Stability of selenium and iodine in the functional meat products prepared with seaweeds under different cooking procedures

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Abstract

Keywords:

Functional
Food
Seaweeds
Selenium
Iodine

Introduction. The aim of this study was determination of the stability of selenium and iodine in the functional meat products prepared with seaweeds under different cooking procedures.

Materials and methods. Three edible seaweeds *Fucus*, *Cystoseira*, and *Laminaria* were used in the study. Different meat products with addition of seaweeds were prepared. Selenium concentration was measured using diaminonaphtalene method. Content of iodine was determined by inverse voltammetry.

Results and discussion. Meat-based food products prepared with seaweeds to enrich them with iodine and selenium were proposed. Seaweed *Laminaria* had too high iodine and selenium contents to be used for preparation of dietary products. *Cystoseira* was the better source of iodine than *Fucus*. All ready-to-eat products with *Cystoseira* had higher iodine content than ones with *Fucus*. Iodine losses were lower and the contents of iodine in ready-to-eat products were higher in the products prepared at lower temperature 100–110 °C (steamed cutlets) in comparison with 170 °C (fried cutlets). Altogether, method used for product preparation had a great influence on iodine losses during cooking. The biggest losses were observed for products prepared in liquid: 50% iodine losses in meat balls braised in sauce and 61% in quenelles cooked in soup. Loss of iodine in dumpling was lower, 38%, maybe due to protection of meat with the dough cover. The lowest loss of iodine, around 17%, was in grilled sausages due to relatively low temperature of cooking and absence of liquid environment.

Cystoseira was a lit bit better source of selenium than *Fucus*. All ready-to-eat products with *Cystoseira* had slightly higher selenium content than ones with *Fucus*. Influence of temperature and method for food preparation was not so evident, selenium losses varied from 19 to 27% for steam cutlets, meat balls and even for quenelles and dumpling prepared with *Laminaria*. The lowest loss of selenium, around 7%, was in the grilled sausages.

Conclusion. Fried and steamed minced-meat cutlets, meat balls, and grilled sausages prepared with addition of 2% (w/w) of seaweeds *Cystoseira* or *Fucus* can be recommended to be used as the functional food supplying needed daily quantity of iodine and selenium.

Article history:

Received 21.05.2020
Received in revised
form 03.09.2020
Accepted 25.03.2021

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DOI: 10.24263/2304-
974X-2021-10-1-12

Introduction

Meat products are essential part of a daily ration supplying human with valuable nutrients. To improve meat products quality these products can be designed as the functional food by direct incorporation of different ingredients during meat processing (Bhat and Bhat, 2011; Zhang et al., 2010). Among ingredients used for the preparation of functional food, edible seaweeds are considered as a good source of antioxidants, dietary fibers, essential amino acids, vitamins, unsaturated fatty acids, carotenoids and abundant minerals that can be incorporated in meat, fish, bakery and others products (Bocanegra et al., 2009; Circuncisao et al., 2018).

It was shown that the addition of seaweeds or seaweeds extracts can improve the health value, shelf-life and quality of food (Roohinejad et al., 2017). There are some attempts to use seaweeds in the preparation of meat-based functional food products. Seaweeds, for example “wakame” (*Undaria pinnatifida*), “nori” (*Porphyra umbilicalis*), and “sea spaghetti” (*Himanthalia elongata*) were used as the sources of bioactive substances to improve fatty acid content of some modified meat products such as frankfurters, patties and restructured steaks (Cofrades et al., 2017). There were also attempts to prepare bread using seaweeds *Lemna minor* or *Ulva rigida* to extend its shelf-life (Kilinc et al., 2013).

Edible seaweed (macroalgae) is a rich source of essential minerals and trace elements needed for human nutrition, particular selenium (Se) and iodine (I) (Circuncisao et al., 2018; Cherry et al., 2019), adequate intakes of which are required for optimal thyroid function (Schomburg and Kohrle, 2008).

The aim of this study was determination of the stability of selenium and iodine in the functional meat products prepared with seaweeds under different cooking procedures (Figure 1).

Figure 1. Research scheme

Materials and methods

Seaweeds

Three edible seaweeds from the brown algae family were chosen for this study: (1) *Fucus*, “sea oak”, which has high contents of iodine, calcium, magnesium, iron and other minerals (Pereira, 2011); (2) Black sea brown alga *Cystoseira*, which is a source of iodine and selenium and is used as a food additive (Pereira, 2016), and *Laminaria*, which traditionally has been used as a food additive being a source of biological active substances including iodine in natural form and it is considered that it may be useful for preventing lifestyle-related diseases (Kılınç, 2013; Shirosaki and Koyama, 2011). Seaweeds have been dried in the conventional oven at 100 °C for 2–3 hours for the moisture content 12–13 %, and then milled to a fine powder. The fine powder of seaweeds before addition to the minced meat was mixed with water with temperature 20°C in the following ratio: mass of *Cystoseira* to water 1:3, mass of *Fucus* or *Laminaria* to water 1:4, and exposed for hydration or 6–12 hours. Moisture content of seaweeds was determined after drying at 105°C to a constant weight.

Trace elements determination

Selenium concentration was measured by minifluorometer (mode TD-360, Turner Design, Sunnyvale, CA, USA) using diaminonaphtalene method (Watkinson, 1966). The samples of biomass were preliminary digested using HNO₃, HClO₄ and HCl. The determination of selenium was made in quartz cuvette 3 ml. The excitation wavelength was 369 nm, the fluorescence emission wavelength was 525 nm.

Content of iodine was determined by inverse voltammetry using voltametric analyser ABA2 (Scientific Industrial Enterprise, Saint Petersburg, Russia) (Korzun and Palamarek, 2014).

Thermal treatment of meat products

Meat products were treated at different temperatures: meat-ball were cooked by braising in sauce at 100 °C, quenelle (meat ball cooked in broth) were cooked at 100 °C, boiling of dumplings was done at 100°C, preparation of steamed minced cutlets was done at 100–110°C, frying of minced cutlets was done at 150–170°C, and cooking of sausages on the grill was done at 110°C.

Technological operations

Fried and steamed minced-meat cutlets. Ingredients for cutlets included chicken meat, beef, semi-fat pork, minced fish, soya mince, and also barley, potato, eggs, onion, carrot, sweet butter, bread, salt and spices. Barley was hydrated with water in ratio 1:2 for 30 minutes. Hydrated seaweeds *Fucus* or *Cystoseira* were added in quantity 2% (by dry weight) to raw stuff and mixed for 7 minutes to obtain indiscrete mass. Eight different recipes were used for cutlets preparation: chicken meat, minced fish, barley with biomass of *Cystoseira* (1) or *Fucus* (2); chicken meat, semi-fat pork, barley with biomass of *Cystoseira* (3) or *Fucus* (4), minced fish, soya mince, with biomass of *Cystoseira* (5) or *Fucus* (6); beef, semi-fat pork, raw potato and biomass of *Cystoseira* (7) or *Fucus* (8). Content of iodine was determined in raw, fried and steamed minced-meat cutlets. Fried minced cutlets were stored at temperature -10 °C for 14 days (freezing) and then content of iodine was checked again.

Meat-ball. Ingredients for meat balls included chicken meat, semi-fat pork, minced fish, taking in different proportions, and also barley, eggs, sweet butter, bread, salt and black pepper. Hydrated seaweeds *Cystoseira* or *Fucus* were added in quantity 2% (by dry weight) to raw stuff and mixed for 7 minutes to obtain indiscrete mass. Meat balls (with weight of 70 g each) were prepared by braising in sauce at temperature 100°C. Four different recipes were used for meat ball preparation: semi-fat pork, chicken meat, rice grits, barley flour, seaweed *Cystoseira* (1) or *Fucus* (2); minced fish, wheat bread, milk, barley flour, seaweed *Cystoseira* (3) or *Fucus* (4).

Quenelles. Quenelles (small meat balls with weight 15 g each) were cooked in a broth at 100°C. Hydrated seaweed *Laminaria* was added in quantity 2% (by dry weight) to raw stuff and mixed for 7 minutes to obtain indiscrete mass. Two different recipes were used for quenelles preparation: semi-fat pork, chicken meat, barley flour, egg, carrot, onion, salt, black pepper and seaweed *Laminaria* (1); minced fish hake, white bread, sweet butter, barley flour, egg, carrot, onion, salt, black pepper and seaweed *Laminaria* (2).

Dumplings. Ingredients for dumplings included minced pork, minced beef, fat pork (recipe 1) and fish pike perch (recipe 2), and also onion, chicken eggs, and spices. Hydrated seaweed *Laminaria* was added in quantity 2% (by dry weight).

Grilled sausages. Sausages on the grill were prepared at 110 °C for 60 min. Ingredients for sausage included chicken meat, semi-fat pork, lard, bean, onion, and species. Hydrated seaweeds *Fucus* (recipes 1 and 3) or *Cystoseira* (recipes 2 and 4) were added in quantity 2% (by dry weight).

Results and discussion

Fried minced-meat cutlets. Iodine losses in minced-meat cutlets after frying at 150–170 °C varied from 20 to 37% in products with *Cystoseira* (recipes 1, 3, 5, and 7) and from 20 to 23% in products with *Fucus* (recipes (2, 4, 6, and 8) (Figure 2).

Figure 2. Iodine losses in fried minced-meat cutlets prepared by different recipes
1 – fried; 2 – fried after freezing

Content of iodine in fried minced-meat cutlets with mass 50 g varied from 276 to 315 mcg: 189 mcg (recipe 1); 215 mcg (recipe 2); 276 mcg (recipe 3); 188 mcg (recipe 4); 315 mcg (recipe 5); 216 mcg (recipe 6); 188 mcg (recipe 7); 186 mcg (recipe 8). It was shown that the losses of iodine depend on recipe notwithstanding what kind of seaweeds was used. During preparation of fried cutlets, the higher losses were observed for recipes 3 and 4, which differed only by seaweed added (3 with *Cystoseira*) and (4 with *Fucus*), and the content of iodine in 50 g of fried minced-meat cutlets were 276 and 188 mcg, respectively. Meanwhile, the lowest losses of iodine were observed for recipes 5 and 6, which also differed only by seaweed added (5 with *Cystoseira*) and (6 with *Fucus*), and the content of iodine in 50 g of fried minced-meat cutlets were 315 and 216 mcg, respectively.

Fried minced-meat cutlets were stored at -10°C for 14 days. Losses of iodine during storage under freezing were negligible, around 2%, and consisted from 23 to 39% in products with *Cystoseira* (recipes 1, 3, 5, and 7) and from 22 to 30% in products with *Fucus* (Figure 2).

Steamed minced-meat cutlets. Losses of iodine in steamed minced-meat cutlets prepared at temperature $100\text{--}110^{\circ}\text{C}$ were lower than in fried ones and were around 22% in products with *Cystoseira* (recipes 1 and 3) and were around 15% in products with *Fucus* (recipes 2 and 4) (Figure 3).

Figure 3. Iodine and selenium losses in steamed minced-meat cutlets prepared by different recipes:
1 – iodine; 2 – selenium

Content of iodine in steamed minced-meat cutlets with mass 50 g varied from 202 to 342 mcg: 342 mcg (recipe 1); 214 mcg (recipe 2); 321 mcg (recipe 3); 202 mcg (recipe 4). Content of iodine in fried minced-meat cutlets prepared without seaweeds (control) with mass 50 g varied from 0.32 mcg to 1.06 mcg.

Losses of selenium in steamed minced-meat cutlets were almost the same for all recipes: around 27% in products with *Cystoseira* (recipes 1 and 3) and around 26% in products with *Fucus* (recipes 2 and 4) (Figure 2). Content of selenium in steamed minced-meat cutlets with mass 50 g were: 40 mcg (recipe 1); 35 mcg (recipe 2); 33 mcg (recipe 3); 30 mcg (recipe 4). Content of selenium in steamed minced-meat cutlets prepared without seaweeds (control) with mass 50 g varied from 20 mcg to 28 mcg.

Meat-balls. Meat-balls and fish-balls were cooked by braising in sauce at 100 °C. Iodine loss in both types of balls with *Cystoseira* (recipes 1 and 3) *Fucus* (recipes 2 and 4) was similar $50.1 \pm 1.6\%$. Contents of iodine in 50 g of balls with *Cystoseira* were 186.2 mcg (recipe 1) and 181.1 mcg (recipe 3); with *Fucus*; 134.9 mcg (recipe 2); 146.3 mcg (recipe 4). Content of iodine in meat balls prepared without seaweeds (control) with mass 50 g varied from 0.01 mcg to 0.04 mcg.

Selenium loss in both types of balls with *Cystoseira* (recipes 1 and 3) or *Fucus* (recipes 2 and 4) was similar $20.1 \pm 1.2\%$. Content of selenium in meat balls with mass 50 g were: 38.9 mcg (recipe 1); 34.1 mcg (recipe 2); 19.2 mcg (recipe 3); 21.6 mcg (recipe 4). Content of selenium in meat balls with mass 50 g prepared without seaweeds (control 1) was 3.6 mcg (control 1 for recipes 1 and 3) and to 6.2 mcg (control 2 for recipes 2 and 4).

Quenelles. Meat quenelles (recipe 1) and fish quenelles (recipe 2) with *Laminaria* with weight 15 g each cooked in the soup at 100°C. Iodine loss was 60.9% for meat quenelles and 56.1% for fish quenelles. Content of iodine in 50 g of quenelles was 574 mcg (recipe 1) and 693 mcg (recipe 2). Selenium loss was 15.9% for meat quenelles and 20.3% for fish quenelles. Content of selenium in 50 g of quenelles was 136 mcg (recipe 1) and 125 mcg (recipe 2).

Dumplings. Meat dumplings (recipe 1) and fish dumplings (recipe 2) with *Laminaria* were boiled at 100 °C. Iodine loss was 38.2% for meat quenelles and 40.6% for fish quenelles. Content of iodine in 50 g of dumplings was 373 mcg (recipe 1) and 339.0 mcg (recipe 2). Selenium loss was 20.1% for meat dumpling and 21.2% for fish quenelles. Contents of selenium in 50 g of dumplings were 82 mcg (recipe 1) and 80 mcg (recipe 2).

Griddle sausages. Sausages on the grill were prepared at 110 °C for 60 min. Hydrated seaweeds *Cystoseira* (recipes 1 and 3) or *Fucus* (recipes 2 and 4) were added in quantity 2% (by dry weight). Losses of iodine and selenium were 15.4 and 7.2% (recipe 1), 16.0 and 6.1 % (recipe 2), 15.0 and 8.2% (recipe 3), 20.5 and 7.7 % (recipe 4), respectively. Content of iodine and selenium, mcg/50g, were 270 and 45.4 (recipe 1), 243 and 39.1 (recipe 2), 306 and 40.2 (recipe 3), 218 and 36.0 (recipe 4), respectively.

Compatible analysis of seaweeds application as a source of selenium and iodine to enhance meat products

Average data of all meat products without taking into account influence of recipes are shown in Table 1.

Cystoseira was the better source of iodine than *Fucus*. All ready-to-eat products with *Cystoseira* had higher iodine content than ones with *Fucus*. Influence of temperature is evident, especially due to comparison of iodine content in fried and steamed minced-meat cutlets: iodine losses were lower and the contents of iodine in ready-to-eat products were higher when in the products prepared at lower temperature 100–110 °C (steamed cutlets) in comparison with 170 °C (fried cutlets). Altogether, method used for product preparation had a great influence on iodine losses during cooking. The biggest losses were observed for products prepared in liquid: 50% iodine losses in meat balls braised in sauce and 61% in quenelles cooked in soup. Loss of iodine in dumpling was lower, 38%, maybe due to protection of meat with the dough cover. The lowest loss of iodine, around 17%, was in grilled sausages due to relatively low temperature of cooking and absence of liquid environment.

Table 1

Losses of iodine and selenium in meat products enriched with seaweeds prepared by different cooking methods

Meat products	Temperature, °C	Seaweed	Iodine		Selenium	
			loss, %	mcg/50g	loss, %	mcg/50g
Fried cutlets	150–170	<i>Cystoseira</i>	27	242	N/d	N/d
		<i>Fucus</i>	22	201	N/d	N/d
Steamed cutlets	100–110	<i>Cystoseira</i>	22	332	27	37
		<i>Fucus</i>	15	208	26	32
Meat ball	100	<i>Cystoseira</i>	50	186	21	39
		<i>Fucus</i>	50	135	19	34
Quenelles	100	<i>Laminaria</i>	61	574	16	136
Dumpling	100	<i>Laminaria</i>	38	373	51	82
Grilled sausages	110	<i>Cystoseira</i>	16	305	8	43
		<i>Fucus</i>	18	200	7	38

Recommended Dietary Allowances (RDAs) for iodine is 150 mcg per day for most adults (Trumbo et al., 2001) and 250 mcg per day for pregnant women (WHO, 2007). It looks that *Laminaria* has too high iodine content, so, it is not reasonable to use it for preparation of functional meat product to prevent over dosage of iodine daily intake. However, *Cystoseira* and *Fucus* can be recommended to be used in quantity 2% for preparation of functional meat product to enrich diet with iodine.

Fried and steamed minced-meat cutlets, meat balls, and grilled sausages prepared with addition of seaweeds *Cystoseira* or *Fucus* can be recommended to be used as functional food supplying needed daily quantity of iodine.

Cystoseira was a lit bit better source of selenium than *Fucus*. All ready-to-eat products with *Cystoseira* had slightly higher selenium content than ones with *Fucus*. Influence of temperature and method for food preparation was not so evident, selenium losses varied from 19 to 27 % for steam cutlets, meat balls and even for quenelles and dumpling prepared with *Laminaria*. The lowest loss of selenium, around 7%, was in the grilled sausages.

According to World Health Organization, the recommended daily intake of selenium is from 30 to 40 µg/day (Kieliszek and Blazejak, 2016). Daily consumption of selenium by population in different countries varies from 28 to 150 µg Se per day. Daily recommended allowances of selenium in Ukraine are 70 µg for men and 55 µg for women (Stabnikova et al., 2019). However, a large part of the Ukrainian population has a shortage of selenium in their rations. For example, daily consumption of selenium by people living in town Slavutich, near Chernobyl nuclear power plant accident site, consists only 26% of recommended daily allowance (Spirichev et al., 2006). It looks that *Laminaria* has too high content of selenium to be used for preparation of dietary products as a source of selenium. However, minced meat cutlets, meat balls and grilled sausages prepared with seaweeds *Cystoseira* and *Fucus* can serve as the sources not only iodine but selenium also.

The quality of meat products with seaweeds were estimated by organoleptic properties such as product appearance, view of the cross-section, consistency, color, taste and smell. The volunteers from the National University of Life and Environmental Sciences and the National University of Food Technologies made conclusion that there was no significant difference between meat products prepared with seaweeds and control ones.

Conclusions

Fried and steamed minced-meat cutlets, meat balls, and grilled sausages prepared with addition of seaweeds *Cystoseira* or *Fucus* can be recommended to be used as functional food supplying needed daily quantity of iodine and selenium.

Losses of iodine in meat products prepared with seaweeds depended on recipe, notwithstanding what kind of seaweeds was used. Meanwhile, losses of iodine during storage at – 10°C for 14 days were negligible, around 2 %. The method that was used for product cooking as well as temperature of cooking had also a great influence on iodine and selenium losses during food preparation. Lowest losses of both elements were observed for grilled sausage.

Seaweed *Laminaria* has too high iodine and selenium contents to be used for preparation of functional meat products. However, minced meat cutlets, meat balls and grilled sausages prepared with seaweeds *Cystoseira* or *Fucus* can serve as the sources for iodine and selenium in preparation of functional meat products for consumption by Ukrainian population.

References

- Bhat Z.F., Bhat H. (2011) Functional meat product. A review, *International Journal of Meat Science*, 1, pp. 1–14.
- Bocanegra A., Bastida S., Benedí J., Rodenas S., Sanchez-Muniz F.J. (2009), Characteristics and nutritional and cardiovascular-health properties of seaweeds, *Journal of Medicinal Food*, 12(2), pp. 236–258.
- Cherry P., O'Hara C., Magee P.J., McSorley E.M., Allsopp P.J. (2019), Risks and benefits of consuming edible seaweeds, *Nutrition Reviews*, 77(5), pp. 307–329.
- Circuncisao A.R., Catarino M.D., Cardoso S.M., Silva A.M.S. (2018), Minerals from macroalgae origin: Health benefits and risks for consumers, *Marine Drugs*, 16(11), p. 400.
- Cofrades S., Benedí J., Garcimartin A., Sanchez-Muniz F.J., Jimenez-Colmenero F. (2017), A comprehensive approach to formulation of seaweed-enriched meat products: From technological development to assessment of healthy properties, *Food Research International*, 99(3), pp. 1084–1094.
- Kieliszek M., Blazejak S. (2016), Current knowledge on the importance of selenium in food for living organisms: a review, *Molecules*, 21, p. 609.
- Kılınç B., Çirik S., Turan G., Tekogul H., Koru E. (2013), Seaweeds for food and industrial applications, in I. Muzzalupo (Ed.), *Food Industry*, Intech, pp. 735–748.
- Korzun V.N., Palamarek K.V. (2014), Concentration of iodine in vegetable cheese pasta, *Food Science and Technology*, 2, pp. 10–14.
- Pereira L. (2011), A review of the nutrient composition of selected edible seaweeds, in V. H. Pomin (Ed.), *Seaweed: Ecology, Nutrient Composition and Medicinal Uses*, Nova Science Publishers, Inc., pp. 281–304.
- Pereira L. (2016), *Edible Seaweeds in the World*. CRC Press.
- Roohinejad S., Koubaa M., Barba F.J., Saljoughian S., Amid M., Greiner R. (2017), Application of seaweeds to develop new food products with enhanced shelf-life, quality and health-related beneficial properties, *Food Research International*, 99 (Pt 3), pp. 1066–1083.
- Schomburg L., Kohrle J. (2008), On the importance of selenium and iodine metabolism for thyroid hormone biosynthesis and human health, *Molecular Nutrition & Food Research*, 52(11), pp. 1235–1246.

Shirosaki M., Koyama T. (2011), *Laminaria japonica* as a food for the prevention of obesity and diabetes, *Advances in Food and Nutrition Research*, 64, pp. 199–212.

Spirichev V.B., Donchenko G.V., Blazheyevich N.V. et al. (2006), Study of vitamin status and provision with micro- and macroelements of limited groups of people at different time periods since the accident at Chernobyl nuclear power plant, *Ukrainian Biochemical Journal*, 78, pp. 5–26.

Stabnikova O., Antonuk M., Stabnikov V., Arsen'eva L. (2019), Ukrainian dietary bread with selenium-enriched malt, *Plant Foods for Human Nutrition*, 74(2), pp. 157–163.

Trumbo P., Yates A.A., Schlicker S., Poos M. (2001), Dietary reference intakes: vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc, *Journal of the Academy of Nutrition and Dietetics*, 101(3), pp. 294–301.

Watkinson J.H. (1966), Fluorometric determinations of selenium in biological material with 2,3, diaminonaphtalene, *Analytical Chemistry*, 38(1), pp. 92–103.

WHO. (2007), World Health Organization. United Nations Children's Fund and International Council for the Control of Iodine Deficiency Disorders. Assessment of iodine deficiency disorders and monitoring their elimination. 3rd ed. Geneva, Switzerland.

Zhang W., Xiao S., Samaraweera H., Lee E J., Ahn D.U. (2010), Improving functional value of meat products, *Meat Science*, 86(1), pp. 15–31.