Ann. Anim. Sci., Vol. 24, No. 1 (2024) 257–268 *DOI: 10.2478/aoas-2023-0064*

sciendo

EFFECT OF BOILING ON CHEMICAL COMPOSITION OF SMALL BROWN SNAIL *(CORNU ASPERSUM ASPERSUM)* MEAT*

Maciej Ligaszewski[1♦], Krzysztof Surówka[2♦], Beata Szymczyk[3♦], Przemysław Pol[1], Barbara Anthony[4]

[1]Department of Small Livestock Breeding, National Research Institute of Animal Production, 32-083 Balice n. Kraków, Poland
[2]Faculty of Food Technology, University of Agriculture in Kraków, 30-149 Kraków, Poland
[3]Department of Animal Nutrition and Feed Science, National Research Institute of Animal Production, 32-083 Balice n. Kraków, Poland
[4]Faculty of Veterinary Medicine, University of Life Sciences in Lublin, 20-950 Lublin, Poland
♦Corresponding authors: mligasze@gmail.com, rtsurowk@cyf-kr.edu.pl, beata.szymczyk@iz.edu.pl

Abstract

The aim of this study was to assess the changes occurring as a result of boiling (100°C, 1 h) small brown snail (*Cornu aspersum aspersum*) meat in relation to its proximate composition, calcium, phosphorus and cholesterol content, as well as the profile of fatty acids and nutritional quality indices of the lipids. This species of snail was selected for research because it is currently of the greatest economic importance among edible terrestrial snails. It was hypothesized that the cooking effect may be different for foot and visceral sac. Samples for the research were collected from 6 populations bred on experimental fields of the National Research Institute of Animal Production in Balice (Poland). The foot and the visceral sac, the edible parts of the snail species under investigation, were analysed separately, raw and boiled in water. The results were then compared to analogous studies carried out by other authors on beef, pork and poultry. It was found that in the visceral sac of *Cornu aspersum aspersum* the shares of dry matter, crude protein, fat, ash, calcium and phosphorus were greater than those in the foot (P<0.05), both in the raw and boiled material, whereas the cholesterol content was higher in the foot (P<0.05). Generally, especially in the foot, the heat treatment elevated the levels of the afore-mentioned quantities, yet the increases were not always statistically significant. Boiling the snail meat caused moderate changes in the fatty acid composition. The profile of the fatty acids and the nutritional quality indices of the foot fat were more advantageous than those in the visceral sac. In both parts of the snail carcass, the polyunsaturated fatty acids/saturated fatty acids (PUFA/SFA) ratio substantially exceeded the minimum value of 0.45 recommended by the British Department of Health. However, the *n-6/n-3* ratio was too high, exceeding the maximum recommended level of 4.0 twofold and as much as threefold in the case of the foot and the visceral sac, respectively. In the foot, due to boiling, an increase of the share of SFA and monounsaturated fatty acids (MUFA) was observed, while PUFA, *n-6* and *n-3* decreased. In the visceral sac, the changes were less pronounced with a slight decrease of the share of SFA and PUFA, and an increase of MUFA. Therefore, in the foot, boiling worsened the PUFA/SFA ratio, the nutritive value index (NVI = (C18:0 + C18:1) / C16:0) and dietary fatty acids having a desirable neutral and hypocholesterolemic effect in humans (DFA = Σ MUFA + Σ PUFA + C18:0), but in the visceral sac these indices practically did not change. On the whole, the trends of the changes in terms of chemical composition due to boiling found in the small brown snail meat are similar to those after heat treatment of meat from popular farm animals, but the ranges of the changes differ.

Key words: edible land snails, *Cornu aspersum*, boiling, proximate composition, health lipid indices

As a result of the human population growth across the globe and civilization development, the consumers' food expectations are growing too. People expect the food industry to provide them with new products. However, they also demand that such products should come from natural resources, be diversified and safe, and have desired sensory properties as well as high nutritional value. In consequence, in many countries there is an increasing interest in resources that have not been part of the local traditional cuisines before. Such resources include edible snails consumed so far mainly in France, Spain, Portugal or Italy (Rygało-Galewska et al., 2022). Nowadays, one hundred thousand tons of snails per year are consumed in Europe, but only 60–70% of the demand is met (Pissia et al., 2021). The brown snail (*Cornu aspersum*) is a species of the greatest economic importance among edible land snails. In nature, it forms two very closely related subspecies, the haplotypes of which are closely related to the biogeographical distribution of the species (Guiller and Madec, 2010). The nominal form, i.e. the small brown snail (*Cornu aspersum aspersum*), is a group of haplotypes characteristic for Western Europe, whereas the large brown snail (*Cornu aspersum maxima*), reaching larger sizes and weights than the European forms, occurs in the Atlas mountain range in North Africa. Snail farming is undergoing a dynamic development also in coun-

*Work financed from statutory activity, project no. 501-140-511.

tries without long traditions in this field, such as Central and Eastern European countries or other countries in the world with a temperate climate. It is gradually becoming an alternative to the production of livestock. The snail production offers an advantageous feed conversion ratio in the range from 0.9 to 1.85 for the species *Cornu aspersum*, it is less labour intensive and cheaper. However, apart from the economic aspects, the environmental factors are also important. The snail production has a lesser impact on climate change (low greenhouse gas emissions) as well as low terrestrial acidification and water eutrophication (Zucaro et al., 2016). It also meets all the requirements for business activities in areas within the Natura 2000 network.

It is reported that snail meat boasts a favourable amino acid composition, low fat content and low energy value (60–80 kcal/100 g) (Morei, 2012; Nkansah et al., 2021), making it a valuable component of a healthy and well-balanced diet. However, the meat composition depends to a high degree on its origin, the way and conditions of animal feeding and living, as confirmed by Gogas et al. (2021) through research on *Cornu aspersum aspersum*. Their results revealed that the meat from snails following a diet containing organic soya had a higher collagen content, whereas the meat from snails fed with pea and lupin offered a higher protein and fat content, healthier fatty acid profile and better antioxidant capacity. Ligaszewski and Pol (2018 a) compared the nutritional value of meat of the species *Cornu aspersum* from a heliciculture and *Helix pomatia* from a natural population and studied the influence of betaine hydrochloride on some production traits during the ontogenic development, showing an important impact of that fodder additive on the protein and fat contents as well as amino acid and fatty acid profiles (Ligaszewski and Pol, 2018 b). In turn, Citil et al. (2014) studied a natural population of the snail *Cornu aspersum* picked up from the Central Anatolia region of Turkey in terms of the effects of the seasons on the fatty acid composition and cholesterol content. The authors concluded that there was an influence of seasonal variations on the level of linolenic acid and *n–3* fatty acids, but the cholesterol content was not affected. Likewise, Çelik et al. (2019), who compared the mineral composition and fatty acid profile of wild and farmed snails of this species, demonstrated that these are affected by the feed content and local soil and water structure, and that both of them have relatively high share of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). All the above-mentioned literature reports were confirmed in an interesting review of the up-to-date knowledge of the economic value and the importance of edible snail farming in Central European countries (Rygało-Galewska et al., 2022).

In the literature, there are few works on the impact of technological processing on the properties of snail meat. Szkucik et al. (2018) compared the fatty acid profiles of raw, frozen and boiled snails *Helix pomatia* and *Cornu aspersum* from two farms. They pointed out, among other things, that thermal processing increases the share of saturated fatty acids (SFA) and decreases that of polyunsaturated fatty acids (PUFA). In turn, Engmann et al. (2012), who studied the effect of various methods of drying on the quality of *Achatina achatina* meat, demonstrated that the methods had different effects on the proximate composition and microbiological quality of dried products. On the other hand, Iwanegbe et al. (2018) focused on an analysis of lipid oxidation and sensory parameters during the storage of seasoned and thermally processed *Archachatina marginata.* The sensory attributes were also studied by López et al. (2015), who sterilized *Cornu aspersum* meat that had been exposed to three different mediums differing in the content of NaCl, citric acid, olive oil, antioxidants and spices. The authors highlighted the positive role of citric acid in stabilizing the meat colour and a negative effect of olive oil on the aroma of the final product. Aroma compounds of raw and thermally processed *Achatina fulica* were studied by Lasekan et al. (2018), who demonstrated that the differences in the aromas of raw, boiled and fried snails directly resulted from the fact that completely different volatile aroma compounds dominated in those products. It was also shown that among the various steps involved in snail processing, steaming and boiling caused a substantial reduction of the population of microorganisms down to the safe level (Parlapani et al., 2014).

An even more technological approach to the use of snail meat was taken by Pissia et al. (2022), who through successive extractions created protein-enriched snail meat concentrate powder from the foot mass of *Cornu aspersum*. The product exhibited enhanced protein solubility and higher values of water and oil binding capacity compared to freeze dried snail meat powder, which could be useful in the preparation of complex and attractive foods formulas. Snail meat powder was also used by Agengo et al. (2022) to boost protein nutritional quality of sorghum-wheat buns. This component offers consumers positive attributes of texture and increases acceptance among school children.

Few authors describe various aspects of snail meat by comparing it to the meat of other animal species. Çağiltay et al. (2011) claim that *Cornu aspersum* snail meat has similar levels of proteins, minerals and fatty acids to the meat of other seafoods, and is an important food source to meet daily nutritional needs. Imevbore (1990) described the fatty acid composition and cholesterol content in edible African giant land snails belonging to the *Achatina* and *Archachatina* genera using fish and broiler meat as reference.

Thus, it seems purposeful to examine, from the point of view of the real nutritional value for consumers, what changes occur in the chemical composition of snail meat as a result of heat treatment enabling it to be consumed by humans and to compare such changes with those taking place in the meat processing in the case of traditional farm animals. There are numerous reports describing the changes in the proximate composition, minerals content, protein quality and fatty acid profile of chicken (Baggio and Bragagnolo, 2006; Cupisti et al., 2006), goose (Goluch et al., 2021; Wereńska et al., 2021), beef (Brugia-

paglia and Destefanis, 2012; Borela et al., 2022), and pork (Vujadinović and Marianowić-Balaban, 2012) undergoing boiling, frying and grilling at various temperatures.

In food processing, the snail carcass can be divided into the foot composed largely of smooth muscle and the visceral sac containing a large hepatopancreas, digestive tract and reproductive system with gonad, covered with mantle. Although the visceral sac of the large brown snail (*Cornu aspersum maxima*) is inedible and can occasionally be used as feed for farmed carnivores and poultry, in the case of the small brown snail (*Cornu aspersum aspersum*) visceral sac like the foot is considered to be edible by humans. For this reason, in this study, the foot and the visceral sac were studied separately. Additionally, a hypothesis was made that the effect of boiling may differ for these two different parts of the snail carcass. Hence, the present investigation aims to study the effect of boiling on the quantitative and qualitative changes occurring in the basic chemical composition of meat and in the content of calcium, phosphorus and cholesterol, as well as in the shape of fatty acid profile and nutritional quality indices of the lipids in both the aforementioned edible parts of the small brown snail (*Cornu aspersum aspersum*).

Material and methods

The material for the research came from 6 populations (n = 6) of the small brown snail (*Cornu aspersum aspersum*) collected for three consecutive seasons (2019–2021) annually from two parallel experimental fields with the same parameters at the National Research Institute of Animal Production in Balice (Poland). The snail reproduction was carried out in the early spring (March) in a properly air-conditioned room of the farm (temperature = 21±1°C, air relative humidity = 70–90%). The parental animals came from the farm of the Institute, where they were hibernated at 6±1°C in a cooling chamber with gentle air circulation. The snails laid eggs in nesting cups with potting soil and then clutches of eggs were moved to breeding boxes where hatching took place after 12–14 days on a thin layer of soil. In mid-May, the hatching was transferred to white mustard (*Sinapis alba*) sown field enclosures with an area of 4 m^2 each, with the initial density of 300 individuals per 1 m^2 of the enclosure area. Over the period of fattening, the density decreased by approx. 15% following natural losses. The enclosures were equipped with a sprinkler system and wooden pallets acting as feeders with fodder poured on their upper surface. The bottoms of the feeders were used to protect the snails from the sun. In the time of commercial rearing, snails were fed *ad libitum* with special industrial compound feed with the following composition: crude protein 17.50%; crude ash 30.12%; crude fat 3.75%; crude fibre 2.06%; mineral calcium 10.81%, phosphorus 0.70% and an addition of exogenous amino acids and micronutrients necessary in snail feeding. At the turn of September and October of each year, seven-month-old snails were collected. At that time, they weighed an average of about 8.9 g and had already reached somatic and functional maturity manifested by the shell opening folded to form a lip and reaching the mechanical strength sufficient for transportation. From each population, about 7.5 kg of snails were collected, and out of this pool 4 kg were selected randomly for studies and subjected to a week-long hibernation at a temperature of 6°C during which the digestive tract was emptied. Hibernated snails were dropped in boiling water for 3 minutes and next cooled under running tap water. Next, the carcass was separated from the shell and split into the foot and the visceral sac using tweezers. The average carcass weight oscillated around 7.8 g, and the foot and visceral sac accounted for approx. 40% and 60% by weight, respectively. A half of the edible part was left raw, while the rest was subjected to one-hour boiling in tenfold excess of water at a temperature of 100°C, then cooled in tap water. The boiling time was chosen based on the results of preliminary studies taking into account the need to achieve the proper snail meat texture. Immediately before analysis, samples were minced by passing them twice through a meat grinder with 3 mm diameter holes. For each population, the following four 400 g aggregate meat samples were selected for analysis: raw and boiled foot, and also raw and boiled visceral sac. All analyses were performed on 6 populations using triplicate repetitions.

Dry matter was determined at 105°C (Polish Standard, 1988), ash at 550°C combustion (AOAC, 1998 a), and protein by the Kjeldahl method (AOAC, 1998 b). Total lipids were assayed using the Bligh and Dyer (1959) method. Briefly, 50 g of a minced sample was homogenised with 150 mL of a mix of chloroform : methanol (1:2). Next, 50 mL of chloroform and 50 mL of distilled water were added to the mixture. The extract was filtered off, then the chloroform layer was separated and, after its evaporation to dryness, total lipids were determined by weight. The contents of calcium (Ca) and phosphorus (P) were determined in 3 g samples of meat after incineration in a muffle furnace at 500°C. The resultant ash was solubilized on crucibles using 6 mol L^{-1} HCl and the residual acid was evaporated on a hot plate. The residue was solubilised with hot distilled water, then filtered through Whatman No. 1 filter paper, rinsed and made up to 50 mL with distilled water. This ash solution was used for further analyses of calcium and phosphorus. The calcium content was found according to the Polish Standard (2002) using flame atomic absorption spectroscopy with a SOLAAR 939/959 spectrophotometer (Unicam, Cambridge, UK) working at λ = 422.7 nm. The phosphorus content was estimated by the standard AOAC (1995) method. To this end, the ash solution was diluted with distilled water and a molybdate-vanadate reagent was added. After 10 minutes, the absorbance of the resultant solution was measured at 430 nm using a Super Aquarius UV/Visible spectrophotometer (Cecil Instruments, UK).

Cholesterol concentration was assayed by the enzymatic method using a commercially available kit

(No. 10 139050035, Boehringer Mannheim/R-Biopharm, Germany). For analysis of higher fatty acids, lipids were extracted in accordance with the method of Folch et al. (1957). The fatty acids were converted into methyl esters by transmethylation using boronitrifluoride – methanol (14% solution). Fatty acid methyl ester analysis was performed by gas chromatography using a Shimadzu GC-2010 Plus camera chromatography system fitted with an Rtx 2330 capillary column (105 m, 0.32 mm, 0.2 micron). Identifications and calculations for each individual fatty acid methyl ester were carried out using a C4-C24 FAME quantitative mix (Supelco, Bellafonte, PA, USA). The fatty acid profile was used to calculate the sum of saturated fatty acids (Σ SFA), monounsaturated fatty acids (Σ MUFA), polyunsaturated fatty acids (Σ PUFA), as well as the sum of *n-3* (Σ *n-3*) and *n-6* (Σ *n-6*) fatty acids. The sum of the shares of unsaturated acids (Σ UFA = Σ MUFA + Σ PUFA) was also found. Moreover, the following nutritional quality indices were calculated: *n-6/n-3*, UFA/SFA, MUFA/SFA, PUFA/SFA, as well as the nutritive value index (NVI = (C18:0 + C18:1) / C16:0) (Chen et al., 2016) and dietary fatty acids having a desirable neutral and hypocholesterolemic effect in humans (DFA = Σ MUFA + Σ PUFA + C18:0) (Janiszewski et al., 2016).

All data were acquired in triplicate from each aggregate sample of each population, then the mean values and their standard errors (SEM) were calculated and presented in tables and figures. Moreover in the tables minimum and maximum values referring to individual measurements are given. Statistical analyses were performed using the CSS Statistica v.12 package (StatSoft, Kraków, Poland). One-way ANOVA and Student-Newman-Keuls multiple range tests were used to assess the significance of differences, defined as $P<0.05$.

Results

Chemical composition of edible parts of the snail carcass

The effect of boiling on the proximate composition as well as the calcium, phosphorus and cholesterol contents in both edible parts of the small brown snail are presented in Table 1 and Figure 1. The data show a statistically significant ($P<0.05$) greater share of dry matter, crude protein, fat and ash in the visceral sac than in the foot, both in the raw material and after thermal treatment. The only exception is the content of protein in boiled samples, which is similar in both parts of the carcass. As a result of boiling, the mean dry matter level increases, but this increase is statistically significant ($P<0.05$) only in the case of the foot. In consequence in this part of the carcass, there is a growth ($P<0.05$) of crude protein and fat by almost 30 and 40%, respectively, which does not occur in the visceral sac. The crude ash concentration also increases as a result of boiling, yet not significantly ($P>0.05$).

Table 1. Proximate composition and calcium (Ca), phosphorus (P) and cholesterol content in raw and boiled edible parts of small brown snail (*Cornu aspersum aspersum*)

Stage of processing	Foot		Visceral sac	
	mean±SEM	min–max	mean±SEM	min–max
		Dry matter (%)		
Raw	18.39±0,73 aA	17.35–19.42	27.84±2.30 B	24.25–30.01
Boiled	23.18±1.2 bA	20.93–24.36	28.55±3.05 B	23.80–31.15
		Crude protein (%)		
Raw	12.99±0.31 aA	11.91–13.98	16.81±0.52 B	15.11–18.44
Boiled	16.83±0.29 b	16.15–17.48	16.77±0.82	15.68–16.98
		Crude fat (%)		
Raw	0.48±0.05 aA	0.31–0.77	2.38±1.02 B	1.06–3.16
Boiled	0.67±0.06 bA	0.41–0.76	2.48±1.22 B	1.00–3.86
		Crude ash (%)		
Raw	1.28±0.11 A	1.11–1.39	2.10±0.28 B	1.77–2.48
Boiled	1.33±0.12 A	1.11–1.46	2.15±0.41 B	1.66–2.56
		Ca (g/kg)		
Raw	2.52±0.31 A	2.18–3.05	3.12±0.52 B	2.55–3.93
Boiled	3.09±0.29 A	2.67–3.53	3.64±0.82 B	2.85–4.69
		P (g/kg)		
Raw	1.45±0.09 aA	1.36–1.57	4.37±0.58 B	3.82–5.41
Boiled	1.98±0.22 bA	1.61–2.23	4.67±0.79 B	3.88–5.86
		Cholesterol (mg/100g)		
Raw	15.2±1.4 aA	13.3–16.8	7.7±0.6 B	7.0–8.3
Boiled	20.3±1.4 bA	18.5–24.4	9.2±1.4 B	6.4–10.2

Mean±SEM – results shown as mean and standard error of the mean (n=6).
Min–max – minimal and maximal results acquired.
Mean values for a given component marked with the different letters in the column differ significantly ($P<0.05$).
Mean values marked with the different capital letters in the row differ significantly ($P<0.05$).

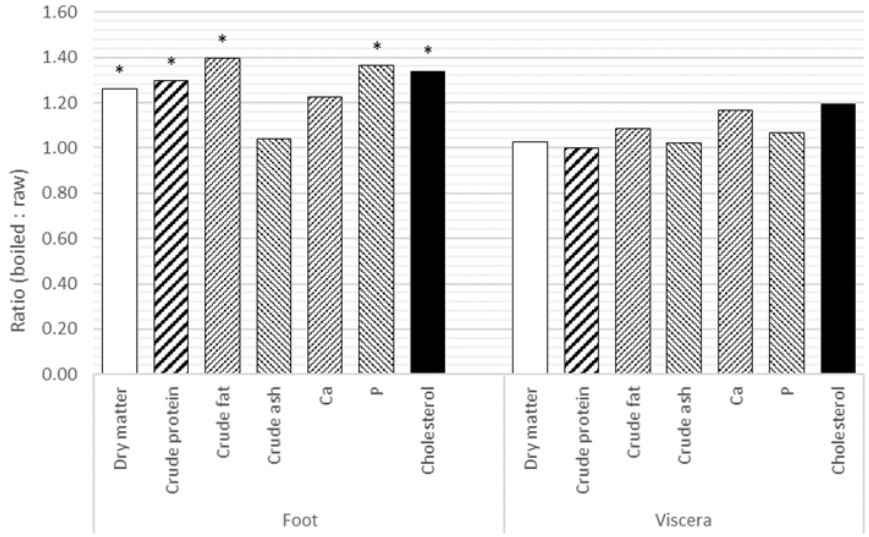


Figure 1. Content ratio of particular constituents in meat of boiled and raw edible parts of small brown snail (*Cornu aspersum aspersum*). Bars marked with asterix mean statistically significant differences between results for raw and boiled samples

When it comes to mineral components, the analysis focused on the contents of calcium (Ca) and phosphorus (P) (Table 1). The foot of the small brown snail contains more calcium than phosphorus, whereas in the visceral sac this relation is reversed. It is also characteristic that both macroelements had higher concentrations in the visceral sac than in the foot ($P<0.05$), both raw and boiled. There is about 20% more calcium in the viscera than in the foot, and about three times more and twice more phosphorus in the raw and boiled visceral sac, respectively. The thermal processing used in this study led to an increase of the concentration of Ca and P, both in the foot and in the viscera. However, in the case of phosphorus, the highest and statistically significant increase ($P<0.05$) was only seen in the foot, as shown in Figure 1.

The cholesterol content was substantially higher in the foot of the snails than in the visceral sac ($P<0.05$) (Table 1). After boiling its concentration increased by about 1/3 in the foot and by about 20% in the visceral sac. However, only for the foot the increase was statistically significant ($P<0.05$) (Table 1, Figure 1).

Fatty acid profiles and lipid quality indices

The percentages of the main fatty acids in the edible parts of *Cornu aspersum aspersum* are given in Table 2. In the group of saturated fatty acids (SFA), the dominant compounds are palmitic acid (C16:0) and stearic acid (C18:0). However, also other acids were detected yet not included in the table: caprylic (C8:0), capric (C10:0), lauric (C12:0), myristic (C14:0), heptadecanoic (C17:0), arachidic (C20:0), heneicosanoic (C21:0), behenic (C22:0) and lignoceric (C24:0) acid, all at much lower levels. A significantly higher palmitic acid (C16:0) share was found in the visceral sac as compared to the foot ($P<0.05$), whereas the proportions of stearic acid (C18:0) were very similar in the profiles of both elements of the carcass.

Among unsaturated fatty acids (UFA), polyunsaturated fatty acids (PUFA) have a noticeably greater share than monounsaturated fatty acids (MUFA) in the foot, while in the visceral sac the situation is opposite. The main MUFA acid is oleic acid (C18:1), accompanied by palmitoleic (C16:1), gadoleic (C20:1) and erucic (C22:1) acids at levels of up to 1%. Oleic acid has on average an almost twofold greater share in the raw visceral sac than in the raw foot. This ratio is only slightly lower in the boiled versions of the two carcass elements. The most abundant PUFA acids are linoleic (C18:2 *n-6*), eicosadienoic (C20:2 *n-11,14*) and arachidonic (C20:4 *n-6*) acids. Apart from them, Table 2 lists also eicosapentaenoic (C20:5 *n-3*) (EPA) and docosahexaenoic (C22:6 *n-3*) (DHA) acids - particularly important from the nutritional point of view. The PUFA group includes also such acids as linolenic (C18:3 *n-3*), eicosatrienoic (C20:3 *n-3*) and eicosatrienoic (C20:3 *n-6*), all detected, but due to very low shares not mentioned in Table 2. Polyunsaturated fatty acids are a dominant fatty acid group in the foot. The acids C20:2 *n-6* and C20:4 *n-6* are about 2.5 and 3 times more abundant in the raw foot than in the visceral sac, while the EPA is as much as ninefold more abundant, and these differences are statistically significant ($P<0.05$). In contrast, the difference in the share of the linoleic acid (C18:2 *n-6*) is lower and not statistically significant ($P>0.05$). In turn, docosahexaenoic acid (DHA) is present almost at the same level in both analysed snail carcass elements. Despite the recorded differences in the contents of particular fatty acids of all types considered here (SFA, UFA, MUFA and PUFA) before and after boiling, the differences were not statistically significant ($P>0.05$). This situation concerns both the foot and the visceral sac. In order to better illustrate the effect of boiling on the fatty acid content and nutritional quality indices of the lipids in the foot and visceral sac, Figures 2 and 3 show the share ratios for boiled and raw samples.

Table 2. Content of fatty acids (% of fat) and nutritional quality indices of the lipids in raw and boiled edible parts of small brown snail (*Cornu aspersum aspersum*)

Stage of processing	Foot		Visceral sac	
	mean±SEM	min–max	mean±SEM	min–max
1	2	3	4	5
		C16:0		
Raw	8.20±1.86 A	5.75–10.69	19.19±8.18 B	8.68–26.43
Boiled	9.54±2.67 A	6.48–12.42	18.14±7.14 B	9.15–25.28
		C18:0		
Raw	15.07±2.51	13.34–17.13	15.62±8.91	9.15–18.85
Boiled	15.53±4.47	3.15–16.70	15.86±8.28	8.54–19.22
		C18:1		
Raw	17.87±2.51 A	14.83–19.82	34.33±8.91 B	22.56–42.95
Boiled	20.47±4.47 A	14.63–24.85	34.44±8.28 B	23.28–42.05
		C18:2 *n-6*		
Raw	17.82±1.63	15.72–20.70	12.81±13.11	3.79–32.94
Boiled	16.88±2.28	15.11–21.25	13.90±12.52	5.48–33.88
		C20:2 *n-11, 14*		
Raw	13.58±0.97 A	12.70–14.98	5.06±1.84 B	3.56–7.90
Boiled	12.71±0.74 A	11.55–13.54	5.27±1.54 B	3.91–7.71
		C20:4 *n-6*		
Raw	13.54±2.27 A	10.70–15.32	4.37±4.16 B	1.26–10.46
Boiled	12.06±3.41 A	8.61–17.34	4.27±3.43 B	1.70–7.88
		C20:5 *n-3* (EPA)		
Raw	2.27±0.57 A	1.55–3.08	0.26±0.	0.10–0.71
Boiled	1.95±0.81 A	1.22–3.13	0.28±0.20 B	0.10–0.62
		C20:6 *n-3* (DHA)		
Raw	0.24±0.14	0.02–0.37	0.24±0.10	0.02-0.22
Boiled	0.25±0.18	0.02–0.41	0.23±0.15	0.09-0.36
		∑ SFA		
Raw	27.55±4.40 A	21.75–32.95	38.17±13.40 B	19.70-49.07
Boiled	29.05±5.34	21.63–33.21	36.87±11.84	19.45-46.02
		∑ UFA		
Raw	72.45±4.40	67.08–78.25	61.83±13.40	50.93-80.30
Boiled	70.94±5.34	66.79–78.37	63.13±11.84	53.98-80.55
		∑ MUFA		
Raw	20.38±3.26 A	15.99–23.22	35.75±9.08 B	23.45-41.64
Boiled	22.51±5.09 A	15.95–26.75	36.35±8.80 B	24.20-42.66
		∑ PUFA		
Raw	52.89±7.20 A	43.86–61.27	25.57±22.80 B	10.34–56.83
Boiled	48.78±10.14 A	40.04–61.17	24.71±20.25 B	11.96–56.35
		∑ *n-3*		
Raw	5.24±0.91 A	4.23–6.36	1.97±1.99 B	0.59–4.74
Boiled	4.48±1.16 A	0.59-4.95	2.01±1.85 B	0.69–3.75
		∑ *n-6*		
Raw	47.65±6.32 A	39.64–55.49	23.61±20.81 B	8.77–52.11
Boiled	44.29±8.98 A	38.12-–6.14	24.69±18.82 B	11.21–46.27
		n-6 / n-3		
Raw	9.25±0.73 A	8.59–10.44	13.65±1.99 B	11.00–15.61
Boiled	9.85±0.59 A	9.23–10.78	13.80±2.50 B	10.42–15.44

Table 2. – contd.

1	2	3	4	5
		UFA / SFA		
Raw	2.71±0.63	2.04–3.60	2.02±1.38	1.04–4.08
Boiled	2.55±0.74	2.01–3.37	2.05±1.28	1.17–4.14
		MUFA / SFA		
Raw	0.71±0.03 A	0.68–0.76	0.99±0.14 B	0.85–1.19
Boiled	0.76±0.04 A	0.70–0.81	1.02±0.13 B	0.90–1.24
		PUFA / SFA		
Raw	2.00±0.62	1.33–2.84	1.03±1.25	0.19–2.89
Boiled	1.80±0.76	1.21–2.88	1.03±1.16	0.27–2.90
		NVI		
Raw	4.02±0.38 A	3.46–4.90	2.60±0.41 B	2.34–3.65
Boiled	3.77±0.30 A	2.74–3.98	2.74±0.42 B	2.42–3.47
		DFA		
Raw	88.34±14.30	76.19–94.73	76.94±17.40	59.93–91.11
Boiled	86.82±18.90	69.14–94.63	76.42±21.00	64.12–89.06

Mean±SEM – results shown as mean and standard error of the mean (n=6).
Min–max – minimal and maximal results acquired.
NVI – nutritive value index = (C18:0 + C18:1) / C16:0.
DFA – dietary fatty acids having a desirable neutral hypocholesterolemic effect in humans = ∑ MUFA + ∑ PUFA + C18:0.
Mean values for each fatty acid and quality index in the column do not differ significantly (P>0.05).
Mean values marked with the different capital letters in the row differ significantly (P<0.05).

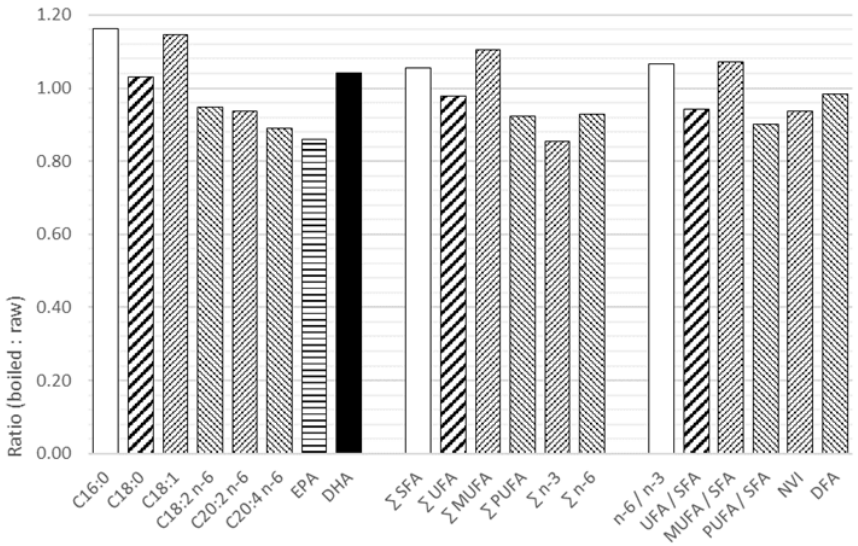


Figure 2. Ratio of fatty acid content and nutritional quality indices of lipids in meat of boiled and raw foot of small brown snail (*Cornu aspersum aspersum*)

The meat of the small brown snail turned out to be a substantially richer source of *n-6* rather than *n-3* acids. The share of these two forms was noticeably greater in the foot than in the visceral sac, which is directly related to the fact that the foot contains about two times more PUFA than the viscera. Even though boiling decreased slightly the average values of Σ *n-3* and Σ *n-6* in the foot and increased those in the visceral sac, the changes are not statistically significant (P>0.05). What is more, statistically significant changes were neither found in the ratios *n-6*/*n-3*, UFA/SFA, MUFA/SFA and PUFA/SFA, nor in NVI and DFA as a result of boiling the foot and viscera. There were, however, significant differences (P<0.05) between the raw foot and visceral sac and the boiled foot and visceral sac in the case of *n-6*/*n-3* and MUFA/SFA as well as the nutritive value index (NVI).

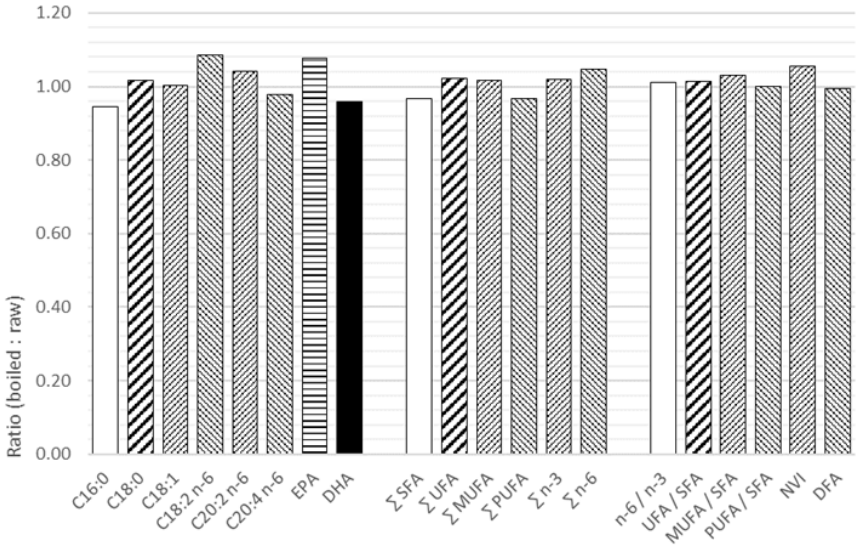


Figure 3. Ratio of fatty acid content and nutritional quality indices of lipids in meat of boiled and raw visceral sac of small brown snail (*Cornu aspersum aspersum*)

Discussion

Thermal processing of meat resources brings about extensive changes in their appearance and physical properties. As tissue is cooked, it first becomes firmer as the proteins are denaturated. Their water holding capacity decreases and a partial loss of fluid from the meat occurs (Hultin, 1985). This leads to an increase of the dry matter content, as observed in our research, especially in the case of the foot of snails *Cornu aspersum aspersum* where this parameter increased by about 1/4 up to 23.18%, only slightly lower than 25.13% that was found by Kougiagka et al. (2022) in boiled fillets of the same species. The same tendency has also been found in the heat treatment of meat of other animal species. Cupisti et al. (2006) found that in beef steak, after boiling, the dry matter content increased by 65.8%, and in chicken breast by 34.5%. Similarly, after deep frying, the dry matter content of beef steak increased by 64.0% (Borela et al., 2022), and according to Brugiapaglia and Destefanis (2012) that increase was 50%. As a result of goose meat boiling, its dry matter content increased by 54.6%, and after roasting by 67.0% (Goluch et al., 2021). The dry matter content in the visceral sac of the snail examined in the present work did not change in a statistically significant way. However, it is difficult to make appropriate comparisons as there are no reports in the scientific literature discussing possible changes in the dry matter content in the offal of farm animals.

The increase in the dry matter content of the boiled carcass resulted in a proportional increase in the protein content in the snail foot. The result of this process is the denaturation of proteins, which increases their digestibility. In the study of Djikeng et al. (2022), boiling with water or steaming for 24 min followed by frying considerably increased the protein content of snail *Archachatina marginata* meat. The studies of Kougiagka et al. (2022) showed that the level of protein in boiled meat of the snail species *Cornu aspersum* was similar to that found in our research. In chicken breast as a result of heat treatment the protein content increased by 27.4% (Cupisti et al., 2006), while in beef steak after frying this content increased by 52.0–55% (Brugiapaglia and Destefanis, 2012; Cupisti et al., 2006). In Kołuda geese as a result of cooking the protein content increased by 60.4% (Goluch et al., 2021), and in pork by up to 78.0% after roasting at 100°C (Vujadinović and Marianowić-Balaban, 2012). In the experiment described in this article, the concentration of fat in raw visceral sac was five times higher than that in raw foot, and after boiling it did not change substantially. However, it increased significantly in the foot meat up to a level similar to that observed by Kougiagka et al. (2022) in boiled wild and farmed *Cornu aspersum aspersum*.

As far as crude ash content is concerned, our research did not reveal statistically significant differences before and after boiling. This is partially in line with the fact that although thermal treatment caused an increase of the concentration of Ca and P in both edible parts of the small brown snail, it was statistically significant ($P<0.05$) only in the case of phosphorus in the foot. Both mineral macroelements play a key role in the metabolism of snails, and in the human diet are involved in, among other things, bone and teeth calcification, and also play an essential role in nutrients oxidation (Djikeng et at., 2022). The levels of calcium and phosphorus observed in *Cornu aspersum aspersum* fall in the range that can be found in the literature for various species of snails (Çağiltay et al., 2011; Özoğul et al., 2005). As in the present study, Çelik et al. (2019) found that these macroelements are more

abundant in the visceral meat than pedal meat, and also that wild snails contain more of them than farmed ones. In turn, Nkansah et al. (2021) examining three *Achatina* and *Archachatina* species showed a strong significant positive correlation between Ca and P.

Also in the case of other farm animals, boiling meat generally leads to an increase of the concentration of phosphorus and calcium. Goluch et al. (2011) found that water bath cooking of White Kołuda geese breast with skin caused an increase of the calcium and phosphorus content by 29% and 21%, respectively. Vujadinović and Marjanović-Balaban (2012), who studied pork meat demonstrated that an increase of those macroelements concentrations depends on the temperature of heat treatment and is stronger in higher temperatures. In contrast, Cupisti et al. (2006) found that, comparing with crude raw samples, the phosphorus retention in cooked beef and chicken breast was reduced by 42% and 63%, respectively.

The level of cholesterol in food is a subject of particular interest given the role this substance plays in shaping consumers' health. Approximately one-third of the cholesterol found in the body pool of the human adult comes from the diet. High levels of blood serum cholesterol have been regarded as a risk factor for cardiovascular disease. Furthermore, positive correlations have been observed between the consumption of foods rich in cholesterol and mortality from this disease (Nawar, 1985). The concentration of cholesterol that was recorded in the present study was relatively low and similar to that in the muscle of wild *Helix aspersa* (Citil et al., 2014) and African giant land snails (Imevbore, 1990). For comparison, its concentration in *Haplotrema sportella* and *Vespericola columbiana* snails and canned *Helix* sp. (Zhu et al., 1994) was about 100 mg/100 g – a few times higher. An increase of the cholesterol content analogous to that found in the present study after boiling of *Cornu aspersum aspersum* had been demonstrated before in comparisons of raw and cooked processed beef, pork and chicken meat products (Baggio and Bragagnolo, 2006).

Technological processes taking place in culinary treatment at a high temperature favour changes in the fat fraction. Usually their character is non-enzymatic consisting in chemical hydrolysis, oxidation, polymerization of fats, especially PUFA, which in turn may lead to changes in the fatty acid composition. However, the basis of these changes is likely not only due to the mechanisms mentioned above, but also the differences in extractability of lipids from the raw and boiled tissues.

Such changes were only partially seen in this work in the foot and visceral sac of small brown snails. In both carcass parts, a greater total share was found for unsaturated fatty acids (UFA) rather than saturated ones (SFA). This is beneficial bearing in mind that the former group includes a substantial share of polyunsaturated fatty acids (PUFA) considered to be the most important from the nutritional point of view. These include essential fatty acids such as linoleic acid (C18:2 *n*-6), α-linolenic acid (C18:3 *n*-3), and compounds belonging to their families, i.e. arachidonic (C20:4 *n*-6), eicosapentaenoic (EPA, C20:5 *n*-3) and docosahexaenoic (DHA, C22:6 *n*-3) acid. The human organism does not have the ability to synthesize double bonds in positions *n*-6 and *n*-3, and that is why linoleic and α- linolenic acids must necessarily be supplemented with food. Long-chain forms emerge from these precursors during the reactions of elongation and desaturation. Fatty acids from the PUFA group are vital in the formation of cell membranes, normal transport and distribution of lipids, and increase the blood flow through coronary vessels of the heart. Moreover, these are the starting material in the production of eicosanoids (prostaglandin, prostacyclin, among others) – biologically active tissue hormone-like substances (Franczyk-Żarów, 2022). The most abundant PUFA found in the snail carcass elements studied in this work – linoleic (C18:2 *n-6*), eicosadienoic (C20:2 *n-11, 14*) and arachidonic (C20:4 *n-6*) acids – were also the main PUFA identified in the garden snail (*Helix aspersa*) studied by Çağiltay et al. (2011) and also *Haplotrema sportella* and *Vespericola columbiana* analyzed by Zhu et al. (1994). The last of the acids listed above was hardly present in the foot and the visceral mass of the wild and farmed *Cornu aspersum* analysed by Çelik et. al. (2019) and *Helix pomatia* studied by Özoğul et al. (2005). Szkucik et al. (2018) did not detect its presence in the raw, cooked and frozen *Cornu aspersum aspersum* either, and the authors only noticed trace amounts of eicosadienoic acid (C20:2 *n-11, 14*), which disappeared after boiling and freezing. The same authors found a similar tendency in the case of *Cornu aspersum maxima*. However, they demonstrated that in edible parts of *Helix pomatia* eicosadienoic acid (C20:2 *n-11, 14*) occurs at a level of 12.77% and, just like the majority of other fatty acids from the PUFA group, it declines during a boiling process. A slight decline effect as a result of boiling was also observed in the present work, mainly in the foot. Heat treatment caused also a decrease of the share of linoleic and arachidonic acids in goose meat (Wereńska et al., 2021), the breast and leg of guajolote (turkey) (Cigarroa-Vázquez et al., 2022) and beef intramuscular fat (Alfaia et al., 2010). However, it did not affect the shares of the fatty acids in beef meatballs, hamburger, pork and chicken sausages (Baggio and Bragagnolo, 2006). A characteristic feature of edible snails is the fact they contain EPA and DHA acids. Still, the shares of the acids are usually lower than those in fish fats. Their levels in commercially important fish species from the seas surrounding Turkey (Özoğul and Özoğul, 2007) were multiple times higher than those found in our research in the case of *Cornu aspersum aspersum* or the levels found by Çelik et al. (2019) in wild and farmed *Helix aspersa,* Citil et al. (2014) in autumn and spring *Helix aspersa*, Özoğul et al. (2005) in Roman snail (*Helix pomatia*) or Zhu et al. (1994) in *Haplotrema sportella* and *Vespericola columbiana* snails. In turn, Szkucik et al. (2018) demonstrated also that cooking *Cornu aspersum aspersum*, just like freezing, causes a statistically signifi-

cant (P<0.01) drop of the share of EPA. Although such a decrease was indeed found in the present work in boiled foot meat, it was not considered statistically significant (P>0.05). Also water bath cooking of goose meat caused a decrease of the EPA and DHA contents (Wereńska et al., 2021), whereas boiling, microwaving and grilling *L. lumborum* muscle from young Portugeese Alentejano purebred bulls did not have a statistically significant influence on their concentrations (Alfaia et al., 2010).

Oleic acid (C18:1), dominant in the MUFA group in snail meat, slightly increased its share in the foot after boiling. This is consistent with the results of Szkucik et al. (2018) not only for *Cornu aspersum aspersum*, but also *Helix pomatia* and *Cornu aspersum maxima*. However, in the case of the fatty acid profile of goose meat such an increase did not take place (Wereńska et al., 2021). In the boiled foot of the small brown snail studied in the present work, there was also an increase of the shares of both main saturated fatty acids: palmitic acid (C16:0) by 16%, and stearic acid (C18:0) by 3%. The same tendency was observed by Szkucik et al. (2018). In our study, there was no such effect in the case of the visceral sac. Cigarroa-Vázquez et al. (2022), analysing thermally treated guajolote meat, and Alfaia et al. (2010), studying beef muscle, noticed an increase of the shares of both these saturated fatty acids. Wereńska et al. (2021) showed that although there was an increase in the share of stearic acid in goose meat regardless of the heat processing method used, the influence on the share of palmitic acid depended on the heat treatment method.

The consequence of the above-mentioned changes of the shares of individual fatty acids as a result of boiling of snails are the total values ∑ SFA, ∑ UFA, ∑ MUFA and ∑ PUFA presented in Table 2. The smallest changes, by barely 1.7%, were found for ∑ MUFA before and after visceral sac boiling, whereas the largest changes by as much as 10.5% were found also for ∑ MUFA in the case of the foot. Like in many other reports on the effect of heat treatment on the content of the fat fraction (Szkucik et al., 2018; Wereńska et al., 2021; Cigarroa-Vázquez et al., 2022; Alfaia et al., 2010), here also a decline of PUFA and an increase of SFA were observed. Polyunsaturated fatty acids (PUFA) are particularly vulnerable to decomposition under oxidation processes. The major pathway involves the autooxidation, initiated by single oxygen ($^1O_2$) self-catalytic free radical mechanism that accounts for the chain reaction of hydroperoxide formation and decomposition (Nawar, 1985). The autooxidation is particularly intensive at an elevated temperature, just like in culinary heat treatment. Similarly to the work on the edible parts of *Helix pomatia*, *Cornu aspersum maxima* and *Cornu aspersum aspersum* (Szkucik et al., 2018) and the studies conducted on beef intramuscular fat (Alfaia et al., 2010), also in the foot of the snails studied in the present work boiling led to a clear increase of ∑ MUFA. Yet, such a regularity was not seen for boiled goose and turkey meat (Wereńska et al., 2021; Cigarroa-Vázquez et al., 2022). What is also interesting is the boiling-induced changes of ∑ *n-3* and ∑ *n-6*, which decreased their shares in the foot, but slightly increased in the visceral sac. A drop of these two indices similar to that found in the foot in the present study had been recorded by Szkucik et al. (2018) in boiled edible parts of three species of snails studied in their work.

The ratios UFA/SFA, MUFA/SFA, and in particular PUFA/SFA as well as *n-6/n-3* are indices widely used to evaluate the nutritional value of edible fats. According to the British Department of Health (1994) the PUFA/SFA ratio in human diets should be above 0.45 to prevent cardiovascular and some other diseases, otherwise it can potentially induce a cholesterol increase in the blood (Mapiye et al., 2011). Moreover, within the PUFA group, the *n-6/n-3* ratio should not exceed 4.0 (Alfaia et al., 2018) and these acids are expected to make up 1/3 of the daily fat requirement (Szkucik et al., 2018).

The PUFA/SFA ratio calculated in this work, both for the foot and visceral sac before and after boiling, is beneficially high and well above the value recommended by the British Department of Health (1994). It is even higher than the value found by Özoğul and Özoğul (2007) for turbot (*Scopthalmus maeticus*) and common sole (*Solea solea*), fish known for their advantageous content of fatty acids, and clearly exceeds the values found in the fat of lamb meat (Karakök et al., 2010), beef (Karakök et al., 2010; Alfaia et al., 2010), goose (Werneńska et al., 2021) or guajolote (Cigarroa-Vázquez et al., 2022). However, when analysing the share of *n-6/n-3* fatty acids in the present study, it was revealed that their ratios exceeded the critical, recommended ratio of 4.0 twofold in the foot and threefold in the visceral sac. In this respect, the snail fat resembles that in goose meat (Wereńska et al., 2021), turkey, beef and lamb (Karakök et al., 2010), and is clearly worse than fish fat (Özoğul and Özoğul, 2007), but much better than the fat present in processed meat products such as beef meatballs, hamburgers and pork sausages (Baggio and Bragagnolo, 2006). Also Citil et al. (2014) recorded higher than critical values of the *n-6/n-3* ratio for the snail *Helix aspersa*, and similarly Özoğul et al. (2005) and Çağiltay et al. (2011) for wild *Helix pomatia*, and Zhu et al. (1994) for *Haploterma sportella* and *Vespericola colombina*. In turn, the ratio was favourable (close to 1) for the visceral and pedal mass of wild *Cornu aspersum*, but in the farmed population of this snail it exceeded 4.0 (Çelik et al., 2019). In line with our results, Szkucik et al. (2018) found that the recommended values were exceeded in the case of the snails *Cornu aspersum aspersum* and *Cornu aspersum maxima.* The authors additionally observed that under the influence of boiling and freezing the ratio *n-6/n-3* increased.

In the literature, there is no information on the changes following heat treatment of snail meat on such nutritional quality indices of lipids as NVI or DFA. When analysing the *Cornu aspersum aspersum* samples in the present study, slightly higher values of these indices were seen in the foot than in the visceral sac, but the boiling-induced changes were not statistically significant. Likewise,

Cigarroa-Vázquez et al. (2022) observed no influence on the NVI of guajolote breast and leg when the meat was boiled and baked, and Wereńska et al. (2021) saw only a slight increase for goose meat when cooked, grilled, roasted and fried. However, the DFA index representing hypocholesterolemic fatty acids slightly decreased during the process of water bath cooking of that meat.

Conclusions

The present study shows that the visceral sac of the small brown snail (*Cornu aspersum aspersum*) in comparison to the foot has a greater dry mass and is a richer source of crude protein, fat, ash, calcium and phosphorus, but contains less cholesterol. Boiling does not lead to statistically significant changes of the contents of these constituents in the visceral sac, but significantly ($P<0.05$) increases the dry mass and the levels of most of them in the foot. Given the content of PUFA, including EPA and DHA, and a good PUFA/SFA ratio, *Cornu aspersum aspersum* snails can be considered a healthy meat source in terms of fatty acid composition. The fatty acid profile of the foot is, however, more advantageous than that of the visceral sac. This is mostly a consequence of an about twice greater share of PUFA, including an almost nine times greater share of EPA, though in both carcass parts studied here the share of the *n-6/n-3* fatty acids exceeds the recommended maximum value of 4.0. The changes of the shares of individual fatty acids observed in this study and, in consequence, the differences in the nutritional quality indices resulting from boiling, however, not confirmed as statistically significant, still play a role in shaping the nutritional value of snail meat. As discussed earlier in this article, similar changes occur as the effect of heat treatment of meat of other species of animals.

References

Agengo F.B., Onyango A.N., Serrem C.A., Okoth J.K. (2022). Effect of incorporation of snail meat powder on sensory attributes and consumer acceptability of sorghum-wheat buns. Food Sci. Nutr., 10: 1820–1829.

Alfaia C.M.M., Alves S.P., Lopes A.F., Fernandes M.J.E., Costa A.S.H., Fontes C.M.G.A., Castro M.L.F., Bessa R.J.B., Prates J.A.M. (2010). Effect of cooking methods on fatty acids, conjugated isomers of linoleic acid and nutritional quality of beef intramuscular fat. Meat Sci., 84: 769–777.

AOAC (1995). Official methods of analysis. Association of Official Analytical Chemists, Inc., Washington, DC, USA.

AOAC (1998 a). Official method 938.08. Ash of seafood. Fish and other marine products. In: Official methods of analysis of AOAC international, Hungerford J.M., Cunniff P. (eds). Gaithersburg, MD: AOAC International, Chapter 35: 6.

AOAC (1998 b). Official method 955.04. Nitrogen (total) in seafood. Fish and other marine products. In: Official methods of analysis of AOAC International, Hungerford J.M., Cunniff P. (eds). Arlington, VA: AOAC International, Chapter 35: 6.

Baggio S.R., Bragagnolo N. (2006). The effect of heat treatment on the cholesterol oxides, cholesterol, total lipid and fatty acid contents of processed meat products. Food Chem., 95: 611–619.

Bligh E.G., Dyer W.J. (1956). A rapid method of total lipid extraction purification. Can. J. Biochem. Physiol., 37: 911–917.

Borela V.L., Rodrigues de Alencar E., Mendonça M.A., Heesup Han H., Raposo A., Ariza-Montes A., Araya-Castillo L., Puppin Zandonadi R. (2022). Influence of different cooking methods on fillet steak physicochemical characteristics. Int. J. Environ Res. Public Health, 19: 606.

British Department of Health (1994). Nutritional aspects of cardiovascular disease. Report on health and social subjects No. 46. London: HMSO.

Brugiapaglia A., Destefanis G. (2012). Effect of cooking method on the nutritional value of Piemontese beef. Meat Sci., 92: 165–301.

Çağıltay F., Erkan N., Tosun D., Selçuk A. (2011). Amino acid, fatty acid, vitamin and mineral contents of the edible garden snail (*Helix aspersa*). J. FisheriesSci. com., 5: 354–363.

Çelik M.Y., Duman M.B., Sarripek M., Gören G.U., Öztürk D.K, Kocatepe D., Karayücel S. (2019). Comparison of fatty acids and some mineral matter profiles of wild and farmed snails, *Cornu aspersum* Müller, 1774. Molluscan Res., 39: 234–240.

Chen Y.Y., Qiao Y., Xiao H., Chen L., Zhao M., Huang M., Zhou G. (2016). Differences in physicochemical and nutritional properties of breast and thigh meat from crossbred chickens, commercial broilers, and spent hens. Asian-Australas. J. Anim. Sci., 29: 855–864.

Cigarroa-Vázquez F.A., Granados-Rivera L.D., Portillo-Salgado R., Ventura-Ríos J., Esponda-Hernández W., Hernández-Marín J.A., Cruz-Tamayo A.A., Bautista-Martinez Y. (2022). Fatty acids profile and healthy lipids indices of native Mexican guajolote meat treated to two heat treatments. Foods, 11: 1509–1519.

Citil O.B., Tekeli Y., Danahaliloglu H., Bucak S. (2014). The effects of seasons on cholesterol content and fatty acid compositions of muscle of *Helix aspersa* living in Konya, Turkey. Afr. J. Tradit. Complement. Altern. Med., 11: 53–56.

Cupisti A., Comar F., Benini O., Lupetti S. (2006). Effect of boiling on dietary phosphate and nitrogen intake. J. Renal. Nutr., 16: 36–40.

Djikeng F.T., Ndambwe C.M.M., Ngangoum E.S., Tiencheu B., Tene S.T., Achidi A.U., Womeni A.M. (2022). Effect of different processing methods on the proximate composition, mineral content and functional properties of snail (*Archachatina marginata*) meat. J. Agric. Food Res., 8: 100298.

Engmann F.N., Ellis W.O., Dzogbefia V.P., Yong-Kun M., Abano E., Owusu J. (2012). A comparative study of three drying methods for preservation of the giant African snail (*Achatina achatina*) meat. Afr. J. Food Sci., 6: 392–400.

Folch J., Less M., Sloane Stanley G.H. (1957). A simple method for the isolation and purification of total lipids from animal tissue. J. Biol. Chem., 226: 497–509.

Franczyk-Żarów M. (2022). Fats in food and nutrition (in Polish). In: Human nutrition, Leszczyńska T., Franczyk-Żarów M. (eds). University of Agriculture in Krakow, Kraków, Poland, pp. 52–74.

Gogas A., Laliotis G.P., Ladoukakis E., Trachana V. (2021). Chemical composition and antioxidant profile of snail (*Cornu aspersum aspersum*) fed diets with different protein sources under intensive rearing conditions. J. Anim. Feed Sci., 30: 391–398.

Goluch Z., Król B., Haraf G., Wołoszyn J., Okruszek A., Wereńska M. (2021). Impact of various types of heat processing on the energy and nutritional values of goose breast meat. Poultry Sci., 100: 1–14.

Guiller A., Madec L. (2010). Historical biogeography of the land snail *Cornu aspersum*: a new scenario inferred from haplotype distribution in the Western Mediterranean Basin. BMC Evolut. Biol., 10: 2–20.

Hultin H.O. (1985). Characteristics of muscle tissue. In: Food Chemistry, Fennema O.R. (ed.). Marcel Dekker Inc., New York, Basel, pp. 725–789.

Imevbore E.A. (1990). Fatty acid and cholesterol contents of three species of the African giant land snails. Die Nahrung, 34: 869–870.

Iwanegbe I., Igene J.O., Emelue G.U., Obaroakpo J.U. (2018). Effect of processing, storage days and storage temperatures on lipid oxidation and palatability of processed snail meat products. Asian Food Sci. J., 6: 1–12.

Janiszewski P., Grześkowiak E., Lisiak D., Borys B., Borzuta K., Pospiech E., Poławska E. (2016). The influence of thermal processing on the fatty acid profile of pork and lamb meat fed diet with increased levels of unsaturated fatty acids. Meat Sci., 111: 161–167.

Karakök S.G., Özoğul Y., Saler M., Özoğul F. (2010). Proximate analysis. Fatty acid profiles and mineral contents of meats: A comparative study. J. Muscle Foods, 21: 210–223.

Kougiagka E., Apostologamvrou C., Hatziioannou M., Giannouli P. (2022). Quality characteristics and microstructure of boiled snail fillet meat. J. Food Process. Preserv., 46: 17079.

Lasekan O., Muniady M., Lin M., Dabaj F. (2018). Identification of characteristic aroma compounds in raw and thermally processed African giant snail (*Achatina fulica*) Chem. Cent. J., 12: 1–10.

Ligaszewski M., Pol P. (2018 a). Wartość odżywcza podstawowych elementów tuszy jadalnego ślimaka szarego (*Cornu aspersum*) oraz ślimaka winniczka (*Helix pomatia*) (in Polish). Wiad. Zoot., LVI: 67–79.

Ligaszewski M., Pol P. (2018 b). Wstępne badania nad jakością produkcji ślimaka jadalnego *Cornu aspersum aspersum* (synonym *Helix aspersa aspersa*) żywionego mieszanką paszową z dodatkiem hydrochlorku betainy (trimetyloglicyny) (in Polish). Wiad. Zoot., LVI: 53–59.

López N., Recebal G., Carrasco C. (2015). Preparation and evaluation of appertized from snail *Helix aspersa* M. Acta Agrón., 64: 1–10.

Mapiye C., Chimonyo M., Dzama K., Hugo A., Strydom P.E., Muchenje V. (2011). Fatty acid composition of beef from Nguni steers supplemented with *Acacia karroo* leaf-meal. J. Food Compos. Anal., 24: 523–528.

Morei V. (2012). Heliciculture – perspective business in the context of sustainable development of rural areas. Sci. Pap. Ser. Manag. Econ. Eng. Agric. Rural Dev., 12: 113–118.

Nawar W.W. (1985). Lipids. In: Food Chemistry, Fennema O.R. (ed.). Marcel Dekker Inc., New York, Basel, pp. 139–244.

Nkansah M.A., Agyei E.A., Opoku F. (2021). Mineral and proximate composition of the meat and shell of three snail species. Heliyon, 7: e08149.

Özoğul Y., Özoğul F. (2007). Fatty acid profiles of commercially important fish species from the Mediterranean, Aegean and Black Seas. Food Chem., 100: 1634–1638.

Özoğul Y., Özoğul F., Olgunoglu A.I. (2005). Fatty acid profile and mineral content of the wild snail (*Helix pomatia*) from the region of the south of the Turkey. Eur. Food Res. Technol., 221: 547–549.

Parlapani F.F., Neofitou C., Boziaris I.S. (2014). Microbiological quality of raw and processed wild and cultured edible snails. J. Sci. Food Agric., 94: 768–772.

Pissia M.A., Matsakidou A., Kiosseoglou V. (2021). Raw materials from snails for food preparation. Future Foods, 3: 100034.

Pissia M.A., Matsakidou A., Paraskevopoulou A., Kiosseoglou V. (2022). Structural characteristics and physicochemical properties of freeze-dried snail meat. LWT – Food Sci. Technol., 155: 112980.

PN-62 A-86783, Polish Standard. (1988). Fish and fish products. Water determination.

PN-EN ISO 6869. (2002). Animal Feeding Stuffs - Determination of the Contents of Calcium, Copper, Iron, Magnesium, Manganese, Potassium, Sodium and Zinc - Method Using Atomic Absorption Spectrometry. Polish Committee for Standardization, Warsaw, Poland.

Rygało-Galewska A., Zglińska K., Niemiec T. (2022). Edible snail production in Europe. Animals, 12: 2732.

Szkucik K., Ziomek M., Paszkiewicz W., Drozd Ł., Gondek M., Knysz P. (2018). Fatty acid profile in fat obtained from edible part of land snail harvested in Poland. J. Vet. Res., 62: 519–526.

Vujadinović D., Marianović-Balaban Ž. (2012). Influence of temperature and heat treatment regime on chemical properties of pork meat. Qual. Life, 3: 49–54.

Wereńska M., Haraf G., Wołoszyn J., Goluch Z., Okruszek A., Teleszko M. (2021). Fatty acid profile and health lipid indices of goose meat in relation to various types of heat treatment. Poultry Sci., 100: 101237.

Zhu N., Dai X., Lin D.S., Connor W.E. (1994). The lipids of slugs and snails: Evolution, diet and biosynthesis. Lipids, 29: 869–875.

Zucaro A., Forte A., De Vico G., Fierro A. (2016). Environmental loading of Italian semi-intensive snail farming system evaluated by means of life cycle assessment. J. Clean. Prod., 125: 56–67.

Received: 30 IX 2022
Accepted: 18 V 2023