Journal of Food Composition and Analysis 36 (2014) 12–23

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Original Research Article

Morphological and biochemical variation of Chinese cabbage (*Brassica rapa* spp. Pekinensis) cultivated using different agricultural practices

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ARTICLE INFO

Article history:
Received 21 February 2014
Received in revised form 3 June 2014
Accepted 17 June 2014
Available online 28 August 2014

Keywords:
Antioxidant
Biomass
Brassica rapa spp. Pekinensis
Carbohydrate
Food analysis
Food composition
HPLC
ICP-OES
Organic cultivation
Conventional cultivation
Metabolites
Mineral content

ABSTRACT

A comparative study was made of the yield, morphological characteristics, biochemical variations and antioxidant activity of Chinese cabbage, grown conventionally, naturally and organically. A significant increase in most amino acids, calcium (63.1 mg/100 g), magnesium (82.4 mg/100 g) and molybdenum (0.12 mg/100 g) was observed with organic cultivation. Conventionally grown Chinese cabbage had higher sugars and organic acid levels than organically grown cabbage, but sucrose level was higher (4.27 g/100 g) in those grown naturally. Though the moisture content of organic and conventional was comparable, the level of crude lipids, ash and carbohydrate content was higher in natural and control grown plants. Under different cultivation methods the total phenolic content was higher with the natural (302 μg/g) followed by organic (283 μg/g) cultivation. Similarly the 1,1-diphenyl-2-picrylhydrazyl and nitrite scavenging potential was highest in natural (70.12, 43.87%) followed by organic (67.28, 42.14%) cultivation. Crop yields were highest with conventional cultivation and slightly increased compared to organic cultivation. Amino acid and phenolic contents were highest with organic cultivation, suggesting that organic cultivation may provide health benefits.

1. Introduction

Plants have always been a major source of food for humans. Due to their metabolic content, they are the primary source for minerals, vitamins, fibre and antioxidants in the human diet. The rapidly growing human population requires more food and the present scenario is very bleak as to whether we will have enough to feed them all. In the near future there will be a greater demand for more food and this demand can be achieved only by increasing the crop yield (Ray et al., 2013). Inorganic fertilisers, pesticides, fungicides are used in agriculture for an increased yield (Mueller et al., 2012; Erickson, 2009). Somogyi and Beck (1993), and Dewailly et al., 1999 studied the effect of these inorganic compounds on humans. These inorganic substances contaminate the field as well as the environment (Ali, 1999). Most pesticides and fungicides are not readily degraded by natural microorganisms but remain in the soil for long periods of time (Sarathchandra et al., 1993; Geiger et al., 2010), reducing its viability. There is a worldwide search for alternative methods to improve soil conditions.

Organic cultivation is spreading worldwide as a result of greater awareness of the adverse effects of inorganic substances used in cultivation. Organic fertilisers and organic pest disease control are believed to have increased the viability of the soil. Natural cultivation is fast gaining acceptance because of the good food quality (Fukuoka, 1985). Natural cultivation was extensively discussed by Xu (2006), who states that fertilisers pollute the soil and weaken its power of productivity. There is also a greater chance for the outbreak of pests from the excessive use of fertilisers; hence natural cultivation gains importance.

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http://dx.doi.org/10.1016/j.jfca.2014.06.009
0889-1575/

Chinese cabbage (*Brassica rapa* spp.) is a major food in Asian countries, chiefly in China, Japan, and Korea. The presence of high therapeutic properties in this crop has been accepted worldwide and it is used in various food preparations. South Korea is one country that consumes large quantities of Chinese cabbage. The quintessential fermented food product of S. Korea is the spicy Chinese cabbage known as *Kimchi*, and it is recognised for its high antioxidant properties (Lee and Kunz, 2005; Park et al., 2011). Even though Chinese cabbage is extensively used in the day-to-day life of Koreans, the biochemical composition, particularly amino acids and minerals, of conventional, organic, and natural cultivation have not been properly studied before.

The main objective of the present study was to evaluate the major biochemical and mineral variations of Chinese cabbage cultivated using three different practices – organic, natural and conventional. In addition, the total phenolic content and antioxidant potential of these plants are compared.

2. Materials and methods

Chinese cabbages grown under three different agricultural practices – natural, organic and conventional conditions – were compared. The main difference between the groups was based on the soil preparation and application of nutrient sources. In conventional agriculture, inorganic fertilisers were applied, whereas in organic cultivation compost was used as fertiliser. The main difference between natural and organic cultivation was that human food waste served as fertiliser. To find the effect of food waste as fertiliser, a nutrient deficit cultivation with no fertiliser on the soil (control) was compared. The field was certified by "Agricultural Organic Certification Center, Yang-Pyong, South Korea" for organic cultivation (Certification No: 3-3-2278).

This experiment was conducted at Hae Rim Won farm at Yang Pyung Goon, Kung Gee Province, S. Korea over a period of two years (2012–2013) and four harvests. Three randomly selected plants from each harvest were analysed separately and based on the cumulative data, a statistical comparison was performed ($n = 12$). All the analyses were made with proper biological replications of plants collected at different harvested seasons.

2.1. Natural cultivation

In the field, the paddy straw was spread on the top of the soil two months prior to the cultivation of the plant. Food wastes at about 1 kg/m^2 was spread on the soil along with paddy straw and no other fertilisers were used after planting the Chinese cabbage.

2.2. Organic cultivation

The compost prepared from the sesame oil and soybean oil waste (after oil extraction) was placed on the soil at 0.4 kg/m^2 along with animal faecal waste based compost (0.5 kg/m^2). The field was processed for a month before plants were cultivated on that soil.

2.3. Conventional cultivation

Nitrogen-phosphorus-potassium (NPK) fertiliser at 0.5 kg/m^2 (4:2:2) was placed on the soil along with boron (15 g/m^2) one month before cultivation. This served as the conventional method.

2.4. Control cultivation

Land that was not processed before cultivation of Chinese cabbage served as the control.

2.5. Morphological variations of Chinese cabbage under different cultivation

The morphological parameters, such as yield, number of leaves, length and width were studied based on conventional methods. Using a balance the biomass of the samples based on fresh weight and dry weight was measured. The length and width were measured using a scale and leaf colour was monitored using a colour difference meter (*Lab*).

2.6. Colour shade of Chinese cabbage under different cultivation systems

Chromaticity of the samples was determined using a Hunter colour difference meter (D-1001 DP digital colour measuring/ difference calculation meter; Nippon Denshoku Co. Ltd., Tokyo, Japan). Five leaves ($n = 5$) from Chinese cabbage grown under each system was measured for their CIE L (lightness), a (redness), and b (yellowness) values. The average was calculated and compared. Standard colour values of L 96.72, a −0.77, b 1.32 was used as the standard calibration plate.

2.7. Determination of soluble materials and pH of Chinese cabbage under different cultivation systems

Sample (1 g) was homogenised with 20 mL of distilled water and centrifuged for 15 min at 3000 rpm. The supernatant was taken and analysed by saccharimeter refraction (N-1E Brix 0–32%; Atago, Tokyo, Japan). Three randomly selected plants from the respective fields were analysed and presented. Brix refractive saccharimeter (Master-M; Atago, Japan) were labelled using° Brix.

For the measurement of pH, AOAC (Association of Official Analytical Chemists) method was applied. In brief 1 g of sample was homogenised with 10 mL of distilled water, and then centrifuged for 15 min at 3000 rpm. The supernatant was separated and its pH measured (420 Benchtop; Orion Research, Beverly, Washington, DC).

2.8. Proximate analysis of Chinese cabbage under different cultivation

General components, such as moisture, protein, lipids, ash and carbohydrates, were performed using the AOAC method. The samples were analysed before and after drying (AOAC, 200 5).

2.9. Extraction of organic acids from Chinese cabbage

Organic acid analysis was performed by following the procedure of Wilson and Work (1981). In brief 5 g sample were added to 100 mL of 80% ethanol solution in a flask with a reflux condenser. The heating mantle temperature was set at 80 °C and after 2 h, the extracts were filtered through Whatman No. 5 filter paper. The extracts obtained were then evaporated to dryness under reduced pressure (50 °C) and redissolved in water (5 mL). Extracts were analysed by HPLC.

2.10. Organic acids analysis by high-performance liquid chromatography (HPLC)

HPLC (Waters 2695; Waters Corp., Waltham, MA) with a YMCpak ODS-AQ (8.3 × 250 mm; YMC Co., Ltd, Kyoto, Japan) column was used for the analysis. The column temperature was set at 30 °C and phosphate buffer (10 mM) served as mobile phase. The flow rate was 0.8 mL min^{-1} and photo diode array (PDA) detection (Waters 2414, Waters Corp.) was used. Authentic standards of oxalic acid, citric acid, tartaric acid, malic acid, acetic acid, succinic acid and lactic acid (Sigma-Aldrich, St Louis, MO) were dissolved in