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Effectivity of Various Refrigerator Brands in Maintaining Freshness and Antioxidant Nutrient Contents of Selected Vegetables and Fruit

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Abstract This study aims to compare the effect of different type of refrigerators in maintaining freshness and antioxidant-nutrient contents of selected vegetables and fruit during the period of three weeks. Randomized controlled trial study was done in Jakarta, in August–November 2019. Celeries, mushrooms and strawberries were used as samples, which were stored in four different brands of refrigerators at 8^0C during three weeks. Data collection included freshness using visual analogue scale, and also vitamin C, vitamin E, fiber contents and antioxidant property using colorimetric assay test, of celeries, mushrooms, strawberries at day 0, 3, 6, 9, 12, 15, 18, and 21 simultaneously. General-linear model was done to the repeated measurements to analyze the difference among four refrigerator brands during the three weeks period. As result, in refrigerator A®, overall freshness was maintained for two weeks for celeries and strawberries, and one week for mushrooms, compared to the other brands, i.e. B®, C® and D®. Similar findings were revealed for vitamin C, E and antioxidant properties. We also found that reduction of vitamin C, E and antioxidant property corresponded with freshness decline. Then, however, along with putrefaction, there were increase of vitamin C, E and antioxidant properties. In conclusion, refrigerator type affected the duration of vegetables and fruit freshness. Putrefaction process increased vitamin C, E content and antioxidant properties however, freshness should be more prioritized in consuming fruits and vegetables.

Keywords: *celery, strawberry, mushroom, freshness, refrigeration, vitamin C, vitamin E, antioxidant, fiber*

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1. Introduction

Vegetables and fruits are source of vitamins, minerals, fibers, water and phyto-substances to support our health and wellness. Based on recommendation by Indonesian Ministry of Health, Indonesian should eat 3-4 portions of vegetables and fruits daily [1]. However, more than 90% of Indonesian cannot meet the recommendation [2]. This may results in hidden hunger, which is a term for vitamin and mineral deficiencies that, in time, will disturb the overall health [3].

In a tropical countries, like Indonesia, vegetables and fruits are available and affordable at any time. However, especially those living in urban setting, people usually buy them weekly rather than daily when they go to buy other food items in the market. On the other hand, consumers are becoming more concerned about the quality and safety of their foods including fruits and vegetables, thus taking their nutritional and sensory aspects into consideration [4]. This results in the necessity for storing them in a way which can keep their freshness and ready to be consumed at any time in a week. However, storage may also reduce the nutrient contents over time, loosing the anti oxidant properties, thus lessen their benefits to support health and wellness [5,6].

Table 1. IEC 62552:2007-specified domestic refrigerator storage temperatures (IEC 2007) [9]

Compartment	Fresh food storage compartment	Chill compartment	Cellar compartment
Definition	Compartment intended for the storage of unfrozen food at the temperature specified	Compartment intended specifically for the storage of highly perishable foodstuff in which the above-specified storage temperature can be maintained	Compartment intended for storage of particular foods and beverages at a temperature warmer than that of the fresh food compartment
Temperature range:	0 to 8 °C (mean ≤ 4 °C)	−2 to +3 °C	+8 to +14 °C

An alternative way to enhance the shelf life and nutritional quality of food items is by refrigeration storage to slow deterioration processes [6,7]. Table 1 shows the specified domestic refrigerator storage based on its temperatures. Acho et al [8], found that refrigeration processing (less than five days at 4°C) of leafy vegetables may be the best time for preserving their nutritive and antioxidant properties.

Type of refrigerator offers different outcome for fruits and vegetable freshness. There are various kinds of refrigerator available in the market. Storage with low temperature (0-13°C) and high relative humidity (80-95%) can reduce water loss and maintain food quality, therefore slowing deterioration and rotting process [7] Although there are many studies regarding refrigerator storage in relation to freshness and nutrients, only a few had been done in Indonesia, especially related to comparing several brands of refrigerators. This study aims to compare the effect of different type of refrigerators in maintaining freshness and antioxidant-nutrient contents of selected vegetables and fruit during the period of three weeks. We hope this study may become an additional knowledge on appropriate food item storing inside refrigerator thus achieving the best freshness and nutritional value.

2. Methods

This double-blind, randomized controlled study was done in Jakarta from August to November 2019. We compared freshness, vitamin C and E content, and also antioxidant property of selected vegetables and fruit stored in 4 different brand of refrigerators during the period of three weeks.

3. Samples

Celeries, mushrooms (white shimeji mushrooms or *Hypsizygus tessellatus*) and strawberries were chosen and purposively bought from a well-guaranteed supermarket. We chose the 3 food items due to easiness to detect rotting process. The samples chosen were of similar sizes and weight. The samples were separated and kept in the crisper drawer in four different refrigerators: A, B, C, and D. All refrigerators have similar general specification i.e. double door, availability of crisper drawers and similar temperature. All samples were stored at 8^0C up to 21 days. Each refrigerator's brand was covered and the refrigerators were sealed. All 4 refrigerators were placed at one selected room.

4. Evaluation of Freshness and Nutrient Contents

At the day of the evaluation, the 3 types of sample were divided into 8 pieces. On day 0, 3, 6, 9, 12, 15, 18 and 21, a total of 2 evaluators, equipped with magnifying glasses, assessed 4 pieces of samples based on the sensory quality using the visual analogue scale. The other 4 samples were taken to the laboratory for vitamin C, vitamin E content, anti oxidant property and fiber analysis. We made sure to not opening the refrigerators' doors for more than 1 minute to avoid excessive temperature changes inside.

For freshness, we used sensory analysis, which consisted of colors, smells, intactness and firmness. Additionally, for celery, we included wrinkled stalks, withered stems and leaves. For mushrooms, we included wrinkles, dryness, slime, and mold growth. Lastly, for strawberry, we included brown spot(s), white mold strands, and slime. Every sensory analysis was marked with green, yellow, and red color; in which green color was defined as the items stayed as fresh as day-0.

Vitamin C and E content, total antioxidant capacity (TAOC) and fiber content were analyzed at Biochemistry and Biomolecular Department Laboratory at Faculty of Medicine *Universitas Indonesia*. Since no human nor animal sample were used, this study did not require any ethical clearance. However, we kept the refrigerator brands confidential during the study.

Vitamin C, vitamin E, total antioxidant capacity and total fiber content were evaluated with colorimetric assay method, using spectrophotometer device. Vitamin C colorimetric assay was used to measure vitamin C levels (Elabscience Catalog number:E-BC-K034), vitamin E assay kit for vitamin E (Elabscience Catalog No: E-BC-K033), total antioxidant capacity assay kit for antioxidant property, and total dietary fiber assay kit for fiber content. General-linear model was done to analyze the difference between each refrigerator on the repeated measurements basis during the three weeks period.

5. Result

Table 2. Overall freshness of celeries, mushrooms and strawberries after being stored in refrigerators for 21 days

Day	CELLERY				STRAWBERRY				MUSHROOM			
	Refrigerators				Refrigerators				Refrigerators			
	A	B	C	D	A	B	C	D	A	B	C	D
0												
3												
6												
9												
12												
15												
18												
21												

Notes: green, if all samples were still fresh; yellow, if 1-2 from 4 samples were still fresh; red, if all samples were not fresh anymore.

Based on overall freshness, the total scores of each sample was different. For celeries, refrigerator A® was the most superior in keeping it stayed fresh up to day-9 compared to the others. Specifically, inside refrigerator A®, the celeries' fresh green color was preserved up to day-9 and no slime appeared up to day-12. Similar result were also noticed in strawberries. Inside refrigerator A®, the overall strawberries' freshness were preserved better to day-9, then rotting process (foul smell, slime and white mold strands) appeared on day-12. On the other hand, for

mushrooms, no significant difference was found between all refrigerators in keeping them stay fresh up to day-6. However, refrigerator A ® was significantly superior in preserving their freshness in terms of color up to day-6, the aroma up to day-15, no appearance of dark spot up to day-21, and no appearance of mold up to day-18. However, no difference was noted regarding the appearance of slime. All the result mentioned above can be seen in Table 2.

In terms of vitamin contents and total antioxidant capacity, Figure 1, Figure 2 and Figure 3 showed, in overall, that strawberries had the highest total antioxidant capacity compared to celeries and mushrooms. Along with days of storage, vitamin C content of celeries and mushrooms continued to decrease to day 21. On the contrary, they were relatively stable for strawberries. Meanwhile, in general, vitamin E content were maintained for the duration of the storage period. However, in celeries, vitamin E content decreased by days. Interestingly, it became the lowest on day 6, then increased afterwards. Vitamin E content of strawberries decreased by days, in which the lowest was also on day-6. However it was increased on day-9 and day-21. For mushrooms, vitamin E content increased on days 9 and 21. In addition, in terms of fiber, this study showed that strawberries had the lowest fiber content compared to celeries and mushrooms, however, it was still preserved throughout the storage time.

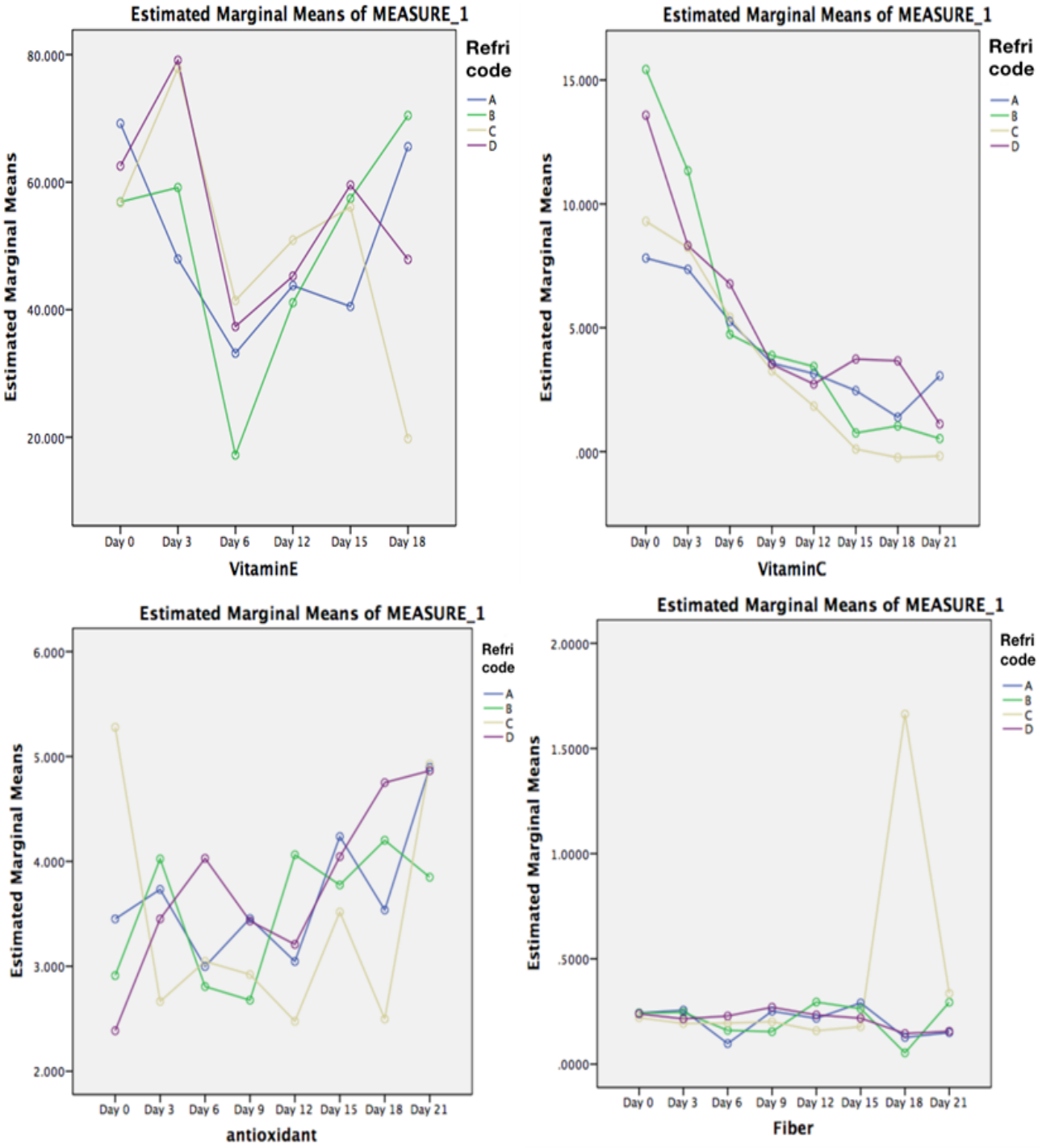

Figure 1. Vitamin E and C, antioxidant property and fiber content in celery (Abbreviations: Refri, Refrigerator)

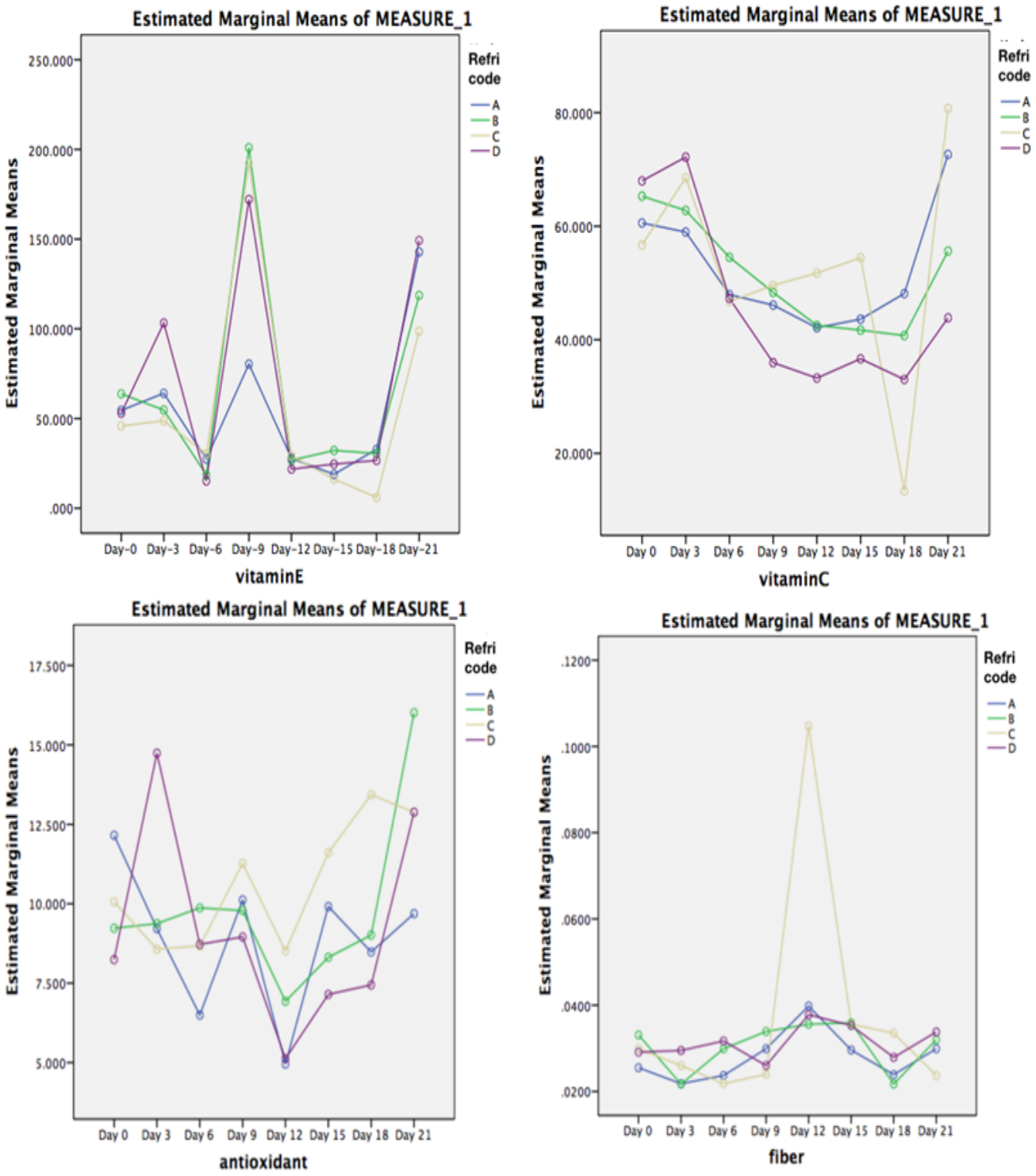

Figure 2. Vitamin E and C, antioxidant property and fiber content in strawberry. (Abbreviations: Refri, Refrigerator)

6. Discussions

Celeries, strawberries and mushrooms were analyzed in 21 days of storage period to be examined for the main quality parameters, i.e. sensory freshness and laboratory analysis. The sensory analysis results showed that refrigerator A® was able to maintain freshness on day 12 for celeries and to day 9 for strawberries compared to B®, C® and D®. Refrigerator A® claimed to have Taste-Lock crisper drawer which retained the humidity thus keeping the meal products fresh for 7 days. While the study did not compare the differences of crisper drawer in the 4 refrigerators, significant sensory analysis result was noted in refrigerator A® to maintain freshness for more than 7 days.

It is widely known that, among other methods, freezing is the oldest and widely used for food preservation due to better taste, texture and nutritional value preservation.[10] Moreover, there are other benefits of low temperature compared to room temperature preservation including deterring microorganism growth, reduced of chemical reactions and delayed of cellular metabolic reactions, thus keeping the freshness longer. By maintaining the low temperatures during storage, the refrigerator can preserve the fruits and vegetables freshness. In this study, refrigerator brand A® might have better technology which could maintain celeries' and strawberries' freshness longer.

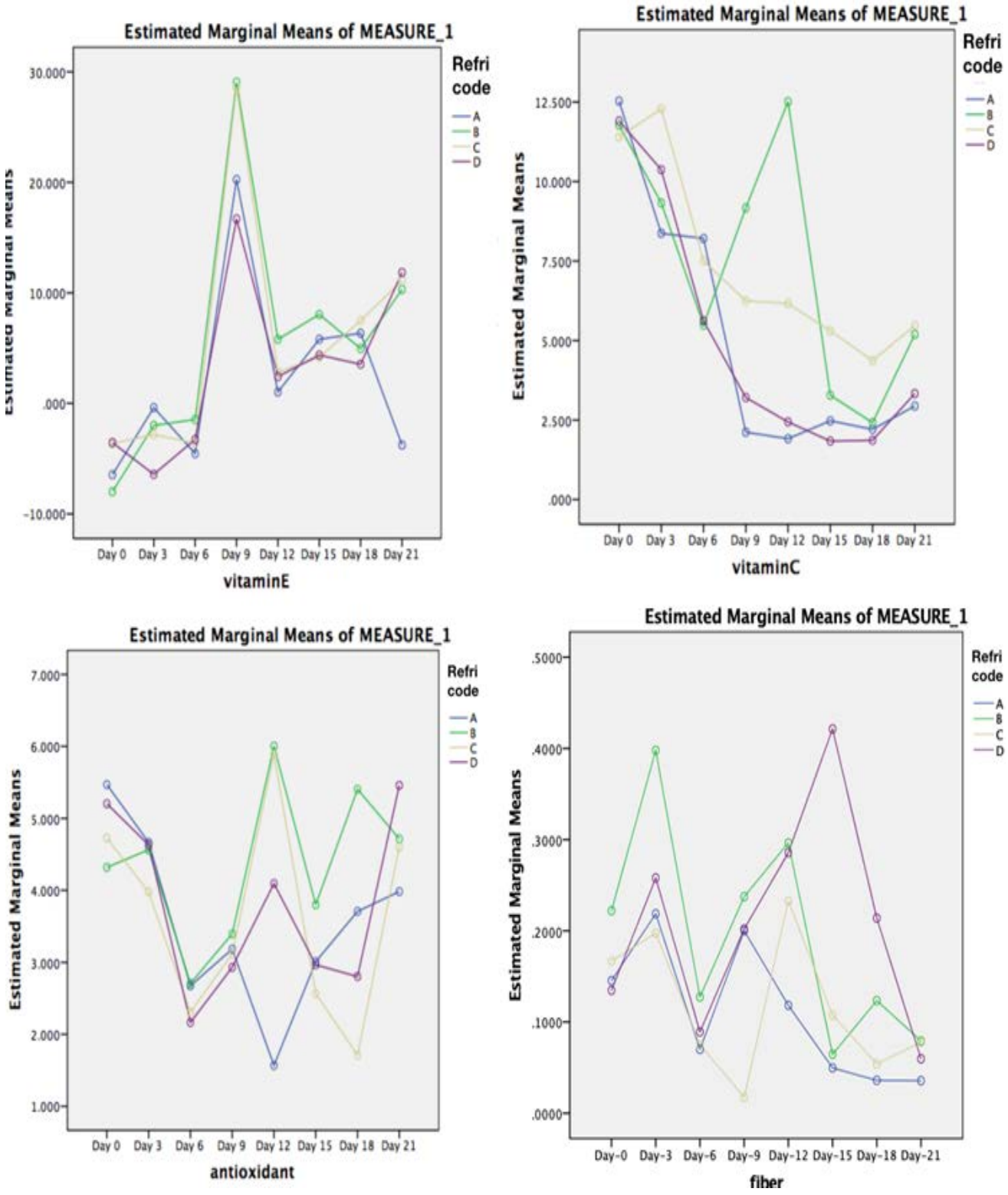

Figure 3. Vitamin E and C, antioxidant property and fiber content in mushroom. (Abbreviations: Refri, Refrigerator)

Compared to celeries and mushrooms, strawberries had the highest total antioxidant capacity, considering their constant high vitamin C and E contents during the storage period [8,11,12]. Findings from a study of antioxidant capacity progress during storage of selected fruits and vegetables showed high antioxidant capacity was associated with high contents of total phenolic compounds, ascorbic acid (vitamin C) and flavonols. Similar to ours, the study also found that fruits and vegetables visually spoiled before any significant antioxidant capacity loss occurred, as also revealed in our study [13].

This study found that vitamin C content decreased rapidly even during the first 3 days of storage for celeries and mushrooms. This result is similar to other studies about the vitamin C content which showed declining of vitamin C content that was in line with freshness reduction [8,13]. On the contrary, vitamin C content of strawberries was relatively stable throughout the 21 days of storage in all refrigerators brand.

Vitamin E content of celeries, strawberries, and

mushrooms tended to decrease after being stored in the refrigerator until day-6. Then, starting at day-12, it increased. This corresponded to the freshness, antioxidant property and vitamin C content. The increased levels of antioxidants after day 6 may cause increased of vitamin E followed by decreased of vitamin C levels. Theoretically, vitamin C is capable to recover oxidized vitamin E, which may explain this study's result. From day-12 afterwards, the vitamin C level depleted because it might had transferred its electrons to the vitamin E [8,10,12]. In addition, compared to celeries and mushrooms, strawberries had the highest total antioxidant capacity considering its high vitamin E level during the whole storage period. The increase of vitamin E and antioxidant property afterwards were in line with the putrefaction process. This is shown by any antioxidant or vitamin E level increase which was consistent with decrease of freshness after day-9.

Strawberry has the lowest fiber content compared to celery and mushroom. Fiber content is affected by type of fruits and vegetables. Therefore, it is beneficial to control water absorption by reducing the amount of moisture absorbed by the food. Theoretically, by reducing the moisture, it will slow down the increase of water activity within the food when exposed to its environment. Thus, the microbial growth is also lessened and its shelf-life could be extended [13,14,15,16]. In our study, even though there were different fiber content between the fruits and vegetables studied, it showed that all refrigerators brand could maintained the fiber content throughout the days of storage.

In conclusion, among four refrigerator brands used in this study, brand A® was more superior compared to others. This study's result showed that refrigerator type affected the duration of vegetables and fruit freshness during storage which are in line with antioxidant property, vitamin E, vitamin C and fiber content. Putrefaction process seemed to increase vitamin C, E content and antioxidant property, however, freshness should be more prioritized in consuming fruits and vegetables.

Conflict of Interests

This study was funded by PT. Electrolux Indonesia. The researcher still kept the studied refrigerators brand closely confidential.

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