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Impact of cooking processes on the toxic metals, macro, and trace elements composition of *Rapana venosa* meat

Barış BAYRAKLI

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Sinop University, Vocational School, Sinop, Türkiye

ORCID IDs of the author(s):
B.B. 0000-0002-1812-3266

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Correspondence:
Barış BAYRAKLI
E-mail: barisbayrakli@gmail.com

ABSTRACT

This study aimed to investigate the impact of the cooking process on the metal content of *Rapana venosa* (rapa whelk) meat. The research analysed macro and trace elements and heavy metals to determine how cooking influenced their concentrations in the meat.

The findings revealed significant changes in the composition of macro elements following cooking. Potassium (K) and sodium (Na) concentrations decreased, while magnesium (Mg) and phosphorus (P) concentrations increased. This suggested that cooking facilitated the transfer of these elements from the meat to the cooking water, thereby affecting the nutritional composition of the meat. Similarly, numerous trace elements exhibited alterations during cooking, with elements such as iron (Fe), zinc (Zn), aluminium (Al), copper (Cu), manganese (Mn), selenium (Se), rubidium (Rb), tin (Sn), barium (Ba), chromium (Cr), nickel (Ni), lithium (Li), molybdenum (Mo), and beryllium (Be) decreasing in concentration. In contrast, zinc (Zn) and barium (Ba) increased. The study also addressed heavy metals, where significant changes were observed in the concentrations of arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb) following cooking. The results indicated that cooking had the potential to reduce the levels of these toxic heavy metals, although it also highlighted an increase in lead levels that warrants further investigation. In summary, this research provides valuable insights into the changes in the metal content of rapa whelk meat induced by the cooking process. The findings contribute to understanding this seafood's nutritional aspects and metal composition, offering potential guidance for health recommendations and inspiring future investigations in this field.

Keywords: *Rapana venosa*, Toxic metals, Cooking impact, Nutritional changes, Trace elements

Introduction

Food resources, particularly seafood, are a critical source of minerals essential for human well-being (Bayrakli, 2021; Yildiz et al., 2023). Minerals like calcium, potassium, zinc, phosphorus, and iron are imperative for a healthy life (Duyar & Bilgin, 2020). Nevertheless, the escalating metal concentrations in marine ecosystems, attributed to industrialisation and urbanisation, have become a substantial concern among consumers (Duyar et al., 2023). Seafood, in its natural state, is acknowledged for its elevated heavy metal content, with these metals being assimilated from their environments through various natural processes inherent in complex marine ecosystems. Notably, the dietary behaviours of marine organisms can significantly influence the accumulation of metals within their habitat (Duyar et al., 2023; Yildiz et al., 2023).

Metals, characterised by high bioaccumulation levels within tissues and potential toxicity and biological degradation (Stankovic et al., 2014), pose substantial health risks to humans (Zhuang et al., 2013). Indeed, trace elements such as copper, manganese, zinc, and iron are essential for metabolic processes in humans and other organisms but can prove toxic at elevated levels (Makedonski et al., 2017). Metals with a pronounced propensity for bioaccumulation in biological organisms, such as arsenic, lead, cadmium, and mercury, unequivocally exhibit toxicity (Mol et al., 2019). These metals can impact central nervous system function, disrupt blood composition, damage the kidneys, lungs, and liver, and substantially reduce energy levels (Hajeb et al., 2014).

Numerous studies have explored metal concentrations in marine gastropods like *Rapana venosa*, consistently demonstrating that the metal accumulation in these organisms closely mirrors the metal concentrations within the marine environment (Ahmed et al., 2011; Y. Liang et al., 2017). However, owing to their restricted mobility within the marine environment, these organisms are acutely susceptible to metal pollution (Hwang et al., 2017). Despite the significant potential of *Rapana venosa* to serve as a basis for developing functional foods with discernible health benefits for humans (Panayotova et al., 2019), the biological accumulation of heavy metals in gastropods underscores the potential threat to human health through consumption (Gedik, 2018).

Extensive literature demonstrates that the cooking processes of seafood can induce substantial alterations in metal content, underscoring the critical importance of vigilant monitoring of metal concentrations in seafood prior to consumption (Atta et al., 1997; Ersoy et al., 2006; Hajeb et al., 2014; Hanaoka et al., 2001; Ichikawa et al., 2006; Jorhem et al., 1994; Laparra et al., 2003, 2004; Perelló et al., 2008; Sengupta et al., 2006).

Consequently, this study seeks to investigate the fluctuations in metal concentrations during the cooking of *Rapana venosa* meat and to evaluate the potential health implications of these changes.

This study represents a paradigm for evaluating the influence of cooking processes on macro, trace elements and toxic metal contents in seafood. The outcomes of this research endeavour will substantially contribute to understanding trace elements and toxic metal concentration changes during the cooking of *Rapana venosa* meat and their broader implications for safe and health-conscious seafood consumption.

Materials and Methods

Sampling and Study Area

Samples totalling 2000 grams were obtained from Sadiklar Seafood Processing Company's plant in Dikmen-Sinop, Turkey. These samples were taken from products that had been de-shelled, cleaned and in their consumable meat state before being subjected to flash freezing.

The samples were sent to the Sinop University Scientific and Technological Research Application and Research Center for laboratory analysis. This centre has a laboratory infrastructure that ensures reliable analysis procedures following standardised protocols.

During the laboratory processing of rapa whelks, 1000 grams were separated to form raw meat samples, while the remaining 1000 grams constituted cooked meat samples. The cooking process for rapa whelks was conducted by boiling them in a stainless steel pressure cooker for 10 minutes using 500 ml of water.

Both groups of rapa whelk samples were individually homogenised, and four samples were taken from each group. Subsequently, label information was added, and the samples were prepared for analysis. Water samples obtained at the beginning and after the cooking process, which consisted of city tap water, were also labelled and prepared for analysis.

Analyses of Elements Contents

All element analyses in the present study were performed in triplicate groups, following the EPA Method 200.3 (Sample Preparation Procedure for Spectrochemical Determination of Total Recoverable Elements in Biological Tissues). Rapa whelk meat samples (1.5 g) were digested in Teflon vessels, including a mixture of concentrated supra pure grade HNO3 and H2O2 (7:1) according to (HPR-FO-67) temperature and pressure profile using a microwave digestion system (Milestone SK10). After adding the acid, Teflon bombs closed, heated at 200ºC for 15 minutes, and kept at the same temperature for another 15 minutes. The digested solution was transferred into a 50mL polypropylene falcon tubes and filled to 50 ml with ultra-pure water. Standard Reference Material (CRM) and blank solutions were prepared using the same procedures. The CRM materials UME CRM 1201 and SEM 2016 mix were used to evaluate the precision and accuracy of the analyses. Inductively Coupled Plasma Spectrometry (ICP-MS Agilent 7700X) was used to measure the concentration Calcium (Ca), Magnesium (Mg), Potassium (K), Phosphorus (P), Sodium (Na), Arsenic (As), Aluminum (Al), Copper (Cu), Iron (Fe), Manganese (Mn), Mercury (Hg), Cadmium (Cd), Lead (Pb), Zinc (Zn), Selenium (Se), Chromium (Cr), Nickel (Ni), Molybdenum (Mo) and Cobalt (Co) through multi-element techniques. During these experiments, all glassware and Teflon bombs were soaked overnight in 10% HNO3, rinsed twice with distilled water and air-dried to avoid contamination before use. Additionally, according to the device specifications, the Limit of Detection (LOD) and Limit of Quantitation (LOQ) values are within the acceptable range. The percentage recoveries of elements ranged between 96.85% and 99.9%, indicating good accuracy.

Statistical analysis

The students' t-test analysis used the SPSS statistical package program (Version 10, SPSS Inc., Chicago, IL, USA) to analyse the data obtained from three periods. The differences among the means were compared using Duncan's multiple range test. A significance level 0.05 was used, and the results were shown as mean values ± SD.

Results and Discussion

Concentrations of macro elements in rapa whelk meat were determined as Mg > P > Ca > K > Na. Statistical analysis revealed significant changes in macro element concentrations in rapa whelk meat compared to initial values ($p < 0.05$) (Table 1). As a result of cooking rapa whelk meat, macro element concentrations of K and Na decreased compared to initial values (8.16% and 17.39%, respectively). At the same time, in water samples, there was an increase in the concentrations of these macro elements in cooking water (227.90% and 43.92%, respectively). This suggests that the cooking process facilitates the transfer of potassium and sodium from meat to water. These results highlight that the cooking process can affect the transfer of macro elements from meat to water and emphasise the impact of these changes on the nutritional composition of meat. Mg and P macro elements increased significantly (27.45% and 24.71%, respectively) during the cooking of rapa whelk meat compared to initial concentrations. These increases indicate that the chemical composition of the meat changes during cooking, and the amounts of these elements in the meat increase. However, Mg and P concentrations in cooking water samples decreased significantly (49.98% and 86.07%, respectively). This suggests that these elements may transfer from water to meat during the cooking process. On the other hand, the Ca macro element increased in both meat and cooking water concentrations compared to initial values due to the cooking process.

The concentrations of trace elements in rapa whelk meat were ranked as follows: Fe > Zn > Al > Cu > Mn > Se > Rb > Sn > Ba > Cr > Ni > Li > Mo > Be (Table 1). The concentrations of these trace elements in cooked rapa whelk meat varied significantly from initial values ($P < 0.05$). The toxic metal and trace elements content results obtained from the present study in rapa whelk, as demonstrated in Table 2, are consistent with the reported ranges provided in the literature. As a result of the cooking process, a decrease was observed in the concentrations of Fe, Zn, Al, Cu, Mn, Se, Rb, Sn, Ba, Cr, Ni, Li, Mo, and Be trace elements compared to the initial concentrations. The reasons for these decreases could be that these elements either passed from rapa whelk meat to water during cooking or underwent chemical changes. Particularly, the decrease in the concentrations of the Fe, Cu, and Li trace elements in cooking water samples may indicate their dissolution from meat or interaction with water. However, the concentrations of Zn and Ba trace elements increased due to cooking compared to initial concentrations. These increases may suggest that these elements are concentrated in the meat during cooking or increased due to other chemical processes. The trace elements Al, Rb, and Cr increased significantly in cooking water concentrations compared to initial values. These increases may indicate that these elements dissolved from rapa whelk meat into the water or interacted with water for other reasons. The concentrations of other trace elements in cooking water were detectable but below measurable levels, indicating that these elements either did not transfer from meat to water during the cooking process or transferred in very small amounts. These results demonstrate that the cooking process significantly impacts the trace element concentrations in rapa whelk meat. It was observed that trace elements transferred from meat to water or concentrated in the meat during cooking. The reasons for these changes may be complex and related to chemical reactions, temperature effects, and other factors. Further research may help us better understand the effects of consuming cooked rapa whelks on human health about these trace elements.

The findings determined the concentration order of the examined toxic metals as follows: As > Cd > Hg > Pb. The statistical analysis results indicate significant changes in the concentrations of toxic metals in rapa whelk meat compared to their initial values after cooking ($P < 0.05$). These changes reflect the effects of the cooking process on the toxic metal content. As a result of cooking, the concentrations of As, Cd, and Hg toxic metals decreased compared to their initial concentrations (31.45%, 27.90%, and 23.47%, respectively). It is well known that toxic metals such as As, Cd, and Hg pose risks to human health, and their seafood intake should be limited. Our findings suggest that the cooking process effectively reduces the levels of these toxic metals. This implies that cooking rapa whelk meat may effectively reduce potential health risks associated with toxic, toxic metals. However, an important result to consider in this study is that the toxic Pb metal showed an increase of 40.13% compared to the initial concentration due to the cooking process. It is believed that certain factors, especially during cooking, may increase lead concentration in meat. This situation requires further examination because lead is a hazardous substance for human health.

Table 1. Concentrations of Macro (ww g kg^{-1}), Trace Elements (ww mg kg^{-1}), and Toxic metals (ww mg kg^{-1}) in Rapa Whelk Meat and Water Samples (mg kg^{-1}) at Initial and Final Stages

Elements	Raw Rapa Whelk Meat	Processed Rapa Whelk Meat	Percentage Change (%)	Initial Water Sample	Water Sample After Cooking Process	Percentage Change (%)
Mg	2.81 ± 0.036^{b}	3.58 ± 0.035^{a}	27.45	8.64 ± 0.021^{a}	4.32 ± 0.0620^{b}	-49.98
P	1.47 ± 0.020^{b}	1.83 ± 0.012^{a}	24.71	0.04 ± 0.003^{a}	0.006 ± 0.0004^{b}	-86.07
Ca	1.23 ± 0.015^{b}	1.65 ± 0.004^{a}	34.16	49.01 ± 0.151^{a}	54.75 ± 0.7108^{b}	11.71
K	1.20 ± 0.018^{a}	1.10 ± 0.005^{b}	-8.16	1.74 ± 0.016^{b}	5.71 ± 0.0607^{a}	227.90
Na	0.55 ± 0.006^{a}	0.45 ± 0.005^{b}	-17.39	15.47 ± 0.089^{b}	22.27 ± 0.0629^{a}	43.92
Fe	33.49 ± 0.320^{a}	30.72 ± 0.265^{b}	-8.28	0.002 ± 0.0004^{a}	0.001 ± 0.0004^{b}	-47.50
Zn	16.85 ± 0.146^{b}	19.84 ± 0.222^{a}	17.78	*	*	*
Al	9.42 ± 0.068^{a}	7.08 ± 0.083^{b}	-24.82	0.002 ± 0.0007^{b}	0.003 ± 0.0006^{a}	82.10
Cu	8.65 ± 0.059^{a}	8.26 ± 0.065^{b}	-4.51	0.005 ± 0.0002^{a}	0.0002 ± 0.0000^{b}	-95.50
Mn	1.41 ± 0.022^{a}	1.36 ± 0.015^{b}	-3.22	*	0.012 ± 0.0006	*
Se	0.47 ± 0.024^{a}	0.42 ± 0.032^{b}	-10.68	*	*	*
Rb	0.37 ± 0.005^{a}	0.34 ± 0.002^{b}	-9.37	0.0003 ± 0.0000	0.015 ± 0.0001	5136.94
Sn	0.32 ± 0.016^{a}	0.26 ± 0.009^{b}	-21.01	*	*	*
Ba	0.24 ± 0.004^{b}	0.30 ± 0.005^{a}	22.31	0.036 ± 0.0000	0.033 ± 0.0005	-8.44
Cr	0.20 ± 0.006^{a}	0.07 ± 0.001^{b}	-62.33	0.0001 ± 0.0000^{b}	0.0005 ± 0.0000^{a}	331.66
Ni	0.14 ± 0.002^{a}	0.08 ± 0.002^{b}	-41.99	*	0.001 ± 0.0000	*
Li	0.02 ± 0.002^{a}	0.02 ± 0.001^{a}	-9.96	0.009 ± 0.0002^{a}	0.003 ± 0.0002^{b}	-67.44
Mo	0.01 ± 0.001^{a}	0.01 ± 0.001^{b}	-31.74	*	*	*
Be	0.004 ± 0.003	*	-4.38	*	*	*
As	3.67 ± 0.055^{a}	2.52 ± 0.010^{b}	-31.45	*	*	*
Cd	0.31 ± 0.003^{a}	0.22 ± 0.002^{b}	-27.90	*	*	*
Hg	0.03 ± 0.000^{a}	0.02 ± 0.001^{b}	-23.47	*	*	*
Pb	0.01 ± 0.000^{b}	0.01 ± 0.000^{a}	40.13	*	*	*

"*" The symbol indicates that a specific element's concentration is below the detectable limits. Different letters used to annotate values among meat samples indicate statistically significant differences ($p < 0.05$). Similarly, values marked with different letters among water samples indicate statistically significant differences ($p < 0.05$).

Cooking seafood has been reported to reduce the concentrations of some toxic metals and trace elements in previous studies by Laparra et al. (2003, 2004), Hanaoka et al. (2001), Hajeb et al. (2014), Ichikawa et al. (2006), Perelló et al. (2008), Atta et al. (1997), Jorhem et al. (1994), Ersoy et al. (2006), and Sengupta et al. (2006). However, other studies, such as those by Burger et al. (2003), have reported that cooking does not always reduce metal concentrations in fish meat. These results indicate that the effects of the cooking process on the behaviour of toxic metals in seafood are complex. These findings may help us better understand the impact of the cooking process on the toxic metal content of rapa whelk meat. However, generalising the effect of cooking on metal levels in seafood can be challenging. Depending on cooking methods and conditions, metal levels in seafood can vary based on the chemical properties of specific elements (Houlbrèque et al., 2011). Understanding how the cooking process affects these toxic metals can contribute to developing health recommendations regarding the consumption of whelk meat. Additionally, factors such as cooking method, duration, temperature, and the cooking medium used are among the various variables that influence the post-cooking behaviour of toxic metals in seafood (Houlbrèque et al., 2011; Ouédraogo & Amyot, 2011). These factors are known to play a role in determining the behaviour of toxic metals after cooking and can lead to variations in results.

In the literature, various results have been reported regarding the effects of cooking on the levels of toxic metals in seafood and their implications for human health. For instance, some studies have shown that the cooking process, despite increasing the amount of toxic metals, reduces their bioavailability (Amiard et al., 2008; Maulvault et al., 2011).

Conclusion

In conclusion, this study examined the metal content of rapa whelk meat and investigated the cooking process's effects on this content. Our findings indicate that both macro and trace elements in rapa whelk meat change the cooking process.

Regarding macro elements, it was observed that the concentration of potassium (K) and sodium (Na) decreased as a result of cooking, while magnesium (Mg) and phosphorus (P) concentrations increased. These changes suggest that cooking facilitates the transfer of these elements from the meat to the cooking water and highlights the impact of the cooking process on the nutritional composition of the meat.

In terms of trace elements, it was found that many trace elements change due to the cooking process. The concentrations of iron (Fe), zinc (Zn), aluminium (Al), copper (Cu), manganese (Mn), selenium (Se), rubidium (Rb), tin (Sn), barium (Ba), chromium (Cr), nickel (Ni), lithium (Li), molybdenum (Mo), and beryllium (Be) decreased. In contrast, zinc (Zn) and barium (Ba) increased. These changes are believed to be related to the transfer of trace elements from the meat to the cooking water or their concentration within the meat.

Regarding toxic metals, it was observed that the concentrations of toxic metals such as arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb) changed as a result of the cooking process. These changes suggest that cooking may be an effective method for reducing the levels of these metals, particularly considering the potential health risks associated with toxic metals. However, the increase in lead levels due to the cooking process requires further investigation.

In conclusion, this study, by examining changes in the metal content of rapa whelk meat and investigating the effects of the cooking process, sheds light on important factors that affect the nutritional value and metal content of rapa whelk meat. This research may contribute to developing health recommendations related to the consumption of rapa whelk meat and serve as a guide for future studies.

Compliance with Ethical Standards

Conflict of interest: The authors declare no actual, potential, or perceived conflict of interest for this article.

Ethics committee approval: Ethical approval was not required for this study.

Data availability: Data will be made available on request.

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Disclosure: -

Table 2. Literature information on various toxic metals and trace elements contents reported for Rapa whelk

As	**Cd**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**	Region	Reference
-	4.9	-	-	-	-	-	0.99	3.5	-	MS, Istanbul	Topçuoğlu et al. (1994) (µg/g dw)
-	1.0	-	-	-	-	-	2.17	3.2	-	BS, Fatsa	Topçuoğlu et al. (1994) (µg/g)
-	0.03-0.22	-	-	-	-	-	-	0.08-0.46	-	BS, Sinop	Bat et al. (2000) (mg/kg dw)
-	1.78	<0.06	-	-	-	-	-	<0.5	-	BS, Iğneada	Topçuoğlu et al. (2002) (µg/g dw)
-	2.19	0.62	-	-	-	-	-	<0.5	-	BS, Amasra	Topçuoğlu et al. (2002) (µg/g)
-	0.37	0.47	-	-	-	-	-	<0.5	-	BS, Perşembe	Topçuoğlu et al. (2002) (µg/g)
-	<0.06	<0.02	-	-	-	-	-	<0.5	-	BS, Rize	Topçuoğlu et al. (2002) (µg/g)
-	0.15-30.61	-	5.52-172.2	-	-	-	0.09-0.66	0.10-0.75	8.65-705	Bohai Sea, China	Liang et al. (2004) (µg/g) dw
-	0.13-0.29	10.23-55.36	-	-	0.007-0.05	-	-	3.32-13.56	-	BS, Kumköy	Mülayim and Balkıs (2015) (mg/kg dw)
-	0.08-0.13	4.43-55.07	-	-	0.06	-	-	1.57-11.97	-	BS, Karaburun	Mülayim and Balkıs (2015) (mg/kg)
-	0.08-0.24	2.42-51.99	-	-	0.002-0.06	-	-	1.93-16.35	-	BS, Kıyıköy	Mülayim and Balkıs (2015) (mg/kg)
-	0.07-0.35	0.79-15.96	-	-	0.005-0.6	-	-	0.86-9.95	-	BS, İğneada	Mülayim and Balkıs (2015) (mg/kg)
-	1.64	-	-	-	0.62	-	-	0.27	-	BS, Romanya	Jitar et al. (2015) (mg/kg)
2.2	0.005	0.04	5.1	4.2	0.11	0.26	0.023	0.32	8.6	BS, Krapetz	Peycheva et al. (2017) µg/g
4.17	0.008	0.05	7.7	9.4	0.08	0.48	0.045	0.12	7.5	BS, Varna	Peycheva et al. (2017) dw
-	0.89-1.75	0.23-0.37	12,89-21,09	-	-	1.28-3.60	0.18-0.25	0.20-0.98	11.70-24.18	BS, Turkey	Gedik (2018)
0.42-15.9	0.05-1.05	0.25-2.89	4.56-26.65	-	0.007-0.037	-	0.07-1.72	0.01-0.41	8.34-65.72	ECS, Xiangshan Bay	Liu et al. (2018)
-	1.113	-	-	-	0.034	-	-	0.045	-	BS, Varna	Zhelyazkov et al. (2018)
28.7-51.1	5.8-14.8	0.66-3.53	19.4-39.3	273-1820	0.65-2.91	2.8-13.4	0.2-3.2	BDL-10.7	124-254	BS, Crimea	Kapranov et al. (2021)(2021) ww
2.52-3.67	**0.22-0.31**	**0.07-0.20**	**8.26-8.65**	**30.72-33.49**	**0.02-0.03**	**1.36-1.41**	**0.08-0.14**	**0.01**	**16.85-19.84**	**BS, Sinop**	**PRESENT STUDY (mg/kg ww)**

BDL: below detectible limits

MS: Marmara Sea; BS: Black Sea; ECS: East China Sea;

dw: dry weight basis; ww: wet weight basis

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