THE INFLUENCE OF TEMPERATURE AND OF THE STORAGE LIFE ON THE CHINESE CABBAGE

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Abstract

The analysis regarding the influence of temperature and of the storage period on the functional quality of the Chinese cabbage is argued in this study by the importance of minimizing the loss of nutritious compounds during the period of storage. In order to ensure a certain frequency in consumption, these functional nutrients that play an important role on the processes of degradation of the health of the human body can be preserved for periods as long as possible at values very close to the values from the moment of harvesting. Functional nutrients act on reactive oxygen species, reduce angiogenesis and the inflammatory process, being considered chemopreventive agents.

Temperature and storage period are environmental factors with significant impact on preserving the high nutritional value of the Brassicaceae vegetables for fresh consumption. In order to preserve their dietary and therapeutic qualities, it is necessary to run a prospective analysis of the storage conditions so these products be present in consumption for as long as possible. The analysis of the most advantageous storage methods that try to reduce losses led to the observation that food quality assurance and product certification are of great importance. Thus, useful information can be obtained on the content of vitamins, minerals, antioxidants and glucosinolates found in larger quantities in cruciferous vegetables. These environmental factors are influenced by the morphological, biological and productive particularities of the species of different origins, cultivated in the pedoclimatic conditions specific to each area. Establishing the temperature range and the storage period in order to reduce the level of several functional components in the Chinese cabbage has led to encouraging results according to which the Chinese cabbage can be stored in the homemade system at temperatures of 2-8ºC for a period long enough to meet consumption demands.

The research on the storage conditions provides valuable information for prospective studies on optimizing the storage of the highest amount of functional components such as glucosinolates and vitamin C in Brassicaceae vegetables, including the Chinese cabbage.

Key words: functional components, Chinese cabbage, storage temperature

INTRODUCTION

A great emphasis has been placed lately on the consumption of vegetables and fruit based on their functional character that plays an important role in nutrition and in maintaining and/or improving health. Being safe sources of vitamins and minerals, they protect the body from various disorders and diseases (Apahidean et al., 2000). When a type of food is recommended in a diet, it is important to know its functional properties of improving at least one function of the organism. This happens thanks to the content in biologically active compounds which positively affects one or more target functions of the orgasm, enhancing the health status, reducing the risk of a disease, thus improving the quality of life (Bei et al., 2018).

Based on the strong functional properties against reactive oxygen species, many studies show that the Chinese cabbage is a good adjuvant in reducing the degree of body damage (Fenwick and Heaney, 1983; Akpolat and Barringer, 2015). Vegetables in the cabbage group are growing in popularity thanks to their anticancer, antioxidant and anti-inflammatory properties (Cartea et al., 2011).

The nutrients that are so varied and rich in the Brassicaceae group of vegetables depend on many factors such as diversity, harvesting period, keeping and storage conditions, processing and cooking conditions, the environment they grow in. These vegetables have a low content of fat and a high content of vitamins, especially vitamin C and E, carotenoids, minerals, fibres, but also of phytochemicals and antioxidant enzymes such as catalase, superoxide dismutase (SOD) and peroxidase which are mainly found in fresh vegetables (Cartea et al., 2011; Gupta, 2011; Tan et al., 2010). In addition to these nutrients, foods in the cabbage group also contain glucosinolates with sulphur, anthocyanins, flavonoids, terpenes, S-methylcysteine sulfoxide, coumarins and other compounds.

The shredding or the chewing of the cabbage species generate bioactive glucosinolate hydrolysis products such as isothiocyanates that are capable of modifying redox processes at the cellular level (Herr and Büchler, 2010; Ranjan et al., 2015) and indol-3-carbinol, a chemopreventive agent that inhibits the proliferation and increases tumour cell apoptosis, inhibiting inflammation and angiogenesis (Alliegro, 2007).

In the acid environment of the stomach, indol-3-carbinol is rapidly converted by extensive and rapid self-condensation into 3,3′-diindolylmethane which is formed from the dimerization of two molecules of indole-3-carbinol. 3,3'-diindolylmethane has inhibitory effect on the activity of HDAC isoenzymes, a class of target proteins with key mediating effect of cellular signals. Decreased HDAC expression was accompanied by increased expression of B-cell lymphoma (pro-apoptotic Bcl-2) which, associated with X (Bax) protein and CDKNs p21 and p27, led to cell cycle arrest and increased rate of apoptosis (Schnekenburger and Diederich, 2015).

Besides affecting the expression of the HDAC mediator, indol-3-carbinol treatments prevent alterations of miRNA gene transcripts that regulate at least 30% of the protein-encoding genes, effects observed in rodent tests following exposure to cigarette smoke or in chemically induced tumourigenesis (Robert and Farrell, 2017). Interestingly, indol-3-carbinol sensitizes gemcitabine-resistant pancreatic cancer cells by regulating miR-21, a key regulator of cell proliferation and apoptosis in various cancer models (Begum et al., 2017).

Glucosinolate is present in relatively high concentrations in these vegetables, but the bioavailability of the isothiocyanate can be reduced by cooking, especially by boiling and microwaving. Glucosinolate metabolites can reduce oxidative stress, limiting metastasis, inflammation, endothelial dysfunction and cardiomyocyte death (Jang M, Cho, 2016; Carrasco-Pozo et al., 2017) with beneficial effects on the cardiovascular system. In order to increase the bioavailability of isothiocyanate in the diet, one must pay attention to the cooking method since these vegetables should be steamed and less cooked so that the glucosinolate content be preserved. It is recommended that these cruciferous vegetables be consumed as soon as possible if they are cut.

MATERIAL AND METHOD

The biological material analysed consisted of the varieties of Granat Chinese cabbage - scientifically called Brassica pekinensis and Vitimo F1 hybrid obtained from an organic vegetable micro-farm and from the supermarket - the conventional sample.

Determining the nutritional quality of the Chinese cabbage requires several determinations regarding:

1. the content in vitamin C, for the role of this vitamin in preserving food quality and for certain storage periods, for the antioxidant properties on the reactive oxygen species.
2. the content of nitrites in order to reduce the risk of transformation into nitrosamines following digestion and metabolism, with increased risk of gastrointestinal cancer in adults.

The determination of the content of vitamin C, glucosinolates and nitrites was carried out every 10 days over a 3-month storage period under controlled temperature conditions at 2-4ºC compared to 8-10ºC in both variants, the organic sample and the conventional sample.

RESULTS AND DISCUSSION

Food quality can be affected and influenced by internal factors that refer to the products' chemical composition, biological and physical properties and by external factors that refer to the composition of the atmospheric air, air temperature and humidity, sunshine duration, chemical fertilizers on crop plants, mechanical stress during product handling.

According to the European Union and to the World Health Organization, food safety is a shared responsibility of all actors involved, from food production until it reaches consumers' tables.

Because the domestic production of Chinese cabbage is deficient especially in summer, but also in spring and autumn which are the favourable seasons for its culture, this study tried to determine the best storage conditions for the Chinese cabbage in case of low temperature, with minimum loss of nutrients over long periods of up to 30 days.

Proper storage conditions and techniques are needed to preserve the quality of agricultural and food products as the active trade in agricultural products currently results in long distribution period.

Table 1

Vitamin C content (mg / 100g f.p.) after 10 days of storage at temperatures of 2-4ºC compared to storage at 8-10ºC

Variety / Hybrid	**Vitamin C content before storage at low temperatures (mg/100g p.p)**		**Vitamin C content after 10 days of storage at temperatures of 2-4ºC (mg/100g p.p)**		**Vitamin C content after 10 days of storage at temperatures of 8-10ºC (mg/100g p.p)**	
	organic sample	conventional sample	organic sample	conventional sample	organic sample	conventional sample
Granat-variety ***pekinensis***	45.76	41.69	44.12	40.24	42.86	38.87
Vitimo F1	49.84	43.24	47.92	41.73	45.19	40.35
Mean	47.8	42.46	46.02	40.98	44.02	39.61

Table 1 shows the influence of storage temperatures on the content of vitamin C. The levels of vitamin C in the Chinese cabbage stored at temperatures of 2-4°C decreased more slowly compared to the levels of vitamin C in the Chinese cabbage stored at temperatures of 8-10°C after a period of 10 days (table 1). It is considered that the low temperatures in the storage facilities have beneficial effects on the quality of the Chinese cabbage thanks to the inhibited enzymatic activity that leads to the limited degradation of vitamin C, degradation that can be influenced by the harvest season.

The loss of vitamin C in the organic sample stored at temperatures of 8-10ºC after 10 days was 2.96% higher than the loss of vitamin C in the organic sample stored at temperatures of 2-4ºC. The loss of vitamin C in the conventional sample was 3.31% higher when stored at temperatures of 8-10ºC than when stored at temperatures of 2-4ºC (table 1). For both samples, the organic one and the conventional one, the decrease of the content of vitamin C after a storage period of 10 days is greater when stored at temperatures of 8-10ºC than when stored at temperatures of 2-4ºC (table 1).

Chinese cabbage harvested in summer is more difficult to store in warehouses for more than a month due to high temperatures and humidity that lead to the degradation of its functional quality and to weight loss (Bae et al., 2015; Kim et al., 2001). Therefore, maintaining proper storage parametres such as air composition in the storage space, temperature and humidity is essential to prevent quality degradation (Kim et al., 2010, Eum et al., 2013a, Kim et al., 1998). Physicochemical indices such as colour, firmness, sugar content, weight and flavour represent qualitative parametres used to assess the functional food quality of the Chinese cabbage.

Table 2

Vitamin C content after 30 days of storage at temperatures of 2-4ºC compared to storage at 8-10ºC

Variety / Hybrid	**Vitamin C content before storage at low temperatures (mg/100 g p.p.)**		**Vitamin C content after 30 days of storage at temperatures of 2-4ºC (mg/100 g p.p.)**		**Vitamin C content after 30 days of storage at temperatures of 8-10ºC (mg/100 g p.p.)**	
	organic sample	conventional sample	organic sample	conventional sample	organic sample	conventional sample
Granat variety ***pekinensis***	45.76	41.69	40.52	36.45	38.63	35.41
Vitimo F1	49.84	43.24	44.29	37.96	41.37	36.79
Mean	47.8	42.46	42.4	37.24	40	35.1

Table 2 shows that, after being stored in the refrigerator at temperatures of 2-4ºC, the vitamin C content in the organic sample decreased on average from 47.8 mg/100g FP to 42.40 mg/100g FP. Thus, the loss of vitamin C after a 30-day storage period was of 5.40 mg/100g FP, that means a percentage of 11.29%. Chinese cabbage can be stored for a period of up to 90 days at temperatures of 2-4ºC, specifying that vitamin C loss can reach up to 45% of the total.

At temperatures of 8-10ºC, the loss of vitamin C in the organic sample after 30 days of storage in the refrigerator was on average 7.80 mg/100 g FP, that means a percentage of 16.31%.

The recorded data shows that the loss of vitamin C in the conventional sample that was stored for 30 days in the refrigerator at temperatures of 2-4ºC decreased on average from 42.46 mg/100 g FP to 37.24 mg/100 g FP. The loss of vitamin C after a period of 30 days was of 5.22 mg/100 g FP, that means a percentage of 12.29%.

The amount of Vitamin C in the conventional sample that was stored in the refrigerator for a period of 30 days at temperatures of 8-10ºC decreased by 6.28 mg/100g FP compared to the moment before storing in the refrigerator, that means a percentage of 15.06%.

Specialised literature has published several studies on the effects of storage temperature on weight variation and nutrient loss (Klieber et al., 2002; Eum et al., 2013b). It has been repeatedly analysed how changes in pH, storage period, temperature and concentration in vitamin C affect the colour of the red cabbage (Tomczak and Czapski, 2007; Devahastin and Niamnuy, 2010). These studies have recently been motivated by the content of abundant functional components with anti-carcinogenic effect and properties in the carotenoids and glucosinolates present in the vegetables from the cabbage group and which are unique functional components for Brassicaceae (Jahangir et al., 2009; Akpolat and Barringer, 2015).

Nitrate, especially from green leafy vegetables, can be converted to nitrite (NO2) by the oral commensal bacteria under the tongue or in the stomach which is then converted to nitric oxide (NO) by non-enzymatic synthesis. For the academic community, the determination of the nitrogen content in vegetables is of great importance due to human safety controversies regarding nitrates and nitrites in the diet (Sindelaar, 2012), such as "dietary nitrate - good or bad?" (Gilchrist, 2010) or "harmful or nurturing?" (Weightman, 2013).

Determinations regarding the nitrite content in two varieties of Chinese cabbage obtained in different culture systems, organic and conventional, revealed significant differences between the experimental variants (Table 3). The content of nitrites in the organic sample of Chinese cabbage was on average between 1.93 mg/kg in the Granat variety and 1.84 mg/kg in the Vitimo F1. The content in nitrites in the conventional sample was of 2.79 mg/kg in the Granat variety and of 2.80 mg/kg in the Vitimo F1 hybrid.

Table 3

Nitrite content after 10 days of storage at temperatures of 2-4ºC compared to temperatures of 8-10ºC

Variety/ Hybrid	**Nitrate content before storage at low temperatures (mg/kg FP)**		**Nitrate content after 10 days of storage at temperatures of 2-4ºC (mg/kg FP)**		**Nitrate content after 10 days of storage at temperatures of 8-10ºC (mg/kg FP)**	
	organic sample	**conventional sample**	**organic sample**	**conventional sample**	**organic sample**	**conventional sample**
Granat variety ***pekinensis***	2.49	2.65	1.93	2.79	2.82	3.97
Vitimo F1	2.38	2.57	1.84	2.8	2.67	3.58
Mean	2.44	2.61	1.89	2.8	2.75	3.78

After 10 days in the refrigerator at 2-4ºC, the average nitrite content was 1.885 mg/kg in the organic sample and 2.795 mg/kg in the conventional one. After 10 days in the refrigerator at 8-10ºC, the average nitrate content increased considerably in both samples, reaching 2.745 mg/kg in the organic sample and 3.775 mg/kg in the conventional one.

The average nitrite content in the Chinese cabbage samples after 30 days of storage at 8-10ºC recorded values of 3.83 mg/kg in the conventional sample and of 3.415 in the organic sample.

Table 4

Nitrite content after 30 days of storage at temperatures of 2-4ºC compared to temperatures of 8-10ºC

Variety/ Hybrid	**Nitrate content before storage at low temperatures (mg/kg FP)**		**Nitrate content after 30 days of storage at temperatures of 2-4ºC (mg/kg FP)**		**Nitrate content after 30 days of storage at temperatures of 8-10ºC (mg/kg FP)**	
	organic sample	**conventional sample**	**organic sample**	**conventional sample**	**organic sample**	**conventional sample**
Granat variety ***pekinensis***	2.49	2.65	2.63	2.87	3.58	3.92
Vitimo F1	2.38	2.57	2.49	2.99	3.25	3.74
Mean	2.44	2.61	2.56	2.93	3.42	3.83

CONCLUSIONS

1. The content of vitamin C in both samples, the organic and the conventional one, decreased in a greater proportion when stored at 8-10ºC than when stored at 2-4ºC for a period of 30 days.

2. The level of nutrients in the Chinese cabbage decreased during storage. However, nutrient reduction rates could be minimized by lowering storage temperatures and by controlling atmosphere conditions.

3. It is important to preserve the nutritional and functional quality of the Chinese cabbage because of the requirements for suitable long-term storage conditions at low temperatures and for maintaining its functional components that are important to human health.

4. The analysis of the influence of temperature and of storage period on the content of nitrites in Chinese cabbage at temperatures of 2-4ºC after a storage period of 30 days revealed that the average content in nitrites in the conventional sample was higher than in the organic one, being of 2.93 mg/kg , respectively of 2.56 mg/kg.

5. The nitrite content was on average higher in the conventional samples compared to the organic ones for both temperature variables after a storage period of 30 days in the refrigerator.

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