Some Technical and Mechanical Properties of Mibuna (*Brassica rapa*var. *Nipposinica*) and Mizuna (*Brassica rapa* var. *japonica*)

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Abstract

In this research, some physical (leaf area, leaf width, stalk width, plant mass, moisture) and mechanical properties (tear resistance, puncture resistance), color parameters (L*, a*, b*, YI) of Mibuna (*Brassica rapa*var. *Nipposinica*) and Mizuna (*Brassica rapa* var. *japonica*) plants that are Far East Origin vegetables were determined and compared. Also respiratory rate and dry matter loss values just after harvesting and 1 week later harvesting were calculated and compared using measured CO_2 concentration values. It was determined that the differences between mean values of physical properties of leaf and stalk parts of mizuna and mibuna plants were found to be statistically significant ($P<0.05$). CO_2 measurements which were made just after harvesting and 1 week later harvesting showed that respiration rate and dry matter loss for mizuna was found faster than those values for mibuna plant. Also it was found that respiration rate and dry matter loss values determined just after harvesting was found higher than those values determined 1 week later harvesting.

Keywords: *Mechanical properties; mibuna, mizuna; physical properties; respiration rate, oriental Cabbage*

Introduction

The cabbage group vegetables are the important vegetables which are growed and consumed all over the world (Cartea et al., 2011). The vegetables of mibuna (*Brassica rapa*var. *nipposinica*) and mizuna (*Brassica rapa*var. *japonica*) known as Japan mustard or called kyonain Japanese are the indispensable salad vegetable which known as Oriental Cabbage in China, Japan, Indonesia, Malaysia and in many countries of Europe. Although the origin of lots ofcabbage group plants which their leaves are considered as vegetables in the world is China, origin of mizuna and mibuna plants is Japan (Khanam et al., 2012) and they are in a dozen vegetables also known as "KyoYasai" for centuries.

100 g mibuna leaf contains 480 mg potassium, 210 mg calcium, 31 mg magnesium, 64 mg phosphorus, 2,1 mg iron, 0.41 mg manganese, 1300 µg beta-tile ten, 110 µg retinol, 55 mg vitamin C, 1.8 mg vitamin E (Alpha-Tocopherol), 120 µg vitamin K, 140 µg folic acid. 100 g mizuna contains 10502 IU vitamin-A, 70 mg vitamin C, 2 mg vitamin E, 6.52% N, 0.56% P, 4.63% K, 8,52 ppm Cu, 241,2 ppm Fe, 53.02 ppm Zn, 2.46% Ca, 0.56% Mg and 57.63 ppm Mn (Eryilmaz Acikgoz, 2012; Anonymous, 2014). Due to the fact that leaves of mizuna and mibuna are very rich in respect of vitamins and minerals and they can be consumed as raw, these plants can be used in the low calorie food chain. Also turning of high glucosinolate compounds of them into isothiocyanate provides resistance of body against to certain diseases (Eşiyok et al., 2008a).

Mizuna has a shallow root system. The body formed on the top of soil shows improvement in the form of rosette andleaves that reachto harvesting maturity on the rosette body are soft, fragmented or flat (Eşiyok et al., 2008a; Varış et al., 2010). Mibuna has a shiny complete leaf of rosette form, svelte, narrow belt form and rounded ends. Both vegetables are cool climate vegetables. While they have toleration up to -6^{0}C temperature, they need 15-18^{0}C optimum temperature. Mibuna that has fast adaptation ability against to the low and high temperatures in addition to its nutritional value can be grown throughout the year in Turkey and countries that have similar climates (Varış et al., 2010; Eşiyok et al., 2008b). In addition to this, it is believed that these vegetables can find wide range distribution area in many countries and they can find place in the country markets same as cress, arugula, parsley, mint etc. vegetables which are appetizing and has edible leaves for salad (Eryilmaz Acikgoz and Altintas, 2011; Eryilmaz Acikgoz, 2012).

The determination of plant material's technical and structural characteristics in agriculture is important forthe designing, construction, operation, increasing the efficiency of agricultural tools and machines such as sowing, seedling planting, spraying and harvesting machines in addition to apply post-harvest operations effectively such as storage, drying, crushing, grinding, packaging, freezing etc. and to take successful results (Husain et al., 1971; Mohsenin, 1980; Cenkowski et al., 1991; Alibaş and Okursoy, 2012).

When the consumable parts of plants are considered, there are lots of researches on the agricultural products that their leaves are consumed. Some of these; elastic properties of the tobacco plant leaves (Henry et al., 2000), element determination in kale (Gündoğdu, 2005), comparison of some kind of chards (Pokluda and Kuben, 2002), metabolism of ascorbic acid in spinach at dark and light storage conditions (Toledo et al., 2003), technical properties of kale, chard, spinach leaves (Alibaş and Okursoy, 2012). Researches performed for mibuna and mizuna plants are generally for determining of the cultivation of these plants or their nutritional content. For example Kalisz et al. (2012), studied on the effects of cultivation period and varieties of mibuna and mizuna plants to their morphological parameters and yield.

In addition to these researches, researches on the changing of water soluble vitamins and fat content for mizuna and mibuna plants during storage (Santos et al., 2012), the weight loss during storage at nano-sized foggy conditions (Hung et al., 2011), the changing of ascorbic acid content during storage (Kopta and Pokluda, 2010), comparison of flavonoid compounds, vitamin C contents and antioxidant properties (Martinez-Sanchez et al., 2008), evaluation of quality in terms of nutritional content (Artemyeva and Solovyeva, 2006) etc. were found. On the other hand, any literature could not be find about determining of technical and structural characteristics of the mibuna and mizuna leaves.

In this research, physical, structural, mechanical, color properties of mibuna and mizuna plants were investigated to use them for designing, calibration and improvement of machines that can be used for either preharvesting or postharvesting processes.

Also, respiratory rate and dry matter loss values were determined according to CO_2 production amount which measured just after harvesting and one week later harvesting. In this way, it was aimed to obtain needed data to predict storage stability namely shelf life of these plants.

Materials and Methods

Materials

This research was performed in February and September in Tekirdag city (40°98' N, 27°48' E) using high tunnel greenhouse covered by polyetilen (PE) with UV additive, which belongs to Namık Kemal University, Vocational School of Technical Sciences, Plant and Animal Production Department. Research was designed as 3 replications according to randomized block experimental design.

The 1340D variety of mibuna and the 1341 (Chilternseeds Firm) variety of mizuna were used for the research (Fig. 1). Seeds were planted to the flowerpots filled with peat (Klasmann-Deilmann, Potground H, Germany) in February (for mibuna) and in September (for mizuna). Some specifications of used peat were given as 160-260 mg/L N, 180-280 mg/L P_2O_5, 200-150 mg/L K_2O, 80-150 mg/L Mg, pH: 6, 0.8% N, 70% organic matter, and 35% C. When the seedlings became 2-3 true leaves (25th and 22nd days for mibuna and mizuna after seed planting) they were planted to prepared places in high tunnel greenhouse with 30x30 cm intervals and 10 plants in each parcel. Some chemical contents of soil of experimental field were given in Table 1. The climate data measured inside the tunnel during the growing of the plants were given at Fig. 2.

Plants were harvested 45 days after seed sowing (Eryilmaz Acikgoz and Altintas, 2011). The pesticides were not used during the growing period because there were no diseases and pests. The plants were carried to the laboratory in order to determine the technical and mechanical properties just after harvesting.

(a) (b)

Figure. 1. Mibuna (a) and mizuna (b) plants (original).

Table 1. Some chemical properties of soil of growing area.

Soil properties	Results
pH	8.01
Salinity (%)	0.07
$CaCO_3$ (%)	2.74
Organic matter (%)	1.35
Ca (%)	0.54
P (ppm)	36.40
K (ppm)	253.80
Mg (ppm)	473.10
Mn (ppm)	5.68
Cu (ppm)	0.81
Fe (ppm)	7.43
Zn (ppm)	0.97

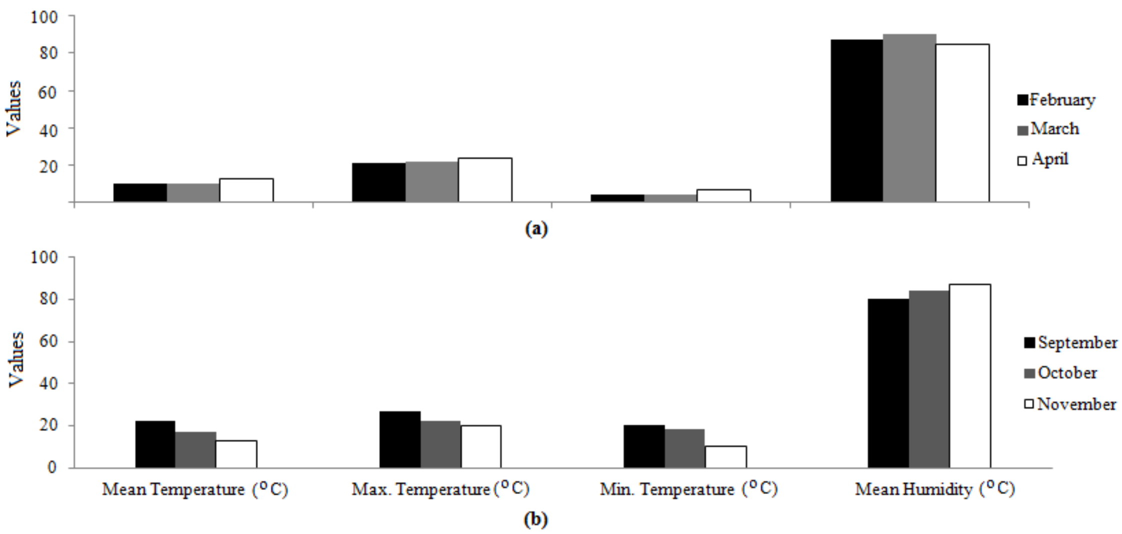


Figure. 2. Meteorological data of high tunnel greenhouse for the months in which the komatsuna was growed (a: for Mibuna; b: for Mizuna).

Determination of physical properties

The LI-COR brand LI-3000A model portable area measurement device was used to measure of the leaf length, width and surface area of mibuna and mizuna plants. A mechanical type micrometer which has measurement range between 0-25 mm was used in order to determine leaf thickness, and the digital sliding calliper which has 0.01 accuracy was used in order to determine stalk thickness. The AND GF-610 brand precision balance with 0.001 accuracy was used for measuring the mass of plants. The measurements were performed using 10 plants with 3 replications by choosing leaves randomly from these plants. The measurements performed 3 replications on these leaves selected randomly.

DHG-9023A brand oven that has 32 liter capacity was used to determine the moisture content of plant samples. The moisture content values were determined as 3 repetitions by the considering of the initial and final mass values of samples before and after drying. Moisture content (M_y) values were calculated according to wet basis using equations given below:

$$M_y = ((m_0 - m_s)/(m_0)) * 100 \quad (1)$$

Where;

m_0: Initial weight of sample (g),

m_s: Final weight of sample (g).

Determination of color parameters

Color measurements were performed using Hunter Lab D25LT Color Measurement device which has big measurement range, and especially which is suitable for color measurements of non-homogeneous materials. The color parameters that are brightness (L) and color coordinates of a and b. L value changes between 0 and 100. 0 shows black color and 100 shows white color. Color coordinates of a and b don’t have any specific measurement interval and they can have positive and negative values. a value represents red-green axis, positive values are for red color, negative values are for green color, and 0 is neutral. If color coordinate of b is positive it shows yellow color and the negative values show the blue color (Anonymous, 1996). The measurements were made using 10 plants and 3 replications were performed on the every plant by choosing leaves randomly. The 3 replication measurements on the randomly chosen leaves from the same plant were made by 3 replications.

Determination of mechanical properties (tear and puncture resistance)

It is important that to determine mechanical properties such as tear, puncture resistanceetc. Which are important important properties in terms of post-harvest processes and shelf life. The basic element of used measurement system in order to determine these features is a hand-held dynamometer which was fixed to a vertical shaft (Shimpo brand, FGN-5B model). In this way, force application to the samples with constant speed was carried out using dynamometer.

The dynamometer was applied to the leaf sample with 30 mm/min speed. On the samples, maximum force applied to the sample during process was recorded to the memory of dynamometer. Different type probes were used during measurements of mechanical properties namely tearing and puncture resistance. Maximum force values measured during process was accepted as force that was needed for tearing and puncturing of the sample related to selected probe. Maximum force values were read from dynamometer directly and were recorded. Measurement on mechanical properties wasperformed as 3 replications by randomly choosing 3 leaves from 10 different plants.

Determination of CO_2 production rate

CO_2 measurement probe that has Testo 650 model datalogger was used to determine the changing of CO_2 values with time which were produced by samples in airtight glass containers. The probewas completely held in glass container during the measurements and the container was stayed to prevent air entering.

Obtained data from probe were transferred to the computer by Testo 650 device and CO_2 producing amount of plant versus time at room temperature was measured with 1 minute interval. Due to the device can make measurement up to the 11500 ppm CO_2 as maximum level, the measurement were stopped atthis level. The CO_2 production values for the plants were determined just after harvesting and 1 week storage period in the refrigerator (+4 °C temperature) after harvesting.

Therefore, the CO_2 values were measured as ppm (parts per million) during the experiment and converted to percentage values (%) using equation as below.

$$A=(B*100)/1.000.000 \qquad (2)$$

Where;

A: CO_2 amount (%),

B: CO_2 amount (ppm).

Determination of respiration rate

Respiratory rate is generally defined as produced gas amount of 1 kg fresh plant in 1 hour (in weight or volume). In static systems, five main factors should be known for determination of respiratory rate (Mikal, 2015). These are;

- the volume of used sealed container (2000 ml),
- sample mass,
- initial CO_2 concentration (t=0 time),
- experiment time,
- final CO_2 concentration.

Respiration rate (RR) was calculated using Equation 3 given as below (Mikal, 2015):

$$RR = \frac{FC - IC}{M * t} * V \qquad (3)$$

Where;

RR: Respiration rate of plants in terms of CO_2 (ml CO_2/kg h),

FC: Final CO_2 concentration (%),

IC: İnitial CO_2 concentration (%),

V: Chamber volume (ml),

M: Plant mass (kg),

t: time (hour).

Determination of dry matter loss

The plant respiratory is accepted as complete oxidation of 6-carbon sugar to the carbon dioxide and water. The chemical equation of plant respiratory is expressed as below (Mikal, 2015):

$$C_6H_{12}O_6 + 6O_2 + 6H_2O \rightarrow 12H_2O + 6CO_2 + 673 \text{ kcal (38ATP)} \quad (4)$$

Expression of this chemical equation (stoichiometric) can be used also for dry matter loss as well as total CO_2 production matter loss as well as total CO_2 production (Greenhill, 1959; Melvin and Simpson, 1963; Simpson, 1961). While producing 264 g of CO_2 during respiration, 180 g sugar is get lost (Mikal, 2015). From these, the dry matter weight loss from 1 kg product for 1 hour is calculated using Equation 5. Weight of plants were measured using AND brand AND GF-610 brand precision balance which has 0.001 g measurement accuracy before and after the CO_2 measurements to determine weight loss on samples due to respiration.

$$DML = RR*10^{-3}*68/100 \quad (5)$$

Where:

DML: Dry matter loss (g/kg h),

RR: Respiration rate of plant CO_2/kg h).

Dry matter loss per hour which can be occurred during the storage period, can be calculated (daily, weekly etc.) using the calculated dry matter loss.

Statistical analysis

In this research, the significance level of the differences between mean values of all determined properties was determined using PASW 18.0 package program.

Results and Discussion

Physical properties

The measured and calculated physical properties of mizuna and mibuna plants were given at Table 2 with their standard deviations. The physical properties such as plant stalk thickness, plant mass, moisture content of leaves and stalks of plants in addition to the dimensions of plants such as leaf area, leaf length, leaf average and maximum leaf width, leaf thickness were found by various measurement and calculation methods. The given values in Table 2 are the mean values of 3 repetitions performed using 10 plants. Standard deviation values on dimensional characteristics of mibuna were found rather higher than the standard deviation values obtained for mizuna. This shows that leaves of mibuna plant are more heterogeneous in respect of dimensional properties than leaves of mizuna plant. It was determined that the average leaf area and leaf width values of mizuna plant were quite bigger than those of mibuna plant. When the mean values of all specified properties given in Table 2 were compared, it was determined that the differences between these properties for mibuna and mizuna plants were not statistically significant ($P<0.05$).

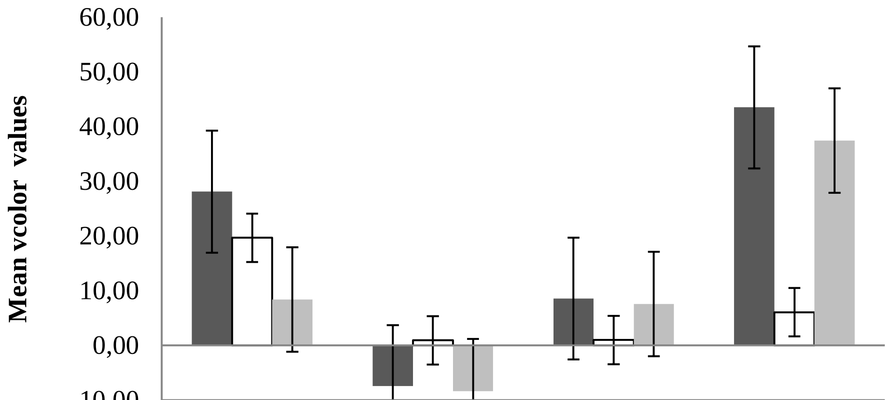
Table 2. Physical properties of plants.

	Mibuna				Mizuna			
Physical property	The Min. Values	The Max. Values	Average values	Standard Deviation	The Min. Values	The Max. Values	Average values	Standard Deviation
Leaf area (mm^2)	48,23	110,87	67,92	17,975	80,98	113,51	94,22	7,952
Leaf length (mm)	19,33	59,57	29,51	9,983	13,43	16,63	15,15	0,975
Average leaf width (mm)	1,40	3,50	2,50	0,622	5,40	7,90	6,94	0,640
Maximum leaf width (mm)	3,83	5,90	4,82	0,519	9,63	10,78	10,11	0,384
Leaf thickness (mm)	0,50	0,54	0,531	0,10	0,2	0,3	0,3	0,02
Stalk thickness (mm)	3,43	6,40	5,30	0,783	0,49	0,60	0,53	0,041
Mass (g)	53,54	146,78	94,97	22,945	44,56	55,23	49,66	2,794
Moisture content values (% w.b.)								
Leaf	0,89	0,91	0,90	0,005	0,87	0,91	0,89	0,010
Stalk	0,94	0,97	0,95	0,007	0,93	0,96	0,94	0,008

Color parameters

The measured brightness (L), redness (a), yellowness (b) and the yellowness index (YI) values for leaves of mizuna and mibuna plants were given in Fig. 3. When the results of 3 replications measurement were analysed, it was determined the differences between L, a, b and yellowness index were significant ($P<0.05$). The colorparameters for kale, chard and spinach were investigated by Alibaş and Okursoy (2012). L, a, b values were measured for chard as

33,33; -8,25 and 12,24, respectively while they measured the L, a, b values for spinach as 32,26; -8,37 and 13,44, respectively. Our results showed that L, a, b values especially measured for chard and spinach leaves were found rather close to values determined formizuna leaves (28,11; -7,44 and 8,58). On the other hand, it was determined that color parameters measured for mizuna leaves were found rather different those values measured for mibuna, chard and spinach leaves. According to these values, it is understand that the leaves of mizuna plant are less bright, redder and less yellow compared to leaves of mibuna, spinach and chard. The big difference between yellowness index values of mibuna and mizuna also supports this result (Fig. 3).



	L	a	b	YI
Mibuna	28,11	-7,44	8,58	43,53
Mizuna	19,70	0,94	0,99	6,07
Difference	8,41	-8,38	7,59	37,46

Figure. 3.The mean color values of mizuna and mibuna plants (Standard deviation values of L, a, b and YI for mizuna were 1,128; 0,086; 0,102 and 0,934, respectively; standard deviation values of L, a, b and YI for mibuna were 1,360; 0,466; 0,717 and 2,862, respectively).

Mechanical properties

It is clear that processes applied after harvesting of plants that are benefited from their leaves such as mibuna and mizuna can cause some mechanical damage ssuch as occurring of tearing and puncturing on their leaves. In order to prevent these damages, the needed precautions should be taken to prevent of affecting mechanical forces to leaves more than this measured values. Preventing of more mechanical effects to leaves namely preventing of mechanical damage can contribute to extend shelf life. Measured tear and puncture resistance values of mibuna and mizuna leaves were given in Fig. 4. Tear resistance values were found rather higher than those of puncture resistance values for both plants. The mean leaf puncture resistance were determined as 0,03 kgf for both plants while the tear resistance values were determined as 0,43 for mibuna and 0,29 kgf for mizuna. The high tearing resistance value for mibuna leaf can be explained with rather higher leaf and stalk thickness values of this plant (mean values are 0,53 and 5,3 mm, respectively) compared to those of values determined for thickness values of mizuna leaf and stalk (mean values are 0,3 and 0,53 mm, respectively). Bigger leaf and stalk thickness caused to more resistant texture of plant. When the 3 repetitions measurement result of this plants were analysed accordingly mechanical properties, it was identified that the difference between tear resistance values is important statistically ($P<0.05$), the difference between puncture resistance is not important statistically ($P>0.05$).When the mean values of mechanical properties measured as 3 repetitions were analysed, it was determined that the differences between tear resistance of the plants were found significant ($P<0.05$) while differences between puncture resistance values of plants were found not significant ($P>0.05$).

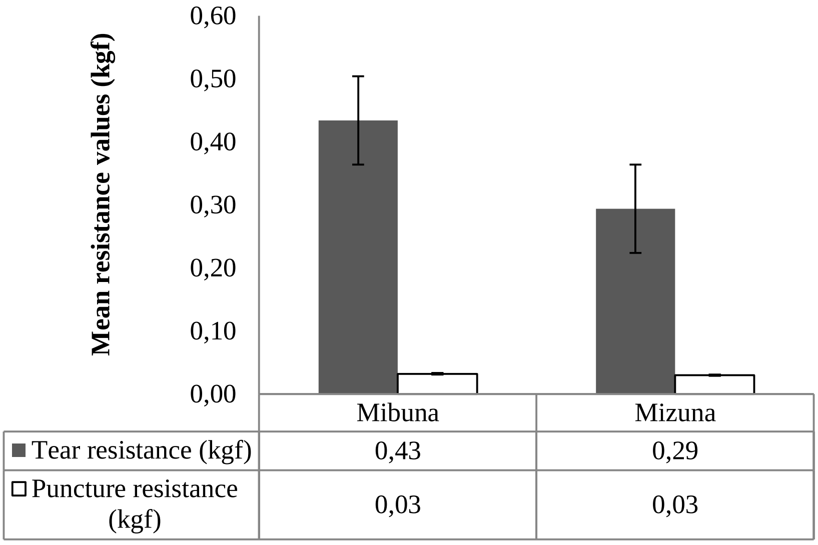


Figure. 4. The mean resistance values of mizuna and mibuna plants (Standard deviation values for tear and puncture resistance for mizuna are 0,062 and 0,007 and for mibuna 0,023; 0,002, respectively).

CO_2 production rate

Changes of CO_2 production rate for the mizuna and mibuna plants measured either just after harvesting or samples that were kept in refrigerator at +4 °C 1 week period after harvesting were plotted as seen in Fig. 5. Samples that were kept in refrigeration condition were waited in room conditions (25 °C) to equilibrate of their temperatures before measurements. When the Fig. 5 was examined, it was seen that CO_2 value which is produced by the both plants just after the harvesting increased very quickly. On the other hand, the CO_2 value produced by mizuna plant increased rather faster compared to CO_2 value produced by mibuna for both just after harvesting and 1 week later harvesting. The product respiratory namely rates of O_2 consumption and CO_2 production are the general results of metabolism. Respiratory rate can be also understood as metabolic rate (Bingöl, 1980). The high metabolic rate of plant just after harvesting caused faster respiration and higher CO_2 production. The initial amount of CO_2 in the environment was measured as 0,0444% during experiments. This value reached to 1.15% after 18 hours for mizuna plants that were tested just after harvesting while it was measured as

0,96% after 18 hours for mibuna plants that were tested just after harvesting. This value reached 1.15% at the end of 28 hours for mizuna plants that were tested 1 week later than harvesting time while this value was determined as 0,80% for mibuna plants at the end of same period. Reason of this difference can be explained by smaller leaf and stalk thicknesses of mizuna plant compared to those values determined for mibuna.

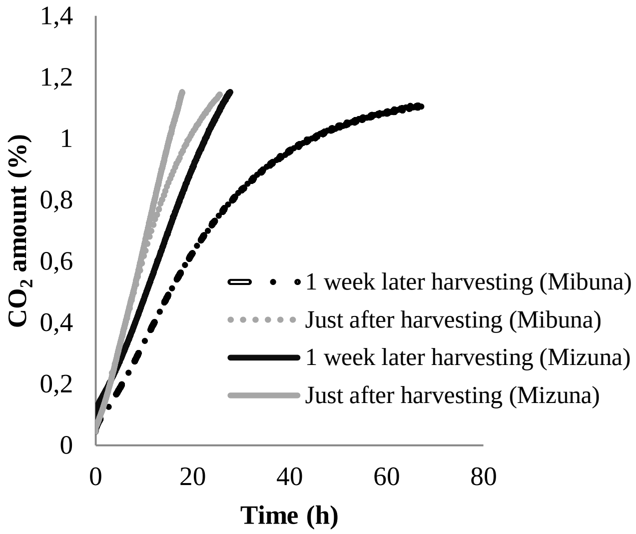


Figure. 5. Change of amount of CO_2 production depending on the storage time.

Respiratory rate and dry matter loss

Changes in respiratory rates (CO_2 production rates) of mizuna and mibuna plants measured just after harvesting and one week after harvesting were given in Fig. 6. As the seen in this figure, respiratory rates measured just after harvesting for both plants were found rather higher compared to those measured 1 week after harvesting depend on CO_2 production rate. Similarly, Richardson (1985) reported that respiration of some fruits was getting to be slower during storage period. It was understood that mizuna plant respiration rate was rather higher compared to those rate measured for mibuna plant according to results of measurements performed both just after harvesting and one week after harvesting. Respiratory rate for mizuna was determined as 409 ml-CO_2/kg-h just after harvesting measurements. It decreased to 258 ml-CO_2/kg-h one week after harvesting. Lower values just after harvesting and 1 week after harvesting were determined as 284 and 105 ml-CO_2/kg-h respectively for mibuna plant which has thicker leaf and stalk structures.

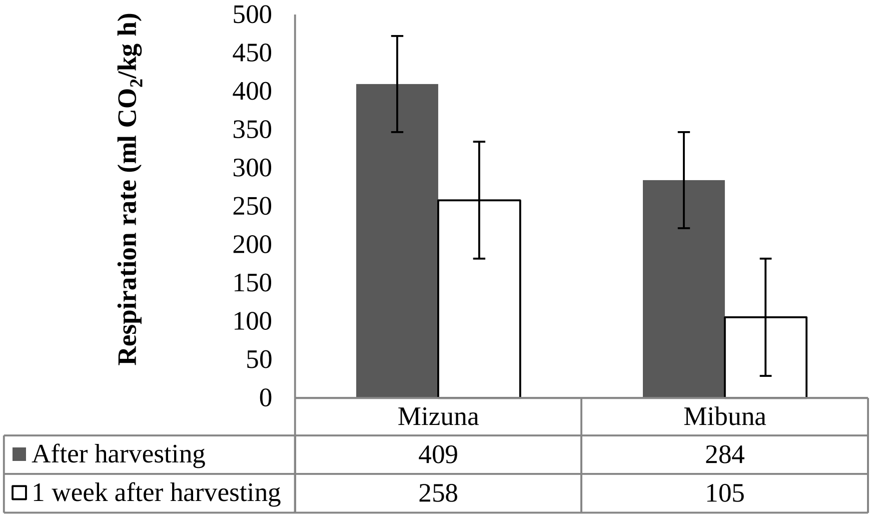
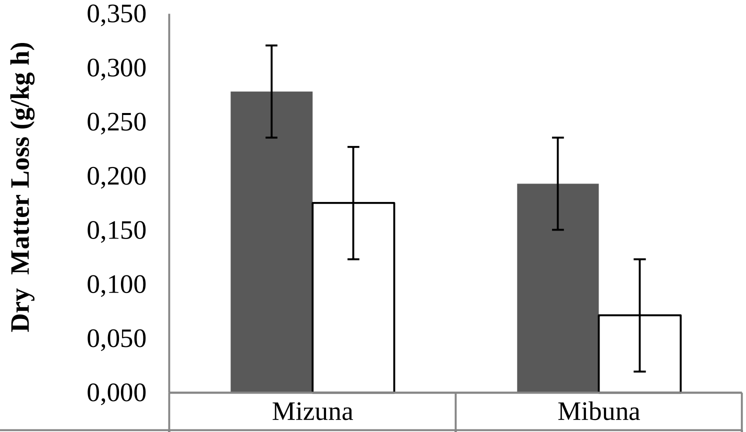


Figure. 6. Change of respiratory rate on mizuna and mibuna samples.

Dry matter loss (g/kg h) changes of mizuna and mibuna determined using respiratory rates were showed in Fig. 7 for just after harvesting and one week after harvesting. It was determined that the highest dry matter losses occurred just after harvesting for both plants related to higher CO_2 production amount and respiratory rate compared to those measured values one week after harvesting. Respiration is fragmentation of starch, sugars and organic acids to some basic molecules such as CO_2 and water etc. and releasing of energy (Kader, 1987). Therefore faster respiration namely more consumption of CO_2 increased the dry matter losses and this situation supports our results. According to this result, it can be said that the dry matter losses in mizuna plant will be higher compared to those values of mibuna plant depend on storage period.



	Mizuna	Mibuna
■ After harvesting	0,278	0,193
□ 1 week after harvesting	0,175	0,071

Figure. 7. Change of dry matter loss depending on the storage time on mibuna and mizuna.

Conclusion

As aresult, it is important to determine the properties of physical, color, mechanical and various respiratory characteristics of cool climate vegetables of mizuna and mibuna plants that have edible leaves and are one of the indispensable salad plants for Far East and Europe. These measured and calculated results are the data which can be used for many product based processes widely especially for designing of special machinery and tools that can be used for postharvesting processes, making of their adjustments, determining of precautions to increase the shelf life during storage, determining of cooling load, determining of drying kinetics, choosing of appropriate drying techniques, sterilization, pressing, canning etc. If biological materials and inorganic materials are compared in respect of designing and development of machinery, the most important disadvantage of the biological materials is that even the constituent parts of same plant are not uniform. Results of this research showed that there are differences among the leaves of the same plant in terms of physical, color and mechanical properties in addition to differences between those properties of mibuna and mizuna plants. Determination of these differences and many measured and calculated data on physical, color and mechanical properties of mizuna and mibuna plants can be used for designing of machinery, equipment and systems.

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