Characterization and functional properties of new everbearing strawberry (Fragaria x ananassa Duch.) cultivar, ‘Summertiara’ berries

Takeshi Nagai¹,²,³*, Misuzu Tamai⁴, Masato Sato⁵, Yasuhiro Tanoue⁶, Norihisa Kai⁶, and Nobutaka Suzuki⁷

¹Graduate School of Agricultural Sciences, Yamagata University, Yamagata 9978555, Japan; ²The United Graduate School of Agricultural Sciences, Iwate University, Iwate 0208550, Japan; ³Graduate School, Prince of Songkla University, Songkhla 90112, Thailand; ⁴Yamagata University, Yamagata 9978555, Japan; ⁵The Farm Village Industry Federation of JA Kushibiki Agricultural Cooperatives, Yamagata 9970341, Japan; ⁶National Fisheries University, Yamaguchi 7596595, Japan; ⁷Nagoya Research Institute, Aichi 4701131, Japan

Corresponding author: *Takeshi Nagai, PhD, Professor, Graduate School of Agricultural Sciences, Yamagata University, Yamagata 9978555, Japan

Submission date: November 29, 2013; Acceptance date: January 23, 2014; Publication date: January 24, 2014

ABSTRACT

Background: In recent years, a new everbearing strawberry cultivar, ‘Summertiara’ was cultivated to supply the strawberries in pre-harvest season from July to October in Japan. For highly research and development of processing of this cultivar, ‘Summertiara’ berries, the objective of this study was to characterize these berries, with relation to chemical parameters, total phenols, total flavonoids, total vitamin C, and total anthocyanins, and was to investigate the solubility and the stability of anthocyanins from the berries. Moreover, the functional properties such as antioxidative activity, active oxygen species scavenging activity, and antihypertensive activity were also evaluated.

Methods: Chemical analysis, colour measurement, and sensory evaluation of new everbearing strawberry cultivar, ‘Summertiara’ berries were performed. Next, the solubility of anthocyanins from the berries and stability of these against pH, temperature, and an incandescent lighting were investigated. Moreover, functional properties of the extracts prepared from berries were elucidated using 5 different methods.

Results: The contents of water, proteins, lipids, carbohydrates, and ash were the same as those of other cultivar berries. The sugar-acid ratio in the berries was low; these were acidulous. By sensory evaluation, the main factors were vivid red colour, aroma, and acidity. The berries were rich in phenols, flavonoids, vitamin C, and anthocyanins. The anthocyanins of the berries
became unstable by heat treatment and light exposures such as visible rays. On the other hand, the extracts prepared from the berries showed the functionalities such as antioxidant activity, active oxygen species scavenging activities, and antihypertensive activity.

**Conclusions:** The strawberry cultivar, ‘Summertiara’ berries were the most suitable for processing ingredient of strawberry-derived products with superior health promoting functionalities.

**Keywords:** Summertiara, everbearing strawberry cultivar, characterization, sensory evaluation, color and storage, functional property

**INTRODUCTION**

Strawberry (*Fragaria x ananassa* Duch.) is a cold-resistant and perennial plant, and is a non-climacteric fruit. It belongs to Rosoideae and is widely cultivated in all parts of the world. The preservation term of the berries at the best quality is very short. After harvesting the berries are stored at low temperatures and modified atmospheres in order to preserve freshness, and then their shelf life can be expanded to at least one week. Strawberry is used not only as fresh fruit, but also as a processing ingredient of strawberry-derived products such as juices, liqueurs, ice cream, yogurts, cakes, preserves, and jams. At present most of them on the commercial sales and distribution are June-bearing strawberry cultivars in Japan. The flower bud initiation of these cultivars is inhibited under high temperature and long photoperiod. So it become to pre-harvest season from July to October in Japan, and the imported strawberries are used to produce the processed foods. Since Ohishi had succeeded to cultivate an everbearing strawberry cultivar, ‘Ohishi-shikinari 1’ in 1954 [1], many everbearing strawberry cultivars (such as ‘Summerberry’, ‘Natsuakari’, ‘Dekoruju’, ‘Kaho’, ‘Summerruby’, and so on) have been cultivated in many area of Japan. In recent year, a new everbearing strawberry cultivar, ‘Summertiara’ was cultivated in Yamagata Prefecture, Tohoku region of Japan.

The presence of bioactive compounds such as flavonoids and ellagic acid derivatives makes the consumption of strawberry suitable for potential health benefits. Dietary intake of flavonoids has been associated to lower risk of heart disease as well as cancer, probably related to the antioxidative activity of these compounds. From the recent studies, the compounds in strawberries have potential power as follows: lower risk of cardiovascular by inhibition of LDL-cholesterol oxidation, promotion of plaque stability, improved vascular endothelial function, and decreased tendency for thrombosis, modulation of the inflammatory process, blocking initiation of carcinogenesis, suppressing progression and proliferation of tumors [2], inhibition of proliferation of human liver cancer cells [3]), inhibition of esophageal cancer [4], anticarcinogenic activities to breast and cervical cancer cells [5], and inhibition of growth and stimulation of apoptosis of human cancer cells [6]. Moreover, the extracts from strawberry showed antithrombotic effect [7], and inhibition of *Helicobacter pylori* with enhanced susceptibility to clarithromycin [8].

Strawberry cultivar’ berries contains large amounts of anthocyanins, the major pigment of strawberry. Particularly, pelargonidin 3-o-glucoside (P3G) is predominant and is responsible for the brights red colour of fresh berries, followed by cyanidin 3-glucoside (C3G), pelargonidin
3-rutinoside, pelargonidin 3-succinate [9], pelargonidin 3-galactoside [10], and pelargonidin 3-
malonylglucoside [11] as minor anthocyanins, flavanols (catechins), and flavonols (quercetin and
kaempferol glycosides) [12,13]. Besides appearance, sweetness, aroma, and acidity, the
development of red, scarlet, or vivid red colour is one of the most important characters affecting
the quality of strawberry. Also it contributes to a consumer’s initial impression and influences
their acceptance. Therefore, for highly research and development of processing of new
everbearing strawberry cultivar, ‘Summertiara’ berries, the objective of this study was to
characterize these berries, with relation to chemical parameters, total phenols, total flavonoids,
total vitamin C, and total anthocyanins, and was to investigate the solubility and the stability of
anthocyanins from the berries. Moreover, the functional properties such as antioxidative activity,
active oxygen species scavenging activity, and antihypertensive activity were also evaluated.

MATERIALS AND METHODS
Materials
The fresh everbearing strawberry cultivar, ‘Summertiara’ berries (weight 3.6-7.4 g, average
weight 4.9 g; Fig. 1A) were gifted from the Farm Village Industry Federation of JA Kushibiki
Agricultural Cooperatives, Yamagata, Japan, transported to our laboratory, and used in the
following tests. Ellagic acid dihydrate, 2,6-di-t-butyl-4-methylphenol (BHT), ACE from bovine
lung (1U), 2,2’-azobis(2-amidinopropane)dihydrochloride (AAPH), α,α’-dipyridyl, chlorogenic
acid, 2-deoxy-d-ribose, ethylenediaminetetraacetic acid disodium salt (EDTA), 1,1-diphenyl-2-
picrylhydrazyl (DPPH), ethyl acetate for spectrochemical analysis grade, hippuryl-l-histidyl-l-
leucine as substrate peptide, linoleic acid, nitroblue tetrazolium salt (NBT), α-tocopherol, and

![Figure 1](image_url)

**Figure 1.** (A) New everbearing strawberry cultivar, ‘Summertiara’ berries, (B) extracts prepared
from the berries

xanthine were purchased from Wako Pure Chemicals Industries, Ltd. (Osaka, Japan). tert-Butyl-
4-hydroxyanisole (BHA) and (+)-catechin were from Tokyo Chemical Industry Co., Ltd. (Tokyo,
Japan). Xanthine oxidase from buttermilk (XOD; 0.27U/mg powder) was from Oriental Yeast
Co., Ltd. (Tokyo, Japan). Trolox was from Cayman Chemical Company (MI, USA).
Pelargonidin 3-α-glucoside (P3G) chloride was from Extrasynthese (Genay cedex, France). All other reagents were of analytical grade.

**Chemical analysis of new everbearing strawberry cultivar, ‘Summertiara’ berries**

AOAC method [14] were used for chemical analysis of new everbearing strawberry cultivar, ‘Summertiara’ berries. Moisture content was measured using a Moisture Determination Balance (FD-600; Kett Electric Laboratory, Tokyo, Japan). Protein content was analyzed by the Kjeldahl method using a conversion factor of 6.25. Lipid content was determined by ether extraction. Ash content was analyzed using a furnance. Sugar content and pH were measured using a refractometer (PAL-Patissier; Atago Co. Ltd., Tokyo, Japan) and a pH meter (PHL-40; DKK Co. Ltd., Tokyo, Japan), respectively. Total phenolic components were determined at 760 nm using ellagic acid as standard [15]. Total flavonoid contents were measured at 510 nm using (+)-catechin as standard [16]. Total vitamin C contents were determined using the α,α’-dipyridyl method [17]. Total anthocyanin contents were measured using P3G chloride as standard [18].

**Colour measurement of new everbearing strawberry cultivar, ‘Summertiara’ berries**

Colour analysis was performed using a Nippon Denshoku Industries Co., Ltd. colorimeter NR-11A (Tokyo, Japan) with illuminant D65 calibrated to black and white standards. The tristimulus L* a* b* measurement mode was used as the relation to human eye response to colour. The L* variable represents lightness (0 for black, 100 for white), the a* scale represents the red-green dimension (-a for greenness, +a for redness), and the b* scale represents the yellow-blue dimension (-b for blueness, +b for yellowness). Colour was measured on three different spots in each and the results were shown as the mean of these measurements.

**Sensory evaluation of new everbearing strawberry cultivar, ‘Summertiara’ berries**

The sensory qualities of new everbearing strawberry cultivar, ‘Summertiara’ berries were evaluated on the basis of appearance, colour, aroma, sweetness, acidity, and overall acceptability on a 7-point Hedonic scale [19] by a panel of 6 panelists consisting of staffs of our laboratories in the Graduate School of Agricultural Sciences, Yamagata University.

**Solubility of anthocyanins from new everbearing strawberry cultivar, ‘Summertiara’ berries**

The berries were lyophilized and the powders were obtained by crushing into pieces using a mortar. To investigate the solubility of anthocyanins from berries, the lyophilized powders were added to 10 volumes of each concentration of ethanol (pH3.5). After 16 h at room temperature in the dark condition, the suspension was centrifuged at 7,740 x g for 10 min. The absorbance of the supernatants was measured at 510 nm.

**Effect of pH on anthocyanins from new everbearing strawberry cultivar, ‘Summertiara’ berries**

The berries were lyophilized and the powders were added to 10 volumes of wide pH range of buffer (pH 2.0-12.0; boric acid-citric acid-trisodium phosphate buffer). After 16 h at room
temperature in the dark condition, the suspension was centrifuged at 7,740 x g for 10 min. The supernatants were used to scan at from 400 to 700 nm.

Stability of anthocyanins from new everbearing strawberry cultivar, ‘Summertiara’ berries
The lyophilized powders were added to 10 volumes of 60 % ethanol (pH 3.5). After 16 h at room temperature in the dark condition, the suspension was centrifuged at 7,740 x g for 10 min. The supernatants were collected and used as following stability tests.

Effect of heat treatment
The supernatants were heated at each temperature (20, 60, 80, and 100°C) for 1 day in the dark condition. The absorbance of the solution was measured at 510 nm and was expressed as the residual quantities of anthocyanins.

Effects of storage temperatures and periods
The supernatants were preserved at each temperature (4, 10, and 30°C) for 3 months in the dark condition. The absorbance of the solution was measured at 510 nm and was expressed as the residual quantities of anthocyanins.

Effect of an incandescent lighting
The supernatants were preserved at room temperature under an incandescent lighting for 3 months. The absorbance of the solution was measured at 510 nm and was expressed as the residual quantities of anthocyanins. The intensity of illumination measured using a digital LUX meter (HEM-DDLM5-K, TSdrena, China) was about 730 LUX.

Functional properties of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries
The berries were weighed, ground in a Potter-Elvehjem homogenizer with a motor-driven Teflon pestle, and centrifuged at 30,000 x g for 30 min at 4°C. The supernatants were filtrated with cheesecloth, and then were used to the following investigation.

Antioxidative activity
The antioxidative activities of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries were measured in a linoleic acid oxidation system described by Nagai and Nagashima [20] with a slight modification of the method of Mitsuda et al. [21]. A 0.083 ml of the extract and 0.208 ml of 0.2 M sodium phosphate buffer (pH 7.0) were mixed with 0.208 ml of 2.5% (w/v) linoleic acid in ethanol in an Eppendorf tube. The oxidation was initiated by the addition of 20.8 μl of 0.1 M AAPH and carried out at 37°C for 200 min in the dark. The degree of oxidation was measured according to the thiocyanate method for measuring peroxides by reading the absorbance at 500 nm after colouring with FeCl₂ and ammonium thiocyanate. BHA (0.01, 0.1, and 1.0 mM), BHT (0.01, 0.1, and 1.0 mM), trolox (0.01, 0.1, and 1.0 mM), ascorbic acid (1 and 5 mM), and α-tocopherol (1 mM) were used as positive control. Distilled water was used as negative control.
Superoxide anion radical scavenging activity
The superoxide anion radical scavenging activities of the extracts made from new everbearing strawberry cultivar, ‘Summertiara’ berries were evaluated as described by Nagai and Nagashima [20] with a slight modification of the method of Rosa et al. [22]. This system contained 0.48 ml of 0.05 M sodium carbonate buffer (pH 10.5), 0.02 ml of 0.15% of BSA, 0.02 ml of 3 mM EDTA, 0.02 ml of 0.75 mM NBT, 0.02 ml of 3 mM xanthine, and 0.02 ml of the extract in an Eppendorf tube. After pre-incubation at 25°C for 10 min, the reaction was started by adding 6 mU XOD and carried out at 25°C for 20 min. The reaction stopped by adding 0.02 ml of 6 mM CuCl. The solution was centrifuged at 12,000 rpm for 5 min, and the absorbance of the reaction mixture was measured at 560 nm and the inhibition rate was calculated by measuring the amount of formazan that was reduced from NBT by superoxide. BHA (0.01, 0.1, and 1.0 mM), trolox (0.01, 0.1, and 1.0 mM), and ascorbic acid (1 and 5 mM) were used as positive control. Distilled water was used as negative control. The IC50 value was defined as the concentration of the extract required to inhibit 50% of superoxide anion radical activity. Moreover, the activity was also expressed as moles of trolox equivalents per kg of fresh weight of strawberries [trolox equivalents antioxidant capacity (TEAC); μmol TE/kg FW].

Hydroxyl radical scavenging activity
The hydroxyl radical scavenging activities of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries were assayed using the deoxyribose method [20] with a slight modification of the method of Chung et al. [23]. The reaction mixture contained 0.45 ml of 0.2 M sodium phosphate buffer (pH 7.0), 0.15 ml of 10 mM 2-deoxy-d-ribose, 0.15 ml of 10 mM FeSO4-EDTA, 0.525 ml of distilled water, and 0.075 ml of the extract in an Eppendorf tube. The reaction was started by the addition of 0.15 ml of 10 mM H2O2. After incubation at 37°C for 4 h, the reaction was stopped by adding 0.75 ml of 1.0% (w/v) of 2-thiobarbituric acid in 50 mM NaOH and 0.75 ml of 2.8% (w/v) trichloroacetic acid. The solution was boiled for 10 min, and then cooled in water. The solution was centrifuged at 12,000 rpm for 5 min, and the absorbance of the supernatants was measured at 520 nm. Hydroxyl radical scavenging activity evaluated as the inhibition rate of 2-deoxy-d-ribose oxidation by hydroxyl radicals. BHA (0.01, 0.1, and 1.0 mM), trolox (0.01, 0.1, and 1.0 mM), and ascorbic acid (1 and 5 mM) were used as positive control. Distilled water was used as negative control. The IC50 value was defined as the concentration of the extract required to inhibit 50% of hydroxyl radical activity. Moreover, the activity was also expressed as TEAC (μmol TE/kg FW).

DPPH radical scavenging activity
The DPPH radical scavenging activities of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries were measured as described by Nagai and Nagashima [20] with a slight modification of the method of Okada and Okada [24]. The assay mixture contained 0.03 ml of 1.0 mM of DPPH radical solution in ethanol, 0.24 ml of 99% of ethanol, and 0.03 ml of the extract in an Eppendorf tube. The mixture was rapidly mixed and after 30 min the absorbance of the mixture was measured at 517 nm. BHA (0.01, 0.1, and 1.0 mM), trolox (0.01, 0.1, and 1.0 mM), and ascorbic acid (1 and 5 mM) were used as positive control. Distilled water was used as negative control. The IC50 value was defined as the concentration of the
extract required to inhibit 50% of DPPH radical activity. Moreover, the activity was also expressed as TEAC (μmol TE/kg FW).

ACE inhibitory activity
The ACE inhibitory activities of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries were performed as described by Nagai and Nagashima [20] with a slight modification of the method of Cushman and Cheung [25]. Twenty-five microliters of the extracts and 95 μl of 0.1 M sodium borate buffer (pH 8.3) containing 4.61 mM hippuryl-l-histidyl-l-leucine as substrate and 1.0 M NaCl in an Eppendorf tube were pre-incubated at 37℃ for 5 min. The mixture was incubated with 5 μl of 0.1 M sodium borate buffer (pH 8.3) containing 1 mM ACE and 1.0 M NaCl at 37℃ for 60 min. By adding 125 μl of 0.1 M HCl the reaction was stopped. The resulting hippuric acid was extracted with 750 μl of ethyl acetate by violently mixing for 15 s. After centrifugation at 6,000 rpm for 3 min, 500 μl of the upper layer was transported into the other tube and evaporated at 80℃ for 2 h. The hippuric acid was dissolved in 500 μl of distilled water, and then the absorbance was measured at 228 nm. The IC₅₀ value was defined as the concentration of the extract required to inhibit 50% of the ACE activity.

Statistical analysis
Each assay was repeated 3 times independently and the results were reported as means ± standard deviation (SD).

RESULTS AND DISCUSSION
Chemical parameters
First, chemical parameters of new everbearing strawberry cultivar, ‘Summertiara’ berries were investigated. As a result, the contents of water, proteins, lipids, carbohydrates, and ash were 89.9, 0.9, 0.1, 8.5, and 0.6 %, respectively (Table 1). These results were the same as those of other strawberry cultivar berries [26].

The berries were weighed, ground, and centrifuged at 30,000 x g for 30 min at 4℃. The supernatants were filtrated with cheesecloth, and then were used to the following investigation. The specific gravity and the pH of the extract were 0.996 and 4.24 at 20℃, respectively (Table 1). The contents of sugars (Brix%) were 7.3% at 20℃. The acid contents of the extracts were measured by titrimetry and the result was indicated as citric acid equivalent. The content was estimated to 1.19% and then the sugar-acid ratio was calculated to 6.13 (Table 1). Sone et al. [27] was investigated the relationship between stability of eating quality of 43 strawberry cultivars and their sugar and organic acid contents. As a result, it reported that the acid contents of these cultivars were from 0.61 to 1.17 % (average 0.81%) as citric acid equivalent. Miyazaki et al. [28] investigated the characteristics of a new processing strawberry cultivar, ‘Benihibari’ and compared with those of other cultivars, ‘America’ and ‘Hokowase’. These Brix% and acid contents were as follows: 7.3, 7.4, and 8.0, respectively and 0.74, 072, and 0.46, respectively. The sugar-acid ratios also were calculated to 9.86, 10.28, and 17.39, respectively. On the other hand, Okimura et al. [29] measured the contents of sugars and acid in new everbearing strawberry cultivars, ‘Natsuakari’ and ‘Dekoruju’, and ‘Summerberry’ as a female parent of ‘Natsuakari’. As a result, these sugar contents (Brix%) were as follows: 8.7, 8.4, and 8.7%,
respectively. The acid contents were as 0.74, 0.72, and 0.99, respectively. That is, the sugar-acid ratios were calculated to 11.8, 11.8, and 8.8, respectively. It was suggested that new everbearing strawberry cultivar, ‘Summertiara’ berries in eating quality were acidulous in comparison with other cultivars and everbearing cultivars.

Table 1. Chemical parameters of new everbearing strawberry cultivar, ‘Summertiara’ berries

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>89.9±0.1(%)</td>
</tr>
<tr>
<td>Proteins</td>
<td>0.9±0.01(%)</td>
</tr>
<tr>
<td>Lipids</td>
<td>0.1±0.02(%)</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>8.5±0.02(%)</td>
</tr>
<tr>
<td>Ash</td>
<td>0.6±0.01(%)</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>0.996±0.003</td>
</tr>
<tr>
<td>pH at 20°C</td>
<td>4.24±0.02</td>
</tr>
<tr>
<td>Brix% at 20°C</td>
<td>7.3±0.1</td>
</tr>
<tr>
<td>Titratable acid content</td>
<td>1.19±0.05 (%)</td>
</tr>
<tr>
<td>Sugar-acid ratio</td>
<td>6.13±0.05</td>
</tr>
<tr>
<td>Total phenols</td>
<td>94.5±0.4*(mg/100g FW)</td>
</tr>
<tr>
<td>Total flavonoids</td>
<td>67.3±0.1**(mg/100g FW)</td>
</tr>
<tr>
<td>Total vitamin C</td>
<td>62.2±0.2(mg/100g FW)</td>
</tr>
<tr>
<td>Total anthocyanins</td>
<td>55.3±0.1*** (mg/100g FW)</td>
</tr>
<tr>
<td>Colour parameter</td>
<td></td>
</tr>
<tr>
<td>surface</td>
<td></td>
</tr>
<tr>
<td>( L^* )</td>
<td>26.57±0.10</td>
</tr>
<tr>
<td>a*</td>
<td>22.14±0.09</td>
</tr>
<tr>
<td>b*</td>
<td>15.51±0.11</td>
</tr>
<tr>
<td>central portion</td>
<td></td>
</tr>
<tr>
<td>( L^* )</td>
<td>40.05±0.13</td>
</tr>
<tr>
<td>a*</td>
<td>17.44±0.19</td>
</tr>
<tr>
<td>b*</td>
<td>10.01±0.14</td>
</tr>
<tr>
<td>homogenate</td>
<td></td>
</tr>
<tr>
<td>( L^* )</td>
<td>14.66±0.04</td>
</tr>
<tr>
<td>a*</td>
<td>19.80±0.03</td>
</tr>
<tr>
<td>b*</td>
<td>10.33±0.03</td>
</tr>
</tbody>
</table>

*ellagic acid equivalent, **(+)-catechin equivalent, ***P3G equivalent

Strawberry is not only a good source of flavonoids and vitamin C [30], but also a very rich source of vitamin E and β-carotene [31]. Next, the contents of total phenolic components, total flavonoids, and total vitamin C of new everbearing strawberry cultivar, ‘Summertiara’ berries were measured and were as follows: 94.5 mg ellagic acid equivalent/100 g FW, 36.2 mg (+)-catechin equivalent/100 g FW, and 62.2 mg/100 g FW, respectively (Table 1). In the recent report, Akutsu et al. [32] investigated the total phenols in the cultivar, ‘Tochiotome’ berries. As a result, the contents of unripe berries (272 mg gallic acid equivalent/100 g FW) were higher than
those of full-ripe ones (234 mg gallic acid equivalent/100 g FW). Then, they also measured the total flavonoid contents in these berries as (+)-catechin equivalent. It found that the unripe berries (4.7 mg/100 g FW) contained more flavonoids than the full-ripe ones (3.6 mg/100 g FW). Moreover, free ellagic acid contents were very low as follows: 0.85 mg/100 g FW (full-ripe berries) and 1.09 mg/100 g FW (unripe ones), respectively. Hänkinen et al. [33] measured the content of ellagic acid in strawberry cultivars, ‘Jonsok’ and ‘Senga’ to investigate the storage condition in a domestic freezer or refrigerator. As a result, the content of ellagic acid of ‘Jonsok’ was 40.3 mg/100 g FW. Ellagic contents of two strawberry cultivars reduced to about 40% during the 9 months of storage at -20° C. Moreover, the content in strawberry jam, one of the processed foods, was about 80% of that in unprocessed strawberries (fresh berries). Willner et al. [34] determined the ellagic acid content in 5 strawberry cultivars, ‘Camarosa’, ‘Sweet Charly’, ‘Chandler’, ‘Osa Grande’, and ‘Milsei’. The contents were the range of about 2.9 to 6.8 mg/100 g FW and were significantly lower than that of ‘Summertiara’. The content of ellagic acid in each cultivar reduced with rising the ripening degree. To investigate the variations in ascorbic acid content among strawberry cultivars on different harvest dates in 1995, Sone et al. [35] measured the ascorbic acid content in 293 cultivars berries. The contents ranged from 15.9 to 114.8 mg/100 g FW (the average was 59.1 mg/100 g FW). Moreover, in 1996, the contents in 149 cultivars ranged from 24.0 to 88.9 mg/100 g FW (the average was 48.1 mg/100 g FW). From these results, it found that the content of vitamin C in ‘Summertiara’ berries was slightly higher than those from other strawberry cultivars.

Colour measurement
The colours of the surface (peels) and the central portion (inside) of new everbearing strawberry cultivar, ‘Summertiara’ berries were investigated and were calculated to 55.3 mg P3G equivalent/100 g FW (Table 1). Yoshida et al. [36] determined the changes in concentration and composition of anthocyanins during color development in fruit of 20 strawberry (Fragaria x ananassa Duch.) cultivars. As a result, P3G was the predominant pigment about 66-94% of total anthocyanins. The contents were the range of 1.75 to 6.94 mg P3G equivalent/100 g FW. On the other hand, Akutsu et al. [32] measured total anthocyanin contents extracted from lyophilized strawberry cultivar, ‘Tochiotome’ berries using 50% acetic acid at room temperature for 24 h. The contents of the anthocyanins in full-ripe and unripe berries were estimated to 17.5 and 9.1 mg P3G equivalent/100 g FW, respectively. In our present investigation, it was shown that the anthocyanin contents of ‘Summertiara’ berries were fairly high compared with other strawberry cultivars.
vivid red (Fig. 1B) (colour parameter $L^* = 14.66$, $a^* = 19.80$, $b^* = 10.33$; Table 1). Besides sweetness, acidity, and aroma, a red or scarlet colour is one of the most important characteristics affecting fruits quality of strawberry cultivars berries. Moreover, it contributes to a consumer’s initial impression. It is well known that anthocyanins are the major pigments of strawberry cultivars berries. Among them, P3G is predominant, followed by C3G [9]. In fact, the total anthocyanin contents were very high (55.3 mg P3G equivalent/100 g fresh berries) in this cultivar, ‘Summertiara’ berries. It suggested that high P3G contents contributed to the vivid red colour of the berries.

Sensory evaluation
The sensory tests of new everbearing strawberry cultivar, ‘Summertiara’ berries were performed on a 7-point Hedonic scale on the basis of 6 parameters by a panel of 6 panelists consisting of staffs of our laboratories in the Graduate School of Agricultural Sciences, Yamagata University. As a result, the main factors were found in intensities and characteristics of colour, aroma, and acidity (Fig. 2). From the result of the sugar-acid ratio (Table 1), the ‘Summertiara’ berries were aromatic flavorful and acidulous and it might be suitable not for eating in the raw but for processing. It is known that more than 360 volatile compounds such as esters, acids, alcohols, aldehydes, ketones, and lactones exists in the strawberries [37]. These compounds are responsible for the floral and fruity aroma in the berries. In particular, aldehydes and furanones play an important role of these aromas [38].

Figure 2. Sensory evaluation of new everbearing strawberry cultivar, ‘Summertiara’

Solubility of anthocyanins in ethanol solution
The solubility of anthocyanins from new everbearing strawberry cultivar, ‘Summertiara’ berries was investigated in each concentration of ethanol solution. As a result, it found that 60 % ethanol was most effective and was as followed in the order 80% > 40% > 90% > 20% (Fig. 3). Surprisingly, the anthocyanins were solubilized more by distilled water (pH 3.5) than by 20, 40,
and 90% ethanol solutions. It indicated that the result was useful for berries production of processed foods making use of its colour.

![Graph](image1)

**Figure 3.** Solubility tests of anthocyanins from new everbearing strawberry cultivar, ‘Summertiara’ berries. The lyophilized powders were added to 10 volumes of each concentration of ethanol (pH 3.5). After 16 h at room temperature in the dark condition, the absorbance of the supernatants was measured at 510 nm.

**Effect of pH**

Anthocyanins may degrade due to various factors such as pH, thermal treatments, light, oxygen, and enzymes [39]. Also the stabilities of anthocyanins may be influenced by other components, particularly the interaction with ascorbic acid, resulting in mutual degradation as reported in strawberry [40]. The absorbance patterns of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries using wide pH range of buffers were investigated by scanning at from 400 to 700 nm. As a result, the stability of anthocyanins was best at pH 2.0, but reduced with rising pH of buffer (Fig. 4).
Figure 4. Effects of pH on anthocyanins from new everbearing strawberry cultivar, ‘Summertiara’ berries. The lyophilized powders were added to 10 volumes of wide pH range of buffer (pH 2.0-12.0). After 16 h at room temperature in the dark condition, the supernatants were used to scan at from 400 to 700 nm.

In the absorption pattern at pH 2.0 at the range of 400 to 460 nm, particularly at 430 nm (as shown in an arrow), it indicated the presence of P3G (Fig. 5) as the major anthocyanin in this berries.

![Structure of pelargonidin 3-α-glucoside](image.png)

**Figure 5.** Structure of pelargonidin 3-α-glucoside

**Effect of heat treatment**

After the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries were heated at each temperature until 1 day in the dark condition, these were immediately cooled in water, and then the absorption of the extracts were measured at 510 nm. As a result, the anthocyanins in the berries were almost stable for 1 day at 20°C (Fig. 6). These were comparably stable for 4 h at 60-100°C, but became suddenly unstable after 4 h at each temperature. In particular, the anthocyanins became drastically unstable by 100°C treatment. The anthocyanin contents after heating for 1 day were as follows: about 68% (60°C), 58% (80°C), and 46% (100°C), respectively (Fig. 5).
Figure 6. Effects of heat treatment on anthocyanins from new everbearing strawberry cultivar, ‘Summertiara’ berries. The lyophilized powders were added to 10 volumes of 60% ethanol (pH 3.5). After 16 h at room temperature in the dark condition, the supernatants were heated at each temperature for 1 day in the dark condition. The absorbance of the solution was measured at 510 nm and was expressed as the residual quantities of anthocyanins.

Akutsu et al. [32] investigated the changes of total polyphenol contents in nonstandard strawberry cultivar, ‘Tochiotome’ berries by heat treatment (60, 80, and 100°C). As a result, the decreasing degrees of polyphenols were low under low temperature and short time conditions. The content after heating at 80°C for 60 min was about 78%, and the decreasing patterns of polyphenols were no difference among the sample species (standard berries, nonstandard berries, full-ripe berries, and mid-ripe berries). Moreover, the anthocyanin contents after same treatment was about 70%, and the decreasing patterns were the same as the patterns of total polyphenols.

Effects of storage temperatures and periods
To investigate the effects of storage temperatures on the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries, extract were preserved at each temperature for 3 months in the dark. As a result, the anthocyanins were relatively stable for 7 days at 4°C (about 98%), but were quickly unstable till 14 days (about 89%), and thereafter were gradually decomposed (about 71% after 90 days) (Fig. 7).

Figure 7. Effects of storage temperatures and periods on anthocyanins from new everbearing strawberry cultivar, ‘Summertiara’ berries. The lyophilized powders were added to 10 volumes of 60% ethanol (pH 3.5). After 16 h at room temperature in the dark condition, the supernatants were preserved at room temperature (4, 10, and 30°C) for 3 months in the dark condition. The absorbance of the solution was measured at 510 nm and was expressed as the residual quantities of anthocyanins.
These tendencies were the same as those of the storage at 10°C. At 30°C the anthocyanin contents were linearly decreased till 14 days (about 57%), and were gradually decreased (about 37% after 90 days). On the contrary, Torreggiani [41] investigated the anthocyanin resistance of frozen strawberry juice. As a result, the anthocyanin contents decreased by 68.8% and 69.7% after 3 and 8 months, respectively. From these investigations it found that temperature is one of the important factors for the stabilities of anthocyanins [42].

Effect of an incandescent lighting

The extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries were tested to investigate the effect of an incandescent lighting. As a result, the anthocyanins were relatively stable for 1 day, but thereafter the anthocyanin contents suddenly decreased till 5 days (about 69%) (Fig. 8). Moreover, the decreasing rates of the anthocyanins became slowly after 5 days, and thereafter the residual contents were as follows: about 41% (30 days), 33% (60 days), and 24% (90 days), respectively. From these investigations, it found that the anthocyanins contained in new everbearing strawberry cultivar, ‘Summertiara’ berries easily decompose by visible rays such as incandescent lighting.

![Figure 8. Effects of an incandescent lighting on anthocyanins from new everbearing strawberry cultivar, ‘Summertiara’ berries. The lyophilized powders were added to 10 volumes of 60% ethanol (pH 3.5). After 16 h at room temperature in the dark condition, the supernatants were preserved at room temperature under an incandescent lighting with 730 LUX for 3 months. The absorbance of the solution was measured at 510 nm and was expressed as the residual quantities of anthocyanins.](image)

Antioxidative activity

The antioxidative activities of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries were investigated to evaluate the inhibition effects at the initiation stage of linoleic acid peroxidation. As a result, each sample species possessed antioxidative activity and the activity increased with an increasing the concentration of the sample (Table 2). The activity for 1% extract was higher than that of 1 mM ascorbic acid, but was lower than those of 0.01 mM BHA, BHT, and trolox. The activity for 10% extract was similar to that of 0.1 mM trolox. On the
other hand, the activity for 100% extract was extremely high and was remarkably higher than those of 1 mM trolox and α-tocopherol and 5 mM ascorbic acid; 100% extract perfectly inhibited a linoleic acid peroxidation for 200 min (Table 2).

**Superoxide anion radical scavenging activity**

Superoxide anion radical scavenging activities of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries were determined using xanthine/xanthine oxidase system. As a result, the activity for 0.1% extract was low as the same as that of 1 mM ascorbic acid (Table 3). This for 1.0% extract was higher than that of 0.01 mM BHA, but was lower than those of 0.1 mM BHA and 0.01 mM trolox. The activity for 10% extract was much higher than those of 1 mM BHA and trolox

**Table 2.** Antioxidative activities of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries

<table>
<thead>
<tr>
<th>Sample</th>
<th>Absorbance (500 nm)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time (min)</td>
<td>50</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Summertiara (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>0.141±0.010</td>
<td>0.408±0.015</td>
<td>1.198±0.021</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>0.080±0.004</td>
<td>0.168±0.007</td>
<td>0.387±0.005</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.006±0.001</td>
<td>0.016±0.002</td>
<td>0.120±0.006</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>0.000</td>
<td>0.000</td>
<td>0.007±0.001</td>
<td></td>
</tr>
<tr>
<td>BHA (mM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01</td>
<td>0.084±0.005</td>
<td>0.120±0.008</td>
<td>0.245±0.012</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>0.056±0.003</td>
<td>0.090±0.006</td>
<td>0.165±0.010</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>0.054±0.002</td>
<td>0.057±0.003</td>
<td>0.100±0.006</td>
<td></td>
</tr>
<tr>
<td>BHT (mM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01</td>
<td>0.082±0.003</td>
<td>0.112±0.009</td>
<td>0.248±0.011</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>0.058±0.004</td>
<td>0.108±0.005</td>
<td>0.173±0.008</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>0.044±0.002</td>
<td>0.051±0.003</td>
<td>0.093±0.005</td>
<td></td>
</tr>
<tr>
<td>Trolox (mM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01</td>
<td>0.084±0.005</td>
<td>0.094±0.006</td>
<td>0.262±0.013</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>0.038±0.002</td>
<td>0.051±0.003</td>
<td>0.123±0.008</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>0.011±0.001</td>
<td>0.031±0.002</td>
<td>0.032±0.002</td>
<td></td>
</tr>
<tr>
<td>Ascorbic acid (mM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>0.022±0.001</td>
<td>0.135±0.006</td>
<td>0.469±0.027</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td>0.016±0.001</td>
<td>0.032±0.003</td>
<td>0.090±0.008</td>
<td></td>
</tr>
</tbody>
</table>
The extract for 100% extract possessed highest scavenging activity as much as 5 mM ascorbic acid (Table 3). The IC$_{50}$ value was calculated to about 4.94% as the extracts prepared from the berries. Moreover, the TEAC against superoxide anion radical was 2.03 x 10$^4$ μmol TE/kg FW. It is known that this radical was effectively scavenged by vitamin C. These results indicated that high scavenging activity against this radical contributed to high concentration of vitamin C in the extracts prepared from the ‘Summertiara’ berries (Table 1).

Table 3. Superoxide anion radical, hydroxyl radical, and DPPH radical scavenging activities of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries

<table>
<thead>
<tr>
<th>Sample</th>
<th>Scavenging activity (%)</th>
<th>Superoxide anion radical</th>
<th>Hydroxyl radical</th>
<th>DPPH radical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summertiara (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>12.2±0.21</td>
<td>9.7±0.12</td>
<td>12.3±0.15</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>33.6±1.23</td>
<td>13.0±0.14</td>
<td>30.9±1.73</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>87.6±3.51</td>
<td>18.9±0.22</td>
<td>87.3±3.00</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>89.8±4.52</td>
<td>52.1±2.17</td>
<td>90.4±3.52</td>
<td></td>
</tr>
<tr>
<td>BHA (mM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01</td>
<td>29.3±0.52</td>
<td>59.1±0.78</td>
<td>5.5±0.04</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>36.4±0.91</td>
<td>93.3±1.39</td>
<td>17.5±0.36</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>51.9±1.36</td>
<td>95.2±1.44</td>
<td>72.7±3.58</td>
<td></td>
</tr>
<tr>
<td>Trolox (mM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01</td>
<td>46.4±0.98</td>
<td>81.5±0.63</td>
<td>0.1±0.01</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>58.1±1.12</td>
<td>91.8±1.17</td>
<td>17.9±0.20</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>76.1±1.89</td>
<td>&gt;100.0</td>
<td>86.3±3.27</td>
<td></td>
</tr>
<tr>
<td>Ascorbic acid (mM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>14.7±0.20</td>
<td>13.2±0.21</td>
<td>3.1±0.04*</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td>89.9±5.31</td>
<td>17.6±0.71</td>
<td>34.1±2.01**</td>
<td></td>
</tr>
</tbody>
</table>

*0.1 mM ascorbic acid; **1.0 mM ascorbic acid

**Hydroxyl radical scavenging activity**

Using the Fenton reaction system, hydroxyl radical scavenging activities of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries were measured. The activity for 1% extract was the same as that of 1 mM ascorbic acid (Table 3). For 10% the activity was about 19% similar to that of 5 mM ascorbic acid. On the other hand, 100% extract showed the middle activity about 52%; that did not amount to any of other antioxidants except for ascorbic acid
The IC$_{50}$ value was calculated to about 93.9% as the extracts prepared from the berries. Moreover, the TEAC against hydroxyl radical was $4.92 \times 10^4$ μmol TE/kg FW.

**DPPH radical scavenging activity**

DPPH radical scavenging activities of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries were investigated. Each extract exhibited the scavenging activity and the activity tended to increase with an increasing degree of the concentration of the extract. The activity for 0.1% extract was fairly high compared with 0.01 mM BHA, and trolox, 0.1 mM BHA, and 1 mM ascorbic acid (Table 3). One percent of extract showed the same activity as that of 5 mM ascorbic acid. The activity for 10% extract was extremely higher than that of 1 mM BHA. Moreover, this was almost similar to that of 1 mM trolox. On the contrary, 100% extract had highest scavenging activity among the samples tested. The IC$_{50}$ value was calculated to about 93.9% as the extracts prepared from the berries. Moreover, the TEAC against DPPH radical was estimated to $1.00 \times 10^7$ μmol TE/kg FW. The DPPH radical scavenging activity is correlated with the total phenol contents. As mentioned above (Table 1), the ‘Summertiara’ berries contained high concentration of the phenols. It suggested that highest DPPH radical scavenging activity of the berries attributed to high contents of total phenol compounds.

**ACE inhibitory activity**

ACE inhibitory activities of the extracts prepared from new everbearing strawberry cultivar, ‘Summertiara’ berries were determined. The protein content was measured by the method of Lowry et al. [43]. As a result, the activity increased with an increasing the concentration of the extract. The activities for 0.1 and 1% extracts were low about 16% (Table 4). Fifty percent of the extract inhibited the ACE activity about 62%. Moreover, 100% extract was the highest activity and its activity was perfectly inhibited the ACE activity (Table 4). The IC$_{50}$ value against ACE activity was measured and was calculated to 1.10 mg protein/ml.

**Table 4.** ACE inhibitory activities of the extracts prepared from new everbearing strawberry cultivar ‘Summertiara’ berries

<table>
<thead>
<tr>
<th>Sample (%)</th>
<th>Activity (%)</th>
<th>IC$_{50}$ (%) (mg protein/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>13.5±0.2</td>
<td>1.10</td>
</tr>
<tr>
<td>1</td>
<td>15.5±0.5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>27.0±2.2</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>62.3±4.7</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>&gt;100.0</td>
<td></td>
</tr>
</tbody>
</table>

In the present study, the chemical parameters of new everbearing strawberry cultivar, ‘Summertiara’ berries were investigated for highly research and development of processing of the berries. As a result, the berries were very rich in phenols, flavonoids, vitamin C, and
anthocyanins. The Brix% was relatively low and titratable acid contents were high; that is, the berries were acidulous. By the sensory evaluation, the main factors of the berries were vivid red colour, aroma, and acidity. It contained a large amount of P3G in the berries; high P3G contents contributed to the colour of the berries. It found that new everbearing strawberry cultivar, ‘Summertiara’ berries might be suitable not to eat in the raw, but to process strawberry-derived products.

The main flavonoids present in strawberries are anthocyanins, which are responsible for the attractive colour development of the fruits, besides being very important for the quality and the evaluation of many fresh and processed fruits. Though they are a good source of natural antioxidants, anthocyanins are quite unstable during processing and storage. Particularly, pH, temperature, time of processing and storage, and light exposure have been found to exert a great influence on anthocyanin stability. Moreover, it is known that the loss of anthocyanins has been attributed to many factors such as phenolic compounds, sugars and sugar degradation products, oxygen, ascorbic acid, fruit maturity, and thawing time. By heat treatment tests, anthocyanins of ‘Summertiara’ berries were comparably stable until 4 h heating at each temperature (20, 60, 80, and 100℃), but above 60℃ became drastically unstable with an increasing degree of the temperature. The effects of storage temperatures and periods were investigated for 3 months in the dark. The anthocyanins were relatively stable for 7 days at 4℃, but were quickly unstable till 14 days, and thereafter gradually decomposed. On the other hand, the anthocyanins contents were linearly decreased till 14 days at 30℃, and were gradually decreased for 90 days.

It is well known that anthocyanins are also easily decomposed by light exposure. The stabilities of the anthocyanins of the berries were tested for 90 days under an incandescent lighting with about 730 LUX. The anthocyanins were relatively stable for 1 day, but thereafter suddenly decomposed till 5 days. Then, the decreasing rates of the anthocyanins became slowly, and the residual contents of the anthocyanin were about 24% after 90 days. The anthocyanins contained in new everbearing strawberry cultivar, ‘Summertiara’ berries decomposed easily by visible rays as incandescent lighting. Melgarejo et al. [44] reported the effects of different temperatures (5 and 25℃) and light exposures (daylight and darkness) on anthocyanin contents and colour development of jams made from the pomegranate cultivar, ‘Mollar’ during five months. The results indicated the stabilities of anthocyanin were closely related with not light exposures but the storage temperatures.

Among anthocyanin derivatives, P3G is the major anthocyanin in strawberry Fragaria x ananassa (153-652 mg/kg FW) [45,46]. On average about 83% of total anthocyanin in strawberry extracts was P3G, and followed by pelargonidin 3-rutinoside (about 8%) and C3G (about 7%). Goiffon et al. [47] analyzed the contents of P3G and C3G in five strawberry varieties, and the percentages of these components were 89-95% and 4-11%, respectively. Ellagic acid is a dietary hydroxybenzoic acid and a hydrolytic product of ellagitannins that may occur in the free form in plants [48]. Ellagic acid is the main phenolic compound in the berries of the family Rosaceae, forming 77-88% of the phenolic compounds, and in the genus Fragaria 51% of the content of phenolic compounds [49]. There are health benefits such as antioxidant, antimutagenic, and anticarcinogenic effects in ellagic acid as well as other phenolic acids [50,51]. From the reasons, in vitro antioxidative activity was investigated in the extracts prepared from everbearing strawberry cultivar, ‘Summertiara’ berries. The extracts exhibited extremely high
antioxidative activity (Table 2), suggesting that a large amount of anthocyanins and phenols such as P3G and ellagic acid contributed to the activity. Active oxygen species scavenging activities were investigated and the extracts possessed the strongest activities: $2.03 \times 10^4 \mu mol$ TE/kg FW (superoxide anion radical scavenging), $4.92 \times 10^4 \mu mol$ TE/kg FW (hydroxyl radical scavenging), and $1.00 \times 10^7 \mu mol$ TE/kg FW (DPPH radical scavenging), respectively. Moreover, the extracts exhibited high ACE inhibitory activity. Overall, the functionalities of new everbearing strawberry cultivar, ‘Summertiara’ berries are associated with high contents of phenols, flavonoids, vitamin C, and anthocyanins.

CONCLUSION
In recent years, new everbearing strawberry cultivar, ‘Summertiara’ was cultivated to supply the strawberries in pre-harvest season from July to October in Japan. The sugar-acid ratio in the berries was low; these were acidulous. By sensory evaluation, the main factors were vivid red colour, aroma, and acidity. The berries were rich in phenols, flavonoids, vitamin C, and anthocyanins. The anthocyanins of the berries became unstable by heat treatment and light exposures such as visible rays. The extract prepared from the berries showed the functionalities such as antioxidant activity, active oxygen species scavenging activities, and antihypertensive activity. From these investigations, it indicated that the strawberry cultivar, ‘Summertiara’ berries are the most suitable for processing ingredient of strawberry-derived products with superior health promoting functionalities.

Competing interests
The authors declare that they have no competing interests.

Authors’ contributions
All authors contributed to this study.

Acknowledgements and Funding
The authors wish to express their gratitude to the help of Yamagata University Regional Industry, Academia and Government Cooperation Project (2012).

REFERENCES


41. Torreggiani D: Modification of glass transition temperature through carbohydrates addition: effect upon colour and anthocyanin pigment stability in frozen strawberry juices. Food Res Inter 1999,32:441-446.