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Animal species and muscle related differences in thiamine and riboflavin contents of Swiss meat

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Animal species and muscle related differences in thiamine and riboflavin contents were studied in pork, chicken, veal and beef. Pork was the best thiamine source and there was no significant difference in thiamine content of longissimus dorsi and shoulder muscles. Also, no difference in thiamine content of chicken breast and thigh was found. In contrast, the riboflavin content significantly differed between the muscles within species (pork and chicken) examined. With the average daily lean meat consumption in Switzerland (105 g day^{-1}), thiamine and riboflavin intakes were approximately 0.5 mg day^{-1} and 0.2 mg day^{-1}, respectively. The recommended daily thiamine intake was met up to 25% for men and 29% for women. Pork itself contributed about 23% (men) and 27% (women). The recommendation for riboflavin intake was met up to 10% for men and 11% for women. © 1997 Elsevier Science Ltd. All rights reserved

INTRODUCTION

Meat, especially pork, has long been recognized as a good source of B vitamins (Briggs & Schweigert, 1990). For example, pork is rich in thiamine (vitamin B_1) and contains much more of this vitamin in comparison to beef, veal and chicken (Souci *et al.*, 1994). Meat is also a good source of riboflavin (vitamin B_2) and its content in cuts of different species is not as variable as thiamine (Bässler *et al.*, 1992; Souci *et al.*, 1994). The thiamine and riboflavin contents of meat have been examined in many studies (Miller *et al.*, 1943; Pence *et al.*, 1945; Moss *et al.*, 1983; Ono *et al.*, 1986; Dawson *et al.*, 1988; Hägg & Kumpulainen, 1994). However, few new data are available. Since animal breeds and feeding practice have changed in recent years, it is possible that the nutrient contents in meat have also altered.

Additionally, information about muscle related differences in thiamine and riboflavin content is limited. In most studies, meat samples were directly selected at the abattoir. Since thiamine and riboflavin are water-soluble vitamins, they can be lost with the meat broth (Bässler *et al.*, 1992). Moreover, it has to be considered that thiamine is relatively unstable in meat (Bognár *et al.*, 1993; Combs, 1992). One reason is the relatively high pH of meat ($\geq$5.5). Another reason is that the major part of thiamine in meat occurs as thiamine diphosphate, which is more sensitive to destruction than the free thiamine found in foods of plant origin (Bässler *et al.*, 1992; Machlin, 1991).

Also, meat contains heme proteins, such as hemoglobin and myoglobin, which exhibit antithiamine activity (Gregory, 1985). Therefore, it is important to provide further information about the vitamin content of meat sold at the retail level.

The objective of our study was to examine the thiamine and riboflavin contents in pork, beef, veal and chicken, available at the Swiss retail market. In addition, the thiamine and riboflavin concentrations of two different pork and chicken muscles were analysed. Finally, the contribution of the average daily meat consumption in Switzerland to meet the recommendation for daily thiamine and riboflavin intake was calculated.

MATERIALS AND METHODS

Samples and chemical analyses

The following meat cuts were purchased from different supermarkets and butchers' shops in Zurich (Switzerland): pork (chop and shoulder), beef (prime rib), chicken (breast and thigh) and veal (chop). Only fresh samples were taken for beef, pork and veal; for chicken samples, 16 fresh and nine frozen birds were chosen. The frozen whole birds were thawed overnight in a refrigerator (4°C) and then prepared for analysis. The

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sample size of every meat cut was 25 pieces. The meat cuts were transported to our laboratory, where the longissimus dorsi muscle from beef prime rib and chop (pork and veal) was immediately separated. The other meat cuts were trimmed of visible fat, skin and connective tissue. The lean meat samples were cut into small pieces. Approximately 20 g of meat was homogenized with 20 ml of 0.2 M and 10 ml of 0.1 M sulphuric acid. The homogenates were stored at −20 °C until analysed.

The thiamine content was determined by the method of Rettenmaier *et al.* (1979) and calculated, using a standard curve, as thiamine chloride hydrochloride. Analysis of the riboflavin content in meat was performed by a modified HPLC method of Schüep and Steiner (1989), in which the filtrate obtained was directly injected without the methanol treatment and the dilution step. The riboflavin concentration was calculated using riboflavin external standards.

Calculations and statistical methods

The statistical per capita meat consumption (slaughter weight) in Switzerland was the basis for calculating the average lean meat consumption. A percentage of lean meat of the slaughter weight of 55%, 65%, 66% and 50% for pork, beef, veal and poultry, respectively, was considered. About 85% of the poultry meat consumed was chicken (Swiss Meat Board, 1995).

To calculate significant differences ($P < 0.05$) in thiamine or riboflavin content of different meat cuts, the analysis of variance (ANOVA) was computed using STATGRAPHICS 5.0. Significance of means was determined using Bonferroni's multiple range test. The Mann–Whitney *U*-test was employed to determine differences between thawed and fresh chicken samples.

RESULTS AND DISCUSSION

The thiamine content of the examined meat cuts is shown in Table 1, and is seen to vary with animal species. Pork was the only meat rich in thiamine, while the meat cuts of the other species were relatively poor in this vitamin. There was no statistically significant difference in the thiamine content between pork longissimus dorsi muscle and pork shoulder muscles (Table 1), or between chicken breast and thigh. A comparison of our thiamine values with the literature data is difficult, because we calculated the thiamine content as thiamine chloride hydrochloride as described in the method of Rettenmaier *et al.* (1979). In many food composition tables it is not clear whether thiamine is expressed as unbound thiamine, thiamine hydrochloride (McCance & Widdowson, 1991) or thiamine chloride hydrochloride. In our study, the average thiamine content in pork was 0.8 mg per 100 g wet wt. Comparable values in the range of 0.8–0.9 mg per 100 g wet wt are published in the literature (Moss *et al.*, 1983; Bodwell & Anderson, 1986; Dawson *et al.*, 1988; McCance & Widdowson, 1991; Souci *et al.*, 1994; Elmadfa *et al.*, 1996). However, Hägg & Kumpulainen (1994) reported a higher thiamine content for pork (1.1 mg per 100 g wet wt). Compared to our values, thiamine contents published in the literature are higher for beef and veal, and lower for chicken (Bodwell & Anderson, 1986; Dawson *et al.*, 1988; McCance & Widdowson, 1991; Souci *et al.*, 1994; Elmadfa *et al.*, 1996). In the current study, no significant muscle related differences in thiamine content of one species (pork and chicken) were found (Table 1). On the other hand, Miller *et al.* (1943), Pence *et al.* (1945) and Moss *et al.* (1983) found significantly higher thiamine contents in pork loin muscles compared to shoulder muscles.

The riboflavin content of the examined meat cuts is also shown in Table 1. The amount of riboflavin in pork and veal longissimus dorsi muscle was significantly higher than in beef ($P < 0.05$). However, muscle related differences of one animal species (pork and chicken) were higher compared to animal species related differences (Table 1). The riboflavin content in shoulder muscles (pork) was nearly twice as high as in longissimus dorsi. Also, chicken thigh had a higher concentration than chicken breast ($P < 0.05$). The muscle

Table 1. Thiamine and riboflavin contents of the examined meat cuts[a]

Meat	Thiamine[b] (mg per 100 g wet wt)			Riboflavin (mg per 100 g wet wt)		
	Mean ± SD	Median	Range	Mean ± SD	Median	Range
Pork						
L.d.m.	0.84 ± 0.23^{b}	0.84	0.38–1.23	0.16 ± 0.02^{b}	0.16	0.13–0.21
Shoulder	0.70 ± 0.31^{b}	0.77	0.12–1.20	0.31 ± 0.06^{d}	0.30	0.21–0.47
Beef (L.d.m.)	0.04 ± 0.01^{a}	0.04	0.03–0.06	0.13 ± 0.02^{a}	0.13	0.10–0.18
Veal (L.d.m.)	0.08 ± 0.03^{a}	0.08	0.04–0.14	0.19 ± 0.02^{b}	0.19	0.15–0.21
Chicken						
Breast	0.14 ± 0.04^{a}	0.13	0.09–0.23	0.15 ± 0.02^{a}	0.15	0.12–0.19
Thigh	0.14 ± 0.03^{a}	0.14	0.10–0.21	0.27 ± 0.04^{c}	0.25	0.20–0.33

[a] $n = 25$, with the exception of chicken (only fresh samples, $n = 16$).
[b] As thiamine chloride hydrochloride.
L.d.m., longissimus dorsi muscle. SD, standard deviation;
[a,b,c,d] Thiamine and riboflavin contents (means) of the meat cuts with different letters are significantly different ($P < 0.05$).

related differences in riboflavin content of pork are in agreement with the results of Moss *et al.* (1983). They also found higher riboflavin contents in shoulder blade roast (0.33 mg per 100 g wet wt) compared to loin chops (0.24 mg per 100 g wet wt). However, their riboflavin content in loin chops was higher than our value (0.16 mg per 100 g wet wt). Also, chicken thigh had a higher riboflavin content than breast. This is in agreement with many food composition tables (Bodwell & Anderson, 1986; McCance & Widdowson, 1991; Elmadfa *et al.*, 1996). We did not examine muscle specific differences in riboflavin content of veal and beef, but Dawson *et al.* (1988) and Ono *et al.* (1986) observed differences in the riboflavin content of different meat cuts from beef and veal.

There is a marked variation in the thiamine contents compared to the riboflavin contents. The coefficient of variation for the thiamine values ranged between 21% and 44% and for the riboflavin contents between 11% and 19%. One explanation for this finding might be that thiamine is more vulnerable than riboflavin and therefore vitamin losses can occur to a greater extent. For example, it is well known that thiamine is lost with the meat broth. Consequently, we found a significantly lower ($P < 0.01$) thiamine content in thawed chicken breast compared to the fresh one (Fig. 1). However, no difference was found in the thiamine content of thawed and fresh chicken thigh. Also, the riboflavin contents of thawed and fresh chicken samples were the same (Fig. 1). These results indicate that thiamine losses

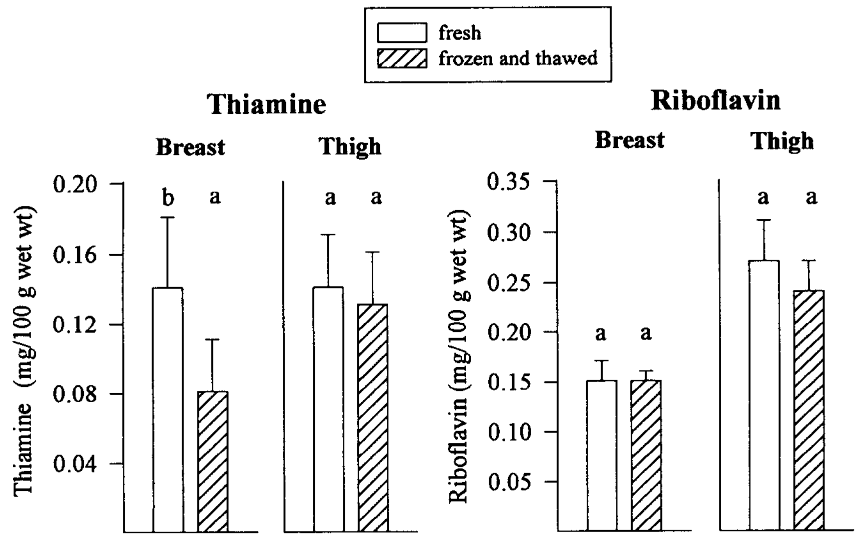

Fig. 1. Thiamine and riboflavin content of fresh ($n = 16$) and frozen and thawed ($n = 9$) chicken breast and thigh samples. Values with different letters are significantly different ($P < 0.01$).

Table 2. Thiamine and riboflavin intake provided by the average daily meat consumption in Switzerland in 1995

Meat	Meat consumption[a] (g day^{-1})	Thiamine[b]		Riboflavin	
		Content[c] (mg per 100 g wet wt)	Intake (mg day^{-1})	Content[c] (mg per 100 g wet wt)	Intake (mg day^{-1})
Pork	53	0.81	0.43	0.23	0.12
Beef	30	0.04	0.01	0.13	0.04
Veal	9	0.08	0.01	0.19	0.02
Chicken[d]	13	0.13	0.02	0.20	0.03
Sum	105		0.47		0.21
German recommendations[e]			Men: 1.9 (25%) Women: 1.6 (29%)		Men: 2.1 (10%) Women: 1.9 (11%)

[a]Calculation based on the statistical per capita meat consumption in Switzerland (Swiss Meat Board, 1995).
[b]As thiamine chloride hydrochloride.
[c]For calculating the average thiamine and riboflavin contents for each animal species (pork and chicken), the mean of the two median values was used.
[d]Fresh and frozen and thawed samples ($n = 25$) were considered.
[e]The recommended daily intake of thiamine and riboflavin given by the German Nutrition Society (1995) allows for preparation losses of 30% and 10%, respectively. The amount (expressed as a percentage) meeting the recommended amount is shown in parentheses.

during frozen storage and thawing might differ, depending on the muscles examined.

Another explanation for the large thiamine variability might be the vitamin content of animal feeds. In general, feed composition has little influence on the amount of water-soluble vitamins in meat, except for niacin and thiamine (Kühne, 1982). Different studies have indicated that pigs can store sufficient amounts of thiamine to meet their requirements while on a thiamine-deficient diet for as long as 2 months (Oltjen & Dinius, 1975). Miller *et al.* (1943) showed that, by feeding a ration supplemented with thiamine, the thiamine content of pork loin increased up to 2.31 ± 0.10 mg per 100 g wet wt compared to 0.95 ± 0.04 mg per 100 g wet wt in the control group. Since thiamine is not supplemented in the pig feeds used in Switzerland, its different naturally occurring content might be responsible for the variation.

Table 2 shows the thiamine and riboflavin intake provided by the average daily meat consumption in Switzerland for 1995. For calculating the thiamine and riboflavin intakes, the mean of the two median values for pork and chicken was used. With a daily meat consumption of 105 g, the thiamine intake was about 0.47 mg day^{-1} and the riboflavin intake about 0.21 mg day^{-1}. The recommended daily thiamine intake (German Nutrition Society, 1995) was met up to 25% for men and up to 29% for women. Pork itself contributed of about 23% (men) and 27% (women).

The contribution of the average daily meat consumption in Switzerland to meet the recommended daily riboflavin intake (German Nutrition Society, 1995) was 10% for men and 11% for women. Since pork was the most consumed meat, it was also the most important riboflavin supplier. The contribution of beef and veal might be slightly underestimated because only the longissimus dorsi muscle was examined and, as shown in other studies (Ono *et al.*, 1986; Dawson *et al.*, 1988), this is the muscle with the lowest riboflavin content.

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