamomile major components, shows 99.99% hydro-distillation extraction of the total oil in both samples (control and 8/9/2 (B) design). Bisabolol oxide A (C15H26O2) was a major compounded with higher percentage 54.00% in chamomile extracted oil from 8/9/2 (B) design, accordingly there was a significant range compared with 38.36 % in control chamomile. α-Bisabolol oxide B was 8.98% in chamomile extracted oil from 8/9/2 (B) design, meanwhile there was a significant range compared with 8.12 % in control chamomile oil, however chamazulene was 3.36 % in the control compared with 0.99% in chamomile extracted oil from 8/9/2 (B) design of solar-assisted stack dryer. Bisabolone oxide was 7.41 % in chamomile oil extracted from control compared with 6.86% in chamomile extracted oil from 8/9/2 (B) design of solar-assisted stack dryer. In the control sample some compound were not determined like (Caryophylleneoxide, Santalol, cis, α-, o-Toluidine, limonen -6-ol, pivalate, 4-Methyl-2H-pyrano[6,5-h]-2H-chromen-2-one, Azulen-2-ol,1,4-dimethyl-7-(1-methylethyl), Geranyl isovalerate, and Docosane), nonetheless, it was determined in 8/9/2 (B) design sample. Furthermore, in 8/9/2 (B) design there were some compound were not determined like (β-Ocimene, trans caryophyllene, trans-p-mentha-2,8-dienol, Ledene, Farnesene, β-Cdainene, δ-Cadinene, Globulol, and Bisabolol oxide A). **Fig 6** showed GC-MS chromatogram of essential oil

Table 1. Chamomile essential oils chemical composition and its control oil

			Chamomile essential oils			
			Control	8/9/2 (B) design		
No.	RT	KI	Area %	Area %	Compound name	Formula
1	7.20	1245	0.57	nd	β-Ocimene	C10H16
2	7.67	1065	0.97	0.55	Artemisia ketone	C10H16O
3	22.35	1412	0.18	nd	trans caryophyllene	C15H24
4	24.06	1442	19.64	7.88	cis-β-Farnesene	C15H24
5	24.47	1122	0.27	nd	trans-p-mentha-2,8-dienol	C10H16O
6	25.00	1500	2.54	0.40	GERMACRENE-D	C15H24
7	25.32	1490	0.37	nd	Ledene	C15H24
8	25.55	1738	1.72	0.17	Bicyclogermacrene	C15H24
9	26.04	1674	1.56	nd	Farnesene	C15H24
10	26.40	1519	0.87	nd	β-Cadainene	C15H24
11	26.48	1530	0.52	nd	δ-Cadinene	C15H24
12	28.33	1624	0.24	0.28	Farnesene epoxide	C15H24O
13	28.58	1573	nd	0.21	Caryophyllene oxide	C15H22O
14	28.88	1640	0.68	1.77	(-)-Spathulenol	C15H24O
15	29.18	1570	0.24	nd	Globulol	C15H26O
16	30.44	1753	0.33	0.58	lanceol, cis	C15H24O
17	30.98	1619	0.60	0.41	Iso spathulenol	C15H24O
18	31.46	1660	1.04	0.73	tau-Cadinol	C15H26O
19	31.90	1651	8.12	8.98	α-Bisabolol oxide B	C15H26O2
20	32.14	1654	0.56	nd	Bisabolol oxide A	C15H26O2
21	32.22	1681	nd	2.57	Santalol, cis,α-	C15H24O
22	32.98	1657	7.41	6.86	Bisabolone oxide	C15H24O2
23	33.12	1664	1.91	1.95	α-Bisabolol	C15H26O
24	34.78	1715	3.36	0.99	Chamazulene	C14H16
25	34.87	1068	nd	0.24	o-Toluidine	C12H12N2
26	35.70	1654	38.36	54.00	Bisabolol oxide A	C15H26O2
27	36.22	1030	nd	0.14	limonen -6-ol, pivalate	C15H24O2
28	38.49	1833	0.29	0.14	2-Pentadecanone, 6,10,14-trimethyl	C18H36O
29	40.40	1830	4.73	5.32	En-in-dicycloether	C13H12O2
30	41.07	1830	0.49	2.30	1,6-Dioxaspiro[4.4]non-3-ene, 2-(2,4-hexadiynylidene)	C13H12O2
31	41.80	1650	nd	0.14	4-Methyl-2H-pyrano[6,5-h]-2H-chromen-2-one	C13H10O3
32	42.60	1934	nd	0.26	Azulen-2-ol,1,4-dimethyl-7-(1-methylethyl)	C15H18O
33	46.66	1542	nd	0.23	Geranyl isovalerate	C15H26O2
34	46.83	2200	nd	0.15	Docosane	C27H56
35	47.84	2066	0.19	0.53	9,12-Octadecadienoic acid (Z,Z)	C18H32O2
36	52.51	2600	0.31	0.26	Hexacosane	C26H54
37	54.61	2375	1.04	0.81	9-Octadecenamide	C18H35NO
38	57.91	2600	0.90	1.14	Hexacosane	C26H54

nd = not determined

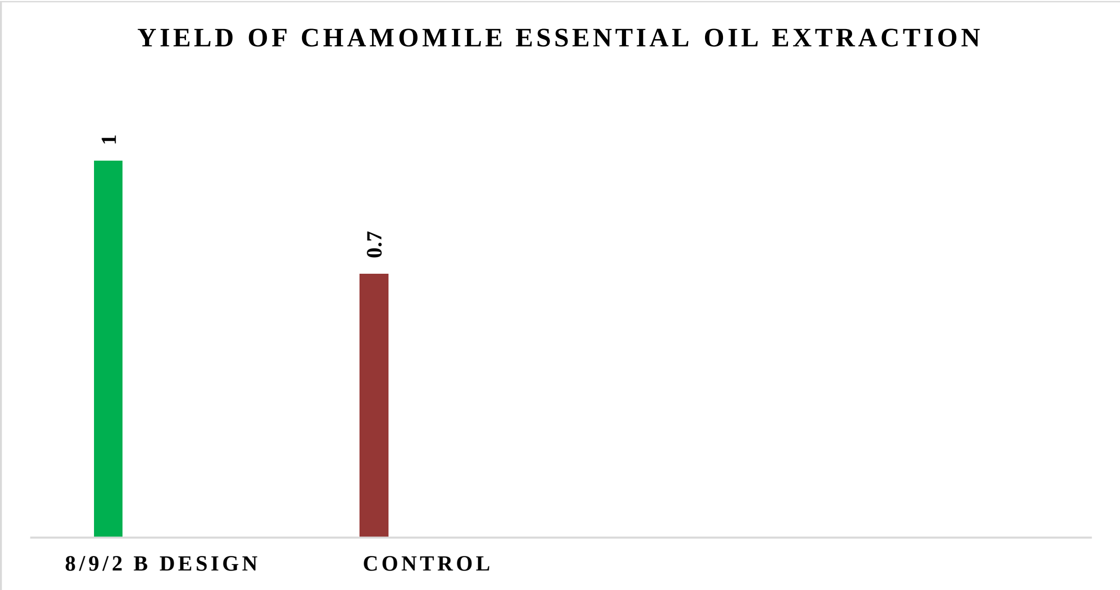

Fig 5. Yield of chamomile essential oil extraction

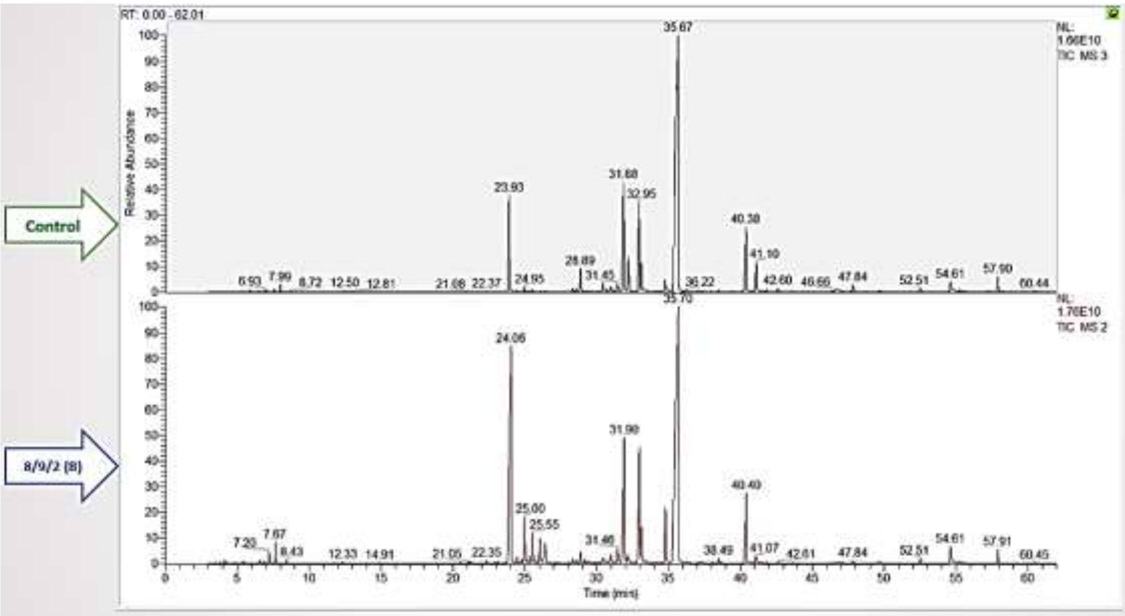

Fig 6. GC–MS chromatogram of chamomile EO 8/9/2 (B) design and control

of chamomile 8/9/2 (B) design of solar-assisted stack dryer and control. After the significant range results of chamomile chemical constituents of essential oil between 8/9/2 (B) design of solar-assisted stack dryer and control, in order to enhance and ensure that the significant range of chamomile chemical constituents of essential oil, probably, the difference in the essential oil component ratio may affect the biological activity of each. Chamomile volatile oil exhibits potent biological activities, which emphasizes its use in folk medicine. Furthermore, all outcomes regarding the bioactivities components of the main volatile oil components propose that the observed activities of the volatile oils are linked to their chemical composition, where bisabolol and α-bisabolol oxide has been found to be the higher active compounds. There was a good connection between antimicrobial, total phenolic content, and antioxidant capacity of the extracts (Kazemi 2015).

4 Conclusion

The effect of new solar-drying designs for chamomile volatile oil yield and its chemical constituents in Egypt have been applied for medicinal and aromatic plant especially chamomile plant in Egypt. The drawbacks of the traditional drying method were overcome. In addition to preserving the chemical components and percentage of essential oil plants. The technology of solar-drying provides an alternative that can dry the medicinal and aromatic plants in clean. It saves time, energy, occupies less area, improves the quality of products, saves the environment, and makes the manufacture more efficiently.

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عزل وتعريف بكتريا غير بادئ حمض اللاكتيك من الجبن البراميلي التقليدي

[23]

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الموجـــــــــــــز

تلعب بكتيريا غير بادئ حمض اللاكتيك (NSLAB) دورًا هاما في جودة وسلامة الجبن البراميلي التقليدي وهو من اصناف الجبن الدمياطى. لذلك كان الهدف من هذه الدراسة هو عزل وتعريفبكتيريا غير بادئ حمض اللاكتيكذات المميزات التكنولوجية المحتملة من الجبن البراميلي التقليدي حيث تم تجميع عدد 33عينة من الجبن البراميلى عشوائياً من متاجر التجزئة بمنطقة القاهرة الكبرى. وتم توصيف العينات بالتحليل الفيزيوكيميائي، والبنائى والميكروبيولوجي. وتم عزل عدد 90 سلالة محتملة لبكتيريا غير الموجودة ببادىء بكتريا حمض اللاكتيك (30 *Lactobacillus spp.* و 35 *Enterococcus spp.*) وذلك على بيئات MRS و KF Streptococci المتخصصة وتم تقييمها من حيث النمو على درجات حرارة مختلفة، وتحمل الملح، والقدرة على تجبن اللبن. وبناءاً على النتائج، تم تعريف 11 عزلة، ذات مميزات تكنولوجية محتملة، وراثيا باستخدام تقنية 16s rRNA، ثم تم تأكيد قدرتها على النمو وتكوين الحموضة في اللبن الفرز خلال 48 ساعة. وتم تعريف الـ 11 عزلة على أنها *Ent. durans*(1), *Ent. faecalis* (5), *Lb. paraplantarum* (1), *Lb. plantarum* (3), and *Lb. rhamnosus* (1), والتي ثبت نشاطها جميعًا في اللبن الفرز وأظهرت نشاطا مضادا لبعض الميكروبات المسببة لفساد وأمراض الغذاء. لذلك تقترح هذه النتائج استخدام عزلات NSLAB المعرفة في هذه الدراسة لتوحيد وتحسين جودة وسلامة الجبن البراميلي والاصناف الفرعية الأخرى ذات الصلة بالجبن الدمياطى.