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VARIATIONS OF NIACIN CONTENT IN SALTWATER FISH AND THEIR RELATION WITH DIETARY RDA IN POLISH SUBJECTS GROUPED BY AGE

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ABSTRACT

Introduction. A rich and natural source of readily assimilated dietary protein together with invaluable vitamins and minerals are fish, particularly the saltwater species. The quality of any given foodstuff is determined by its nutritional value, which in turn depends on the food type and methods used for manufacture, processing and storage. Many fish products contain fewer water soluble vitamins than the source foodstuff as a result of using various technologies during food processing, such as smoking or deep freezing, where vitamins are often either degraded or leached out. In the case of niacin it is relatively easy to make good such losses by eating niacin-rich foods or by taking dietary supplements e.g. the essential amino acid L-tryptophan.

Objectives. To determine niacin content in sea fish that are commonly available on the Polish market and to assess whether this dietary source is sufficient to satisfy the RDA requirements for various age groups of selected subjects living in Poland.

Material and methods. Niacin levels were measured firstly in 10 saltwater fish species together with butterfish and Norwegian salmon that formed a separate group. Altogether, 15 types of fish products were analysed in all. They consisted of smoked fish: whitefish, butterfish, sprat, trout, herring (kippers) and mackerel, and frozen fish: butterfish, Norwegian salmon, sole, grenadier and panga. Each product was measured as ten replicates, thus in total 150 analyses were performed. A microbiologically-based method was used for the niacin determination, with enzyme hydrolysis by 40 mg papain and diastase on a 2 g sample (according to the AOAC procedure) to release the free form from the bioavailable form that is bound to NAD and NADP.

Results. The most plentiful sources of niacin were found in smoked fish with the highest amounts in butterfish, after warm temperature smoking, and in mackerel; respectively 9.03 and 8.90 mg/100 g. Such 100 g portions of smoked fish are a good dietary source of niacin, in that for men and women above 19 years of age, they constitute respectively 22% - 56% and 25% - 64% of the RDA (Recommended Daily Allowance). The highest levels of niacin in frozen fish were found in butterfish and Norwegian salmon; respectively 8.05 and 5.75 mg/100 g which in turn represent respectively 10% - 50% and 11% - 56% of the RDA in men and women aged above 19 years.

Conclusions. Niacin concentrations varied according to fish species. The richest dietary sources were smoked fish consisting of butterfish, after warm temperature smoking, and mackerel. In frozen fish, butterfish and Norwegian salmon had the highest niacin amounts. A 100 g serving of such sea fish can, to quite a large extent, satisfy the adult RDA.

Key words: *niacin, nicotinic acid, nicotinamide, fish*

STRESZCZENIE

Wprowadzenie. Ryby zwłaszcza morskie stanowią naturalne źródło łatwo przyswajalnego białka oraz wielu cennych witamin i minerałów. Witamina B_3 to grupa związków w skład których wchodzą kwas nikotynowy (niacyna) oraz amid kwasu nikotynowego (nikotynamid). Stosunkowo łatwo uzupełniać niedobory niacyny spożywając regularnie produkty bogate w tą witaminę, jak i białko lub szeroko dostępne na rynku suplementy diety.

Cel badań. Celem pracy było oznaczenie zawartości niacyny w łatwo dostępnych na rynku rybach morskich, a także ocena analizowanych ryb jako potencjalnego dobrego źródła niacyny w diecie człowieka (RDA) w różnych grupach wiekowych.

Materiał i metody. Oznaczono zawartość niacyny w piętnastu rodzajach ryb słonowodnych. w rybach wędzonych (sieja, ryba maślana, szprot, pstrąg, śledź oraz makrela) i mrożonych (ryba maślana, łosoś norweski, sola, grenadier, panga). Łącznie przebadano 150 produktów rybnych. Niacynę oznaczono metodą mikrobiologiczną według AOAC stosując hydrolizę en-

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zymatyczną za pomocą papainy i diastazy w celu wyodrębnienia witaminy z analizowanych próbek. Metoda enzymatyczna pozwala na wyodrębnienie tylko biologicznie dostępnych form niacyny związanych w NAD i NADP.

Wyniki. Najlepszym źródłem niacyny były ryby wędzone, a najwięcej witaminy stwierdzono w wędzonych na ciepło rybie maślanej (9,03 mg/100 g) i makreli (8,90 mg/100 g). Porcja ryby wędzonej (100 g) może być bardzo dobrym źródłem niacyny realizując normy dziennego zapotrzebowania dla kobiet i mężczyzn w wieku powyżej 19 lat, odpowiednio w zakresie wartości od 24% do 64% i od 21% do 56%. W grupie badanych ryb mrożonych najwyższą zawartość niacyny zawierała ryba maślana (7,89 mg/100 g) i łosoś norweski (5,75 mg/100 g). Porcja ryby mrożonej (100 g) pokrywała dzienne zapotrzebowanie na niacynę normy dla kobiet i mężczyzn w wieku powyżej 19 lat, odpowiednio w zakresach od 11% do 56% i od 10% do 49%.

Wnioski. Przeprowadzone analizy zawartości niacyny wykazały zróżnicowanie pomiędzy poszczególnymi gatunkami ryb. Wykazano, iż najlepszym źródłem niacyny są ryby wędzone, spośród których najwięcej analizowanej witaminy posiadają ryba maślana wędzona na ciepło oraz makrela. W grupie ryb mrożonych najwyższą zawartość niacyny oznaczono w rybie maślanej oraz w łososiu norweskim. Porcja ryby morskiej (100 g) może być bardzo dobrym źródłem niacyny.

Słowa kluczowe: *niacyna, kwas nikotynowy, amid kwasu nikotynowego, ryby*

INTRODUCTION

Sea food, especially that consisting of so called ‘dark meat’, provides an excellent source of dietary niacin. Furthermore, the presence of tryptophan, which lends the meat its dark colouration, is a precursor in the biosynthesis of kynurenine, serotonin and NAD; being the biologically active form of niacin (Figure 1). A 60 mg amount of tryptophan is sufficient for generating 1 mg niacin. This reaction pathway requires B group vitamins as enzyme cofactors.

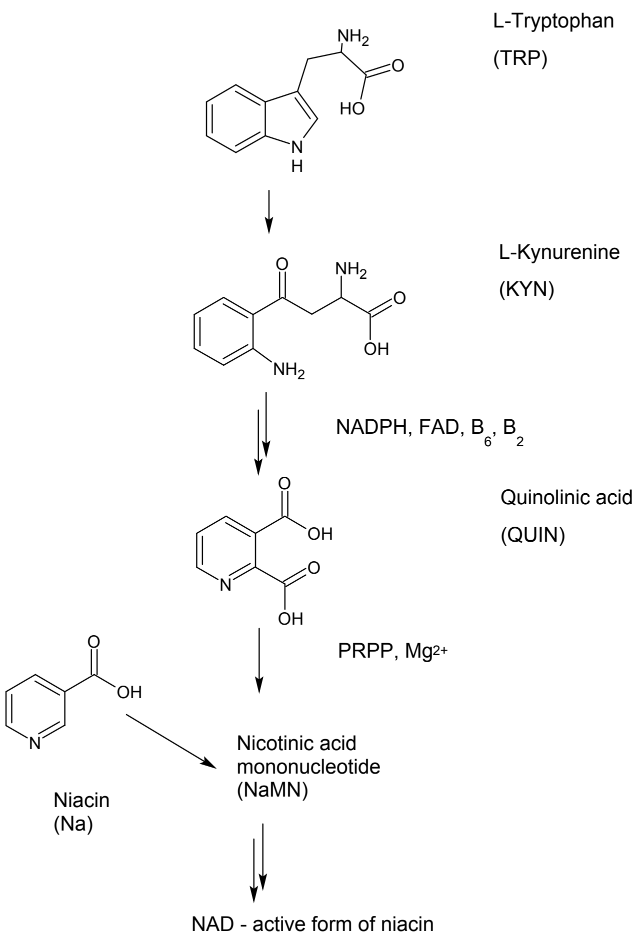

Figure 1. The niacin pathway of tryptophan metabolism

Reasons for any niacin deficiencies may be malnourishment, alcoholism, medicines used for treating Parkinson’s Disease or hydrazine derivatives used in treating tuberculosis and inflammation. A diet containing fish affords many nutritional advantages [5, 17]. It should be stressed that fish protein has a high nutritional value and fish also contain long chain polyunsaturated fatty acids EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid), microelements and vitamins [12-14, 18, 19, 21, 22]. A 100 g portion of fish covers half the daily requirement for tryptophan rich protein; tryptophan being a niacin precursor. Some publications suggest that there may be significant differences in vitamin and fat content between farmed fish with those living free. This may also depend on the fish species, age, the season when fished (captured) and the type and availability of feed. Data on these topics are sparse. [16].

The study aims were to determine the niacin content in various species of sea fish, that included those who had been smoked (under warm or cold conditions) or deep frozen in relation to the sources of the human dietary requirement for niacin; RDA [12-14]. The types of fish chosen were ones that were fatty, saltwater species, easily available on the market and frequently consumed in Poland, as determined from previous dietary surveys.

MATERIAL AND METHODS

The study material were samples of fish products that had been smoked (under either warm or cold conditions) or deep frozen; Table 2 and Table 3. The fish samples consisted of fillets, flakes, cutlets and whole carcasses. Ten fish species were analysed; whitefish, butterfish, sprat, trout, herring, mackerel, Norwegian salmon, sole, grenadier and panga that amounted to

Table 1. Accuracy and precision of niacin determination

Niacin content in fish (mg/100 g)	n	Spiked (mg/100 g)	Recovery (%)	SD (%)	Relative error (%)
7.89 ±015	10	3	97.87	2.89	- 2.13
		6	103.04	3.13	+3.04

n - number of samples, SD- standard deviation

15 fish products in total. Each were analysed as 10 replicates. Three samples of fish flesh were obtained after homogenising and mixing each fish product type. Previously, the fish had been thawed at 4°C, after being frozen for over 24 hours under laboratory conditions, then the thawed water was discarded. This being similar to how fish is prepared domestically in the kitchen and on average the discarded water amounted to a 6% loss. Niacin was isolated from the samples (2 g) after enzymatic hydrolysis using papain and diastase (40 mg) according to the AOAC method [1, 15]. A microbiological method [1, 7] was then used to determine niacin using the *Lactobacillus plantarum* ATCC No. 8014 strain.

Niacin is one of the most stable water soluble vitamins in solution and its biological activity is retained following thermal, light, pH or oxidation treatment. Both acid or enzymatic hydrolysis is thus possible for releasing free niacin from its biologically bound form where it can be liberated from coenzymes or through matrix degradation. When performing mineral acid hydrolysis, this process is however non-physiological and may release nicotinic acid which is not normally bio-available. Studies by *Ndaw* et al. [18] have demonstrated that by replacing acid hydrolysis by enzymes it is possible to isolate niacin liberated from its NAD and NADP bound forms.

The precision and accuracy of the method were established, at highly acceptable levels, on samples spiked with known amounts of niacin (Table 1). Results were checked to see if levels were sufficient to satisfy the RDA requirements for adult subjects aged above 19 years by their concordance with amended reference values of nutrition in Poland, supplied by the Polish Institute of Food and Nutrition [8].

RESULTS AND DISCUSSION

Niacin concentrations found in the tested fish samples are shown in Tables 2 and 3. In smoked fish, the highest niacin concentrations were found in butterfish (warm treatment) and mackerel at respectively 9.03 and 8.90 mg/100 g. The lowest levels in smoked fish were recorded in whitefish and sprats (whole and flesh), respectively 3.50 and 4.06 – 4.58 mg/100 g (Table 2). In the deep frozen fish, the highest amounts measured were in butterfish (respectively 8.05 and 7.11 mg/100 g in cutlets and fillets) and Norwegian salmon (5.05 - 8.85 mg/100 g), whereas the lowest levels were in sole, grenadier and panga; respectively 1.96, 1.71 and 1.53 mg/100 g (Table3). The observed differences in niacin concentrations between smoked and deep frozen fish could be explained by water losses incurred in the latter during thawing, as well as the type of treatment (warm or cold) used in smoking. As aforementioned, the thawing loss was 6% due to the discarding of water. Results were subjected to statistical analysis by ANOVA using $p \leq 0.05$ as showing significance. For butterfish, the treatment differences between warm and cold smoking was compared and found to be significantly different at $p = 0.001$.

The niacin levels found in the 100 g fish portions are shown in relation to RDA requirements; for smoked fish (Table 2) and deep frozen fish (Table 3) - taking into account the age, gender and physiological status of the human population. Using the mean RDA values for children, a 100 g portion of butterfish (warm smoked) and smoked mackerel, fulfils their RDA by respectively 113 and 111% (Table 2). Niacin reference values for boys are equivalent to those of adult men; the same

Table 2. Niacin content in smoked fish according to the RDA for the Polish population

Fish type	n	Niacin content (mg/100 g) X± SD	RDA requirement in 100 g of fish product (%)						
			Children 1-9 years	Men		Women			
				10–18 years	≥ 19 years	10–18 years	≥ 19 years	pregnant	nursing
Smoked butterfish (warm)	10	9.03± 0.05	112.88	56.44	56.44	64.50	64.50	50.17	53.12
Smoked mackerel	10	8.90 ± 0.09	111.25	55.63	55.63	63.57	63.57	49.44	52.35
Smoked trout	10	5.65± 0.04	70.63	35.31	35.31	40.36	40.36	31.39	33.24
Smoked butterfish (cold)	10	5.54± 0.13	69.25	34.63	34.63	39.57	39.57	30.78	32.59
Smoked herring	10	4.99± 0.20	62.38	31.19	31.19	35.64	35.64	27.72	29.35
Smoked sprats -flesh	10	4.58± 0.28	57.25	28.63	28.63	32.71	32.71	25.44	26.94
Smoked sprats -whole	10	4.06± 0.10	50.75	25.38	25.38	29.00	29.00	22.56	23.88
Smoked whitefish	10	3.50± 0.21	43.75	21.88	21.88	25.00	25.00	19.44	20.59

n - number of samples; X- average; SD- standard deviation

Table 3. Niacin content in frozen fish according to the RDA for the Polish population

Fish type	n*	Niacin content (mg/100 g) X± SD	RDA requirement in 100 g of fish product (%)						
			Children 1-9 years	Men		Women			
				10–18 years	10– 18 years	10–18 years	10–18 years	10–18 years	nursing
Butterfish (cutlet)	10	8.05 ± 0.15	100.63	50.31	50.31	57.50	57.50	44.72	47.35
Butterfish (fillet)	10	7.11 ± 0.15	88.88	44.44	44.44	50.79	50.79	39.50	41.82
Norwegian salmon steak, tail	10	5.85 ± 0.12	73.13	36.56	36.56	41.79	41.79	32.50	34.41
Norwegian salmon cutlet	10	5.05 ± 0,15	63.13	31.56	31.56	36.07	36.07	28.06	29.71
Sole, fillet	10	1.96 ± 0.08	24.50	12.25	12.25	14.00	14.00	10.89	11.53
Grenadier, fillet	10	1.71 ± 0.11	21.38	10.69	10.69	12.21	12.21	9.50	10.06
Panga, fillet	10	1.53 ± 0.10	19.13	9.56	9.56	10.93	10.93	8.50	9.00

n– number of samples; X- average; SD- standard deviation

applying to girls and adult women. Here, it was found that the RDA was satisfied by respectively 56% and 64% in men and women for both warm treated smoked butterfish and smoked mackerel; these being at the highest levels. Those fish showing the lowest RDA fulfilment were whitefish at 44% RDA in children and 22% and 25% respectively for men and women (Table 3).

In the frozen fish, sole grenadier and panga least satisfied the RDA where respectively they supplied 24%, 21% and 19% in children. For men the corresponding results were 12%, 11% and 10% whilst 14%, 12% and 11% for women. A butterfish portion (100 g cutlet) best satisfied the RDA in children and in men and women; respectively 50% and 57%. There were almost 1.6 and 1.3 fold higher niacin levels in butterfish smoked respectively under warm and cold conditions compared to deep frozen butterfish. It is suggested that this arose from technological losses incurred during processing and the water loss during thawing.

As a component of two vital coenzymes NAD^+ and $NADP^+$ in electron transport, niacin takes part in oxidation/reduction reactions catalysed by dehydrogenases [22]. It is vital for normal nervous system function where it protects against oxidative stress and takes part in the syntheses of the sex hormones: cortisol, thyroxin and insulin [6, 9]. Dietary niacin deficiency in children leads to many functional disorders, leading to the development of diet-related diseases, developmental and mental dysfunction [7]. As a nicotinic acid, niacin increases plasma HDL-cholesterol, whilst at the same time decreases fatty acids that induce arteriosclerosis, such as triglycerides, VLDL-cholesterol, LDL-cholesterol and Lipoprotein A [2]. Furthermore, a high dose of niacin can reduce inflammation [8].

Current nutritional recommendations clearly indicate that fish should be eaten 2 – 3 times weekly and that the dietary presence of 'oily fish' and certain 'fruits of the sea' is beneficial to the health of those at risk of cardiovascular disease, in pregnant women and the elderly [4, 7, 10, 11, 17, 20]. Due to their high nutritional value, fish should be consumed much more than is currently the case in Poland, where in fact fish consumption is falling.

CONCLUSIONS

1. The study demonstrated wide variations of niacin content for different fish species. The highest levels were found in warm smoked butterfish or smoked mackerel whilst those levels highest in frozen fish were butterfish and Norwegian salmon.
2. A 100 g portion of smoked fish can be an important dietary source of niacin, satisfying the RDA by 22 - 56% in men and 25 - 64% in women.
3. In frozen fish, a 100 g portion satisfies the niacin RDA by 10 - 50% in men and 11 – 57% in women.

Conflict of interests

The authors declare no conflict of interest.

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