Influence of Cultivar Type of Strawberry Fruits on Its Volatile Constituents

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Abstract
Five strawberry (Fragaria x ananassa. Duch.) cultivars (Festival, Red Merlin, Suzana, Tamar and Winter Dawn) were analysed using solvent-solvent extraction method and GC/MS system to compare between the volatile constituents responsible for the aroma in different fresh and frozen cultivars. The main identified compounds were Tetradecene (15.41%), 2E-dodecene-1-ol (13.78%), Nerolidol (11.37%), E-14-hexadecenal (17.27%) and Octadecanol (17.65%). The present study explains the effect of freezing on aroma content for different strawberry cultivars. Nutritional value contents of the fruits were also estimated which illustrate the importance of fruits as a main source of vitamin C and potassium. The antimicrobial activity of the volatile constituents were estimated and were exhibited a significant results (20-32mm zone of inhibition) against number of human pathogenic microorganisms, compared with the standard antibiotic (20-22 mm zone of inhibition) using the agar well diffusion method.
Keywords: Fragaria x ananassa, antimicrobial, cultivars, volatile constituents.

1. Introduction

Strawberry (Fragaria x ananassa.Duch., Rosaceae), a hybrid between two octaploide species F.virginiana and F.chiloensis, is grown all over the world (Ménager et al., 2004, Hancock & Luby 1993). A strawberry is one of the most commonly consumed berries(Tulipani et al., 2008). Its flavor is a complex combination of sweetness, acidity and aroma(Hummer & Hancock., 2009)and its aroma is a complex mixture of different aromatic compounds (Furanones, esters, aldehydes, alcohols, sulfur containing compounds) which have been extensively studied (Dirinck et al., 1981;Berna et al., 2007;Pyysalo et al., 1979;Perez et al., 1992). More than 360 compounds have been identified in strawberry aroma (Zabetakis & Holden., 1997). These volatile constituents act as a signal of ripeness (Schwab et al., 2008).

The quantitatively and qualitatively identified compounds in the strawberry aroma are esters (Olías et al., 2002;Forney et al., 2000), which responsible for the fruity note of strawberry (Gomes da Silva & Chaves das Neves., 1999). They comprised from 25% to 90% of the total volatiles in fresh ripe fruits (Pyysalo et al., 1979;Schreier., 1980;Douillard & Guichard., 1990). Furaneol and mesifurane are from the most important contributors to aroma and are the most important furanones in strawberry fruit (Ménager et al., 2004;Pyysalo et al., 1979;Hirvi & Honkanen., 1982;Pérez et al., 1996;Larsen & Poll., 1992;Wein et al., 2002;Jetti et al., 2007; Shu et al., 1985;Fukuhara et al., 2005). However, the aroma profile of strawberry differs by many factors mainly by cultivar type (Forney et al., 2000;Hakala et al., 2002).

There is a notable difference between the fruits of diploid wild species (F.vesca) and the modern cultivated species not only in the size and yield of the fruits but also in the flavor and aroma profile of them (Pyysalo et al., 1979). The monoterpene linalool and sesquiterpenenerolidol were detected only in the cultivated fruits while wild strawberry emitted other monoterpenes such as (α-pinene, β-myrcene, α-terpineol, and β-phellandrene), myrtenyl acetate and low levels of myrtenol which were not detected in the cultivated species (Aharoni et al., 2004). Methylanthranilate is very important compound responsible for the typical unique character of the wood strawberry (F.vesca) aroma which is characterized by an intensive spicy aromatic and flowery note (Ulrich et al., 1997).

Carbohydrates and sugars are important strawberry flavor components (Zabetakis & Holden., 1997). Strawberries are composed of approximately 90% water and 10% total soluble solids, and contain numerous important dietary components including vitamins, minerals, folate and fiber, and considered a rich source of phytochemical compounds mostly represented by polyphenols (Hummer & Hancock., 2009;Schwab & Raab., 2004;Giampieri et al., 2012).Carbohydrates are one of the main soluble components in strawberry fruit and provide energy for metabolic changes (Zabetakis & Holden., 1997;Schwab & Raab., 2004). The primary organic acid in strawberries is citric acid, which constitutes 88% of the total acids (Schwab & Raab., 2004).

They are rich in vitamin C which makes them an important source of this vitamin for human nutrition (Hummer & Hancock., 2009;Giampieri et al., 2012;Scalzo et al., 2005;Carr & Frei., 1999). Vitamin C was found to be one of the most important components responsible for more than 30% of the total antioxidant capacity of strawberry extracts (Tulipani et al., 2008;Wang et al., 1996). Strawberries widely cultivated in Egypt at least in five governorates and represent one of the most important vegetable crops (Embaby., 2007). So in our work we concerned with five cultivars of strawberry grown in Egypt to compare between them in the volatile constituents, nutritional value and measurement the antimicrobial activity of its volatile constituents against number of pathogenic microbes.

2.Materials and methods

2.1. Plant materials

Five different cultivars of cultivated strawberry (Festival, Red Merlin, Suzana, Tamar, Winter Dawn) were obtained from Pico farms, Om saber farm, Behira governorate, Egypt. Were harvested at the optimum stage of ripeness during the summer of (2009, 2010). The authentication and genetic diversity level of these fruits performed by Agricultural research center, Agricultural genetic engineering research institute, using RAPD-PCR system. About 500 gm of each cultivar was used in the same day of harvesting for the investigation of volatile constituents, and the remainder was deep-frozen at -20°C for three months before analysis. A part of the former samples was used for antimicrobial activity investigation. Another 250 gm of each cultivar used for comparing the nutritional value contents.

2.2 Isolation of volatile constituents

Fresh and deep-frozen strawberries (500 gm each) were homogenized (5 min) in a blender (without calyces) and then each one suspended in 500 ml of n-hexane. The slurry was extracted three times by n-hexane solvent (each time with 500 ml of organic solvent) the solvent-solvent extraction method previously reported by many authors (Pyysalo et al., 1979; Kafkas et al, 2005; Hirvi & Honkanen., 1982; Ulrich et al., 2006).The fractions were collected and evaporated under vacuum using rotary evaporator at 36 °C till dryness. The same extract used for antimicrobial activity investigation.

2.2.1 Qualitative and quantitative analysis of the volatile constituents

GC-MS analysis was performed with an Aglient 6890 gas chromatograph equipped with an Aglient mass spectrometric detector, with a direct capillary interface and fused silica capillary column HP-5MS (30 m X 320 µm X 0.25 µm film thickness), (Kafkas et al., 2005; Loughrin & Kasperbauer., 2002). The injector temperature was 250 °C for pulsed splitless mode and the injection size was 1.0 µl. Helium was used as carrier gas at approximately 1.0 ml/min; the solvent delay was 3 min. The GC temperature program was started at 60°C (3 min) then elevated to 260°C at rate of 8°C/min. The detector temperature was set at 280°C. The volatile compounds were identified by comparing the mass spectral data with the Wiley library. (Wiley7Nist05 and Nist05 mass spectral data base was used in the identification of the separated peaks), Adams book(Adams., 2007).

2.3 Antimicrobial activity conditions

The volatiles of each cultivar were individually tested against pathogenic microorganisms Bacillus subtilisATCC6633 and Staphylococcus aureus ATCC 29213 as Gram positive bacteria, Klebseillapeneumoniae ATCC13883 as Gram negative bacteria, Candida AlbicansNRRL Y-477 and local isolateAspergillusnigerGAss.467 using the agar well diffusion method(Perez et al., 1990). Antimicrobial activity was evaluated by measuring the zone of inhibition against the test organisms and compared with that of the standard. The observed zone of inhibition is presented in **Table 3**. The experiment was carried out in triplicate and the average zone of inhibition was calculated.

2.4 Nutritional value

2.4.1 Proximates, Vitamin C and minerals determination

The samples were analysed to determine (moisture, proteins, fat, carbohydrates and ash) and vitamin C according to the AOAC procedures (Cunniff., 1995), performed at National institute of nutrition. Minerals determination applied using the wet digestion method of samples, exactly (2-5g) of each of the five cultivars puree was digested. This digested solution analyzed using atomic absorption spectrometer (Perkin Elmer 3300), performed at Food technology research institute in Agricultural research center according to the methods of AOAC (Horwitz., 2000), the absorption measurement of the elements in strawberry samples was read out and given in **Table 4**.

3. Results and Discussion

3.1. Volatile constituents elucidation

Table 1 and **table 2**, show the percentage of each compound identified in the volatile constituents of five different cultivars of strawberry (fresh and frozen). The results illustrated how much the cultivar type and freezing affects on these constituents quantitatively and qualitatively (Ozcan & Barringer., 2011).

The percentage of total esters content of Red Merlin and Winter Dawn showed significant increase upon freezing especially Red Merlin, the other four cultivars showed significant decrease especially Tamar cultivar, this agree with result of (Douillard & Guichard., 1990).

On general aldehydes decreased upon freezing except two cultivars Festival and Winter Dawn which showed a significant increase. A significant increase in the level of decanal was showen on freezing in Festival, Red Merlin and Tamar cultivars. The decanal percentage increase was from (0.96, 0.43, 1.74 %) to (7.84, 8.08, 9.5 %) respectively which make the net result of total aldehydes of these cultivars increased.

On the otherwise all Ketones content decreased in all cultivars except in Tamar cultivar increased. Generally Ketones did not show notable differences upon freezing. But alcohols content increase in all cultivars upon freezing except Festival cultivar showed lower level of alcohols, and the notable increases represented by Suzana and Tamar cultivars.

Terpenoids are responsible for the fruity citrus aroma of strawberries(Jetti et al., 2007). The percentage of terpenes decreased by freezing in all cultivars. Linalool decreased in all cultivars upon freezing except Suzana and Tamar cultivars, linalool previously identified in many studies (Gomes da Silva & Chaves das Neves., 1999;Schreier., 1980;Jetti et al., 2007;Ozcan & Barringer., 2011;Ulrich et al., 2006;Jouquand et al., 2008;Kafkas et al. 2005;Abanda-Nkpwatt et al., 2006). Geraniol the most abundant terpene in all cultivars and show significant increase about its fold concentration on freezing in Red Merlin, Suzana and Tamar cultivars. On the otherwise citronellal was not detected in all frozen cultivars. But Tetrahydrocitronellene show significant decrease in frozen fruits ofFestival and Red Merlin.

Lactones contribute to fruity coconut aroma and their concentration varied depends on cultivar type (Jetti et al., 2007). Gamma dodecalactone and gamma decalactone identified in almost cultivars but gammaNonalactone and delta undecalactone identified only in fresh Winter Dawn cultivar and in general their concentration decreased on freezing.

3.2 Antimicrobial activity of volatile constituents

The volatile constituents of different five strawberry cultivars did not exhibit any effects on the fungi but have powerful inhibition effects on the four different types of bacteria. On previous studies strawberry flavor inhibited many microbial strains than plum and apricot extract used by (Kotzekidou et al., 2008). Microbial strains had different sensitivities against volatile constituents. Festival cultivar possessed the strongest antimicrobial activity followed by the Winter Dawn cultivar, then followed by Tamar and Red Merlin with even antimicrobial activity except the effect against Bacillus subtilis where Red Merlin showed more inhibition effect than Tamar cultivar. The weakest antimicrobial effects were measured with Suzana cultivar. The most sensitive microorganism to strawberry volatile constituents isBacillus subtilis. All results are illustrated in **Table 3**.

3.3 Nutritional value

The highest content of protein was found in Festival cultivar (1.04gm%) followed bySuzana cultivar (0.97gm%), Red Merlin (0.62gm%), Tamar and winter Dawn cultivars showed even content (0.59gm%).

The highest content of fat was in Festival, Red Merlin, Suzana cultivars (0.2gm%) followed by Winter Dawn (0.18gm%) and finally Tamar cultivar (0.12gm%).

Carbohydrate content showed the highest value in Suzana cultivar (9.46gm%) followed by Festival cultivar (8.46gm%) and other cultivars which have the lesser content were Tamar, Winter Dawn, Red Merlin (7.87, 7.66, 7.45gm%) respectively.

Tamar cultivar has the highest content of vitamin C followed by Red Merlin and Winter Dawn cultivars which have the same level of vitamin C (28mg%), then Festival cultivar (24mg%) then Suzana cultivar (22.7mg%).

All cultivars showed high moisture content .The highest content was in Red Merlin, Winter Dawn and Tamar cultivars (91.49, 91.4, 91.18gm%) respectively. Festival and Suzana cultivars had a lower moisture content of (89.96, 89.03gm%) respectively.

The minerals contents showed that Suzana cultivar had the highest level of phosphorus (306.377 mg/kg) followed by Festival (303.214 mg/kg), Tamar cultivar (220.065 mg/kg), then Winter Dawn and Red Merlin cultivars which had nearly the same level of phosphorus (213.9, 213.72mg/kg) respectively. Also Suzana cultivar showed the highest level of magnesium (190.148 mg/kg) followed by Festival cultivar (179.977 mg/kg), then Winter Dawn cultivar (174.158 mg/kg), Tamar cultivar (171.335 mg/kg)and finally Red Merlin cultivar (165.635 mg/kg). Festival cultivar showed the highest level of calcium (191.86 mg/kg) followed by Winter Dawn cultivar (174 mg/kg), then Tamar cultivar (163.733 mg/kg), then Suzana cultivar (156.58 mg/kg)and finally Red Merlin cultivar (145.71 mg/kg). Suzana showed the highest level of Potassium (255.206 mg/100g) followed by Winter Dawn cultivar (235.350 mg/100gm), then Festival cultivar (204.27 mg/100gm), then Red Merlin cultivar (174.715 mg/100gm) and finally Tamar cultivar (140.128 mg/100gm). Phosphorous and potassium represented the most significant minerals found in strawberry. The results of the nutritional value obtained for the studied strawberry cultivars are shown in **Table 4**.

Conclusion

From our study on five different cultivars of strawberry which widely spread in Egypt especially Festival and Red Merlin cultivars we noted that the volatile constituents of strawberries were varied by freezing and cultivar genotype. This variation was quantitatively and qualitatively which not preferred by freezing conditions. Festival cultivar was the most stable one and possesses less sensitivity to freezing and also showed the highest antimicrobial activity, generally moisture content of strawberry is high, and has good nutritional value with low calories. The five strawberry cultivars discussed considered a good source of vitamin C and potassium and other important minerals. In conclusion, strawberry considered very good nutritive fruit with low calorie which make it a promising material for studying their anti-obesity and anti-diabetic effect.

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Table1.Comparative quantitative analysis of volatile constituents (percentage) identified in five fresh and frozen strawberry cultivars.

Volatile compounds	F_{Fresh}	F_{Frozen}	R_{Fresh}	R_{Frozen}	S_{Fresh}	S_{Frozen}	T_{Fresh}	T_{Frozen}	W_{Fresh}	W_{Frozen}
Esters										
Propyl hexanoate	0.47	1.12	0.07	1.95	-	0.69	-	0.12	0.3	1.27
Hexenylphenyl acetate	0.34	0.23	0.19	0.16	0.24	0.07	0.7	0.09	0.21	0.26
Benzyl salicylate	0.47	0.16	0.17	0.21	0.89	-	0.46	-	0.24	0.18
Nerolidol acetate	0.17	0.19	0.19	0.16	0.06	0.09	0.03	0.1	0.25	0.22
Phenylethyloctanoate	0.26	0.22	0.18	0.29	0.57	-	0.38	0.1	0.27	0.22
Benzyl acetate	0.3	0.18	0.18	0.21	1.2	0.01	0.78	-	0.62	0.24
Phenethylcinnamate	0.57	0.42	-	-	0.73	0.09	0.71	-	0.59	0.46
Phenyl ethyl phenyl acetate	0.28	-	0.12	0.26	1.36	-	0.5	0.18	0.55	0.16
Methyl octadecanoate	0.35	-	-	-	-	0.03	1.1	0.18	0.16	-
Ethyl octadecanoate	0.2	-	-	-	0.32	6.12	15.52	5.83	0.09	7.95
Octadecanol acetate	1.49	-	0.94	1.65	-	1.5	2.27	1.35	1.05	1.99
Heptylisobutanoate	1.11	0.74	0.67	8.02	5.44	1.12	0.52	1.52	0.37	0.72
Aldehydes										
Nonanal	0.47	0.11	-	-	-	-	0.67	-	0.23	0.17
2E-octenal	0.26	0.44	1.48	-	-	2.33	0.83	0.76	-	0.41
Decanal	0.96	7.84	0.43	8.08	3.65	1.03	1.74	9.5	4.07	7.7
2E,4Z-decadienal	0.51	0.64	0.65	0.54	1.08	2.42	-	-	-	0.35
Undecanal	0.26	0.42	0.69	0.5	0.95	1.93	0.21	0.81	0.18	0.44
Dodecanal	2.4	2.9	3.48	2.92	3.9	2.01	2.56	2.48	0.98	2.86
E-14-hexadecenal	17.27	10.64	13.69	11.49	3.05	8.34	1.1	0.18	13.93	10.57
Ketones										
2-undecanone	0.23	-	0.31	0.25	0.32	0.23	0.22	0.81	0.18	0.21
3-dodecanone	0.32	0.2	3.48	0.83	1.91	1.09	1.18	1.28	0.4	0.18
Alcohols										
Undecanol	0.92	0.29	0.33	-	0.63	3.25	0.46	2.32	0.23	0.28
2E-dodecene-1-ol	3.8	5.72	4.86	7.06	0.14	11.65	0.43	13.78	2.48	5.73
Octadecanol	17.65	12.21	13.81	13.17	11	11.72	15.71	13.83	14.15	12.6
Terpenes										
Linalool	0.5	0.44	0.54	0.01	0.16	0.19	0.23	0.8	0.83	0.1
Geraniol	6.82	7.84	4.76	8.08	1.72	9.64	6.42	9.5	4.07	7.7
Nerolidol	4.06	2.93	0.83	-	0.3	0.83	-	-	11.37	3.44
Citronellal	0.68	-	0.77	-	0.15	-	0.48	-	0.22	-
p-menth-1-en-9-al	-	-	0.09	-	0.67	-	0.2	0.1	0.15	-
E-p-menthane	0.42	0.04	-	-	0.19	0.18	0.26	-	-	0.02
Dehydroxycislinalool oxide	1.67	0.54	1.7	0.64	4.06	2.74	2.37	0.14	0.76	0.4
Tetrahydrocitronellene	4.64	0.44	5.29	0.64	0.44	2.62	2.66	2.44	1.19	0.2
Lactones										
ɤ-Dodecalactone	1.21	0.83	-	-	3.08	0.87	3.91	0.29	1.19	0.52
ɤ- Decalactone	-	-	3.44	4.66	-	1.35	0.27	-	-	-
ɤ- Nonalactone	-	-	-	-	-	-	-	-	0.17	-
ɤ -undecalactone	-	-	-	-	-	-	-	-	0.23	-
Other compounds										
Tetradecene	15.41	7.42	10.36	8.02	1.59	5.42	3.7	5.79	9.82	7.7
Methylgamma ionone	1.15	0.58	0.75	0.73	4.46	2.53	2.41	3.71	0.78	0.63

Abbreviation of each cultivar: F= Festival, R= Redmerlin, S= Suzana, T= Tamar and W= Winter Dawn.

Table 2.Identified compounds in volatile constituents of five different cultivars (fresh and frozen) of strawberries

No.	Compound	KI	RRt	Mass	Festival		Red Merlin		Suzana		Tamar		Winter Dawn	
					fresh	frozen	fresh	frozen	fresh	frozen	fresh	frozen	fresh	frozen
1	Tetrahydrocitronellene	937	0.262	142	4.64	0.44	5.29	0.64	0.44	2.62	2.66	2.44	1.19	0.2
2	E-P-menthane	979	0.295	140	0.42	0.04	-	-	0.19	0.18	0.26	-	-	0.02
3	Dehydroxy(Z)linalool oxide	1008	0.328	152	1.67	0.54	1.7	0.64	4.06	2.74	2.37	0.14	0.76	0.4
4	2E-octenal	1060	0.323	126	0.26	0.44	1.48	-	-	2.33	0.83	0.76	-	0.41
5	Propyl hexanoate	1095	0.318	158	0.47	1.12	0.07	1.95	-	0.69	-	0.12	0.3	1.27
6	Linalool	1097	0.34	154	0.5	0.44	0.54	0.01	0.16	0.19	0.23	0.8	0.83	0.1
7	Nonanal	1101	0.37	142	0.47	0.11	-	-	-	-	0.67	-	0.23	0.17
8	Citronellal	1153	0.391	154	0.68	-	0.77	-	0.15	-	0.48	-	0.22	-
9	Benzyl acetate	1162	0.411	150	0.3	0.18	0.18	0.21	1.2	0.01	0.78	-	0.62	0.24
10	Decanal	1202	0.432	156	0.96	7.84	0.43	8.08	3.65	1.03	1.74	9.5	4.07	7.7
11	Heptylisobutanoate	1250	0.454	186	1.11	0.74	0.67	8.02	5.44	1.12	0.52	1.52	0.37	0.72
12	Geraniol	1253	0.475	154	6.82	7.84	4.76	8.08	1.72	9.64	6.42	9.5	4.07	7.7
13	2-undecanone	1294	0.495	170	0.23	-	0.31	0.25	0.32	0.23	0.22	0.81	0.18	0.21
14	P-menth-1-en-9-al	1295	0.516	154	-	-	0.09	-	0.67	-	0.2	0.1	0.15	-
15	Undecanal	1307	0.538	170	0.26	0.42	0.69	0.5	0.95	1.93	0.21	0.81	0.18	0.44
16	2E,4E-decadienal	1317	0.595	152	0.51	0.64	0.65	0.54	1.08	2.42	-	-	-	0.35
17	ɤ - Nonalactone	1361	0.651	156	-	-	-	-	-	-	-	-	0.17	-
18	Undecanol	1370	0.662	172	0.92	0.29	0.33	-	0.63	3.25	0.46	2.32	0.23	0.28
19	Tetradecene	1389	0.672	196	15.41	7.42	10.36	8.02	1.59	5.42	3.7	5.79	9.82	7.7
20	3-dodecanone	1391	0.694	184	0.32	0.2	3.48	0.83	1.91	1.09	1.18	1.28	0.4	0.18
21	Dodecanal	1409	0.724	184	2.4	2.9	3.48	2.92	3.9	2.01	2.56	2.48	0.98	2.86
22	ɤ -decalactone	1467	0.793	170	-	-	3.44	4.66	-	1.35	0.27	-	-	-
23	2E-dodecene-1-ol	1472	0.791	184	3.8	5.72	4.86	7.06	0.14	11.65	0.43	13.78	2.48	5.73
24	Methyl gamma ionone	1482	0.789	206	1.15	0.58	0.75	0.73	4.46	2.53	2.41	3.71	0.78	0.63
25	Nerolidol	1563	0.828	222	4.06	2.93	0.83	-	0.3	0.83	-	-	11.37	3.44
26	ɤ - undecalactone	1571	0.854	184	-	-	-	-	-	-	-	-	0.23	-
27	Hexenyl phenyl acetate	1634	0.888	218	0.34	0.23	0.19	0.16	0.24	0.07	0.7	0.09	0.21	0.26
28	ɤ -dodecalactone	1678	0.926	198	1.21	0.83	-	-	3.08	0.87	3.91	0.29	1.19	0.52
29	E-Nerolidol acetate	1717	0.964	264	0.17	0.19	0.19	0.16	0.06	0.09	0.03	0.1	0.25	0.22
30	E-14-hexadecenal	1824	0.972	238	17.27	10.64	13.69	11.49	3.05	8.34	1.1	0.18	13.93	10.57
31	Phenyl ethyl octanoate	1847	0.981	248	0.26	0.22	0.18	0.29	0.57	-	0.38	0.1	0.27	0.22
32	Benzyl salicylate	1866	0.985	228	0.47	0.16	0.17	0.21	0.89	-	0.46	-	0.24	0.18
33	Phenyl ethyl phenyl acetate	1914	0.99	240	0.28	-	0.12	0.26	1.36	-	0.5	0.18	0.55	0.16
34	Octadecanol	2078	1	270	17.65	12.21	13.81	13.17	11	11.72	15.71	13.83	14.15	12.6
35	Methyl octadecanoate	2125	1.018	298	0.35	-	-	-	-	0.03	1.1	0.18	0.16	-
36	Phenethylcinnamate	2180	1.129	252	0.57	0.42	-	-	0.73	0.09	0.71	-	0.59	0.46
37	Ethyl octadecanoate	2197	1.241	312	0.2	-	-	-	0.32	6.12	15.52	5.83	0.09	7.95
38	Octadecanol acetate	2210	1.474	312	1.49	-	0.94	1.65	-	1.5	2.27	1.35	1.05	1.99

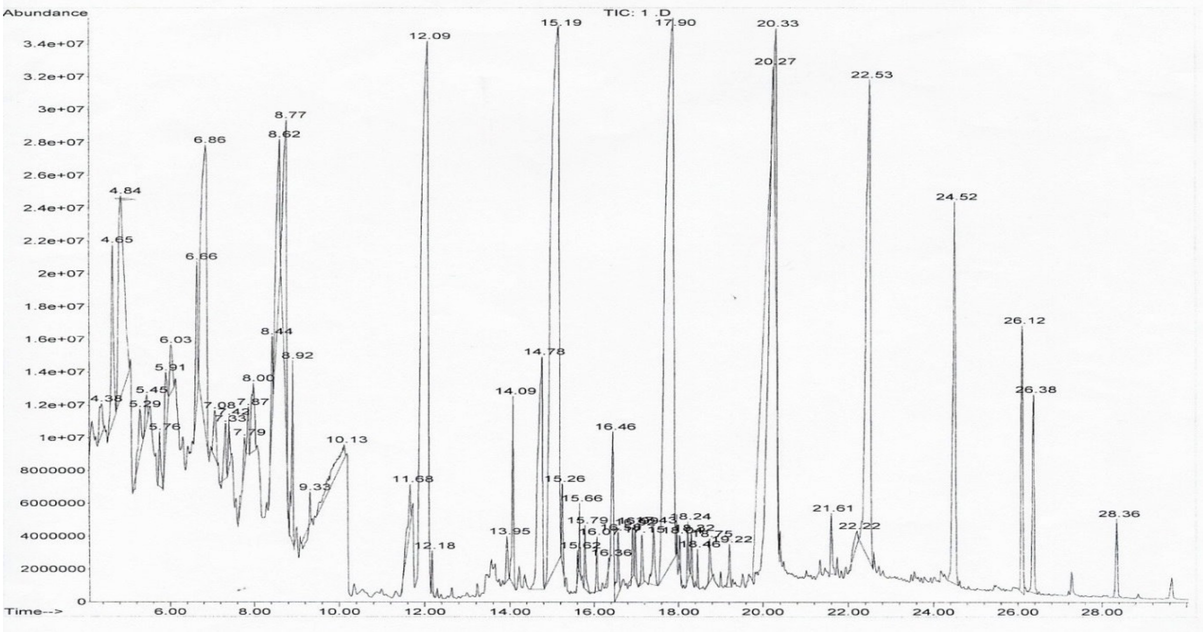

Figure 1. Total ion chromatogram of GC/MS analysis of n-hexane extract of fresh Festival cultivar fruits

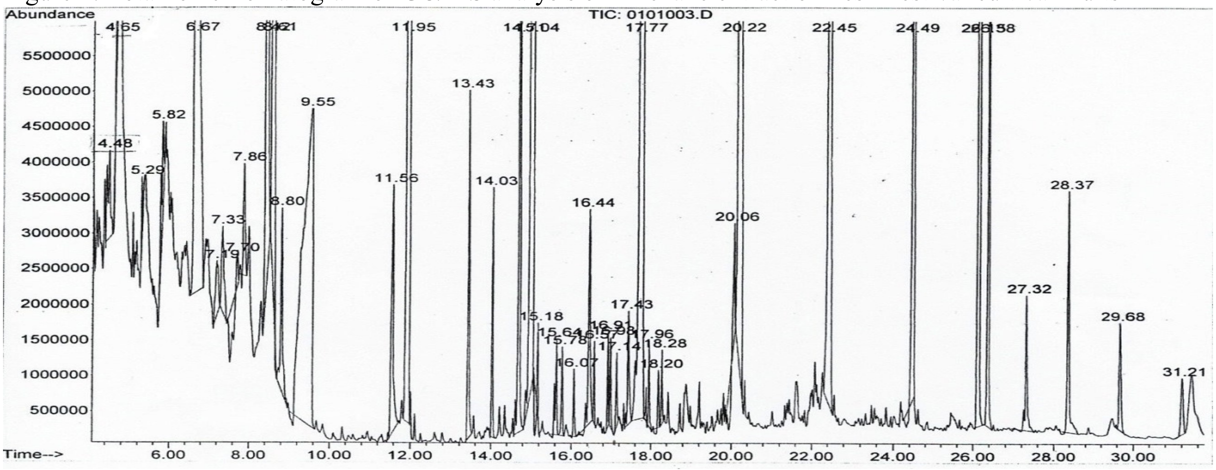

Figure 2.Total ion chromatogram of GC/MS analysis of n-hexane extract of frozen Festival cultivar fruits

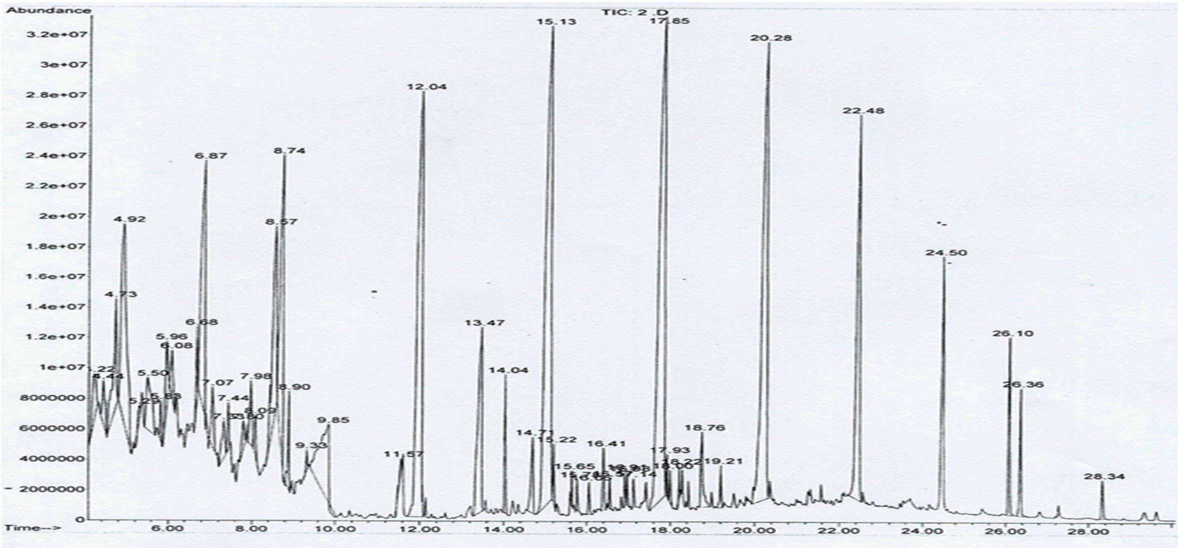

Figure 3.Total ion chromatogram of GC/MS analysis of n-hexane extract of fresh Red Merlin cultivar fruits

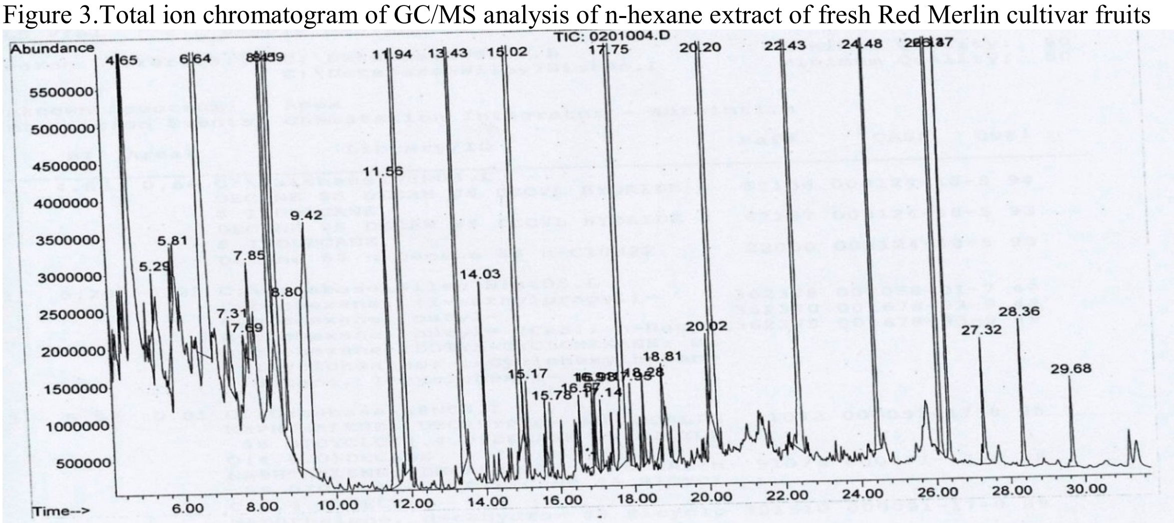

Figure 4.Total ion chromatogram of GC/MS analysis of n-hexane extract of frozen Red Merlin cultivar fruits

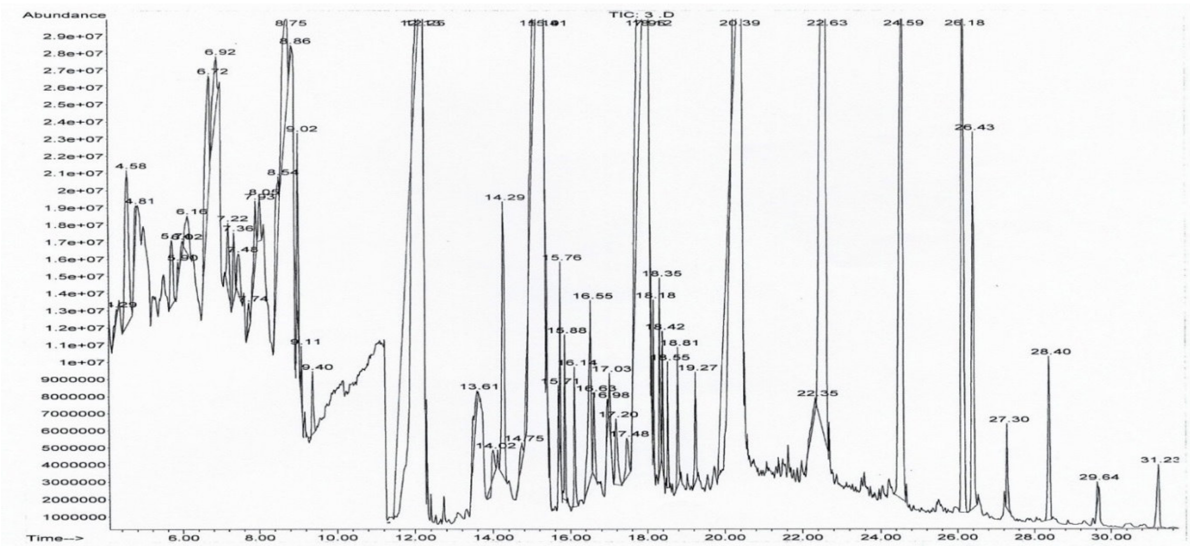

Figure 5.Total ion chromatogram of GC/MS analysis of n-hexane extract of fresh Suzana cultivar fruits

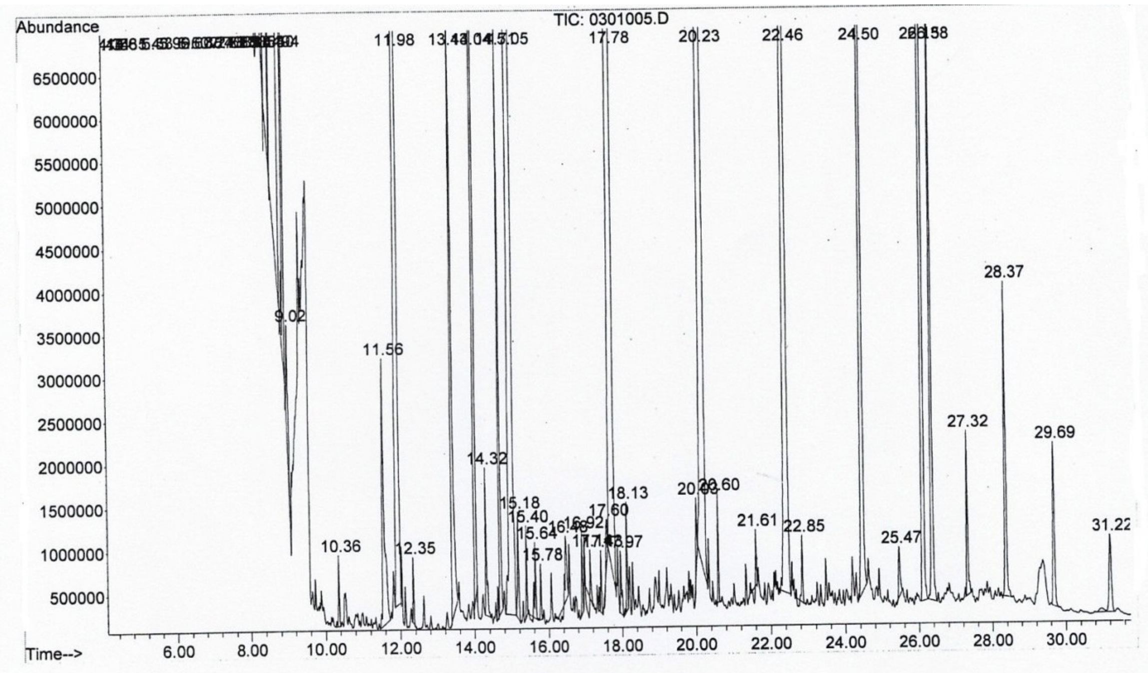

Figure 6.Total ion chromatogram of GC/MS analysis of n-hexane extract of frozen Suzana cultivar fruits

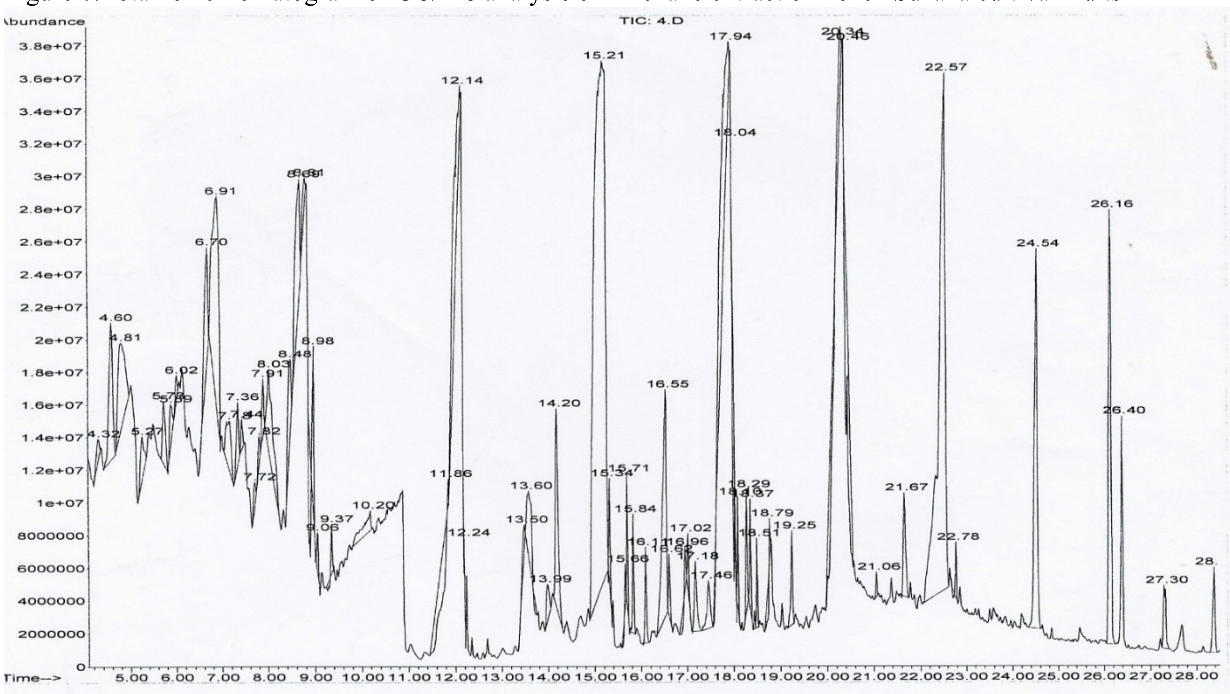

Figure 7.Total ion chromatogram of GC/MS analysis of n-hexane extract of fresh Tamar cultivar fruits

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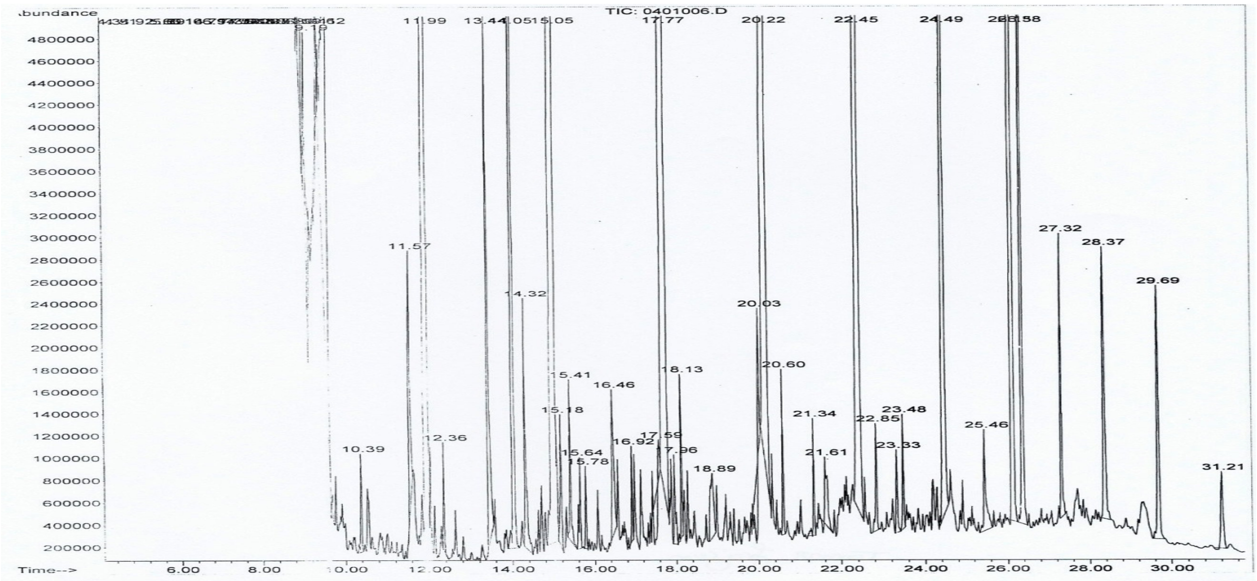

Figure 8.Total ion chromatogram of GC/MS analysis of n-hexane extract of frozen Tamar cultivar fruits

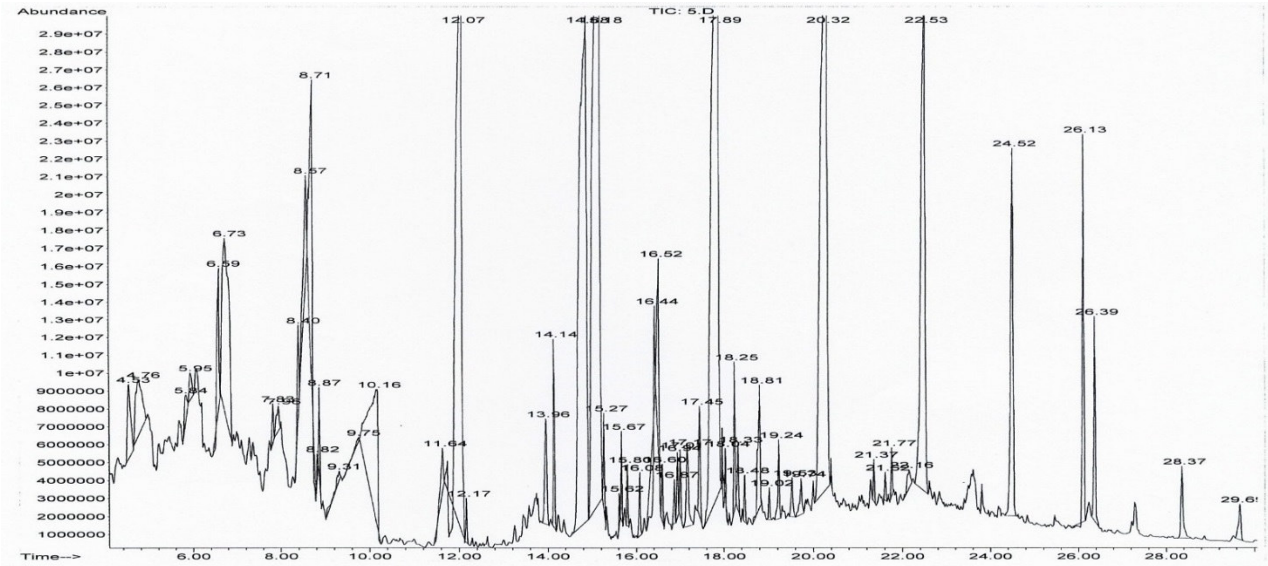

Figure 9.Total ion chromatogram of GC/MS analysis of n-hexane extract of fresh Winter Dawn cultivar fruits

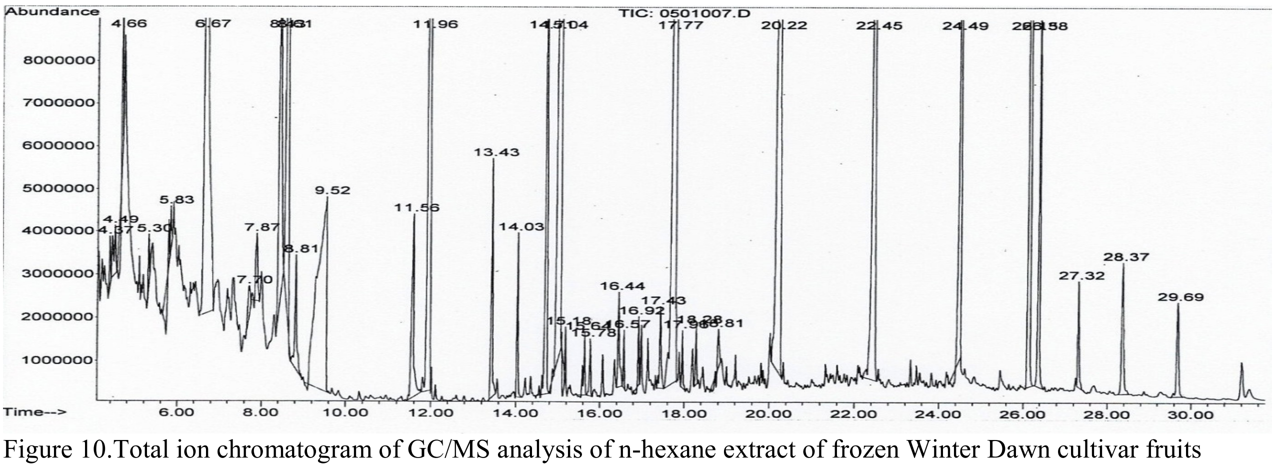

Figure 10.Total ion chromatogram of GC/MS analysis of n-hexane extract of frozen Winter Dawn cultivar fruits

Table 3. Antimicrobial activity of volatile constituents of strawberries expressed as inhibition diameter zones in millimeters (mm) against the pathological strains based on well diffusion assay.

Micro-organism	Festival	Red Merlin	Suzana	Tamar	Winter Down	Standard	
						Ciprofloxacin	Ketoconazole
Bacillus subtilis ATCC6633	32	32	20	20	25	22	-ve
Staphylococcusaureus ATCC 29213	25	20	17	20	26	22	-ve
KlebseillapeneumoniaeATCC13883	28	20	17	20	27	25	-ve
CandidaAlbicans NRRLY-477	30	20	17	20	26	-ve	23
Aspirgillusniger GA.467	-ve	-ve	-ve	-ve	-ve	-ve	22

Table 4.Nutritional value of five different cultivars of garden strawberry cultivated in Egypt.

	Proximates					Vitamins	Minerals			
Cultivar name	Protein	Fats	Carbohydrates	Moisture	Ash	Vitamin c	Phosphorus (p)	Magnesium (Mg)	Calcium (Ca)	Potassium (K)
	gm%					mg%	mg/kg			mg/100g
Festival	1.04	0.2	8.46	89.96	0.34	24	303.214	179.977	191.86	204.27
Redmerlin	0.62	0.2	7.45	91.49	0.24	28	213.72	165.635	145.71	174.715
Suzana	0.97	0.2	9.46	89.03	0.34	22.7	306.377	190.148	156.58	255.406
Tamar	0.59	0.12	7.87	91.18	0.24	47.4	220.065	171.335	163.733	140.128
Winter Dawn	0.59	0.18	7.66	91.4	0.17	28	213.9	174.158	174	235.350