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Physiological properties of novel melon cultivars (cv. Meloni and cv. Tacapa Green Black) during storage

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Abstract

Melon (*Cucumis melo* L.) has polymorphic varieties that affect genetic diversity. Melon cv. Meloni and cv. Tacapa Green Black are new cultivars produced by Universitas Gadjah Mada. The information about respiration rate, volatile compounds, and firmness, including the impact on storage time of those novel cultivars, is not available yet. This work aimed to investigate the respiration rate, volatile compounds, and firmness of melon cv. Meloni and Tacapa Green Black during 20 days of storage at a temperature of 21°C. Based on respiration rate measurement, melon cv. Meloni and cv. Tacapa Green Black are classified into climacteric and non-climacteric fruit, respectively. The volatile compounds were extracted using solvent extraction followed by gas chromatography-mass spectrometry (GC-MS). It identified more than seventy volatile compounds in melon cv. Meloni, whereas only 20 volatile compounds were found in cv. Tacapa Green Black at harvest time and altered during storage. Melon cv. Meloni has a highly aromatic volatile compound but short shelf life according to firmness. Whereas cv. Tacapa Green Black could be stored until 20 days in form shape but lacking volatile compounds. Melon cv. Meloni and cv. Tacapa Green Black has good potential and could be a promising commercial horticultural product.

1. Introduction

Melon fruits have unique ripening behaviour. It could belong to climacteric and non-climacteric fruit (Obando-ulloa *et al.*, 2008). The respiration rate is one of the parameters to determine the ripening behaviour of fruit. The measurement of respiration rate could be one of the ways to predict the fruit shelf life. This is due to respiration being strongly related to fruit quality parameters such as volatile compounds to compose aroma and firmness. During storage, the rapid respiration rate can lead to shorter shelf life and vice versa (Workneh and Osthoff, 2010). The characteristic of climacteric melons is usually more aromatic but loses firmness rapidly rather than non-climacteric melons (Shalit *et al.*, 2001; Saladie *et al.*, 2015). The aroma and firmness are the crucial attributes of melon fruit quality perceived by consumers (Lester, 2006). The volatile compounds in charge of the key contributors to the unique aroma of melon are various and cultivar dependence (Nuñez-Palenius *et al.*, 2008). Melon cv. Meloni and Tacapa Green Black are new cultivars produced by Universitas Gadjah Mada. Both cultivars have prominent characteristics. Melon cv. Meloni has an oval shape of the fruit, orange-fleshed colour, sweet (7-16% Brix), pleasant aroma, and smooth yellow skin (Amalia, 2016). Moreover, melon cv. Tacapa Green Black has a big round shape of the fruit, green yellowish fleshed colour, sweet (7-11% Brix), resistant to powdery mildew, and long storage time (Aristya and Daryono, 2012). Those novel cultivars have different characteristics compared with the other melon cultivars. Since the melons are new cultivars, the respiration rate, volatile compounds, and firmness, including the impact of storage time of those characteristics in melon cv. Meloni and Tacapa Green Black are not available yet. Therefore, this study aimed to investigate the respiration rate, volatile compounds, and firmness of those novel cultivars and their alteration during storage.

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2. Materials and methods

2.1 Materials

Melon cv. Meloni and Tacapa Green Black were grown in a greenhouse at Universitas Gadjah Mada experimental farm from September until November 2020. The fruits were harvested at the full ripe stage at 39 days after pollination (DAP) and transferred gently to the Laboratory of Food Engineering in Faculty of Agricultural Technology Universitas Gadjah Mada using partitioned corrugated boxes among melon fruit to avoid mechanical injury during transportation. All chemicals used in the experiment were analytical grades such as N-pentane, dichloromethane, Ethanol, Sodium hypochlorite, 2.5% glutaraldehyde, sodium phosphate buffer pH 7.2 (Merck), ethyl decanoate as internal standard (Sigma), and CO_2 standard (Samator).

2.2 The storage condition of melon fruits

The selected melon fruits without decay were washed thoroughly in cold running tap water. Then immersed in 50 ppm sodium hypochlorite (Merck) 5.25% for 1 min for reducing the microbial in the skin of melon fruits. The melons were rinsed in a cold running tap again to remove sodium hypochlorite residue and allowed to drain. Samples were kept in a storage room at 21ºC that simulated commercial temperature and 74% RH during 20 days of storage in a partitioned corrugated box.

2.3 Respiration rate measurement

The respiration rate of melon was examined by the following method of Oh *et al.* (2011) with minor modification. Three fruits from each cultivar were retained individually in a 16.3 L air-tight jar for 3 hrs at 20°C. After incubation, 1 mL of headspace gas was withdrawn by tight syringe and injected into gas chromatography (GC-2010 Plus, Shimadzu, Oregon, USA) equipped with Rt-Q-BOND (30m, 0.32 mm ID, 10 µm df) (Restek, Bellefonte, PA, USA), and thermal conductivity detector (TCD). The carrier gas was nitrogen at the flow rate of 0.8 mL/s. The temperatures in the injector, oven, and detector were 150, 70, and 200°C, respectively. The quantification of carbon dioxide used was the carbon dioxide standard. The CO_2 production was expressed mg kg^{-1} fruit h^{-1}.

2.4 Volatile compounds extraction

Approximately 400 g of fruit flesh were extracted using a maceration method following the Nussbaumer and Hostettler (1996) method with some modifications. The fruit fleshes were homogenized and macerated with 540 mL mixture of n-pentane and dichloromethane (Merck, Darmstadt, Germany) (2:1, v/v), followed by an addition 10 µL ethyl decanoate (Sigma-Aldrich, Saint Louis, MO, USA) (2.15 µg/mL) as internal standard. The macerated sample was incubated at -20ºC for 24 hrs. After the maceration, the extract was decanted and dried over anhydrous sodium sulphate (Merck, Darmstadt, Germany). The free water extract was concentrated by rotary evaporator to approximately 5 mL and finally flushed with nitrogen gas to 1 mL and stored at -20ºC before analysis

2.5 Volatile compounds identification

The identification of volatile compounds was based on the reference method (Lignou *et al.*, 2014), with minor modifications. The volatile compounds of the extracted sample were identified by GC-MS Agilent 7890A with CTC PAL auto sample with MS Agilent 5975C detector (Agilent, Santa Clara, CA). The instrument was equipped with a capillary column DB-WAX Agilent JW (30m × 250 µm × 0.25 µm) and a split -less injector. This study used helium was used as a carrier gas, and the flow rate was 0.8 mL/min. The injector temperature was 250°C, and the volume of injection was 0.5 µL. The oven temperature program was 40°C for 2 mins and raised to 240°C at 4°C/min. The mass spectrometer was recorded in the electron ionization mode at 70 eV, a source temperature of 200°C and a scan range from *m/z* 29 to 550. Each component was identified using a mass spectra database (NIST 14 Library), Linear Retention Indices (LRI), and literature data. The retention time of the n-alkanes series (C_{11}-C_{28}) was used to calculate linear retention indices (LRI) according to the Van den Dool and Kratz equation (Van den Dool and Kratz, 1963).

2.6 Flesh firmness measurement

The flesh firmness was measured at 0, 10, and 20 days of storage. The fruits were peeled and sliced longitudinally. Seeds were removed, and the seed cavity was cleaned by removing 1 to 2 mm tissue. Melon was cut into three parts as follows: (1) near the fruit stalk, (2) in the middle, and (3) at the end of the fruit. Cut into 2×2×2 cm cubes. Every cube was run in duplicate. The texture parameter was analysed by CT3 Texture Analyzer (Brookfield, Middleborough, MA, USA) equipped with a TA41 probe. The probe diameter was 6 mm. The penetration depth was 5 mm, with a probing rate was 1 mm/s (Munira *et al.*, 2013)

2.7 Microstructure cell wall

The microstructure of the cell wall was determined by performing the reference method (Samuel *et al.*, 1993). The flesh was cut into 1 × 1 × 0.5 cm, then immersed in 2.5% glutaraldehyde, buffered with 0.1 M sodium phosphate buffer pH 7.2 for 24 hrs at room

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temperature. The fixed pieces were dried with a vacuum drier and observed by scanning electron microscopy (SEM) JSM-6510LA (JEOL, Tokyo, Japan).

2.8 Statistical analysis

The data obtained were statistically analysed using Univariate analysis of variance (ANOVA) followed by Duncan's Multiple Range Test with a 95% confidence level to determine the degree of difference in values between treatments. Principal Component Analysis (PCA) was conducted to investigate the interaction among volatile compounds using Minitab 19.

3. Results and discussion

3.1 Respiration rate of melon cv. Meloni and Tacapa Green Black during storage

The respiration rate during storage has a strong influence on fruit quality, such as aroma and texture properties. As new cultivars, melon cv. Meloni and cv. Tacapa Green Black respiration rate should be measured and classified into climacteric or non-climacteric. The respiration rate of cv. Meloni and cv. Tacapa Green Black during 20 days of storage was shown in Figure 1. The respiration rate of cv. Meloni increased transients until the sixth day (89 mg/kg. Hour) and declined considerably until the 20th day. The melon cv. Meloni showed climacteric behaviour with respiration having a well-defined peak at the sixth day of storage. According to Mishra and Gamage (2007), the respiration rate of melon cv. Meloni was included in the high respiration group. A high respiration rate led to a high breakdown of carbon compounds to produce volatile compounds. Unfortunately, the high respiration rate could lead to loss of flesh firmness and shorter shelf life of melon fruit (Saladie *et al.*, 2015).

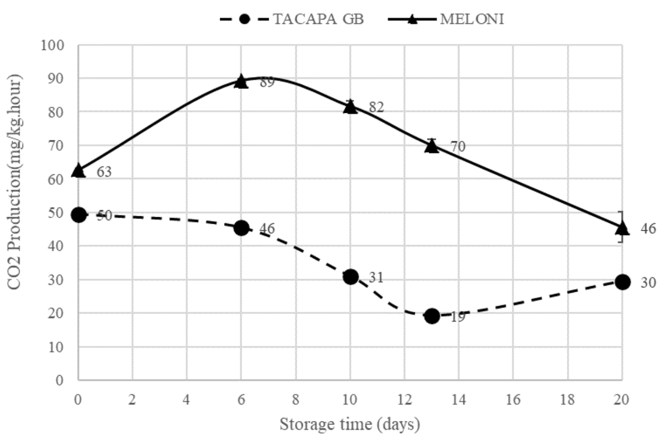

Figure 1. Respiration rate of melon cv. Meloni and Tacapa Green Black during 20 days of storage at 21°C.

Vice versa, the respiration rate of melon cv. Tacapa Green Black tended to decrease from 50 to 30 mg/kg. An hour at the end of storage and no respiratory burst. The pattern of cv. Tacapa Green Black respiration shows non -climacteric behaviour, corresponding with Obando-ulloa *et al.* (2008) and Miccolis and Saltveit (1995) reported that carbon dioxide production of several melon cultivars declined during storage. The low respiration rate could delay flesh softening during postharvest storage and prolong the shelf life of melon fruit (Pech *et al.*, 2008) but led to a lack of aromatic volatile compounds (Obando-ulloa *et al.*, 2008).

3.2 Volatile compounds profile of melon cv. Meloni and Tacapa Green Black during storage

The volatile compounds of melon cv. Meloni and Tacapa Green Black were identified by Gas Chromatography-Mass Spectrometry (GC-MS Agilent 7890A with CTC PAL auto sample with MS Agilent 5975C detector). The results of GC-MS are summarized in Table 1. At the time of harvest (0 days) and after 20 days of storage, solvent extraction revealed 74 and 58 volatile compounds in melon cv. Meloni, respectively. Meanwhile, only twenty volatile compounds were found in melon cv. Tacapa Green Black during harvest (0 days) and storage (20 days). During 20 days of storage, the total volatile compound concentration in cv. Meloni decreased by 64%, while it increased by 41% in cv. Tacapa Green Black.

From Table 1, it is shown that melon cv. Meloni has much more volatile compounds compared to cv. Tacapa Green Black. This result aligns with the respiration rate measurement of this study where melon cv. Meloni has been indicated as a climacteric fruit that shows climacteric behaviour with high levels of respiration. Aromatic volatile compounds are abundant in climacteric melon varieties such as the reticulatus and cantalupensis groups (e.g., cantaloupes). Non-climacteric melon varieties, such as the indoors variety, do not experience a respiratory burst, resulting in a lack of aroma (Saladie *et al.*, 2015).

Table 1 shows the highest number of volatile compounds in cv. Meloni at 0 days is benzyl alcohol. After storage, the concentration declined from 1917 µg/kg dry weight (DW) to 313 µg/kg DW. The odour description of benzyl alcohol is floral, fruity, and balsamic (Verzera *et al.*, 2011). This compound could be used as a substrate to form benzyl acetate through benzyl -alcohol acyltransferase enzyme activity (Shalit *et al.*, 2000). This result was proven by the increasing concentration of benzyl acetate from 43 µg/kg DW to 569 µg/kg DW at the end of storage. In contrast, Beaulieu (2005) reported that the benzyl acetate concentration in melon cv. Athena and cv. Sol Real declined during 11 days of storage. Benzyl acetate is a significant compound in several melon cultivars (Aubert

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Table 1. The volatile compounds (µg/kg dry weight) identified in melon cv. Meloni and cv. Tacapa Green Black at harvest time and after 20 days of storage at 21°C.

Code	Compounds	CAS	LRI[a]	Meloni (days)		Tacapa Green Black (days)	
				0	20	0	20
	Esters						
E1	Butyl acetate	123-86-4		115	211	ND	14
E2	Pentyl acetate	628-63-7	1177	ND	18	ND	ND
E3	Oxalic acid, isobutyl hexyl ester	1000309-37-1	1217	ND	11	ND	ND
E4	Ethyl hexanoate	123-66-0	1237	ND	10	ND	ND
E5	2-Methylbut-2-en-1-yl acetate	33425-30-8	1250	ND	8	ND	ND
E6	Hexyl acetate	142-92-7	1275	19	95	ND	28
E7	3-Hexen-1-ol, acetate, (E)-	3681-82-1	1318	ND	24	ND	ND
E8	Ethyl octanoate	16630-66-3	1437	ND	14	14	ND
E9	1,2-Propanediol, diacetate	623-84-7	1515	303	56	ND	13
E10	2,3-Butanediol, diacetate	1114-92-7	1527	34	161	ND	7
E11	2-Furanmethanol, acetate	623-17-6	1538	32	10	ND	ND
E12	1,2-Ethanediol, diacetate	111-55-7	1550	ND	89	ND	ND
E13	Methyl 3-hydroxy-1-azetidinecarboxylate	118972-97-7	1560	ND	6	ND	ND
E14	1,2-Propanediol, 1-acetate	627-69-0	1581	175	ND	ND	ND
E15	cis-3-Nonen-1-ol, acetate	13049-88-2	1607	ND	6	ND	ND
E16	1,3-Butanediol, diacetate	1117-31-3	1625	ND	63	ND	ND
E17	1,3-Propanediol, diacetate	628-66-0	1658	ND	60	ND	ND
E18	3-6-Nonadien-1-yl-acetate	76649-26-8	1668	68	10	ND	ND
E19	Benzyl acetate	140-11-4	1728	43	569	ND	284
E20	1,4-Butanediol, diacetate	628-67-1	1781	ND	73	ND	ND
E21	2-Penten-1-ol, acetate, (Z)-	42125-10-0	1792	ND	22	ND	ND
E22	Acetic acid, 2-phenylethyl ester	103-45-7	1815	ND	24	ND	50
E23	1,5-Diacetoxypentane	6963-44-6	1890	ND	19	ND	ND
E24	Phthalic acid, butyl iso-hexyl ester	1000309-03-6	2544	79	ND	ND	ND
E25	Dibutyl phthalate	84-74-2	2622	180	ND	ND	ND
E26	Butyl isobutyl phthalate	17851-53-5	2701	660	ND	ND	ND
	TOTAL			1709	1559	14	396
	Alcohols						
C1	1-Octanol, 3,7-dimethyl-	106-21-8		78	ND	ND	ND
C2	1-Propanol, 2-methyl-	78-83-1	1101	94	ND	ND	ND
C3	3-Pentanol	584-02-1	1116	ND	128	120	122
C4	3-Ethyl-2-pentanol	609-27-8	1128	44	748	388	587
C5	1-Butanol, 2-methyl-	137-32-6	1211	833	7	ND	ND
C6	1-Dodecanol, 2-hexyl-	110225-00-8	1246	50	ND	ND	ND
C7	1-Butanol, 3-methyl-	123-51-3	1255	204	36	11	23
C8	2-Propanol, 1-(1-methylethoxy)-	3944-36-3	1290	ND	ND	18	0
C9	2-Hexanol	626-93-7	1311	99	38	24	16
C10	1-Hexanol	111-27-3	1361	ND	10	ND	ND
C11	1-Decanol, 2-hexyl-	2425-77-6	1343	16	ND	ND	ND
C12	1-Octen-3-ol	3391-86-4	1456	19	7	ND	ND
C13	1,3-Dioxolane-2-methanol, 2,4-dimethyl-	53951-43-2	1546	ND	30	ND	ND
C14	1-Butanol, 3-methoxy-	2517-43-3	1568	ND	86	ND	45
C15	1-Hepten-4-ol	3521-91-3	1605	29	21	ND	ND
C16	4-Penten-2-ol	625-31-0	1621	ND	ND	21	ND
C17	p-Menth-8-en-1-ol	138-87-4	1635	104	ND	ND	ND
C18	(6Z)-Nonen-1-ol	35854-86-5	1725	91	ND	ND	ND
C19	3,6-Nonadien-1-ol, (E,Z)-	56805-23-3	1758	155	ND	ND	ND
C20	1,5-Pentanediol, 1-acetate	68750-23-2	1758	ND	20	ND	ND

[a]Linear retention index on DB-WAX column, calculated from a linear equation between each pair of straight chain n-alkanes C11-C28.

ND: not detected.

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Table 1 (Cont.). The volatile compounds (µg/kg dry weight) identified in melon cv. Meloni and cv. Tacapa Green Black at harvest time and after 20 days of storage at 21°C.

Code	Compounds	CAS	LRI[a]	Meloni (days)		Tacapa Green Black (days)	
				0	20	0	20
C20	1,5-Pentanediol, 1-acetate	68750-23-2	1758	ND	20	ND	ND
C21	3-Piperidinol	6859-99-0	1801	ND	6	ND	ND
C22	p-Cymen-8-ol	1197-01-9	1852	78	ND	13	ND
C23	Benzyl alcohol	100-51-6	1880	1917	313	140	66
C24	1,4-Pentanediol	626-95-9	1898	ND	10	18	ND
C25	Phenylethyl Alcohol	58783	1915	118	39	18	26
C26	3-Phenylpropanol	122-97-4	2051	25	6	18	ND
C27	Ethanol, 2-(vinyloxy)-	764-48-7	2497	25	ND	ND	ND
	TOTAL			3980	1507	788	885
	Benzenes						
B1	Benzene, chloro-	108-90-7	1222	47	ND	ND	ND
B2	Benzene, 1-ethyl-2-methyl-	611-14-3	1224	77	ND	ND	ND
B3	Benzene, 1-ethyl-3-methyl-	620-14-4	1244	51	ND	ND	ND
B4	Benzene, 1,2,3-trimethyl-	526-73-8	1279	160	ND	ND	ND
B5	Benzene, 1-chloro-4-methyl-	106-43-4	1313	ND	ND	13	12
B6	Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	1323	90	ND	ND	ND
B7	Mesitylene	108-67-8	1333	107	ND	ND	ND
B8	Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	1351	54	ND	ND	ND
B9	Benzene, 1-ethyl-2,3-dimethyl-	933-98-2	1364	1118	ND	5	ND
B10	Benzene, 1,2,3,5-tetramethyl-	527-53-7	1421	86	ND	ND	ND
B11	Benzene, 1,2,4,5-tetramethyl-	95-93-2	1432	145	ND	ND	ND
B12	Benzene, 1-methyl-4-(1-methylpropyl)-	1595-16-0	1445	28	ND	ND	ND
B13	Benzene, 1,2,3,4-tetramethyl-	488-23-3	1484	60	ND	ND	ND
B14	Benzyl chloride	100-44-7	1512	105	157	86	74
B15	Benzene, (dichloromethyl)-	98-87-3	1713	ND	14	ND	11
B16	4-Methylstyrene	622-97-9	1943	ND	14	ND	ND
	TOTAL			2127	186	104	97
	Aldehydes						
D1	Nonanal	124-19-6	1394	38	ND	ND	ND
D2	Benzaldehyde	100-52-7	1520	239	19	29	ND
D3	Benzaldehyde, 2-hydroxy-	69437	1673	19	ND	ND	ND
D4	Benzaldehyde, 3-hydroxy-4-methoxy-	621-59-0	2564	74	ND	ND	ND
	TOTAL			370	19	29	ND
	Ketones						
K1	Acetoin	513-86-0	1285	385	116	38	ND
K2	2-Acetoxy-3-butanone	4906-24-5	1383	ND	52	ND	ND
K3	2-Pentanone, 4-hydroxy-	4161-60-8	1461	ND	12	34	14
K4	1,3-dioxolan-2-one,4,5-dimethyl-	4437-70-1	1616	ND	8	ND	ND
K5	Acetophenone	98-86-2	1648	37	ND	ND	ND
K6	2-Hexanone, 3-methyl-	2550-21-2	1663	ND	15	ND	ND
K7	Furaneol	3658-77-3	1676	18	59	ND	ND
K8	2-Pyrrolidinone, 1-methyl-	872-50-4	1682	223	10	ND	ND
K9	Ethanone, 1-(2-methylphenyl)-	577-16-2	1772	8	ND	ND	ND
K10	trans-β-Ionone	79-77-6	1940	36	ND	ND	ND
K11	2,4-Pentanedione, 3-(9-decenyl)-	185053-96-7	2007	63	31	ND	ND
K12	2-Hexanone	591-78-6	2063	25	19	ND	ND
K13	Bupropion	34911-55-2	2077	ND	4	ND	ND

[a]Linear retention index on DB-WAX column, calculated from a linear equation between each pair of straight chain n-alkanes C11-C28.

ND: not detected.

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Table 1 (Cont.). The volatile compounds (µg/kg dry weight) identified in melon cv. Meloni and cv. Tacapa Green Black at harvest time and after 20 days of storage at 21°C.

Code	Compounds	CAS	LRI[a]	Meloni (days)		Tacapa Green Black (days)	
				0	20	0	20
K14	2(3H)-Furanone, 5-hexyldihydro- (γ-decalactone)	706-14-9	2144	ND	12	ND	ND
K15	2(3H)-Furanone, dihydro-4-hydroxy-	5469-16-9	2168	ND	ND	ND	8
K16	3-(Ethyl-hydrazono)-butan-2-one	1000194-94-0	2251	ND	16	ND	ND
K17	Benzophenone	119-61-9	2478	33	ND	ND	ND
	TOTAL			827	355	72	22
	Phenols						
P1	Butylated Hydroxytoluene	128-37-0	1912	16	ND	ND	ND
P2	Phenol, 2-methoxy-3-(2-propenyl)-	15314	2168	46	ND	ND	ND
P3	Phenol, m-tert-butyl-	585-34-2	2292	675	ND	ND	ND
P4	2,4-Di-tert-butylphenol	96-76-4	2317		ND	11	9
P5	TOTAL			737	ND	11	9
P6	Terpenoids						
P7	D-Limonene	5989-27-5	1199	61	ND	ND	ND
P8	o-Cymene	527-84-4	1269	93	ND	ND	ND
P9	p-Cymene	99-87-6	1407	108	ND	ND	ND
P10	Longifolene	475-20-7	1566	56	ND	ND	ND
P11	Fenchol	1632-73-1	1587	43	ND	ND	ND
P12	Terpineol	1000411-59-6	1701	261	ND	ND	ND
P1	γ-Terpineol	586-81-2	1705	86	ND	ND	ND
P2	(E)-β-Famesene	18794-84-8	2164	31	ND	ND	ND
	TOTAL			740	ND	ND	ND
	Naphthalenes						
N1	Naphthalene	91-20-3	1734	70	ND	ND	ND
N2	Naphthalene, 2-methyl-	91-57-6	1843	252	ND	ND	ND
N3	Naphthalene, 1,6-dimethyl-	575-43-9	1956	55	ND	ND	ND
N4	Naphthalene, 1,4-dimethyl-	571-58-4	1993	29	ND	ND	ND
N5	Naphthalene, 1,6,7-trimethyl-	2245-38-7	2097	24	ND	ND	ND
	TOTAL			430	ND	ND	ND
	Sulphur compounds						
S1	Methyl 2-(methylthio) acetate	16630-66-3	1407	ND	8	ND	ND
S2	1-Octadecanesulphonyl chloride	1000342-70-4	1440	20	ND	ND	ND
S3	Ethyl (methylthio) acetate	4455-13-4	1447	ND	6	ND	ND
S4	Thiirane, methyl-	1072-43-1	1493	ND	312	19	56
S5	Ethanol, 2-(methylthio)-	5271-38-5	1533	54	12	ND	ND
S6	Sulfide, allyl methyl	10152-76-8	1630	ND	25	ND	ND
	TOTAL			75	363	19	56

[a]Linear retention index on DB-WAX column, calculated from a linear equation between each pair of straight chain n-alkanes C11-C28.
ND: not detected.

and Bourger, 2004) but has a lower concentration in other fruits such as mango cv. San Diego (Pino *et al.*, 2005), mangaba (*Hancornia speciosa* Gomes) fruit (Sampaio and Nogueira, 2006), and raspberry (Aprea *et al.*, 2015). Benzyl acetate has an odour threshold of 15µg/kg (Buttery *et al.*, 1982). The odour description of benzyl acetate is fruity, fresh, floral, sweet, and pine (Amaro *et al.*, 2012). It could be an important key compound contributing to the aroma of melon cv. Meloni. The identification of volatile compounds after 20 days of storage revealed that 3-ethyl-2-pentanol and benzyl acetate are the most volatile compounds in cv. Meloni.

Furaneol and trans-β-ionone were found exclusively in cv. Meloni in this study. Furaneol content was 18 g/kg

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DW at harvest and increased to 59 g/kg DW after 20 days of storage. Furaneol is scarcely found in melon fruits and only in trace amounts (Hayata *et al.*, 2003; Lignou *et al.,* 2013). Furaneol has an odour described as strawberry-like, caramel-like, and sweet (Hayata *et al.*, 2003). Furaneol, which has a low odour threshold in the water of 5 g/kg (Du *et al.*, 2010), could contribute to the aroma of melon cv. According to Hayata *et al.* (2003), furaneol had high flavour dilution and emerged to be a potent odorant in Miyabi melon. Moreover, trans-β-ionone with flower and raspberry odour description can only be detected at harvest time in cv. Meloni (36 µg/kg DW). The melon cv. Meloni has orange flesh. Trans- β-ionone which is mostly found in orange-fleshed melon, is a carotenoid-derivate volatile compound produced from β-carotene cleaved by carotenoid cleavage dioxygenase (El Hadi *et al.*, 2013). The low odour threshold of trans-β-ionone (0.1 µg/kg in water (Du *et al.*, 2010) also could have contributed to the aroma of cv. Meloni.

Table 1 shows that alcohols were found to be the dominant volatile compounds in melon cv. Tacapa Green Black. During 20 days of storage, the dominant volatile compound in melon cv. Tacapa Green Black is 3-ethyl-2 -pentanol. The concentration increased from 388 to 587 g/kg DW after 20 days of storage. Shalit *et al.* (2001) reported that aldehyde and alcohol were the most abundant volatile compounds in the cultivar Rochet fruit, a non-climacteric melon. For the first time, 2(3H)-Furanone, dihydro-4-hydroxy- was discovered in melon fruit in this study. Furthermore, Pereira *et al.* (2011) also reported this compound was found for the first time in the green flesh kiwi cv. Hayward and the yellow flesh Chickasaw plum cv.Marsh. The odour description of this compound was fruity (Wang *et al.*, 2018). Parthasarathy *et al.* (2015) identified 2(3H)-Furanone, dihydro-4hydroxy as the second highest (18.61%) antifungal metabolite in unripe healthy mango peel cv. Neelum against *Colletotrichum gleosporiodes* and *Lasiodiplodia theobromae*.

The odour activity value (OAV) was calculated as the ratio of the concentration of a volatile compound to its odour detection threshold in water (Zhu *et al.*, 2018). The OAV was used to assess the volatile compounds that contribute to the overall melon aroma. The threshold values using data from the literature. According to Hasbullah *et al.* (2021), compounds that have the odour active value (OAV) of more than one are considered to contribute to the aroma of melon. Calculating the OAV is required to determine the volatile compounds that contribute to the melon cv. Meloni and cv. Tacapa Green Black aroma. However, searching through several papers does not reveal that all volatile compounds found in melon cv. Meloni and cv. Tacapa Green Black have a threshold. Only volatile compounds with known thresholds will be calculated for the OAV in this study. Table 2 shows the OAV of volatile compounds in melon cv. Meloni and cv. Tacapa Green Black during storage has a high presence and an important role in the aroma. Generally, odorants with high OAVs are more likely to be important, although aroma synergy and suppression exist (Du *et al.*, 2010). Table 2 indicates that there are nine different compounds (OAV > 1) in cv. Meloni is both at 0 and 20 days of storage. Meanwhile, during 0 and 20 days of storage, the volatile compounds with an OAV greater than one in melon cv. Tacapa Green Black are three and four distinct compounds, respectively (Table 2). During the storage period, Trans-β-Ionone, furaneol, Benzaldehyde, Benzyl alcohol, (6Z)-Nonen-1-ol, 1-Butanol, 2-methyl-, Benzyl acetate, Hexyl acetate, and Butyl acetate were the compounds with the highest odour-activity values (OAV > 10) in cv. Meloni. The compounds with OAVs > 10 in cv. Tacapa Green Black was benzaldehyde, benzyl acetate, and hexyl acetate (Table 2). Benzaldehyde has an aroma aromatic, sweet, and almond (Verzera *et al.* 2011; Zhu *et al.,* 2018). Benzaldehyde had an OAV of 1328 in melon cv. Meloni, which was 8 times higher than in cv. Tacapa Green Black at 0 days of storage. Hexyl acetate and benzyl acetate could be important odorants in both cultivars. The OAV of hexyl acetate and benzyl acetate in cv Meloni was 3 and 2 times higher, respectively than in cv. Tacapa Green Black. Both compounds contributed to the fruity aroma. Furthermore, in cv. Meloni also had 19 times higher OAV of benzyl alcohol compared to cv. Tacapa Green Black, which also contributes to the higher fresh fruit aroma in cv. Meloni.

A principal component analysis (PCA) was commonly utilized to objectively analyze and compare multiple independent volatile compounds found in different cultivars (Aubert and Bourger, 2004; Yang *et al.*, 2009; Ningrum *et al.*, 2019). In this study, PCA was used to visualize the distinctions between melon cv. Meloni and Tacapa Green Black during storage based on their volatile compounds (based on Table 1). The first two principal components explained 95% of the total variance of the volatile compounds in the melon aroma (Figure 2). The first principal component (PC1) and the second principal component (PC2) exhibited 64.6% and 30.4% of the variation, respectively. The first principal component (PC 1) mainly discriminates Meloni at the harvest time (Meloni 0) from the others, whereas the second principal component (PC2), clearly divides two cultivars, Meloni and Tacapa Green Black to both periods of storage.

Only melon cv. Meloni (0 days) located on the first

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Table 2. Odour activity values of selected volatile compounds in melon cv. Meloni and cv. Tacapa Green Black during storage.

Compounds	Meloni		Tacapa Green Black		Odour Threshold (µg/kg)	Odour Activity Value (OAV)			
	M0	M20	T0	20		M0	M20	T0	20
Esters									
Butyl acetate	115	211	ND	14	10[b]	12	21	NA	1
Ethyl hexanoate	ND	10	ND	ND	1[c]	NA	10	NA	NA
Hexyl acetate	19	95	ND	28	2[c]	10	48	NA	14
Ethyl octanoate	ND	14	14	ND	2[d]	NA	7	7	NA
Benzyl acetate	43	569	ND	284	15[b]	NA	38	NA	19
Alcohols									
3-Pentanol	ND	128	120	122	30000[d]	NA	<1	<1	<1
3-Ethyl-2-pentanol	44	748	388	587	NF	NA	NA	NA	NA
1-Butanol, 2-methyl-	833	7	ND	ND	0.83[e]	1004	8	NA	NA
1-Butanol, 3-methyl-	204	36	11	23	30000[d]	<1	<1	<1	<1
1-Hexanol	ND	10	ND	ND	300[a]	NA	<1	NA	NA
(6Z)-Nonen-1-ol	91	ND	ND	ND	1[b]	91	NA	NA	NA
Benzyl alcohol	1917	313	140	66	100[b]	19	3	1	1
Phenylethyl Alcohol	118	39	18	26	35[e]	3.4	1.1	<1	<1
Aldehydes									
Nonanal	38	ND	ND	ND	5[f]	8	NA	NA	NA
Benzaldehyde	239	19	29	ND	0.18[e]	1328	106	161	NA
Ketones									
Acetoin	385	116	38	ND	800[h]	<1	<1	<1	NA
Furaneol	18	59	ND	ND	0.04[g]	450	1475	NA	NA
trans-β-Ionone	36	ND	ND	ND	0.1[b]	360	NA	NA	NA
Terpenoids									
D-Limonene	61	ND	ND	ND	200[b]	<1	NA	NA	NA
Terpineol	261	ND	ND	ND	350[h]	<1	NA	NA	NA

ND: not detected, NA: not applicable, NF: not found.

[a]Zhu *et al.* (2018), [b]Du *et al.* (2010), [c]Buttery *et al.* (1982), [d]Jiang *et al.* (2013), [e]Ruth (1986), [f]Yang *et al.* (2009), [g]National Center for Biotechnology Information, [h]Leffingwell and Associates (2021).

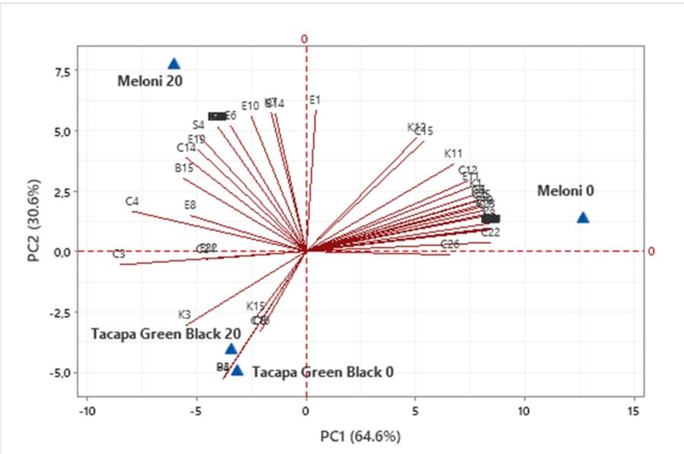

Figure 2. Principal Component Analysis (PCA) biplot of volatile compound in melon cv. Meloni and Tacapa Green Black (for codes, see Table 1).

axis positive side, are particularly characterized by greater contents of some esters (Butyl acetate (E1), 1,2-Propanediol, diacetate (E9), 2-Furanmethanol, acetate (E11), 1,2-Propanediol, 1-acetate (E14), 3-6-Nonadien-1-yl-acetate (E18), Phthalic acid, butyl isohexyl ester (E24), Dibutyl phthalate (E25), and Butyl isobutyl phthalate (E26)), alcohols (1-Octanol, 3,7-dimethyl- (C1), 1-Propanol, 2-methyl- (C2), 1-Butanol, 2-methyl- (C5), 1-Dodecanol, 2-hexyl- (C6), 1-Butanol, 3-methyl- (C7), 2-Hexanol (C9), 1-Decanol, 2-hexyl- (C11), 1-Octen-3-ol (C12), 1-Hepten-4-ol (C15), p-Menth-8-en-1-ol (C17), (6Z)-Nonen-1-ol (C18), 3,6-Nonadien-1-ol, (E,Z)- (C19), p-Cymen-8-ol (C22), Benzyl alcohol (C23), Phenylethyl Alcohol (C26), and Ethanol, 2-(vinyloxy)- (C27)), some benzenes (Benzene, chloro- (B1), Benzene, 1-ethyl-2-methyl- (B2), Benzene, 1-ethyl-3-methyl- (B3), Benzene, 1,2,3-trimethyl- (B4), Benzene, 1-ethyl-3,5-dimethyl- (B6), Mesitylene (B7), Benzene, 2-ethyl-1,4-dimethyl- (B8), Benzene, 1-ethyl-2,3-dimethyl- (B9), Benzene, 1,2,3,5-tetramethyl- (B10), Benzene, 1,2,4,5-tetramethyl- (B11), Benzene, 1-methyl-4-(1-methylpropyl)- (B12), and Benzene, 1,2,3,4-tetramethyl- (B13)), all of aldehydes (Nonanal (D1), Benzaldehyde (D2), Benzaldehyde, 2-hydroxy- (D3), and Benzaldehyde, 3-hydroxy-4-methoxy- (D4)), some ketones (Acetoin (K1), Acetophenone (K5), 2-Pyrrolidinone, 1-methyl- (K8), Ethanone, 1-(2-methylphenyl)- (K9), trans-β-Ionone (K10), 2,4-Pentanedione, 3-(9-decenyl)- (K11), 2-Hexanone (K12), and Benzophenone (K17)), phenols (P1-P12, except P4), all of naphthalenes (N1-N5), and some sulphurs (1-Octadecanesulphonyl chloride (S2) and Ethanol, 2-

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(methylthio)- (S5)).

Based on the distribution of the second principal component analysis (PC2), shows that melon cv. Meloni has a higher number of volatile compounds than cv. Tacapa Green Black. Melon cv. Meloni is more aromatic compared to melon cv. Tacapa Green Black. Both melon cv. Tacapa Green Black located on the negative side of PC2, strongly related to 2,4-Di-tert-butylphenol (P4), 2 (3H)-Furanone, dihydro-4-hydroxy- (K15), 2-Pentanone, 4-hydroxy- (K3), Benzene, 1-chloro-4-methyl- (B5), and 4-Penten-2-ol (C16), 2-Propanol, and 1-(1-methylethoxy)- (C8).

3.3 Change of melon cv. Meloni and Tacapa Green Black flesh firmness during storage

The flesh firmness of melon cv. Meloni and cv. Tacapa Green Black during 20 days of storage was shown in Figure 3. Jackman *et al.* (1990) described that firmness values reflect the integrity of pericarp tissue, where fruit-softening enzymes are primarily localized. According to Figure 3, the flesh firmness of melon cv. Meloni declined remarkably from 2711 g force at 0 days to 680 g force at 20 days conforming with the mostly climacteric melons during storage (Fallik *et al.*, 2001; Supapvanich *et al.*, 2011; Munira *et al.*, 2013; Supapvanich and Tucker, 2013) reported that the firmness of Galia melon declined during market storage simulation. The loss of firmness or softening could occur due to the disruption of the primary cell wall (Crookes and Grierson, 1983). This presumption will be proven by the result of scanning electron microscopy analysis to observe the cell walls during storage. Simandjuntak *et al.* (1996) suggested that one of the problems with melon fruits was softening during storage. Based on consumer acceptance, quality fruit is rejected if the loss of initial firmness is more than 30% (Harker *et al.*, 2008; Goncalves *et al.*, 2017). Melon cv. Meloni had an approximate loss of initial firmness of 45.67% on the 10th day. It assumed that cv. Meloni at 39 DAP or full ripe could not be stored for more ten than days to perceive the excellent quality of melon cv. Meloni according to texture properties. This result was aligned with Wyllie *et al.* (1996) reported that cv. Makdimon, as a highly aromatic cultivar that was picked in full maturity, tended to have a short shelf life.

In contrast, the flesh firmness of cv. Tacapa Green Black remained stable during 20 days of storage. The storage period did not alter the flesh firmness of the cv. Tacapa Green Black significantly ($p<0.05$). That can be correlated with non-climacteric behaviour. That contrasts with the previous studies that reported firmness reduction during storage in some inodourus melons such as cv Honey World (Supapvanich *et al.*, 2011) and cv. Amarillo (Di Venere *et al.*, 2000). Miccolis and Saltveit (1995) reported firmness of flesh decreased during three weeks in all six cultivars of var. inodourus (Amarelo, Golden Casaba, Honeydew, Honey Loupe, Juan Canary, and Paceco). The shelf life of cv. Tacapa Green Black was longer than cv. Meloni. It could be stored until 20 days in a firm shape. This excellent trait of cv. Tacapa Green Black could be beneficial during supply chain distribution until the consumer's hand.

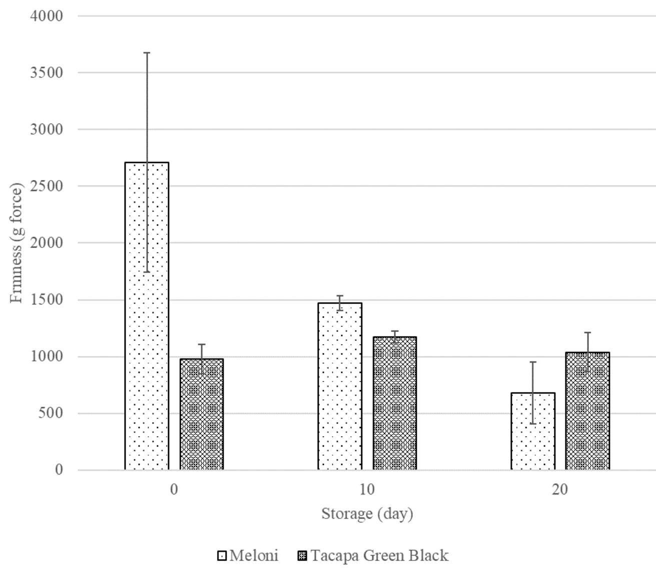

Figure 3. Flesh firmness of melon cv. Meloni and Tacapa Green Black during 20 days of storage at 21°C.

3.4 Microstructure cell wall identification of melon cv. Meloni and Tacapa Green Black flesh during storage

Scanning electron microscopy was conducted to explain how cell walls of parenchyma cells (Lecha, 2000) form or condition from the mesocarp part of flesh during storage and is related to firmness. Melon cv. Meloni lost firmness after storage, although melon cv. Tacapa Green Black did not. Figure 4 shows scanning electron microscopy of the flesh of cv. Meloni and Tacapa Green Black at a magnification of 500x via SEM. The cell wall microscopy of flesh cv. Meloni is shown in Figures 4A-B-C. At day 0 (Figure 4A), the cell walls of cv. Meloni was still firm and the form was evident.

On the tenth day of storage, the firmness began to deteriorate (Figure 4B). A section of the cell walls was damaged and lost its rigidity. The cell walls had virtually all been damaged after 20 days of storage (Figure 4C), and the shape was no longer visible. The microstructure of cell walls changes during storage possibly due to the loss of firmness. It might be because of cell disruption during storage (Crookes and Grierson, 1983). Brummell (2006) reported that the enhancement of electrolyte leakage indicates a membrane integrity degradation in the fruit cell walls. Ergun *et al.* (2005) also reported that the loss of firmness in the whole Galia melon during 20

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days at 20ºC was consistent with increasing electrolyte leakage. Furthermore, in melon cv. Veldrantais and Dulce, cell wall degradation and softening of the fruit are expected due to increased activity of polygalacturonases, glucan endo-1,3-β-glucosidases and β-d-xylosidases enzymes (Saladie *et al.*, 2015). Meanwhile, Rojas-Graü *et al.* (2006) found that the loss of firmness in Honeydew melon correlated with the loss of turgor pressure.

In contrast, the cell walls of cv. Tacapa Green Black (Figures 4D, 4E and 4F) did not change remarkably during 20 days of storage. It was relatively the same at 0, 10, and 20 days. It aligned with the firmness result of cv. Tacapa Green Black reminded stable during storage. Saladie *et al.* (2015) reported that the firmness of non-climacteric melon such as Piel de Sapo varieties which is commonly green-fleshed remained firm during storage.

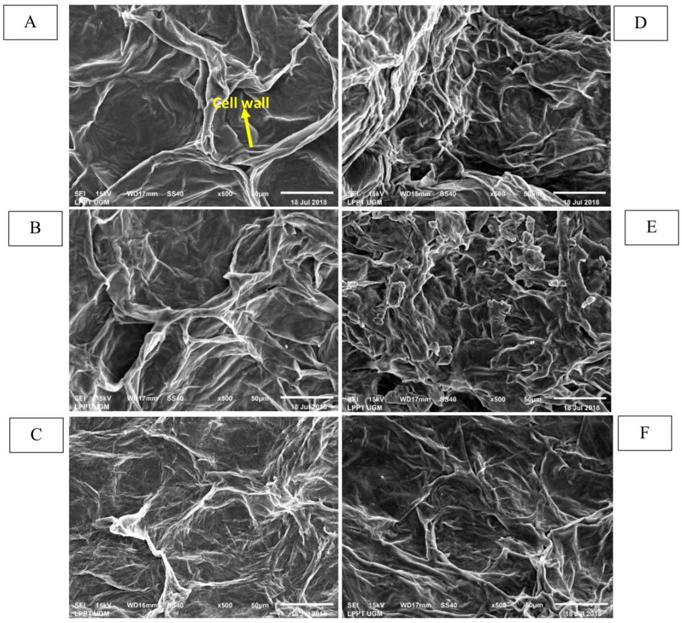

Figure 4. Scanning electron microscopy of melon cv. Meloni (A-B-C) and Tacapa Green Black (D-E-F). A is meloni at 0 day, B is meloni at 10 days, C is meloni at 20 days. D is Tacapa Green Black at 0 day, E is Tacapa Green Black at 10 days, F is Tacapa Green Black at 20 days. Magnification 500×.

4. Conclusion

Melon cv. Meloni and cv. Tacapa Green Black are new cultivars from Indonesia. Based on the respiration rate, cv. Meloni and Tacapa Green Black are classified as climacteric and non-climacteric melon, respectively. The volatile compounds in fruit are the key important factors related to consumer preferences. The volatile compounds were extracted from two different melon cultivars during storage using maceration extraction and then analyzed using GC-MS. Principal component analysis showed that Melon cv. Meloni and Tacapa Green Black contain different volatile compound profiles, of which cv. Meloni is more aromatic than cv. Tacapa Green Black due to the higher number of volatile compounds that have high odour activity values. During 20 days of storage, the firmness of cv. Meloni declined, whereas melon cv. Tacapa Green Black remained firm. The firmness result is assisted by a scanning electron microscopy (SEM) result that showed the microstructure of cell walls during storage. These physiological properties are essential as potential markers for a different cultivar of melon fruit.

Conflict of interest

The authors declare no conflict of interest.

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