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Content of Coenzyme Q10 in Selected Food Products and in Daily Food Rations

Chemistry

KEYWORDS : Coenzyme Q10, food, dietary intake

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ABSTRACT

The article deals with content of coenzyme Q10 in selected food products, such as products intended for particular nutritional use of infants and young children (e.g. meat-based baby foods in jars), milk and dairy products, fish and fish preserves, cereals, meat, chicken eggs, as well as in daily food rations. The applied method employed direct n-hexane extraction and high performance liquid chromatography (HPLC) with DAD detection. In the examined food items, the coenzyme Q10 content ranged from 1.2 to 10.4 µg/g in meat, from 0.8 to 27.9 in daily food ratios, up to 545 µg/g in fish and fish-containing products, up to 38.0 µg/g in cereal products. The estimated average daily intakes coenzyme Q10 calculated from our results and statistical data on Polish daily food consumption was 5.4 mg.

1. Introduction

Coenzyme Q1$_0$, also referred to as vitamin Q_{10}, ubiquinone, or ubidecarenone (2,3-dimethoxy-5-methyl-6-polyprenyl-1,4-benzoquinone) belongs to the homologous series of ubiquinones (Fig 1). Coenzyme Q_{10} is a lipophilic substance, easily soluble in lipids, at the same time sparingly soluble in methanol or ethanol, and completely insoluble in water (Crane, 2001).

Coenzyme Q_{10} is present in all eukaryotic and prokaryotic cells, including the membranes of Golgi apparatus, endoplasmic reticulum, lysosomes, peroxisomes, and in small quantities also in microsomes (Crane, 2001). By interacting with membrane proteins it stabilizes them, enhancing their resistance against harmful agents (Crane, 2001, Greenberg et al., 1990). It exhibits oxidizing-reduction properties (Fig.2) (Siemieniuk et al, 2005). In human body, under normal conditions, in each cell there are two forms of coenzyme Q10 – oxidized, i.e. ubiquinone (CoQ_{10}), and reduced. i.e. ubiquinol ($CoQ_{10}H_2$) which remain in balance (Ruiz-Jimenez et al., 2007; Siemieniuk et al, 2005; Breithaupt et al., 2006). The reduction potential of the coenzyme into DMF (dimethylformamide) equals -602mV (Prince et al., 1983). It should be emphasized that the antioxidative properties exhibist the reduced form of the coenzyme – ubiquinol ($CoQ_{10}H_2$), as well as of the ubisemiquinone radical ($CoQ_{10}H$) (James et al., 2004; Siemieniuk et al, 2005).

Coenzyme Q10 is an essential link in electron transport chain (ETC) (Lenaz et al, .2007). Inside cells, it takes active part in passing electrons from Complex I or II to Complex III. Additionally, it is responsible for transferring protons which carried across the membrane form the co-called electrochemical gradient, and are subsequently employed in ATP synthesis (Siemieniuk et al, 2005). The reduced form of coenzyme Q present in the cellular hydrophobic structures regenerates the reduced form of vitamin E (Siemieniuk et al, 2005; Rodowski, 1998; Sikora, 2001; Chaudiere, 1999). It prevents both initiation and propagation of the lipid peroxidation process (Siemieniuk et al, 2005).

In both eukaryotic and prokaryotic cells various homologues are encountered which differ in their number of isoprene residues. For instance, from yeast and mold ubiquinones containing polyprenyl chain built of six (Q_6), seven (Q_7) and eight (Q_8) isoprene residues have been isolated. By the same token, in some vertebrate (fish, rats), and also in humans, the presence of Q_9 and Q_{10} has been noted (Battino M et al., 1990, Bliznakov et al., 1986).

Coenzyme Q_{10} is synthesized in human body in amounts necessary for performing its physiological role (Siemieniuk et al, 2005, Mattila et al., 2001). Its maximum concentration occurs at the age of 19-20 in organs which require the most energy to function properly, such as the heart, liver, nervous system, kidneys and pancreas (Siemieniuk et al., 2005). Following the processes related to aging, concentration of coenzyme Q10 drops (Kalen et al., 1989; Rodriguez-Acuna, 2008). What is more, diseases (Overvad et al., 1999, Hirano et al., 2012; Mishley et al., 2012), poor diet and stress (Langedijk et al., 1996, Yamashida et al., 1997) contribute to the decline of the coenzyme levels, resulting in a decreased energetic function of the body (Kumar et al., 2009). Coenzyme Q10 deficiency can be to some extent corrected with proper diet, because food constitutes an external source of the substance.

The principal dietary source of coenzyme Q10 is meat, particularly raw, along with offal: heart, kidneys, liver and spleen (Mattila et al., 2001), that is organs with the highest energetic demands. Outstandingly large amounts of ubiquinone can be found in fish (Souchet et al., 2007). As a rule, higher quantities of the coenzyme are found in products of animal origin, whereas lower in plant-based foods (Mattila et al., 2001, Weber et al., 1997; Kubo et al., 2008). Evaluation of everyday food products with regard to the content of coenzyme Q10 is vitally important, considering the fact that these products should be assessed not just by their nutritional value, but also as source of important micro-nutrients with salutogenic properties.

The review of reference literature allows us to conclude that studies involving examination of coenzyme Q10 content in foods have been relatively infrequent (Weber et al., 1997; Mattila et al., 2001, Souchet et al., 2007; Belanger et al., 2008; Kubo et al., 2008; Ercan, 2011).

The present article deals with investigation into the content of the coenzyme in selected food products and whole daily food plans from mass catering facilities located in hospitals, care centers, orphanages, boarding houses, schools and kindergartens in Podlaskie region (Poland). Additionally, it contains information pertaining to the impact which the preparation of the dishes (e.g. thermal processing) exerts on the observed values of the coenzyme Q10 content.

2. Materials and methods

2.1. Reagents

Coenzyme Q10, ubiquinone 50 ($C_{50}H_{90}O_4$) from Sigma-Aldrich.

All the reagents used in the analysis: methanol, n-hexane were of HPLC grade.

2.2. Food samples under investigation

The samples of food products that were subject to analysis were retrieved form popular supermarkets and grocery stores. The daily food rations were obtained from selected mass catering facilities located in hospitals, care centers, orphanages, boarding houses, schools and kindergartens in Podlaskie region.

Content of coenzyme Q10 was denoted in samples from the following groups of foods:

products intended for particular nutritional use of infants and young children (meat-based baby foods in jars)

milk and dairy products (3.2% fat milk, condensed milk, natural and fruit yoghurt, kefir, cream cheese, hard cheese, curd)

fish and seafood products (crab sticks, flatfish carcass, smoked mackerel, herring rolls in oil)

cereals (crisp bread, bran and oat flakes, breakfast cereal snacks, rice wafers, honey muesli)

meat (pork ham and neck, rabbit)

chicken eggs

entire daily food rations from catering facilities

2.3. Preparation of food samples

To determine content of coenzyme Q_{10}, the procedure recommended by International Coenzyme Q10 Association was used which employed a one-step sample preparation as described by Mosca et al. in 2002. All the samples were initially homogenized to achieve consistent structure and uniform distribution of ingredients. Next, for each of the samples a portion of 1 g was weighted and further homogenized with the addition of 1 ml of double distilled water. Subsequently, 0.5 ml of thus obtained homogenate was transferred into a 5 ml centrifuge tube. Protein components were precipitated with 0.5 ml of methanol. The sample prepared in such a way was then mixed with 1.5 ml of n-hexane on a vortex mixer, and later rotated on a centrifuge for 7 minutes at 4000 rpm.

After the centrifugation, the organic layer was transferred by means of a Pasteur pipette to another test tube, and the whole extraction process was repeated for the original sample. Eventually, the two extracts were combined and subjected to HPLC analysis.

2.4. HPLC analysis

High-performance liquid chromatography (HPLC) system, Thermo Separation (USA), including Spectra System UV3000 detector, P2000 Binary Gradient Pump, Rheodyne injection valve with a 20 µl sample loop. ChromQuest Chromatography Data System software for Windows NT was used to collect and store data. The analysis was performed with the use of a Lichrosphere LC-18 HPLC column with the dimensions: 15 mm length x 4.6 mm I.D. and 5 µm particle size. Mixture of methanol : n-hexane mixture in the ratio of 72:28 v/v was used as mobile phase. The mobile phase flow rate was equal to 1 mL min^{-1}, and the chromatograms were monitored at 275 nm

2.5. Method validation

Before proceeding to investigate the food samples, the method of analysis was validated. The calibration curve in the range of 0.1 – 50 µg/ml was prepared, obtaining correlation coefficient of 0.999. Repeatability and reproducibility of the results for the 3 µg/ml concentration of the coenzyme expressed by relative standard deviation (RSD) was respectively 2.6% and 2.1%. The observed mean retention time was 3.16 ± 0.46 µg/ml. The limit of qualification equaled 0.25 µg/ml, whereas the limit of detection was 0.1 µg/ml. The average coenzyme Q10 recovery was found to be between 70 and 120% depending on the kind of the sample, its consistency, and the actual content of the coenzyme in the sample (Table 1).

3. Results and discussion

Coenzyme Q10 was extracted from the samples by means of liquid-liquid extraction with n-hexane after their previous deproteinization. The procedure is quick and straightforward, and the observed recovery rates proved its effectiveness with all kinds of the investigated food samples.

The authors established that the coenzyme was present practically in all groups of the investigated food products except for milk and dairy product. The results pertaining to denotation of coenzyme Q10 in various food samples are compiled in Table 1.

To be precise, trace quantities of the substance found in milk and dairy products were below LOD of the used method, with the possible exception of hard cheese in which the observed levels of coenzyme Q10 content were between 1.1 - 1.4 µg/g. According to the expectations, the richest source of the coenzyme constituted meat and fish, in which the denoted values oscillated between 1.3 and 20.1 µg/g. Specifically, in the case of fish and their preserves the marked content was between 0 and 545 µg/g, with particularly high values in this group of products observed in processed mackerel and herring.

Furthermore, in the course of analysis cereal products such as bread or cereal flakes were scrutinized. In this group, the content of coenzyme Q_{10} varied between 0.1 and 38.0 µg/g.

The results constituted a basis for estimating daily intake of the coenzyme with average Polish diet. For this purpose, the authors used data published by Central Statistical Office of Poland concerning average consumption of particular food products (Statistical Yearbook, 2013). It turned out that thus calculated value of daily intake of the coenzyme equaled 5.5 mg. This figure is compliant with the values cited in literature (Weber et al., 1997; Mattila et al., 2000; Mattila, 2001; Kubo et al., 2008; Young-Hee et al., 2011).

Table 1

Analysis of daily food plans in canteens proved that quantities of coenzyme in daily food rations can differ significantly from the estimated average daily intake. The data gathered in Table 3 show that the content of coenzyme Q_{10} varies in very broad range from 0.80 to 27.87 µg/g. The divergence, principally, was caused by variability in qualitative composition (e.g. the number of meat dishes) and processing method (boiling, roasting) and quality of used raw material. According to the recently published by Reig resuls the level of coenzyme Q10 im animal derived food depends on oxidative pattern of muscles and type of meat (Reig et al., 2015). The qualitative composition of the studied daily rations is presented in Table 2.

Table 2

Finally, the analysis of coenzyme Q10 content in food products for particular nutritional use for infants and young children yielded a very interesting outcome. In particular, the content of the coenzyme in this group of product was substantial, i.e. amounted to 45.2±8.2 µg/g, testifying to their health-promoting properties. The contents of coenzyme Q10 in examined products

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for infants varied in the range 9.61 to 108.76 **µg/g**. The details of examined infants foods with the assayed content of coenzyme Q_{10} are presented in Table 3.

Table 3

The amount of micronutrients in a daily food plan relies on a number of factors, such as the quantitative composition (i.e. presence of particular groups of products), the length of thermal processing (boiling, frying, roasting), and the used additions (e.g. fats). Weber et al., (1997) put under investigation changes in the coenzyme Q10 content which occur during boiling. The conclusion was that thermal processing did not significantly affect the observed results (Weber et al., 1997; Tobin et al., 2014). Within the framework of the present study, the authors investigated to what extent the method of thermal processing had influence on the content of coenzyme Q10 in the analyzed samples. To this end, pork neck, rabbit meat and chicken eggs were subjected to thermal processing (roasting and boiling). Pork and rabbit meat was roasted at 160°C for 15 minutes, and also boiled at 100°C for 1 hour. The chicken egg samples were boiled for 7 minutes at a temperature of 100°C. During preparation of the food, except for water, no seasoning or oil were used. The obtained results are presented in Table 4.

Basically, the conclusion was that high temperature facilitated extraction of the coenzyme from the processed material. It may be speculated that this came as a result of disintegration of cellular structures in the course of thermal processing which expedited the extraction of the analyte. In comparison to raw meat, higher content of the coenzyme was observed in the roasted samples, and the highest in the boiled samples. As for the analyzed chicken egg samples, higher content of coenzyme Q10 was denoted in the boiled yolk in relation to the raw yolk (Table 4).

Table 4

4. Conclusion

Analyzing food material usually poses a complex research problem. The results are to a large degree determined by both form of the samples and the physicochemical properties of the analyzed substance. The above fact seems to hold true also for the results obtained within the scope of the present study. Extraction of coenzyme Q10 from the products pre-treated by thermal processing was more efficient than from raw material. This phenomenon was most probably related to thermal decomposition of cellular structures entailing simultaneous release of plasma membrane compounds. Daily intake of coenzyme Q10, as estimated relying on average daily food consumption in Poland, was equal to 5.5 mg. This value largely depended on the qualitative composition of the diet.

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